Core Data Programming Guide

Cocoa > Design Guidelines

2009-03-04

Contents

Figures, Tables, and Listings

Introduction to Core Data Programming Guide

The Core Data framework provides generalized and automated solutions to common tasks associated with object life-cycle and object graph management, including persistence. Its features include:

- Built-in management of undo and redo beyond basic text editing
- Automatic validation of property values to ensure that individual values lie within acceptable ranges and that combinations of values make sense
- Change propagation, including maintaining the consistency of relationships among objects
- Grouping, filtering, and organizing data in memory and in the user interface
- Automatic support for storing objects in external data repositories
- Optional integration with Cocoa bindings to support automatic user interface synchronization

Who Should Read This Document

You should read this document to gain an understanding of the Core Data framework. You are expected to be familiar with the basics of Cocoa development, including the Objective-C language and memory management.

Important: Although this document provides a thorough treatment of the fundamentals of the Core Data framework, simply reading from start to finish is not a good strategy for learning how to use the technology effectively. Instead, you should typically augment your understanding by following the related tutorials provided in the Reference Library. For a description of the recommended learning path, see *Core Data Overview*.

Organization of This Document

The following articles explain the problems the Core Data Framework addresses, the solutions it provides, its basic functionality, and common tasks you might perform:

- "Core Data Basics" (page 17) describes the fundamental aspects of the technology.
- "Managed Object Models" (page 27) describes the features of a managed object model.
- "Using a Managed Object Model" (page 31) describes how you use a managed object model in your application.
- "Managed Objects" (page 37) describes the features of a managed object, the `NSManagedObject` class, and how and why you might implement a custom class to represent an entity.

- "Managed Object Accessor Methods" (page 41) describes how to write accessor methods for custom managed objects.
- "Creating and Deleting Managed Objects" (page 51) describes how to correctly instantiate and delete managed objects programmatically.
- "Fetching Managed Objects" (page 57) describes how to fetch managed objects, and some considerations to ensure that fetches are efficient.
- "Using Managed Objects" (page 59) describes issues related to manipulating managed objects in your application.
- "Memory Management Using Core Data" (page 69) describes aspects of memory management when using Core Data.
- "Relationships and Fetched Properties" (page 73) describes relationships, how to model them, and issues related to manipulating relationships between managed objects. It also describes fetched properties, which are like weak unidirectional relationships.
- "Non-Standard Persistent Attributes" (page 83) describes how to use attributes with non-standard value types (such as colors and C-structures).
- "Managed Object Validation" (page 93) describes types of validation, how to implement validation methods, and when to use validation.
- "Faulting and Uniquing" (page 99) describes how Core Data constrains the size of the object graph, and ensures that each managed object within a managed object context is unique.
- "Using Persistent Stores" (page 103) describes how you create a persistent store, how you can migrate a store from one type to another, and manage store metadata.
- "Core Data and Cocoa Bindings" (page 107) describes how Core Data integrates with and leverages Cocoa bindings.
- "Change Management" (page 111) describes the issues that may arise if you create multiple managed object contexts or multiple persistence stacks.
- "Persistent Store Features" (page 117) describes the features of the different types of store, and how you can configure the behavior of the SQLite store.
- "Multi-Threading with Core Data" (page 121) describes some issues related to multi-threading a Core Data application.
- "Core Data Performance" (page 125) describes techniques you can use to ensure a Core Data application is as efficient as possible.
- "Troubleshooting Core Data" (page 133) describes common errors developers make when using Core Data, and how to correct them.
- "Efficiently Importing Data" (page 143) describes how you can import data into a Core Data application.
- "Core Data FAQ" (page 175) provides answers to questions frequently asked about Core Data.
- "Glossary" (page 183) provides a glossary of terms used in Core Data.

Many enhancements were introduced for Core Data on Mac OS X v10.5. This document addresses primarily the v10.5 release, however where possible an explanation of functionality on v10.4 is also provided inline. To avoid confusion, the following articles from the v10.4 release of the documentation are provided in full.

- "Mac OS X v10.4: Using Managed Objects" (page 151) describes issues related to manipulating managed objects in your application on Mac OS X v10.4.

- "Mac OS X v10.4: Managed Object Accessor Methods" (page 159) describes how to implement custom accessor methods on Mac OS X v10.4.
- "Mac OS X v10.4: Non-Standard Persistent Attributes" (page 165) describes how to use attributes with non-standard value types (such as colors and C-structures) on Mac OS X v10.4.
- "Mac OS X v10.4: Versioning" (page 171) describes how to deal with changes to your application's schema and data migration on Mac OS X v10.4.

See Also

You should also refer to:

- *Core Data Overview*
- *Core Data Utility Tutorial*
- *Creating a Managed Object Model with Xcode*
- *Core Data Snippets*
- Building a Sample Core Data Application (ADC Video)
- *CoreRecipes* (ADC Sample Code)
- *ManagedObjectDataFormatter* (A plugin for Xcode)

Core Data Basics

Core Data addresses two main areas of functionality: object graph management, and object persistence. Object graph management includes undo and redo, validation, and maintaining the integrity of relationships between objects. Object persistence means saving objects to and fetching objects from a persistent store (such as a file on disk). Typically, you are responsible for writing all the code to support this functionality. The Core Data Framework provides an infrastructure to manage these tasks for you.

Introduction

Core Data provides an infrastructure for object graph management and persistence. This article first describes what is an object graph and introduces some basic terminology. It then describes the basic Core Data architecture, and the way you use the framework. In order both to manage the object graph and to support object persistence, Core Data needs a rich description of the objects it operates on. You provide this description by creating a "managed object model"—a schema that describes the entities your application uses and the relationships between them. The managed object model is described in the penultimate section, before a description of some things that Core Data is not. For another high-level description of Core Data, see Developing with Core Data.

Object Graphs

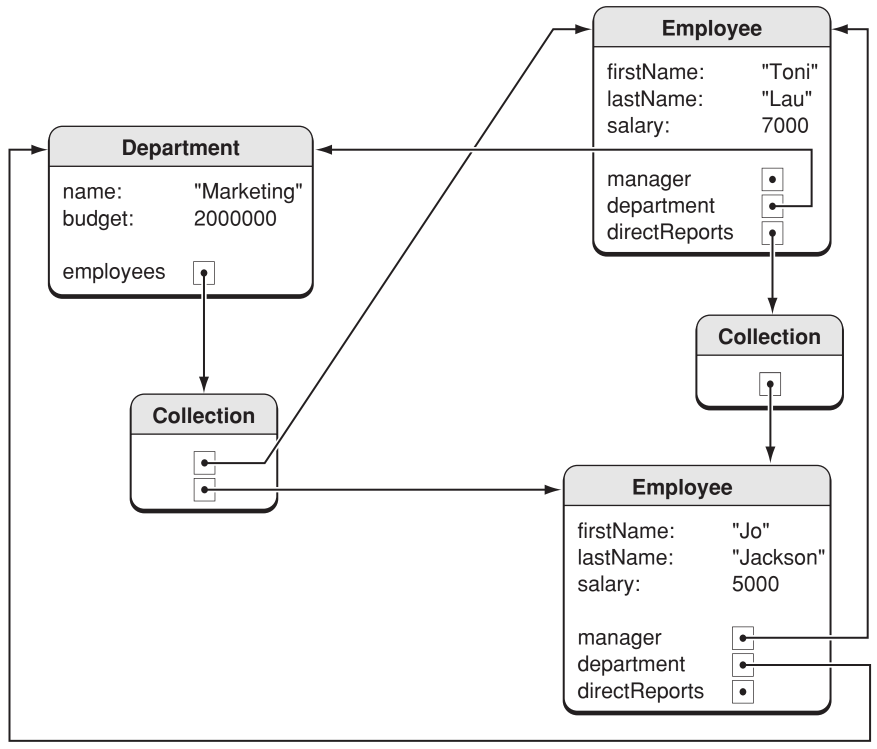
An object graph is a collection of objects, including the relationships between them. It is important to understand what an object graph is, and in particular how relationships between objects are represented in order to fully appreciate the functionality Core Data provides.

In most applications you face the task of managing a graph of model objects (model in the sense of the Model-View-Controller design pattern—see "The Model-View-Controller Design Pattern" in Cocoa Design Patterns). These represent the data in your application—for example, graphics objects, to-do items, or employee objects. Consider the following example, which will be used throughout the remainder of this document.

In the example, an employee is represented by an Employee object that has a number of properties: attributes representing first name, last name, and salary, and relationships to a manager and to the department in which they work. (To understand the differences between property, attribute, and relationship, see "Object Modeling" in Cocoa Design Patterns.) A department in which employees work is represented by a Department object that has attributes representing a name and budget.

A group of three objects—an employee, the employee's manager (also an employee), and the department in which the employee works—represents a small object graph, as illustrated in Figure 1 (page 18). Note that a to-one relationship is represented by a reference to the destination object, and a to-many relationship is represented by a collection object—an `NSMutableSet` object—that contains references to the objects representing its members.

Figure 1 Employee object graph



In addition to the relationships between an employee and his or her manager and the department, you should also consider the reverse relationships—between a manager and the employees that report to the manager (`directReports`) and between department and the employees that work in the department (`employees`). In this example these inverse relationships are modeled. It is possible for relationships to be navigable in only one direction (if you are never interested in finding out from a department object what employees are associated with it, then you do not have to model that relationship), however you are strongly encouraged always to model relationships in both directions.

The Core Data framework also defines another kind of relationship (not illustrated here) known as a **fetched property**. A fetched property is an array calculated by executing a fetch request (see "Fetch Requests" (page 22)) associated with the source object's entity. Fetched properties allow a weak, unidirectional relationship. An example is an iTunes smart playlist, if expressed as a property of a containing object. Songs don't "belong" to a particular playlist, and the playlist may remain even after the songs have been deleted or a remote server has become inaccessible. Note, however, that unlike a smart playlist, fetched properties are not dynamically updated. Fetched properties are also useful for modeling cross-store relationships.

Note : This document uses the employees example for reasons of expediency and clarity. It represents a rich but easily understood problem domain. The utility of the Core Data framework, however, is not restricted to database-style applications, nor is there an expectation of client-server behavior. The framework is equally useful as the basis of a vector graphics application such as Sketch or a presentation application such as Keynote.

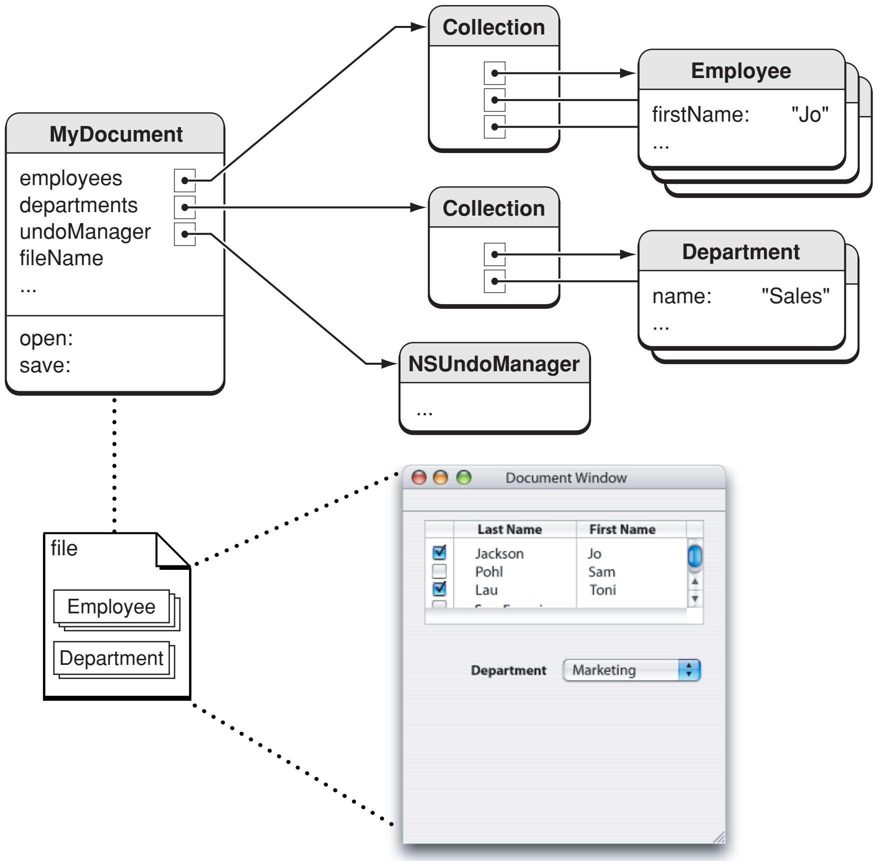
Basic Core Data Architecture

In most applications, you need a means to open a file containing an archive of objects, and a reference to at least one root object. You also need to be able to archive all the objects to a file and—if you want to support undo—to track changes to the objects.

In an employee management application, you need a means to open a file containing an archive of employee and department objects, and a reference to at least one root object—for example, the array of all employees—as illustrated in Figure 2 (page 20). You also need to be able to archive to a file all the employees and all the departments.

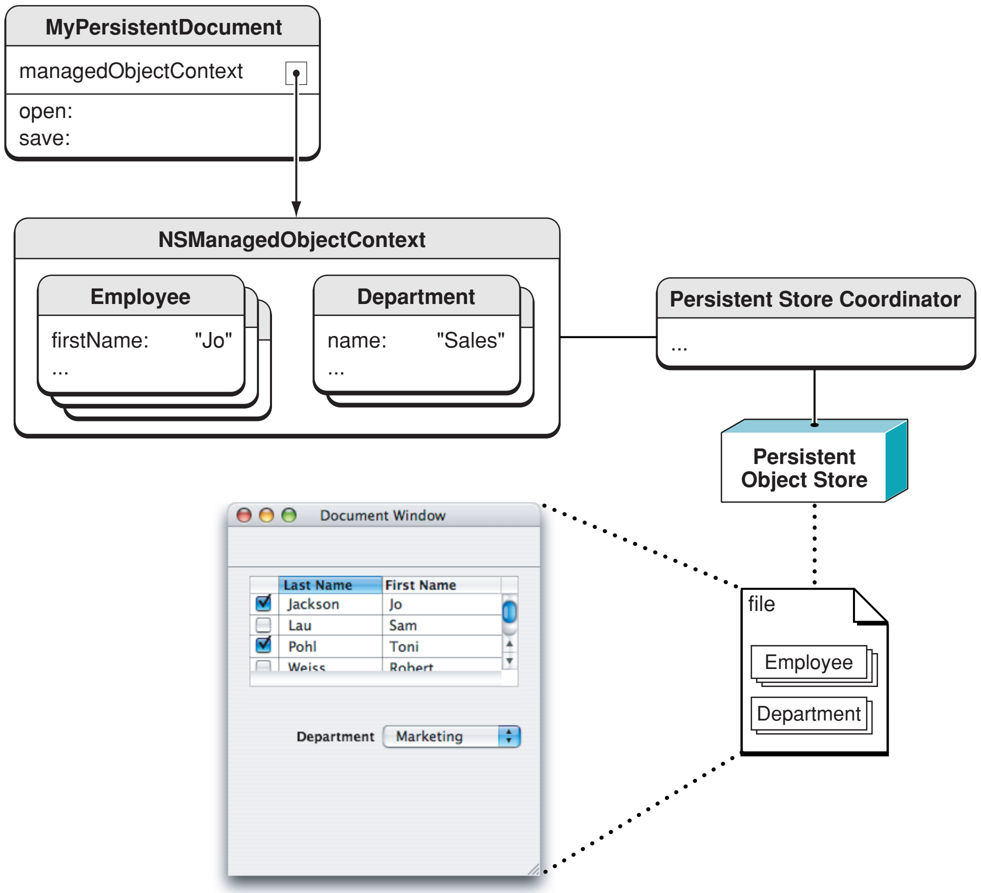
You are responsible for writing the code that manages these tasks either in whole or in part. The Cocoa document architecture provides an application structure and functionality that helps to reduce the burden, but you still have to write methods to support archiving and unarchiving of data, to keep track of the model objects, and to interact with an undo manager to support undo.

Figure 2 Document management using the standard Cocoa document architecture



Using the Core Data framework, most of this functionality is provided for you automatically, primarily through an object known as a **managed object context** (or just context). The managed object context serves as your gateway to an underlying collection of framework objects—collectively known as the **persistence stack**—that mediate between the objects in your application and external data stores. At the bottom of the stack are **persistent object stores**, as illustrated in Figure 3 (page 21).

Figure 3 Document management using Core Data



Note that Core Data is not restricted to document-based applications—indeed it is possible to create a Core Data–based utility with no user interface at all (see *Core Data Utility Tutorial*). The same principles apply in other applications.

Managed Object Contexts

You can think of a managed object context as an intelligent scratch pad. When you fetch objects from a persistent store, you bring temporary copies onto the scratch pad where they form an object graph (or a collection of object graphs). You can then modify those objects however you like. Unless you actually save those changes, however, the persistent store remains unaltered.

Objects that tie into the Core Data framework are known as **managed objects**. All managed objects must be registered with a managed object context. You add objects to the graph and remove objects from the graph using the context. The context tracks the changes you make, both to individual objects' attributes and to the relationships between objects. By tracking changes, the context is able to provide undo and redo support for you. It also ensures that if you change relationships between objects, the integrity of the object graph is maintained.

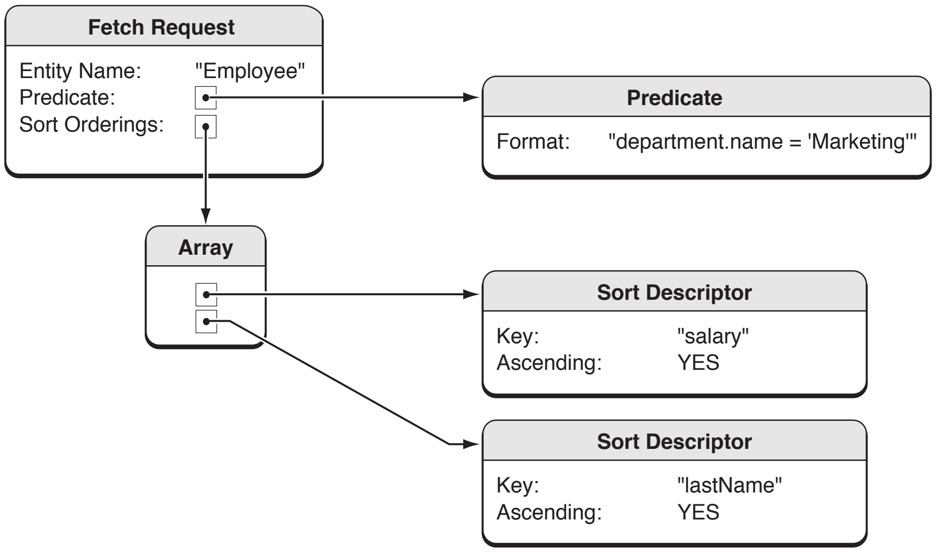
If you choose to save the changes you've made, the context ensures that your objects are in a valid state. If they are, then the changes are written to the persistent store (or stores) and new records added for objects you created and records removed for objects you deleted.

You may have more than one managed object context in your application. For every object in a persistent store there may be at most one corresponding managed object associated with a given context (for more details, see "Faulting and Uniquing" (page 99)). To consider this from a different perspective, a given object in a persistent store may be edited in more than one context simultaneously. Each context, however, has its own managed object that corresponds to the source object, and each managed object may be edited independently. This can lead to inconsistencies during a save—Core Data provides a number of ways to deal with this (see, for example, "Using Managed Objects" (page 59)).

Fetch Requests

To retrieve data using a managed object context, you create a **fetch request**. A fetch request is an object that specifies what data you want, for example, "all Employees," or "all Employees in the Marketing department ordered by salary, highest to lowest." A fetch request has three parts. Minimally it must specify the name of an entity (by implication, you can only fetch one type of entity at a time). It may also contain a predicate object that specifies conditions that objects must match and an array of sort descriptor objects that specifies the order in which the objects should appear, as illustrated in Figure 4 (page 22).

Figure 4 An example fetch request



You send a fetch request to a managed object context, which returns the objects that match your request (possibly none) from the data sources associated with its persistent stores. Since all managed objects must be registered with a managed object context, objects returned from a fetch are automatically registered with the context you used for fetching. Recall though that for every object in a persistent store there may be at most one corresponding managed object associated with a given context (see "Faulting and Uniquing" (page 99)). If a context already contains a managed object for an object returned from a fetch, then the existing managed object is returned in the fetch results.

The framework tries to be as efficient as possible. Core Data is demand driven, so you don't create more objects than you actually need. The graph does not have to represent all the objects in the persistent store. Simply specifying a persistent store does not bring any data objects into the managed object context. When you fetch a subset of the objects from the persistent store, you only get the objects you asked for. If you follow a relationship to an object that hasn't been fetched, it is fetched automatically for you. If you stop using an object (if it's not retained) then it will be deallocated. Note that this is not the same as removing it from the graph.

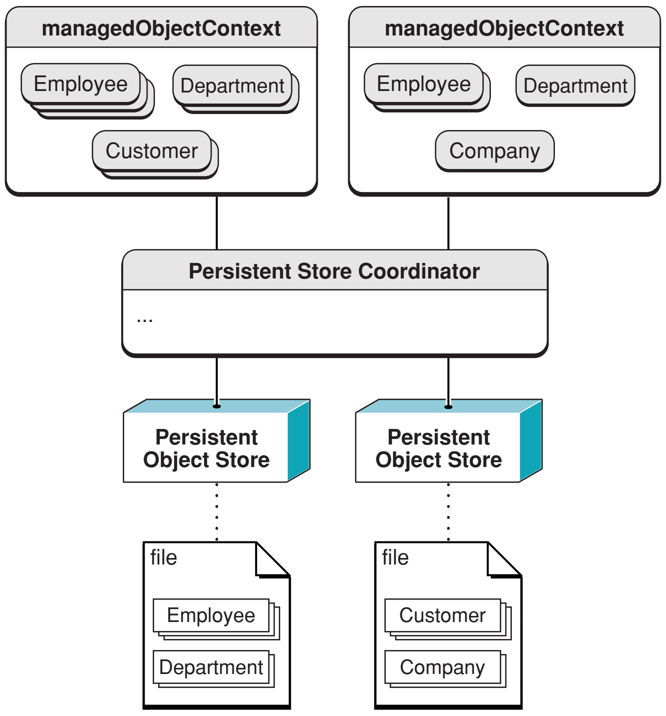
Persistent Store Coordinator

As noted earlier, the collection of framework objects that mediate between the objects in your application and external data stores is referred to collectively as the persistence stack. At the top of the stack are managed object contexts, at the bottom of the stack are persistent object stores. Between managed object contexts and persistent object stores there is a **persistent store coordinator**.

In effect, a persistent store coordinator defines a stack. The coordinator is designed to present a façade to the managed object contexts so that a group of persistent stores appears as a single aggregate store. A managed object context can then create an object graph based on the union of all the data stores the coordinator covers. Note that a coordinator can only be associated with one managed object model. If you want to put different entities into different stores, you must partition your model entities by defining configurations within the managed object models (see "Configurations" (page 30)).

Figure 5 (page 23) shows an example where employees and departments are stored in one file, and customers and companies in another. When you fetch objects, they are automatically retrieved from the appropriate file, and when you save, they are archived to the appropriate file.

Figure 5 Advanced persistence stack



Persistent Stores

A given persistent object store is associated with a single file or other external data store and is ultimately responsible for mapping between data in that store and corresponding objects in a managed object context. Normally, the only interaction you have with a persistent object store is when you specify the location of a new external data store to be associated with your application (for example, when the user opens or saves a document). Most other interactions with the Core Data framework are through the managed object context.

Your application code—and in particular the application logic associated with managed objects—should not make any assumptions about the persistent store in which data may reside. Core Data provides native support for several file formats. You can choose which to use depending on the needs of your application. If at some stage you decide to choose a different file format, your application architecture remains unchanged. Moreover, if your application is suitably abstracted, then you will be able to take advantage of later enhancements to the framework without any additional effort. For example—even if the initial implementation is able to fetch records only from the local file system—if an application makes no assumptions about where it gets its data from, then if at some later stage support is added for a new type of remote persistent store, it should be able to use this new type with no code revisions.

Persistent Documents

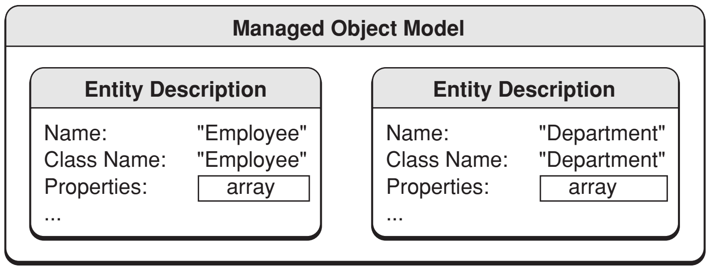
You can create and configure the persistence stack programmatically. In many cases, however, you simply want to create a document-based application able to read and write files. The `NSPersistentDocument` class is a subclass of `NSDocument` that is designed to let you easily take advantage of the Core Data framework. By default, an `NSPersistentDocument` instance creates its own ready-to-use persistence stack, including a managed object context and a single persistent object store. There is in this case a one-to-one mapping between a document and an external data store.

The `NSPersistentDocument` class provides methods to access the document's managed object context and provides implementations of the standard `NSDocument` methods to read and write files that use the Core Data framework. By default you do not have to write any additional code to handle object persistence. A persistent document's undo functionality is integrated with the managed object context.

Managed Objects and the Managed Object Model

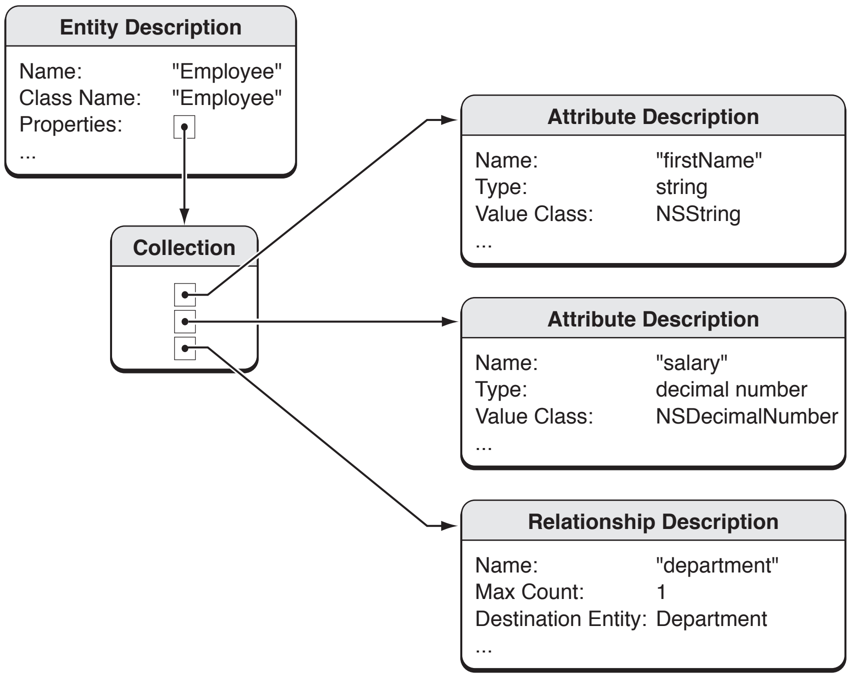
In order both to manage the object graph and to support object persistence, Core Data needs a rich description of the objects it operates on. A **managed object model** is a schema that provides a description of the managed objects, or entities, used by your application, as illustrated in Figure 6 (page 25). You typically create the managed object model graphically using Xcode's Data Model Design tool. (If you wish you can construct the model programmatically at runtime.)

Figure 6 Managed object model with two entities



The model is composed of a collection of entity description objects that each provide metadata about an entity, including the entity's name, the name of the class that represents it in your application (this does not have to be the same as its name), and its attributes and relationships. The attributes and relationships in turn are represented by attribute and relationship description objects, as illustrated in Figure 7 (page 25).

Figure 7 Entity description with two attributes and a relationship



Managed objects must be instances of either `NSManagedObject` or of a subclass of `NSManagedObject`. `NSManagedObject` implements all the basic behavior required of a managed object. A managed object has a reference to the entity description for the entity of which it is an instance. It refers to the entity description to discover metadata about itself, including the name of the entity it represents and information about its attributes and relationships.

`NSManagedObject` is able to represent any entity. It uses a private internal store to maintain its properties. You can access the properties using key-value coding—the object refers to the entity description to determine what are valid keys. You need to create a subclass of `NSManagedObject` (and hence write source code) only if you want to implement additional behavior or if you want to use attribute types that Core Data does not support. For example, if you want to use custom accessors for properties—so that you could, say, invoke a `salary` method rather than rely on key-value coding —you would implement a subclass of `NSManagedObject` for the Employee entity. Similarly, if you want to specify a `fullName` method that returns a concatenation of an Employee's first and last names, you use a subclass. Core Data natively supports only a limited—but useful!—set of types of attribute (`NSString`, `NSNumber`, `NSData`, and `NSDate`). If you want to represent the salary attribute of an Employee using a `float` or if you want to use a custom class to represent an employee's photograph, again you do so with a subclass.

`NSManagedObject`'s ability to represent any entity presents another significant benefit. In traditional Cocoa application development, you need to create object classes to represent the model objects. This involves hand-coding classes with instance variables and, typically, suitable accessor methods. As your application evolves and class and variable names change, you have to rewrite the corresponding source files. Using the Core Data framework, instead of hand-coding concrete classes you can often simply use `NSManagedObject`.

What Core Data Is Not

Having given an overview of what Core Data is, it is also useful to correct some common misperceptions and state what it is not.

- Core Data is not a relational database or a relational database management system (RDBMS). Core Data provides an infrastructure for change management and for saving objects to and retrieving them from storage. It can use SQLite as one of its persistent store types. It is not, though, in and of itself a database.

  To further illustrate this point, you could for example use just an in-memory store in your application. You could use Core Data for change tracking and management, but never actually save any data in a file.

- Core Data is not a silver bullet. It does not remove the need to write code. Although it is possible to create a sophisticated application solely using the Xcode data modeling tool and Interface Builder, for more real-world applications you will still have to write code.

- Core Data does not rely on Cocoa bindings. Core Data integrates well with Cocoa bindings and leverages the same technologies—and used together they can significantly reduce the amount of code you have to write—but it is possible to use Core Data without bindings. You can readily create a Core Data application without a user interface (see *Core Data Utility Tutorial*).

Managed Object Models

Much of Core Data's functionality depends on the schema you create to describe your application's entities, their properties, and the relationships between them. The schema is represented by a managed object model—an instance of `NSManagedObjectModel`. In general, the richer the model, the better Core Data is able to support your application. This article describes the features of a managed object model, how you create one, and how you use it in your application.

Features of a Managed Object Model

A managed object model is an instance of the `NSManagedObjectModel` class. It describes a schema—a collection of entities—that you use in your application. (If you do not understand the term "entity"—or the related terms, "property," "attribute," and "relationship"—you should first read "Core Data Basics" (page 17) and the "Object Modeling" section in Cocoa Design Patterns.)

Entities

A model contains `NSEntityDescription` objects that represent the model's entities. Two important features of an entity are its name, and the name of the class used to represent the entity at runtime. You should be careful to keep clear the differences between an entity, the class used to represent the entity, and the managed objects that are instances of that entity.

An `NSEntityDescription` object may have `NSAttributeDescription` and `NSRelationshipDescription` objects that represent the properties of the entity in the schema. An entity may also have fetched properties, represented by instances of `NSFetchedPropertyDescription`, and the model may have fetch request templates, represented by instances of `NSFetchRequest`.

In a model, entities may be arranged in an inheritance hierarchy, and entities may be specified as abstract.

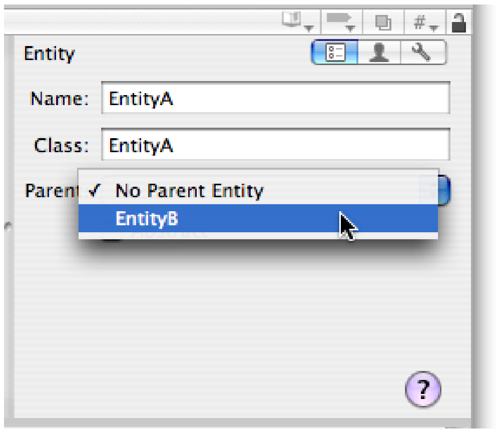
Entity Inheritance

Entity inheritance works in a similar way to class inheritance, and is useful for the same reasons. If you have a number of entities that are similar, you can factor the common properties into a super-entity. Rather than specifying the same properties in several entities, you can define them in one and the sub-entities inherit them. For example, you might define a Person entity with attributes firstName and lastName, and sub-entities Employee and Customer which inherit those attributes.

In many cases, you also implement a custom class to correspond to the entity from which classes representing the sub-entities also inherit. Rather than implementing business logic common to all the entities several times over, you implement them in one place and they are inherited by the subclasses.

If you create a model using the data modeling tool in Xcode, you specify an entity's parent by selecting the name of the entity from the Parent pop-up menu in the entity Info pane, as shown in Figure 1 (page 28).

Figure 1 Selecting a parent entity in Xcode



If you want to create an entity inheritance hierarchy in code, you must build it top-down. You cannot set an entity's super-entity directly, you can only set an entity's sub-entities (using the method `setSubentities:`). To set a super-entity for a given entity, you must therefore set an array of sub-entities for that super entity and include the current entity in that array.

Abstract Entities

You can specify that an entity is abstract—that is, that you will not create any instances of that entity. You typically make an entity abstract if you have a number of entities that all represent specializations of (inherit from) a common entity which should not itself be instantiated. For example, in a drawing application you might have a Graphic entity that defines attributes for x and y coordinates, color, and drawing bounds. You never, though, instantiate a Graphic. Concrete sub-entities of Graphic might be Circle, TextArea, and Line.

Properties

An entity's properties are its attributes and relationships, including its fetched properties (if it has any). Amongst other features, each property has a name and a type. Attributes may also have a default value. Note that a property name cannot be the same as any no-parameter method name of `NSObject` or `NSManagedObject`, for example, you cannot give a property the name "description" (see `NSPropertyDescription`).

Transient properties are properties that you define as part of the model, but which are not saved to the persistent store as part of an entity instance's data. Core Data does track changes you make to transient properties, so they are recorded for undo operations.

Note: If you undo a change to a transient property that uses non-modeled information, Core Data does not invoke your set accessor with the old value—it simply updates the snapshot information.

Attributes

Core Data natively supports a variety of attribute types, such as string, date, and integer (represented as instances of `NSString`, `NSDate`, and `NSNumber` respectively). If you want to use an attribute type that is not natively supported, you can use one of the techniques described in Non-Standard Persistent Attributes (page 83).

You can specify that an attribute is optional—that is, it is not required to have a value. In general, however, you are discouraged from doing so—especially for numeric values (typically you can get better results using a mandatory attribute with a default value—in the model—of `0`). The reason for this is that SQL has special comparison behavior for `NULL` that is unlike Objective-C's `nil`. `NULL` in a database is not the same as `0`, and searches for `0` will not match columns with `NULL`.

```
false == (NULL == 0)
false == (NULL != 0)
```

Moreover, `NULL` in a database is not equivalent to an empty string or empty data blob, either:

```
false == (NULL == @"")
false == (NULL != @"")
```

This has no bearing on relationships.

Relationships

Core Data supports to-one and to-many relationships, and **fetched properties**. Fetched properties represent weak, one-way relationships. In the employees and departments domain, a fetched property of a department might be "recent hires" (employees do not have an inverse to the recent hires relationship).

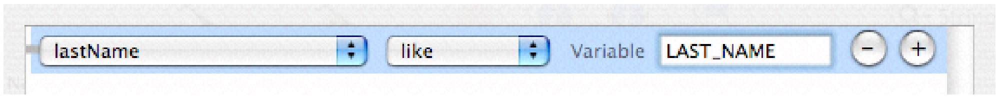
You can specify the optionality and cardinality of a relationship, and its delete rule. You should typically model a relationship in both directions. A many-to-many relationship is one in which a relationship and its inverse are both to-many. Relationships are described in greater detail in "Relationships and Fetched Properties" (page 73).

Fetch Request Templates

You use the `NSFetchRequest` class to describe fetch requests to retrieve objects from a persistent store. It is often the case that you want to execute the same request on multiple occasions, or execute requests that follow a given pattern but which contain variable elements (typically supplied by the user). For example, you might want to be able to retrieve all publications written by a certain author, perhaps after a date specified by the user at runtime.

You can predefine fetch requests and store them in a managed object model as named templates. This allows you to pre-define queries that you can retrieve as necessary from the model. Typically, you define fetch request templates using the Xcode data modeling tool (see *Xcode Tools for Core Data*). The template may include variables, as shown in Figure 2.

Figure 2 Xcode predicate builder



For more about using fetch request templates, see "Accessing and Using a Managed Object Model at Runtime" (page 32).

User Info Dictionaries

Many of the elements in a managed object model—entities, attributes, and relationships—have an associated user info dictionary. You can put whatever information you want into a user info dictionary, as key-value pairs. Common information to put into the user info dictionary includes version details for an entity, and values used by the predicate for a fetched property.

Configurations

A configuration has a name and an associated set of entities. The sets may overlap—that is, a given entity may appear in more than one configuration. You establish configurations programmatically using `setEntities:forConfiguration:` or using the Xcode data modeling tool (see *Xcode Tools for Core Data*), and retrieve the entities for a given configuration name using `entitiesForConfiguration:`.

You typically use configurations if you want to store different entities in different stores. A persistent store coordinator can only have one managed object model, so by default each store associated with a given coordinator must contain the same entities. To work around this restriction, you can create a model that contains the union of all the entities you want to use. You then create configurations in the model for each of the subsets of entities that you want to use. You can then use this model when you create a coordinator. When you add stores, you specify the different store attributes by configuration. When you are creating your configurations, though, remember that you cannot create cross-store relationships.

Using a Managed Object Model

This article describes how you use a managed object model in your application.

Creating and Loading a Managed Object Model

You usually create a model in Xcode, as described in *Creating a Managed Object Model with Xcode*. You can also create a model entirely in code, as show in Listing 3 (page 35) and described in *Core Data Utility Tutorial*—typically, however, this is too long-winded to consider in anything but the most trivial application. (You are nevertheless encouraged to review the tutorial to gain an understanding of what the modeling tool does, and in particular to gain an appreciation that the model is simply a collection of objects.)

Compiling a Data Model

A data model is a deployment resource. In addition to details of the entities and properties in the model, a model you create in Xcode contains information about the diagram—its layout, colors of elements, and so on. This latter information is not needed at runtime. The model file is compiled to remove the extraneous information and make runtime loading of the resource as efficient as possible. The `xcdatamodel` "source" file is compiled into a `mom` deployment file using the model compiler, `momc`.

`momc` is located in `/Library/Application Support/Apple/Developer Tools/Plug-ins/XDCoreDataModel.xdplugin/Contents/Resources/`. If you want to use it in your own build scripts, its usage is `momc source destination`, where *`source`* is the path of the Core Data model to compile and *`destination`* is the path of the output `mom` file.

Loading a Data Model

In many cases, you do not have to write any code to load a model. If you use a document-based application, `NSPersistentDocument` manages the task of finding and loading your application's model for you. If you use the Core Data Application template, the application delegate includes code to retrieve the model. Note that the name of a model—as represented by the filename used to store it on disk—is not relevant at runtime. Once the model is loaded by Core Data, the filename is meaningless and has no use, so you can name the model file whatever you like.

If you want to load a model yourself, there are two mechanisms you can use, each with its own benefits:

- You can create a merged model from a specific collection of bundles, using the class method `mergedModelFromBundles:`.
- You can load a single model from a specific URL, using the instance method `initWithContentsOfURL:`.

The class method is useful in cases where segregation of models is not important—for example, you may know your application and a framework it links to both have models you need or want to load. The class method allows you to easily load all of the models at once without having to consider what the names are, or put in specialized initialization code to ensure all of your models are found

In cases where you have more than one model, however—and particularly in cases where the models represent different versions of the same schema—knowing which model to load is essential (merging together models with the same entities at runtime into a single collection would cause naming collisions and errors). In these situations, you use the instance method. Additionally, there may be situations when you want to store the model outside of the bundle for your application, thus requiring the need to reference it via a file-system URL.

Note there is also a class method, `modelByMergingModels:`, which merges a given array of models much like the `mergedModelFromBundles:` method does. Thus, you can still load individual models via URLs and then unify them before instantiating a coordinator with them.

Changing a Model

Since a model describes the structure of the data in a persistent store, changing any parts of a model that alters the schema renders it incompatible with (and so unable to open) the stores it previously created. If you change your schema, you therefore need to migrate the data in existing stores to new version (see "Mac OS X v10.4: Versioning" (page 171)). For example, if you add a new entity or a new attribute to an existing entity, you will not be able to open old stores; if you add a validation constraint or set a new default value for an attribute, you will be able to open old stores.

Accessing and Using a Managed Object Model at Runtime

It is important to realize that, at runtime, a managed object model is simply a graph of objects. This knowledge is especially useful if you need to gain access to details of the model programmatically. You might need to do this either to modify the model (you can do this only before it is used at runtime, see `NSManagedObjectModel`), or to retrieve information such as a localized entity name, the data type of an attribute, or a fetch request template.

There are a number of ways you can access a managed object model at runtime. Through the persistence stack you ultimately get the model from the persistent store coordinator. Thus to get the model from a managed object context, you use the following code:

```
[[aManagedObjectContext persistentStoreCoordinator] managedObjectModel];
```

You can also retrieve the model from an entity description, so given a managed object you can retrieve its entity description and hence the model, as shown in the following example.

```
[[aManagedObject entity] managedObjectModel];
```

In some cases, you maintain a "direct" reference to the model—that is, a method that returns the model directly. `NSPersistentDocument` provides `managedObjectModel` that returns the model associated with the persistent store coordinator used by the document's managed object context. If you use the Core Data Application template, the application delegate maintains a reference to the model.

Creating Fetch Request Templates Programmatically

You can create fetch request templates programmatically and associate them with a model using `setFetchRequestTemplate:forName:` as illustrated in Listing 1. Recall, though, that you can only modify the model before it has been used by a store coordinator.

Listing 1 Creating a fetch request template programmatically

```
NSManagedObjectModel *model = ...;
NSFetchRequest *requestTemplate = [[NSFetchRequest alloc] init];
NSEntityDescription *publicationEntity =
    [[model entitiesByName] objectForKey:@"Publication"];
[requestTemplate setEntity:publicationEntity];

NSPredicate *predicateTemplate = [NSPredicate predicateWithFormat:
    @"(mainAuthor.firstName like[cd] $FIRST_NAME) AND \
        (mainAuthor.lastName like[cd] $LAST_NAME) AND \
        (publicationDate > $DATE)"];
[requestTemplate setPredicate:predicateTemplate];

[model setFetchRequestTemplate:requestTemplate
    forName:@"PublicationsForAuthorSinceDate"];
[requestTemplate release];
```

Accessing Fetch Request Templates

You can retrieve and use a fetch request template as illustrated in the code fragment in "Accessing and Using a Managed Object Model at Runtime." The substitution dictionary must contain keys for all the variables defined in the template; if you want to test for a null value, you must use an `NSNull` object—see Using Predicates.

Listing 2 Using a fetch request template

```
NSManagedObjectModel *model = ...;
NSError *error = nil;
NSDictionary *substitutionDictionary = [NSDictionary dictionaryWithObjectsAndKeys:
    @"Fiona", @"FIRST_NAME", @"Verde", @"LAST_NAME",
    [NSDate dateWithTimeIntervalSinceNow:-31356000], @"DATE", nil];
NSFetchRequest *fetchRequest =
    [model fetchRequestFromTemplateWithName:@"PublicationsForAuthorSinceDate"
            substitutionVariables:substitutionDictionary];
NSArray *results =
    [aManagedObjectContext executeFetchRequest:fetchRequest error:&error];
```

If the template does not have substitution variables, you must either:

1. Use `fetchRequestFromTemplateWithName:substitutionVariables:` and pass `nil` as the variables argument; or

2. Use `fetchRequestTemplateForName:` and `copy` the result.

   If you try to use the fetch request returned by `fetchRequestTemplateForName:`, this generates an exception ("`Can't modify a named fetch request in an immutable model`").

Localizing a Managed Object Model

You can localize most aspects of a managed object model, including entity and property names and error messages. It is important to consider that localization also includes "localization into your own language." Even if you do not plan to provide foreign-language versions of your application, you can provide a better experience for your users if error messages show "natural language" names rather than "computer language" names (for example, "First Name is a required property" rather than "firstName is a required property").

You localize a model by providing a localization dictionary that follows the pattern shown in the table below.

Table 1 Keys and values in a localization dictionary for a managed object model

Key	Value	Note
"`Entity/`NonLocalizedEntityName"	"LocalizedEntityName"	
"`Property/`NonLocalizedPropertyName`/Entity/`EntityName"	"LocalizedPropertyName"	1
"`Property/`NonLocalizedPropertyName"	"LocalizedPropertyName"	
"`ErrorString/`NonLocalizedErrorString"	"LocalizedErrorString"	

Note: (1) For properties in different entities with the same non-localized name but which should have different localized names.

You can access the localization dictionary using the method `localizationDictionary`. Note, however, that in the implementation in Mac OS X version 10.4, `localizationDictionary` may return `nil` until Core Data lazily loads the dictionary for its own purposes (for example, reporting a localized error).

Strings File

The easiest way to localize a model is to create a corresponding strings file—the strings file name is the same as the model file name, but with a `.strings` rather than a `.xcdatamodel` extension (for example, for a model file named `MyDocument.xcdatamodel` the corresponding strings file is `MyDocumentModel.strings`—if your model file name already includes the suffix "Model", you must append a further "Model", so the strings file corresponding to `JimsModel.xcdatamodel` would be the rather unlikely-looking `JimsModelModel.strings`). The file format is similar to a standard strings file you use for localization (see Strings Files) but the key and value pattern follows that shown in Table 1 (page 34).

A strings file for a model that includes an employee entity might contain the following:

```
"Entity/Emp" = "Employee";
"Property/firstName" = "First Name";
"Property/lastName" = "Last Name";
"Property/salary" = "Salary";
```

A further example is given in *NSPersistentDocument Core Data Tutorial*.

Setting a Localization Dictionary Programmatically

You can set a localization dictionary at runtime using the `NSManagedObjectModel` method `setLocalizationDictionary:`. You must create a dictionary with keys and values as shown in Table 1 (page 34), and associate it with the model. You must ensure you do this before the model is used to fetch or create managed objects, as the model is uneditable thereafter. The listing shown in Listing 3 (page 35) illustrates the creation in code of a managed object model including a localization dictionary. The entity is named "Run" and is represented at runtime by the Run class. The entity has two attributes, "date" and "processID"—a date and an integer respectively. The process ID has a constraint that its value must not be less than zero.

Listing 3 Creating a managed object model in code

```
NSManagedObjectModel *mom = [[NSManagedObjectModel alloc] init];
NSEntityDescription *runEntity = [[NSEntityDescription alloc] init];
[runEntity setName:@"Run"];
[runEntity setManagedObjectClassName:@"Run"];
[mom setEntities:[NSArray arrayWithObject:runEntity]];
[runEntity release];

NSMutableArray *runProperties = [NSMutableArray array];

NSAttributeDescription *dateAttribute = [[NSAttributeDescription alloc] init];
[runProperties addObject:dateAttribute];
[dateAttribute release];
[dateAttribute setName:@"date"];
[dateAttribute setAttributeType:NSDateAttributeType];
[dateAttribute setOptional:NO];

NSAttributeDescription *idAttribute= [[NSAttributeDescription alloc] init];
[runProperties addObject:idAttribute];
[idAttribute release];
[idAttribute setName:@"processID"];
[idAttribute setAttributeType:NSInteger32AttributeType];
[idAttribute setOptional:NO];
[idAttribute setDefaultValue:[NSNumber numberWithInt:0]];

NSPredicate *validationPredicate = [NSPredicate predicateWithFormat:@"SELF >= 0"];
NSString *validationWarning = @"Process ID < 0";
[idAttribute setValidationPredicates:[NSArray arrayWithObject:validationPredicate]
    withValidationWarnings:[NSArray arrayWithObject:validationWarning]];

[runEntity setProperties:runProperties];

NSMutableDictionary *localizationDictionary = [NSMutableDictionary dictionary];
[localizationDictionary setObject:@"Process ID"
    forKey:@"Property/processID/Entity/Run"];
[localizationDictionary setObject:@"Date"
    forKey:@"Property/date/Entity/Run"];
[localizationDictionary setObject:@"Process ID must not be less than 0"
    forKey:@"ErrorString/Process ID < 0"];
[mom setLocalizationDictionary:localizationDictionary];
```

Managed Objects

This article provides basic information about what is a managed object, how its is data stored, how you implement a custom managed object class, object life-cycle issues, and faulting. There are several other articles in the *Core Data Programming Guide* that describe other aspects of using managed objects:

- "Creating and Deleting Managed Objects" (page 51)
- "Fetching Managed Objects" (page 57)
- "Using Managed Objects" (page 59)

Basics

Managed objects are instances of the `NSManagedObject` class, or of a subclass of `NSManagedObject`, that represent instances of an entity. `NSManagedObject` is a generic class that implements all the basic behavior required of a managed object. You can create custom subclasses of `NSManagedObject`, although this is often not required. If you do not need any custom logic for a given entity, you do not need to create a custom class for that entity. You might implement a custom class, for example, to provide custom accessor or validation methods, to use non-standard attributes, to specify dependent keys, to calculate derived values, or to implement any other custom logic.

A managed object is associated with an entity description (an instance of `NSEntityDescription`) that provides metadata about the object (including the name of the entity that the object represents and the names of its attributes and relationships) and with a managed object context that tracks changes to the object graph.

It is important to understand that a managed object is an abstraction, and works in conjunction with a managed object context ("context"). In a given context, a managed object provides a representation of data records in a persistent store. In a given context, for a given record in a persistent store, there can be only one corresponding managed object, but there may be multiple contexts each containing a separate managed object representing that record. Put another way, there is a to-one relationship between a managed object and the data record it represents, but a to-many relationship between the data record and corresponding managed objects.

The context acts as a scratchpad. You can create and register managed objects with it, make changes to the objects, and undo and redo changes as you wish. If you make changes to managed objects associated with a given context, those changes remain local to that context until you commit the changes by sending the context a `save:` message. At that point—provided that there are no validation errors—the changes are committed to the store. As a corollary, simply creating a managed object does not cause it to be saved to a persistent store, and deleting a managed object does not cause the record to be removed from the store—you must save the context to commit the change.

Properties and Data Storage

In some respects, an `NSManagedObject` acts like a dictionary—it is a generic container object that efficiently provides storage for the properties defined by its associated `NSEntityDescription` object. `NSManagedObject` provides support for a range of common types for attribute values, including string, date, and number (see `NSAttributeDescription` for full details). There is therefore commonly no need to define instance variables in subclasses. There are some performance considerations to bear in mind if you use large binary data objects—see "Large Data Objects (BLOBs)" (page 130).

Non-Standard Attributes

`NSManagedObject` provides support for a range of common types for attribute values, including string, date, and number (see `NSAttributeDescription` for full details). By default, `NSManagedObject` stores its properties as objects in an internal structure, and in general Core Data is more efficient working with storage under its own control rather using custom instance variables.

Sometimes you want to use types that are not supported directly, such as colors and C structures. For example, in a graphics application you might want to define a Rectangle entity that has attributes color and bounds that are an instance of `NSColor` and an `NSRect` struct respectively. This may require you to create a subclass of `NSManagedObject`, and is described in "Non-Standard Persistent Attributes" (page 83).

Dates and Times

`NSManagedObject` represents date attributes using `NSDate` objects, and stores times internally as an `NSTimeInterval` value since the reference date (which has a time zone of GMT). Time zones are not explicitly stored—indeed you should always represent a Core Data date attribute in GMT, this way searches are normalized in the database. If you need to preserve the time zone information, you need to store a time zone attribute in your model. This may again require you to create a subclass of `NSManagedObject`.

Custom Managed Object Classes

In combination with the entity description in the managed object model, `NSManagedObject` provides a rich set of default behaviors including support for arbitrary properties and value validation. There are nevertheless many reasons why you might wish to subclass `NSManagedObject` to implement custom features. There are also, however, some things to avoid when subclassing.

Overriding Methods

`NSManagedObject` itself customizes many features of `NSObject` so that managed objects can be properly integrated into the Core Data infrastructure. Core Data relies on `NSManagedObject`'s implementation of the following methods, which you should therefore not override: `primitiveValueForKey:`, `setPrimitiveValue:forKey:`, `isEqual:`, `hash`, `superclass`, `class`, `self`, `zone`, `isProxy`, `isKindOfClass:`, `isMemberOfClass:`, `conformsToProtocol:`, `respondsToSelector:`, `retain`, `release`, `autorelease`, `retainCount`, `managedObjectContext`, `entity`, `objectID`, `isInserted`, isUpdated, isDeleted, and isFault. You are discouraged from overriding description—if this method fires a fault during a debugging operation, the results may be unpredictable—and initWithEntity:insertIntoManagedObjectContext:. You should typically not override the key-value coding methods such as valueForKey: and setValue:forKeyPath:.

In addition to methods you should not override, there are others that if you do override you should invoke the superclass's implementation first, including awakeFromInsert, awakeFromFetch, and validation methods such as validateForUpdate:.

Custom Accessor Methods

On Mac OS X v10.5, Core Data dynamically generates efficient public and primitive get and set attribute accessor methods and relationship accessor methods for managed object classes. Typically, therefore, there's no need to write custom accessor methods for properties that are defined in the entity of a managed object's corresponding managed object model. Should you wish to do so, however, there are several implementation patterns you must follow; these are described in "Managed Object Accessor Methods" (page 41). (If you are using Mac OS X v10.4, Core Data does not dynamically generate accessor methods—for implementation patterns, see "Mac OS X v10.4: Managed Object Accessor Methods" (page 159).)

Object Life-Cycle—Initialization and Deallocation

It is important to appreciate that Core Data "owns" the life-cycle of managed objects. With faulting and undo, you cannot make the same assumptions about the life-cycle of a managed object as you would of a standard Cocoa object—managed objects can be instantiated, destroyed, and resurrected by the framework as it requires.

When a managed object is created, it is initialized with the default values given for its entity in the managed object model. In many cases the default values set in the model may be sufficient. Sometimes, however, you may wish to perform additional initialization—perhaps using dynamic values (such as the current date and time) that cannot be represented in the model.

In a typical Cocoa class, you usually override the designated initializer (often the init method). In a subclass of NSManagedObject, there are three different ways you can customize initialization —by overriding initWithEntity:insertIntoManagedObjectContext:, awakeFromInsert, or awakeFromFetch. You should not override init. You are discouraged from overriding initWithEntity:insertIntoManagedObjectContext: as state changes made in this method may not be properly integrated with undo and redo. The two other methods, awakeFromInsert and awakeFromFetch, allow you to differentiate between two different situations.

awakeFromInsert is invoked only once in the lifetime of an object—when it is first created (immediately after you invoke initWithEntity:insertIntoManagedObjectContext: or insertNewObjectForEntityForName:inManagedObjectContext:. You can use awakeFromInsert to initialize special default property values, such as the creation date of an object, as illustrated in the following example.

```
- (void) awakeFromInsert
{
    [super awakeFromInsert];
    [self setCreationDate:[NSDate date]];
}
```

`awakeFromFetch` is invoked when an object is re-initialized from a persistent store (during a fetch). You can override it to, for example, establish transient values and other caches. Change processing is explicitly disabled around `awakeFromFetch` so that you can conveniently use public set accessor methods without dirtying the object or its context. This does mean, however, that you should not manipulate relationships, as changes will not be properly propagated to the destination object or objects. Instead, you can override `awakeFromInsert` or employ any of the run loop related methods such as `performSelector:withObject:afterDelay:`.

You should typically not override `dealloc` or `finalize` to clear transient properties and other variables. Instead, you should override `didTurnIntoFault`. `didTurnIntoFault` is invoked automatically by Core Data when an object is turned into a fault and immediately prior to actual deallocation. You might turn a managed object into a fault specifically to reduce memory overhead (see "Reducing Memory Overhead" (page 129)), so it is important to ensure that you properly perform clean-up operations in `didTurnIntoFault`.

Validation

`NSManagedObject` provides consistent hooks for validating property and inter-property values. You typically should not override `validateValue:forKey:error:`, instead you should implement methods of the form `validate<Key>:error:`, as defined by the `NSKeyValueCoding` protocol. If you want to validate inter-property values, you can override `validateForUpdate:` and/or related validation methods.

You should not call `validateValue:forKey:error:` within custom property validation methods—if you do so you will create an infinite loop when `validateValue:forKey:error:` is invoked at runtime. If you do implement custom validation methods, you should typically not call them directly. Instead you should call `validateValue:forKey:error:` with the appropriate key. This ensures that any constraints defined in the managed object model are applied.

If you implement custom inter-property validation methods (such as `validateForUpdate:`), you should call the superclass's implementation first. This ensures that individual property validation methods are also invoked. If there are multiple validation failures in one operation, you should collect them in an array and add the array—using the key `NSDetailedErrorsKey`—to the userInfo dictionary in the `NSError` object you return.

Faulting

Managed objects typically represent data held in a persistent store. In some situations a managed object may be a "fault"—an object whose property values have not yet been loaded from the external data store—see "Faulting and Uniquing" (page 99) for more details. When you access persistent property values, the fault "fires" and the data is retrieved from the store automatically. This can be a comparatively expensive process (potentially requiring a round trip to the persistent store), and you may wish to avoid unnecessarily firing a fault (see "Faulting Behavior" (page 126)).

Although the `description` method does not cause a fault to fire, if you implement a custom `description` method that accesses the object's persistent properties, this will cause a fault to fire. You are strongly discouraged from overriding `description` in this way.

Note that there is no way to load individual attributes of a managed object on an as-needed basis. For patterns to deal with large attributes, see "Large Data Objects (BLOBs)" (page 130).

Managed Object Accessor Methods

This article explains why you might want to implement custom accessor methods for managed objects, and how to implement them for attributes and for relationships. It also illustrates how to implement primitive accessor methods.

Overview

On Mac OS X v10.5, Core Data dynamically generates efficient public and primitive get and set attribute accessor methods and relationship accessor methods for managed object classes. Typically, therefore, there's no need to for you to write accessor methods for properties that are defined in the entity of a managed object's corresponding managed object model—although you may use the Objective-C 2 properties feature to declare properties to suppress compiler warnings. To get the best performance—and to benefit from type-checking—you use the accessor methods directly, although they are also key-value coding (KVC) compliant so if necessary you can use standard key-value coding methods such as `valueForKey:`. You do need to write custom accessor methods if you use transient properties to support non-standard data types (see "Non-Standard Persistent Attributes" (page 83)) or if you use scalar instance variables to represent an attribute.

Mac OS X v10.4: This article describes accessor methods for Mac OS X v10.5; if you are using Mac OS X v10.4, see "Mac OS X v10.4: Managed Object Accessor Methods" (page 159).

Custom implementation

The implementation of accessor methods you write for subclasses of `NSManagedObject` is typically different from those you write for other classes.

- If you do not provide custom instance variables, you retrieve property values from and save values into the internal store using primitive accessor methods.
- You must ensure that you invoke the relevant access and change notification methods (`willAccessValueForKey:`, `didAccessValueForKey:`, `willChangeValueForKey:`, `didChangeValueForKey:`, `willChangeValueForKey:withSetMutation:usingObjects:`, and `didChangeValueForKey:`).

  `NSManagedObject` disables automatic key-value observing (KVO, see *Key-Value Observing Programming Guide*) change notifications, and the primitive accessor methods do not invoke the access and change notification methods.
- In accessor methods for properties that are *not* defined in the entity model, you can either enable automatic change notifications or invoke the appropriate change notification methods.

You can use the Xcode data modeling tool to generate the code for accessor methods for any modeled property.

Key-value coding access pattern

The access pattern key-value coding uses for managed objects is largely the same as that used for subclasses of `NSObject`—see `valueForKey:`. The difference is that, if after checking the normal resolutions `valueForKey:` would throw an unbound key exception, the key-value coding mechanism for `NSManagedObject` checks whether the key is a modeled property. If the key matches an entity's property, the mechanism looks first for an accessor method of the form `primitive`*Key*, and if that is not found then looks for a value for *key* in the managed object's internal storage. If these fail, `NSManagedObject` throws an unbound key exception (just like `valueForKey:`).

Dynamically-Generated Accessor Methods

By default, Core Data dynamically creates efficient public and primitive get and set accessor methods for modeled properties (attributes *and* relationships) of managed object classes. This includes the key-value coding mutable proxy methods such as `add<Key>Object:` and `remove<Key>s:`, as detailed in the documentation for `mutableSetValueForKey:`—managed objects are effectively mutable proxies for all their to-many relationships.

Note: If you choose to implement your own accessors, the dynamically-generated methods never replace your own code.

For example, given an entity with an attribute `firstName`, Core Data automatically generates `firstName`, `setFirstName:`, `primitiveFirstName`, and `setPrimitiveFirstName:`. *Core Data does this even for entities represented by* `NSManagedObject`. To suppress compiler warnings when you invoke these methods, you should use the Objective-C 2.0 declared properties feature (see Declared Properties), as described in "Declaration" (page 42).

The property accessor methods Core Data generates are by default `(nonatomic, retain)`—*this is the recommended configuration*. The methods are `nonatomic` because non-atomic accessors are more efficient than atomic accessors, and in general it is not possible to assure thread safety in a Core Data application at the level of accessor methods. (To understand how to use Core Data in a multi-threaded environment, see Multi-Threading with Core Data (page 121).)

In addition to always being `nonatomic`, dynamic properties only honor `retain` or `copy` attributes—`assign` is treated as `retain`. You should use `copy` sparingly as it increases overhead. You cannot use `copy` for relationships because `NSManagedObject` does not adopt the `NSCopying` protocol, and it's irrelevant to the behavior of to-many relationships.

Important: If you specify `copy` for a to-one relationship, you will generate a *run-time* error.

Declaration

You can use Objective-C 2 properties to declare properties of managed object classes—you typically do this so that you can use the default accessors Core Data provides without generating compiler warnings. *The easiest way to generate the declarations is to select the relationship in the Xcode modeling tool and choose Design > Data Model > Copy Obj-C 2.0 Method Declarations to Clipboard.* and then modify the code if necessary.

You declare attributes and relationships as you would properties for any other object, as illustrated in the following example. When you declare a to-many relationship, the property type should be `NSSet *`. (The value returned from the get accessor is *not* a KVO-compliant mutable proxy—for more details, see "To-many relationships" (page 60).)

```
@interface Employee : NSManagedObject
{ }
@property(nonatomic, retain) NSString* firstName, lastName;
@property(nonatomic, retain) Department* department;
@property(nonatomic, retain) Employee* manager;
@property(nonatomic, retain) NSSet* directReports;
@end
```

If you are not using a custom class, you can declare properties in a category of `NSManagedObject`:

```
@interface NSManagedObject (EmployeeAccessors)
{ }
@property(nonatomic, retain) NSString* firstName, lastName;
@property(nonatomic, retain) Department* department;
@property(nonatomic, retain) Employee* manager;
@property(nonatomic, retain) NSSet* directReports;
@end
```

You can use the same techniques to suppress compiler warnings for the automatically-generated to-many relationship mutator methods, for example:

```
@interface Employee (DirectReportsAccessors)

- (void)addDirectReportsObject:(Employee *)value;
- (void)removeDirectReportsObject:(Employee *)value;
- (void)addDirectReports:(NSSet *)value;
- (void)removeDirectReports:(NSSet *)value;

@end
```

You typically retain attributes, although to preserve encapsulation where the attribute class has a mutable subclass and it implements the `NSCopying` protocol you can also use `copy`, for example:

```
@property(nonatomic, copy) NSString* firstName, lastName;
```

Implementation

You can specify an implementation using the `@dynamic` keyword, as shown in the following example—although since `@dynamic` is the default, there is no need to do so:

```
@dynamic firstName, lastName;
@dynamic department, manager;
@dynamic directReports;
```

There should typically be no need for you to provide your own implementation of these methods, unless you want to support scalar values. The methods that Core Data generates at runtime are more efficient than those you can implement yourself.

Inheritance

If you have two subclasses of `NSManagedObject` where the parent class implements a dynamic property and its subclass (the grandchild of `NSManagedObject`) overrides the methods for the property, those overrides cannot call `super`.

```
@interface Parent : NSManagedObject
@property(nonatomic, retain) NSString* parentString;
@end

@implementation Parent
@dynamic parentString;
@end

@interface Child : Parent
@end

@implementation Child
- (NSString *)parentString
{
    // this throws a "selector not found" exception
    return parentString.foo;
}
@end
```

Custom Attribute and To-One Relationship Accessor Methods

Important: You are strongly encouraged to use dynamic properties (that is, properties whose implementation you specify as `@dynamic`) instead of creating custom implementations for standard or primitive accessor methods.

If you want to implement your own attribute or to-one relationship accessor methods, you use the primitive accessor methods to get and set values from and to the managed object's private internal store. You must invoke the relevant access and change notification methods, as illustrated in Listing 1 (page 44). `NSManagedObject`'s implementation of the primitive set accessor method handles memory management for you.

Listing 1 Implementation of a custom managed object class illustrating attribute accessor methods

```
@interface Department : NSManagedObject
{
}
@property(nonatomic, retain) NSString *name;
@end

@interface Department (PrimitiveAccessors)
- (NSString *)primitiveName;
- (void)setPrimitiveName:(NSString *)newName;
@end
```

```
@implementation Department

@dynamic name;

- (NSString *)name
{
    [self willAccessValueForKey:@"name"];
    NSString *myName = [self primitiveName];
    [self didAccessValueForKey:@"name"];
    return myName;
}

- (void)setName:(NSString *)newName
{
    [self willChangeValueForKey:@"name"];
    [self setPrimitiveName:newName];
    [self didChangeValueForKey:@"name"];
}
@end
```

The default implementation does not copy attribute values. If the attribute value may be mutable and implements the `NSCopying` protocol (as is the case with `NSString`, for example), you can copy the value in a custom accessor to help preserve encapsulation (for example, in the case where an instance of `NSMutableString` is passed as a value). This is illustrated in Listing 2 (page 45). Notice also that (for the purposes of illustration) in this example the get accessor is not implemented—since it's not implemented, Core Data will generate it automatically.

Listing 2 Implementation of a custom managed object class illustrating copying setter

```
@interface Department : NSManagedObject
{
}
@property(nonatomic, copy) NSString *name;
@end

@implementation Department

@dynamic name;

- (void)setName:(NSString *)newName
{
    [self willChangeValueForKey:@"name"];
    // NSString implements NSCopying, so copy the attribute value
    NSString *newNameCopy = [newName copy];
    [self setPrimitiveName:newNameCopy];
    [newNameCopy release];
    [self didChangeValueForKey:@"name"];
}
@end
```

If you choose to represent an attribute using a scalar type (such as `NSInteger` or `CGFloat`), or as one of the structures supported by `NSKeyValueCoding` (`NSRect`, `NSPoint`, `NSSize`, `NSRange`), then you should implement accessor methods as illustrated in Listing 3 (page 46). If you want to use any other attribute type, then you should use a different pattern, described in Non-Standard Persistent Attributes (page 83).

Listing 3 Implementation of a custom managed object class illustrating a scalar attribute value

```
@interface Circle : NSManagedObject
{
    CGFloat radius;
}
@property CGFloat radius;
@end

@implementation Circle

- (CGFloat)radius
{
    [self willAccessValueForKey:@"radius"];
    float f = radius;
    [self didAccessValueForKey:@"radius"];
    return f;
}

- (void)setRadius:(CGFloat)newRadius
{
    [self willChangeValueForKey:@"radius"];
    radius = newRadius;
    [self didChangeValueForKey:@"radius"];
}
@end
```

Custom To-Many Relationship Accessor Methods

Important: You are strongly encouraged to use dynamic properties (that is, properties whose implementation you specify as `@dynamic`) instead of creating custom implementations for standard or primitive accessor methods.

You usually access to-many relationships using `mutableSetValueForKey:`, which returns a proxy object that both mutates the relationship and sends appropriate key-value observing notifications for you. There should typically be little reason to implement your own collection accessor methods for to-many relationships. If they are present, however, the framework calls the mutator methods (such as `add<Key>Object:` and `remove<Key>Object:`) when modifying a collection that represents a persistent relationship. (Note that fetched properties do not support the mutable collection accessor methods.) In order for this to work correctly, you must implement an `add<Key>Object:/remove<Key>Object:` pair, an `add<Key>:/remove<Key>:` pair, or both pairs. You may also implement other get accessors (such as `countOf<Key>:`, `enumeratorOf<Key>:`, and `memberOf<Key>:`) and use these in your own code, however these are not guaranteed to be called by the framework.

Important: For performance reasons, the proxy object returned by managed objects for `mutableSetValueForKey:` does not support `set<Key>:` style setters for relationships. For example, if you have a to-many relationship `employees` of a Department class and implement accessor methods `employees` and `setEmployees:`, then manipulate the relationship using the proxy object returned by `mutableSetValueForKey:@"employees"`, `setEmployees:` is *not* invoked. You should implement the other mutable proxy accessor overrides instead.

If you do implement collection accessors for model properties, they must invoke the relevant KVO notification methods. Listing 4 (page 47) illustrates the implementation of accessor methods for a to-many relationship—`employees`—of a Department class. *The easiest way to generate the implementation is to select the relationship in the Xcode modeling tool and choose Design > Data Model > Copy Obj-C 2.0 Method {Declarations/Implementations} to Clipboard.*

Listing 4 A managed object class illustrating implementation of custom accessors for a to-many relationship

```
@interface Department : NSManagedObject
{
}
@property (nonatomic, retain) NSString * name;
@property (nonatomic, retain) NSSet *employees;
@end


@interface Department (DirectReportsAccessors)

- (void)addEmployeesObject:(Employee *)value;
- (void)removeEmployeesObject:(Employee *)value;
- (void)addEmployees:(NSSet *)value;
- (void)removeEmployees:(NSSet *)value;

- (NSMutableSet*)primitiveEmployees;
- (void)setPrimitiveEmployees:(NSMutableSet*)value;

@end


@implementation Department

@dynamic name;
@dynamic employees;

- (void)addEmployeesObject:(Employee *)value
{
    NSSet *changedObjects = [[NSSet alloc] initWithObjects:&value count:1];

    [self willChangeValueForKey:@"employees"
          withSetMutation:NSKeyValueUnionSetMutation
          usingObjects:changedObjects];
    [[self primitiveEmployees] addObject:value];
    [self didChangeValueForKey:@"employees"
          withSetMutation:NSKeyValueUnionSetMutation
          usingObjects:changedObjects];

    [changedObjects release];
}

- (void)removeEmployeesObject:(Employee *)value
{
    NSSet *changedObjects = [[NSSet alloc] initWithObjects:&value count:1];

    [self willChangeValueForKey:@"employees"
          withSetMutation:NSKeyValueMinusSetMutation
          usingObjects:changedObjects];
    [[self primitiveEmployees] removeObject:value];
    [self didChangeValueForKey:@"employees"
          withSetMutation:NSKeyValueMinusSetMutation
          usingObjects:changedObjects];

    [changedObjects release];
}

- (void)addEmployees:(NSSet *)value
{
    [self willChangeValueForKey:@"employees"
          withSetMutation:NSKeyValueUnionSetMutation
          usingObjects:value];
    [[self primitiveEmployees] unionSet:value];
    [self didChangeValueForKey:@"employees"
          withSetMutation:NSKeyValueUnionSetMutation
          usingObjects:value];
}

- (void)removeEmployees:(NSSet *)value
{
    [self willChangeValueForKey:@"employees"
          withSetMutation:NSKeyValueMinusSetMutation
          usingObjects:value];
    [[self primitiveEmployees] minusSet:value];
    [self didChangeValueForKey:@"employees"
          withSetMutation:NSKeyValueMinusSetMutation
          usingObjects:value];
}
```

Custom Primitive Accessor Methods

Primitive accessor methods are similar to "normal" or public key-value coding compliant accessor methods, except that Core Data uses them as the most basic data methods to access data, consequently they do *not* issue key-value access or observing notifications. Put another way, they are to `primitiveValueForKey:` and `setPrimitiveValue:forKey:` what public accessor methods are to `valueForKey:` and `setValue:forKey:`.

Typically there should be little reason to implement primitive accessor methods. They are, however, useful if you want custom methods to provide direct access to instance variables for persistent Core Data properties. The example below contrasts public and primitive accessor methods for an attribute, `int16`, of type `Integer 16`, stored in a custom instance variable, `nonCompliantKVCivar`.

```
// primitive get accessor
- (short)primitiveInt16 {
    return nonCompliantKVCivar;
}

// primitive set accessor
- (void)setPrimitiveInt16:(short)newInt16 {
    nonCompliantKVCivar = newInt16;
}

// public get accessor
- (short)int16 {
    short tmpValue;
    [self willAccessValueForKey: @"int16"];
    tmpValue = nonCompliantKVCivar;
    [self didAccessValueForKey: @"int16"];
    return tmpValue;
}

// public set accessor
- (void)setInt16:(short)int16 {
    [self willChangeValueForKey: @"int16"];
    nonCompliantKVCivar = int16;
    [self didChangeValueForKey:@"int16"];
}
```

Creating and Deleting Managed Objects

The Core Data Framework relieves you from the need to implement many of the mechanisms needed to manage data-bearing (model) objects. It does, though, impose the requirement that model objects are instances of, or instances of classes that inherit from, `NSManagedObject`, and that the model objects are properly integrated in to the Core Data infrastructure. This document first describes the basic pieces of the infrastructure you need to create a managed object, and how to easily instantiate an instance of a managed object and integrate it into that infrastructure. It then describes the processes that are abstracted by the convenience methods you typically use to create a managed object; how to assign an object to a particular store; and finally how to delete a managed object.

Creating, Initializing, and Saving a Managed Object

A managed object is an instance of an Objective-C class. From this perspective, it is no different from any other object you use—you can simply create an instance using `alloc`. A managed object differs from other objects in three main ways—a managed object:

- Must be an instance of `NSManagedObject` or of a class that inherits from `NSManagedObject`
- Exists in an environment defined by its managed object context
- Has an associated entity description that describes the properties of the object

In principle, there is therefore a lot of work to do to create a new managed object and properly integrate it into the Core Data infrastructure. In practice, however, this task is made easy by a convenience class method (`insertNewObjectForEntityForName:inManagedObjectContext:`) of `NSEntityDescription`. The following example shows the easiest way to create a new instance of an entity named "Employee".

```
NSManagedObject *newEmployee = [NSEntityDescription
    insertNewObjectForEntityForName:@"Employee"
    inManagedObjectContext:context];
```

The method returns an instance of whatever class is defined in the managed object model to represent the entity, initialized with the default values given for its entity in the model.

In many cases the default values you set in the model may be sufficient. Sometimes, however, you may wish to perform additional initialization—perhaps using dynamic values (such as the current date and time) that cannot be represented in the model. In a typical Cocoa application you would override the class's `init` method to provide this functionality. With `NSManagedObject`, you are discouraged from overriding `initWithEntity:insertIntoManagedObjectContext:`; instead, Core Data provides several other means of initializing values—these are described in "Object Life-Cycle—Initialization and Deallocation" (page 39).

Simply creating a managed object does not cause it to be saved to a persistent store. The managed object context acts as a scratchpad. You can create and register objects with it, make changes to the objects, and undo and redo changes as you wish. If you make changes to managed objects associated with a given context, those changes remain local to that context until you commit the changes by sending the context a `save:` message. At that point—provided that there are no validation errors—the changes are committed to the store.

See also "Assigning an Object to a Store" (page 54).

Behind the Scenes of Creating a Managed Object

Although `NSEntityDescription`'s convenience method makes it easy to create and configure a new managed object, it may be instructive to detail what is happening behind the scenes. If this is not of current interest, you may safely skip this section (go to "Assigning an Object to a Store" (page 54))—you are encouraged, however, to revisit this material to ensure that you fully understand the process.

In order to properly integrate a managed object into the Core Data infrastructure there are two elements you need:

- A managed object context
- An entity description

The Managed Object Context

The context is responsible for mediating between its managed objects and the rest of the Core Data infrastructure. The infrastructure is in turn responsible for, for example, translating changes to managed objects into undo actions maintained by the context, and also into operations that need to be performed on the persistent store with which the managed object is assigned.

The context is in effect also your gateway to the rest of the Core Data infrastructure. As such, it is expected that you either keep a reference to the context, or you have a means of easily retrieving it—for example, if you are developing a document-based application that uses `NSPersistentDocument`, you can use the document class's `managedObjectContext` method.

The Entity Description

An entity description specifies (amongst other things) the name of an entity, the class used to represent the entity, and the entity's properties. The entity description is important since a given class may be used to represent more than one entity—by default all entities are represented by `NSManagedObject`. Core Data uses the entity description to determine what properties a managed object has, what needs to be saved to or retrieved from the persistent store, and what constraints there are on property values. Entity descriptions are properties of a managed object model. For more information about creating a model, see *Xcode Tools for Core Data* and *Creating a Managed Object Model with Xcode*.

Given a managed object context, you could retrieve the appropriate entity description through the persistent store coordinator as illustrated in the following example:

```
NSManagedObjectContext *context = /* assume this exists */;
NSManagedObjectModel *managedObjectModel =
    [[context persistentStoreCoordinator] managedObjectModel];
NSEntityDescription *employeeEntity =
    [[managedObjectModel entitiesByName] objectForKey:@"Employee"];
```

In practice, you would use the convenience method `entityForName:inManagedObjectContext:` of `NSEntityDescription` which does the same thing—as illustrated in the following example:

```
NSManagedObjectContext *context = /* assume this exists */;
NSEntityDescription *employeeEntity = [NSEntityDescription
            entityForName:@"Employee"
            inManagedObjectContext:context];
```

Creating a Managed Object

Mac OS X v10.4: This section describes usage patterns for Mac OS X v10.5; if you are using Mac OS X v10.4, see "Creating a Managed Object on Mac OS X v10.4" (page 53).

Fundamentally `NSManagedObject` is an Objective-C class like any other Objective-C class. You can create a new instance using `alloc`.

Like various other classes, `NSManagedObject` imposes some constraints on instance creation. As described earlier, you must associate the new managed object instance with the entity object that defines its properties and with the managed object context that defines its environment. You cannot therefore initialize a managed object simply by sending an `init` message, you must use the designated initializer—`initWithEntity:insertIntoManagedObjectContext:`—which sets both the entity and context:

```
NSManagedObject *newEmployee = [[NSManagedObject alloc]
            initWithEntity:employeeEntity
            insertIntoManagedObjectContext:context];
```

This is in effect what `NSEntityDescription`'s convenience method `insertNewObjectForEntityForName:inManagedObjectContext:` does for you (note though that `insertNewObjectForEntityForName:inManagedObjectContext:` returns an autoreleased object)—including the entity instance look-up described in "The Entity Description" (page 52). This is why you should typically use that method rather than `NSManagedObject`'s `initWithEntity:insertIntoManagedObjectContext:`.

An important additional point here is that `initWithEntity:insertIntoManagedObjectContext:` returns an instance of the class specified by the entity description to represent the entity. If you want to create a new Employee object and in the model you specified that the Employee entity should be represented by a custom class, say `Employee`, it returns an instance of `Employee`. If you specified that the Employee entity should be represented by `NSManagedObject`, it returns an instance of `NSManagedObject`.

Creating a Managed Object on Mac OS X v10.4

Fundamentally `NSManagedObject` is an Objective-C class like any other Objective-C class. You can create a new instance using `alloc`. To create a new managed object, you create an instance of the class you specified for that entity in the managed object model. If you want to create a new Employee object and in the model you specified that the Employee entity should be represented by a custom class, say `Employee`, you create an instance of `Employee`. If you specified that the Employee entity should be represented by `NSManagedObject`, you create an instance of `NSManagedObject`.

Like various other classes, `NSManagedObject` imposes some constraints on instance creation. As described earlier, you must associate the new managed object instance with the entity object that defines its properties and with the managed object context that defines its environment. You cannot therefore initialize a managed object simply by sending an `init` message, you must use the designated initializer—`initWithEntity:insertIntoManagedObjectContext:`—which sets both the entity and context:

```
NSManagedObject *newEmployee = [[NSManagedObject alloc]
            initWithEntity:employeeEntity
            insertIntoManagedObjectContext:context];
```

A complicating factor, however, is that a given entity may be represented by a different class at different points in the life-cycle of your application. At the beginning, it may be that you represent all entities with `NSManagedObject`. Later you may create a custom class—you may even rename it. It may be prudent, therefore, to not hard-code the class name, but instead to create an instance of whatever class the entity specifies should be used, as *illustrated* in the following example (note that typically you should not write this code yourself).

```
NSString *className = [employeeEntity managedObjectClassName];
Class entityClass = NSClassFromString(className);
NSManagedObject *newEmployee = [[entityClass alloc]
            initWithEntity:employeeEntity
            insertIntoManagedObjectContext:context];
```

This is in effect what `NSEntityDescription`'s convenience method `insertNewObjectForEntityForName:inManagedObjectContext:` does for you (note though that `insertNewObjectForEntityForName:inManagedObjectContext:` returns an autoreleased object)—which is why you should typically use that method rather than `NSManagedObject`'s `initWithEntity:insertIntoManagedObjectContext:`.

Assigning an Object to a Store

Typically there is only one persistent store for a given entity, and Core Data automatically ensures that new objects are saved to this store when the object's managed object context is saved. Sometimes, however, you may have multiple writable stores for a given entity—for example you may store some data in a specific document and some in a common global repository (say, a store in the user's Application Support folder). In this situation you must specify the store in which the object is to reside.

You specify the store for an object using the `NSManagedObjectContext` method, `assignObject:toPersistentStore:`. This method takes as its second argument the identifier for a store. You obtain the store identifier from the persistent store coordinator, using for example `persistentStoreForURL:`. The following example illustrates the complete process of creating a new managed object and assigning it to a global store.

```
NSURL *storeURL = ... ; // URL for path to global store

id globalStore = [[context persistentStoreCoordinator]
    persistentStoreForURL:storeURL];

NSManagedObject *newEmployee = [NSEntityDescription
    insertNewObjectForEntityForName:@"Employee"
    inManagedObjectContext:context];
```

```
[context assignObject:newEmployee toPersistentStore:globalStore];
```

Note that of course the object is not saved to the store until the managed object context is saved.

Deleting a Managed Object

Deleting a managed object is straightforward. You simply send its managed object context a `deleteObject:` message, passing the object you want to delete as the argument.

```
[aContext deleteObject:aManagedObject];
```

This removes the managed object from the object graph. Just as a new object is not saved to the store until the context is saved, a deleted object is not removed from the store until the context is saved.

Relationships

When you delete a managed object it is important to consider its relationships and in particular the delete rules specified for the relationships. If all of a managed object's relationship delete rules are Nullify, then for that object at least there is no additional work to do (you may have to consider other objects that were at the destination of the relationship—if the inverse relationship was either mandatory or had a lower limit on cardinality, then the destination object or objects might be in an invalid state). If a relationship delete rule is Cascade, then deleting one object may result in the deletion of others. If a rule is Deny, then before you delete an object you must remove the destination object or objects from the relationship, otherwise you will get a validation error when you save. If a delete rule is No Action, then you must ensure that you take whatever steps are necessary to ensure the integrity of the object graph. For more details, see "Relationship Delete Rules" (page 74).

Deleted status and notifications

You can find out if a managed object has been marked for deletion by sending it an `isDeleted` message. If the return value is `YES`, this means that the object will be deleted during the next save operation, or put another way, that the object is marked deleted for the current (pending) transaction. In addition, when you send a managed object context a `deleteObject:` message, the context posts a `NSManagedObjectContextObjectsDidChangeNotification` notification that includes the newly-deleted object in its list of deleted objects. Note, however, that an object being marked for deletion from a context is not the same as its being marked for deletion from a persistent store. If an object is created and deleted within the same transaction—that is, without an intervening save operation—it will not appear in the array returned by `NSManagedObjectContext`'s `deletedObjects` method or in the set of deleted objects in a `NSManagedObjectContextDidSaveNotification` notification.

Fetching Managed Objects

This article describes how to fetch managed objects and discusses some considerations for ensuring that fetching is efficient.

Fetching Managed Objects

You fetch managed objects by sending a fetch request to a managed object context. You first create a fetch request. As a minimum you must specify an entity for the request. You can get the entity from your managed object model using the `NSEntityDescription` method `entityForName:inManagedObjectContext:`. You may also set a predicate (for details about creating predicates, see *Predicate Programming Guide*), sort descriptors, and other attributes if necessary. You retrieve objects from the context using `executeFetchRequest:error:`, as illustrated in the example below.

Listing 1 Example of creating and executing a fetch request

```
NSManagedObjectContext *moc = [self managedObjectContext];
NSEntityDescription *entityDescription = [NSEntityDescription
    entityForName:@"Employee" inManagedObjectContext:moc];
NSFetchRequest *request = [[[NSFetchRequest alloc] init] autorelease];
[request setEntity:entityDescription];

// Set example predicate and sort orderings...
NSNumber *minimumSalary = ...;
NSPredicate *predicate = [NSPredicate predicateWithFormat:
    @"(lastName LIKE[c] 'Worsley') AND (salary > %@)", minimumSalary];
[request setPredicate:predicate];

NSSortDescriptor *sortDescriptor = [[NSSortDescriptor alloc]
    initWithKey:@"firstName" ascending:YES];
[request setSortDescriptors:[NSArray arrayWithObject:sortDescriptor]];
[sortDescriptor release];

NSError *error = nil;
NSArray *array = [moc executeFetchRequest:request error:&error];
if (array == nil)
{
    // Deal with error...
}
```

Note that you cannot fetch using a predicate based on transient properties (although you can use transient properties to filter in memory yourself). Moreover, It is also important to note that there are some interactions between fetching and the type of store—for details, see "Store Types and Behaviors" (page 117). To summarize, though, if you execute a fetch directly, you should typically not add *Objective-C-based* predicates or sort descriptors to the fetch request. Instead you should apply these to the results of the fetch. If you use an array controller, you may need to subclass `NSArrayController` so you can have it not pass the sort descriptors to the persistent store and instead do the sorting after your data has been fetched.

If you use multiple persistence stacks in your application, or if multiple applications might access (and modify) the same store simultaneously, fetching is also important in ensuring that data values are current —see "Ensuring Data Is Up-to-Date" (page 66).

Retrieving Specific Objects

If your application uses multiple contexts and you want to want to test whether an object has been deleted from a persistent store, you can create a fetch request with a predicate of the form `self == %@`. The object you pass in as the variable can be either a managed object or a managed object ID, as in the following example:

```
NSFetchRequest *request = [[[NSFetchRequest alloc] init] autorelease];
NSEntityDescription *entity =
    [NSEntityDescription entityForName:@"Employee"
            inManagedObjectContext:managedObjectContext];
[request setEntity:entity];

NSPredicate *predicate =
    [NSPredicate predicateWithFormat:@"self == %@", targetObject];
[request setPredicate:predicate];

NSError *error = nil;
NSArray *array = [managedObjectContext executeFetchRequest:request error:&error];
if (array != nil) {
    int count = [array count]; // may be 0 if the object has been deleted
    // …
}
else // deal with error…
```

The count of the array returned from the fetch will be `0` if the target object has been deleted. If you need to test for the existence of several objects, it is more efficient to use the `IN` operator than it is to execute multiple fetches for individual objects, for example:

```
NSPredicate *predicate = [NSPredicate predicateWithFormat:@"self IN %@",
                                    arrayOfManagedObjectIDs];
```

Fetching and Entity Inheritance

If you define an entity inheritance hierarchy (see "Entity Inheritance" (page 27)), when you specify a super-entity as the entity for a fetch request, the request returns all matching instances of the super-entity and of sub-entities. In some applications, you might specify a super-entity as being abstract (see "Abstract Entities" (page 28)). To fetch matching instances of all concrete sub-entities of the abstract entity, you set the entity for fetch specification to be the abstract entity. In the case of the domain described in "Abstract Entities," if you specify a fetch request with the Graphic entity, the fetch returns matching instances of Circle, TextArea, and Line.

Using Managed Objects

This document describes issues related to using and manipulating managed objects in your application.

Mac OS X v10.4: This article describes usage patterns for Mac OS X v10.5; if you are using Mac OS X v10.4, see "Mac OS X v10.4: Using Managed Objects" (page 151).

Accessing and Modifying Properties

Core Data automatically generates efficient public and primitive get and set accessor methods for modeled properties (attributes *and* relationships) of managed object classes (see "Managed Object Accessor Methods" (page 41)). When you access or modify properties of a managed object, you should use these methods directly.

Most relationships are inherently bidirectional. Any changes made to the relationships between objects should maintain the integrity of the object graph. Provided that you have correctly modeled a relationship in both directions and set the inverses, modifying one end of a relationship automatically updates the other end—see "Manipulating Relationships and Object Graph Integrity" (page 75).

Attributes and to-one relationships

You access attributes and and to-one relationships of a managed object using standard accessor methods or using the Objective-C 2.0 dot syntax (see Declared Properties) as illustrated in the following code fragment:

```
NSString *firstName = [anEmployee firstName];
Employee *manager = anEmployee.manager;
```

Similarly, you can use either standard accessor methods or the dot syntax to modify attributes; for example:

```
newEmployee.firstName = @"Stig";
[newEmployee setManager:manager];
```

In the cases of both getters and setters, the dot syntax is exactly equivalent to standard method invocation. For example, the following two statements use identical codepaths:

```
[[aDepartment manager] setSalary:[NSNumber numberWithInteger:100000]];
aDepartment.manager.salary = [NSNumber numberWithInteger:100000];
```

You can also use key-value coding (KVC) to get or set the value of a simple attribute as illustrated in the following code fragment. Using KVC, though, is considerably less efficient than using accessor methods, so you should only use KVC when necessary (for example when you are choosing the key or keypath dynamically).

```
[newEmployee setValue:@"Stig" forKey:@"firstName"];
[aDepartment setValue:[NSNumber numberWithInteger:100000]
forKeyPath:@"manager.salary"];
```

You must change attribute values in a KVC-compliant fashion. For example, the following typically represents a programming error:

```
NSMutableString *mString = [NSMutableString stringWithString:@"Laurie"];
[newEmployee setFirstName:mString];
[mString setString:@"Laura"];
```

For mutable values, you should either transfer ownership of the value to Core Data, or implement custom accessor methods to always perform a copy. The previous example may not represent an error if the class representing the Employee entity declared the `firstName` property `(copy)` (or implemented a custom `setFirstName:` method that copied the new value). It is important to note, of course, that after the invocation of `setString:` (in the third code line) the value of `firstName` would still be "Laurie" and not "Laura".

There should typically be no reason to invoke the primitive accessor methods except within custom accessor methods (see "Managed Object Accessor Methods" (page 41)).

To-many relationships

To access a to-many relationship (whether the destination of a one-to-many relationship or a many-to-many relationship), you use the standard get accessor or dot syntax. A to-many relationship is represented by a set, as illustrated in the following code fragment:

```
NSSet *managersPeers = [managersManager directReports];
NSSet *departmentsEmployees = aDepartment.employees;
```

When you access the destination of a relationship, you may initially get a fault object (see "Faulting and Uniquing" (page 99))—the fault fires automatically if you make any changes to it. On Mac OS X v10.5 and later you check whether the relationship is a fault or not using `NSManagedObject`'s `hasFaultForRelationshipNamed:` method.

You can in principle manipulate an entire to-many relationship in the same way you do a to-one relationship, using either a custom accessor method or (more likely) key-value coding, as in the following example.

```
NSSet *newEmployees = [NSSet setWithObjects:employee1, employee2, nil];
[aDepartment setEmployees:setOfEmployees];

NSSet *newDirectReports = [NSSet setWithObjects:employee3, employee4, nil];
manager.directReports = newDirectReports;
```

Typically, however, you do not want to set an entire relationship, instead you want to add or remove a single element at a time. To do this, you should use `mutableSetValueForKey:` or one of the automatically-generated relationship mutator methods (see "Dynamically-Generated Accessor Methods" (page 42)):

```
NSMutableSet *employees = [aDepartment mutableSetValueForKey:@"employees"];
[employees addObject:newEmployee];
[employees removeObject:firedEmployee];

// or
[aDepartment addEmployeesObject:newEmployee];
[aDepartment removeEmployeesObject:firedEmployee];
```

It is important to understand the difference between the values returned by the dot accessor and by `mutableSetValueForKey:`. `mutableSetValueForKey:` returns a mutable proxy object. If you mutate its contents, it will emit the appropriate key-value observing (KVO) change notifications for the relationship. The dot accessor simply returns a set. If you manipulate the set as shown in this code fragment:

```
[aDepartment.employees addObject:newEmployee]; // do not do this!
```

then KVO change notifications are *not* emitted and the inverse relationship is not updated correctly.

Recall that the dot simply invokes the accessor method, so for the same reasons:

```
[[aDepartment employees] addObject:newEmployee]; // do not do this, either!
```

Saving Changes

Simply modifying a managed object does not cause the changes to be saved to a store. The managed object context acts as a scratchpad. You can make changes to the objects, and undo and redo changes as you wish. If you make changes to managed objects associated with a given context, those changes remain local to that context until you commit the changes by sending the context a `save:` message. At that point—provided that there are no validation errors—the changes are committed to the persistent store.

See also "Ensuring Data Is Up-to-Date" (page 66).

Managed Object IDs and URIs

An `NSManagedObjectID` object is a universal identifier for a managed object, and provides basis for uniquing in the Core Data Framework. A managed object ID uniquely identifies the same managed object both between managed object contexts in a single application, and in multiple applications (as in distributed systems). Like the primary key in the database, an identifier contains the information needed to exactly describe an object in a persistent store, although the detailed information is not exposed. The framework completely encapsulates the "external" information and presents a clean object oriented interface.

```
NSManagedObjectID *moID = [managedObject objectID];
```

It is important to note that there are two forms of an object ID. When a managed object is first created, Core Data assigns it a temporary ID; only if it is saved to a persistent store does Core Data assign a managed object a permanent ID. You can readily discover whether an ID is temporary:

```
BOOL isTemporary = [[managedObject objectID] isTemporaryID];
```

You can also transform an object ID into a URI representation:

```
NSURL *moURI = [[managedObject objectID] URIRepresentation];
```

Given a managed object ID or a URI, you can retrieve the corresponding managed object using `managedObjectIDForURIRepresentation:` or `objectWithID:`.

An advantage of the URI representation is that you can archive it—although note that in many cases you should not archive a temporary ID since this is obviously subject to change. You could, for example, store archived URIs in your application's user defaults to save the last selected group of objects in a table view. You can also use URIs to support copy and paste operations (see "Copying and Copy and Paste" (page 62)) and drag and drop operations (see "Drag and Drop" (page 63)).

You can use object IDs to define "weak" relationships across persistent stores (where no hard join is possible). For example, for a weak to-many relationship you store as archived URIs the IDs of the objects at the destination of the relationship, and maintain the relationship as a transient attribute derived from the object IDs.

You can sometimes benefit from creating your own unique ID (UUID) property which can be defined and set for newly inserted objects. This allows you to efficiently locate specific objects using predicates (though before a save operation new objects can be found only in their original context).

Copying and Copy and Paste

It is difficult to solve the problem of copying, or supporting copy and paste, in a generic way for managed objects. You need to determine on a case-by-case basis what properties of a managed object you actually want to copy.

Copying Attributes

If you just want to copy a managed object's attributes, then in many cases the best strategy may be in the copy operation to create a dictionary (property list) representation of a managed object, then in the paste operation to create a new managed object and populate it using the dictionary. For an example, see *NSPersistentDocument Core Data Tutorial*—see also Copying in *Model Object Implementation Guide*. You can use the managed object's ID (described in "Managed Object IDs and URIs" (page 61)) to support copy and paste. Note, however, that the technique needs to be adapted to allow for copying of new objects.

A new, unsaved, managed object has a temporary ID. If a user performs a copy operation and then a save operation, the managed object's ID changes and the ID recorded in the copy will be invalid in a subsequent paste operation. To get around this, you use a "lazy write" (as described in Implementing Copy and Paste). In the copy operation, you declare your custom type but if the managed object's ID is temporary you do not write the data—but you do keep a reference to the original managed object. In the `pasteboard:provideDataForType:` method you then write the current ID for the object.

As a further complication, it is possible that the ID is still temporary during the paste operation, yet you must still allow for the possibility of future paste operations after an intervening save operation. You must therefore re-declare the type on the pasteboard to set up lazy pasting again, otherwise the pasteboard will retain the temporary ID. You cannot invoke `addTypes:owner:` during `pasteboard:provideDataForType:`, so you must use a delayed perform—for example:

```
- (void)pasteboard:(NSPasteboard *)sender provideDataForType:(NSString *)type
{
    if ([type isEqualToString:MyMOIDType]) {
        // assume cachedManagedObject is object originally copied
        NSManagedObjectID *moID = [cachedManagedObject objectID];
        NSURL *moURI = [moID URIRepresentation];
        [sender setString:[moURI absoluteString] forType:MyMOIDType];
        if ([moID isTemporaryID]) {
            [self performSelector:@selector(clearMOIDInPasteboard:)
```

```
                    withObject:sender afterDelay:0];
        }
    }
    // implementation continues...
}

- (void)clearMOIDInPasteboard:(NSPasteboard *)pb
{
    [pb addTypes:[NSArray arrayWithObject:MyMOIDType] owner:self];
}
```

Copying Relationships

If you want to copy relationships you also need to consider the objects related to those first tier of related objects—if you are not careful, it is possible that you will copy the whole object graph (which may not be what you want!). If you want to copy a to-one relationship, you need to decide whether the copy of the destination should be a new object or a reference. If it is a reference, what should happen to the inverse relationship to the original object—should making a copy redefine relationships between other objects? You need to make similar decisions for to-many relationships.

Drag and Drop

You can perform drag and drop operations with managed objects—such as, for example, transferring an object from one relationship to another—using a URI representation, as described in "Managed Object IDs and URIs" (page 61).

```
NSURL *moURI = [[managedObject objectID] URIRepresentation];
```

You can put the URI on a dragging pasteboard, from which you can later retrieve it and recreate a reference to the original managed object using the persistent store coordinator, as illustrated in the following code sample.

```
NSURL *moURL = // get it from the pasteboard ...
NSManagedObjectID *moID = [[managedObjectContext persistentStoreCoordinator]
    managedObjectIDForURIRepresentation:moURL];
// assume moID non-nil...
NSManagedObject *mo = [managedObjectContext objectWithID:moID];
```

Note that this assumes that drag and drop is "within a single persistence stack"—that is, that if there is more than one managed object context involved that they use a shared persistent store coordinator—or that the object(s) being dragged and dropped are in a store referenced by the persistent store coordinators.

If you want to copy-and-paste via drag-and-drop then you must put a suitable representation of the managed object onto the pasteboard, get the representation during the drop method, and initialize a new managed object using the representation (see "Copying and Copy and Paste" (page 62)).

Validation

The Core Data framework provides a clean infrastructure for supporting validation, both through logic encapsulated in the object model and through custom code. In the managed object model, you can specify constraints on values that a property may have (for example, an Employee's salary cannot be negative, or that every employee must belong to a Department). There are two forms of custom validation methods—those that follow standard key-value coding conventions (see Key-Value Validation) to validate a value for a single attribute, and a special set (`validateForInsert:`, `validateForUpdate:`, and `validateForDelete:`) for validating the whole object at different stages of its life-cycle (insertion, update, and deletion). The latter may be particularly useful for validating combinations of values—for example, to ensure that an employee can be entered into a stock purchase plan only if their period of service exceeds a given length and their pay grade is at or above a certain level.

Model-based constraints are checked and validation methods are invoked automatically before changes are committed to the external store to prevent invalid data being saved. You can also invoke them programmatically whenever necessary. You validate individual values using `validateValue:forKey:error:`. The managed object compares the new value with the constraints specified in the model, and invokes any custom validation method (of the form `validate<Key>:error:`) you have implemented. Even if you implement custom validation methods, you should typically not call custom validation methods directly. This ensures that any constraints defined in the managed object model are applied.

For more about implementing validation methods, see Model Object Validation.

Undo Management

The Core Data framework provides automatic support for undo and redo. Undo management even extends to transient properties (properties that are not saved to persistent store, but are specified in the managed object model).

Managed objects are associated with a managed object context. Each managed object context maintains an undo manager. The context uses key-value observing to keep track of modifications to its registered objects. You can make whatever changes you want to a managed object's properties using normal accessor methods, key-value coding, or through any custom key-value-observing compliant methods you define for custom classes, and the context registers appropriate events with its undo manager.

To undo an operation, you simply send the context an `undo` message and to redo it send the context a `redo` message. You can also roll back all changes made since the last save operation using `rollback` (this also clears the undo stack) and reset a context to its base state using `reset`.

You also can use other standard undo manager functionality, such grouping undo events. Core Data, though, queues up the undo registrations and adds them in a batch (this allows the framework to coalesce changes, negate contradictory changes, and perform various other operations that work better with hindsight than immediacy). If you use methods other than `beginUndoGrouping` and `endUndoGrouping`, to ensure that any queued operations are properly flushed you must first therefore send the managed object context a `processPendingChanges` message.

For example, in some situations you want to alter—or, specifically, disable—undo behavior. This may be useful if you want to create a default set of objects when a new document is created (but want to ensure that the document is not shown as being dirty when it is displayed), or if you need to merge new state from another thread or process. In general, to perform operations without undo registration, you send an undo manager a `disableUndoRegistration` message, make the changes, and then send the undo manager an `enableUndoRegistration` message. Before each, you send the context a `processPendingChanges` message, as illustrated in the following code fragment:

```
NSManagedObjectContext *moc = ...;
[moc processPendingChanges];  // flush operations for which you want undos
[[moc undoManager] disableUndoRegistration];
// make changes for which undo operations are not to be recorded
[moc processPendingChanges];  // flush operations for which you do not want
undos
[[moc undoManager] enableUndoRegistration];
```

Faults

Managed objects typically represent data held in a persistent store. In some situations a managed object may be a "fault"—an object whose property values have not yet been loaded from the external store. When you access persistent property values, a fault "fires" and its persistent data is retrieved automatically from the store. In some circumstances you may explicitly turn a managed object into a fault (typically to ensure that its values are up to date, using `NSManagedObjectContext`'s `refreshObject:mergeChanges:`). More commonly you encounter faults when traversing relationships.

When you fetch a managed object, Core Data does not automatically fetch data for other objects to which it has relationships (see "Faulting" (page 99)). Initially, an object's relationships are represented by faults (unless the destination object has already been fetched—see "Uniquing" (page 101)). If, however, you access the relationship's destination object or objects, their data are retrieved automatically for you. For example, suppose you fetch a single Employee object from a persistent store when an application first launches, then (assuming these exist in the persistent store) its `manager` and `department` relationships are represented by faults. You can nevertheless ask for the employee's manager's last name as shown in the following code example:

```
NSString *managersName =
        [[anEmployee valueForKey:@"manager"] valueForKey:@"lastName"];
```

or more easily using key paths:

```
NSString *managersName =
        [anEmployee valueForKeyPath:@"manager.lastName"];
```

In this case, the data for destination Employee object (the manager) is retrieved for you automatically.

There is a subtle but important point here. Notice that, in order to traverse a relationship—in this example to find an employee's manager—you do not have to explicitly *fetch* the related objects (that is, you do not create and execute a fetch request). You simply use key-value coding (or if you have implemented them, accessor methods) to retrieve the destination object (or objects) and they are created for you automatically by Core Data. For example, you could ask for an employee's manager's manager's department's name like this:

```
NSString *departmentName = [anEmployee
valueForKeyPath:@"manager.manager.department.name"];
```

(This assumes, of course, that the employee is at least two levels deep in the management hierarchy.) You can also use collection operator methods. You could find the salary overhead of an employee's department like this:

```
NSNumber *salaryOverhead = [anEmployee
valueForKeyPath:@"department.employees.@sum.salary"];
```

In many cases, your initial fetch retrieves a starting node in the object graph and thereafter you do not execute fetch requests, you simply follow relationships.

Ensuring Data Is Up-to-Date

If two applications are using the same data store, or a single application has multiple persistence stacks, it is possible for managed objects in one managed object context or persistent object store to get out of sync with the contents of the repository. If this occurs, you need to "refresh" the data in the managed objects, and in particular the persistent object store (the snapshots) to ensure that the data values are current.

Refreshing an object

Managed objects that have been realized (their property values have been populated from the persistent store) as well as pending updated, inserted, or deleted objects, are never changed by a fetch operation without developer intervention. For example, consider a scenario in which you fetch some objects and modify them in one editing context; meanwhile in another editing context you edit the same data and commit the changes. If in the first editing context you then execute a new fetch which returns the same objects, you do not see the newly-committed data values—you see the existing objects in their current in-memory state.

To refresh a managed object's property values, you use the managed object context method `refreshObject:mergeChanges:`. If the `mergeChanges` flag is `YES`, the method merges the object's property values with those of the object available in the persistent store coordinator; if the flag is `NO`, the method simply turns an object back into a fault without merging (which also causes other related managed objects to be released, so you can use this method to trim the portion of your object graph you want to hold in memory).

Note that an object's staleness interval is the time that has to pass until the store re-fetches the snapshot. This therefore only affects firing faults—moreover it is only relevant for SQLite stores (the other stores never re-fetch because the entire data set is kept in memory).

Merging changes with transient properties

If you use `refreshObject:mergeChanges:` with the `mergeChanges` flag `YES`, then any transient properties are restored to their pre-refresh value after `awakeFromFetch` is invoked. This means that, if you have a transient property with a value that depends on a property that is refreshed, the transient value may become out of sync.

Consider an application in which you have a Person entity with attributes `firstName` and `lastName`, and a *cached* transient derived property, `fullName` (in practice it might be unlikely that a `fullName` attribute would be cached, but the example is easy to understand). Suppose also that `fullName` is calculated and cached in a custom `awakeFromFetch` method.

A Person, currently named "Sarit Smith" in the persistent store, is edited in two managed object contexts:

- In context one, the corresponding instance's `firstName` is changed to "Fiona" (which causes the cached `fullName` to be updated to "Fiona Smith") and the context saved.

  In the persistent store, the person is now “Fiona Smith”.
- In context two, corresponding instance's `lastName` is changed to "Jones", which causes the cached `fullName` to be updated to "Sarit Jones".

  The object is then refreshed with the `mergeChanges` flag `YES`. The refresh fetches “Fiona Smith” from the store.
  - `firstName` was *not* changed prior to the refresh; the refresh causes it to be updated to the new value from the persistent store, so it is now "Fiona".
  - `lastName` *was* changed prior to the refresh; so, after the refresh, it is set back to its modified value—"Jones".
  - The *transient* value, `fullName`, was also changed prior to the refresh. After the refresh, its value is restored to "Sarit Jones" (to be correct, it should be "Fiona Jones").

The example shows that, because pre-refresh values are applied *after* `awakeFromFetch`, you cannot use `awakeFromFetch` to ensure that a transient value is properly updated following a refresh (or if you do, the value will subsequently be overwritten). In these circumstances, the best solution is to use an additional instance variable to note that a refresh has occurred and that the transient value should be recalculated. For example, in the Person class you could declare an instance variable `fullNameIsValid` of type `BOOL` and implement the `didTurnIntoFault` method to set the value to `NO`. You then implement a custom accessor for the `fullName` attribute that checks the value of `fullNameIsValid`—if it is `NO`, then the value is recalculated.

Memory Management Using Core Data

In general, when you use Core Data you should follow the traditional Cocoa guidelines relating to memory management. There are, however, some additional considerations.

Note: On Mac OS X v10.5 and later, you can use Core Data in a garbage-collected environment (see *Garbage Collection Programming Guide*). Discussion in this article that is strictly related to a managed memory environment does not apply if you use garbage collection (for example, if you use garbage collection then retain cycles—as discussed in "Breaking Relationship Retain Cycles" (page 70)—are not a problem).

Instance and Data Life-Cycles

It is important to understand that the life-cycle of the data a managed object represents is largely independent of the lifetime of individual managed object instances. In order to add a record to a persistent store, you must allocate and initialize a managed object—and then save the managed object context. When you remove a record from a persistent store, you should ensure its corresponding managed object is eventually deallocated. In between these events, however, you can create and destroy any number of instances of a managed object that represent the same record in a given persistent store.

`NSEntityDescription` provides a convenience method—`insertNewObjectForEntityForName:inManagedObjectContext:`—to create a new managed object and insert it into an editing context. Although the method name includes the word "new," it returns an autoreleased object. This appears to be in contravention of the Cocoa rule that "new" methods return retained objects, however in this case the object returned is of a different class than that to which the message is sent.

The Role of the Managed Object Context

Managed objects know what managed object context they're associated with, and managed object contexts know what managed objects they contain. *By default*, though, the references between a managed object and its context are weak—in a managed memory environment, *neither* object retains the other.

This means that in general you cannot rely on a context to ensure the longevity of a managed object instance, and you cannot rely on the existence of a managed object to ensure the longevity of a context. Put another way, just because you fetched an object doesn't mean it will stay around. A managed object's lifetime is by default determined by the run loop—autoreleased managed objects will be deallocated when the run loop's autorelease pool is released.

The exception to this rule is that a managed object context maintains a strong reference to (in a managed memory environment it retains) any changed (inserted, deleted, and updated) objects until the pending transaction is committed (with a `save:`) or discarded (with a `reset` or `rollback`). Note that the undo manager may also retain changed objects—see "Change and Undo Management" (page 70).

You can change a context's default behavior such that it does retain its managed objects by sending it a `setRetainsRegisteredObjects:` message (with the argument `YES`)—this makes the managed objects' lifetimes depend on the context's. This can be a convenience if you are caching smaller data sets in memory—for example if the context controls a temporary set of objects that may persist beyond a single event cycle, such as when editing in a sheet. It can also be useful if you are using multiple threads and passing data between them—for example if you are performing a background fetch and passing object IDs to the main thread. The background thread needs to retain the objects it pre-fetched for the main thread until it knows the main thread has actually used the object IDs to fault local instances into itself.

You should typically use a separate container to retain only those managed objects you really need. You can use an array or dictionary, or an object controller (for example an `NSArrayController` instance) that explicitly retains the objects it manages. The managed objects you don't need will then be deallocated when possible (for example, when relationships are cleared).

If you have finished with a managed object context, or for some other reason you want to "disconnect" a context from its persistent store coordinator, you should *not* set the context's coordinator to `nil`:

```
// this will raise an exception
[myManagedObjectContext setPersistentStoreCoordinator:nil];
```

Instead, you should simply relinquish ownership of the context (in a managed memory environment you send it a `release` message) and allow it to be deallocated normally.

Breaking Relationship Retain Cycles

When you have relationships between managed objects, each object maintains a strong reference to the object or objects to which it is related. In a managed memory environment, this causes retain cycles (see Object Ownership and Disposal) that can prevent deallocation of unwanted objects. To ensure that retain cycles are broken, when you're finished with an object you can use the managed object context method `refreshObject:mergeChanges:` to turn it into a fault.

You typically use `refreshObject:mergeChanges:` to refresh a managed object's property values. If the `mergeChanges` flag is `YES`, the method merges the object's property values with those of the object available in the persistent store coordinator. If the flag is `NO`, however, the method simply turns an object back into a fault without merging, which causes it to release related managed objects. This breaks the retain cycle between that managed object and the other managed objects it had retained.

Note that, of course, before the objects are deallocated everything outside the graph that is retaining them must release them. See also "Change and Undo Management" (page 70).

Change and Undo Management

Managed objects that have pending changes (insertions, deletions, or updates) *are* retained by their context until their context is sent a `save:`, `reset` , `rollback`, or `dealloc` message, or the appropriate number of undos to undo the change.

The undo manager associated with a context retains any changed managed objects. By default, the context's undo manager keeps an unlimited undo/redo stack. To limit your application's memory footprint, you should make sure that you scrub (using `removeAllActions`) the context's undo stack as and when appropriate. Unless you retain a context's undo manager, it is deallocated with its context.

If you do not intend to use Core Data's undo functionality, you can reduce your application's resource requirements by setting the context’s undo manager to `nil`. This may be especially beneficial for background worker threads, as well as for large import or batch operations.

Relationships and Fetched Properties

There are a number of things you have to decide when you create a relationship. What is the destination entity? Is it a to-one or a to-many? Is it optional? If it's a to-many, are there maximum or minimum numbers of objects that can be in the relationship? What should happen when the source object is deleted? You can provide answers to all these in the model. One of the particularly interesting cases is a many-to-many relationship; there are two ways to model these, and which one you choose will depend on the semantics of your schema.

When you modify an object graph, it is important to maintain referential integrity. Core Data makes it easy for you to alter relationships between managed objects without causing referential integrity errors. Much of this behavior derives from the relationship descriptions specified in the managed object model.

Core Data does not let you create relationships that cross stores. If you need to create a relationship from objects in one store to objects in another, you should consider using fetched properties.

Relationship Definitions in the Model

Creating a relationship in a managed object model is straightforward, but there are a number of aspects of a relationship that you need to specify properly. The most immediately obvious features are the relationship's name, the destination entity, and the **cardinality** (is it a to-one relationship, or a to-many relationship). The most important features with respect to object graph integrity, however, are the inverse relationship and the delete rule. The validity of the graph is affected by the settings for optionality and for maximum and minimum count.

Relationship Fundamentals

A relationship specifies the entity, or the parent entity, of the objects at the destination. This can be the same as the entity at the source (a **reflexive** relationship). Relationships do not have to be homogeneous. If the Employee entity has two sub-entities, say Manager and Flunky, then a given department's employees may be made up of Employees (assuming Employee is not an abstract entity), Managers, Flunkies, or any combination thereof.

You can specify a relationship as being to-one or to-many. To-one relationships are represented by a reference to the destination object. To-many relationships are represented by mutable sets (although fetched properties are represented by arrays). Implicitly, "to-one" and "to-many" typically refer to "one-to-one" and "one-to-many" relationships respectively. A many-to-many relationship is one where a relationship and its inverse are both to-many. These present some additional considerations, and are discussed in greater detail in "Many-to-Many Relationships" (page 76).

You can also put upper and lower limits on the number of objects at the destination of a to-many relationship. The lower limit does not have to be zero. You can if you want specify that the number of employees in a department must lie between 3 and 40. You also specify a relationship as either optional or not optional. If a relationship is not optional, then in order to be valid there must be an object or objects at the destination of the relationship.

Cardinality and optionality are orthogonal properties of a relationship. You can specify that a relationship is optional, even if you have specified upper and/or lower bounds. This means that there do not have to be any objects at the destination, but if there are then the number of objects must lie within the bounds specified.

It is important to note that simply defining a relationship does not cause a destination object to be created when a new source object is created. In this respect, defining a relationship is akin to declaring an instance variable in a standard Objective-C class. Consider the following example.

```
@interface Widget : NSObject
{
    Sprocket *sprocket;
}
```

If you create an instance of Widget, an instance of Sprocket is not created unless you write code to cause it to happen (for example, by overriding the `init` method). Similarly, if you define an Address entity, and a non-optional to-one relationship from Employee to Address, then simply creating an instance of Employee does not create a new Address instance. Likewise, if you define a non-optional to-many relationship from Employee to Address with a minimum count of `1`, then simply creating an instance of Employee does not create a new Address instance.

Inverse Relationships

Most relationships are inherently bi-directional. If a Department has a to-many relationship to the Employees that work in a Department, there is an inverse relationship from an Employee to the Department. The major exception is a fetched property, which represents a weak one-way relationship—there is no relationship from the destination to the source (see "Fetched Properties" (page 80)).

You should typically model relationships in both directions, and specify the inverse relationships appropriately. Core Data uses this information to ensure the consistency of the object graph if a change is made (see "Manipulating Relationships and Object Graph Integrity" (page 75)). For a discussion of some of the reasons why you might want to not model a relationship in both directions, and some of the problems that might arise if you don't, see "Unidirectional Relationships" (page 79).

Relationship Delete Rules

A relationship's delete rule specifies what should happen if an attempt is made to delete the source object. Note the phrasing in the previous sentence—"if an attempt is made…". If a relationship's delete rule is set to Deny, it is possible that the source object will not be deleted. Consider again a department's employees relationship, and the effect that the different delete rules have.

Deny

If there is at least one object at the relationship destination, then the source object cannot be deleted.

For example, if you want to remove a department, you must ensure that all the employees in that department are first transferred elsewhere (or fired!) otherwise the department cannot be deleted.

Nullify

Set the inverse relationship for objects at the destination to null.

For example, if you delete a department, set the department for all the current members to null. This only makes sense if the department relationship for an employee is optional, or if you ensure that you set a new department for each of the employees before the next save operation.

Cascade

Delete the objects at the destination of the relationship.

For example, if you delete a department, fire all the employees in that department at the same time.

No Action

Do nothing to the object at the destination of the relationship.

For example, if you delete a department, leave all the employees as they are, even if they still believe they belong to that department.

It should be clear that the first three of these rules are useful in different circumstances. For any given relationship it is up to you to choose which is most appropriate, depending on the business logic. It is less obvious why the No Action rule might be of use, since if you use it you have the possibility of leaving the object graph in an inconsistent state (employees having a relationship to a deleted department).

If you use the No Action rule, it is up to you to ensure that the consistency of the object graph is maintained. You are responsible for setting any inverse relationship to a meaningful value. This may be of benefit in a situation where you have a to-many relationship and there may be a large number of objects at the destination.

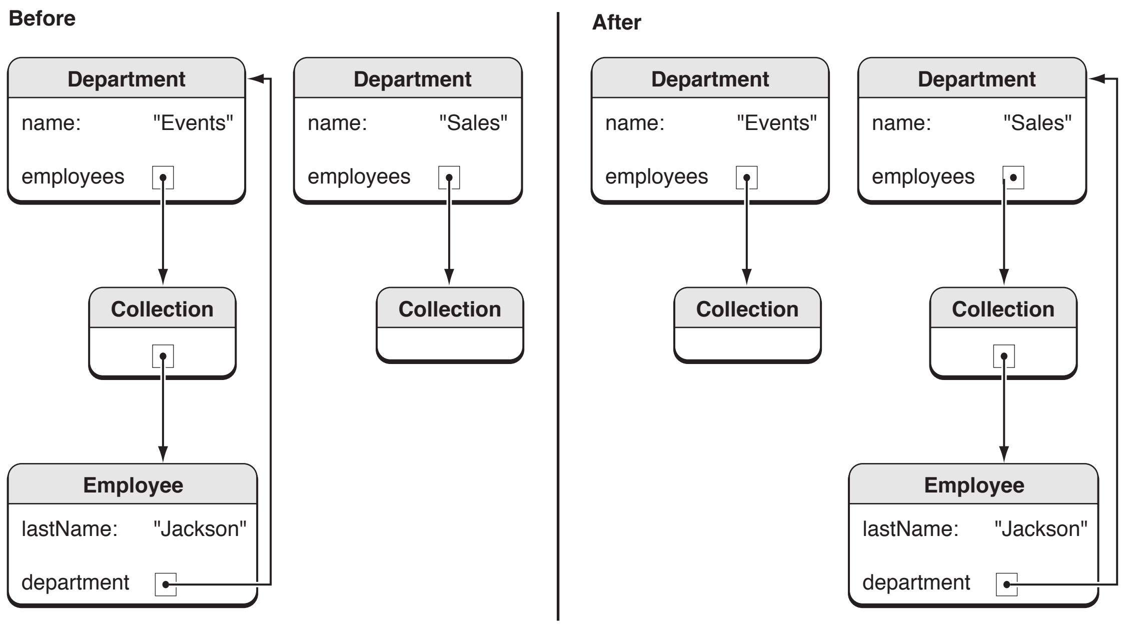
Manipulating Relationships and Object Graph Integrity

In general, programmatically manipulating relationships is straightforward. For examples of how to manipulate relationships programmatically, see "Accessing and Modifying Properties" (page 59)

Since Core Data takes care of the object graph consistency maintenance for you, you only need to change one end of a relationship and all other aspects are managed for you. This applies to to-one, to-many, and many-to-many relationships. Consider the following examples.

An employee's relationship to a manager implies a reverse relationship between a manager and the manager's employees. If a new employee is assigned to a particular manager, it is important that the manager be made aware of this responsibility. The new employee must be added to the manager's list of reports. Similarly, if an employee is transferred from one department to another, a number of modifications must be made, as illustrated in Figure 1 (page 76). The employee's new department is set, the employee is removed from the previous department's list of employees, and the employee is added to the new department's list of employees.

Figure 1 Transferring an employee to a new department



Without the Core Data framework, you must write several lines of code to ensure that the consistency of the object graph is maintained. Moreover you must be familiar with the implementation of the Department class to know whether or not the inverse relationship should be set (this may change as the application evolves). Using the Core Data framework, all this can be accomplished with a single line of code:

```
anEmployee.department = newDepartment;
```

By reference to the managed object model, the framework automatically determines from the current state of the object graph which relationships must be established and which must be broken.

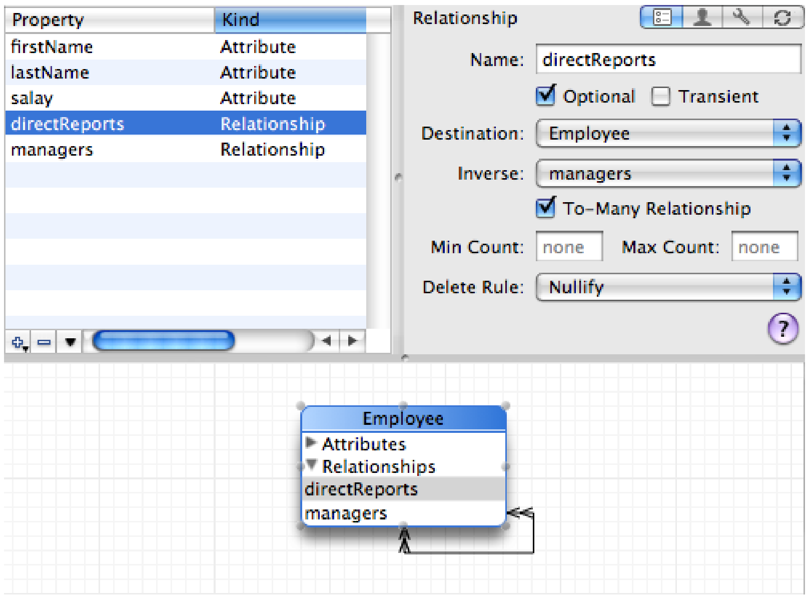
Many-to-Many Relationships

You define a many-to-many relationship using two to-many relationships. The first to-many relationship goes from the first entity to the second entity. The second to-many relationship goes from the second entity to the first entity. You then set each to be the inverse of the other. (If you have a background in database management and this causes you concern, don't worry: if you use a SQLite store, Core Data automatically creates the intermediate join table for you.)

Important: You must define many-to-many relationships in both directions—that is, you must specify two relationships, each being the inverse of the other. You can't just define a to-many relationship in one direction and try to use it as a many-to-many. If you do, you will end up with referential integrity problems.

This works even for relationships back to the same entity (often called "reflexive" relationships). For example, if an employee may have more than one manager (and a manager can have more than one direct report), then you can define a to-many relationship `directReports` from Employee to itself that is the inverse of another to-many relationship, `employees`, again from Employee to itself. This is illustrated in Figure 2 (page 77).

Figure 2 Example of a reflexive many-to-many relationship



Property	Kind
firstName	Attribute
lastName	Attribute
salay	Attribute
directReports	Relationship
managers	Relationship

Relationship

Name: directReports

[✓ Optional] Transient

Destination: Employee

Inverse: managers

[✓ To-Many Relationship]

Min Count: none Max Count: none

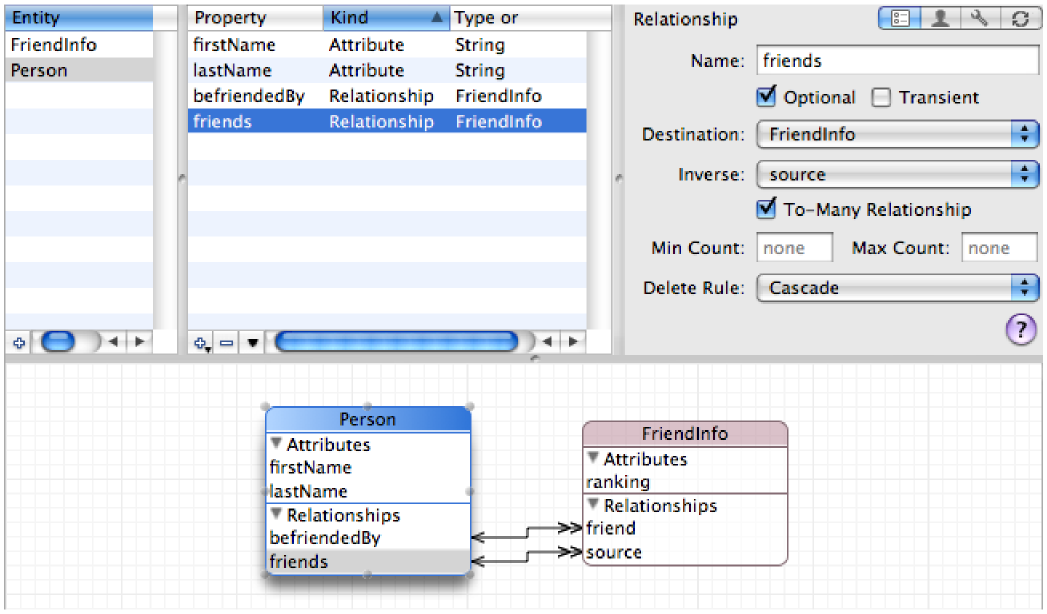
Delete Rule: Nullify

A relationship can also be the inverse of itself. For example, a Person entity may have a `cousins` relationship that is the inverse of itself.

Important: On Mac OS X v10.4, many-to-many relationships do not work with SQLite stores if the relationship is an inverse of itself (such as is the case with cousins).

You should also consider, though, the semantics of the relationship and how it should be modeled. A common example of a relationship that is initially modeled as a many-to-many relationship that's the inverse of itself is "friends." Although it's the case that you are your cousin's cousin whether they like it or not, it's not necessarily the case that you are your friend's friend. For this sort of relationship, you should use an intermediate ("join") entity. An advantage of the intermediate entity is that you can also use it to add more information to the relationship—for example a "FriendInfo" entity might include some indication of the strength of the friendship with a "ranking" attribute. This is illustrated in Figure 3 (page 78)

Figure 3 A model illustrating a "friends" relationship using an intermediate entity



Entity
FriendInfo
Person

Property	Kind	Type or
firstName	Attribute	String
lastName	Attribute	String
befriendedBy	Relationship	FriendInfo
friends	Relationship	FriendInfo

Relationship

Name: friends

[✓ Optional] Transient

Destination: FriendInfo

Inverse: source

[✓ To-Many Relationship]

Min Count: none Max Count: none

Delete Rule: Cascade

In this example, Person has two to-many relationships to FriendInfo: `friends` represents the source person's friends, and `befriendedBy` represents those who count the source as their friend. FriendInfo represents information about one friendship, "in one direction." A given instance notes who the source is, and one person they consider to be their friend. If the feeling is mutual, then there will be a corresponding instance where `source` and `friend` are swapped. There are several other considerations when dealing with this sort of model:

- To establish a friendship from one person to another, you have to create an instance of FriendInfo. If both people like each other, you have to create two instances of FriendInfo.
- To break a friendship, you must delete the appropriate instance of FriendInfo.
- The delete rule from Person to FriendInfo should be cascade. If a person is removed from the store, then the FriendInfo instance becomes invalid, so must also be removed.

  As a corollary, the relationships from FriendInfo to Person must not be optional—an instance of FriendInfo is invalid if the `source` or `friend` is null.
- To find out who one person's friends are, you have to aggregate all the `friend` destinations of the `friends` relationship, for example:

  ```
  NSSet *personsFriends = [aPerson valueForKeyPath:@"friends.friend"];
  ```

  Conversely, to find out who consider a given person to be their friends, you have to aggregate all the `source` destinations of the `befriendedBy` relationship, for example:

  ```
  NSSet *befriendedByPerson = [aPerson valueForKeyPath:@"befriendedBy.source"];
  ```

Unidirectional Relationships

It is not *strictly* necessary to model a relationship in both directions. In some cases it may be useful not to, for example when a to-many relationship may have a very large number of destination objects and you are rarely likely to traverse the relationship (you may want to ensure that you do not unnecessarily fault in a large number of objects at the destination of a relationship). Not modeling a relationship in both directions, however, imposes on you a great number of responsibilities, to ensure the consistency of the object graph, for change tracking, and for undo management. For this reason, the practice is strongly discouraged. It typically only makes sense to model a to-one relationship in one direction.

If you create a model with unidirectional relationships (relationships where you have specified no inverse), your object graph may end up in an inconsistent state.

The following example illustrates a situation where only modeling a relationship in one directions might cause problems. Consider a model in which you have two entities, Employee and Department, with a to-one relationship, "department", from Employee to Department. The relationship is non-optional and has a "deny" delete rule. The relationship does not have an inverse. Now consider the following code sample:

```
Employee *employee;
Department *department;
// assume entity instances correctly instantiated
[employee setDepartment:department];
[managedObjectContext deleteObject:department];
BOOL saved = [managedObjectContext save:&error];
```

The save succeeds (despite the fact that the relationship is non-optional) as long as `employee` is not changed in any other way. Because there is no inverse for the Employee.department relationship, `employee` is not marked as changed when `department` is deleted (and therefore `employee` is not validated for saving).

If you then add the following line of code:

```
id x = [employee department];
```

`x` will be a fault to "nowhere" rather than `nil`.

If, on the other hand, the "department" relationship has an inverse (and the delete rule is not No Action), everything behaves "as expected" since `employee` is marked as changed during delete propagation.

This illustrates why, in general, you should avoid using unidirectional relationships. Bidirectional relationships provide the framework with additional information with which to better maintain the object graph. If you do want to use unidirectional relationships, you need to do some of this maintenance yourself. In the case above, this would mean that after this line of code:

```
[managedObjectContext deleteObject:department];
```

you should write:

```
[employee setValue:nil forKey:@"department"]
```

The subsequent save will now (correctly) fail because of the non-optional rule for the relationship.

Cross-Store Relationships

You must be careful not to create relationships from instances in one persistent store to instances in another persistent store, as this is not supported by Core Data. If you need to create a relationship between entities in different stores, you typically use fetched properties (see "Fetched Properties" (page 80)).

Fetched Properties

Fetched properties represent weak, one-way relationships. In the employees and departments domain, a fetched property of a department might be "recent hires" (employees do not have an inverse to the recent hires relationship). In general, fetched properties are best suited to modeling cross-store relationships, "loosely coupled" relationships, and similar transient groupings.

A fetched property is like a relationship, but it differs in several important ways:

- Rather than being a "direct" relationship, a fetched property's value is calculated using a fetch request. (The fetch request typically uses a predicate to constrain the result.)
- A fetched property is represented by an array, not a set. The fetch request associated with the property can have a sort ordering, and thus the fetched property may be ordered.
- A fetched property is evaluated lazily, and is subsequently cached.

In some respects you can think of a fetched property as being similar to a smart playlist, but with the important constraint that it is not dynamic. If objects in the destination entity are changed, you must reevaluate the fetched property to ensure it is up-to-date. You use `refreshObject:mergeChanges:` to manually refresh the properties—this causes the fetch request associated with this property to be executed again when the object fault is next fired.

There are two special variables you can use in the predicate of a fetched property—`$FETCH_SOURCE` and `$FETCHED_PROPERTY`. The source refers to the specific managed object that has this property, and you can create key-paths that originate with this, for example `university.name LIKE [c] $FETCH_SOURCE.searchTerm`. The `$FETCHED_PROPERTY` is the entity's fetched property description. The property description has a userInfo dictionary that you can populate with whatever key-value pairs you want. You can therefore change some expressions within a fetched property's predicate or (via key-paths) any object to which that object is related.

To understand how the variables work, consider a fetched property with a destination entity Author and a predicate of the form, `(university.name LIKE [c] $FETCH_SOURCE.searchTerm) AND (favoriteColor LIKE [c] $FETCHED_PROPERTY.userInfo.color)`. If the source object had an attribute `searchTerm` equal to "Cambridge", and the fetched property had a user info dictionary with a key "color" and value "Green", then the resulting predicate would be `(university.name LIKE [c] "Cambridge") AND (favoriteColor LIKE [c] "Green")`. This would match any Authors at Cambridge whose favorite color is green. If you changed the value of searchTerm in the source object to, say, "Durham", then the predicate would be `(university.name LIKE [c] "Durham") AND (favoriteColor LIKE [c] "Green")`.

The most significant constraint is that you cannot use substitutions to change the structure of the predicate—for example you cannot change a LIKE predicate to a compound predicate, nor can you change the operator (in this example, `LIKE [c]`). Moreover, on Mac OS X version 10.4, this only works with the XML and Binary stores as the SQLite store will not generate the appropriate SQL.

Non-Standard Persistent Attributes

Core Data supports a range of common types for values of persistent attributes, including string, date, and number. Sometimes, however, you want an attribute's value to be a type that is not supported directly. For example, in a graphics application you might want to define a Rectangle entity that has attributes `color` and `bounds` that are an instance of `NSColor` and an `NSRect` struct respectively. This article describes the two ways in which you can use non-standard attribute types: using transformable attributes, or by using a transient property to represent the non-standard attribute backed by a supported persistent property.

Note: If you are using Mac OS X v10.4, read "Mac OS X v10.4: Non-Standard Persistent Attributes" (page 165) instead.

Introduction

Persistent attributes must be of a type recognized by the Core Data framework so that they can be properly stored to and retrieved from a persistent store. Core Data provides support for a range of common types for persistent attribute values, including string, date, and number (see `NSAttributeDescription` for full details). Sometimes, however, you want to use types that are not supported directly, such as colors and C structures.

You can use non-standard types for persistent attributes either by using transformable attributes or by using a *transient* property to represent the non-standard attribute backed by a supported persistent property. The principle behind the two approaches is the same: you present to consumers of your entity an attribute of the type you want, and "behind the scenes" it's converted into a type that Core Data can manage. The difference between the approaches is that with transformable attributes you specify just one attribute and the conversion is handled automatically. In contrast, with transient properties you specify two attributes and you have to write code to perform the conversion.

Transformable Attributes

The idea behind transformable attributes is that you access an attribute as a non-standard type, but behind the scenes Core Data uses an instance of `NSValueTransformer` to convert the attribute to and from an instance of `NSData`. Core Data then stores the data instance to the persistent store. By default, Core Data uses the `NSKeyedUnarchiveFromDataTransformerName` transformer, however you can specify your own transformer if you want.

To use a transformable attribute, you first simply add an attribute to your entity and specify that it is transformable. If you are using the model editor in Xcode, select Transformable in the Type popup; if you are setting the type programmatically, use `setAttributeType:` and pass `NSTransformableAttributeType` as the parameter. You then specify the name of the transformer to use: if you are using the model editor in Xcode, type the name in the Value Transformer Name text field; if you are setting the name programmatically, use `setValueTransformerName:`. (You don't have to specify a name if you are using the default transformer.) If you specify a custom transformer, it must transform an instance of the non-standard data type into an instance of `NSData` and support reverse transformation.

In principle, you don't have to do anything else. In practice, to suppress compiler warnings you should declare a property for the attribute as shown in the following example (notice `favoriteColor`):

```
@interface Employee :  NSManagedObject
{
}

@property (nonatomic, retain) NSString * firstName;
@property (nonatomic, retain) NSString * lastName;
@property (nonatomic, retain) NSSet* directReports;
@property (nonatomic, retain) Employee * manager;
@property (nonatomic, retain) Department * department;

@property (nonatomic, retain) NSColor * favoriteColor;

@end
```

You can also add an implementation directive, but (since the default is `dynamic`) this is not necessary.

```
@implementation Employee

@dynamic firstName;
@dynamic lastName;
@dynamic directReports;
@dynamic manager;
@dynamic department;

@dynamic favoriteColor;

@end
```

You can now use the attribute as you would any other standard attribute, as illustrated in the following code fragment:

```
Employee *newEmployee =
    [NSEntityDescription insertNewObjectForEntityForName:@"Employee"
        inManagedObjectContext:myManagedObjectContext];

newEmployee.firstName = @"Captain";
newEmployee.lastName = @"Scarlet";
newEmployee.favoriteColor = [NSColor redColor];
```

Custom Code

The following sections illustrate implementations for object and scalar values. Both start, however, with a common task—you must specify a persistent attribute.

Note: The example for an object value uses an instance of `NSColor`; if you are using Mac OS X v10.5, you should typically use a transformable attribute instead.

Basic Approach

To use non-supported types, in the managed object model you define two attributes. One is the attribute you actually want (its value is for example a color object or a rectangle struct). This attribute is transient. The other is a "shadow" representation of that attribute. This attribute is persistent.

You specify the type of the transient attribute as undefined (`NSUndefinedAttributeType`). Since Core Data does not need to store and retrieve transient properties, you can use any object type you want for the attribute in your implementation. Core Data does, though, track the state of transient properties so that they can participate in the object graph management (for example, for undo and redo).

The type of the shadow attribute must be one of the "concrete" supported types. You then implement a custom managed object class with suitable accessor methods for the transient attribute that retrieve the value from and store the value to the persistent attribute.

The basic approach for object and scalar values is the same—you must find a way to represent the unsupported data type as one of the supported data types—however there is a further constraint in the case of scalar values.

Scalar Value Constraints

A requirement of the accessor methods you write is that they must be key-value coding (and key-value observing) compliant. Key-value coding only supports a limited number of structures—`NSPoint`, `NSSize`, `NSRect`, and `NSRange`.

If you want to use a scalar type or structure that is not one of those supported directly by Core Data and not one of the structures supported by key-value coding, you must store it in your managed object as an object—typically an `NSValue` instance, although you can also define your own custom class. You will then treat it as an object value as described later in this article. It is up to users of the object to extract the required structure from the `NSValue` (or custom) object when retrieving the value, and to transform a structure into an `NSValue` (or custom) object when setting the value.

The Persistent Attribute

For any non-standard attribute type you want to use, you must choose a supported attribute type that you will use to store the value. Which supported type you choose depends on the non-standard type and what means there are of transforming it into a supported type. In many cases you can easily transform a non-supported object into an `NSData` object using an archiver. For example, you can archive a color object as shown in the following code sample. The same technique can be used if you represent the attribute as an instance of `NSValue` or of a custom class (note that your custom class would, of course, need to adopt the `NSCoding` protocol or provide some other means of being transformed into a supported data type).

```
NSData *colorAsData = [NSKeyedArchiver archivedDataWithRootObject:aColor];
```

You are free to use whatever means you wish to effect the transformation. For example, you could transform an `NSRect` structure into a string object (strings can of course be used in a persistent store).

```
NSRect aRect; // instance variable
NSString *rectAsString = NSStringFromRect(aRect);
```

You can transform the string back into a rectangle using `NSRectFromString`. You should bear in mind, however, that since the transformation process may happen frequently, you should ensure that it is as efficient as possible.

Typically you do not need to implement custom accessor methods for the persistent attribute. It is an implementation detail, the value should not be accessed other than by the entity itself. If you do modify this value directly, it is possible that the entity object will get into an inconsistent state.

An Object Attribute

If the non-supported attribute is an object, then in the managed object model you specify its type as undefined, and that it is transient. When you implement the entity's custom class, there is no need to add an instance variable for the attribute—you can use the managed object's private internal store. A point to note about the implementations described below is that they cache the transient value. This makes accessing the value more efficient—it is also necessary for change management. If you define custom instance variables, you should clean up these variables in `didTurnIntoFault` rather than `dealloc` or `finalize`.

There are two strategies both for getting and for setting the transient value. You can retrieve the transient value either "lazily" (on demand—described in "The On-demand Get Accessor" (page 86)) or during awakeFromFetch (described in "The Pre-calculated Get" (page 87)). It may be preferable to retrieve it lazily if the value may be large (if for example it is a bitmap). For the persistent value, you can either update it every time the transient value is changed (described in "The Immediate-Update Set Accessor" (page 87)), or you can defer the update until the object is saved (described in "The Delayed-Update Set Accessor" (page 88)).

The On-demand Get Accessor

In the get accessor, you retrieve the attribute value from the managed object's private internal store. If the value is `nil`, then it is possible it has not yet been cached, so you retrieve the corresponding persistent value, then if that value is not `nil`, transform it into the appropriate type and cache it. The following example illustrates the on-demand get accessor for a color attribute.

```
- (NSColor *)color
{
    [self willAccessValueForKey:@"color"];
    NSColor *color = [self primitiveColor];
    [self didAccessValueForKey:@"color"];
    if (color == nil)
    {
        NSData *colorData = [self colorData];
        if (colorData != nil)
        {
            color = [NSKeyedUnarchiver unarchiveObjectWithData:colorData];
            [self setPrimitiveColor:color];
        }
    }
    return color;
}
```

The Pre-calculated Get

Using this approach, you retrieve and cache the persistent value in `awakeFromFetch`.

```
- (void)awakeFromFetch
{
    [super awakeFromFetch];
    NSData *colorData = [self colorData];
    if (colorData != nil)
    {
        NSColor *color;
        color = [NSKeyedUnarchiver unarchiveObjectWithData:colorData];
        [self setPrimitiveColor:color];
    }
}
```

In the get accessor you then simply return the cached value.

```
- (NSColor *)color
{
    [self willAccessValueForKey:@"color"];
    NSColor *color = [self primitiveColor];
    [self didAccessValueForKey:@"color"];
    return color;
}
```

This technique is useful if you are likely to access the attribute frequently—you avoid the conditional statement in the get accessor.

The Immediate-Update Set Accessor

In this set accessor, you set the value for both the transient and the persistent attributes at the same time. You transform the unsupported type into the supported type to set as the persistent value. You must ensure that you invoke the key-value observing change notification methods, so that objects observing the managed object—including the managed object context—are notified of the modification. The following example illustrates the set accessor for a color attribute.

```
- (void)setColor:(NSColor *)aColor
{
    [self willChangeValueForKey:@"color"];
    [self setPrimitiveValue:aColor forKey:@"color"];
    [self didChangeValueForKey:@"color"];
    [self setValue:[NSKeyedArchiver archivedDataWithRootObject:aColor]
                forKey:@"colorData"];
}
```

The main disadvantage with this approach is that the persistent value is recalculated each time the transient value is updated, which may be a performance issue.

The Delayed-Update Set Accessor

In this technique, in the set accessor you only set the value for the transient attribute. You implement a `willSave` method that updates the persistent value just before the object is saved.

```
- (void)setColor:(NSColor *)aColor
{
    [self willChangeValueForKey:@"color"];
    [self setPrimitiveValue:aColor forKey:@"color"];
    [self didChangeValueForKey:@"color"];
}

- (void)willSave
{
    NSColor *color = [self primitiveValueForKey:@"color"];
    if (color != nil)
    {
       [self setPrimitiveValue:[NSKeyedArchiver archivedDataWithRootObject:color]
                 forKey:@"colorData"];
    }
    else
    {
        [self setPrimitiveValue:nil forKey:@"colorData"];
    }
    [super willSave];
}
```

If you adopt this approach, you must take care when specifying your optionality rules. If color is a required attribute, then (unless you take other steps) you must specify the color attribute as not optional, and the color data attribute as optional. If you do not, then the first save operation may generate a validation error.

When the object is first created, the value of `colorData` is `nil`. When you update the color attribute, the `colorData` attribute is unaffected (that is, it remains `nil`). When you save, `validateForUpdate:` is invoked before `willSave`. In the validation stage, the value of `colorData` is still `nil`, and therefore validation fails.

Scalar Values

You can declare properties as scalar values, but for scalar values Core Data cannot dynamically generate accessor methods—you must provide your own implementations (see Managed Object Accessor Methods (page 41)). Note that Core Data automatically synthesizes the primitive accessor methods (`primitiveLength` and `setPrimitiveLength:`), however you need to declare them to suppress compiler warnings.

For objects that will be used in either a Foundation collection or an AppKit view, you should typically allow Core Data to use its default storage instead of creating scalar instances to hold property values:

- There is CPU and memory overhead in creating and destroying autoreleased `NSNumber` object wrappers for your scalars;
- Core Data optimizes at runtime any accessor methods you do not override—for example, it inlines the access and change notification method calls.

The advantages of allowing Core Data to manage its own storage usually outweigh any advantages of interacting directly with scalar values, although if you suspect that this is not true for your application you should use performance analysis tools to check.

You can declare properties as scalar values. Core Data cannot, though, dynamically generate accessor methods for scalar values—you must provide your own implementations. If you have an attribute `length` that is specified in the model as a `double` (`NSDoubleAttributeType`), in the interface file you declare `length` as:

```
@property double length;
```

In the implementation file, you implement accessors that invoke the relevant access and change notification methods, and the primitive accessors. Core Data automatically synthesizes the primitive accessor methods (`primitiveLength` and `setPrimitiveLength:`), but you need to declare them to suppress compiler warnings.

```
@interface MyManagedObject (PrimitiveAccessors)
- (NSNumber *)primitiveLength;
- (void)setPrimitiveLength:(NSNumber *)newLength;
@end


- (double)length
{
    [self willAccessValueForKey:@"primitiveLength"];
    NSNumber *tmpValue = [self primitiveLength];
    [self didAccessValueForKey:@"primitiveLength"];
    return (tmpValue!=nil) ? [tmpValue doubleValue] : 0.0; // or a suitable
representation for nil
}

- (void)setLength:(double)value
{
    NSNumber* temp = [[NSNumber alloc] initWithDouble: value];
    [self willChangeValueForKey:@"primitiveLength"];
    [self setPrimitiveLength:temp];
    [self didChangeValueForKey:@"primitiveLength"];
    [temp release];
}
```

A Non-Object Attribute

If the non-supported attribute is one of the structures supported by key-value coding (`NSPoint`, `NSSize`, `NSRect`, or `NSRange`), then in the managed object model you again specify its type as undefined, and that it is transient. When you implement the entity's custom class, you typically add an instance variable for the attribute. For example, given an attribute called `bounds` that you want to represent using an `NSRect` structure, your class interface might be like that shown in the following example.

```
@interface MyManagedObject : NSManagedObject
{
    NSRect bounds;
}
- (NSRect)bounds;
- (void)setBounds:(NSRect)aRect;
@end
```

Alternatively, if you want to give the instance variable a name other than the name of the attribute, you should also implement primitive get and set accessors (see "Custom Primitive Accessor Methods" (page 48)), as shown in the following example.

```
@interface MyManagedObject : NSManagedObject
{
    NSRect myBounds;
}
- (NSRect)primitiveBounds;
- (void)setPrimitiveBounds:(NSRect)aRect;
- (NSRect)bounds;
- (void)setBounds:(NSRect)aRect;
@end
```

The primitive methods simply get and set the instance variable—they do not invoke key-value observing change or access notification methods—as shown in the following example.

```
- (NSRect)primitiveBounds
{
    return myBounds;
}
- (void)setPrimitiveBounds:(NSRect)aRect
    myBounds = aRect;
}
```

Whichever strategy you adopt, you then implement accessor methods mostly as described for the object value. For the get accessor you can adopt either the lazy or pre-calculated technique, and for the set accessor you can adopt either the immediate update or delayed update technique. The following sections illustrate only the former versions of each.

The Get Accessor

In the get accessor, you retrieve the attribute value from the managed object's private internal store. If the value has not yet been set, then it is possible it has not yet been cached, so you retrieve the corresponding persistent value, then if that value is not `nil`, transform it into the appropriate type and cache it. The following example illustrates the get accessor for a rectangle (this example makes a simplifying assumption that the bounds width cannot be `0`, so if the value is `0` then the bounds has not yet been unarchived).

```
- (NSRect)bounds
{
    [self willAccessValueForKey:@"bounds"];
    NSRect aRect = bounds;
    [self didAccessValueForKey:@"bounds"];
    if (aRect.size.width == 0)
    {
        NSString *boundsAsString = [self boundsAsString];
        if (boundsAsString != nil)
        {
            bounds = NSRectFromString(boundsAsString);
        }
    }
    return bounds;
}
```

The Set Accessor

In the set accessor, you must set the value for both the transient and the persistent attributes. You transform the unsupported type into the supported type to set as the persistent value. You must ensure that you invoke the key-value observing change notification methods, so that objects observing the managed object—including the managed object context—are notified of the modification. The following example illustrates the set accessor for a rectangle.

```
- (void)setBounds:(NSRect)aRect
{
    [self willChangeValueForKey:@"bounds"];
    bounds = aRect;
    [self didChangeValueForKey:@"bounds"];
    NSString *rectAsString = NSStringFromRect(aRect);
    [self setValue:rectAsString forKey:@"boundsAsString"]; }
```

Type-Checking

If you define an attribute to use a non-standard type, you can also specify the name of the class used to represent the value, using `setAttributeValueClassName:`. If you do, Core Data automatically checks any value set and throws an exception if it is an instance of the wrong class.

You can only set the value class name in code. The following example shows how you can modify the managed object model of a subclass of `NSPersistentDocument` to include a value class name for a non-standard attribute (`favoriteColor`) represented in this case by a an instance of a custom class, `MyColor`. Notice the subsequent programming error in setting the Captain Scarlet's favorite color to an instance of `NSColor`.

```
- (NSManagedObjectModel *)managedObjectModel
{
    if (myManagedObjectModel == nil)
    {
        NSBundle *bundle = [NSBundle bundleForClass:[self class]];
        NSString *path = [bundle pathForResource:@"MyDocument" ofType:@"mom"];
        NSURL *url = [NSURL fileURLWithPath:path];
        myManagedObjectModel = [[NSManagedObjectModel alloc]
initWithContentsOfURL:url];

        NSEntityDescription *employeeEntity =
            [[myManagedObjectModel entitiesByName] objectForKey:@"Employee"];
        NSAttributeDescription *favoriteColorAttribute =
            [[employeeEntity attributesByName] objectForKey:@"favoriteColor"];

        // set the attribute value class to MyColor
        [favoriteColorAttribute setAttributeValueClassName:@"MyColor"];
    }

    return myManagedObjectModel;
}


- (void)windowControllerDidLoadNib:(NSWindowController *)windowController
{
    [super windowControllerDidLoadNib:windowController];
    Employee *newEmployee =
        [NSEntityDescription insertNewObjectForEntityForName:@"Employee"
            inManagedObjectContext:[self managedObjectContext]];

    newEmployee.firstName = @"Captain";
    newEmployee.lastName = @"Scarlet";
    newEmployee.favoriteColor = [NSColor redColor]; // exception thrown here
}
```

Note that the attribute value class must actually exist at runtime. If you misspell the class name itself (for example, `MyColour` instead of `MyColor`), the check succeeds silently.

Managed Object Validation

There are two types of validation—property-level and inter-property. You use property-level validation to ensure the correctness of individual values; you use inter-property validation to ensure the correctness of combinations of values.

Core Data Validation

Cocoa provides a basic infrastructure for model value validation described in Model Object Validation in *Model Object Implementation Guide*. This approach, however, requires you to write code for all the constraints you want to apply. Core Data allows you to put validation logic into the managed object model. You can specify maximum and minimum values for numeric and date attributes; maximum and minimum lengths for string attributes, and a regular expression that a string attribute must match. You can also specify constraints on relationships, for example that they are mandatory or cannot exceed a certain number. You can therefore specify most common constraints on attribute values without writing any code.

If you do want to customize validation of individual properties, you use standard validation methods as defined by the `NSKeyValueCoding` protocol and described in "Property-Level Validation" (page 93)). Core Data also extends validation to validation of relationships and inter-property values. These are described in "Inter-Property validation" (page 95).

It is important to understand that *how* to validate is a model decision, *when* to validate is a user interface or controller-level decision (for example, a value binding for a text field might have its "validates immediately" option enabled). Moreover, at various times, inconsistencies are expected to arise in managed objects and object graphs.

There is nothing to disallow an in-memory object from becoming inconsistent on a temporary basis. The validation constraints are applied by Core Data only during a "save" operation or upon request (you can invoke the validation methods directly as and when you wish). Sometimes it may be useful to validate changes as soon as they are made and to report errors immediately. This can prevent the user being presented with a long list of errors when they finally come to save their work. If managed objects were required to be always in a valid state, it would amongst other things force a particular workflow on the end-user. This also underpins the idea of a managed object context representing a "scratch pad"—in general you can bring managed objects onto the scratch pad and edit them however you wish before ultimately either committing the changes or discarding them.

Property-Level Validation

The `NSKeyValueCoding` protocol specifies a method—`validateValue:forKey:error:`—that provides general support for validation methods in a similar way to that in which `valueForKey:` provides support for accessor methods.

If you want to implement logic in addition to the constraints you provide in the managed object model, you should not override `validateValue:forKey:error:`. Instead you should implement methods of the form `validate<Key>:error:`.

Important: If you do implement custom validation methods, you should typically not invoke them directly. Instead you should call `validateValue:forKey:error:` with the appropriate key. This ensures that any constraints defined in the managed object model are also applied.

In the method implementation, you check the proposed new value and if it does not fit your constraints you return `NO`. If the error parameter is not `null`, you also create an `NSError` object that describes the problem, as illustrated in this example.

```
-(BOOL)validateAge:(id *)ioValue error:(NSError **)outError {
    if (*ioValue == nil) {
        // trap this in setNilValueForKey? new NSNumber with value 0?
        return YES;
    }
    if ([*ioValue floatValue] <= 0.0) {
        if (outError != NULL) {
            NSString *errorStr = NSLocalizedStringFromTable(
                @"Age must greater than zero", @"Employee",
                @"validation: zero age error");
            NSDictionary *userInfoDict = [NSDictionary
dictionaryWithObject:errorStr
                forKey:NSLocalizedDescriptionKey];
            NSError *error = [[[NSError alloc]
initWithDomain:EMPLOYEE_ERROR_DOMAIN
                code:PERSON_INVALID_AGE_CODE
                userInfo:userInfoDict] autorelease];
            *outError = error;
        }
        return NO;
    }
    else {
        return YES;
    }
    // . . .
```

It is important to note that the input value is a pointer to object reference (an `id *`). This means that in principle you can change the input value. Doing so is, however, strongly discouraged, as there are potentially serious issues with memory management (see Key-Value Validation in *Key-Value Coding Programming Guide*). You should not call `validateValue:forKey:error:` within custom property validation methods. If you do, you will create an infinite loop when `validateValue:forKey:error:` is invoked at runtime.

If you change the input value in a `validate<Key>:error:` method, you must ensure that you only change the value if it is invalid or uncoerced. The reason is that, since the object and context are now dirtied, Core Data may validate that key again later. If you keep performing a coercion in a validation method, this can therefore produce an infinite loop. Similarly, you should also be careful if you implement validation and `willSave` methods that produce mutations or side effects—Core Data will revalidate those changes until a stable state is reached.

Inter-Property validation

It is possible for the values of all the individual attributes of an object to be valid and yet for the combination of values to be invalid. Consider, for example, an application that stores information about people including their age and whether or not they have a driving license. For a Person object, `12` might be a valid value for an `age` attribute, and `YES` is a valid value for a `hasDrivingLicense` attribute, but (in most countries at least) this combination of values would be invalid.

`NSManagedObject` provides additional loci for validation—update, insertion, and deletion—through the `validateFor`... methods such as `validateForUpdate:`. If you implement custom inter-property validation methods, you call the superclass's implementation first to ensure that individual property validation methods are also invoked. If the superclass's implementation fails (that is, if there is an invalid attribute value), then you can:

1. Return `NO` and the error created by the superclass's implementation.

2. Continue to perform validation, looking for inconsistent combinations of values.

If you continue, you must make sure that any values you use in your logic are not themselves invalid in such a way that your code might itself cause errors (for example, if there is an attribute whose value is required to be greater than `0`, which is actually `0` so fails validation but which you use as a divisor in a computation). Moreover, if you discover further validation errors, you must combine them with the existing error and return a "multiple errors error" as described in "Combining Validation Errors" (page 97).

The following example shows the implementation of an inter-property validation method for a Person entity that has two attributes, `birthday` and `hasDrivingLicense`. The constraint is that a person aged less than 16 years cannot have a driving license. This constraint is checked in both `validateForInsert:` and `validateForUpdate:`, so the validation logic itself is factored into a separate method.

Listing 1 Inter-property validation for a Person entity

```
- (BOOL)validateForInsert:(NSError **)error
{
    BOOL propertiesValid = [super validateForInsert:error];
    // could stop here if invalid
    BOOL consistencyValid = [self validateConsistency:error];
    return (propertiesValid && consistencyValid);
}

- (BOOL)validateForUpdate:(NSError **)error
{
    BOOL propertiesValid = [super validateForUpdate:error];
    // could stop here if invalid
    BOOL consistencyValid = [self validateConsistency:error];
    return (propertiesValid && consistencyValid);
}


- (BOOL)validateConsistency:(NSError **)error
{
    static     NSCalendar *gregorianCalendar;

    BOOL valid = YES;
    NSDate *myBirthday = [self birthday];
    if ((myBirthday != nil) && ([[self hasDrivingLicense] boolValue] == YES))
{

        if (gregorianCalendar == nil) {
            gregorianCalendar = [[NSCalendar alloc]
initWithCalendarIdentifier:NSGregorianCalendar];
        }
        NSDateComponents *components = [gregorianCalendar
components:NSYearCalendarUnit
                                                           fromDate:myBirthday
                                                             toDate:[NSDate
date]
                                                            options:0];
        int years = [components year];

        if (years < 16) {

            valid = NO;

            // don't create an error if none was requested
            if (error != NULL) {

                NSBundle *myBundle = [NSBundle bundleForClass:[self class]];
                NSString *drivingAgeErrorString = [myBundle
localizedStringForKey:@"TooYoungToDriveError"
                                  value:@"Person is too young to have a driving
 license."
                                  table:@"PersonErrorStrings"];

              NSMutableDictionary *userInfo = [NSMutableDictionary dictionary];
                [userInfo setObject:drivingAgeErrorString
forKey:NSLocalizedFailureReasonErrorKey];
                [userInfo setObject:self forKey:NSValidationObjectErrorKey];

              NSError *drivingAgeError = [NSError errorWithDomain:PERSON_DOMAIN

code:NSManagedObjectValidationError
                                                           userInfo:userInfo];

                // if there was no previous error, return the new error
                if (*error == nil) {
                    *error = drivingAgeError;
                }
                // if there was a previous error, combine it with the existing
 one
                else {
                    *error = [self errorFromOriginalError:*error
error:drivingAgeError];
                }
            }
        }
    }
    return valid;
}
```

Combining Validation Errors

If there are multiple validation failures in a single operation, you create and return a "multiple errors error"—that is, an `NSError` object with the code `NSValidationMultipleErrorsError`. You add individual errors to an array and add the array—using the key `NSDetailedErrorsKey`—to the user info dictionary in the `NSError` object. This pattern also applies to errors returned by the superclass's validation method. Depending on how many tests you perform, it may be convenient to define a method that combines an existing `NSError` object (which may itself be a multiple errors error) with a new one and returns a new multiple errors error.

The following example shows the implementation of a simple method to combine two errors into a single multiple errors error. How the combination is made depends on whether or not the original error was itself a multiple errors error.

Listing 2 A method for combining two errors into a single multiple errors error

```
- (NSError *)errorFromOriginalError:(NSError *)originalError error:(NSError
*)secondError
{
    NSMutableDictionary *userInfo = [NSMutableDictionary dictionary];
    NSMutableArray *errors = [NSMutableArray arrayWithObject:secondError];

    if ([originalError code] == NSValidationMultipleErrorsError) {

        [userInfo addEntriesFromDictionary:[originalError userInfo]];
       [errors addObjectsFromArray:[userInfo objectForKey:NSDetailedErrorsKey]];
    }
    else {
        [errors addObject:originalError];
    }

    [userInfo setObject:errors forKey:NSDetailedErrorsKey];

    return [NSError errorWithDomain:NSCocoaErrorDomain
                               code:NSValidationMultipleErrorsError
                           userInfo:userInfo];
}
```

Faulting and Uniquing

Core Data uses two features to ensure that the object graph is no larger than is necessary and that a given instance of an entity is not represented more than once in a given managed object context. These features are known as faulting and uniquing respectively.

Faulting

Consider an application that allows a user to fetch and edit details about a single employee. The application requires in memory only an object that represents that employee. The employee, however, has a relationship to a manager and to a department. These objects in turn have other relationships. If it were a requirement that the object graph be complete, then in order to edit a single attribute of a single employee it would be necessary to create objects to represent the whole corporate structure. Core Data avoids this situation by using a technique known as **faulting**.

Important: Only a managed object, or the collection that represents a to-many relationship, can be a fault. There is no way to load individual properties of a managed object. For patterns to deal with large attributes, see "Large Data Objects (BLOBs)" (page 130).

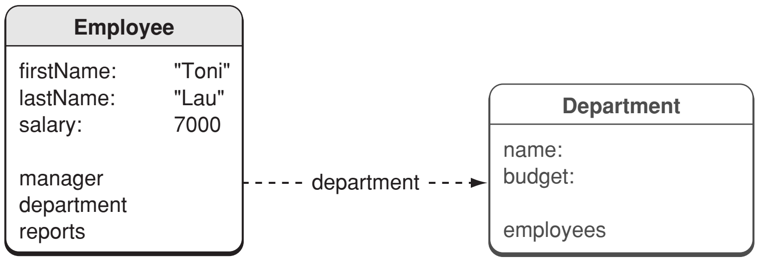
Core Data faults are analogous to virtual memory page faults—they are simply scoped to objects instead of memory pages. The `malloc` and `calloc` functions do not guarantee whether the memory they "allocate" for you actually exists—until you actually use it. Even if you do get a pre-existing page from `malloc`, it may not be in physical memory. In an analogous way, in Core Data a fault is a placeholder object that represents an object that has not yet been fully **realized** or a collection of objects in a relationship. (To-many relationships have two levels of faulting. The first is for a collection—the set—that represents the contents of the relationship by identity. The second is for the faulting of the individual destination objects.) It is an instance of the class appropriate to the relationship's destination, but its persistent variables are not yet initialized.

Fault handling is transparent. If at some stage a persistent property of a fault object is accessed, then Core Data automatically retrieves the data for the object and initializes the object (see `NSManagedObject` for a list of methods that do not cause faults to fire). This process is commonly referred to as **firing** the fault.

Note: Core Data avoids the term "unfaulting" because it is confusing. There's no "unfaulting" a virtual memory page fault. Page faults are triggered, caused, fired, or encountered. Of course, you can release memory back to the kernel in a variety of ways (using the functions `vm_deallocate`, `munmap`, or `sbrk`). Core Data describes this as "turning an object into a fault".

Consider the following example. When an application launches you retrieve a single Employee object from a persistent store. Initially its manager, department, and reports relationships are represented by faults. Figure 1 shows an employee's department relationship represented by a fault. Although the fault is an instance of the Department class, it has not yet been realized—none of its persistent instance variables have yet been set. If you send the Department object a message to get, say, its name, then the fault fires—and in this situation Core Data executes a fetch for you to retrieve all the object's attributes.

Figure 1 A department represented by a fault



Firing Faults

There should typically be no need to fire a fault yourself. Core Data automatically fires faults when necessary (when a persistent property of a fault is accessed). Moreover, firing faults individually can be inefficient, and there are better strategies for getting data from the persistent store (see "Batch Faulting and Pre-fetching with the SQLite Store" (page 127)). If you find that you need to, however, you can explicitly fire a fault by sending an object a `willAccessValueForKey:` message, passing `nil` as the argument.

For more about how to efficiently deal with faults and relationships, see "Fetching Managed Objects" (page 125).

Turning Objects Into Faults

There are good reasons for turning a realized object into a fault, which you can do using `refreshObject:mergeChanges:` (typically passing `NO` as the *`mergeChanges`* argument). Turning a managed object into a fault releases unnecessary memory, sets its in-memory property values to `nil`, and releases any retains on related objects. This can be useful in pruning the object graph (see "Reducing Memory Overhead" (page 129)), as well as ensuring property values are current (see "Ensuring Data Is Up-to-Date" (page 66)). When an object turns into a fault, it is sent a `didTurnIntoFault` message. You may implement a custom `didTurnIntoFault` method to perform various "housekeeping" functions (see, for example, "Ensuring Data Is Up-to-Date" (page 66)).

Realizing a Managed Object

It is important to understand the different ways in which a managed object is realized.

- If you execute a fetch using `executeFetchRequest:error:`, this always results in a round trip to the persistent store to fetch the data. The objects returned in the results array are fully realized, and their data is stored in a cache (held by the persistent store coordinator).
- If you fire a fault, Core Data does *not* go back to the store *if* the data is available in the cache. With a cache hit, converting a fault into a realized managed object is very fast—it is basically the same as normal instantiation of a managed object. If the data is not available in the cache, Core Data automatically executes a fetch for the fault object; this results in a round trip to the persistent store to fetch the data, and again the data is cached in memory.

The corollary of the second point is that whether an object is a fault is not the same as whether its data has been retrieved from the store. Whether or not an object is a fault simply means whether or not a given managed object has all its attributes populated and is ready to use. If you need to determine whether or not an object is a fault, you can send it an `isFault` message without firing the fault. If `isFault` returns `NO`, then the data must be in memory. However, if `isFault` returns `YES`, it does *not* imply that the data is *not* in memory. The data may be in memory, or it may not, depending on many factors influencing caching.

Faults and KVO Notifications

When Core Data faults in an object, key-value observing (KVO) change notifications (see *Key-Value Observing Programming Guide*) are sent for the object's properties. If you are observing properties of an object that is turned into a fault and the fault is subsequently realized, you therefore receive change notifications for properties whose values have not in fact changed.

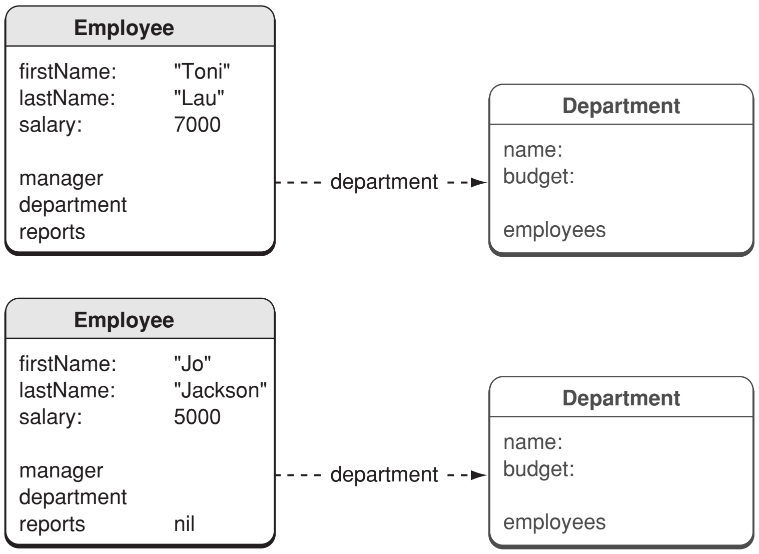
While the values are not changing semantically from your perspective, the literal bytes in memory are changing as the object is materialized. The key-value observing mechanism requires Core Data to issue the notification whenever the values change as considered from the perspective of pointer comparison. KVO needs these notifications to track changes across keypaths and dependent objects.

Uniquing

In some circumstances you may fetch the same data in different ways in different parts of an application. (This is less likely to be a problem when you manage the object graph yourself and the whole graph is in memory at the same time—you either have an explicit reference to a given object or traverse relationships to reach an object.)

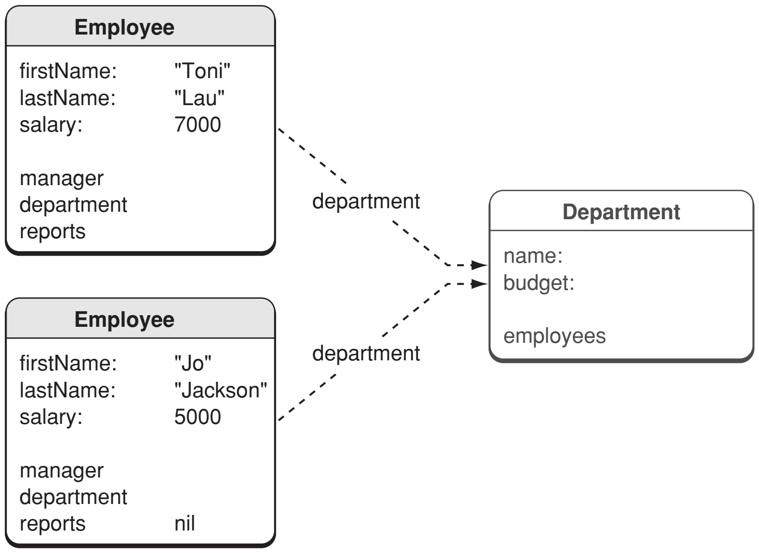
For example, consider the hypothetical situation illustrated in Figure 2; two employees have been fetched into *a single managed object context*. Each has a relationship to a department, but the department is currently represented by a fault.

Figure 2 Independent faults for a department object



It would appear that each employee has a separate department, and if you asked each employee for their department in turn—turning the faults into regular objects—you would have two separate Department objects in memory. However, if both employees belong to the same department (for example, "Marketing"), then Core Data ensures that (in a given managed object context) only one object representing the Marketing department is ever created. If both employees belong to the same department, their department relationships would both therefore reference the same fault, as illustrated in Figure 3.

Figure 3 Uniqued fault for two employees working in the same department



More generally, all the managed objects in a given context that refer to the Marketing Department object refer to the same instance—they have a single view of Marketing's data—*even if it is a fault*. The mechanism by which Core Data ensures that—in a given managed object context—an entry in a persistent store is associated with only one managed object is known as **uniquing**.

If Core Data did not use uniquing, then if you fetched all the employees and asked each in turn for their department—thereby firing the corresponding faults—a new Department object would be created every time. This would result in a number of objects, each representing the same department, that could contain different and conflicting data. When the context was saved, it would be impossible to determine which is the correct data to commit to the store.

It is important to note that the discussion has focused on a single managed object context. Each managed object context represents a different view of the data. If the same employees are fetched into a second context, then they—and the corresponding Department object—are all represented by different objects in memory. The objects in different contexts *may* have different and conflicting data. It is precisely the role of the Core Data architecture to detect and resolve these conflicts at save time.

Using Persistent Stores

This article describes how you create a persistent store, and how you can migrate a store from one type to another, and manage store metadata. For more about persistent store types, the differences between them, and how you can configure aspects of their behavior, see "Persistent Store Features" (page 117).

Creating and Accessing a Store

Access to stores is mediated by an instance of `NSPersistentStoreCoordinator`. You should not need to directly access a file containing a store. From a persistent store coordinator, you can retrieve an object that represents a particular store on disk. On Mac OS X v10.5 and later, Core Data provides an `NSPersistentStore` class to represent persistent stores.

To create a store, you use a persistent store coordinator. You must specify the type of the store to be created, optionally a configuration of managed object model associated with the coordinator, and its location if it is not an in-memory store. The following code fragment illustrates how you can create a read-only XML store:

```
NSManagedObjectContext *moc = /* get a context from somewhere */ ;
NSPersistentStoreCoordinator *psc = [moc persistentStoreCoordinator];
NSError *error = nil;
NSDictionary *options =
    [NSDictionary dictionaryWithObject:[NSNumber numberWithBool:1]
                    forKey:NSReadOnlyPersistentStoreOption];

NSPersistentStore *roStore =
    [psc addPersistentStoreWithType:NSXMLStoreType
                    configuration:nil URL:url
                    options:options error:&error];
```

To retrieve a store object from a coordinator, you use the method `persistentStoreForURL:`. You can use a store to restrict a fetch request to a specific store, as shown in the following code fragment:

```
NSPersistentStoreCoordinator *psc =  /* get a coordinator from somewhere */ ;
NSURL *myURL = ...; // assume this exists
NSPersistentStore *myStore = [psc persistentStoreForURL:myURL];
NSFetchRequest *request = [[NSFetchRequest alloc] init];
[request setAffectedStores:[NSArray arrayWithObject:myStore]];
```

Changing a Store's Type and Location

You can migrate a store from one type or location to another (for example, for a Save As operation) using the `NSPersistentStoreCoordinator` method `migratePersistentStore:toURL:options:withType:error:`. After invocation of this method, the original store is removed from the coordinator, thus store is therefore no longer a useful reference. The method is illustrated in the following code fragment, which shows how you can migrate a store from one location to another. If the old store type is XML, then the example also converts the store to SQLite

```
NSPersistentStoreCoordinator *psc = [aManagedObjectContext persistentStoreCoordinator];
NSURL *oldURL, *newURL; // define URLs...
NSError *error = nil;
NSPersistentStore *xmlStore = [psc persistentStoreForURL:oldURL];
NSPersistentStore *sqLiteStore = [psc migratePersistentStore:xmlStore
    toURL:newURL
    options:nil
    withType:NSSQLiteStoreType
    error:&error];
```

Core Data follows the procedure below to migrate a store:

1. Create a temporary persistence stack
2. Mount the old and new stores
3. Load all objects from the old store
4. Migrate the objects to the new store

   The objects are given temporary IDs, then assigned to the new store. The new store then saves the newly assigned objects (committing them to the external repository).

   Core Data then informs other stacks that the object IDs have changed (from the old to the new stores), which is how things "keep running" after a migration.

5. Unmount old store
6. Return the new store

An error can occur if:

- You provide invalid parameters to the method
- Core Data cannot add the new store
- Core Data cannot remove the old store

In the latter two cases, you get the same errors you would if you called `addPersistentStore:` or `removePersistentStore:` directly. if an error occurs when adding or removing the store, you should treat this as an exception since the persistence stack is likely to be in an inconsistent state.

If something fails during the migration itself, instead of an error you get an exception. In these cases, Core Data unwinds cleanly and there should be no repair work necessary. You can examine the exception description to determine what went wrong—there is a wide variety of possible errors, ranging from "disk is full" and "permissions problems" to "The SQLite store became corrupted" and "Core Data does not support cross store relationships".

Store Metadata

You can associate metadata with a store so that (if you write a suitable importer) it can be efficiently indexed by Spotlight. `NSPersistentStoreCoordinator` provides a class method, `metadataForPersistentStoreWithURL:error:`, that allows you to retrieve metadata from a store without the overhead of creating a persistence stack. On Mac OS X v10.5 and later, you can also use the `NSPersistentStore` method `metadataForPersistentStoreWithURL:error:`.

On Mac OS X v10.5 and later, you set the metadata for a store using the `NSPersistentStore` method `setMetadata:forPersistentStoreWithURL:error:`.

The metadata is a dictionary of key-value pairs, where a key may be either custom for your application, or one of the standard set of Spotlight keys such as `kMDItemKeywords`. Core Data automatically sets values for `NSStoreType` and `NSStoreUUID`, so you should make a mutable copy of the existing metadata then add your own keys and values, as illustrated in the following code fragment.

```
NSError *error = nil;
NSURL *storeURL = /* URL for persistent store */ ;

NSDictionary *metadata =
   [NSPersistentStore metadataForPersistentStoreWithURL:storeURL error:&error]
if (metadata == nil)
{
    /* deal with the error */
}
else
{
    NSMutableDictionary *newMetadata =
            [[metadata mutableCopy] autorelease];
    [newMetadata setObject:[NSArray arrayWithObject:@"MyKeyWord"]
            forKey:(NSString *)kMDItemKeywords];
    // set additional key-value pairs as appropriate
    [NSPersistentStore setMetadata:newMetadata
                       forPersistentStoreWithURL:storeURL
                       error:&error];
}
```

Mac OS X v10.4: On Mac OS X v10.4, you set the metadata for a store using `NSPersistentStoreCoordinator`'s `setMetadata:forPersistentStore:` method. This takes as its second argument a store identifier. You retrieve a store identifier from the persistent store coordinator, using the URL as an identifier, as illustrated in the following code fragment.

```
NSURL *url = /* the URL for a store */ ;
NSManagedObjectContext *managedObjectContext =
        /* get a managed object context from somewhere */ ;
NSPersistentStoreCoordinator *psc =
        [managedObjectContext persistentStoreCoordinator];
id pStore = [psc persistentStoreForURL:url];
```

If `pStore` is not `nil`, you can set the metadata.

```
if (pStore != nil) {
    NSMutableDictionary *metadata =
          [[[psc metadataForPersistentStore:pStore] mutableCopy] autorelease];
    [metadata setObject:[NSArray arrayWithObject:@"MyKeyWord"]
            forKey:(NSString *)kMDItemKeywords];
    // set additional key-value pairs
    [psc setMetadata:metadata forPersistentStore:pStore];
}
```

Note that setting the metadata for a store does not change the information on disk until the store is actually saved.

You should be careful about what information you put into metadata. First, Spotlight imposes a limit to the size of metadata. Second, replicating an entire document in metadata is probably not useful. Note, though, that is is possible to create a URL to identify a particular object in a store (using `URIRepresentation`)—the URL may be useful to include as metadata.

An example of setting metadata and writing an importer is given in *NSPersistentDocument Core Data Tutorial*.

Core Data and Cocoa Bindings

Changes made to objects' property values should be propagated to the user interface, and user interface elements displaying the same property should be kept synchronized. Cocoa bindings provides a control layer for Cocoa but, whereas the Core Data framework focuses on the model, Cocoa bindings focus on the user interface. In many situations, Cocoa bindings makes it easy to keep the user interface properly synchronized. The Core Data framework is designed to interoperate seamlessly with, and enhance the utility of, Cocoa bindings.

Cocoa bindings and Core Data are largely orthogonal. In general, Cocoa bindings work in exactly the same way with managed objects as with other Cocoa model objects. You can also use the same predicate objects and sort descriptors as you use to fetch objects from the persistent store to filter and sort objects in memory—for example to present in a table view. This gives you a consistent API set to use throughout your application. There, however, are a few (typically self-evident) differences in configuration and operation.

In addition to the issues described in this article, there are a few other areas where the interaction between Core Data and Cocoa Bindings may cause problems; these are described in "Troubleshooting Core Data" (page 133), in particular:

- "Custom relationship set mutator methods are not invoked by an array controller" (page 139)
- "Cannot access contents of an object controller after a nib is loaded" (page 140)
- "Table view or outline view contents not kept up-to-date when bound to an NSArrayController or NSTreeController object" (page 141)

Modulo these exceptions, everything that is discussed and described in *Cocoa Bindings Programming Topics* applies equally to Core Data-based applications and you should use the same techniques for configuring and debugging bindings when using Core Data as you would if you were not using Core Data.

Additions to Controllers

The main area where Core Data adds to Cocoa bindings is in the configuration of the controller objects such as `NSObjectController` and `NSArrayController`. Core Data adds the following features to those classes:

- A reference to a managed object context that is used for all fetches, insertions, and deletions.

  If a controller's content is a managed object or collection of managed objects, you must either bind or set the managed object context for the controller.
- An entity name that is used instead of the content object class to create new objects
- A reference to a fetch predicate that constrains what is fetched to set the content if the content is not set directly
- A content binding option ("Deletes Objects On Remove") that—if the content is bound to a relationship—specifies whether objects removed from the controller are deleted in addition to being removed from the relationship

Automatically Prepares Content Flag

If the "automatically prepares content" flag (see, for example, `setAutomaticallyPreparesContent:`) is set for a controller, the controller's initial content is fetched from its managed object context using the controller's current fetch predicate. It is important to note that the controller's fetch is executed as a delayed operation performed after its managed object context is set (by nib loading)—this therefore happens after `awakeFromNib` and `windowControllerDidLoadNib:`. This can create a problem if you want to perform an operation with the contents of an object controller in either of these methods, since the controller's content is `nil`. You can work around this by executing the fetch "manually" with `fetchWithRequest:merge:error:`. You pass `nil` as the fetch request argument to use the default request, as illustrated in the following code fragment.

```
- (void)windowControllerDidLoadNib:(NSWindowController *) windowController
{
    [super windowControllerDidLoadNib:windowController];

    NSError *error;
    BOOL ok = [arrayController fetchWithRequest:nil merge:NO error:&error];
    // ...
```

Entity Inheritance

If you specify a super entity as the entity for a fetch request, the fetch returns matching instances of the entity and sub-entities (see "Fetching and Entity Inheritance" (page 58)). As a corollary, if you specify a super entity as the entity for a controller, it fetches matching instances of the entity and any sub-entities. If you specify an abstract super-entity, the controller fetches matching instances of concrete sub-entities.

Filter Predicate for a To-many Relationship

Sometimes you may want to set up a filter predicate for a search field that lets a user filter the contents of an array controller based on the destination of a to-many relationship. If you want to search a to-many relationship, you need to use an `ANY` or `ALL` in the predicate. For instance, if you want to fetch Departments in which at least one of the employees has the first name "Matthew", you use an `ANY` operator as shown in the following example:

```
NSPredicate *predicate = [NSPredicate predicateWithFormat:
    @"ANY employees.firstName like 'Matthew'"];
```

You use the same syntax in a search field's predicate binding:

```
ANY employees.firstName like $value
```

Note: You cannot use the `contains` operator (for example, `ANY employees.firstName contains 'Matthew'`) because the `contains` operator does not work with the `ANY` operator.

Things are more complex, however, if you want to match prefix and/or suffix—for instance, if you want to look for Departments in which at least one of the employees has the first name “Matt”, “Matthew”, “Mattie”, or any other name beginning with “Matt”. Fundamentally you simply need to add wildcard matching:

```
NSPredicate *predicate = [NSPredicate predicateWithFormat:
    @"ANY employees.firstName like 'Matt*'"];
```

You *cannot*, though, use the same syntax within a search field's predicate binding:

```
// does not work
ANY employees.firstName like '$value*'
```

The reasons for this are described in *Predicate Programming Guide*—putting quotes in the predicate format prevents the variable substitution from happening. Instead, you must use substitute any wildcards first as illustrated in this example:

```
NSString *value = @"Matt";
NSString *wildcardedString = [NSString stringWithFormat:@"%@*", value];
[[NSPredicate predicateWithFormat:@"ANY employees.firstName like %@",
wildcardedString];
```

By implication, therefore, you must write some code to support this behavior.

Note: You may find that search field predicate bindings filter results inconsistently with wildcard characters. This is due to a bug in `NSArrayController`. The workaround is to create a subclass of `NSArrayController` and override `arrangeObjects:` to simply invoke `super`‘s implementation.

Change Management

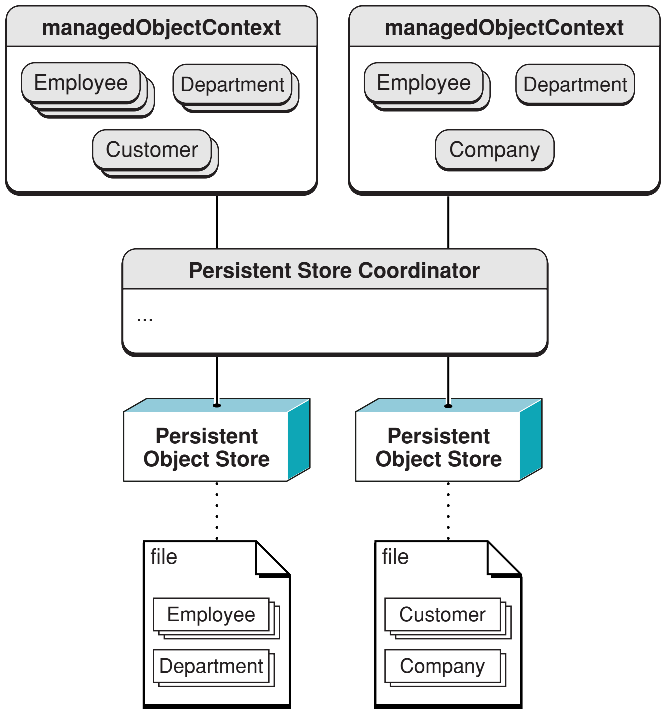
The collection of framework objects that mediate between the objects in your application and external data stores is referred to collectively as the "persistence stack." At the top of the stack are managed object contexts, at the bottom of the stack are "persistent object stores." Between managed object contexts and persistent object stores there is a persistent store coordinator.

Core Data provides a default configuration of the persistence stack that is composed of a single managed object context, a persistent store coordinator, and a single persistent object store with an external data store. In a given stack there can be only one persistent store coordinator, however you may add managed object contexts and/or persistent object stores if required. You may also create additional stacks if you require.

Persistence Stacks

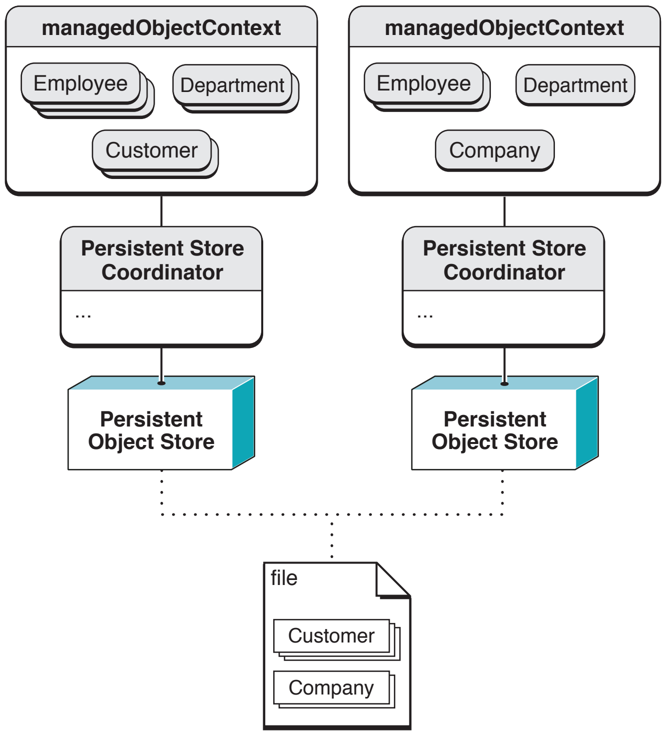
The persistent store coordinator is designed to present a façade to the managed object contexts so that a group of persistent stores appears as a single aggregate store. A managed object context can then create an object graph based on the union of all the data stores the coordinator covers. An example is illustrated in Figure 1, where employees and departments are stored in one file, and customers and companies in another. When you fetch objects they are automatically retrieved from the appropriate file, and when you save, they are archived to the appropriate file.

Figure 1 Advanced persistence stack



In effect, a persistent store coordinator "defines" a stack—whether you have a single application with multiple stacks, or multiple applications. For example, the image shown in Figure 2 (page 112) could represent two stacks within a single application accessing the same store or two applications accessing the same store.

Figure 2 Two persistence stacks accessing a common store



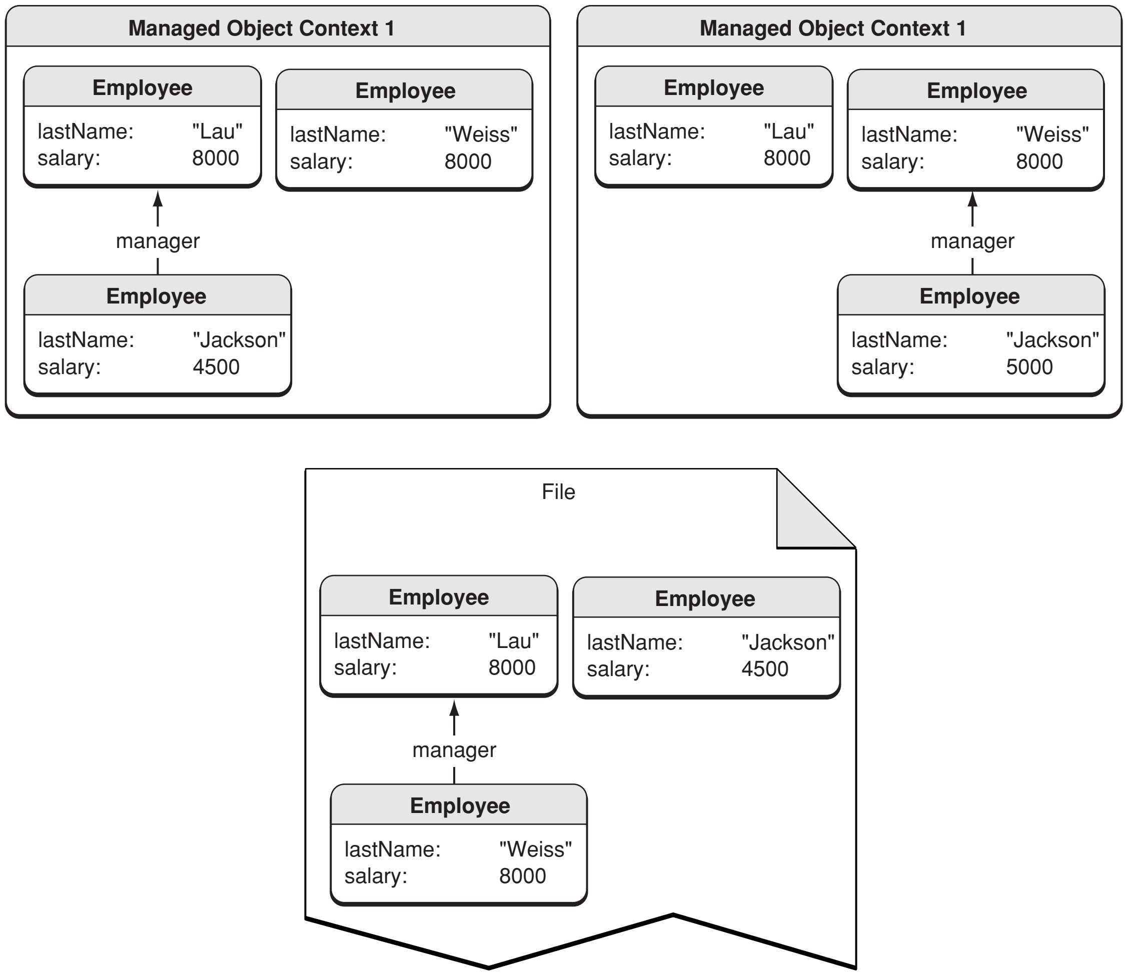
If you need to create a new stack, then you create a new persistent store coordinator, and add persistent stores as appropriate. You might do this to support file versioning—each coordinator (and thus managed object context) may use different copies, and hence different versions, of a managed object model.

There are no methods for you to interact directly with a persistent object store. If necessary, you can get identifiers for a coordinator's underlying object stores. This allows you to determine, for example, whether a store has already been added, or whether two objects come from the same store.

Disjoint Edits

The object graph associated with any given managed object context must be internally consistent. If you have multiple managed object contexts in the same application, however, it is possible that may each contain objects that represent the same entries in the persistent store, but whose characteristics are mutually inconsistent. In an employee application, for example, you might have two separate windows that display the same set of employees, but distributed between different departments and with different managers, as shown in Figure 3.

Figure 3 Managed object contexts with mutually inconsistent data values



Ultimately though there can only be one “truth,” and differences between these views must be detected and reconciled when data is saved. When one of the managed object contexts is saved, its changes are pushed through the persistent store coordinator to the persistent store. When the second managed object context is saved, conflicts are detected using a mechanism called **optimistic locking**; how the conflicts are resolved depends on how you have configured the context.

Conflict Detection and Optimistic Locking

When Core Data fetches an object from a persistent store, it takes a **snapshot** of its state. A snapshot is a dictionary of an object’s persistent properties—typically all its attributes and the global IDs of any objects to which it has a to-one relationship. Snapshots participate in optimistic locking. When the framework saves, it compares the values in each edited object’s snapshot with the then-current corresponding values in the persistent store.

- If the values are the same, then the store has not been changed since the object was fetched, so the save proceeds normally. As part of the save operation, the snapshots' values are updated to match the saved data.

- If the values differ, then the store has been changed since the object was fetched or last saved; this represents an optimistic locking failure.

Conflict Resolution

You can get an optimistic locking failure if more than one persistence stack references the same external data store (whether you have multiple persistence stacks in a single application or you have multiple applications). In this situation there is the possibility that the same conceptual managed object will be edited in two persistence stacks simultaneously. In many cases, you want to ensure that subsequent changes made by the second stack do not overwrite changes made by the first, but there are other behaviors that may be appropriate. You can choose the behavior by choosing for the managed object context a merge policy that is suitable for your situation.

The default behavior is defined by the `NSErrorMergePolicy`. This policy causes a save to fail if there are any merge conflicts. In the case of failure, the save method returns with an error with a `userInfo` dictionary that contains the key `@"conflictList"`; the corresponding value is an array of conflict records. You can use the array to tell the user what differences there are between the values they are trying to save and those current in the store. Before you can save you must either fix the conflicts (by re-fetching objects so that the snapshots are updated) or choose a different policy. The `NSErrorMergePolicy` is the only policy that generates an error. Other policies—`NSMergeByPropertyStoreTrumpMergePolicy`, `NSMergeByPropertyObjectTrumpMergePolicy`, and `NSOverwriteMergePolicy`—allow the save to proceed by merging the state of the edited objects with the state of the objects in the store in different ways. The `NSRollbackMergePolicy` discards in-memory state changes for objects in conflict and uses the persistent store's version of the objects' state.

Snapshot Management

An application that fetches hundreds of rows of data can build up a large cache of snapshots. Theoretically, if enough fetches are performed, a Core Data-based application can contain all the contents of a store in memory. Clearly, snapshots must be managed in order to prevent this situation.

Responsibility for cleaning up snapshots rests with a mechanism called **snapshot reference counting**. This mechanism keeps track of the managed objects that are associated with a particular snapshot—that is, managed objects that contain data from a particular snapshot. When there are no remaining managed object instances associated with a particular snapshot (which Core Data determines by maintaining a list of these references), that snapshot is released.

Communicating Changes Between Contexts

If you use more than one managed object context in an application, Core Data does not automatically notify one context of changes made to objects in another. In general, this is because a context is intended to provide a scratch pad where you can make changes to objects in isolation, and if you wish you can discard the changes without affecting other contexts. If you do need to synchronize changes between contexts, how a change should be handled depends on the user visible semantics you want in the second context, and on the state of the objects in the second context.

Consider an application with two managed object contexts and a single persistent store coordinator. If a user deletes an object in the first context (`moc1`), you may need to inform the second context (`moc2`) that has been deleted. In all cases, `moc1` posts an `NSManagedObjectContextDidSave` notification that your application should register for and use as the trigger for whatever actions it needs to take. This notification contains information not only about deleted objects, but also about changed objects. You need to handle these changes since they may be the result of the delete (most of the ways this can happen involve transient relationships or fetched properties).

There are multiple axes you must consider when deciding how you want to handle your delete notification. The important ones are:

- What other changes exist in the second context?
- Does the instance of the object that was deleted have changes in the second context?
- Can the changes made in the second context be undone?

These are somewhat orthogonal, and what actions you take to synchronize the contexts depend on the semantics of your application. The following three strategies are presented in order of increasing complexity.

1. The simplest case is when the object itself has not changed in `moc2` and you do not have to worry about undo; in this situation, you can just delete the object. The next time `moc2` saves, the framework will notice that you are trying to re-delete an object, ignore the optimistic locking warning, and continue without error.

2. If you do not care about the contents of `moc2`, you can simply reset it (using `reset`) and refetch any data you need after the reset. This will reset the undo stack as well, and the deleted object is now gone. The only issue here is determining what data to refetch. You can do this by, before you reset, collecting the IDs (`objectID`) of the managed objects you still need and using those to reload once the reset has happened (you must exclude the deleted IDs, and it is best to create fetch requests with `IN` predicates to avoid problems will not being able to fulfill faults for deleted IDs).

3. If the object has changed in `moc2`, but you do not care about undo, your strategy depends on what it means for the semantics of your application. If the object that was deleted in `moc1` has changes in `moc2`, should it be deleted from `moc2` as well? Or should it be resurrected and the changes saved? What happens if the original deletion triggered a cascade delete for objects that have not been faulted into `moc2`? What if the object was deleted as part of a cascade delete?

   There are two workable options (a third, unsatisfactory option is described later):

   a. The simplest strategy is to just discard the changes by deleting the object.

   b. Alternatively, if the object is standalone, you can set the merge policy on the context to `NSMergePolicyOverwrite`. This will cause the changes in the second context to overwrite the delete in the database.

      Note that this will cause *all* changes in `moc2` to overwrite any changes made in `moc1`.

The preceding are the best solutions, and are least likely to leave your object graph in an unsustainable state as a result of something you missed. There are various other strategies, but all are likely to lead to inconsistencies and errors. They are listed here as examples so that you can recognize them and avoid them. *If you find yourself trying to adopt any of these strategies, you should redesign your application's architecture to follow one of the patterns described previously.*

1. If you have a situation like 3(b) above, but the object *not* standalone, and for some reason you want to save those changes, the best you're likely to be able to do is to resurrect the part of the graph that had been loaded into `moc2`, which may or may not make sense in the context of your application. Again you do this by setting the merge policy to `NSMergePolicyOverwrite`, but you also need some up-front application design, and some meddling with the objects in the 'deleted' object's relationships.

   In order for the world to make some amount of sense later, you need to automatically fault in any relationships that might need to be resurrected when you fault in the object. Then, when you get a delete notification, you need to make the context think all the objects related to the deleted object have changed, so that they will be saved as well. This will bloat your application's memory use, since you'll end up with possibly irrelevant data as a precaution against something that may not happen, and if you're not careful, you can end up with your database in a hybrid state where it is neither what `moc1` tried to create, nor what `moc2` would expect (for example, if you missed a relationship somewhere and you now have partial relationships, or orphaned nodes).

2. The second worst of all worlds is when you have changes to other objects you can't blow away in the second MOC, the object itself has changes that you are willing to discard, and you care about undo. You can't reset the context, because that loses the changes. If you delete the object, the delete will get pushed onto the undo stack and will be undoable, so the user could undo, resave, and run into the semantic problems mentioned in 3 above, only worse because you have not planned for them.

   The only real way to solve this is to—separately, in your application code—keep track of the objects which are changed as a result of the delete. You then need to track user undo events, and when the user undoes past a delete, you can then "rerun" the deletion. This is likely to be complex and inefficient if a significant number of changes are propagated.

3. The worst case is you have changes to other objects you cannot discard, the object has changes you want to keep, and you care about undo. There may be a way to deal with this, but it will require considerable effort and any solution is likely to be complicated and fragile.

Persistent Store Features

Core Data provides several types of persistent store. This article describes the features and benefits of each, and how you can migrate from one type of store to another.

Important: On Mac OS X v10.4, there is no explicit class for persistent stores—you can only type a store instance as an `id`—consequently there is also no API for persistent store objects. The techniques described below generally also apply to Mac OS X v10.4, but where a type is given as `NSPersistentStore *` you should use `id`.

Store Types and Behaviors

Core Data provides three sorts of disk-based persistent store—XML, atomic, and SQLite—and an in-memory store. From the application code perspective, in general you should not be concerned about implementation details for any particular store. You should interact with managed objects and the persistence stack. There are, however, some behavioral differences between the types of store that you should consider when deciding what type of store to use.

	XML	**Atomic**	**SQLite**	**In-Memory**
Speed	Slow	Fast	Fast	Fast
Object Graph	Whole	Whole	Partial	Whole
Other Factors	Externally parseable			No backing required

Store-specific behavior

Given the abstraction that Core Data offers, there is no typically need to use the same store throughout the development process. It is common, for example, to use the XML store early in a project life-cycle, since it is fairly human-readable and you can inspect a file to determine whether or not it contains the data you expect. In a deployed application that uses a large data set, you typically use an SQLite store, since this offers high performance and does not require that the entire object graph reside in memory. You might use the binary store if you want store writes to be atomic.

It is important to note, however, that there are some interactions between fetching and the type of store. In the XML, binary, and in-memory stores, evaluation of the predicate and sort descriptors is performed in Objective-C with access to all Cocoa's functionality, including the comparison methods on `NSString`. The SQL store, on the other hand, compiles the predicate and sort descriptors to SQL and evaluates the result in the database itself. This is done primarily for performance—databases are much faster at this (it's what they're designed for)—but it means that evaluation happens in a non-Cocoa environment, and so sort descriptors (or predicates) that rely on Cocoa cannot work. The supported sort selectors are `compare:` and `caseInsensitiveCompare:`. Note that in addition you cannot sort on transient properties using the SQLite store.

File-systems supported by the SQLite store

The SQLite store supports reading data from a file that resides on any type of file-system. The SQLite store does not in general, however, support writing directly to file-systems which do not implement byte-range locking. For DOS filesystems and for some NFS file system implementations that do not support byte-range locking correctly, SQLite will use "<dbfile>.lock" locking, and for SMB file systems it uses flock-style locking.

To summarize: byte-range locking file systems have the best concurrent read/write support; these include HFS+, AFP, and NFS. File systems with simplistic file locking are also supported but do not allow for as much concurrent read/write access by multiple processes; these include SMB, and DOS. The SQLite store does *not* support writing to WebDAV file-systems (this includes iDisk).

Configuring a SQLite Store's Save Behavior

When Core Data saves a SQLite store, SQLite updates just part of the store file. Loss of that partial update would be catastrophic, so you may want to ensure that the file is written correctly before your application continues. Unfortunately, doing so means that in some situations saving even a small set of changes to an SQLite store can considerably longer than saving to, say, an XML store. (For example, where saving to an XML file might take less than a hundredth of a second, saving to an SQLite store may take almost half a second. This is not an issue for XML or Binary stores—since they are atomic, there is a much lower likelihood of data loss that involves corruption of the file, especially since the writes are typically atomic and the old file is not deleted until the new has been successfully written.)

fsync on Mac OS X: Since on Mac OS X the `fsync` command does not make the guarantee that bytes are written, SQLite sends a `F_FULLFSYNC` request to the kernel to ensures that the bytes are actually written through to the drive platter. This causes the kernel to flush all buffers to the drives and causes the drives to flush their track caches. Without this, there is a significantly large window of time within which data will reside in volatile memory—and in the event of system failure you risk data corruption.

Core Data provides a way to control sync behavior in SQLite using two independent pragmas, giving you control over the tradeoff between performance and reliability:

- `synchronous` controls the frequency of disk-syncing

  ```
  PRAGMA synchronous FULL [2] / NORMAL [1] / OFF [0]
  ```

- `full_fsync` controls the type of disk-sync operation performed

  ```
  PRAGMA fullfsync 1 / 0
  ```

  On Mac OS X v10.5, the default is 0.

The pragmas are publicly documented at http://sqlite.org/pragma.html.

You can set both pragmas using the key `NSSQLitePragmasOption` in the options dictionary when opening the store. The `NSSQLitePragmasOption` dictionary contains pragma names as keys and string values as objects, as illustrated in the following example:

```
NSPersistentStoreCoordinator *psc = /* assume this exists */ ;

NSMutableDictionary *pragmaOptions = [NSMutableDictionary dictionary];
[pragmaOptions setObject:@"NORMAL" forKey:@"synchronous"];
[pragmaOptions setObject:@"1" forKey:@"fullfsync"];

NSDictionary *storeOptions =
    [NSDictionary dictionaryWithObject:pragmaOptions
forKey:NSSQLitePragmasOption];
NSPersistentStore *store;
NSError *error;
store = [psc addPersistentStoreWithType:NSSQLiteStoreType
            configuration: nil
            URL:url
            options:storeOptions
            error:&error];
```

Mac OS X v10.4: Mac OS X v10.4 uses `full_fsync` by default. Since the `fsync` command does not make the guarantee that bytes are written, SQLite sends a `F_FULLFSYNC` request to the kernel. This causes the kernel to flush all buffers to the drives and causes the drives to flush their track caches.

In Mac OS X v10.4, there are only two settings to control the way in which data in a SQLite-based store is written to disk. If you want to trade risk of data corruption against the time taken to save a file, you can set the defaults key `com.apple.CoreData.SQLiteDebugSynchronous` to one of three values:

`0`: Disk syncing is switched off

`1`: Normal

`2` (The default): Disk syncing is performed via the `fctl` `FULL_FSYNC` command—a costly operation but one that guarantees data is written to disk

Important: Note that the default behaviors on Mac OS X v10.4 an 10.5 are different. On Mac OS X v10.4, SQLite uses `FULL_FSYNC` by default; on Mac OS X v10.5 it does not.

Custom store types

On Mac OS X v10.5 and later you can create your own atomic store types. For details, see *Atomic Store Programming Topics*.

On Mac OS X v10.4 , you cannot write your own object store which interoperates transparently with the Core Data stack. You can, however, manage object persistence yourself by using an in-memory store. Before you load your data, you create an in-memory store. When you load your data, you create instances of the appropriate model classes and insert them into a managed object context, associate them with the in-memory store (see `insertObject:` and `assignObject:toPersistentStore:`). The managed objects are then fully integrated into the Core Data stack and benefit from features such as undo management. You are also responsible, however, for saving the data. You must register to receive `NSManagedObjectContextDidSaveNotification` notifications from the managed object context, and upon receipt of the notification save the managed objects to the persistent store.

Security

Core Data makes no guarantees regarding the security of persistent stores from untrusted sources and cannot detect whether files have been maliciously modified. The SQLite store offers slightly better security than the XML and binary stores, but it should not be considered inherently secure. Note that you should also consider the security of store metadata since it is possible for data archived in the metadata to be tampered with independently of the store data. If you want to ensure data security, you should use a technology such as an encrypted disk image.

Multi-Threading with Core Data

There may be perceived performance advantages that accrue from using multiple threads with Core Data. In particular, if you execute a large or complex fetch that takes some time, you might execute the full fetch on a background thread. It is important to consider, however, that most of the Application Kit is not thread safe and that you need to take considerable care that object graphs do not get into an inconsistent state.

Thread Safety Fundamentals

There are several issues to bear in mind when using multi-threading in a Core Data application:

- Any time you manipulate or access your object graph, you may be using the associated managed object context.

  Core Data does not present a situation where reads are "safe" but changes are "dangerous"—*every* operation is "dangerous" because every operation can trigger faulting.

- Managed objects themselves are not thread safe.

  If you want to work with a managed object across different threads, you must lock its context (see `NSLocking`). If you try to pass actual objects, share contexts between threads, and so on, you must be *extremely* careful about locking (and as a consequence you are likely to negate any benefit you may otherwise derive from multi-threading). Working with a managed object across different threads is therefore strongly discouraged, as described in "General Guidelines" (page 122).

- Passing object IDs (which are immutable) across thread boundaries makes dealing with threading much easier.

  To make a managed object from one context visible in another, you pass its managed object ID and use `objectWithID:` on the receiving thread's managed object context to get a local version of the managed object. Note that the corresponding managed objects must have been saved—you cannot pass the ID of a newly-inserted managed object to another context.

  On Mac OS X v10.5, you can use the API provided by `NSFetchRequest` to facilitate working with data across threads. For example, you can configure a fetch request to return objectIDs but include the row data (and update the row cache)—this can be useful if you're just going to pass those object IDs from a background thread to another thread.

- A persistent store coordinator provides to its managed object contexts the façade of one virtual store.

  For completely concurrent operations you need a different coordinator for each thread.

- On Mac OS X v10.5, `executeFetchRequest:error:` intrinsically scales its behavior appropriately for the hardware and work load.

  If necessary, the Core Data will create additional private threads to optimize fetching performance. You will not improve absolute fetching speed by creating background threads for the purpose (although it may still be appropriate to fetch in a background thread for enhanced responsiveness—that is, to prevent your application from blocking).

- It is important to consider the application environment.

For the most part, the Application Kit is not thread safe; in particular, Cocoa bindings and controllers are not thread safe—if you are using these technologies, multi-threading may be complex.

General Guidelines

In general, you should not use any given managed object or managed object context in more than one thread. Instead, you should give each thread its own entirely private managed object context and keep their associated object graphs separated on a per-thread basis. If you do this, there is no need to lock contexts during access. You can use one persistent store coordinator per group of cooperating threads (for example, for your application or for each document).

There are three patterns you can adopt to support multi-threading in a Core Data application; in order of preference they are:

1. Create a separate managed object context for each thread and share a single persistent store coordinator.

   If you need to "pass" managed objects between threads, you just pass their object IDs.

   If you want to aggregate a number of operations in one context together as if a virtual single transaction, you can lock the persistent store coordinator to prevent other managed object contexts using the persistent store coordinator over the scope of several operations.

2. Create a separate managed object context and persistent store coordinator for each thread.

   If you need to "pass" managed objects between threads, you just pass their object IDs.

   Using a separate persistent store coordinator for each thread allows for completely concurrent operations.

3. Pass managed objects or managed object contexts between threads.

   This approach is strongly discouraged. You must ensure that you apply locks as appropriate and necessary.

Locking

Generally, you only need to lock a managed object context (and not even then if you ensure that each thread has its own private context, as described in "General Guidelines" (page 122)). If you do choose to share a managed object context or a persistent store coordinator between threads, you must ensure that any method invocations are made from a thread-safe scope. For locking, you should use the `NSLocking` methods on managed object context and persistent store coordinator instead of implementing your own mutexes. These methods help provide contextual information to the framework about the application's intent—that is, in addition to providing a mutex, they help scope clusters of operations.

Typically you lock the context or coordinator using `tryLock` or `lock`. If you do this, the framework will ensure that what it does behind the scenes is also thread-safe. For example, if you create one context per thread, but all pointing to the same persistent store coordinator, Core Data takes care of accessing the coordinator in a thread-safe way (`NSManagedObjectContext`'s `lock` and `unlock` methods handle recursivity).

If you lock (or successfully `tryLock`) a context, that context must be retained until you invoke `unlock`. If you don't properly retain a context in a multi-threaded environment, you may cause a deadlock.

Fetching in a Background Thread

One of the simplest multi-threading techniques you can use with Core Data to improve application responsiveness is to execute a fetch request on a background thread. (Note that this technique is only useful if you are using an SQLite store, since data from binary and XML stores is read into memory immediately on open.) This means that if a fetch is complicated or returns a large amount of data, you can return control to the user and display results as they arrive. For an example of how to do this, see the `BackgroundFetching` example in `/Developer/Examples/CoreData/`.

You use two managed object contexts associated with a single persistent store coordinator. You fetch in one managed object context on a background thread, and pass the *object IDs* of the fetched objects to another thread. In the second thread (typically the application's main thread, so that you can then display the results), you use the second context to fault in objects with those object IDs (you use `objectWithID:` to instantiate the object).

Saving

Performing a save operation in a detached thread is error-prone unless you take additional steps to prevent the application from quitting before the save is completed. Specifically, all `NSThread`-based threads are "detached" (see the documentation for `pthread` for complete details) and a process runs only until all not-detached threads have exited. The work a detached thread is performing is therefore considered optional, and the process may terminate at any time. (Most users do not consider saving to be optional work!) In Cocoa, only the main thread is not-detached. If you need to save on other threads, you must write additional code such that the main thread prevents the application from quitting until all the save operation is complete.

Core Data Performance

In general, Core Data is very efficient. For many applications, an implementation that uses Core Data may be more efficient than a *comparable* application that does not. It is possible, however, to use the framework in such a way that its efficiency is reduced. This article describes how to get the most out of Core Data.

Introduction

Core Data is a rich and sophisticated object graph management framework capable of dealing with large volumes of data. The SQLite store can scale to terabyte sized databases with billions of rows/tables/columns. Unless your entities themselves have very large attributes (although see "Large Data Objects (BLOBs)" (page 130)) or large numbers of properties, 10,000 objects is considered to be a fairly small size for a data set.

For a very simple application it is certainly the case that Core Data adds some overhead (compare a vanilla Cocoa document-based application with a Cocoa Core Data document-based application), however Core Data adds significant functionality. For a small overhead, even a simple Core Data-based application supports undo and redo, validation, object graph maintenance, and provides the ability to save objects to a persistent store. If you implemented this functionality yourself, if it quite likely that the overhead would exceed that imposed by Core Data. As the complexity of an application increases, so the proportionate overhead that Core Data imposes typically decreases while at the same time the benefit typically increases (supporting undo and redo in a large application, for example, is usually *hard*).

`NSManagedObject` uses an internal storage mechanism for data that is highly optimized. In particular, it leverages the information about the types of data that is available through introspecting the model. When you store and retrieve data in a manner that is key-value coding and key-value observing compliant, it is likely that using `NSManagedObject` will be faster than any other storage mechanism—including for the the simple get/set cases. In a modern Cocoa application that leverages Cocoa Bindings, given that Cocoa Bindings is reliant upon key-value coding and key-value observing it would be difficult to build a raw data storage mechanism that provides the same level of efficiency as Core Data.

Like all technologies, however, Core Data can be abused. Using Core Data does not free you from the need to consider basic Cocoa patterns, such as memory management. You should also consider how you fetch data from a persistent store. If you find that your application is not performing as well as you would like, you should use profiling tools such as Shark to determine where the problem lies (see Performance & Debugging).

Fetching Managed Objects

Each round trip to the persistent store (each fetch) incurs an overhead, both in accessing the store and in merging the returned objects into the persistence stack. You should avoid executing multiple requests if you can instead combine them into a single request that will return all the objects you require. You can also minimize the number of objects you have in memory.

Fetch Predicates

How you use predicates can significantly affect the performance of your application. If a fetch request requires a compound predicate, you can make the fetch more efficient by ensuring that the most restrictive predicate is the first, especially if the predicate involves text matching (`contains`, `endsWith`, `like`, and `matches`) since correct Unicode searching is slow. If the predicate combines textual and non-textual comparisons, then it is likely to be more efficient to specify the non-textual predicates first, for example `(salary > 5000000) AND (lastName LIKE 'Quincey')` is better than `(lastName LIKE 'Quincey') AND (salary > 5000000)`. For more about creating predicates, see *Predicate Programming Guide*.

Fetch Limits

You can set a limit to the number of objects a fetch will return using the method `setFetchLimit:` as shown in the following example.

```
NSFetchRequest *request = [[[NSFetchRequest alloc] init] autorelease];
[request setFetchLimit:100];
```

If you are using the SQLite store, you can use a fetch limit to minimize the working set of managed objects in memory, and so improve the performance of your application.

If you do need to retrieve a large number of objects, you can make your application appear more responsive by executing two fetches. In the first fetch, you retrieve a comparatively small number of objects—for example, 100—and populate the user interface with these objects. You then execute a second fetch to retrieve the complete result set (that is, you execute a fetch without a fetch limit).

Note that there is no way to "batch" fetches (or in database terms, to set a cursor). That is, you cannot fetch the "first" 100 objects, then the second 100, then the third, and so on.

In general, however, you are encouraged to use predicates to ensure that you retrieve only those objects you require.

Faulting Behavior

Firing faults can be a comparatively expensive process (potentially requiring a round trip to the persistent store), and you may wish to avoid unnecessarily firing a fault. You can safely invoke the following methods on a fault without causing it to fire: `isEqual:`, `hash`, `superclass`, `class`, `self`, `zone`, `isProxy`, `isKindOfClass:`, `isMemberOfClass:`, `conformsToProtocol:`, `respondsToSelector:`, `retain`, `release`, `autorelease`, `retainCount`, `description`, `managedObjectContext`, `entity`, `objectID`, `isInserted`, `isUpdated`, `isDeleted`, and `isFault`.

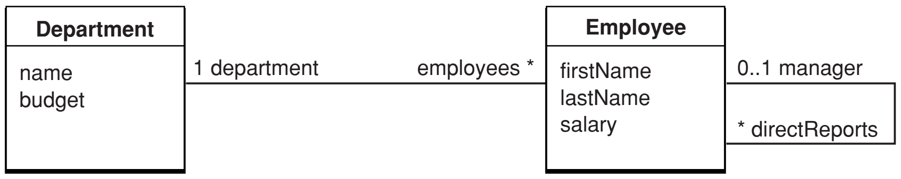
Since `isEqual` and `hash` do not cause a fault to fire, managed objects can typically be placed in collections without firing a fault. Note, however, that invoking key-value coding methods on the collection object might in turn result in an invocation of `valueForKey:` on a managed object, which would fire a fault. In addition, although the default implementation of `description` does not cause a fault to fire, if you implement a custom `description` method that accesses the object's persistent properties, this will cause a fault to fire.

Note that just because a managed object is a fault, it does not necessarily mean that the data for the object are not in memory—see the definition for `isFault`.

Batch Faulting and Pre-fetching with the SQLite Store

When you execute a fetch, Core Data fetches just instances of the entity you specify. In some situations (see "Faulting" (page 99)), the destination of a relationship is represented by a fault. Core Data automatically resolves (fires) the fault when you access data in the fault. This lazy loading of the related objects is much better for memory use, and much faster for fetching objects related to rarely used (or very large) objects. It can also, however, lead to a situation where Core Data executes separate fetch requests for a number of individual objects.

If data for a fault has not been cached (see "Faulting" (page 99)), Core Data performs a separate round trip to the persistent store for each fault fired. This incurs a comparatively high overhead. Since Core Data automatically resolves the fault when you access data in the fault, this can lead to an inefficient pattern where a Core Data executes fetch requests for a number of individual objects. For example, given a model:



you might fetch a number of Employees and ask each in turn for their Department's name, as shown in the following code fragment.

```
// create fetch request for Employees -- includes predicate
// (if you don't have a predicate here, you should probably just fetch all the
 Departments...)
NSArray *fetchedEmployees = [moc executeFetchRequest:employeesFetch error:&error];
for (Employee *employee in fetchedEmployees)
{
    NSLog(@"%@ -> %@ department", employee.name, employee.department.name);
}
```

This might lead to the following behavior:

```
Jack -> Sales [fault fires]
Jill -> Marketing [fault fires]
Benjy -> Sales
Gillian -> Sales
Hector -> Engineering [fault fires]
Michelle -> Marketing
```

Here, there are four round trips to the persistent store (one for the original fetch of Employees, and three for individual Departments) which represents a considerable overhead on top of the minimum (two—one for each entity).

There are two techniques you can use to mitigate this effect—**batch faulting** and **pre-fetching**.

Batch faulting

You can batch fault a collection of objects by executing a fetch request using a predicate with an `IN` operator, as illustrated by the following example. (In a predicate, `self` represents the object being evaluated—see Predicate Format String Syntax.)

```
NSArray *array = [NSArray arrayWithObjects:fault1, fault2, ..., nil];
NSPredicate *predicate = [NSPredicate predicateWithFormat:@"self IN %@", array];
```

On Mac OS X v10.5, when you create a fetch request you can use the `NSFetchRequest` method `setReturnsObjectsAsFaults:` to ensure that managed objects are not returned as faults.

Pre-fetching

Pre-fetching is in effect a special case of batch-faulting, performed immediately after another fetch. The idea behind pre-fetching is the anticipation of future needs. When you fetch some objects, sometimes you know that soon after you will also need related objects which may be represented by faults. To avoid the inefficiency of individual faults firing, you can pre-fetch the objects at the destination.

On Mac OS X v10.5, you can use the `NSFetchRequest` method `setRelationshipKeyPathsForPrefetching:` to specify an array of relationship keypaths to prefetch along with the entity for the request. For example, given an Employee entity with a relationship to a Department entity: if you fetch all the employees then for each print out their name and the name of the department to which they belong, you can avoid the possibility of a fault being fired for each Department instance by prefetching the department relationship, as illustrated in the following code fragment:

```
NSManagedObjectContext *context = /* get the context */;
NSEntityDescription *employeeEntity = [NSEntityDescription
    entityForName:@"Employee" inManagedObjectContext:context];
NSFetchRequest *request = [[NSFetchRequest alloc] init];
[request setEntity:employeeEntity];
[request setRelationshipKeyPathsForPrefetching:
    [NSArray arrayWithObject:@"department"]];
```

On Mac OS X v10.4, you create a fetch request to fetch just those instances of the destination entity that are related to the source objects you just retrieved, this reduces the number of fetches to two (the minimum). How (or whether) you implement the pre-fetch depends on the cardinality of the relationship.

- If the inverse relationship is a to-one, you can use a predicate with the format, `@"%K IN %@"` where the first argument is the key name for the inverse relationship, and the second argument an array of the original objects.
- If the inverse relationship is a to-many, you first collect the object IDs from the faults you care about (being careful not touch other attributes). You then create a predicate with the format, `@"SELF IN %@"`, where the argument is the array of object IDs.
- If the relationship is a many-to-many, pre-fetching is not recommended.

You could implement pre-fetching for the department relationship in the previous example as follows.

```
NSEntityDescription *deptEntity = [NSEntityDescription entityForName:@"Department"
        inManagedObjectContext:moc];
NSArray *deptOIDs = [fetchedEmployees valueForKeyPath:@"department.objectID"];
NSPredicate *deptsPredicate = [NSPredicate predicateWithFormat:
        @"SELF in %@", deptOIDs];
NSFetchRequest *deptFetch = [[[NSFetchRequest alloc] init] autorelease];
[deptFetch setEntity:deptEntity];
[deptFetch setPredicate:deptsPredicate];
// execute fetch...
```

If you know something about how the data will be accessed or presented, you can further refine the fetch predicate to reduce the number of objects fetched. Note, though, that this technique can be fragile—if the application changes and needs a different set of data, then you can end up pre-fetching the wrong objects.

For more about faulting, and in particular the meaning of the value returned from `isFault`, see "Faulting and Uniquing" (page 99).

Reducing Memory Overhead

It is sometimes the case that you want to use managed objects on a temporary basis, for example to calculate an average value for a particular attribute. This causes your object graph, and memory consumption, to grow. You can reduce the memory overhead by re-faulting individual managed objects that you no longer need, or you can reset a managed object context to clear an entire object graph. You can also use patterns that apply to Cocoa programming in general.

- You can re-fault an individual managed object using `NSManagedObjectContext`'s `refreshObject:mergeChanges:` method. This has the effect of clearing its in-memory property values thereby reducing its memory overhead. (Note that this is not the same as setting the property values to `nil`—the values will be retrieved on demand if the fault is fired—see "Faulting and Uniquing" (page 99).)
- On Mac OS X v10.5, when you create a fetch request you can set `includesPropertyValues` to `NO` to reduce memory overhead by avoiding creation of objects to represent the property values. You should typically only do so, however, if you are sure that either you will not need the actual property data or you already have the information in the row cache, otherwise you will incur multiple trips to the persistent store.
- You can use `NSManagedObjectContext`'s `reset` method to remove all managed objects associated with a context and "start over" as if you'd just created it. Note that any managed object associated with that context will be invalidated, and so you will need to discard any references to and re-fetch any objects associated with that context in which you are still interested.
- Objects returned by fetching and other API are usually autoreleased as required by the Cocoa programming guidelines. If you iterate over a lot of objects, you may need to allocate and release your own autorelease pools to gain a finer-grain level of memory management.
- If you do not intend to use Core Data's undo functionality, you can reduce your application's resource requirements by setting the context's undo manager to `nil`. This may be especially beneficial for background worker threads, as well as for large import or batch operations.
- Finally, Core Data does not by default retain managed objects (unless they have unsaved changes). If you have lots of objects in memory, you should determine why they are still retained. Managed objects do retain each other through relationships, which can easily create cycles. You can break retain cycles by re-faulting objects (again by using `NSManagedObjectContext`'s `refreshObject:mergeChanges:` method).

Large Data Objects (BLOBs)

If your application uses large BLOBs ("Binary Large OBjects" such as image and sound data), you need to take care to minimize overheads. The exact definition of "small", "modest", and "large" is fluid and depends on an application's usage. A loose rule of thumb is that objects in the order of kilobytes in size are of a "modest" sized and those in the order of megabytes in size are "large" sized. Some developers have achieved good performance with 10MB BLOBs in a database. On the other hand, if an application has millions of rows in a table, even 128 bytes might be a "modest" sized CLOB (Character Large OBject) that needs to be normalized into a separate table.

In general, if you *need* to store BLOBs in a persistent store, you should use an SQLite store. The XML and binary stores require that the whole object graph reside in memory, and store writes are atomic (see "Persistent Store Features" (page 117)) which means that they do not efficiently deal with large data objects. SQLite can scale to handle extremely large databases. Properly used, SQLite provides good performance for databases up to 100GB, and a single row can hold up to 1GB (although of course reading 1GB of data into memory is an expensive operation no matter how efficient the repository).

A BLOB often represents an attribute of an entity—for example, a photograph might be an attribute of an Employee entity. For small to modest sized BLOBs (and CLOBs), you should create a separate entity for the data and create a to-one relationship in place of the attribute. For example, you might create Employee and Photograph entities with a one-to-one relationship between them, where the relationship from Employee to Photograph replaces the Employee's photograph attribute. This pattern maximizes the benefits of object faulting (see "Faulting and Uniquing" (page 99)). Any given photograph is only retrieved if it is actually needed (if the relationship is traversed).

It is better, however, if you are able to store BLOBs as resources on the filesystem, and to maintain links (such as URLs or paths) to those resources. You can then load a BLOB as and when necessary.

Analyzing Performance

Analyzing Fetch Behavior with SQLite

With Mac OS X version 10.4.3 and later, you can use the user default `com.apple.CoreData.SQLDebug` to log to `stderr` the actual SQL sent to SQLite. (Note that user default names are case sensitive.) For example, you can pass the following as an argument to the application:

```
-com.apple.CoreData.SQLDebug 1
```

Higher levels of debug numbers produce more information, although this is likely to be of diminishing utility.

The information the output provides can be useful when debugging performance problems—in particular it may tell you when Core Data is performing a large number of small fetches (such as when firing faults individually). The output differentiates between fetches that you execute using a fetch request and fetches that are performed automatically to realize faults.

Instruments

With Mac OS X version 10.5, you can use the Instruments application (by default in /Developer/Applications/) to analyze the behavior of your application. There are several Instruments probes specific to Core Data:

- Core Data Fetches

  Records invocations of `executeFetchRequest:error:`, providing information about the entity against which the request was made, the number of objects returned, and the time taken for the fetch.

- Core Data Saves

  Records invocations of `save:` and the time taken to do the save.

- Core Data Faults

  Records information about object and relationship fault firing. For object faults, records the object being faulted; for relationship faults, records the source object and the relationship being fired. In both cases, records the time taken to fire the fault.

- Core Data Cache Misses

  Traces fault behavior that specifically results in filesystem activity—indicating that a fault was fired for which no data was available—and records the time taken to retrieve the data.

All the instruments provide a stack trace for each event so that you can see what caused it to happen.

When analyzing your application, you should of course also take into account factors not directly related to Core Data, such as overall memory footprint, object allocations, use and abuse of other API such as the key-value technologies and so on.

Troubleshooting Core Data

This article outlines some of the common issues encountered in applications that use Core Data and provides clues as to correcting the problem.

When troubleshooting Core Data-based applications, it is important to consider that Core Data provides functionality that builds on top of functionality provided by other parts of Cocoa. When attempting to diagnose a problem with an application that uses Core Data, you should take care to distinguish between issues that are specific to Core Data and those that arise because of an error with another framework or to an implementation or architectural patten. Poor performance, for example, may not be due to Core Data per se, but instead are due to a failure to observe standard Cocoa techniques of memory management or resource conservation; or if a user interface does not update properly, this may be due to an error in how you have configured Cocoa bindings.

Object Life-Cycle Problems

Merge errors

Problem: You see the error message, "`Could not merge changes`".

Cause: Two different managed object contexts tried to change the same data. This is also known as an optimistic locking failure.

Remedy: Either set a merge policy on the context, or manually (programmatically) resolve the failure. You can retrieve the currently committed values for an object using `committedValuesForKeys:`, and you can re-fault the object (so that when it is next accessed its data values are retrieved from its persistent store) using `refreshObject:mergeChanges:`.

Assigning a managed object to a different store

Problem: You see an exception that looks similar to this example.

```
<NSInvalidArgumentException> [<MyMO 0x3036b0>_assignObject:toPersistentStore:]:
Can't reassign an object to a different store once it has been saved.
```

Cause: The object you are trying to assign to a store has already been assigned and saved to a different store.

Remedy: To move an object from one store to another, you must create a new instance, copy the information from the old object, save it to the appropriate store, and then delete the old instance.

Fault cannot be fulfilled

Problem: You see the error message, "`Core Data could not fulfill a fault`".

Cause: The corresponding object's underlying data has been deleted from the persistent store.

Remedy: You should discard this object.

This problem can occur in at least two situations:

First:

- Start with a retained reference to a managed object.
- Delete the managed object via the managed object context.
- Save changes on the object context.

  At this point, the deleted object has been turned into a fault. It isn't destroyed because doing so would violate the rules of memory management.
- Try to retrieve an attribute or relationship from the previously retained reference.

Core Data will try to fault the faulted managed object but will fail to do so because the object has been deleted from the store. That is, there is no longer an object with the same global ID in the store.

Second:

- Delete an object from a managed object context.
- Fail to break all relationships from other objects to that object.
- Save changes.

At this point, if you try to fire the relationship from some other object to that object, it may fail (this depends on the details of the configuration of the relationship as that affects how the relationship is stored).

The delete rules for relationships affect relationships only from the source object to other objects (including inverses). Without potentially fetching large numbers of objects, possibly without reason, there is no way for Core Data to efficiently clean up the relationships to the object.

Keep in mind that a Core Data object graph is directional. That is, a relationship has a source and a destination. Following a source to a destination does not necessarily mean that there is an inverse relationship. So, in that sense, you need to ensure that you are properly maintaining the object graph across deletes.

In practice, a well-designed object graph does not require much manual post-deletion clean up. If you consider that most object graphs have "entry points" that in effect act as a root node for navigating the graph and that most insertion and deletion events are rooted at those nodes just like fetches, then delete rules take care of most of the work for you. Similarly, since smart groups and other "casual" relationships are generally best implemented with fetched properties, various ancillary collections of entry points into the object graph generally do not need to be maintained across deletes because fetched relationships have no notion of permanence when it comes to objects found via the fetched relationship.

Managed object invalidated

Problem: You see an exception that looks similar to this example:

```
<NSObjectInaccessibleException> [<MyMO 0x3036b0>_assignObject:toPersistentStore:]:
The NSManagedObject with ID:#### has been invalidated.
```

Cause: Either you have removed the store for the fault you are attempting to fire, or the managed object's context has been sent a `reset` message.

Remedy: You should discard this object. If you add the store again, you can try to fetch the object again.

Class is not key-value coding compliant

Problem: You see an exception that looks similar to the following example.

```
<NSUnknownKeyException> [<MyMO 0x3036b0> valueForUndefinedKey:]:
this class is not key value coding-compliant for the key randomKey.
```

Cause: Either you used an incorrect key, or you initialized your managed object with `init` instead of `initWithEntity:inManagedObjectContext:`.

Remedy: Use a valid key (check the spelling and case carefully—also review the rules for key-value coding compliance in *Key-Value Coding Programming Guide*), or ensure that you use the designated initializer for `NSManagedObject` (see `initWithEntity:insertIntoManagedObjectContext:`).

Entity class does not respond to invocations of custom methods

Problem: You define an entity that uses a custom subclass of `NSManagedObject`, then in code you create an instance of the entity and invoke a custom method, as illustrated in this code fragment:

```
NSManagedObject *entityInstance =
    [NSEntityDescription insertNewObjectForEntityForName:@"MyEntity"
            inManagedObjectContext:managedObjectContext];
[entityInstance setAttribute: newValue];
```

You get a runtime error like this:

```
"2005-05-05 15:44:51.233 MyApp[1234] ***
    -[NSManagedObject setNameOfEntity:]: selector not recognized [self = 0x30e340]
```

Cause: In the model, you may have misspelled the name of the custom class for the entity.

Remedy: Ensure that the spelling of name of the custom class in the model matches the spelling of the custom class you implement.

Custom accessor methods are not invoked, key dependencies are not obeyed

Problem: You define a custom subclass of `NSManagedObject` for a particular entity and implement custom accessors methods (and perhaps dependent keys). At runtime, the accessor methods are not called and the dependent key is not updated.

Cause: In the model, you did not specify the custom class for the entity.

Remedy: Ensure that the model specifies of name of the custom class for the entity (that is, that it is not `NSManagedObject`).

Problems with Fetching

SQLite store does not work with sorting

Problem: You create a sort descriptor that uses a comparison method defined by `NSString`, such as the following:

```
NSSortDescriptor *mySortDescriptor = [[NSSortDescriptor alloc]
        initWithKey:@"lastName" ascending:YES
        selector:@selector(localizedCaseInsensitiveCompare:)];
```

You then either use this descriptor with a fetch request or as one of an array controller's sort descriptors. At runtime, you might see an error message that looks similar to the following:

```
NSRunLoop ignoring exception 'unsupported NSSortDescriptor selector:
        localizedCaseInsensitiveCompare:' that raised during posting of
        delayed perform with target 3e2e42 and selector 'invokeWithTarget:'
```

Cause: Exactly how a fetch request is executed depends on the store—see "Fetching Managed Objects" (page 57).

Remedy: If you are executing the fetch directly, you should not use Cocoa-based sort operators—instead you should sort the returned array in memory. If you are using an array controller, you may need to subclass `NSArrayController` so you can have it not pass the sort descriptors to the database and instead do the sorting after your data has been fetched.

Problems with Saving

SQLite store takes a "long time" to save

Problem: You are using an SQLite store and notice that it takes longer to save to the SQLite store than it does to save the same data to an XML store.

Cause: This is probably expected behavior. The SQLite store ensures that all data is written correctly to disk—see "Configuring a SQLite Store's Save Behavior" (page 118).

Remedy: First determine whether the time taken to save will be noticeable to the user. This is typically likely to be the case only if you configure your application to frequently save automatically—for example, after every edit that the user makes. First, consider changing the store's save behavior (switch off full sync). Then consider saving data only after a set period (for example, every 15 seconds) instead of after every edit. If necessary, consider choosing a different store—for example, the binary store.

Cannot save documents because entity is null

Problem: You have Core Data document-based application that is unable to save. When you try to save the document you get an exception:

```
Exception raised during posting of notification.  Ignored.  exception: Cannot
perform operation since entity with name 'Wxyz' cannot be found
```

Cause: This error is emitted by an instance of `NSObjectController` (or one of its subclasses) that is set in Entity mode but can't access the entity description in the managed object model associated with the entity name specified in Interface Builder. In short, you have a controller in entity mode with an invalid entity name.

Remedy: Select in turn each of your controllers in Interface Builder, and press Command-1 to show the inspector. For each controller, ensure you have a valid entity name in the "Entity Name" field at the top.

Exception generated in retainedDataForObjectID:withContext.

Problem: You add an object to a context. When you try to save the document you get an error that looks like this:

```
[date] My App[2529:4b03] cannot find data for a temporary oid: 0x60797a0
<<x-coredata:///MyClass/t8BB18D3A-0495-4BBE-840F-AF0D92E549FA195>x-coredata:///MyClass/t8BB18D3A-0495-4BBE-840F-AF0D92E549FA195>
```

an exception in `-[NSSQLCore retainedDataForObjectID:withContext:]`, and the backtrace looks like:

```
#1    0x9599a6ac in -[NSSQLCore retainedDataForObjectID:withContext:]
#2    0x95990238 in -[NSPersistentStoreCoordinator(_NSInternalMethods)
_conflictsWithRowCacheForObject:andStore:]
#3    0x95990548 in -[NSPersistentStoreCoordinator(_NSInternalMethods)
_checkRequestForStore:originalRequest:andOptimisticLocking:]
#4    0x9594e8f0 in -[NSPersistentStoreCoordinator(_NSInternalMethods)
executeRequest:withContext:]
#5    0x959617ec in -[NSManagedObjectContext save:]
```

The call to `_conflictsWithRowCacheForObject:` is comparing the object you're trying to save with its last cached version from the database. Basically, it's checking to see if any other code (thread, process, or just a different managed object context) changed this object out from underneath you.

Core Data does not do this check on newly inserted objects because they could not have existed in any other scope. They haven't been written to the database yet.

Cause: You may have forced a newly inserted object to "lose" its inserted status and then changed or deleted it. This could happen if you passed a temporary object ID to `objectWithID:`. You may have passed an inserted object to another managed object context.

Remedy: There are a number of possible remedies, depending on what was the root cause:

- Do not pass an inserted (not yet saved) object to another context. Only objects that have been saved can be passed between contexts.
- Do not invoke `refreshObject:` on a newly-inserted object.
- Do not make a relationship to an object that you never insert into the context.
- Ensure that you use the designated initializer for instances of `NSManagedObject`.

Before you save (frame #6 in the stack trace), the context's `updatedObjects` and `deletedObjects` sets should only have members whose object ID returns `NO` from `isTemporaryID`.

Debugging Fetching

With Mac OS X version 10.4.3 and later, you can use the user default `com.apple.CoreData.SQLDebug` to log to `stderr` the actual SQL sent to SQLite. (Note that user default names are case sensitive.) For example, you can pass the following as an argument to the application:

```
-com.apple.CoreData.SQLDebug 1
```

Higher levels of debug numbers produce more information, although using higher numbers is likely to be of diminishing utility.

The information the output provides can be useful when debugging performance problems—in particular it may tell you when Core Data is performing a large number of small fetches (such as when firing faults individually). Like file I/O, executing many small fetches is expensive compared to executing a single large fetch. For examples of how to correct this situation, see "Faulting Behavior" (page 126).

Important: Using this information for reverse engineering to facilitate direct access to the SQLite file is *not* supported. It is exclusively a debugging tool.

As this is for debugging, the exact format of the logging is subject to change without notice. You should not, for example, pipe the output into an analysis tool with the expectation that it will work on all OS versions.

Managed Object Models

My application generates the message "+entityForName: could not locate an NSManagedObjectModel"

Problem: The error states clearly the issue—the entity description cannot find a managed object model from which to access the entity information.

Cause: The model may not be included in your application resources. You may be trying to access the model before it has been loaded.

Remedy: Be sure that the model is included in your application resources and that the corresponding "project target" option in Xcode is selected.

The class method you invoked requires an entity name and context, and it is through the context that the entity gets the model. Basically, it looks like:

context ---> coordinator ---> model

In general, when working with Core Data and you have problems like these, you should ensure:

- That the managed object context is not `nil`
- If you are managing your own Core Data stack, that the managed object context has an associated coordinator (`setPersistentStoreCoordinator:` after allocating)
- That the persistent store coordinator has a valid model

If you are using `NSPersistentDocument`, then the "magic" for getting the managed object model is that it is instantiated using the `mergedModelFromBundles:` method when the document is initialized.

The documentation also gives you enough information on how to debug and hooks for debugging: there are a handful of methods listed in the "Getting and setting the persistence objects" section of the API reference for `NSPersistentDocument` for either modifying or inspecting the Core Data objects your document is working with. Simply overriding the implementations, calling super, and inspecting the returned values would give you more information about what may (or may not) be occurring.

Bindings Integration

Many problems relating to bindings are not specific to Core Data, and are discussed in Troubleshooting Cocoa Bindings. This section describes some additional problems that could be caused by the interaction of Core Data and bindings.

Custom relationship set mutator methods are not invoked by an array controller

Problem: You have implemented set mutator methods for a relationship as described in "Custom To-Many Relationship Accessor Methods," and have bound the `contentSet` binding of an `NSArrayController` instance to a relationship (as illustrated by the Employees array controller in *NSPersistentDocument Core Data Tutorial*), but the set mutator methods are not invoked when you add objects to and remove objects from the array controller.

Cause: This is a bug.

Remedy: You can work around this by adding `self` to the `contentSet` binding's key path. For example, instead of binding to [Department Object Controller]`.selection.employees`, you would bind to [Department Object Controller]`.selection.self.employees`.

Cannot access contents of an object controller after a nib is loaded

Problem: You want to perform an operation with the contents of an object controller (an instance of `NSObjectController`, `NSArrayController`, or `NSTreeController`) after a nib file has been loaded, but the controller's content is `nil`.

Cause: The controller's fetch is executed as a delayed operation performed after its managed object context is set (by nib loading)—the fetch therefore happens after `awakeFromNib` and `windowControllerDidLoadNib:`.

Remedy: You can execute the fetch “manually” with `fetchWithRequest:merge:error:`—see “Core Data and Cocoa Bindings” (page 107).

Cannot create new objects with array controller

Problem: You cannot create new objects using an `NSArrayController`. For example, when you click the button assigned to the `add:` action, you get an error similar to the following:

```
2005-05-05 12:00:)).000 MyApp[1234] *** NSRunLoop
ignoring exception 'Failed to create new object' that raised
during posting of delayed perform with target 123456
and selector 'invokeWithTarget:'
```

Cause: In your managed object model, you may have specified a custom class for the entity, but you have not implemented the class.

Remedy: Implement the custom class, or specify that the entity is represented by `NSManagedObject`.

A table view bound to an array controller doesn't display the contents of a relationship

Problem: You have a table view bound to an array controller that you want to display the contents of a relationship, but nothing is displayed and you get an error similar to the following:

```
2005-05-27 14:13:39.077 MyApp[1234] *** NSRunLoop ignoring exception
'Cannot create NSArray from object <_NSFaultingMutableSet: 0x3818f0> ()
of class _NSFaultingMutableSet - consider using contentSet
binding instead of contentArray binding' that raised during posting of
delayed perform with target 385350 and selector 'invokeWithTarget:'
```

Cause: You bound the controller's `contentArray` binding to a relationship. Relationships are represented by sets.

Remedy: Bind the controller's `contentSet` binding to the relationship.

A new object is not added to the relationship of the object currently selected in a table view

Problem: You have a table view that displays a collection of instances of an entity. The entity has a relationship to another entity, instances of which are displayed in a second table view. Each table view is managed by an array controller. When you add new instances of the second entity, they are not added to the relationship of the currently-selected instance of the first.

Cause: The two array controllers are not related. There is nothing to tell the second array controller about the first.

Remedy: Bind the second array controller's `contentSet` binding to the key path that specifies the relationship of the selection in the first array controller. For example, if the first array controller manages the Department entity, and the second the Employee entity, then the `contentSet` binding of the second array controller should be `[Department Controller].selection.employees`.

Table view or outline view contents not kept up-to-date when bound to an NSArrayController or NSTreeController object

Problem: You have a table view or outline view that displays a collection of instances of an entity. As new instances of the entity are added and removed, the table view is not kept in sync.

Cause: If the controller's content is an array that you manage yourself, then it is possible you are not modifying the array in a way that is key-value observing compliant.

If the controller's content is fetched automatically, then you have probably not set the controller to "Automatically prepare content."

Alternatively, the controller may not be properly configured.

Remedy: If the controller's content is a collection that you manage yourself, then ensure you modify the collection in a way that is key-value observing compliant—see Troubleshooting Cocoa Bindings.

If the controller's content is fetched automatically, set the "Automatically prepares content" switch for the controller in the Attributes inspector in Interface Builder (see also `automaticallyPreparesContent`). Doing so means that the controller tracks inserts into and deletions from its managed object context for its entity.

If neither of these is a factor, check to see that the controller is properly configured (for example, that you have set the entity correctly).

Efficiently Importing Data

This article describes how you can efficiently import data into a Core Data application and turn the data into managed objects to save to a persistent store. It discusses some of the fundamental Cocoa patterns you should follow, and patterns that are specific to Core Data.

Cocoa Fundamentals

In common with many other situations, when you use Core Data to import a data file it is important to remember "normal rules" of Cocoa application development apply, particularly if you are using a managed memory environment (as opposed to garbage collection). If you import a data file that you have to parse in some way, it is likely you will create a large number of autoreleased objects. These can take up a lot of memory and lead to paging. Just as you would with a non-Core Data application, you can use local autorelease pools to put a bound on how many additional objects reside in memory (for example, if you create a loop to iterate over data you can use an inner autorelease pool that you release and re-create every few times through your main loop). You can also create objects using `alloc` and `init` and then `release` them when you no longer need them—this avoids putting them in an autorelease pool in the first place. For more about the interaction between Core Data and memory management, see "Reducing Memory Overhead" (page 129).

You should also avoid repeating work unnecessarily. One subtle case lies in creating a predicate containing a variable. If you create the predicate as shown in the following example, you are not only creating a predicate every time through your loop, you are *parsing* one.

```
// loop over employeeIDs
// anID = ... each employeeID in turn
// within body of loop
NSString *predicateString = [NSString stringWithFormat:
        @"employeeID == %@", anID];

NSPredicate *predicate = [NSPredicate predicateWithFormat:predicateString];
```

To create a predicate from a formatted string, the framework must parse the string and create instances of predicate and expression objects. If you are using the same form of a predicate many times over but changing the value of one of the constant value expressions on each use, it is more efficient to create a predicate once and then use variable substitution (see Creating Predicates). This technique is illustrated in the following example.

```
// before loop
NSString *predicateString = [NSString stringWithFormat
        @"employeeID == $EMPLOYEE_ID"];
NSPredicate *predicate = [NSPredicate predicateWithFormat:predicateString];

// within body of loop
NSDictionary *variables = [NSDictionary dictionaryWithObject:anID
        forKey:@"EMPLOYEE_ID"];
NSPredicate *localPredicate = [predicate
predicateWithSubstitutionVariables:variables];
```

Reducing Peak Memory Footprint

If you import a large amount of data into a Core Data application, you should make sure you keep your application's peak memory footprint low by importing the data in batches and purging the Core Data stack between batches. The relevant issues and techniques are discussed in "Core Data Performance" (page 125) (particularly "Reducing Memory Overhead" (page 129)) and "Memory Management Using Core Data" (page 69), but they're summarized here for convenience.

Importing in batches

First, you should typically create a separate managed object context for the import, and set its undo manager to `nil`. (Contexts are not particularly expensive to create, so if you cache your persistent store coordinator you can use different contexts for different working sets or distinct operations.)

```
NSManagedObjectContext *importContext = [[NSManagedObjectContext alloc] init];
NSPersistentStoreCoordinator *coordinator = /* retrieve the coordinator */ ;
[importContext setPersistentStoreCoordinator:coordinator];
[importContext setUndoManager:nil];
```

(If you have an existing Core Data stack, you can get the persistent store coordinator from another managed object context.) Setting the undo manager to `nil` means that:

1. You don't waste effort recording undo actions for changes (such as insertions) that will not be undone;
2. The undo manager doesn't maintain strong references to changed objects and so prevent them from being deallocated (see "Change and Undo Management" (page 70)).

You should import data and create corresponding managed objects in batches (the optimum size of the batch will depend on how much data is associated with each record and how low you want to keep the memory footprint). At the beginning of each batch you create a new autorelease pool. At the end of each batch you need to save the managed object context (using `save:`) and then drain the pool. (Until you save, the context needs to retain all the pending changes you've made to the inserted objects.)

The process is illustrated in the following example, although note that you would typically include suitable error-checking.

```
NSAutoreleasePool *pool = [[NSAutoreleasePool alloc] init];
NSUInteger count = 0, LOOP_LIMIT = 1000;
NSDictionary *newRecord;
NSManagedObject *newMO;

// assume a method 'nextRecord' that returns a dictionary representing the next
// set of data to be imported from the file

while (newRecord = [self nextRecord])
{
    // create managed object(s) from newRecord

    count++;
    if (count == LOOP_LIMIT)
    {
        [importContext save:outError];
```

```
            [importContext reset];
            [pool drain];

            pool = [[NSAutoreleasePool alloc] init];
            count = 0;
        }
    }
```

Dealing with retain cycles

There is an additional issue that complicates matters in a managed memory environment (it doesn't affect applications that use garbage collection). Managed objects with relationships nearly always create unreclaimable retain cycles. If during the import you create relationships between objects, you need to break the retain cycles so that the objects can be deallocated when they're no longer needed. To do this, you can either turn the objects into faults, or reset the whole context. For a complete discussion, see "Breaking Relationship Retain Cycles" (page 70).

Document-based example

The following example illustrates how you could implement a subclass of `NSDocumentController` to allow your application to open a legacy file format and import the data into a new Core Data store. It assumes three additional methods: `openURLForReadingLegacyData:error:` to open the legacy file, `nextRecord` that returns a dictionary containing the data from the next record in the file, and `closeLegacyFile` to close the legacy file. As a further simplification, it assumes that the legacy file contains data for only one entity.

```
NSString *CORE_DATA_DOCUMENT_TYPE = @"CoreDataStoreDocumentType";
NSString *ENTITY_NAME = @"MyEntity";
NSUInteger LOOP_LIMIT = 5000;


@implementation MyDocumentController

- (id)openDocumentWithContentsOfURL:(NSURL *)absoluteURL
      display:(BOOL)displayDocument error:(NSError **)outError

{
    NSString *filePath = [absoluteURL relativePath];
    NSString *fileExtension = [filePath pathExtension];
    NSString *type = [self typeFromFileExtension:fileExtension];

    if ([type isEqualToString:CORE_DATA_DOCUMENT_TYPE])
    {
        return [super openDocumentWithContentsOfURL:absoluteURL
                      display:displayDocument error:outError];
    }

    BOOL ok = [self openURLForReadingLegacyData:absoluteURL error:outError];
    if (!ok)
    {
        return nil;
    }

    NSString *extension = [[self fileExtensionsFromType:CORE_DATA_DOCUMENT_TYPE]
```

```
                                     objectAtIndex:0];
    NSString *storePath = [[filePath stringByDeletingPathExtension]
                                     stringByAppendingPathExtension:extension];

    NSFileManager *fm = [NSFileManager defaultManager];
    if ([fm fileExistsAtPath:storePath])
    {
        ok = [fm removeItemAtPath:storePath error:outError];
        if (!ok)
        {
            return nil;
        }
    }

    NSURL *storeURL = [NSURL fileURLWithPath:storePath];

    NSString *modelPath = [[NSBundle mainBundle] pathForResource:@"MyDocument"
                                                 ofType:@"mom"];
    NSURL *modelURL = [NSURL fileURLWithPath:modelPath];

    NSManagedObjectModel *model = [[[NSManagedObjectModel alloc]
            initWithContentsOfURL:modelURL] autorelease];

    NSPersistentStoreCoordinator *psc = [[[NSPersistentStoreCoordinator alloc]
            initWithManagedObjectModel:model] autorelease];

    NSPersistentStore *store = [psc addPersistentStoreWithType:NSSQLiteStoreType
            configuration:nil URL:storeURL options:0 error:outError];
    if (store == nil)
    {
        return nil;
    }

    NSManagedObjectContext *importContext = [[NSManagedObjectContext alloc] init];
    [importContext setPersistentStoreCoordinator:psc];
    [importContext setUndoManager:nil];


    NSEntityDescription *entity = [NSEntityDescription entityForName:ENTITY_NAME
            inManagedObjectContext:importContext];

    NSAutoreleasePool *pool = [[NSAutoreleasePool alloc] init];
    NSUInteger count = 0;
    NSDictionary *newRecord;
    NSManagedObject *newMO;

    while (newRecord = [self nextRecord])
    {
        /*
         It is more efficient to cache the entity and use initWithEntity:
         insertIntoManagedObjectContext: than to use the typically-more-convenient
         NSEntityDescription method
insertNewObjectForEntityForName:inManagedObjectContext:.
         It is also more efficient to release the new managed object than it is to add
 it
         to the autorelease pool.  It can safely be released here since, because
         it's a newly-inserted object, the managed object context retains it.
         */
        newMO = [[NSManagedObject alloc] initWithEntity:entity
                       insertIntoManagedObjectContext:importContext];
;
        [newMO setValuesForKeysWithDictionary:newRecord];

        [newMO release];

        count++;
        if (count == LOOP_LIMIT)
        {
            ok = [importContext save:outError];
            if (!ok)
            {
                [importContext release];
                [pool drain];
                [self closeLegacyFile];
                return nil;
            }
            /*
             reset is not actually needed in this example since we're not creating
             any relationships but this would be one place to put it if we were
             [importContext reset];
             or:
             for (NSManagedObject* mo in [importContext registeredObjects])
             {
                 [importContext refreshObject:mo mergeChanges:NO];
             }
             */

            [pool drain];

            pool = [[NSAutoreleasePool alloc] init];
            count = 0;
        }
    }

    ok = [importContext save:outError];
    [self closeLegacyFile];

    [importContext release];
    [pool drain];

    if (!ok)
    {
        return nil;
    }
    return [super openDocumentWithContentsOfURL:storeURL
                  display:displayDocument error:outError];
}
```

Implementing Find-or-Create Efficiently

A common technique when importing data is to follow a "find-or-create" pattern, where you set up some data from which to create a managed object, determine whether the managed object already exists, and create it if it does not.

There are many situations where you may need to find existing objects (objects already saved in a store) for a set of discrete input values. A simple solution is to create a loop, then for each value in turn execute a fetch to determine whether there is a matching persisted object and so on. This pattern does not scale well. If you profile your application with this pattern, you typically find the fetch to be one of the more expensive operations in the loop (compared to just iterating over a collection of items). Even worse, this pattern turns an `O(n)` problem into an `O(n^2)` problem.

It is much more efficient—when possible—to create all the managed objects in a single pass, and then fix up any relationships in a second pass. For example, if you import data that you know you does not contain any duplicates (say because your initial data set is empty), you can just create managed objects to represent your data and not do any searches at all. Or if you import "flat" data with no relationships, you can create managed objects for the entire set and weed out (delete) any duplicates before save using a single large `IN` predicate.

If you do need to follow a find-or-create pattern—say because you're importing heterogeneous data where relationship information is mixed in with attribute information—you can optimize how you find existing objects by reducing to a minimum the number of fetches you execute. How to accomplish this depends on the amount of reference data you have to work with. If you are importing 100 potential new objects, and only have 2000 in your database, fetching all of the existing and caching them may not represent a significant penalty (especially if you have to perform the operation more than once). However, if you have 100,000 items in your database, the memory pressure of keeping those cached may be prohibitive.

You can use a combination of an `IN` predicate and sorting to reduce your use of Core Data to a single fetch request. Suppose, for example, you want to take a list of employee IDs (as strings) and create Employee records for all those not already in the database. Consider this code, where Employee is an entity with a `name` attribute, and `listOfIDsAsString` is the list of IDs for which you want to add objects if they do not already exist in a store.

First, separate and sort the IDs (strings) of interest.

```
// get the names to parse in sorted order
NSArray *employeeIDs = [[listOfIDsAsString componentsSeparatedByString:@"\n"]
        sortedArrayUsingSelector: @selector(compare:)];
```

Next, create a predicate using `IN` with the array of name strings, and a sort descriptor which ensures the results are returned with the same sorting as the array of name strings. (The `IN` is equivalent to an SQL `IN` operation, where the left-hand side must appear in the collection specified by the right-hand side.)

```
// create the fetch request to get all Employees matching the IDs
NSFetchRequest *fetchRequest = [[[NSFetchRequest alloc] init] autorelease];
[fetchRequest setEntity:
        [NSEntityDescription entityForName:@"Employee"
inManagedObjectContext:aMOC]];
[fetchRequest setPredicate: [NSPredicate predicateWithFormat: @"(employeeID IN
 %@)", employeeIDs]];

// make sure the results are sorted as well
[fetchRequest setSortDescriptors: [NSArray arrayWithObject:
        [[[NSSortDescriptor alloc] initWithKey: @"employeeID"
                ascending:YES] autorelease]]];
```

Finally, execute the fetch.

```
NSError *error;
NSArray *employeesMatchingNames = [aMOC
        executeFetchRequest:fetchRequest error:&error];
```

You end up with two sorted arrays—one with the employee IDs passed into the fetch request, and one with the managed objects that matched them. To process them, you walk the sorted lists following these steps:

1. Get the next ID and Employee. If the ID doesn't match the Employee ID, create a new Employee for that ID.

2. Get the next Employee: if the IDs match, move to the next ID and Employee.

Regardless of how many IDs you pass in, you only execute a single fetch, and the rest is just walking the result set.

The listing below shows the complete code for the example in the previous section.

```
// get the names to parse in sorted order
NSArray *employeeIDs = [[listOfIDsAsString componentsSeparatedByString:@"\n"]
        sortedArrayUsingSelector: @selector(compare:)];

// create the fetch request to get all Employees matching the IDs
NSFetchRequest *fetchRequest = [[[NSFetchRequest alloc] init] autorelease];
[fetchRequest setEntity:
        [NSEntityDescription entityForName:@"Employee"
inManagedObjectContext:aMOC]];
[fetchRequest setPredicate: [NSPredicate predicateWithFormat: @"(employeeID IN
 %@)", employeeIDs]];

// make sure the results are sorted as well
[fetchRequest setSortDescriptors: [NSArray arrayWithObject:
        [[[NSSortDescriptor alloc] initWithKey: @"employeeID"
                ascending:YES] autorelease]]];
// Execute the fetch
NSError *error;
NSArray *employeesMatchingNames = [aMOC
        executeFetchRequest:fetchRequest error:&error];
```

Mac OS X v10.4: Using Managed Objects

Many enhancements were introduced for Core Data on Mac OS X v10.5. For the benefit of developers who need to develop for earlier releases, this article describes issues related to using and manipulating managed objects on Mac OS X v10.4.

Accessing and Modifying Properties

To access or modify properties of a managed object, by default you use key-value coding, using the name of a property (as defined in the managed object model) as a key. This general principle applies both to attributes and relationships. There are some special considerations for to-many relationships.

Attributes

You can access attributes of a managed object using key-value coding, as illustrated in the following code fragment.

```
NSString *firstName = [newEmployee valueForKey:@"firstName"];
NSNumber *salary = [newEmployee valueForKey:@"salary"];
```

If you have defined a custom class for a given entity and implemented your own accessor methods, you can call those directly as illustrated in the following code fragment—note that in the second case the salary is represented by a float value (see "Managed Object Accessor Methods" (page 41) for more details).

```
NSString *firstName = [newEmployee firstName];
float salary = [newEmployee salary];
```

The following code fragment illustrates how you can use key-value coding to change the value of a simple attribute.

```
[newEmployee setValue:@"Stig" forKey:@"firstName"];
[newEmployee setValue:[NSNumber numberWithFloat:1000.0] forKey:@"salary"];
```

If you have defined a custom class for a given entity and implemented your own accessor methods (see "Managed Object Accessor Methods" (page 41) for implementation details), again you can call those directly as illustrated in the following code fragment.

```
[newEmployee setFirstName:@"Stig"];
[newEmployee setSalary:1000.0];
```

Key-value coding will, of course, also work if you've specified a custom class and custom accessors.

You must change attribute values in a KVC-compliant fashion. For example, the following typically represents a programming error:

```
NSMutableString *mString = [NSMutableString stringWithString:@"Stag"];
```

```
[newEmployee setValue:mString forKey:@"firstName"];
[mString setString:@"Stig"];
```

For mutable values, you should either transfer ownership of the value to Core Data, or implement custom accessor methods to always perform a copy. The previous example would not represent an error if the class representing the Employee entity implemented a custom `setFirstName:` accessor method that copied the new value. It is important to note, of course, that after the invocation of `setString:` (in the third code line) the value of `firstName` would still be “Stag” and not “Stig”.

There should typically be no reason to invoke the primitive KVC set method (`setPrimitiveValue:forKey:`) or any custom primitive setters (see “Managed Object Accessor Methods” (page 41)) except within accessor methods for derived properties.

Relationships

You access and modify a to-one relationship using key-value coding or a custom accessor method, just as you would an attribute—for example:

```
[newEmployee setValue:anotherEmployee forKey:@"manager"];
NSManagedObject *managersManager = [anotherEmployee manager];
```

To access a to-many relationship (whether the destination of a one-to-many relationship or a many-to-many relationship), you typically use key-value coding. A to-many relationship is represented by a set, as illustrated in the following code fragment:

```
NSSet *managersPeers = [managersManager valueForKey:@"directReports"];
```

Note that when you access the destination of a relationship, you may initially get a fault object (see “Faulting and Uniquing” (page 99))—the fault fires automatically if you make any changes to it.

You can manipulate an entire to-many relationship in the same way you do a to-one relationship, using either a custom accessor method or (more likely) key-value coding, as in the following example.

```
[aDepartment setValue:setOfEmployees forKey:@"employees"];
```

Typically, however, you do not want to set an entire relationship, instead you want to add or remove a single element at a time. In this case, you use `mutableSetValueForKey:` which returns a proxy object that both mutates the relationship and sends appropriate key-value observing notifications for you.

```
NSMutableSet *employees = [aDepartment mutableSetValueForKey:@"employees"];
[employees addObject:aNewEmployee];
[employees removeObject:aFiredEmployee];
```

There should typically be little reason to implement your own collection accessor methods (such as `add<Key>Object:` and `remove<Key>Object:`) for to-many relationships, however if you do so you may call these directly.

If you do implement custom accessors, you must take care to implement an `add<Key>Object:/remove<Key>Object:` pair, an `add<Key>:/remove<Key>:` pair, or both pairs and ensure that they send the relevant key-value observing notifications—see “Managed Object Accessor Methods” (page 41) for implementation details.

Most relationships are inherently bidirectional. Any changes made to the relationships between objects should maintain the integrity of the object graph. Provided that you have correctly modeled a relationship in both directions and set the inverses, modifying one end of a relationship automatically updates the other end—see "Manipulating Relationships and Object Graph Integrity" (page 75).

Saving changes

Simply modifying a managed object does not cause the changes to be saved to a store. The managed object context acts as a scratchpad. You can make changes to the objects, and undo and redo changes as you wish. If you make changes to managed objects associated with a given context, those changes remain local to that context until you commit the changes by sending the context a `save:` message. At that point—provided that there are no validation errors—the changes are committed to the persistent store.

See also "Ensuring Data Is Up-to-Date" (page 66).

Managed Object IDs and URIs

An `NSManagedObjectID` object is a universal identifier for a managed object, and provides basis for uniquing in the Core Data Framework. A managed object ID uniquely identifies the same managed object both between managed object contexts in a single application, and in multiple applications (as in distributed systems). Like the primary key in the database, an identifier contains the information needed to exactly describe an object in a persistent store, although the detailed information is not exposed. The framework completely encapsulates the "external" information and presents a clean object oriented interface.

```
NSManagedObjectID *moID = [managedObject objectID];
```

It is important to note that there are two forms of an object ID. When a managed object is first created, Core Data assigns it a temporary ID; only if it is saved to a persistent store does Core Data assign a managed object a permanent ID. You can readily discover whether an ID is temporary:

```
BOOL isTemporary = [[managedObject objectID] isTemporaryID];
```

You can also transform an object ID into a URI representation:

```
NSURL *moURI = [[managedObject objectID] URIRepresentation];
```

Given a managed object ID or a URI, you can retrieve the corresponding managed object using `managedObjectIDForURIRepresentation:` or `objectWithID:`.

An advantage of the URI representation is that you can archive it—although note that in many cases you should not archive a temporary ID since this is obviously subject to change. You could, for example, store archived URIs in your application's user defaults to save the last selected group of objects in a table view. You can also use URIs to support copy and paste operations (see "Copying and Copy and Paste" (page 62)) and drag and drop operations (see "Drag and Drop" (page 63)).

You can use object IDs to define "weak" relationships across persistent stores (where no hard join is possible). For example, for a weak to-many relationship you store as archived URIs the IDs of the objects at the destination of the relationship, and maintain the relationship as a transient attribute derived from the object IDs.

You can sometimes benefit from creating your own unique ID (UUID) property which can be defined and set for newly inserted objects. This allows you to efficiently locate specific objects using predicates (though before a save operation new objects can be found only in their original context).

Copying and Copy and Paste

It is difficult to solve the problem of copying, or supporting copy and paste, in a generic way for managed objects. You need to determine on a case-by-case basis what properties of a managed object you actually want to copy.

Copying Attributes

If you just want to copy a managed object's attributes, then in many cases the best strategy may be in the copy operation to create a dictionary (property list) representation of a managed object, then in the paste operation to create a new managed object and populate it using the dictionary. For an example, see *NSPersistentDocument Core Data Tutorial*—see also Copying in *Model Object Implementation Guide*. You can use the managed object's ID (described in "Managed Object IDs and URIs" (page 61)) to support copy and paste. Note, however, that the technique needs to be adapted to allow for copying of new objects.

A new, unsaved, managed object has a temporary ID. If a user performs a copy operation and then a save operation, the managed object's ID changes and the ID recorded in the copy will be invalid in a subsequent paste operation. To get around this, you use a "lazy write" (as described in Implementing Copy and Paste). In the copy operation, you declare your custom type but if the managed object's ID is temporary you do not write the data—but you do keep a reference to the original managed object. In the `pasteboard:provideDataForType:` method you then write the current ID for the object.

As a further complication, it is possible that the ID is still temporary during the paste operation, yet you must still allow for the possibility of future paste operations after an intervening save operation. You must therefore re-declare the type on the pasteboard to set up lazy pasting again, otherwise the pasteboard will retain the temporary ID. You cannot invoke `addTypes:owner:` during `pasteboard:provideDataForType:`, so you must use a delayed perform—for example:

```
- (void)pasteboard:(NSPasteboard *)sender provideDataForType:(NSString *)type
{
    if ([type isEqualToString:MyMOIDType]) {
        // assume cachedManagedObject is object originally copied
        NSManagedObjectID *moID = [cachedManagedObject objectID];
        NSURL *moURI = [moID URIRepresentation];
        [sender setString:[moURI absoluteString] forType:MyMOIDType];
        if ([moID isTemporaryID]) {
            [self performSelector:@selector(clearMOIDInPasteboard:)
                    withObject:sender afterDelay:0];
        }
    }
    // implementation continues...
}

- (void)clearMOIDInPasteboard:(NSPasteboard *)pb
{
    [pb addTypes:[NSArray arrayWithObject:MyMOIDType] owner:self];
}
```

Copying Relationships

If you want to copy relationships you also need to consider the objects related to those first tier of related objects—if you are not careful, it is possible that you will copy the whole object graph (which may not be what you want!). If you want to copy a to-one relationship, you need to decide whether the copy of the destination should be a new object or a reference. If it is a reference, what should happen to the inverse relationship to the original object—should making a copy redefine relationships between other objects? You need to make similar decisions for to-many relationships.

Drag and Drop

You can perform drag and drop operations with managed objects—such as, for example, transferring an object from one relationship to another—using a URI representation, as described in "Managed Object IDs and URIs" (page 61).

```
NSURL *moURI = [[managedObject objectID] URIRepresentation];
```

You can put the URI on a dragging pasteboard, from which you can later retrieve it and recreate a reference to the original managed object using the persistent store coordinator, as illustrated in the following code sample.

```
NSURL *moURL = // get it from the pasteboard ...
NSManagedObjectID *moID = [[managedObjectContext persistentStoreCoordinator]
    managedObjectIDForURIRepresentation:moURL];
// assume moID non-nil...
NSManagedObject *mo = [managedObjectContext objectWithID:moID];
```

Note that this assumes that drag and drop is "within a single persistence stack"—that is, that if there is more than one managed object context involved that they use a shared persistent store coordinator—or that the object(s) being dragged and dropped are in a store referenced by the persistent store coordinators.

If you want to copy-and-paste via drag-and-drop then you must put a suitable representation of the managed object onto the pasteboard, get the representation during the drop method, and initialize a new managed object using the representation (see "Copying and Copy and Paste" (page 62)).

Validation

The Core Data framework provides a clean infrastructure for supporting validation, both through logic encapsulated in the object model and through custom code. In the managed object model, you can specify constraints on values that a property may have (for example, an Employee's salary cannot be negative, or that every employee must belong to a Department). There are two forms of custom validation methods—those that follow standard key-value coding conventions (see Key-Value Validation) to validate a value for a single attribute, and a special set (`validateForInsert:`, `validateForUpdate:`, and `validateForDelete:`) for validating the whole object at different stages of its life-cycle (insertion, update, and deletion). The latter may be particularly useful for validating combinations of values—for example, to ensure that an employee can be entered into a stock purchase plan only if their period of service exceeds a given length and their pay grade is at or above a certain level.

Model-based constraints are checked and validation methods are invoked automatically before changes are committed to the external store to prevent invalid data being saved. You can also invoke them programmatically whenever necessary. You validate individual values using `validateValue:forKey:error:`. The managed object compares the new value with the constraints specified in the model, and invokes any custom validation method (of the form `validate<Key>:error:`) you have implemented. Even if you implement custom validation methods, you should typically not call custom validation methods directly. This ensures that any constraints defined in the managed object model are applied.

For more about implementing validation methods, see Model Object Validation.

Undo Management

The Core Data framework provides automatic support for undo and redo. Undo management even extends to transient properties (properties that are not saved to persistent store, but are specified in the managed object model).

Managed objects are associated with a managed object context. Each managed object context maintains an undo manager. The context uses key-value observing to keep track of modifications to its registered objects. You can make whatever changes you want to a managed object's properties using normal accessor methods, key-value coding, or through any custom key-value-observing compliant methods you define for custom classes, and the context registers appropriate events with its undo manager. To undo an operation you simply send the context an `undo` message and to redo it send the context a `redo` message. You can also roll back all changes made since the last save operation using `rollback` (this also clears the undo stack) and reset a context to its base state using `reset`.

In some situations you want to alter—or, specifically, disable—undo behavior. This may be useful, for example, if you want to create a default set of objects when a new document is created (but want to ensure that the document is not shown as being dirty when it is displayed), or if you need to merge new state from another thread or process. In general, to perform operations without undo registration, you send an undo manager a `disableUndoRegistration` message, make the changes, and then send the undo manager an `enableUndoRegistration` message. Core Data, however, queues up the undo registrations and adds them in a batch (this allows the framework to coalesce changes, negate contradictory changes, and perform various other operations that work better with hindsight than immediacy). To ensure that any queued operations are properly flushed, before you disable and enable undo registration you sent the managed object context a `processPendingChanges` message, as illustrated in the following code fragment:

```
NSManagedObjectContext *moc = ...;
[moc processPendingChanges];  // flush operations for which you want undos
[[moc undoManager] disableUndoRegistration];
// make changes for which undo operations are not to be recorded
[moc processPendingChanges];  // flush operations for which you do not want
undos
[[moc undoManager] enableUndoRegistration];
```

Faults

Managed objects typically represent data held in a persistent store. In some situations a managed object may be a "fault"—an object whose property values have not yet been loaded from the external store. When you access persistent property values, a fault "fires" and its persistent data is retrieved automatically from the store. In some circumstances you may explicitly turn a managed object into a fault (typically to ensure that its values are up to date, using `NSManagedObjectContext`'s `refreshObject:mergeChanges:`). More commonly you encounter faults when traversing relationships.

When you fetch a managed object, Core Data does not automatically fetch data for other objects to which it has relationships (see "Faulting" (page 99)). Initially, an object's relationships are represented by faults (unless the destination object has already been fetched—see "Uniquing" (page 101)). If, however, you access the relationship's destination object or objects, their data are retrieved automatically for you. For example, suppose you fetch a single Employee object from a persistent store when an application first launches, then (assuming these exist in the persistent store) its `manager` and `department` relationships are represented by faults. You can nevertheless ask for the employee's manager's last name as shown in the following code example:

```
NSString *managersName =
        [[anEmployee valueForKey:@"manager"] valueForKey:@"lastName"];
```

or more easily using key paths:

```
NSString *managersName =
        [anEmployee valueForKeyPath:@"manager.lastName"];
```

In this case, the data for destination Employee object (the manager) is retrieved for you automatically.

There is a subtle but important point here. Notice that, in order to traverse a relationship—in this example to find an employee's manager—you do not have to explicitly *fetch* the related objects (that is, you do not create and execute a fetch request). You simply use key-value coding (or if you have implemented them, accessor methods) to retrieve the destination object (or objects) and they are created for you automatically by Core Data. For example, you could ask for an employee's manager's manager's department's name like this:

```
NSString *departmentName = [anEmployee
valueForKeyPath:@"manager.manager.department.name"];
```

(This assumes, of course, that the employee is at least two levels deep in the management hierarchy.) You can also use collection operator methods. You could find the salary overhead of an employee's department like this:

```
NSNumber *salaryOverhead = [anEmployee
valueForKeyPath:@"department.employees.@sum.salary"];
```

In many cases, your initial fetch retrieves a starting node in the object graph and thereafter you do not execute fetch requests, you simply follow relationships.

Ensuring Data Is Up-to-Date

If two applications are using the same data store, or a single application has multiple persistence stacks, it is possible for managed objects in one managed object context or persistent object store to get out of sync with the contents of the repository. If this occurs, you need to "refresh" the data in the managed objects, and in particular the persistent object store (the snapshots) to ensure that the data values are current.

Refreshing an object

Managed objects that have been realized (their property values have been populated from the persistent store) as well as pending updated, inserted, or deleted objects, are never changed by a fetch operation without developer intervention. For example, consider a scenario in which you fetch some objects and modify them in one editing context; meanwhile in another editing context you edit the same data and commit the changes. If in the first editing context you then execute a new fetch which returns the same objects, you do not see the newly-committed data values—you see the existing objects in their current in-memory state.

To refresh a managed object's property values, you use the managed object context method `refreshObject:mergeChanges:`. If the `mergeChanges` flag is `YES`, this method merges the object's property values with those of the object available in the persistent store coordinator; if the flag is `NO`, the method simply turns an object back into a fault without merging (which also causes other related managed objects to be released, so you can use this method to trim the portion of your object graph you want to hold in memory).

Note that an object's staleness interval is the time that has to pass until the store re-fetches the snapshot. This therefore only affects firing faults—moreover it is only relevant for SQLite stores (the other stores never re-fetch because the entire data set is kept in memory).

Merging changes with transient properties

If you use `refreshObject:mergeChanges:` with the `mergeChanges` flag `YES`, then any transient properties are restored to their pre-refresh value after `awakeFromFetch` is invoked. This means that, if you have a transient property with a value that depends on a property that is refreshed, the transient value may become out of sync. Consider an application in which you have a Person entity with attributes `firstName` and `lastName`, and a *cached* transient derived property, `fullName` (in practice it might be unlikely that a `fullName` attribute would be cached, but the example is easy to understand).

A Person, currently named "Alissa Eejaysing," is edited in two managed object contexts. In one context, the corresponding instance's `lastName` attribute is changed to "Wijesinghe" and the context saved. Afterwards, in the other context, the corresponding Person instance is modified such that the `firstName` is "Lasantha"—which in turn causes the `fullName` attribute to be updated to "Lasantha Eejaysing"—then refreshed with the mergeChanges flag `YES`. Since `firstName` was changed prior to the refresh, it remains "Lasantha". Since `lastName` was unchanged, the refresh causes it to be updated to the new value from the persistent store, so it is now "Wijesinghe." The transient value, however, is not updated. The value of `fullName` remains "Lasantha Eejaysing" (rather than the correct "Lasantha Wijesinghe").

Note that the pre-refresh values are applied *after* `awakeFromFetch`, so you cannot use `awakeFromFetch` to ensure that a transient value is properly updated following a refresh (or if you do, the value will subsequently be overwritten). In these circumstances, the best solution is to use an additional instance variable to note that a refresh has occurred and that the transient value should be recalculated. For example, in the Person class you could declare an instance variable `fullNameIsValid` of type `BOOL` and implement the `didTurnIntoFault` method to set the value to `NO`. You then implement a custom accessor for the `fullName` attribute that checks the value of `fullNameIsValid`—if it is `NO`, then the value is recalculated.

Mac OS X v10.4: Managed Object Accessor Methods

On Mac OS X v10.5, Core Data dynamically generates accessor methods for you. For the benefit of developers who need to develop for earlier releases, this article describes how to write accessor methods on Mac OS X v10.4.

This article explains why you might want to implement custom accessor methods for managed objects, and how to implement them for attributes and for relationships. It also illustrates how to implement primitive accessor methods.

Introduction

There is in general no *need* to write custom accessor methods for properties that are defined in the entity of a managed object's corresponding managed object model. You can access properties using standard key-value coding methods such as `valueForKey:`. It may be convenient to implement custom accessors to benefit from compile-time type checking and to avoid errors with misspelled key names. You do need custom accessor methods if you use transient properties to support non-standard data types (see "Non-Standard Persistent Attributes" (page 83)) or if you use scalar instance variables to represent an attribute.

Key-value Coding Access Pattern

The access pattern key-value coding uses for managed objects is largely the same as that used for subclasses of `NSObject`—see `valueForKey:`. The difference is that, if after checking the normal resolutions `valueForKey:` would throw an unbound key exception, the key-value coding mechanism for `NSManagedObject` checks whether the key is a modeled property. If the key matches an entity's property, the mechanism looks first for an accessor method of the form `primitive`*Key*, and if that is not found then looks for a value for *key* in the managed object's internal storage. If these fail, `NSManagedObject` throws an unbound key exception (just like `valueForKey:`).

Custom Accessors

The implementation of accessor methods you write for subclasses of `NSManagedObject` is typically different from those you write for other classes.

- If you do not provide custom instance variables, you retrieve property values from and save values into the internal store using primitive accessor methods (you usually use `primitiveValueForKey:` and `setPrimitiveValue:forKey:`, however you can also implement your own custom primitive accessor methods).

- You must ensure that you invoke the relevant access and change notification methods. `NSManagedObject` disables automatic notifications for key-value observing (KVO, see *Key-Value Observing Programming Guide*), and the primitive accessor methods do not invoke the access and change notification methods (`willAccessValueForKey:`, `didAccessValueForKey:`, `willChangeValueForKey:`, and `didChangeValueForKey:`).
- In accessor methods for properties that are *not* defined in the entity model, you can either enable automatic change notifications or invoke the appropriate change notification methods.

You can use the Xcode data modeling tool to generate the code for accessor methods for any modeled property.

Attribute Accessor Methods

Attribute accessors use the primitive accessor methods to get and set values from and to the managed object's private internal store. You must invoke the relevant access and change notification methods, as illustrated in Listing 1 (page 44). `NSManagedObject`'s implementation of the primitive set accessor method handles memory management for you.

Listing 1 Implementation of a custom managed object class illustrating attribute accessor methods

```
@interface Department : NSManagedObject
{
}
- (NSString *)name;
- (void)setName:(NSString *)newName
@end

@implementation Department

- (NSString *)name
{
    [self willAccessValueForKey:@"name"];
    NSString *n = [self primitiveValueForKey:@"name"];
    [self didAccessValueForKey:@"name"];
    return n;
}

- (void)setName:(NSString *)newName
{
    [self willChangeValueForKey:@"name"];
    [self setPrimitiveValue:newName forKey:@"name"];
    [self didChangeValueForKey:@"name"];
}
@end
```

Note, however, that the default implementation does not copy attribute values. If the attribute value may be mutable and implements the `NSCopying` protocol (as is the case with `NSString`, for example), it is typically useful to copy the value in a custom accessor to help preserve encapsulation (for example, in the case where an instance of `NSMutableString` is passed as a value). The `setName:` method shown in Listing 1 (page 44) would be implemented as follows:

```
- (void)setName:(NSString *)newName
```

```
{
    [self willChangeValueForKey:@"name"];
    // NSString implements NSCopying, so copy the attribute value
    NSString *nameCopy = [newName copy];
    [self setPrimitiveValue:nameCopy forKey:@"name"];
    [nameCopy release];
    [self didChangeValueForKey:@"name"];
}
@end
```

If you choose to represent an attribute using a scalar type (such as `int` or `float`), or as one of the structures supported by `NSKeyValueCoding` (`NSRect`, `NSPoint`, `NSSize`, `NSRange`), then you should implement accessor methods as illustrated in Listing 3 (page 46). If you want to use any other attribute type, then you should use a different pattern, described in Non-Standard Persistent Attributes (page 83).

Listing 2 Implementation of a custom managed object class illustrating a scalar attribute value

```
@interface Circle : NSManagedObject
{
    float radius;
}
- (float)radius;
- (void)setRadius:(float)newRadius
@end

@implementation Circle

- (float)radius
{
    [self willAccessValueForKey:@"radius"];
    float f = radius;
    [self didAccessValueForKey:@"radius"];
    return f;
}

- (void)setRadius:(float)newRadius
{
    [self willChangeValueForKey:@"radius"];
    radius = newRadius;
    [self didChangeValueForKey:@"radius"];
}
@end
```

Relationship Accessor Methods

You usually access to-many relationships using `mutableSetValueForKey:`, which returns a proxy object that both mutates the relationship and sends appropriate key-value observing notifications for you. There should typically be little reason to implement your own collection accessor methods for to-many relationships. If they are present, however, the framework calls the mutator methods (such as `add<Key>Object:` and `remove<Key>Object:`) when modifying a collection that represents a persistent relationship. (Note that fetched properties do not support the mutable collection accessor methods.) In order for this to work correctly, you must implement an `add<Key>Object:/remove<Key>Object:` pair, an `add<Key>:/remove<Key>:`

pair, or both pairs. You may also implement other get accessors (such as `countOf<Key>:`, `enumeratorOf<Key>:`, and `memberOf<Key>:`) and use these in your own code, however these are not guaranteed to be called by the framework.

Important: For performance reasons, the proxy object returned by managed objects for `mutableSetValueForKey:` does not support `set<Key>:` style setters for relationships. For example, if you have a to-many relationship `employees` of a Department class and implement accessor methods `employees` and `setEmployees:`, then manipulate the relationship using the proxy object returned by `mutableSetValueForKey:@"employees"`, `setEmployees:` is *not* invoked. You should implement the other mutable proxy accessor overrides instead.

If you do implement collection accessors for model properties, they must again call the relevant KVO notification methods. Listing 4 (page 47) illustrates the implementation of accessor methods for a to-many relationship—`employees`—of a Department class.

Listing 3 Implementation of a custom managed object class illustrating a to-many relationship

```
@interface Department : NSManagedObject
{
}
- (void)addEmployeesObject:(Employee *)anEmployee;
- (void)addEmployees:(NSSet *)employeesToAdd;
- (void)removeEmployeesObject:(Employee *)anEmployee;
- (void)removeEmployees:(NSSet *)employeesToRemove;
- (void)intersectEmployees:(NSSet *)employeesToIntersect;
@end

@implementation Department

// add the given Employee instance to the employees relationship
- (void)addEmployeesObject:(Employee *)anEmployee
{
   NSSet *changedObjects = [[NSSet alloc] initWithObjects:&anEmployee count:1];
    [self willChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueUnionSetMutation
            usingObjects:changedObjects];
    [[self primitiveValueForKey: @"employees"] addObject: anEmployee];
    [self didChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueUnionSetMutation
            usingObjects:changedObjects];
    [changedObjects release];
}

// add the given Employee instances to the employees relationship
- (void)addEmployees:(NSSet *)employeesToAdd
{
    [self willChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueUnionSetMutation
            usingObjects:employeesToAdd];
    [[self primitiveValueForKey:@"employees"] unionSet:employeesToAdd];
    [self didChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueUnionSetMutation
            usingObjects:employeesToAdd];
}
```

```
// remove the given Employee instance from the employees relationship
- (void)removeEmployeesObject:(Employee *)anEmployee
{
   NSSet *changedObjects = [[NSSet alloc] initWithObjects:&anEmployee count:1];
    [self willChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueMinusSetMutation
            usingObjects:changedObjects];
    [[self primitiveValueForKey: @"employees"] removeObject: anEmployee];
    [self didChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueMinusSetMutation
            usingObjects:changedObjects];
    [changedObjects release];
}

// remove the given Employee instances from the employees relationship
- (void)removeEmployees:(NSSet *)employeesToRemove
{
    [self willChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueMinusSetMutation
            usingObjects:employeesToRemove];
    [[self primitiveValueForKey:@"employees"] minusSet:employeesToRemove];
    [self didChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueMinusSetMutation
            usingObjects:employeesToRemove];
}

// trim the employees relationship to only those Employee instances in
employeesToIntersect
- (void)intersectEmployees:(NSSet *)employeesToIntersect
{
    [self willChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueIntersectSetMutation
            usingObjects:employeesToIntersect];
   [[self primitiveValueForKey:@"employees"] intersectSet:employeesToIntersect];
    [self didChangeValueForKey:@"employees"
            withSetMutation:NSKeyValueIntersectSetMutation
            usingObjects:employeesToIntersect];
}
@end
```

Primitive Accessor Methods

Primitive accessor methods are similar to "normal" or public key-value coding compliant accessor methods, except that Core Data uses them as the most basic data methods to access data, consequently they do *not* issue key-value access or observing notifications. Put another way, they are to `primitiveValueForKey:` and `setPrimitiveValue:forKey:` what public accessor methods are to `valueForKey:` and `setValue:forKey:`. If for an attribute `attributeName` you implement `primitiveAttributeName` and `setPrimitiveAttributeName:`, then Core Data will use these methods in place of `primitiveValueForKey:@"attributeName"` and `setPrimitiveValueForKey:@"attributeName"`.

Primitive accessor methods are useful if you want custom methods to provide direct access to instance variables for persistent Core Data properties, although typically there should be little reason to implement them. The example below contrasts public and primitive accessor methods for an attribute, `int16`, of type `Integer 16`, stored in a custom instance variable, `nonCompliantKVCivar`.

```
// primitive get accessor
- (short)primitiveInt16 {
    return nonCompliantKVCivar;
}

// primitive set accessor
- (void)setPrimitiveInt16:(short)newInt16 {
    nonCompliantKVCivar = newInt16;
}

// public get accessor
- (short)int16 {
    short tmpValue;
    [self willAccessValueForKey: @"int16"];
    tmpValue = nonCompliantKVCivar;
    [self didAccessValueForKey: @"int16"];
    return tmpValue;
}

// public set accessor
- (void)setInt16:(short)int16 {
    [self willChangeValueForKey: @"int16"];
    nonCompliantKVCivar = int16;
    [self didChangeValueForKey:@"int16"];
}
```

Mac OS X v10.4: Non-Standard Persistent Attributes

On Mac OS X v10.5, Core Data provides transformable attributes to make it easy to use non-standard attribute types. For the benefit of developers who need to develop for earlier releases, this article describes how to support non-standard attribute types on Mac OS X v10.4.

Core Data supports a range of common types for values of persistent attributes, including string, date, and number. Sometimes, however, you want an attribute's value to be a type that is not supported directly. For example, in a graphics application you might want to define a Rectangle entity that has attributes `color` and `bounds` that are an instance of `NSColor` and an `NSRect` struct respectively. This article how you can use non-standard attribute types by using a transient property to represent the non-standard attribute backed by a supported persistent property.

Introduction

Persistent attributes must be of a type recognized by the Core Data framework so that they can be properly stored to and retrieved from a persistent store. Core Data provides support for a range of common types for persistent attribute values, including string, date, and number (see `NSAttributeDescription` for full details). Sometimes, however, you want to use types that are not supported directly, such as colors and C structures.

You can use non-standard types for persistent attributes by using a *transient* property to represent the non-standard attribute backed by a supported persistent property. You present to consumers of your entity an attribute of the type you want, and “behind the scenes” it’s converted into a type that Core Data can manage. You use a transient property to represent the non-standard attribute and write code to convert it to a standard persistent property.

The following sections illustrate implementations for object and scalar values. Both start, however, with a common task—you must specify a persistent attribute.

Basic Approach

To use non-supported types, in the managed object model you define two attributes. One is the attribute you actually want (its value is for example a color object or a rectangle struct). This attribute is transient. The other is a "shadow" representation of that attribute. This attribute is persistent. You specify the type of the transient attribute as undefined (`NSUndefinedAttributeType`). The type of the shadow attribute must be one of the "concrete" supported types. You then implement a custom managed object class with suitable accessor methods for the transient attribute that retrieve the value from and store the value to the persistent attribute. The basic approach for object and scalar values is the same—you must find a way to represent the unsupported data type as one of the supported data types—however there is a further constraint in the case of scalar values.

Scalar Value Constraints

A requirement of the accessor methods you write is that they must be key-value coding (and key-value observing) compliant. Key-value coding only supports a limited number of structures—`NSPoint`, `NSSize`, `NSRect`, and `NSRange`.

If you want to use a scalar type or structure that is not one of those supported directly by Core Data and not one of the structures supported by key-value coding, you must store it in your managed object as an object—typically an `NSValue` instance, although you can also define your own custom class. You will then treat it as an object value as described later in this article. It is up to users of the object to extract the required structure from the `NSValue` (or custom) object when retrieving the value, and to transform a structure into an `NSValue` (or custom) object when setting the value.

The Persistent Attribute

For any non-standard attribute type you want to use, you must choose a supported attribute type that you will use to store the value. Which supported type you choose depends on the non-standard type and what means there are of transforming it into a supported type. In many cases you can easily transform a non-supported object into an `NSData` object using an archiver. For example, you can archive a color object as shown in the following code sample. The same technique can be used if you represent the attribute as an instance of `NSValue` or of a custom class (note that your custom class would, of course, need to adopt the `NSCoding` protocol or provide some other means of being transformed into a supported data type).

```
NSData *colorAsData = [NSKeyedArchiver archivedDataWithRootObject:aColor];
```

You are free to use whatever means you wish to effect the transformation. For example, you could transform an `NSRect` structure into a string object (strings can of course be used in a persistent store).

```
NSRect aRect; // instance variable
NSString *rectAsString = NSStringFromRect(aRect);
```

You can transform the string back into a rectangle using `NSRectFromString`. You should bear in mind, however, that since the transformation process may happen frequently, you should ensure that it is as efficient as possible.

Typically you do not need to implement custom accessor methods for the persistent attribute. It is an implementation detail, the value should not be accessed other than by the entity itself. If you do modify this value directly, it is possible that the entity object will get into an inconsistent state.

An Object Attribute

If the non-supported attribute is an object, then in the managed object model you specify its type as undefined, and that it is transient. When you implement the entity’s custom class, there is no need to add an instance variable for the attribute—you can use the managed object's private internal store. A point to note about the implementations described below is that they cache the transient value. This makes accessing the value more efficient—it is also necessary for change management.

There are two strategies both for getting and for setting the transient value. You can retrieve the transient value either "lazily" (on demand—described in "The On-demand Get Accessor" (page 86)) or during awakeFromFetch (described in "The Pre-calculated Get" (page 87)). It may be preferable to retrieve it lazily if the value may be large (if for example it is a bitmap). For the persistent value, you can either update it every time the transient value is changed (described in "The Immediate-Update Set Accessor" (page 87)), or you can defer the update until the object is saved (described in "The Delayed-Update Set Accessor" (page 88)).

The On-demand Get Accessor

In the get accessor, you retrieve the attribute value from the managed object's private internal store. If the value is `nil`, then it is possible it has not yet been cached, so you retrieve the corresponding persistent value, then if that value is not `nil`, transform it into the appropriate type and cache it. The following example illustrates the on-demand get accessor for a color attribute.

```
- (NSColor *)color
{
    [self willAccessValueForKey:@"color"];
    NSColor *color = [self primitiveValueForKey:@"color"];
    [self didAccessValueForKey:@"color"];
    if (color == nil) {
        NSData *colorData = [self valueForKey:@"colorData"];
        if (colorData != nil) {
            color = [NSKeyedUnarchiver unarchiveObjectWithData:colorData];
            [self setPrimitiveValue:color forKey:@"color"];
        }
    }
    return color;
}
```

The Pre-calculated Get

Using this approach, you retrieve and cache the persistent value in `awakeFromFetch`.

```
- (void)awakeFromFetch
{
    [super awakeFromFetch];
    NSData *colorData = [self valueForKey:@"colorData"];
    if (colorData != nil) {
        NSColor *color;
        color = [NSKeyedUnarchiver unarchiveObjectWithData:colorData];
        [self setPrimitiveValue:color forKey:@"color"];
    }
}
```

In the get accessor you then simply return the cached value.

```
- (NSColor *)color
{
    [self willAccessValueForKey:@"color"];
    NSColor *color = [self primitiveValueForKey:@"color"];
    [self didAccessValueForKey:@"color"];
    return color;
}
```

This technique is useful if you are likely to access the attribute frequently—you avoid the conditional statement in the get accessor.

The Immediate-Update Set Accessor

In this set accessor, you set the value for both the transient and the persistent attributes at the same time. You transform the unsupported type into the supported type to set as the persistent value. You must ensure that you invoke the key-value observing change notification methods, so that objects observing the managed object—including the managed object context—are notified of the modification. The following example illustrates the set accessor for a color attribute.

```
- (void)setColor:(NSColor *)aColor
{
    [self willChangeValueForKey:@"color"];
    [self setPrimitiveValue:aColor forKey:@"color"];
    [self didChangeValueForKey:@"color"];
    [self setValue:[NSKeyedArchiver archivedDataWithRootObject:aColor]
                forKey:@"colorData"];
}
```

The main disadvantage with this approach is that the persistent value is recalculated each time the transient value is updated, which may be a performance issue.

The Delayed-Update Set Accessor

In this technique, in the set accessor you only set the value for the transient attribute. You implement a `willSave` method that updates the persistent value just before the object is saved.

```
- (void)setColor:(NSColor *)aColor
{
    [self willChangeValueForKey:@"color"];
    [self setPrimitiveValue:aColor forKey:@"color"];
    [self didChangeValueForKey:@"color"];
}

- (void)willSave
{
    NSColor *color = [self primitiveValueForKey:@"color"];
    if (color != nil) {
       [self setPrimitiveValue:[NSKeyedArchiver archivedDataWithRootObject:color]
                forKey:@"colorData"];
    }
    else {
        [self setPrimitiveValue:nil forKey:@"colorData"];
    }
    [super willSave];
}
```

If you adopt this approach, you must take care when specifying your optionality rules. If color is a required attribute, then (unless you take other steps) you must specify the color attribute as not optional, and the color data attribute as optional. If you do not, then the first save operation may generate a validation error.

When the object is first created, the value of `colorData` is `nil`. When you update the color attribute, the `colorData` attribute is unaffected (that is, it remains `nil`). When you save, `validateForUpdate:` is invoked before `willSave`. In the validation stage, the value of `colorData` is still `nil`, and therefore validation fails.

A Non-Object Attribute

If the non-supported attribute is one of the structures supported by key-value coding (`NSPoint`, `NSSize`, `NSRect`, or `NSRange`), then in the managed object model you again specify its type as undefined, and that it is transient. When you implement the entity's custom class, you typically add an instance variable for the attribute. For example, given an attribute called `bounds` that you want to represent using an `NSRect` structure, your class interface might be like that shown in the following example.

```
@interface MyManagedObject : NSManagedObject
{
    NSRect bounds;
}
- (NSRect)bounds;
- (void)setBounds:(NSRect)aRect;
@end
```

Alternatively, if you want to give the instance variable a name other than the name of the attribute, you should also implement primitive get and set accessors (see "Custom Primitive Accessor Methods" (page 48)), as shown in the following example.

```
@interface MyManagedObject : NSManagedObject
{
    NSRect myBounds;
}
- (NSRect)primitiveBounds;
- (void)setPrimitiveBounds:(NSRect)aRect;
- (NSRect)bounds;
- (void)setBounds:(NSRect)aRect;
@end
```

The primitive methods simply get and set the instance variable—they do not invoke key-value observing change or access notification methods—as shown in the following example.

```
- (NSRect)primitiveBounds
{
    return myBounds;
}
- (void)setPrimitiveBounds:(NSRect)aRect
    myBounds = aRect;
}
```

Whichever strategy you adopt, you then implement accessor methods mostly as described for the object value. For the get accessor you can adopt either the lazy or pre-calculated technique, and for the set accessor you can adopt either the immediate update or delayed update technique. The following sections illustrate only the former versions of each.

The Get Accessor

In the get accessor, you retrieve the attribute value from the managed object's private internal store. If the value has not yet been set, then it is possible it has not yet been cached, so you retrieve the corresponding persistent value, then if that value is not `nil`, transform it into the appropriate type and cache it. The following example illustrates the get accessor for a rectangle (this example makes a simplifying assumption that the bounds width cannot be `0`, so if the value is `0` then the bounds has not yet been unarchived).

```
- (NSRect)bounds
{
    [self willAccessValueForKey:@"bounds"];
    NSRect aRect = bounds;
    [self didAccessValueForKey:@"bounds"];
    if (aRect.size.width == 0) {
        NSString *boundsAsString = [self boundsAsString];
        if (boundsAsString != nil) {
            bounds = NSRectFromString(boundsAsString);
        }
    }
    return bounds;
}
```

The Set Accessor

In the set accessor, you must set the value for both the transient and the persistent attributes. You transform the unsupported type into the supported type to set as the persistent value. You must ensure that you invoke the key-value observing change notification methods, so that objects observing the managed object—including the managed object context—are notified of the modification. The following example illustrates the set accessor for a rectangle.

```
- (void)setBounds:(NSRect)aRect
{
    [self willChangeValueForKey:@"bounds"];
    bounds = aRect;
    [self didChangeValueForKey:@"bounds"];
    NSString *rectAsString = NSStringFromRect(aRect);
    [self setValue:rectAsString forKey:@"boundsAsString"]; }
```

Mac OS X v10.4: Versioning

On Mac OS X v10.5, Core Data provides an infrastructure to support versioning of managed object models and migration of data from one schema to another (see *Core Data Model Versioning and Data Migration Programming Guide*). This article describes how you can implement versioning yourself on Mac OS X v10.4.

As applications evolve over time, it is often the case that the schema changes. This article gives an overview of how you can migrate data from a store using one schema to another store using a different schema.

Important: This is a preliminary document. Although this document has been reviewed for technical accuracy, it is not final. Apple Computer is supplying this information to help you plan for the adoption of the technologies and programming interfaces described herein. Newer versions of this document may be provided in the future. For information about updates to this and other developer documentation, view the New & Updated sidebars in subsequent releases of the Reference Library.

Versioning Issues

Core Data stores are conceptually bound to the managed object model used to create them. If you change any part of a model that alters the actual schema, this renders it incompatible with (and so unable to open) the stores it previously created. For example, if you add a new entity or a new attribute to an existing entity (which does change the schema), you will not be able to open old stores; if you add a validation constraint or set a new default value for an attribute (which doesn't change the actual schema), you will be able to open old stores. If you change your schema, you therefore need to migrate the data in existing stores to new version.

General Technique

Migrating data from a store with one schema to a different store using a different schema is an extremely hard problem to solve in a general purpose fashion that is both flexible and exhibits good performance. Core Data does not provide a generic mechanism to assist in this, so if you change your application's model you must migrate your data yourself. The typical steps you should take are as follows:

1. When you save a store, put a version number in the metadata. If a store does not have a version number key, you typically treat it as version 1. (For an example of how to set the metadata in an application that uses `NSPersistentDocument`, see *NSPersistentDocument Core Data Tutorial*.)

2. Before opening a store, first retrieve the metadata and check the version number.

   You do not need a model (or to know the type of the store) to retrieve the metadata—you can use `NSPersistentStoreCoordinator`'s `metadataForPersistentStoreWithURL:error:` method without even creating a persistence stack.

3. If the store version number is the current version, simply open the store and continue as normal.

4. If the store version number is a previous version, then:

   a. Retrieve the appropriate previous model.

   b. Initialize an "importer" Core Data stack with the previous model and the store you want to open.

   c. Initialize the new Core Data stack with the current model and—if it's available—the store you want to save to.

   d. Fetch all the objects from the old store and copy them to the new store, mapping from from the old to the new schema as necessary.

A complete example is provided in the *CoreRecipes* sample code.

Migrating Data

The majority of work is involved in mapping from from the old to the new schema (step 4(d) above). Where appropriate, you need to map from instances of an old entity to a new entity and from old attributes to new (setting default values where necessary), and you need to ensure that relationships are properly maintained.

In the simplest case—if your data set is small—you can fetch everything into memory using the original model and convert all your objects in a single pass. This approach reduces the likelihood of errors in conversion.

- You iterate through your (old) model taking the entities one by one, fetching all the objects for that entity using a managed object context associated with the "importer" persistence stack.
- For each managed object, you create a corresponding new object using the new model and the new persistence stack. You iterate through the object's attributes and relationships (as defined by its entity description) making copies. "Copying" a relationship requires creating a new managed object for the destination and filling in its properties.
- You handle the new IDs in the new store with a dictionary, mapping the object IDs from the old store into the new object IDs.

If you need to avoid having two versions of the same class in the same runtime or if you do not want to rename your model classes with each conflicting update to the model, you can load a previous version of your model and, before using it, edit all entities such that they no longer use custom classes (so that all entities are instantiated using `NSManagedObject`). Then you can use this model to load the data from the old store and populate the new store using your new model. You can also temporarily disable validation if necessary.

If you have a very large data set that it is impractical to bring into memory all at once, you can adopt other strategies. You can iterate through your (old) model and fetch the entities one by one. You can start by converting all entities that are relatively standalone (for example, those that are more or less select lists like categories or priorities or other items that typically show up in pop-up menus in the user interface), creating an old-global ID to new-global ID mapping as each is converted. You then traverse the collection of "root" entities one by one, making new instances in the new model, converting as needed. You can limit memory footprint first by restricting the number of instances you use at any point in through the use of selective fetch requests, then by trimming the object graph as necessary (see "Memory Management Using Core Data" (page 69)).

Development Strategies

Implementing a proper versioning strategy is a non-trivial task. Nevertheless, an important consideration is that typically the model should not change frequently outside of the development environment. If you are mutating models at runtime (and you are not developing an application specifically for creating models), then you should consider whether your model sufficiently describes your application's data.

During the development process it is still likely that you will want to create test data sets, and recreating these for every iteration of the schema can be time-consuming. Nevertheless, time spent early in the project on supporting data migration is unlikely to be wasted in the long term if you need to support versioning in future releases.

If you are using test-driven development, you should write code in your tests that generates clean test data on the fly, rather than hand-craft data files containing test data or keep around the generated test data files. If you do this, you have no data migration issues to worry about—you just need to refactor the code that generates test data when you refactor your model. Refactoring tests and test data as the code under test changes is normal in test-driven development, and from this perspective you should view your data model as "code."

Core Data FAQ

This document provides answers to questions frequently asked about Core Data.

Where does a Managed Object Context Come From?

Where a managed object context comes from is entirely application-dependent. In a Cocoa document-based application using `NSPersistentDocument`, the persistent document typically creates the context, and gives you access to it through the `managedObjectContext` method.

In a single-window application, if you create your project using the standard project assistant, the application delegate (the instance of the AppDelegate class) again creates the context, and gives you access to it through the `managedObjectContext` method. In this case, however, the code to create the context (and the rest of the Core Data stack) is explicit. It is written for you automatically as part of the template.

Note that you should not use instances of subclasses of `NSController` directly to execute fetches (for example, you should not create an instance of `NSArrayController` specifically to execute a fetch). Controllers are for managing the interaction between your model objects and your human interface. At the model object level, you should just use a managed object context to perform the fetches directly.

I have a to-many relationship from Entity A to Entity B. How do I fetch the instances of Entity B related to a given instance of Entity A?

You don't. More specifically, there is no need to explicitly *fetch* the destination instances, you simply invoke the appropriate key-value coding or accessor method on the instance of Entity A. If the relationship is called "widgets", then if you have implemented a custom class with a similarly named accessor method, you simply write:

```
NSSet *asWidgets = [instanceA widgets];
```

Otherwise you use key-value coding:

```
NSMutableSet *asWidgets = [instanceA mutableSetValueForKey:@"widgets"];
```

How do I fetch objects in the same order I created them?

Objects in a persistent store are unordered. Typically you should impose order at the controller or view layer, based on an attribute such as creation date. If there is order inherent in your data, you need to explicitly model that.

How do I copy a managed object from one context to another?

First, note that in a strict sense you are not copying the object. You are conceptually creating an additional reference to the same underlying data in the persistent store.

To copy a managed object from one context to another, you can use the object's object ID, as illustrated in the following example.

```
NSManagedObjectID *objectID = [managedObject objectID];
NSManagedObject *copy = [context2 objectWithID:objectID];
```

I have a key whose value is dependent on values of attributes in a related entity—how do I ensure it is kept up to date as the attribute values are changes and as the relationship is manipulated?

There are many situations in which the value of one property depends on that of one or more other attributes in another entity. If the value of one attribute changes, then the value of the derived property should also be flagged for change. How you ensure that key-value observing notifications are posted for these dependent properties depends on which version of Mac OS X you're using and the cardinality of the relationship.

Mac OS X v10.5 and later for a to-one relationship

If you are targeting Mac OS X v10.5 and later, and there is a to-one relationship to the related entity, then to trigger notifications automatically you should either override `keyPathsForValuesAffectingValueForKey:` or implement a suitable method that follows the pattern it defines for registering dependent keys.

For example, you could override `keyPathsForValuesAffectingValueForKey:` as shown in the following example:

```
+ (NSSet *)keyPathsForValuesAffectingValueForKey:(NSString *)key
{
    NSSet *keyPaths = [super keyPathsForValuesAffectingValueForKey:key];

    if ([key isEqualToString:@"fullNameAndDepartment"])
    {
        NSSet *affectingKeys = [NSSet setWithObjects:@"lastName", @"firstName",
                                                    @"department.deptName",
nil];
        keyPaths = [keyPaths setByAddingObjectsFromSet:affectingKeys];
    }
    return keyPaths;
}
```

Or, to achieve the same result, you could just implement `keyPathsForValuesAffectingFullNameAndDepartment` as illustrated in the following example:

```
+ (NSSet *)keyPathsForValuesAffectingFullNameAndDepartment
{
    return [NSSet setWithObjects:@"lastName", @"firstName",
                                 @"department.deptName", nil];
}
```

Mac OS X v10.4 and to-many relationships on Mac OS X v10.5

If you are targeting Mac OS X v10.4, `setKeys:triggerChangeNotificationsForDependentKey:` does not allow key-paths, so you cannot follow the pattern described above.

If you are targeting Mac OS X v10.5, `keyPathsForValuesAffectingValueForKey:` does not allow key-paths that include a to-many relationship. For example, suppose you have an Department entity with a to-many relationship (`employees`) to a Employee, and Employee has a `salary` attribute. You might want the Department entity have a `totalSalary` attribute that is dependent upon the salaries of all the Employees in the relationship. You can *not* do this with, for example, `keyPathsForValuesAffectingTotalSalary` and returning `employees.salary` as a key.

There are two possible solutions in both situations:

1. You can use key-value observing to register the parent (in this example, Department) as an observer of the relevant attribute of all the children (Employees in this example). You must add and remove the parent as an observer as child objects are added to and removed from the relationship (see Registering for Key-Value Observing). In the `observeValueForKeyPath:ofObject:change:context:` method you update the dependent value in response to changes, as illustrated in the following code fragment:

```
- (void)observeValueForKeyPath:(NSString *)keyPath ofObject:(id)object
change:(NSDictionary *)change context:(void *)context
{
    if (context == totalSalaryContext) {
        [self updateTotalSalary];
    }
    else
    // deal with other observations and/or invoke super...
}
- (void)updateTotalSalary
{
    [self setTotalSalary:[self valueForKeyPath:@"employees.@sum.salary"]];
}
- (void)setTotalSalary:(NSNumber *)newTotalSalary
{
    if (totalSalary != newTotalSalary) {
        [self willChangeValueForKey:@"totalSalary"];
        [totalSalary release];
        totalSalary = [newTotalSalary retain];
        [self didChangeValueForKey:@"totalSalary"];
    }
}
```

```
- (NSNumber *)totalSalary
{
    return totalSalary;
}
```

2. You can register the parent with the application's notification center as an observer of its managed object context. The parent should respond to relevant change notifications posted by the children in a manner similar to that for key-value observing.

How do I get undo/redo for free in my non-document-architecture-based app?

In a Core Data document-based application, the standard `NSDocument` undo manager is replaced by the document's managed object context's undo manager. In a non-document-based application, your window's delegate can supply the managed object context's undo manager using the `windowWillReturnUndoManager:` delegate method. If your window delegate has an accessor method for the managed object context (as is the case if you use the Core Data Application template), your implementation of `windowWillReturnUndoManager:` might be as follows.

```
- (NSUndoManager *) windowWillReturnUndoManager:(NSWindow *)sender {
    return [[self managedObjectContext] undoManager];
}
```

How do I create a user interface from an entity?

There are two ways to create a user interface from an entity: on Mac OS X v10.4 and later you use the Xcode modeling tool in conjunction with Interface Builder; on Mac OS X v10.5 and later you can also use just Interface Builder.

On Mac OS X v10.4 and later, in the Data Modeling Tool, you can Option-click an entity in the Data Modeling tool in Xcode and drag it to a window or box in Interface Builder. See *NSPersistentDocument Core Data Tutorial* for an example. You must make sure that Xcode is the foreground application when you do this—Option-clicking on Xcode while it is not foreground will make it foreground and hide all other applications, including Interface Builder.

On Mac OS X v10.5 and later, in Interface Builder you can drag a Core Data Entity item from the Library onto a window or box. Interface Builder then presents a panel that allows you to select the entity you want from the currently-open Xcode projects.

Note that you can also create and configure an `NSController` instance in Interface Builder. As in the case of creating a user interface, you Option-click an entity in the Data Modeling tool in Xcode (or select the Core Data Entity item from the Library), but you drag it to a the Interface Builder file window. For editing one object, an `NSObjectController` instance is created; for editing many objects, an `NSArrayController` instance is created.

It is important to realize that neither Xcode nor Interface Builder does anything "special" when you create an interface this way. You could create and configure the interface yourself if you wanted—it would just take longer.

In Xcode's predicate builder, why don't I see any properties for a fetched property predicate?

If you want to create a predicate for a fetched property in the predicate builder in Xcode, but don't see any properties, you have probably not set the destination entity for the fetched property.

When I remove objects from a detail table view managed by an array controller, why are they not removed from the object graph?

If an array controller manages the collection of objects at the destination of a relationship, then by default the remove method simply removes the current selection from the relationship. If you want removed objects to be deleted from the object graph, then you need to enable the "Deletes Objects On Remove" option for the `contentSet` binding.

(This is particularly relevant if you create a user interface by dragging entities from the Xcode data modeling tool. See *NSPersistentDocument Core Data Tutorial* for an example.)

How do I get the GUI to validate the data entered by the user?

Core Data validates all managed objects when a managed object context is sent a `save:` message. In a Core Data document-based application, this is when the user saves the document. You can have the GUI validate it as the data is being entered by selecting the "Validates Immediately" option for a value binding in the Interface Builder bindings inspector. If you establish the binding programmatically, you supply in the binding options dictionary a value of `YES` (as an `NSNumber` object) for the key `NSValidatesImmediatelyBindingOption` (see Binding Options).

For details of how to write custom validation methods, see the subclassing notes for `NSManagedObject`.

How do I initialize a store with default data?

There are two issues here: creating the data, and ensuring the data is imported only once.

There are several ways to create the data.

- You can create the managed objects directly in code (as trivially illustrated in *NSPersistentDocument Core Data Tutorial*).
- You can create a property list—or some other file-based representation—of the data, and store it as an application resource. When you want to use it, you must open the file and parse the representation to create managed objects.
- You can create a separate persistent store that contains the default data. When you want to use it, you must copy the objects from the defaults store to the newly-created store.

There are also several ways to ensure that the defaults are imported only once. If you are creating a document-based application using , you can follow the guideline described in *NSPersistentDocument Core Data Tutorial* (that is, you initialize the defaults in `initWithType:error:`).

If you are using a non-document-based application and started with the standard application template then after these lines of code:

```
if ( ![fileManager fileExistsAtPath:applicationSupportFolder isDirectory:NULL]
 )
{
   [fileManager createDirectoryAtPath:applicationSupportFolder attributes:nil];
}
url = [NSURL fileURLWithPath: [applicationSupportFolder
stringByAppendingPathComponent: @"Delete.xml"]];
```

you can add a check to determine whether the file at the url exists. If it doesn't, you need to import the data.

If there is some reason that there might be a possibility that the store (hence file) gets created but the data is not imported, then you might consider adding a metadata flag to the store. You can check the metadata (using `metadataForPersistentStoreWithURL:error:`) more efficiently than executing a fetch (and it does not require you to hard code any default data values).

How efficient is Core Data?

Throughout the development of Core Data, the engineering team compared the runtime performance of a generic Core Data application with that of a similar application developed without using Core Data. In general, the Core Data implementation performed better. There may nevertheless be opportunities for further optimization, and the team continues to pursue performance aggressively. For a discussion of how you can ensure you use Core Data as efficiently as possible, see "Core Data Performance" (page 125).

Core Data looks similar to EOF. What are the differences?

Core Data and EOF (the Enterprise Objects Framework that ships with WebObjects) share a common heritage, but have different goals. EOF is a Java-based framework that connects as a client to a database server. Core Data is an Objective-C-based framework designed to support desktop application development. Core Data supports a number of features not supported by EOF, and vice-versa.

Features Supported Only by EOF

EOF allows you to use custom SQL, shared editing contexts, and nested editing contexts. Core Data does not provide the equivalent of an `EOModelGroup`—the `NSManagedObjectModel` class provides methods for merging models from existing models, and for retrieving merged models from bundles.

EOF supports pre-fetching and batch faulting of relationships, on Mac OS X v10.4 Core Data does not. On Mac OS X v10.5, when you create a fetch request, you can use `setRelationshipKeyPathsForPrefetching:` to specify key paths for relationships that should be fetched with the target entity.

Features Supported Only by Core Data

Core Data supports fetched properties; multiple configurations within a managed object model; local stores; store aggregation (the data for a given entity may be spread across multiple stores); customization and localization of property names and validation warnings; and the use of predicates for property validation.

Class Mapping

There are parallels between many of the classes in Core Data and EOF.

- `NSManagedObject` corresponds to `EOGenericRecord`.
- `NSManagedObjectContext` corresponds to `EOEditingContext`.
- `NSManagedObjectModel` corresponds to `EOModel`.
- `NSPersistentStoreCoordinator` corresponds to `EOObjectStoreCoordinator`.
- `NSEntityDescription`, `NSPropertyDescription`, `NSRelationshipDescription`, and `NSAttributeDescription` correspond to `EOEntity`, `EOProperty`, `EORelationship`, and `EOAttribute` respectively.

Change Management

There is an important behavioral difference between EOF and Core Data with respect to change propagation. In Core Data, peer managed object contexts are *not* "kept in sync" in the same way as editing contexts in EOF. Given two managed object contexts connected to the same persistent store coordinator, and with the "same" managed object in both contexts, if you modify one of the managed objects then save, the other is *not* re-faulted (changes are not propagated from one context to another). If you modify then save the other managed object, then (at least if you use the default merge policy) you will get an optimistic locking failure.

Multi-Threading

The policy for locking a Core Data managed object context in a multithreaded environment is not the same policy as for an editing context in EOF.

Glossary

attribute A simple property of an entity that is typically not another entity (for example, an Employee object's first name).

core data stack The ordered collection of objects from a managed object context, through a persistent object store coordinator, to a persistent store or collection of persistent stores. A stack is effectively defined by a persistent store coordinator (see persistent store coordinator)—there is one and only one per stack. Creating a new persistent store coordinator implies creating a new stack.

entity An abstract description of a data-bearing object equivalent to "model" in the Model-View-Controller design pattern. The components of an entity are called attributes, and the references to other models are called relationships. Together, attributes and relationships are known as properties. Entities are to managed objects what Class is to instances of a class, or—using a database analogy—entities are to managed objects what tables are to rows.

fault A placeholder object that represents an object that has not yet been loaded from an external data store. A fault may represent a single object in the case of a to-one relationship, or a collection in the case of a to-many relationship.

faulting Transparent loading of objects on demand from an external data store.

fetch To retrieve data from a persistent store—akin to a database `SELECT` operation. The result of a fetch is the creation of a collection of managed objects that are registered with the managed object context used to issue the request.

fetch request An instance of `NSFetchRequest` that specifies an entity and optionally a set of constraints, represented by an `NSPredicate` object , and an array of sort descriptors (instances of `NSSortDescriptor`). These are akin to the table name, `WHERE` clause, and `ORDER BY` clauses of a database `SELECT` statement respectively. A fetch request is executed by being sent to a managed object context.

fetched property A property of an entity that is defined by a fetch request. Fetched properties allow a weak, unidirectional relationship. An example is a dynamic iTunes playlist, if expressed as a property of a containing object. Songs don't "belong" to a particular playlist, especially when they're on a remote server. The playlist may remain even after the songs have been deleted or the remote server has become inaccessible. (Consider also a Spotlight live query.)

inserting The process of adding a managed object to a managed object context so that the object becomes part of the object graph and will be committed to a persistent store.Typically "insertion" refers only to the initial creation of a managed object. Thereafter, managed objects retrieved from a persistent store (see persistent store) are considered as being fetched (see fetch). There is a special method (`awakeFromInsert`) that is invoked only once during the lifetime of a managed object when it is first inserted into a managed object context (see managed object context). A managed object must be inserted into a managed object context before it is considered part of the object graph. A managed object context is responsible for observing changes to managed objects (for the purposes of undo support and maintaining the integrity of the object graph), and can only do so if new objects are inserted.

key-value coding A mechanism for accessing an object's properties indirectly.

managed object An object that is an instance of `NSManagedObject` or a subclass of `NSManagedObject`. After creation it should be registered with a managed object context.

managed object context An object that is an instance of `NSManagedObjectContext`. An `NSManagedObjectContext` object represents a single "object space" or scratch pad in an application. Its primary responsibility is to manage a collection of managed objects. These objects form a group of related model objects that represent an internally consistent view of one or more persistent stores. The context is a powerful object with a central role in the life-cycle of managed objects, with responsibilities from life-cycle management (including faulting) to validation, inverse relationship handling, and undo/redo.

managed object model An object that is an instance of `NSManagedObjectModel`. An `NSManagedObjectModel` object describes a schema, a collection of entities (data models) that you use in your application.

object graph A collection of interrelated objects. In Core Data, an object graph is associated with a managed object context. Moreover, when using Core Data, the object graph may be incomplete, with the edges represented by faults (see fault).

optimistic locking You can consider optimistic locking to be akin to specifying a `WHERE` clause in a database `UPDATE` statement... `WHERE` clause determined by constituents of snapshot(s) corresponding to object(s) being updated.

persistent store A repository in which objects may be stored. A repository is typically a file, which may be XML, binary, or a SQL database. The store format is transparent to the application. Core Data also provides an in-memory store that lasts no longer than the lifetime of a process.

persistent store coordinator An object that is an instance of `NSPersistentStoreCoordinator`. A coordinator associates persistent stores and a configuration of a managed object model and presents a facade to managed object contexts such that a group of persistent stores appears as a single aggregate store.

primitive accessor An accessor method that gets or sets a variable directly, without invoking access or change notification methods (such as `willAccessValueForKey:` and `didChangeValueForKey:`). Primitive accessors are typically used to initialize an object's variables when it is fetched from a persistent store. In this way, any side effects from any custom accessor methods are avoided.

property A component of an entity that is either an attribute or a relationship. Properties are to entities what instance variables are to classes.

refault Turn an object into a fault. The next time it is accessed, its variables may be re-fetched from the relevant persistent store, depending on the caching mechanism.

relationship In one entity, a reference to one instance of another entity (a to-one relationship) or to a collection of instances of another entity (a to-many relationship). For example, an Employee object's manager is an example of a to-one relationship.

snapshot A record of the state of an entry fetched from a persistent store at the time is it fetched. The information in a snapshot is used to support the framework's optimistic locking mechanism. In some persistent stores it is also used when changes are committed back to a data source to update only the attributes that were changed since the last fetch.

transient property A property of an entity that is not saved to a persistent data store, but which is recorded for undo and redo operations in memory.

uniquing Ensuring that an object graph does not have multiple objects representing the same entry in a persistent store. Core Data accomplishes uniquing by using the information it maintains in the mapping of each managed object to its corresponding entry in a persistent store.

validation The process of ensuring that a property value is valid—for example, that it is of the correct type, and its value lies within a prescribed range. The Core Data framework provides an infrastructure to allow values to be tested for validity before they can be applied to an object. There are three aspects to validation: model-based validation, attribute validation using custom validation methods, inter-attribute validation (consistency checking) for update, insert, and delete.

Document Revision History

This table describes the changes to *Core Data Programming Guide*.

Date	Notes
2009-03-04	Minor revision to accommodate new Getting Started document.
2008-11-19	Enhanced discussion of managing undo operations.
2008-02-08	Enhanced the discussions of legacy data importing and memory management.
	Added a discussion of many-to-many relationships in "Relationships and Fetched Properties" (page 73).
2007-12-11	Corrected typographical errors.
2007-10-31	Updated for Mac OS X v10.5. Made several minor enhancements.
2007-08-30	Made major changes to content and added information on persistent store features.
2007-08-23	Enhanced memory management article; noted that NSManagedObject subclasses do not use all accessor methods with mutableSetValueForKey:.
2007-07-16	Enhanced discussion of threading options; added note about constraints of use of relationship accessor methods.
2007-03-15	Noted the file systems supported by the SQLite store.
2007-02-08	Clarified the behavior of entity inheritance in fetching; split "Managed Object Models" into two articles.
2007-01-08	Updated FAQ, "Memory Management Using Core Data", and "Core Data and Cocoa Bindings".
2006-12-05	Added a discussion of faulting and KVO notifications to "Faulting and Uniquing."
2006-11-09	Enhanced discussion of accessing and modifying properties and of creating and initializing managed objects.
2006-10-03	Enhanced the discussion of copying managed objects.
2006-09-05	Enhanced troubleshooting and multi-threading articles; incorporated validation article.
2006-07-24	Made minor revisions to "Persistent Stores."
2006-06-28	Corrected minor typographical errors.

Date	Notes
2006-05-23	Added links to sample code and detail to the section on copy and paste.
	Added "Before You Start" article.
2006-04-04	Added section on fetch request templates to Managed Object Models. Enhanced description of managed object lifecycle.
2006-03-08	Enhanced "Change Management" and "Faulting and Uniquing" articles; clarified meaning of SQLite debugging flag.
2006-02-07	Added notes about SQL logging to "Fetching Managed Objects" and about test-driven development to "Versioning."
2006-01-10	Added a new, preliminary article on threading. Added a new article, "Managed Objects," taken mainly from the NSManagedObject API reference.
2005-12-06	Augmented the articles "Faulting and Uniquing" and "Persistent Stores."
2005-11-09	Added article on importing legacy files.
2005-10-04	Corrected various minor typographical errors.
2005-09-08	Added new articles to describe managed object models and versioning.
2005-08-11	Added articles on memory management and fetching managed objects. Streamlined the introduction to "Managed Object Accessor Methods."
2005-07-07	Corrected various minor typographic errors, made several clarifications. Added article on Troubleshooting.
2005-06-04	Added article on managed object accessor methods. Corrected method listings in "Non-Standard Attributes" article; other minor enhancements.
2005-04-29	Update to include discussion of relationship manipulation, and enhancement to discussion of memory management.
	Updated for public release of Mac OS X v10.4. Changed title from "Core Data." First public version.