Quartz Programming Guide for QuickDraw Developers

Carbon > Graphics & Imaging

2006-09-05

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Simultaneously published in the United States and Canada.

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Introduction to Quartz Programming Guide for QuickDraw Developers

Note: This document was previously titled *Transitioning to Quartz 2D*.

Quartz is an advanced, two-dimensional drawing engine accessible from all Mac OS X application environments outside of the kernel. It provides low-level, lightweight 2D rendering with unmatched output fidelity regardless of display or printing device. Quartz is the Mac OS X replacement for QuickDraw. Quartz not only replaces QuickDraw, but because its imaging model is substantially different than that of QuickDraw, Quartz can offer more advanced drawing capabilities. The differences between imaging models mean that QuickDraw functions can't simply be replaced by Quartz functions. Transitioning a QuickDraw application to one that uses only Quartz requires a thoughtful approach.

The purpose of this document is to help developers replace their QuickDraw code with Quartz code that achieves equivalent (or more) functionality. It provides strategies and guidance along with routines that use Quartz to achieve functionality similar to QuickDraw routines.

Who Should Read This Document?

Any developer who uses QuickDraw functions in their Mac OS X application will benefit from reading this document. This document assumes that the reader has programming experience with the QuickDraw API. It also assumes basic knowledge of the Quartz imaging model. Before starting this document, you may want to read the overview of Quartz in *Quartz 2D Programming Guide*. As you read this document, you may find it helpful to keep the programming guide as well as *Quartz 2D Reference Collection* handy.

Note: The QuickDraw API is deprecated in Mac OS X v10.4. That means that Apple no longer plans to develop QuickDraw software or documentation. There is no better time than now to completely remove QuickDraw code from your application.

Organization of This Document

This document is organized into the following chapters:

- "Strategies" (page 11) lists the tasks you should complete before rewriting your code and provides strategies for analyzing and revising your code. This chapter is important to read first, because it points to relevant sections in other chapters, or to other relevant resources.
- "Basic Drawing" (page 17) covers the fundamentals of drawing in Quartz with an emphasis on what's different from QuickDraw.
- "Using Color" (page 41) discusses QuickDraw and Quartz colors and shows how to create color spaces.

- "Converting PICT Data" (page 45) shows how to convert PICT data so that it can be used in Quartz and shows how to move data to and from the pasteboard in Mac OS X.
- "Working With Bitmap Image Data" (page 59) shows how, using Quartz, to accomplish a variety of image manipulation tasks that are equivalent to the sorts of tasks you could accomplish using QuickDraw.
- "Masking" (page 65), discusses how to replace mask regions in QuickDraw using masking techniques in Quartz.
- "Updating Regions" (page 69) provides strategies and code examples for how to update windows and use overlay windows in Quartz in place of updating regions in QuickDraw.
- "Hit Testing" (page 75) describes Quartz functions that are suited for hit testing and provides routines you can use for hit testing in Quartz.
- "Offscreen Drawing" (page 81) discusses how to use bitmap graphics contexts and CGLayer objects for offscreen drawing.
- "Performance" (page 85) outlines coding practices that ensure your code performs well.
- "Glossary" (page 89) lists common QuickDraw terms and defines them in terms of Quartz terminology.

See Also

You might find these items of value as you move QuickDraw code to Quartz:

- JustDraw and MouseTracking code samples. These are available from the Graphics & Imaging Quartz Reference Library on the ADC website.
- *Color Management Overview*. This document provides a brief introduction to the principles of color perception, color spaces, and color management systems. To use color effectively in Quartz, you'll want to be familiar with the concepts related to color and color spaces.
- Mailing lists. Join the quartz-dev mailing list to discuss problems using Quartz in Mac OS X. If you're having a problem, chances are other developers have faced the same challenge and may be able to help you. Others like you are moving to Quartz from QuickDraw!
- Technical notes and Technical Q&As. Keep up to date on the latest technical information by visiting the Graphics & Imaging Quartz Reference Library. Technical notes and Q&A documents typically provide solutions for thorny problems that don't crop up too often. If you can't find a solution in a programming guide, look at these.

Strategies

The QuickDraw to Quartz imaging models are different enough that rewriting your application so that is uses only Quartz is not trivial. Your hard work will be worthwhile. Making the transition opens a world of possibilities for tasks that you can perform with Quartz but could not dream of accomplishing with QuickDraw. Just as QuickDraw was revolutionary in its time, Quartz is today. In Mac OS X v10.4, Quartz introduces a wealth of new features that makes the switchover even more compelling. Quartz has many more convenience functions, improved performance, and a lot of new documentation. What's more, Quartz is fully integrated with other Mac OS X v10.4 technologies, such as Core Image, which makes image processing a snap. There is no better time than now to roll up your sleeves and get to work removing that old QuickDraw code!

This chapter provides overall strategies for revising your code to use only Quartz, while the remaining chapters in the book show how to accomplish specific tasks using Quartz. Where appropriate, the strategies in this chapter cross-reference specific tasks so you can get ideas (and perhaps some code) for how to modify your own application.

Before You Start

Make sure you are using a development environment that supports Quartz, such as Xcode.

Gather up the latest Quartz documentation so that it is readily accessible to you.

- *Quartz 2D Programming Guide*. If you haven't read this document yet, at least read the overview and the table of contents so that you know what's covered in the book. Take a quick scan through the book.
- *Quartz 2D Reference Collection*. You'll need to look up function definitions as you start rewriting your code.

Locate the Carbon Sketch application and familiarize yourself with the code and what the application does. By looking at the code, you can get ideas on how to rearchitect your application to use only Quartz for drawing. You can find Carbon Sketch on the ADC Reference Library site:

http://developer.apple.com/samplecode/GraphicsImaging/idxQuartz-title.html#doclist

The application performs many tasks needed in a drawing application. For example, it:

- Draws all artwork using Quartz
- Uses an overlay window to handle selection, dragging, and resizing objects
- Performs hit testing using a 1-pixel bitmap context
- Copy and pastes PDF data using the PasteBoard API
- Uses Quartz Generic color spaces

Analyze Your Code

Analyze your QuickDraw code so that you can understand what needs to change. Then develop a plan before you start reworking your code. Keep in mind that many things have changed in Mac OS X, and especially in Mac OS X v10.4. Technologies other than QuickDraw are deprecated in Mac OS X v10.4, including QuickDraw Text, Display Manager, and Draw Sprockets.

If, after analyzing your code, you plan to stick with the C APIs in the Carbon framework, you may want to use HIView along with Quartz. The HIToolbox offers many technologies that are complementary to Quartz (such as HIShape) and that will ensure that your application is updated for the 21st century.

If you decide to completely rewrite your application in all respects, you might want to think about moving to Cocoa. You can use the Quartz API in any framework outside of the kernel. When you use Cocoa, you can call Quartz directly and you can also use Cocoa drawing methods, which are built on top of Quartz.

As you analyze your code, take a careful look at how you use QuickDraw. Sometimes you'll find that Quartz provides functional equivalents for your QuickDraw code, but more often than not you'll need to think differently. Your application will benefit most if you can think beyond QuickDraw. That is, don't just look for ways to accomplish the same task in Quartz. Take some time to think about how your application currently works and how you might be able to leverage the new capabilities that Mac OS X provides to improve the user experience of your application, not just maintain parity with your QuickDraw version.

General Strategies

The following strategies are useful for revising QuickDraw applications to use Quartz:

1. Think differently, especially for those items that don't have equivalent functionality in Quartz—such as arithmetic transfer modes, `SeedCFill`, `SearchProcs`—but that you still need to find a substitute for.

2. Focus on functionality, not functions. The approach of translating QuickDraw idioms into Quartz won't work in most cases, especially for calls to `CopyBits` and the regions functions.

3. Analyze your use of regions to see what functionality each use provides. Then revise the code accordingly. You may have used regions for a variety of purposes; you'll find alternative strategies throughout this guide. See "Regions Replacement Strategies" (page 13).

4. Analyze your `CopyBits` calls to see what functionality each call provides. Then revise the code accordingly. You probably used `CopyBits` and related functions to achieve a number of tasks in QuickDraw; you'll find alternative strategies throughout this guide. See "CopyBits Replacement Strategies" (page 14).

5. Account for differences between the QuickDraw and Quartz coordinate systems. If you use HIView along with Quartz, make sure you are familiar with how HIView handles coordinates. See "Coordinate Space" (page 17).

6. Use alpha. It's fully supported in Quartz. See The Alpha Value in *Quartz 2D Programming Guide*.

7. Convert PICT data to PDF and provide conversion support in your application to handle legacy PICT files that your users may need to open. See "Converting PICT Data" (page 45).

8. Support PDF data for Copy and Paste actions. Only PDF content fully captures Quartz drawing, and you'll want to ensure fidelity of content. See "Converting PICT Data" (page 45).

9. Save and restore graphics states appropriately. See "Graphics State and Global Effects" (page 20).
10. Revise your hit testing code. See "Hit Testing" (page 75).
11. Think device independence and resolution independence. See "Drawing Destinations" (page 19).
12. Identify the shortcomings of your QuickDraw application to see where you can use new features of Quartz to improve your application.
13. Remove code that compensates for QuickDraw shortcomings. For example, XOR drawing isn't needed by most applications that use Quartz. The `GrafProcs` bottleneck tricks simply don't apply in Quartz.
14. Optimize your code to ensure that your application performs at its best. See "Performance" (page 85).

Regions Replacement Strategies

Regions served many purposes in QuickDraw. You'll want to analyze your code to see what purpose each use of regions serves.

If you use QuickDraw regions for:

- Drawing shapes, then instead use paths to construct arbitrary shapes and use Quartz convenience functions to draw rectangles, circles, ovals, ellipses, and lines. See "Alternatives to QuickDraw Drawing Functions" (page 36) and "Constructing and Drawing Shapes" (page 23). In Quartz, you can draw directly to a destination, or you can use the `CGPathRef` data type to build up a complex shape that you draw later and reuse anytime you'd like.
- Clipping regions, consider one of the Quartz context clipping functions, such as `CGContextClip` or `CGContextClipToMask`. See"Clipping" (page 34).
- Hit test, then use paths or a 1x1 bitmap graphics context. See "Hit Testing" (page 75).
- Masking, then there are a number of approaches you can take, depending on what you want to accomplish. Consider the Quartz function `CGContextClipToMask`, take a look at what you can accomplish with blend modes, and for images, consider `CGImageMaskCreate`, `CGImageCreateWithMask`, and `CGImageCreateWithMaskingColors`. See "Masking" (page 65) and "Color Blend Modes" (page 21).

If you want to:

- Create a `RgnHandle`, consider using an HIShape object, which is an abstract shape object that replaces the old QuickDraw region handle. HIShape objects are the preferred way to describe regions in HIView views that use Quartz. See *HIShape Reference*. If you are not using HIView, take a look at CGPath objects (`CGPathRef` data type), which you can use to draw reusable shapes. See "Constructing and Drawing Shapes" (page 23).
- Update a region shape, see "Updating Regions" (page 69).

CopyBits Replacement Strategies

Many years of development and optimization made the QuickDraw function `CopyBits` an exceptionally fast, general-purpose blitter. QuickDraw is based on bitmap graphics, and `CopyBits` makes perfect sense in that environment. The Quartz imaging model does not provide for pixel drawing operations or bit copying functionality. The fact that Quartz is not based on bits gives rise to its many cool features, including its ability to maintain device and resolution independence. Quartz does have the capability for you to draw bits, should you need to do so, but most of the time you'll want to adopt strategies for replacing `CopyBits`, `CopyMask`, and `CopyDeepMask`—strategies that leverage Quartz rather than seek parity with QuickDraw.

The functions `CopyBits`, `CopyMask`, and `CopyDeepMask` were used to achieve so many results in QuickDraw that you'll want to read all the replacement strategies before you decide which course of action to take. If you use the QuickDraw functions `CopyBits`, `CopyMask`, or `CopyDeepMask` for:

- Moving bits from a GWorld to the screen. See "Working With Bitmap Image Data" (page 59) and "Offscreen Drawing" (page 81).
- Offscreen drawing, check out the `CGLayerRef` data type and how to use it with the function `CGLayerCreateWithContext`. You might also investigate `HIViewCreateOffscreenImage`. See "Using a CGLayer Object for Offscreen Drawing" (page 82).
- Fast scrolling, consider using HIView to create a scrolling view (see the function `HIScrollViewCreate`). See *HIView Programming Guide* and *HIView Reference* for more information.
- Image animation, use overlay windows. See "Using Overlay Windows" (page 70).
- Highlighting portions of an image, use overlay windows. See "Updating Regions" (page 69).
- Converting from one pixel depth to another, then eliminate code that changes pixel depth. Modern hardware has plenty of memory and rendering horsepower, and there is no longer any motivation to reduce image depth.
- Scaling or resizing an image, you can instead use the Quartz function `CGContextDrawImage` and then adjust the destination rectangle to get the desired scaling.
- Clipping or cropping an image, consider the Quartz functions `CGImageCreateWithImageInRect`, `CGImageCreateWithMask`, and `CGContextClipToMask`. You can create thumbnail images in Quartz using the function `CGImageSourceCreateThumbnailAtIndex`. All four functions are introduced in Mac OS X v10.4. See Creating Images in *Quartz 2D Programming Guide*.
- Color blending using transfer modes, consider using blend modes in Quartz. See "Color Blend Modes" (page 21), which allows blending shapes using translucent color. In *Quartz 2D Programming Guide*, see Setting Blend Modes and Using Blend Modes With Images.

  Quartz doesn't have an functions that operate on a per-pixel basis, but Core Image does. If you want to perform image processing on a per pixel basis, you can convert a Quartz image to a Core Image image, perform the operation, and pass the processed image back to Quartz. See *Core Image Programming Guide* and Moving Data Between Quartz 2D and Core Image in *Quartz 2D Programming Guide*.
- Creating transparency effects, then use the alpha channel to specify the translucency of a color. See The Alpha Value in *Quartz 2D Programming Guide*.
- Creating image masks, consider using `CGImageMaskCreate`. See "Masking" (page 65).
- Storing and retrieving images, then use the Quartz image-source and image-destination functions. These handle the common image file formats in use today, including JPEG, PNG, TIFF, JPEG2000. See *CGImageSource Reference*, *CGImageDestination Reference*, and Data Management in *Quartz 2D Programming Guide*.

- Inverting colors, consider using the exclusion or difference blend modes. In *Quartz 2D Programming Guide*, see Setting Blend Modes and Using Blend Modes With Images.
- Colorizing an image, consider using blend modes. See "Colorizing an Image" (page 21).

Basic Drawing

There are some basic similarities between drawing in QuickDraw and Quartz. Drawing, whether in QuickDraw or Quartz, involves obtaining a preconfigured drawing environment, specifying the geometry of shapes, and applying color to shape outlines, interiors, or both. But there are many differences that you will want to be aware of.

One important difference is that QuickDraw does not always make a clear distinction between specifying the geometry of an object and drawing the object. For example, you can't specify lines, ovals, or rounded rectangles without drawing them. In Quartz, there is a clean separation between constructing an object (operations such as adding a rectangle to a path or creating a shading) and drawing the object (operations such as stroking and filling the path or drawing the shading).

There are many other differences. This chapter discusses basic drawing issues and how to accomplish a variety of drawing tasks using Quartz.

- "Coordinate Space" (page 17) describes the QuickDraw, Quartz, and HIView coordinate systems, and how to convert between QuickDraw and Quartz coordinates.
- "Drawing Destinations" (page 19) compares QuickDraw and Quartz destinations and provides references to code examples that shows how to obtain graphics contexts.
- "Graphics State and Global Effects" (page 20) lists the Quartz graphics state parameters.
- "Color Blend Modes" (page 21) discusses how paint is composited to a background in Quartz and provides examples of using blend modes to colorize one image and draw a portion of another.
- "Alternatives to QuickDraw Drawing Functions" (page 36) lists many QuickDraw region functions and suggests alternative functions in Quartz.
- "Constructing and Drawing Shapes" (page 23) shows how to construct and draw two-dimensional shapes in Quartz and provides emulation routines for many QuickDraw functions.
- "Converting an Arbitrary QuickDraw Region to a Quartz Path" (page 32) provides a generalized routine for handling region conversions.
- "Anti-aliasing" (page 33) describes what it is in Quartz and what settings affect it.
- "Clipping" (page 34) compares QuickDraw and Quartz clipping and shows how to use clipping to draw the intersection and difference of two shapes.

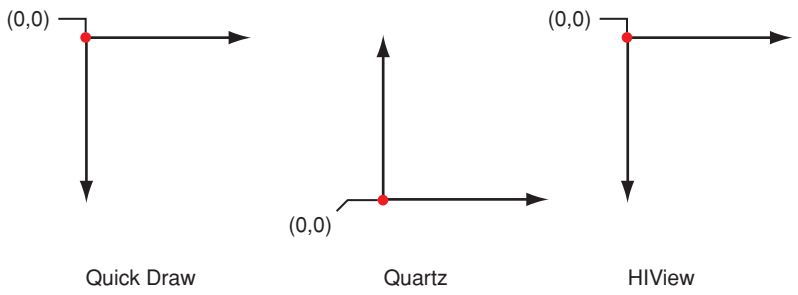
Coordinate Space

QuickDraw and Quartz coordinate space differ most in the location you draw to and the location of the origin. In Quartz, you draw to user space, which is device-independent and pixel-free. By drawing to user space, you can send the same drawing to any number of destinations—screen, printer, bitmap, PDF—and Quartz converts the user space coordinates to the appropriate device space coordinates. No math required on your part!

When you draw with Quartz, you need only to work in user space. If for some reason your application needs to obtain the affine transform that Quartz uses to convert between user and device space, you can call the function `CGContextGetUserSpaceToDeviceSpaceTransform`, introduced in Mac OS X v10.4. Quartz also adds functions in Mac OS X v10.4 that convert geometries (points, sizes, and rectangles) between device and user space.

The Quartz user space is modeled on the Cartesian plane—coordinates are single-precision, floating-point numbers, and by default, the positive y-axis extends upward. In a new graphics context, the origin corresponds to the lower-left corner of the page, as shown in Figure 2-1. QuickDraw, by comparison, uses integer coordinates whose origin corresponds to the upper-left corner of a page. HIView, uses floating-point coordinates whose origin corresponds to the upper-left corner of a page.

Figure 2-1 Comparison of origins for QuickDraw, Quartz, and HIView



You can use Quartz translation and scaling functions to convert between coordinate systems. Listing 2-1 shows how to switch from Quartz coordinates to one whose origin is in the upper-left corner by modifying the context matrix prior to drawing.

Listing 2-1 Code that transforms the Quartz origin to be at the upper-left

```
CGContextSaveGState (myContext);
CGContextTranslateCTM (myContext, 0, myOrigin.y + myPortHeight);
CGContextScaleCTM (myContext, 1.0f, -1.0f);
// Your drawing code here.
CGContextRestoreGState (myContext);
```

The function `CGContextTranslateCTM` translates the coordinate system so that the *y* values are moved toward the top of the HIView by the height of the HIView bounding rectangle. If you were to draw now, your drawing would be outside the HIView, not in a visible area.

The function `CGContextScaleCTM` code flips the y-coordinates by a factor of –1.0, effectively flipping the coordinates into the HIView. After this operation, the origin is at the lower left of the HIView, with the y values increasing from bottom to top. The x values are unchanged; they still increase from left to right.

Tip: Spend time to figure out the coordinates and to translate from one coordinate system to the other. Quartz transforms make it easy to switch back and forth, but it's also easy to make mistakes until you have practiced. Be careful not to perform transformations in the wrong order. If drawing doesn't show up as you expect, use the function `CGContextGetClipBoundingBox` to see if the bounding box of the drawing area is where you expect it to be. See Transforms in *Quartz 2D Programming Guide* for more information.

If you use HIView in conjunction with Quartz, and draw to a graphics context that you obtain from HIView, that graphics context uses HIView coordinates. HIView places the origin in the upper-left corner of the view, but it uses floating-point values just like Quartz does. HIView uses the upper left to ensure that the coordinates of objects, such as controls, do not change as the user resizes the window. When you want to draw a Quartz image (CGImage) to an HIView, make sure that you use the HIView function `HIViewDrawCGImage`, which orients the image appropriately for the HIView coordinate system.

Keep in mind that text drawing is affected by the coordinate system. Quartz, the HIToolBox, and ATSUI are among the APIs that provide support for drawing text. You need to be aware of the coordinate-system assumptions made by each text drawing function as well as the transformations you've performed on the Quartz coordinate system. For example, if you use the default Quartz coordinate system and the Quartz text drawing functions (`CGContextShowText`, `CGContextShowTextAtPoint`, `CGContextShowGlyphs`, and so forth), then text is drawn in the correct orientation. If you use the default Quartz coordinate system and the HIToolbox text drawing functions (such as `HIThemeDrawTextBox`), text appears inverted. In the case of `HIThemeDrawTextBox` you can remedy this by specifying the option `kHIThemeOrientationInverted`.

The details of text drawing and coordinate systems aren't discussed here. It's an issue you'll want to investigate further. However, if you draw text and it either doesn't appear or it appears inverted, take a close look at the coordinate system, the transformations you've performed, and the assumptions of the text drawing function you use. Also keep in mind that Quartz has a text matrix that can be transformed separately from default user space. For more information, see Text in *Quartz 2D Programming Guide*.

Drawing Destinations

In Quartz, all drawing takes place in a drawing environment called a graphics context. You can think of a graphics context as being equivalent to a QuickDraw grafport. Graphics contexts are really drawing destinations that are preconfigured for a specific use, including drawing to a window or printer, creating PDF content, creating a bitmap, drawing to an OpenGL context, or drawing to an offscreen layer. Some graphics contexts are multipaged, such as PDF and printing contexts. Every graphics context has a graphics state stack that you can use to save snapshots of the current drawing state. This allows you to modify the drawing state and then return back to a previous state.

Although graphics contexts are specialized for different drawing destinations, Quartz is designed to make as few assumptions as possible about the output device. For example, the Print Preview feature in Mac OS X redirects your output from a printing context to a PDF document and then to a raster display, with no loss of information or quality. This means that you simply draw to user space and let Quartz convert those coordinates appropriately for the graphics context.

Before you perform any drawing in Quartz, you need to obtain a graphics context because most drawing functions operate on a graphics context; that's where your drawing is directed. Quartz provides creation functions for bitmap graphics contexts, PDF graphics contexts, OpenGL graphics contexts, and layers (which are derived from a graphics context, described in CGLayer Drawing in *Quartz 2D Programming Guide*).

You obtain graphics contexts that are used for drawing to windows or a printer from the appropriate framework. Carbon (HIView) and Cocoa provide window graphics contexts. See Creating a Window Graphics Context in *Quartz 2D Programming Guide*.

The Printing framework manages printing graphics contexts. In Mac OS X v10.4, you use the printing functions `PMSessionBeginCGDocument` and `PMSessionGetCGGraphicsContext`. Prior to Mac OS X v10.4 you use `PMSessionSetDocumentFormatGeneration` passing the constant `kPMGraphicsContextCoreGraphics`. See Obtaining a Graphics Context for Printing in *Quartz 2D Programming Guide*.

Graphics State and Global Effects

In a drawing environment the graphics state defines the global framework within which graphics operations execute. A well-designed graphics state model helps to create a stable, consistent drawing environment and makes it easier to use a graphics API.

Quartz doesn't maintain any global graphics state as QuickDraw does. Instead, the drawing state is maintained for each graphics context. Graphics contexts have attributes that are fixed at creation time, and parameters that you can modify while drawing. For example, in a bitmap context the pixel data is an attribute and the fill color is a parameter.

Every graphics context has a graphics state stack that you can use to save and restore snapshots of the current drawing state using the functions `CGContextSaveGState` and `CGContextRestoreGState`. There is no way in Quartz for you to get the current setting for a graphics state parameter. If you want that information, you need to track the settings yourself. Perhaps a better approach is to think in terms of bracketing your code with calls to save and restore the graphics state. Quartz provides "set" functions for changing each graphic state parameter. Graphics state parameters are discussed in detail in various chapters in *Quartz 2D Programming Guide*. Start with the Graphics State section in the overview chapter, which includes a cross reference to the chapter that's appropriate for a particular graphics state parameter.

The graphic state parameters include the following:

- Current transformation matrix (CTM)
- Clipping area
- Line characteristics: width, join, cap, dash, miter limit
- Anti-aliasing setting
- Color: fill and stroke setting
- Global alpha value (transparency)
- Rendering intent
- Color space: fill and stroke settings
- Text settings: font, font size, character spacing, text drawing mode
- Blend mode

Color Blend Modes

`CopyBits` uses transfer modes to combine pixels in a source and destination image in different ways. As stated earlier, Quartz has no replacement for QuickDraw transfer modes. But depending on what you want to achieve, Quartz blend modes might provide the answer. In Quartz, compositing is based on alpha information. A graphics context has a global alpha parameter that determines the opacity of any object that's drawn, including images. In addition, an image can have its own alpha channel that determines the opacity of each pixel when the image is composited with the background.

In Mac OS X v10.4 and later, Quartz provides an additional compositing parameter, called the **blend mode**, that determines how source and background colors interact. (Quartz blend modes are based on PDF blend modes.) You can use the blend mode to get special compositing effects such as tinting and colorizing when drawing images. The blend mode is a part of the graphics state in a context, and you can change it by passing a constant to the function `CGContextSetBlendMode`.

When the blend mode is the default value (`kCGBlendModeNormal`), the blend color is simply the source color. In the normal blend mode Quartz performs alpha blending by combining the components of the source color with the components of the destination color using the formula:

```
destination = (alpha * source) + (1 - alpha) * destination
```

Other blend modes combine source and background colors in various ways. For example, the darken blend mode selects the darker of the source and background colors. While blend modes and transfer modes are not the same mathematically, there may be some blend modes that could be used as replacements for transfer modes.

Blend modes are described in detail in *Quartz 2D Programming Guide*. In the next two sections you'll see how you can use the color blend mode to colorize an image and the lighten blend mode to show part of an image. But for detailed information about using all the Quartz blend modes, including examples of the sorts of results you can get, see Setting Blend Modes. If you depend heavily on transfer modes for advanced imaging effects, also take a look at the *Core Image Programming Guide*, which describes Core Image blend mode filters.

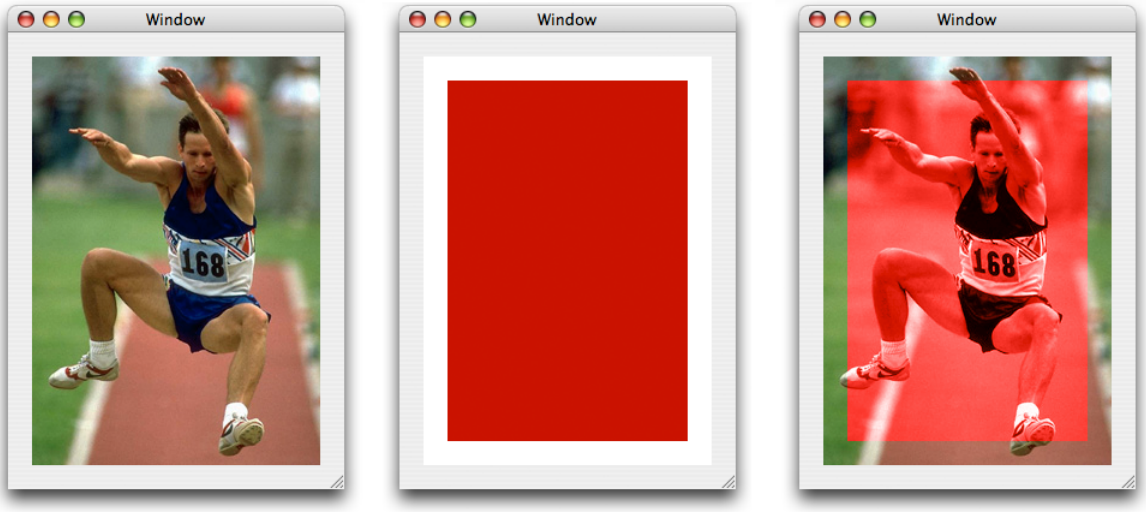
Colorizing an Image

One way that you can use the color blend mode is to colorize an image. Draw the image you want to colorize. Then set the blend mode by passing the constant `kCGBlendModeColor` to the function `CGContextSetBlendMode`. Draw and fill a rectangle (or other shape) using the color you want to use for colorizing the image. The code in Listing 2-2 draws a fully opaque red rectangle (see Figure 2-2 (page 22)) over the image of the jumper, to achieve the result shown on the right side of the figure. Note that the entire image of the jumper is not colorized because the red rectangle is smaller than the image.

Listing 2-2 Code that uses the color blend mode

```
CGContextSaveGState (context);
CGContextDrawImage(context, myRect1, image);
CGContextSetBlendMode(context, kCGBlendModeColor);
CGContextSetRGBFillColor (context, 0.8, 0.0, 0.0, 1.0);
CGContextFillRect (context, myRect2);
CGContextSaveGState (context);
```

Figure 2-2 A jumper, a red rectangle, and the jumper image colorized



Showing Part of an Image

Another interesting effect you can achieve by using a blend mode is to show only a portion of an image. Normally you would achieve this effect using clipping. You use the lighten blend mode and an opaque black shape that defines the area of the image that you want to show. As shown in Listing 2-3, you fill a shape (here the code uses a rectangle) with opaque black, set the blend mode to `kCGBlendModeLighten`, and then draw the image. Figure 2-3 (page 23) shows the rectangle, the original image of a jumper, and the resulting image. The part of the image you can see coincides exactly with the rectangle.

Listing 2-3 Code that uses the lighten blend mode to show part of an image

```
CGContextSaveGState (context);
CGContextSetRGBFillColor (context, 0.0, 0.0, 0.0, 1.0);
CGContextFillRect (context, myRect);
CGContextSetBlendMode (context, kCGBlendModeLighten);
CGContextDrawImage (context, contextRect, image);
CGContextRestoreGState (context);
```

Figure 2-3 An opaque black rectangle, a jumper, and the resulting image

Constructing and Drawing Shapes

You define arbitrary two-dimensional shapes in Quartz using graphics paths. If you haven't already done so, you should read Paths in *Quartz 2D Programming Guide*. That chapter describes the rich set of path construction and drawing operations, and also describes how to use a path as a clipping mask.

Quartz provides two sets of functions for drawing paths. One set draws directly to a graphics context. These functions are defined in *CGContext Reference* and each use the CGContext prefix. You construct a path in a graphics context by calling functions that add to the path (lines, rectangle, ellipses, and so forth). Then you paint the path (by stroking, filling, or both). After you paint the path, it is no longer accessible; it's gone from the context.

The other set of functions draws to a CGPath object (`CGPathRef`) data type. These functions are defined in *CGPath Reference*, and each use the CGPath prefix. You call functions that build a path in the CGPath object. Then you paint the path (by stroking, filling, or both). As long as you keep the CGPath object around, you can paint the path whenever you like. For shapes that you plan to reuse, CGPath objects are what you want to use.

Here are a few important differences between paths and regions:

- Paths are designed with device and resolution independence in mind. There's no notion of adding pixels to a path or converting a bitmap into a path.
- The functions you use to construct a path are entirely separate from the functions you use to draw the path.
- Paths have a direction. The elements in a path—lines, curves, and so on—are sequentially ordered, and this information is retained in the path definition.
- Path operations for adding Bézier curves make it possible to construct shapes with complex, curvilinear contours. QuickDraw has nothing comparable to this feature.
- When a path is filled with color or used for clipping, Quartz uses standard, well-defined fill rules to determine the area inside the path.

The next sections show how to implement functions that are equivalent to the QuickDraw function `PaintArc`, `FrameArc`, `PaintOval`, `FrameOval`, `PaintRect`, and `FrameRect`. You'll also see how to create rounded rectangles and how to draw the union and symmetric difference of two shapes. Most of the code in the next sections is excerpted from the QuartzShapes sample code project, which you can download from http://developer.apple.com/samplecode/.

Arcs: Replacing FrameArc and PaintArc

Figure 2-4 shows examples of arcs that are stroked or filled. In Quartz, the general procedure for drawing a shape is to first construct a path and then to fill it, stroke it, or fill and stroke it. To emulate the QuickDraw functions `FrameArc` and `PaintArc`, you first need to write a function that creates an arc path. Listing 2-4 (page 24) shows a routine that constructs an arc path.

Figure 2-4 Arcs drawn using Quartz

In addition to the graphics context that you want to draw to, the `pathForArc` routine takes the same parameters that you would pass to the `FrameArc` and `PaintArc` functions: a rectangle whose center specifies the origin of the arc you want to draw as well as the x radius and y radius of the arc, the starting angle (in degrees), and the angle (in degrees) of the arc. A detailed explanation for each numbered line of code appears following the listing.

Listing 2-4 A routine that constructs an arc path

```
void pathForArc (CGContextRef context, CGRect r,
                    int startAngle, int arcAngle)
{
    float start, end;

    CGContextSaveGState(context);                                          // 1
    CGContextTranslateCTM(context, r.origin.x + r.size.width/2,            // 2
                                r.origin.y + r.size.height/2);,

    CGContextScaleCTM(context, r.size.width/2, r.size.height/2);           // 3
    if (arcAngle > 0) {                                                    // 4
        start = (90 - startAngle - arcAngle) * M_PI / 180;
        end = (90 - startAngle) * M_PI / 180;
    } else {
        start = (90 - startAngle) * M_PI / 180;
        end = (90 - startAngle - arcAngle) * M_PI / 180;
    }
    CGContextAddArc (context, 0, 0, 1, start, end, false);                 // 5
```

```
    CGContextRestoreGState(context);                                    // 6
}
```

Here's what the code does:

1. Saves the graphic state. You need to change the current transformation matrix (CTM), so you'll want to save the graphics state and then restore it later.
2. Translates the CTM by the x origin of the arc plus half the width and the y origin of the arc plus half the height.
3. Scales the CTM by half the width and half the height.
4. Computes the starting and ending angle as measured in radians from the positive x-axis, taking into consideration whether the angle passed to `pathForArc` is positive or negative.
5. Adds the arc path to the current context. This call does not paint the arc. The function `CGContextAddArc` takes a graphics context, the x- and y- coordinates (in user space) that define the center of the arc. The radius of the arc (in user space coordinates), the angle (in radians) to the starting point of the arc, the angle (in radians) to the ending point of the arc, and a Boolean value that indicates the direction to draw the path.
6. Restores the graphics state.

The `frameArc` routine shown in Listing 2-5, strokes an arc so that its origin is centered in the rectangle that you pass to the function. It calls the `pathForArc` routine to create the arc prior to filling the arc and `CGContextStrokePath` to perform the actual stroking.

Listing 2-5 A routine that frames (strokes) an arc

```
void frameArc(CGContextRef context, CGRect r,
    int startAngle, int arcAngle)
{

    CGContextBeginPath (context);
     pathForArc (context,r,startAngle,arcAngle);
    CGContextStrokePath(context);
}
```

The `paintArc` routine shown in Listing 2-6 fills an arc so that its origin is centered in the rectangle that you pass to the function. It calls the `pathForArc` routine to create the arc prior to filling the arc and calls `CGContextFillPath` to perform the fill operation.

Listing 2-6 A routine that paints (fills) an arc

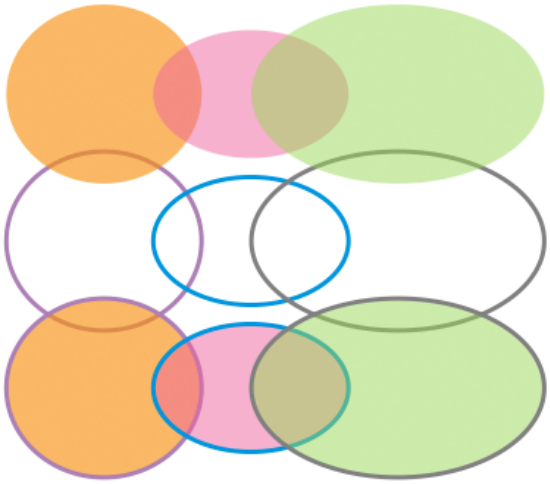
```
void paintArc (CGContextRef context, CGRect r,
                        int startAngle, int arcAngle)
{

    CGContextBeginPath (context);
    CGContextMoveToPoint (context, r.origin.x + r.size.width/2,
                            r.origin.y + r.size.height/2);
     pathForArc (context,r,startAngle,arcAngle);
    CGContextClosePath (context);
    CGContextFillPath (context);
}
```

Ovals: Replacing FrameOval and Paint Oval

Figure 2-5 shows examples of ovals that are stroked, filled, and both stroked and filled. Prior to Mac OS X v10.4, to emulate the QuickDraw functions `FrameOval` and `PaintOval`, you first need to write a function that creates an oval (or elliptical) shaped path. Starting in Mac OS X v10.4, you can frame ovals using the function `CGContextStrokeEllipseInRect`, which strokes (frames) an ellipse that fits in the specified rectangle. You paint (fill) ovals using the function `CGContextFillEllipseInRect`, which fills (paints) an ellipse that fits in the specified rectangle.

Figure 2-5 Ovals drawn using Quartz



The emulation functions are provided in case you need code that runs on versions of Mac OS X prior to v10.4. Listing 2-7 constructs an oval path. Listing 2-8 (page 27) paints an oval, and Listing 2-9 (page 27) frames one. A detailed explanation for each number line of code in Listing 2-7 follows the listing.

Listing 2-7 A routine that constructs an oval path

```
void addOvalToPath(CGContextRef context, CGRect r)
{
    CGContextSaveGState(context);                                          // 1

     CGContextTranslateCTM(context, r.origin.x + r.size.width/2,           // 2
                                r.origin.y + r.size.height/2);
     CGContextScaleCTM(context, r.size.width/2, r.size.height/2);          // 3
    CGContextBeginPath(context);                                           // 4
    CGContextAddArc(context, 0, 0, 1, 0, 2*pi, true);                      // 5

    CGContextRestoreGState(context);                                       // 6
}
```

Here's what the code does:

1. Saves the graphics state so that you can restore it later.
2. Transforms the origin of the CTM to the center of the bounding rectangle. The center of the bounding rectangle will be the center of the oval.

3. Scales the CTM so that a radius of 1 is equal to the bounds of the rectangle,
4. Creates a new, empty path in the graphics context.
5. Adds a circle to the path in the graphics context. But because the CTM is transformed, the circle is subjected to that transformation. After transformation, the circle becomes an oval that lies just inside the bounding rectangle.
6. Restores the graphics state to what it was prior to transforming the CTM.

The `paintOval` routine shown in Listing 2-8 calls the `addOvalToPath` routine, passing a rectangle to center the oval in, and then fills the path using the Quartz function `CGContextFillPath`.

Listing 2-8 A routine that paints (fills) an oval

```
void paintOval(CGContextRef context, CGRect r)
{
    addOvalToPath (context,r);
    CGContextFillPath (context);
}
```

The `frameOval` routine shown in Listing 2-9 calls the `addOvalToPath` routine, passing a rectangle to center the oval in, and then strokes the path using the Quartz function `CGContextStrokePath`. In QuickDraw, `FrameOval` completely insets the oval in the rectangle. In the `frameOval` routine, the path is inset but the stroke is painted with one-half its thickness on each side of the path.

Listing 2-9 A routine that frames (strokes) an oval

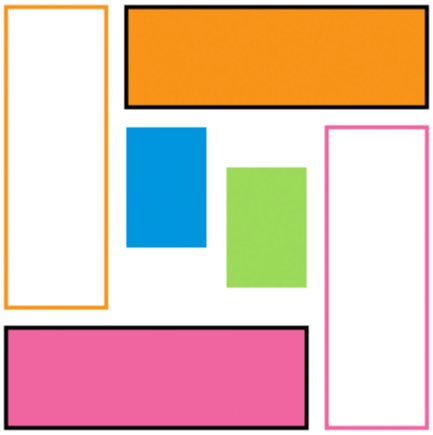
```
void frameOval(CGContextRef context, CGRect r)
{
    addOvalToPath(context,r);

    CGContextStrokePath(context);
}
```

Rectangles: Replacing FrameRect and PaintRect

Figure 2-6 shows examples of rectangles that are stroked, filled, and both stroked and filled. Quartz provides convenience functions for stroking and painting rectangles. You can simply use the Quartz functions `CGContextStrokeRect` and `CGContextFillRect`. Keep in mind that in QuickDraw, framing routines completely inset a shape in the specified rectangle. In Quartz, stroking paints a line such that one-half its thickness is on each side of the path.

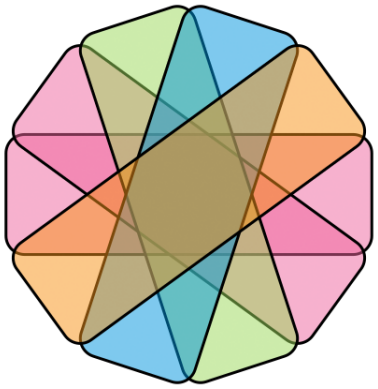
Figure 2-6 Rectangles drawn using Quartz



Rounded Rectangles

Figure 2-7 shows a series of rounded rectangles that are stroked with black and filled using a variety of translucent colors. To draw a rounded rectangle, you first need to write a function that creates a rounded rectangle path, and then create functions that stroke and fill the rounded rectangle.

Figure 2-7 Rounded rectangles drawn using Quartz



The `addRoundedRectToPath` routine shown in Listing 2-10 (page 29) constructs a rounded rectangle path by using a series of calls to the function `CGContextAddArcToPoint`. Although you can simply use the code in the listing to construct rounded rectangles, it's worth taking a moment to understand the `CGContextAddArcToPoint` function. This function adds the arc of a circle to the current subpath. When you call this function directly, you supply two pairs of coordinates— (*x1*,*y1*) and (*x2*,*y2*)—that define two tangent lines, and a radius that defines the curvature of the arc.

The arc constructed by the function `CGContextAddArcToPoint` is tangent to two lines: the line from the current point to (*x1*,*y1*), and the line from (*x1*,*y1*) to (*x2*,*y2*). The start and end points of the arc are the tangent points of the lines. If the current point and the first tangent point of the arc (the starting point) are not equal, Quartz appends a straight line segment from the current point to the first tangent point. After adding the arc, the current point is reset to the end point of arc (the second tangent point).

Now take a look at the `addRoundedRectToPath` routine in Listing 2-10 (page 29). The routine takes a graphics context, a rectangle into which the rounded rectangle must fit, and the width and height of the oval that defines the rounded corners. A detailed explanation for each numbered line of code appears following Listing 2-10.

Listing 2-10 A routine that constructs a rounded rectangle path

```
static void addRoundedRectToPath(CGContextRef context, CGRect rect,
                        float ovalWidth,float ovalHeight)

{
    float fw, fh;

    if (ovalWidth == 0 || ovalHeight == 0) {                          // 1
        CGContextAddRect(context, rect);
        return;
    }

    CGContextSaveGState(context);                                     // 2

    CGContextTranslateCTM (context, CGRectGetMinX(rect),              // 3
                           CGRectGetMinY(rect));
    CGContextScaleCTM (context, ovalWidth, ovalHeight);               // 4
    fw = CGRectGetWidth (rect) / ovalWidth;                           // 5
    fh = CGRectGetHeight (rect) / ovalHeight;                         // 6

    CGContextMoveToPoint(context, fw, fh/2);                          // 7
    CGContextAddArcToPoint(context, fw, fh, fw/2, fh, 1);             // 8
    CGContextAddArcToPoint(context, 0, fh, 0, fh/2, 1);               // 9
    CGContextAddArcToPoint(context, 0, 0, fw/2, 0, 1);                // 10
    CGContextAddArcToPoint(context, fw, 0, fw, fh/2, 1);              // 11
    CGContextClosePath(context);                                      // 12

    CGContextRestoreGState(context);                                  // 13
}
```

Here's what the code does:

1. If the width or height of the oval is 0, adds a rectangle to the graphics context and returns. In addition, the corner reduces to a right angle, which is simply an ordinary rectangle.
2. Saves the graphics state so that you can restore it later.
3. Translates the origin of the graphics context to the lower-left corner of the rectangle.
4. Normalizes the scale of the graphics context so that the width and height of the arcs are 1.0.
5. Calculates the width of the rectangle in the new coordinate system.
6. Calculates the height of the rectangle in the new coordinate system.
7. Moves to the mid point of the right edge of the rectangle.
8. Adds an arc to the starting point. This is the upper-right corner of the rounded rectangle.
9. Adds an arc that defines the upper-left corner of the rounded rectangle.

10. Adds an arc that defines the lower-left corner of the rounded rectangle.
11. Adds an arc that defines the lower-right corner of the rounded rectangle.
12. Closes the path, which connects the current point to the starting point, and terminates the subpath.
13. Restores the graphics state to what it was previously.

The `strokeRoundedRect` routine, shown in Listing 2-11, calls the `addRoundedRectToPath` routine, passing a rectangle, and the oval width and height to use for rounding. The routine then strokes the path by using the Quartz function `CGContextStrokePath`.

Listing 2-11 A routine that frames (strokes) a rounded rectangle

```
void strokeRoundedRect(CGContextRef context, CGRect rect, float ovalWidth,
                       float ovalHeight)
{
    CGContextBeginPath(context);
    addRoundedRectToPath(context, rect, ovalWidth, ovalHeight);
    CGContextStrokePath(context);
}
```

The `fillRoundedRect` routine shown in Listing 2-12 calls the `addRoundedRectToPath` routine, passing a rectangle, and the oval width and height to use for rounding. The routine then fills the path using the Quartz function `CGContextFillPath`.

Listing 2-12 A routine that paints (fills) a rounded rectangle

```
void fillRoundedRect (CGContextRef context, CGRect rect,
                        float ovalWidth, float ovalHeight)

{
    CGContextBeginPath(context);
    addRoundedRectToPath(context, rect, ovalWidth, ovalHeight);
    CGContextFillPath(context);
}
```

Drawing the Union and Symmetric Difference of Two Shapes

QuickDraw provides functions to find the union, intersection, or difference of two regions. Quartz has no comparable set operations for paths. However, it's possible to mimic these operations when filling areas in a path with overlapping shapes. This example demonstrates how to draw the union and symmetric difference (XOR) of two shapes. Drawing the intersection and difference requires clipping, which is described in "A Basic Clipping Example" (page 35) in the section "Clipping" (page 34).

Figure 2-8 shows the path used in this example. The arrows indicate the counterclockwise direction of each shape.

Figure 2-8 A path with two overlapping shapes

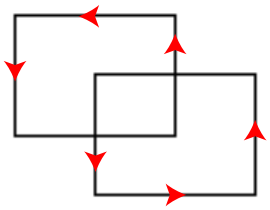
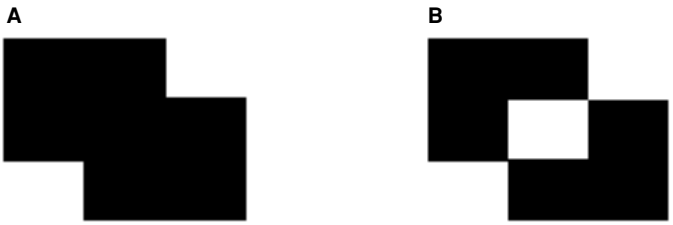


Figure 2-9 shows a drawing of the union and symmetric difference (XOR) of the two shapes. Their union is drawn using the nonzero winding number fill rule, and their symmetric difference is drawn using the even-odd fill rule. (These rules are described in detail in *Quartz 2D Programming Guide*.)

Figure 2-9 Drawing the union (A) and symmetric difference (B) of two shapes



Listing 2-13 defines the two shapes and constructs path objects that contain one or both shapes. A detailed explanation for each numbered line of code follows the listing.

Listing 2-13 Code that uses fill rules to draw the union and symmetric difference of two shapes

```
const float width = 80.0;
const float height = 60.0;

CGRect rect1 = {{ 0, height/2 }, { width, height }};
CGRect rect2 = {{ width/2, 0 }, { width, height }};
CGRect rects[2] = { rect1, rect2 };

// Shapes 1 and 2 are declared here but used in the clipping example
CGMutablePathRef shape1 = CGPathCreateMutable();
CGMutablePathRef shape2 = CGPathCreateMutable();
CGMutablePathRef shapes = CGPathCreateMutable();

CGPathAddRect (shape1, NULL, rect1);
CGPathAddRect (shape2, NULL, rect2);
CGPathAddRects (shapes, NULL, rects, 2);

CGContextSaveGState (ctx);
CGContextBeginPath (ctx);                                          // 1

// union
CGContextAddPath (ctx, shapes);                                    // 2
CGContextFillPath (ctx);                                           // 3

CGContextTranslateCTM (ctx, width * 3, 0);
```

```
// symmetric difference (XOR)
CGContextAddPath (ctx, shapes);                                    // 4
CGContextEOFillPath (ctx);                                         // 5

CGContextRestoreGState (ctx);
// Your code should include calls to CGPathRelease to release each path
```

Here's what the code does:

1. Replaces the current path (if any) in the context with a new, empty path.
2. Adds the two shapes to the current path.
3. Fills the current path using the nonzero winding number rule. Both shapes have the same direction, so the entire area is filled.
4. Adds the two shapes to the current path again. This is necessary because the fill operation in the previous step consumes the path.
5. Fills the path using the even-odd rule. This time, the area common to both shapes is not filled.

Converting an Arbitrary QuickDraw Region to a Quartz Path

Regions in QuickDraw and paths in Quartz are very different abstractions. Regions are pixel based and don't retain any information about the contours or boundaries of the shapes they represent. Paths are vector-based representations of the contours of shapes, with no concept of pixels. Converting a region into a path may be inefficient, and the contours of the converted path may not look smooth or scale well. Quartz does not provide a function to convert a region into a path. If at all possible, you will want to replace our use of regions with Quartz abstractions rather than perform this type of conversion. However, if you must, it is possible to write a program to perform the conversion yourself.

This section demonstrates how to write code that converts an arbitrary QuickDraw region into a Quartz path by taking a divide-and-conquer approach. The first step is to describe a region in terms of vectors. Rectangles are ideal for this purpose. It turns out that any region can be decomposed into a sequence of rectangles in top-down or left-right order. QuickDraw provides the function `QDRegionToRects` for exactly this purpose.

On the Quartz side, several functions exist for adding rectangles to graphics paths. The only remaining problem is to convert the rectangles into the floating-point `CGRect` format used by Quartz, which is easy to do.

The sample code in Listing 2-14 shows how to write two custom functions that work together to perform the conversion. A detailed explanation for each numbered line of code follows the listing.

- `MyConvertRegionToPath` creates a new path, performs the conversion, and returns the path to the caller.
- `MyRegionToRectsCallback` converts a QuickDraw rectangle into a Quartz rectangle and appends it to the new path.

When you use the converted path to draw in a graphics context with a flipped coordinate space, the path will have the same orientation as the region.

Listing 2-14 Routines that convert a QuickDraw region into a Quartz path

```
OSStatus MyConvertRegionToPath (RgnHandle region, CGPathRef* outPath)
{
    RegionToRectsUPP proc = NewRegionToRectsUPP (MyRegionToRectsCallback);
    CGPathRef path = CGPathCreateMutable();
    OSStatus err = noErr;

    err = QDRegionToRects (
        region, kQDParseRegionFromTopLeft, proc, (void*)path);                  // 1

    if (err == noErr) {
        *outPath = path;                                                        // 2
    }
    else {
        CGPathRelease (path);
        *outPath = NULL;
    }

    DisposeRegionToRectsUPP (proc);
    return err;
}

OSStatus MyRegionToRectsCallback (
    UInt16 message, RgnHandle region, const Rect *rect, void *data)
{
    if (message == kQDRegionToRectsMsgParse)
    {
        Rect qd = *rect;
        CGRect cg = CGRectMake (
            qd.left, qd.top, qd.right - qd.left, qd.bottom - qd.top);           // 3

        CGPathAddRect (
            (CGMutablePathRef)data, NULL, cg);                                  // 4
    }

    return noErr;
}
```

Here's what the code does:

1. Converts the region into a path.
2. Passes the converted path back to the caller.
3. Converts the QuickDraw rectangle into a Quartz rectangle, using the upper-left point as the origin.
4. Adds the Quartz rectangle to the path being constructed.

Anti-aliasing

Anti-aliasing is used in 2D graphics to smooth and soften the jagged (or aliased) edges you sometimes see when graphical objects such as text, line art, and images are drawn in a bitmap context. Anti-aliased objects are more accurately represented, more appealing to the eye, and more realistic.

Quartz provides a clear advantage over QuickDraw when it comes to anti-aliasing because Quartz uses anti-aliasing to draw shapes as well as text. Quartz also provides several levels of additional text anti-aliasing or text smoothing for LCD displays. QuickDraw supports anti-aliasing for text only, and its algorithm is limited to 16 shades of gray, with glyphs always positioned on pixel boundaries.

Quartz anti-aliasing maintains consistent high-quality rendering at any resolution by finding the best representation for a particular device. In graphics contexts that support anti-aliasing, by default everything drawn is anti-aliased. Images are drawn with anti-aliasing along their borders, causing them to appear to blend smoothly into the adjacent background.

Compared with QuickDraw, Quartz text anti-aliasing is more sophisticated. Quartz anti-aliasing uses a coverage model to compute the degree to which nearby pixels in device space are covered or contained by the drawing primitive. The coverage data determines the opacity of partially covered pixels. Anti-aliasing uses 8-bit opacity, which provides 256 different opacity levels. The opacity depth could increase in the future, as device capabilities and algorithms improve.

You can turn anti-aliasing off for a particular bitmap graphics context by calling the Quartz function `CGContextSetShouldAntialias`. The anti-aliasing setting is part of the graphics state.

Beginning in Mac OS X v10.4, you can also control whether or not to allow anti-aliasing for a particular bit-oriented graphics context by using the function `CGContextSetAllowsAntialiasing`. Pass `true` to this function to allow anti-aliasing, and `false` not to allow it. This setting is not part of the graphics state. Quartz performs anti-aliasing for a bit-oriented graphics context if you allow anti-aliasing (by passing `true` to `CGContextSetAllowsAntialiasing`) and you set the anti-aliasing setting graphics state parameter to `true` (by calling `CGContextSetShouldAntialias`).

Clipping

Quartz uses clipping to limit drawing in a graphics context. Quartz functions that clip (`CGContextClip`, `CGContextEOClip`) intersect the clip with the current clip, "trimming" the clipping area in a cookie-cutter-like manner. The primary differences between clipping in Quartz and QuickDraw are as follows:

- When your application creates a graphics context or obtains a context that's created elsewhere, the clipping area in the context is already configured for a specific use. The default clipping area in a new graphics context is typically the entire page or window content area.
- You cannot directly access the clipping area. Instead, Quartz provides clipping functions that modify the clipping area for you. You can save and later restore the current clipping area, along with the entire graphics state, by using the functions `CGContextSaveGState` and `CGContextRestoreGState`.
- When you call one of the Quartz clipping functions, the new clipping area is the intersection of the current clipping area with (1) the area inside a filled path or (2) a grayscale image or image mask.

  Note: Modifying the clipping area is always an intersection operation. This is fundamentally different from corresponding QuickDraw operations, which typically replace the clipping region with a new one.

- Because of how intersection works, clipping functions can't extend the clipping area beyond its current bounds.

Quartz Clipping Functions

Quartz has these functions available for clipping:

- `CGContextClip` intersects the current clipping area with the filled area of the current path, using the non zero winding rule.
- `CGContextEOClip` intersects the current clipping area with the filled area of the current path, using the even-odd rule. Often, you'll find that `CGContextEOClip` is more convenient to use than the function `CGContextClip`. For QuickDraw-style intersections, even-odd rules match better.
- `CGContextClipToMask` , available starting in Mac OS X v10.4, intersects the clipping area in a graphics context with a mask. The mask can be an image mask or a grayscale image. For more information, see Masking an Image by Clipping the Context in *Quartz 2D Programming Guide*.

The *Quartz 2D Programming Guide* describes how clipping works in more detail and discusses the difference between the winding and even-odd rules for determining the inside of a shape.

Tip: If drawing doesn't show up as you expect, use the function `CGContextGetClipBoundingBox` for debugging. By looking at the bounding box returned by this function, you can determine whether the coordinates are wrong or whether your drawing is not near what you clipped out.

A Basic Clipping Example

This example is a continuation of "Drawing the Union and Symmetric Difference of Two Shapes" (page 30). Quartz does not provide functions that compute the difference or intersection of two paths, but this example demonstrates how to use clipping to achieve a similar effect. That is, to draw the intersection and difference of two shapes in a single path (see Figure 2-8 (page 31)).

In Figure 2-10, the intersection of two shapes is drawn by clipping with each shape separately and then filling the shapes. For simplicity, this example uses rectangular paths. Typically you would use this approach with more complex paths. Their difference (shape 1 - shape 2) is drawn by clipping with both shapes using the even-odd rule, and then drawing the first shape.

Figure 2-10 Drawing the intersection (C) and difference (D) of two shapes

Listing 2-15 shows how to draw the filled areas in black.

Listing 2-15 Code that uses clipping to draw the intersection and difference of two shapes

```
// intersection
CGContextSaveGState (ctx);                                    // 1
```

```
CGContextAddPath (ctx, shape1);                                    // 2
CGContextClip (ctx);
CGContextAddPath (ctx, shape2);
CGContextClip (ctx);
CGContextAddPath (ctx, shapes);                                    // 3
CGContextFillPath (ctx);
CGContextRestoreGState (ctx);                                      // 4

CGContextTranslateCTM (ctx, width * 3, 0);

// difference
CGContextSaveGState (ctx);
CGContextAddPath (ctx, shapes);                                    // 5
CGContextEOClip (ctx);
CGContextAddPath (ctx, shape1);                                    // 6
CGContextFillPath (ctx);
CGContextRestoreGState (ctx);
```

Here's what the code does:

1. Saves the graphics state. This is done because step 2 modifies the clipping area, a part of the graphics state.
2. Intersects the clipping area with each shape individually. This has the effect of removing the area not common to both shapes from the clipping area. As with drawing operations, clipping consumes the current path.
3. Fills the shapes using the clip defined in the step 2.
4. Restores the clipping area to its previous state, saved in step 1.
5. Intersects the clipping area with both shapes using the even-odd rule. This has the effect of removing the area common to both shapes from the clipping area.
6. Constructs and fills a path consisting of the first shape, using the clip defined in step 5.

Alternatives to QuickDraw Drawing Functions

QuickDraw region functions do not have exact replacements in Quartz, but there are many alternatives in Quartz that work just as well. A good approach is to find an alternative and study how it's used in code examples such as the CarbonSketch sample application that's available from the ADC Reference Library. Table 2-1 (page 36) lists alternatives to some of the QuickDraw region functions.

See also "Constructing and Drawing Shapes" (page 23), "Converting an Arbitrary QuickDraw Region to a Quartz Path" (page 32), and "Clipping" (page 34).

Table 2-1 Alternatives to region functions

QuickDraw function	Alternatives
`ClipRect` replaces the clipping region with a region that's a rectangle.	`CGContextClipToRect` intersects the current clipping area with a rectangle.

QuickDraw function	Alternatives
`CopyRgn` makes a copy of a region.	`CGPathCreateCopy` and `CGPathCreateMutableCopy` make a copy of a path.
`DiffRgn` finds the difference of two regions.	There's no analogue for this function in Quartz. `HIShapeDifference` finds the difference of two shapes.
`DisposeRgn` frees the memory allocated for a region.	`CGPathRelease` decrements the retain count of a path.
`EmptyRgn` determines whether a region is empty.	`CGPathIsEmpty` determines whether a path is empty.
`EraseRgn` fills a region using the current background pattern.	To erase the area within a path, you simply fill it with opaque color. In a bitmap context, you can use `CGContextClearRect` to create a transparent background for new drawing.
`FillOval` and `PaintOval` fill an oval using a pattern. `FrameOval` draws an outline inside an oval.	`CGContextAddEllipseInRect` adds an ellipse (oval) to the current path. `CGContextFillEllipseInRect` fills an ellipse that fits inside the specified rectangle. `CGContextStroke-EllipseInRect` strokes an ellipse that fits inside the specified rectangle.
`FillRgn` and `PaintRgn` fill a region using a pattern.	`CGContextFillPath` and `CGContextEOFillPath` paint the interior of a path with the current fill color. You also can fill a path using a custom pattern—see Patterns in *Quartz 2D Programming Guide*.
`FrameRgn` strokes along the inside of a region's boundary.	`CGContextStrokePath` strokes along the center of a path. `CGContextStrokeLineSegments` adds an array of line segments to the current path, and strokes the path.
`GetClip` obtains the current clip region.	The clipping area in a graphics context is not accessible. `CGContextGetClipBoundingBox` finds the smallest rectangle completely enclosing all points in the current clipping area, including any control points.
`MapRgn` changes the size of a region.	You can apply a scaling transform in a context before using a path. CGPath functions also allow you to apply a transform during path construction.
`NewRgn` creates an empty region.	`CGPathCreateMutable` creates an empty path.
`OffsetRgn` changes the position of a region in its coordinate space.	CGPath functions allow you to translate a path's coordinates during path construction. `CGContextTranslateCTM` changes the origin in a context, which affects the current path.
`OpenRgn` begins a region definition. `CloseRgn` ends the definition and saves the result.	Analogues for these functions aren't needed in Quartz, because path construction operations are separate from path drawing operations.
`PtInRgn` determines whether a region contains a specified pixel.	`CGPathContainsPoint` determines whether a path contains a specified point in user space.

QuickDraw function	Alternatives
`RectRgn` and `SetRectRgn` change the shape of a region into a rectangle.	`CGPathAddRect` adds a rectangle to a path. `CGContextAddRect` adds a rectangle to the current path in a context.
`RectInRgn` determines whether a rectangle intersects a region.	There's no analogue for this function in Quartz. Instead, consider the function `HIShapeIntersectRect`, which determines whether a rectangle intersects a shape.
`SectRgn` finds the intersection of two regions.	There's no analogue for this function in Quartz. Instead, consider the function `HIShapeIntersect`, which finds the intersection of two shapes.
`SetClip` replaces the current clip region with another region.	`CGContextClip` and `CGContextEOClip` intersect the current clipping area with the area inside the current path.
`SetEmptyRgn` sets an existing region to be empty.	`CGContextBeginPath` replaces the current path in a context with an empty path. (All drawing and clipping operations also consume the current path.)
`UnionRgn` finds the union of two regions.	There's no analogue for this function in Quartz. Instead, consider the function `HIShapeUnion`, which finds the union of two shapes.

Relevant Resources

In *Quartz 2D Programming Guide*, see:

- CGLayer Drawing
- Creating a Window Graphics Context
- Masking an Image by Clipping the Context
- Obtaining a Graphics Context for Printing
- Patterns
- Paths
- Setting Blend Modes
- Transforms

See these reference documents:

- *CGAffineTransform Reference*
- *CGContext Reference*
- *CGGeometry Reference*
- *CGImage Reference*
- *CGLayer Reference*

- *CGPath Reference*
- *HIView Reference*
- *HIShape Reference*

For those interested in image processing, see *Core Image Programming Guide*.

Using Color

In Quartz, everything drawn on the page has color information associated with it. Color components are floating-point values ranging from 0.0 (no color) to 1.0 (full intensity). To support transparency, colors include an alpha component that ranges from 0.0 (transparent) to 1.0 (opaque). Quartz supports drawing with transparency in all types of graphics contexts. There are many uses for transparency in Mac OS X. For example, you can use translucent overlay windows to indicate selection.

Quartz colors are always associated with a color space. This ensures that colors are reproduced faithfully regardless of the drawing destination. Quartz supports separate color spaces for stroking and filling. Further, bitmap images and shadings are drawn to their own color spaces. When drawing is rendered to a destination, Quartz uses ColorSync to achieve accurate color matching.

If color fidelity is critical to your application, you'll need to learn how to manage colors and how to use calibrated color spaces in Quartz. If you don't need a sophisticated level of color-matching in your application, don't panic. Using colors and color spaces in Quartz is straightforward. Starting in Mac OS X v10.4, you can use Generic color spaces, which let Quartz manage color for you in the best way possible, without your needing to know all the particulars of calibrated color spaces.

If you haven't worked with color spaces, you might want to read *Color Management Overview* to learn the terminology and basic concepts associated with color and color spaces. This document discusses color perception, the dimensions associated with color, device-dependent and device-independent color spaces, color component values, color matching systems, rendering intents, color profiles, and ColorSync.

Regardless of your needs, before you start to work with color in Quartz, read Color and Color Spaces in *Quartz 2D Programming Guide*.

Converting Between QuickDraw RGB and Quartz RGB

The QuickDraw RGB data type provides storage for the red, green, and blue components of an RGB color, as shown in Listing 3-1. Values for a QuickDraw color component can range from 0 to 65,535. Quartz RGB colors have an additional component for alpha. The values for each component are floating-point, and can range in value from 0.0 (component not present) to 1.0.

Listing 3-1 The QuickDraw RGBColor data type

```
struct RGBColor {
   unsigned short red;
   unsigned short green;
   unsigned short blue;
};
```

The `ConvertRGBColortoCGrgba` routine in Listing 3-2 shows how to convert from QuickDraw RGB to Quartz RGB. The `CGrgba` structure in the listing contains components for red, green, blue, and alpha. To convert, the `ConvertRGBColortoCGrgba` routine divides each QuickDraw color component by 65,535. The alpha value that's passed to the routine gets assigned to the Quartz RGB color.

Listing 3-2 A routine that converts RGB color to Quartz RGBA

```
struct CGrgba {
        float r;
        float g;
        float b;
        float a;
}

void ConvertRGBColorToCGrgba (const RGBColor* inRGB,
                    float alpha,
                    CGrgba* outCGrgba)
{
    outCGrgba->r = (float)inRGB->red   / 65535.0;
    outCGrgba->g = (float)inRGB->green / 65535.0;
    outCGrgba->b = (float)inRGB->blue  / 65535.0;
    outCGrgba->a = alpha;
}
```

Creating Color Spaces

Generic color spaces let the system choose the best possible color representation for a given device and application. These are device-independent color spaces that are easy to use and recommended. Starting in Mac OS X v10.4, you can call the function `CGColorSpaceCreateWithName`, passing the constant `kCGColorSpaceGenericRGB`. Use of DeviceRGB is not recommended.

If your code must run in versions of Mac OS X prior to Mac OS X v10.4, see the `GetGenericRGBColorSpace` routine shown in Listing 3-3 (page 42). This routine creates a GenericRGB color space by calling the application-defined routine `OpenGenericProfile` once. `CreateGenericRGBColorSpace` keeps the color space so that it can return the color space whenever this routine is called.

Listing 3-3 A routine that creates a generic RGB color space

```
CGColorSpaceRef CreateGenericRGBColorSpace(void)
{
    static CGColorSpaceRef genericRGBColorSpace = NULL;

    if (genericRGBColorSpace == NULL)
    {
        CMProfileRef genericRGBProfile = OpenGenericProfile();

        if (genericRGBProfile)
        {
            genericRGBColorSpace = CGColorSpaceCreateWithPlatformColorSpace
                                    (genericRGBProfile);
            if (genericRGBColorSpace == NULL)
                fprintf(stderr, "Couldn't create the generic
                                RGB color space\n");

            // This routine opened the profile so it must close it
            CMCloseProfile(genericRGBProfile);
        }
    }
    return genericRGBColorSpace;
```

```
}
```

The `OpenGenericProfile` routine (see Listing 3-4) locates, opens, and returns a reference to the ColorSync profile for the calibrated Generic RGB color space. It is up to the caller to call the function `CMCloseProfile` when done with the profile reference that this function returns.

Listing 3-4 A routine that returns a reference to a calibrated GenericRGB color space

```
#define kGenericRGBProfilePathStr
        "/System/Library/ColorSync/Profiles/Generic RGB Profile.icc"

CMProfileRef OpenGenericProfile(void)
{
    static CMProfileRef cachedRGBProfileRef = NULL;

    // Create the profile reference only once
    if (cachedRGBProfileRef == NULL)
    {
        OSStatus            err;
        CMProfileLocation   loc;

        loc.locType = cmPathBasedProfile;
        strcpy(loc.u.pathLoc.path, kGenericRGBProfilePathStr);

        err = CMOpenProfile(&cachedRGBProfileRef, &loc);

        if (err != noErr)
        {
            cachedRGBProfileRef = NULL;
            // Log a message to the console
            fprintf (stderr, "Couldn't open generic profile due to
                                error %d\n",(int)err);
        }
    }

    if (cachedRGBProfileRef)
    {
        // Clone the profile reference so that the caller has
        // their own reference, not our cached one.
        CMCloneProfileRef (cachedRGBProfileRef);
    }

    return cachedRGBProfileRef;
}
```

Relevant Resources

In *Quartz 2D Programming Guide*, see

- Color and Color Spaces

See these reference documents:

- *CGColor Reference*

- *CGColorSpace Reference*

For those new to color spaces, see *Color Management Overview*.

Converting PICT Data

The QuickDraw picture (PICT) format is the graphics metafile format in Mac OS 9 and earlier. A picture contains a recorded sequence of QuickDraw imaging operations and associated data, suitable for later playback to a graphics device on any platform that supports the PICT format.

In Mac OS X, the Portable Document Format (PDF) is the native metafile and print-spooling format. PDF provides a convenient, efficient mechanism for viewing and printing digital content across all platforms and operating systems. PDF is better suited than the PICT format to serve as a general-purpose metafile format for digital documents. PDF offers these advantages:

- PDF represents the full range of Quartz graphics. The PICT format cannot be used to record drawing in a Quartz context.
- PDF allows multiple pages. The PICT format can represent only a single drawing space—there's no concept of multiple pages.
- PDF supports a wide variety of color spaces. The PICT format supports RGB and grayscale color, but lacks support for other types of color spaces such as CMYK, Lab, and DeviceN.
- PDF supports embedded Type 1 and TrueType fonts and font subsets. Embedded fonts aren't supported in pictures, so text can't be fully represented.
- PDF supports compression of font, image, and page data streams. PICT supports compression for images, but in many cases the PDF representation of PICT data is more compact.
- PDF supports encryption and authentication. The PICT format has no built-in security features.

As you convert your QuickDraw application to one that uses only Quartz, there are two primary issues you'll face with respect to PICT data:

- You will need to handle PICT data that you previously shipped with your application. The best approach is to convert is to another format (JPG, PNG, PDF) and use those formats with Quartz.
- You will want to support PICT data in your applications. This includes support for copying and pasting PDF to the pasteboard and opening existing documents.

This chapter provides approaches for handling PICT data and also shows how to handle PDF data from the Clipboard.

Reading and Writing Picture Data

This section provides examples of how you can read and write picture data for the purpose of converting it to PDF or another Quartz-compatible format. Some general strategies include the following:

- As you convert data, you may find that some PICTs don't convert well. In these cases, you'll want to first convert the PICT to a pixel picture first. See "Avoiding PICT Wrappers for Bitmap Images" (page 46).

- For PICTs that are wrappers for JPEG data, use the function `CGImageCreateWithJPEGDataProvider` for the JPEG data rather than working with the PICT.
- If your application uses predefined PICT files or resources that are drawn repeatedly, you can convert them into PDF and place them in the Resources folder inside the application bundle. See "Converting QDPict Pictures Into PDF Documents" (page 48).
- Use Quartz data providers to work with QDPict data. See "Creating a QDPict Picture From Data in Memory" (page 47) and "Creating a QDPict Picture From a PICT File" (page 48).
- If you need to draw PICT data scaled, evaluate which type of scaling is best for your purposes. See "Scaling QDPict Pictures" (page 49).

Avoiding PICT Wrappers for Bitmap Images

A popular strategy used by QuickDraw developers is to create a PICT wrapper around a bitmap image. With a bitmap image inside a `PICT` container, the picture acts as a transport mechanism for the image. If the bitmap is a JPEG or other image data, it's best to create a CGImage from that data. For example, you can draw the bitmap to a bitmap graphics context and then create a CGImage by calling the function `CGBitmapContextCreateImage` (available starting in Mac OS X v10.4). If the bitmap is JPEG or PNG data, you can use `CGImageCreateWithJPEGDataProvider` or `CGImageCreateWithPNGDataProvider` to create a CGImage.

PICT uses a vector-based format. If you use the `CopyBits` function to create a `PICT` representation of a bitmap image by opening a QuickDraw picture, and copying an image onto itself (by specifying the same pixel map as source and destination), then you replace the vector-based format with at bit-based one. In general, the wrapper strategy in QuickDraw is not a good one. As you move your code to Quartz, you'll want to convert PICTs to PDF documents. There is no need to create PICT wrappers to do so.

PDF is the format used to copy-and-paste between applications in Mac OS X. It's also the metafile format for Quartz because PDF is resolution independent. Although you can use a PDF wrapper for a bitmap image (just as PICT has been used) if you wrap a PDF with a bitmap image, the bitmap is limited by resolution at which it was created.

To convert existing PICT images to PDF documents, you can use the QuickDraw QDPict API. This API is declared in the interface file `QDPictToCGContext.h` in the Application Services framework. Note that if a QuickDraw picture contains drawing operations such as `CopyBits` that use transfer modes that don't have an analogue in PDF, the PDF representation may not look exactly the same.

The QDPict API includes these data types and functions:

- `QDPictRef`—An opaque type that represents picture data in the Quartz drawing environment. An instance of this type is called a QDPict picture.
- `QDPictCreateWithProvider` and `QDPictCreateWithURL`,—Functions that create QDPict pictures using picture data supplied with a Quartz data provider or with a PICT file.
- `QDPictDrawToCGContext`—A function that draws a QDPict picture into a Quartz graphics context. If redrawing performance is an issue, draw the PICT into a PDF graphics context, save it as a PDF document, and then use the PDF document with the Quartz routines for drawing PDF data, such as the function `CGContextDrawPDFPage`.

Creating a QDPict Picture From Data in Memory

To create a QDPict picture from picture data in memory, you call `QDPictCreateWithProvider` and supply the data using a Quartz data provider. When you create the provider, you pass it a pointer to the picture data—for example, by dereferencing a locked `PicHandle`.

When using the functions `QDPictCreateWithURL` and `QDPictCreateWithProvider`, the picture data must begin at either the first byte or the 513th byte. The picture bounds must not be an empty rectangle.

Listing 4-1 shows how to implement this method using two custom functions—a creation function, and a release function associated with the data provider. A detailed explanation of each numbered line of code follows the listing.

Listing 4-1 Routines that create a QDPict picture from PICT data

```
QDPictRef MyCreateQDPictWithData (void *data, size_t size)
{
    QDPictRef picture = NULL;

    CGDataProviderRef provider =
    CGDataProviderCreateWithData (NULL, data, size, MyReleaseProc);          // 1

    if (provider != NULL)
    {
        picture = QDPictCreateWithProvider (provider);                       // 2
        CFRelease (provider);
    }

    return picture;
}

void MyReleaseProc (void *info, const void *data, size_t size)               // 3
{
    if (info != NULL) {
        /* release private information here */
    };

    if (data != NULL) {
        /* release picture data here */
    };
}
```

Here's what the code does:

1. Creates a Quartz data provider for your picture data. The parameters are private information (not used here), the address of the picture data, the size of the picture data in bytes, and your custom release function.

2. Creates and returns a QDPict picture unless the picture data is not valid.

3. Handles the release of any private resources when the QDPict picture is released. This is a good place to deallocate the picture data, if you're finished using it.

Creating a QDPict Picture From a PICT File

To create a QDPict picture from picture data in a PICT file, you call `QDPictCreateWithURL` and specify the file location with a Core Foundation URL. Listing 4-2 shows how to implement this method using an opaque `FSRef` file specification.

Listing 4-2 A routine that creates a QDPict picture using data in a PICT file

```
QDPictRef MyCreateQDPictWithFSRef (const FSRef *file)
{
    QDPictRef picture = NULL;

    CFURLRef url = CFURLCreateFromFSRef (NULL, file);
    if (url != NULL)
    {
        picture = QDPictCreateWithURL (url);
        CFRelease(url);
    }

    return picture;
}
```

Converting QDPict Pictures Into PDF Documents

Listing 4-3 shows how to write a function that converts a QDPict picture into a PDF document stored in a file. A detailed explanation of each numbered line of code follows the listing. (Source code to create the URL and the optional PDF auxiliary information dictionary is not included here.)

Listing 4-3 Code that converts a picture into a single-page PDF document

```
void MyConvertQDPict (QDPictRef picture, CFURLRef url,
                      CFDictionaryRef dict)
{
    CGContextRef context = NULL;
    CGRect bounds = QDPictGetBounds (picture);
    bounds.origin.x = 0;
    bounds.origin.y = 0;

    context = CGPDFContextCreateWithURL (url, &bounds, dict);                // 1
    if (context != NULL)
    {
        CGContextBeginPage (context, &bounds);                               // 2
        (void) QDPictDrawToCGContext (context, bounds, picture);             // 3
        CGContextEndPage (context);                                          // 4
        CGContextRelease (context);                                          // 5
    }
}
```

Here's what the code does:

1. Creates a PDF graphics context that directs the PDF content stream to a URL. If the URL is a file, the filename should end with the `.pdf` extension. The second parameter uses the picture bounds to specify the media box. The third parameter is an optional PDF auxiliary information dictionary, which contains the title and creator of the PDF document.

2. Begins a new page. In a PDF context, all drawing outside of an explicit page boundary is ignored. Here the page size (or media box) is the picture bounds, but you could specify any page size.
3. Draws the picture. The drawing rectangle is identical to the picture bounds, so there is no change of scale.
4. Ends the current PDF page.
5. Releases the PDF context, which finalizes the PDF content stream and finishes creating the file.

Note: Quartz provides an opaque type called `CGPDFDocumentRef` for working with existing PDF documents. When you need to examine, draw, or print a PDF page, you create an object of this type. `CGPDFDocumentRef` isn't needed here because the objective is to create a PDF document, not to use it.

Scaling QDPict Pictures

When drawing a picture in a Quartz context, you have two ways to change the horizontal or vertical scale of the picture:

- Create a drawing rectangle by applying the change of scale to the bounds rectangle returned by `QDPictGetBounds` and pass this drawing rectangle to `QDPictDrawToCGContext`. When the picture is rendered, patterns are not scaled along with other graphic elements. This is the same behavior as that of the `DrawPicture` function. For example, compare the original picture in Figure 4-1 (page 50) with the scaled picture in Figure 4-2 (page 50).
- Before drawing the picture, apply the appropriate affine transformation—for example, by calling `CGContextScaleCTM`. When the picture is rendered, the entire picture is scaled, including patterns. The effect is equivalent to viewing the picture with the Preview application and clicking the Zoom In button. Compare the original in Figure 4-1 (page 50) with the scaled picture in Figure 4-3 (page 51) to see how this looks.

Listing 4-4 shows how to implement both types of scaling. A detailed explanation of each numbered line of code follows the listing.

Listing 4-4 A routine that uses two ways to scale a QDPict picture

```
void MyScaleQDPict (QDPictRef picture, CFURLRef url)
{
    float scaleXY = 2.0;
    CGRect bounds = QDPictGetBounds (picture);                              // 1
    float w = (bounds.size.width) * scaleXY;
    float h = (bounds.size.height) * scaleXY;
    CGRect scaledBounds = CGRectMake (0, 0, w, h);
    bounds.origin.x = 0;
    bounds.origin.y = 0;

    CGContextRef context = CGPDFContextCreateWithURL (url, NULL, NULL);     // 2
    if (context != NULL)
    {
        /* page 1: scale without affecting patterns */
        CGContextBeginPage (context, &scaledBounds);
        (void) QDPictDrawToCGContext (context, scaledBounds, picture);      // 3
```

```
        CGContextEndPage (context);

        /* page 2: scale everything */
        CGContextBeginPage (context, &scaledBounds);
        CGContextScaleCTM (context, scaleXY, scaleXY);                          // 4
        (void) QDPictDrawToCGContext (context, bounds, picture);                // 5
        CGContextEndPage (context);

        CGContextRelease (context);
    }
}
```

Here's what the code does:

1. Creates a Quartz rectangle that represents the origin and size of the picture in user space. The resolution is 72 units per inch and the origin is (0,0).
2. Creates a PDF context that renders into a file. The choice of PDF is arbitrary—you can draw QDPict pictures in any type of Quartz graphics context.
3. Draws the picture into a scaled drawing rectangle. Patterns are not scaled along with the other graphic elements in the picture.
4. Applies the scaling transform to the current transformation matrix (CTM) in the graphics context. This scaling affects all subsequent drawing.
5. Draws the picture into a drawing rectangle with the same dimensions. This time the picture is scaled by the CTM, including patterns.

Figure 4-1 Original picture

Figure 4-2 Scaling with a larger drawing rectangle (patterns not affected)

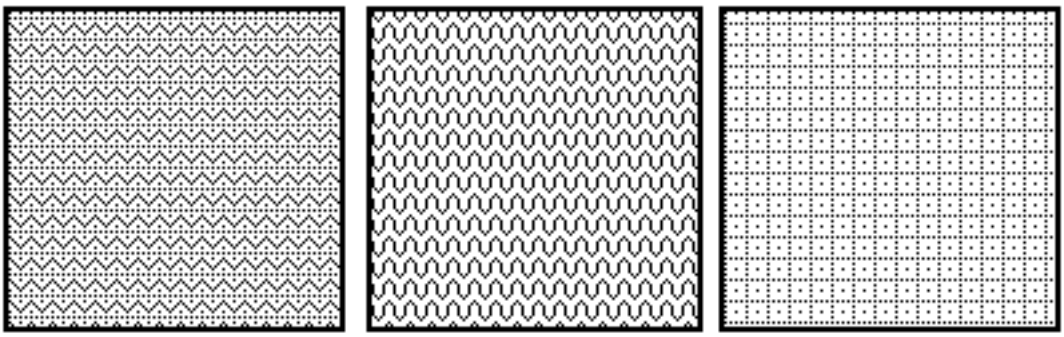
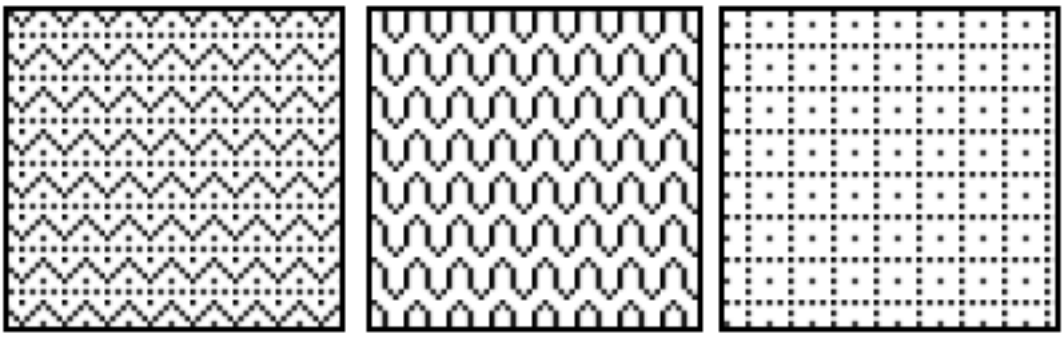


Figure 4-3 Scaling with a matrix transform (patterns affected)



Working With PICT Data on the Clipboard (Pasteboard)

In Mac OS X, the Clipboard supports a rich set of data formats, including PDF. Beginning in Mac OS X version 10.3 (Panther), Carbon applications can use the Pasteboard Manager to exchange PDF data using the Clipboard or any other pasteboard. The Pasteboard Manager provides a robust data transport mechanism for user interface services such as copying, cutting, pasting, and dragging data of various flavors, and for generic interprocess communication.

A pasteboard is a global resource that uses Core Foundation data types to exchange information. Data formats called flavors are specified using uniform type identifiers. Supported flavors include plain text, rich text, PICT, and PDF. For a more detailed description of pasteboards, see *Pasteboard Manager Programming Guide*. For more information about uniform type identifiers, see *Uniform Type Identifiers Overview*.

To draw a PDF version of a QuickDraw picture and copy the PDF data to the Clipboard using the Pasteboard Manager, you need to do the following:

1. Create a Quartz data consumer to transfer the rendered output from a PDF context into a CFData object for the Pasteboard Manager.
2. Create a PDF context using your data consumer, draw content in this context, and release the context.
3. Create a `PasteboardRef` representation of the Clipboard, clear the current contents, and write your PDF data to it.

Listing 4-5 shows how to implement this procedure. A detailed explanation of each numbered line of code follows the listing. (To simplify this listing, `OSStatus` result codes are cast to `void`. If you use this sample code in an actual application, you should remove the casts and add the necessary error handling.)

Listing 4-5 Code that pastes the PDF representation of a picture to the Clipboard

```
size_t MyPutBytes (void* info, const void* buffer, size_t count)                    // 1
{
    CFDataAppendBytes ((CFMutableDataRef) info, buffer, count);
    return count;
}

void MyCopyQDPictToClipboard (QDPictRef picture)
{
```

```
    static CGDataConsumerCallbacks callbacks = { MyPutBytes, NULL };

    CFDataRef data = CFDataCreateMutable (kCFAllocatorDefault, 0);                  // 2
    if (data != NULL)
    {
        CGDataConsumerRef consumer = NULL;
        consumer = CGDataConsumerCreate ((void*) data, &callbacks);                 // 3
        if (consumer != NULL)
        {
            CGContextRef context = NULL;
            CGRect bounds = QDPictGetBounds (picture);
            bounds.origin.x = 0;
            bounds.origin.y = 0;
            context = CGPDFContextCreate (consumer, &bounds, NULL);                 // 4
            CGDataConsumerRelease (consumer);
            if (context != NULL)
            {
                /* convert PICT to PDF */
                CGContextBeginPage (context, &bounds);
                (void) QDPictDrawToCGContext (context, bounds, picture);            // 5
                CGContextEndPage (context);
                CGContextRelease (context);                                         // 6

                /* copy PDF to clipboard */
                PasteboardRef clipboard = NULL;
                (void) PasteboardCreate (kPasteboardClipboard, &clipboard);         // 7
                (void) PasteboardClear (clipboard);                                 // 8
                (void) PasteboardPutItemFlavor (clipboard,                          // 9
                        (PasteboardItemID) 1, kUTTypePDF,
                        data, kPasteboardFlavorNoFlags);
                CFRelease (clipboard);
            }
        }
    CFRelease (data); // You should ensure that data is not NULL.
    }
}
```

Here's what the code does:

1. Implements a custom callback function to handle the PDF content stream coming from a Quartz PDF context. This function copies the PDF bytes from a Quartz-supplied buffer into a mutable `CFDataRef` object.
2. Creates a mutable `CFDataRef` object for the PDF data.
3. Creates a Quartz data consumer that uses the custom callback.
4. Creates a PDF context to draw the picture, using the data consumer.
5. Draws the QDPict picture in the PDF context.
6. Releases the PDF context, which "finalizes" the PDF data.
7. Creates an object of type `PasteboardRef` that serves as a data transport channel for a new or existing pasteboard—in this case, the Clipboard.
8. Clears the Clipboard of its current contents and makes it mutable.

9. Adds the PDF data to the Clipboard. Since there's only one data item, the item identifier is `1`. The uniform type identifier for PDF is declared in the interface file `UTCoreTypes.h` inside the Application Services framework.

Now that you've seen how to copy PICT data to the pasteboard, see Listing 4-6, which contains a routine that you can use to copy any Quartz drawing to the pasteboard. This routine is from the CarbonSketch sample application. The routine `AddWindowContextToPasteboardAsPDF` takes two parameters: a pasteboard reference and an application-defined data type that tracks various attributes of the drawing document, such as its size and content.

Listing 4-6 A routine that copies window content to the pasteboard (Clipboard)

```
static OSStatus AddWindowContentToPasteboardAsPDF (
                        PasteboardRef pasteboard, const DocStorage *docStP)
{
    OSStatus    err     = noErr;
    CGRect  docRect = CGRectMake (0, 0, docStP->docSize.h,
                                  docStP->docSize.v);
    CFDataRef       pdfData = CFDataCreateMutable (kCFAllocatorDefault, 0);
    CGContextRef            pdfContext;
    CGDataConsumerRef       consumer;
    CGDataConsumerCallbacks cfDataCallbacks = {MyCFDataPutBytes,
                                        MyCFDataRelease };

    err = PasteboardClear (pasteboard);                                     // 1
    require_noerr err, PasteboardClear_FAILED);

    consumer = CGDataConsumerCreate ((void*)pdfData, &cfDataCallbacks);     // 2

    pdfContext = CGPDFContextCreate (consumer, &docRect, NULL);             // 3
    require(pdfContext != NULL, CGPDFContextCreate_FAILED);

    MyDrawIntoPDFPage (pdfContext, docRect, docStP, 1);                     // 4
    CGContextRelease (pdfContext);                                          // 5

    err = PasteboardPutItemFlavor( pasteboard, (PasteboardItemID)1,         // 6
                        kUTTypePDF, pdfData, kPasteboardFlavorNoFlags );
    require_noerr( err, PasteboardPutItemFlavor_FAILED );

CGPDFContextCreate_FAILED:
PasteboardPutItemFlavor_FAILED:
    CGDataConsumerRelease (consumer);                                       // 7


PasteboardClear_FAILED:
    return err;
}
```

Here's what the code does:

1. Clears the pasteboard of its contents so that this application can own it and add its own data.

2. Creates a data consumer to receive the data from the application.

3. Creates a PDF graphics context, providing the data consumer, the rectangle that defines the size and location of the PDF page, and `NULL` for the auxiliary dictionary. The entire PDF page is supplied here, but in your application you restrict the data you paste to the contents of the selection made by the user. In this example, there isn't any additional information to be used by the PDF context when generating the PDF, so the auxiliary dictionary is `NULL`.
4. Calls an application-defined function to draw the actual data into the PDF graphics context. You need to supply your own drawing function here.
5. Releases the PDF graphics context, which finalizes the PDF data.
6. Puts the PDF data (supplied by the data consumer) on the pasteboard. The `PasteboardPutItemFlavor` function takes the pasteboard cleared earlier, the identifier for the item to add flavor data for, a flavor type, the data to add, and a bit field of flags for the specified flavor.
7. Releases the data consumer.

Copying PDF Data From the Clipboard (Pasteboard)

To bring PDF data back into your application you retrieve the PDF data from the pasteboard, create a Quartz data provider that copies the PDF data into a Quartz buffer, and use the provider to create a `CGPDFDocumentRef` object. You can call `CGContextDrawPDFDocument` to draw the PDF version of your picture in any graphics context. The `PasteboardContainsPDF` routine in Listing 4-7 is taken from the CarbonSketch sample application.

The routine checks whether the pasteboard provided to it contains PDF data. If it does, the PDF data is returned as CFData in the `pdfData` parameter. A detailed explanation for each numbered line of code appears following the listing.

Listing 4-7 A routine that gets PDF data from the pasteboard (Clipboard)

```
static Boolean PasteboardContainsPDF (PasteboardRef inPasteboard,
                                      CFDataRef* pdfData)
{
    Boolean             gotPDF      = false;
    OSStatus            err         = noErr;
    ItemCount           itemCount;
    UInt32              itemIndex;

    err = PasteboardGetItemCount (inPasteboard, &itemCount);                    // 1
    require_noerr(err, PasteboardGetItemCount_FAILED);

    for (itemIndex = 1; itemIndex <= itemCount; ++itemIndex)                    // 2
    {
        PasteboardItemID    itemID;
        CFArrayRef          flavorTypeArray;
        CFIndex             flavorCount;
        CFIndex             flavorIndex;

        err = PasteboardGetItemIdentifier (inPasteboard,                        // 3
                            itemIndex, &itemID );
        require_noerr( err, PasteboardGetItemIdentifier_FAILED );
```

```
        err = PasteboardCopyItemFlavors (inPasteboard, itemID,                  // 4
                                &flavorTypeArray );
        require_noerr( err, PasteboardCopyItemFlavors_FAILED );
        flavorCount = CFArrayGetCount( flavorTypeArray );                       // 5
        for (flavorIndex = 0; flavorIndex < flavorCount; ++flavorIndex)
        {
            CFStringRef             flavorType;
            CFComparisonResult      comparisonResult;

            flavorType = (CFStringRef)CFArrayGetValueAtIndex (                  // 6
                                        flavorTypeArray, flavorIndex );
            comparisonResult = CFStringCompare(flavorType,                      // 7
                                       kUTTypePDF, 0);
            if (comparisonResult == kCFCompareEqualTo)
            {
                if (pdfData != NULL)
                {
                    err = PasteboardCopyItemFlavorData( inPasteboard,           // 8
                                itemID, flavorType, pdfData );
                    require_noerr (err,
                            PasteboardCopyItemFlavorData_FAILED );
                }
                gotPDF = true;                                                  // 9
                break;
            }

PasteboardCopyItemFlavorData_FAILED:
PasteboardGetItemFlavorFlags_FAILED:
        }
        CFRelease(flavorTypeArray);                                             // 10
PasteboardCopyItemFlavors_FAILED:
PasteboardGetItemIdentifier_FAILED:
        ;
    }
PasteboardGetItemCount_FAILED:
    return gotPDF;                                                              // 11
}
```

Here's what that code does:

1. Gets the number of items on the pasteboard.
2. Iterates through each item on the pasteboard.
3. Gets the unique identifier for this pasteboard item.
4. Copies the flavor types for that item ID into an array. Note that the flavor type array is a `CFArrayType` that you need to release later.
5. Gets a count of the flavor types in the array. You need to iterate through these to find the PDF flavor.
6. Gets the flavor type stored in a specific location in the array.
7. Checks for the PDF flavor type. Note that in Mac OS X v10.4 you should use the universal type `kUTTypePDF`, as shown here, instead of `CFSTR('com.adobe.pdf')`.
8. Copies the PDF data, if any is found.

9. Sets the `gotPDF` flag to `true`.
10. Releases the array.
11. Returns `true` if successful.

After you get the PDF data from the pasteboard, you can draw it in your application, using a routine similar to the `DrawPDFData` routine shown in Listing 4-8. The routine takes a `CFDataRef` data type (which is what you get from the routine in Listing 4-7 (page 54) when you copy data from the pasteboard), a graphics context, and a destination rectangle. A detailed explanation for each numbered line of code appears following the listing.

Listing 4-8 A routine that draws PDF data

```
static void MyPDFDataRelease (void *info, const void *data, size_t size)
{
    if(info != NULL)
        CFRelease((CFDataRef)info);
}

static void DrawPDFData (CGContextRef ctx, CFDataRef pdfData,
                         CGRect dstRect)
{
    CGDataProviderRef   provider;
    CGPDFDocumentRef    document;
    CGPDFPageRef        page;
    CGRect              pageSize;

    CFRetain (pdfData);
    provider = CGDataProviderCreateWithData (pdfData,                       // 1
                        CFDataGetBytePtr(pdfData),
                        CFDataGetLength(pdfData), MyPDFDataRelease);
    document = CGPDFDocumentCreateWithProvider (provider);                  // 2
    CFRelease(provider);                                                    // 3
    page = CGPDFDocumentGetPage (document, 1);                              // 4
    pageSize = CGPDFPageGetBoxRect (page, kCGPDFMediaBox);                  // 5

    CGContextSaveGState(ctx);                                               // 6
    MySetupTransform(ctx, pageSize, dstRect);                               // 7
// Scale pdf page into dstRect, if the pdf is too big
    CGContextDrawPDFPage (ctx, page);                                       // 8
    CGContextRestoreGState(ctx);                                            // 9

    CFRelease(document);                                                    // 10
}
```

Here's what the code does:

1. Creates a data provider to read PDF data provided to your application from a `CGDataRef` data source. Note that you need to supply a release function for Quartz to call when it frees the data provider.
2. Creates a CGPDFDocument object using data supplied by the data provider you just created.
3. Releases the data provider. You should release a data provider immediately after using it to create the CGPDFDocument object.

4. Gets the first page of the newly created document.
5. Gets the media box rectangle for the PDF. You need this to determine how to scale the content later.
6. Saves the graphics state so that you can later restore it.
7. Calls an application-defined routine to set a transform, if necessary. This routine (which you would need to write) determines whether the PDF is too big to fit in the destination rectangle, and transforms the context appropriately.
8. Draws the PDF document into the graphics context that is passed to the `DrawPDFData` routine.
9. Restores the graphics state.
10. Releases the PDF document object.

Relevant Resources

See these reference documents:

- *CGContext Reference*
- *CGImage Reference*
- *CGPDFDocument Reference*
- *Pasteboard Manager Reference*
- *QuickDraw Reference*, describes the `QDPictRef` data type that represents a QuickDraw picture in the Quartz graphics environment.

For comprehensive information about using pasteboards in Carbon applications, see *Pasteboard Manager Programming Guide*.

For more information about uniform type identifiers, see the document *Uniform Type Identifiers Overview*.

To learn more about drawing QDPict pictures in a Carbon application, see the project example *CGDrawPicture* in the Graphics & Imaging Quartz Sample Code Library.

Working With Bitmap Image Data

A Quartz image (`CGImageRef` data type) is an abstract representation of a bitmap image that encapsulates image data together with information about how to interpret and draw the data. A Quartz image is immutable—that is, you cannot "draw into" a Quartz image or change its attributes. You use Quartz images to work with bitmap data in a device-independent manner while taking advantage of built-in Quartz features such as color management, anti-aliasing, and interpolation.

This chapter provides strategies for performing the following tasks:

- "Moving Bits to the Screen" (page 59) outlines the functions you can use to move bits, should you really need to do so.
- "Getting Image Data and Creating an Image" (page 59) discusses strategies for obtaining bitmap image data.
- "Changing Pixel Depth" (page 60) discusses why changing pixel depth is not an issue in Quartz.
- "Drawing Subimages" (page 61) shows a variety of ways that you can use Quartz to draw a portion of an image.
- "Resizing Images" (page 63) gives information on changing the size or scaling of an image.

Moving Bits to the Screen

The Quartz imaging model does not provide the same sort of bit-copying functionality as QuickDraw because Quartz is not based on bitmap graphics. Most of the time you'll want to adopt strategies that are not bit-based. However if you really need to draw bits, Quartz has the capability. To draw bits, create a bitmap graphics context and draw into it. You can then create an image from the bitmap graphics context by calling the function `CGBitmapContextCreateImage` (available starting in Mac OS X v10.4). To draw the image to screen, call `CGContextDrawImage`, supplying the appropriate windows graphics context.

Drawing to a bitmap graphics context, caching the drawing to a CGImage, and then drawing the image to a window graphics context is faster than copying the bits back from the backing store. (Note that you can no longer assume that window back buffers are in main memory.) Keep in mind that the source pixels of a CGImage are immutable.

Getting Image Data and Creating an Image

Quartz image data can originate from three types of sources: a URL that specifies a location, a CFData object, which is a simple allocated buffer, and raw data, for which you provide a pointer and a set of callbacks that take care of memory management for the data.

To obtain image data from a data source, you use either a data provider (prior to Mac OS X v10.4) or an image source (starting in Mac OS X v.10.4). You can think of data providers and image sources as "data managers." Quartz uses a data manager to obtain the source image data. The data manager handles the messy details of supplying bytes in their correct sequence—for example, a JPEG data provider might handle the task of decompressing the image data.

Here is the general procedure for getting image data from a data source and creating an image from it:

1. Create the data manager. If your application runs only in Mac OS X v10.4, use one of the CGImageSource creation functions. If your image data is in a common format (JPEG, PNG, and so forth) you can use the function `CGImageSourceCreateWithURL`. If your image data is in a nonstandard or proprietary format, you'll need to set up a data provider along with callbacks for managing the data. For more information, see Data Management in *Quartz 2D Programming Guide*.

2. Supply the data manager to an image creation function. If you've created an image source, you supply the CGImageSource object to the function `CGImageSourceCreateImageAtIndex`. Image source indexes are zero based, so if your image file contains only one image, supply `0`. If you've created a data provider, you supply it as a parameter to an image creation function (`CGImageCreate`, `CGImageCreateWithJPEGDataProvider`, or `CGImageCreateWithPNGDataProvider`). For a description of all the image creation functions in Quartz, see Bitmap Images and Image Masks in *Quartz 2D Programming Guide*.

To draw the newly created Quartz image in a graphics context, you call `CGContextDrawImage` and specify the destination rectangle for the image. This function does not have a parameter for a source rectangle; if you want to crop the image or extract a subimage, you'll need to write some additional code—see "Drawing Subimages" (page 61).

When you move image data from QuickDraw to Quartz, you might notice that the pixels in an image drawn in a Quartz graphics context look different from the pixels in the same image in QuickDraw. Changes are due to factors such as:

- Anti-aliasing around the edges of the image
- Image interpolation due to scaling
- Alpha-based blending of image pixels with background pixels
- Color matching, if the image and context color spaces are different
- Color adjustments to match the display hardware

Changing Pixel Depth

For historical reasons, QuickDraw supports pixel formats with depths that range from 1 through 32 bits. When copying pixels between ports that have different formats and depths, the `CopyBits` function automatically converts each source pixel to the destination depth. (When the depth is reduced, `CopyBits` also uses dithering to maintain image quality.)

Applications that run on older systems can sometimes save memory and improve rendering performance by using `CopyBits` to reduce the depth of images that are drawn. Modern hardware has plenty of memory and rendering horsepower, and there is no longer any motivation to reduce image depth.

Mac OS X supports direct displays with pixel depths of 16 or 32, and Quartz bitmap contexts support 16-bit and 32-bit pixel formats. Quartz requires these higher depths to ensure that images can always be rendered faithfully on any destination device.

Drawing Subimages

In QuickDraw, you can use `CopyBits` to move a rectangular section of the source pixel map to the destination pixel map. This feature allows you to crop an image by copying a subimage.

Some applications have used this feature as a way to optimize the storage, management, and retrieval of small images. These applications assemble and cache numerous small images in a single offscreen buffer and use `CopyBits` to copy them to the screen as needed. For example, a game could cache all the images used on each level of play, making image management easier and improving performance.

Unlike `CopyBits`, `CGContextDrawImage` does not allow you to specify a source rectangle. However, there are some good solutions in Quartz for drawing subimages of larger images. In Mac OS X v10.4 and later, you can use the function `CGImageCreateWithImageInRect` to create a subimage to draw. Otherwise, you can draw a subimage using a clip, a bitmap context, or a custom data provider.

Using CGImageCreateWithImageInRect

Introduced in Mac OS X v10.4, the function `CGImageCreateWithImageInRect` uses a source rectangle to create a subimage from an existing Quartz image. Because the subimage is also a Quartz image (`CGImageRef`), Quartz can cache the subimage for better drawing performance. To draw the subimage, you use the function `CGContextDrawImage`.

For more information and a code example, see Bitmap Images and Image Masks in *Quartz 2D Programming Guide*.

Using a Clip

This approach draws the entire image into a graphics context and clips the drawing to get the desired subimage. As in `CopyBits`, you specify source and destination rectangles. The source rectangle defines the desired subimage, and the destination rectangle determines the clip. The full image is drawn into a third drawing rectangle, which is carefully constructed so that `CGContextDrawImage` translates and scales the image appropriately to get the desired effect. You should specify the source rectangle in image units and the destination rectangle in user space units.

Listing 5-1 shows how you could implement this solution. A detailed explanation of each numbered line of code follows the listing.

A drawback to this approach is that clipping an image may introduce anti-aliased edges when the subimage is rendered. For information on controlling anti-aliasing in a context, see Graphics Contexts in *Quartz 2D Programming Guide*.

Listing 5-1 A routine that draws a subimage by clipping, translating, and scaling

```
void MyDrawSubImage (
```

```
    CGContextRef context, CGImageRef image, CGRect src, CGRect dst)
{
    /* the default drawing rectangle */
    float w = (float) CGImageGetWidth(image);
    float h = (float) CGImageGetHeight(image);
    CGRect drawRect = CGRectMake (0, 0, w, h);                          // 1

    if (!CGRectEqualToRect (src, dst))
    {                                                                   // 2
        float sx = CGRectGetWidth(dst) / CGRectGetWidth(src);
        float sy = CGRectGetHeight(dst) / CGRectGetHeight(src);
        float dx = CGRectGetMinX(dst) - (CGRectGetMinX(src) * sx);
        float dy = CGRectGetMinY(dst) - (CGRectGetMinY(src) * sy);
        drawRect = CGRectMake (dx, dy, w*sx, h*sy);
    }

    CGContextSaveGState (context);                                      // 3
    CGContextClipToRect (context, dst);                                 // 4
    CGContextDrawImage (context, drawRect, image);                      // 5
    CGContextRestoreGState (context);
}
```

Here's what the code does:

1. Defines the drawing rectangle. If the source and destination rectangles are identical, the default values are correct.
2. The source and destination rectangles are different, so the image needs to be scaled and translated. This code block adjusts the drawing rectangle so that `CGContextDrawImage` performs the desired transformation; Quartz draws the image to fit the destination rectangle.
3. Pushes the current graphics state onto the state stack, in preparation for changing the clipping area.
4. Sets the clipping area to the destination rectangle.
5. Draws the image such that the desired subimage is visible in the clipping area.

Using a Bitmap Context

You can use a bitmap context to draw a subimage by following these steps:

1. Call the function `CGBitmapContextCreate` to create a bitmap that's large enough for the subimage data and that uses the appropriate pixel format for the source image data. The pixel format of the bitmap context must be one of the supported formats—for more information, see Bitmap Images and Image Masks in *Quartz 2D Programming Guide*.
2. Create a drawing rectangle. You will want to draw the image so that Quartz writes into the bitmap precisely the subimage data that's wanted. To accomplish this, draw the full image into a rectangle of the same size, and then translate the rectangle so that the origin of the subimage is aligned with the origin in the bitmap context.
3. Draw the source image into the bitmap context by calling the function `CGContextDrawImage`. The drawing rectangle is translated such that the bitmap ends up containing precisely the pixel data in the subimage.

After drawing the source image in the bitmap context, you use the context data to create a Quartz image that represents the subimage. In Mac OS X v10.4 and later, you can use the function `CGBitmapContextCreateImage` to create this image. You can draw the image in any graphics context or save it for later use.

Using a Custom Data Provider

In this method, you create a custom data provider that supplies the bytes in the subimage and use this data provider to create a Quartz image (`CGImageRef`). To use this method, you need to have direct access to the source image data.

One way to implement this method is to write a set of callback functions for a sequential-access data provider. Your `GetBytes` callback function needs to extract the pixel values in a subimage from the full bitmap and supply these bytes to the caller. When you create a data provider that uses your callbacks, you can also pass private information, such as the base address of the bitmap and the subimage rectangle. Quartz passes this information to your callbacks.

For each different subimage you want to draw, be sure to create a new data provider, and a new Quartz image to represent the subimage.

Resizing Images

In QuickDraw, the `CopyBits` function is often used to change the size or scale of an image, vertically or horizontally or both. Pixels are averaged during shrinking.

In Quartz, you can resize an image by drawing the image into a smaller or larger destination rectangle. Given the dimensions of the source image, you compute the dimensions of the destination rectangle needed to achieve the desired scaling. Then you use `CGContextDrawImage` to draw the image in the destination rectangle.

Quartz also allows you to scale (as well as rotate, skew, and translate) all subsequent drawing in a graphics context—including images—using an affine transformation.

Quartz draws images using an interpolation (or pixel-smoothing) algorithm that provides high-quality results when the image is scaled. When you create a Quartz image, you specify whether interpolation should be used when the image is drawn in a Quartz context. You can also use the function `CGContextSetInterpolationQuality` to set the level of interpolation quality in the context. This parameter is merely a hint to the context—not all contexts support all interpolation quality levels.

Relevant Resources

In *Quartz 2D Programming Guide*, see:

- Bitmap Images and Image Masks, which shows how to work with images and image masks.
- Data Management, which discusses strategies for getting data into and out of Quartz using data providers, image sources, and image destinations.

See these reference documents:

- *CGImage Reference*
- *CGImageDestination Reference*
- *CGImageSource Reference*
- *CGDataConsumer Reference*
- *CGDataProvider Reference*

Masking

In QuickDraw, masking can be accomplished using bitmaps that to determine how color information is copied from the pixels in a source image to the corresponding pixels in a destination image. Masks are passed to the QuickDraw functions `CopyMask` and `CopyDeepMask` in the `maskBits` parameter. Masks can have a depth of up to 8 bits per component.

QuickDraw uses the following compositing formula to compute the contribution of each color component in the source and destination pixels:

```
(1 - mask) x source + (mask) x destination
```

In this formula, the mask values are normalized to range from 0 through 1. High mask values reduce the contribution of source pixels—in effect, the mask contains "inverse alpha" information with respect to the source bitmap.

Quartz supports two kinds of masks:

- An **image mask**. This is a specialized image (`CGImageRef`), created by calling the function `CGImageMaskCreate`, that contains only inverse alpha information. Image masks can have a depth of up to 8 bits per pixel. Quartz image masks are a direct analogue of QuickDraw masks; the same compositing formula is used to apply mask values to source and destination color values, but on a per pixel basis:

  ```
  (1 - mask) x source + (mask) x destination
  ```

  For more information about image masks, see Bitmap Images and Image Masks in *Quartz 2D Programming Guide*.

- A **masking image**. In Mac OS X v10.4 and later, you can mask an image with another image by calling the function `CGImageCreateWithMask` and supplying an image as the `mask` parameter rather than an image mask. Use an image as a mask when you want to achieve an effect opposite of what you get when you mask an image with an image mask. Source samples of an image that is used as a mask operate as alpha values. An image sample value (S):

  - Equal to 1 paints the corresponding image sample at full coverage.
  - Equal to 0 blocks painting the corresponding image sample.
  - Greater than 0 and less than 1 allows painting the corresponding image sample with an alpha value of S.

Starting in Mac OS X v10.4, you can use the function `CGImageCreateWithMask` to mask an image with either an image mask or an image. The function `CGImageCreateWithMaskingColors` is used for chroma key masking. Masks can also be intersected with the current clipping area in a graphics context using the function `CGContextClipToMask`.

Replacing Mask Regions

In the QuickDraw functions `CopyBits` and `CopyDeepMask`, the mask region parameter prevents some of the pixels in the source image from being copied to the destination, similar to the clipping region in a graphics port. A procedure that uses this type of binary mask might look like this:

1. Use `CalcCMask` or `SeedCFill` to create a bitmap of the mask.
2. Use `BitmapToRegion` to create a mask region.
3. Use `CopyBits`, passing the mask region as the last parameter.

Prior to Mac OS X v10.4, there is no direct support in Quartz for combining an image with a mask at runtime. To apply a clipping mask to an image, the recommended solution is to set up the clipping area in the context before drawing the image. This approach works well whenever you can specify the shape of the clipping mask using a graphics path.

Think Differently: Do you really need to use a mask? The Quartz alpha channel lets you create artwork that has built-in masking. It's much more efficient to use the alpha channel to achieve masking effects than to try to mimic the masking that was required to achieve certain effects in QuickDraw.

When it's difficult to construct a path to specify the desired clip, you can use the alpha channel in an image as a built-in clipping mask. (The alpha channel is an extra component that determines the color opacity of each sample or pixel in an image. When the image is drawn, the alpha channel is used to control how the image is blended or composited with background color.) When a mask is an integral part of an image, as in a game sprite, you can use a photo editing application to transfer the mask into the alpha channel of the image permanently.

In Mac OS X v10.4, Quartz provides some new solutions for applications that need to apply clipping masks to images:

- The function `CGContextClipToMask` intersects the clipping area in a context with a mask. In this solution, all subsequent drawing is affected.
- The function `CGImageCreateWithMask` combines an image with a clipping mask. The mask can be a grayscale image that serves as an alpha mask, or an Quartz image mask that contains inverse alpha information.

Both solutions use masks that are bitmap images with a pixel depth of up to 8 bits. Typically, the mask is the same size as the image to which it is applied.

For more information about using masks, see Bitmap Images and Image Masks in *Quartz 2D Programming Guide*.

Relevant Resources

In *Quartz 2D Programming Guide*, see:

- Bitmap Images and Image Masks

See these reference documents:

- *CGContext Reference*
- *CGImage Reference*

Updating Regions

Prior to Mac OS X, the Mac OS Toolbox relied on the concept of invalidating regions that needed updating. When a portion of a window needed updating, the Event Manager sent an update event to your application. Your application responded by calling the Window Manager function `BeginUpdate`, redrawing the region that needed updating and then calling `EndUpdate` to signal that you were finished with the update. By using `BeginUpdate` and `EndUpdate`, the Window Manager tracked the actual areas that needed updating and your drawing was clipped only to the areas that needed updating, thus optimizing performance. To achieve a similar functionality in Mac OS X, you use HIView. See "Updating Windows" (page 69).

In your QuickDraw application, you might have used region updating in conjunction with XOR to minimize the amount of drawing that needed to be done for animation or editing. Quartz does not support XOR, but it does support transparent windows. You create a transparent window, position it on top of your existing window, and then use the overlay to draw your animation or perform your text editing. When you're done, you throw away the overlay and update the original window, if necessary. See "Using Overlay Windows" (page 70), which describes how to provide a selection rectangle (marching ants) around a user-selected shape and how to provide visual feedback when the user drags a selection.

If you need to handle the content in a scrolling rectangle, use HIView to create a scrolling view (see the function `HIScrollViewCreate`). This provides an easy way to display a scrollable image. You can simply embed an image view within the scroll view and the scroll view automatically handles the scrolling of the image. You don't need to install handlers for live feedback, adjust scroller positions and sizes, or move pixels. See *HIView Programming Guide* and *HIView Reference* for more information.

Updating Windows

Quartz does not handle window invalidation and repainting. That's the job of whatever window system is in use—Cocoa or Carbon. Quartz is exactly like QuickDraw in this regard. QuickDraw doesn't know anything about invalidation and update regions; that's always been handled by the Window Manager.

To eliminate unnecessary drawing in your application, you can follow one of two approaches— draw the changed areas only, or intersect the changed areas with the context's clipping area before drawing the window. If the changed area is a complex shape, it may be sufficient to clip using a bounding box that encloses the shape instead of trying to construct a path that represents the shape.

Carbon applications need to use windows in compositing mode, and then, instead of drawing into the window content area, draw into views. An application can invalidate all or part of a view using functions such as

- `HIViewSetNeedsDisplay`, which marks a view as needing to be completely redrawn, or completely valid.
- `HIViewSetNeedsDisplayInRect`, which marks a rectangle contained in a view as needing to be redrawn, or valid. The rectangle that you pass to the function is intersected with the visible portion of the view.

- `HIViewSetNeedsDisplayInShape`, which marks a portion of a view as either needing to be redrawn or valid. The shape that you pass to the function is intersected with the visible portion of the view.

When the application draws in the Quartz context obtained from the Carbon even `kEventControlDraw`, the clipping area is already configured to eliminate unnecessary drawing. For more information, see *Upgrading to the Mac OS X HIToolbox*, *HIView Programming Guide*, and *HIView Reference*.

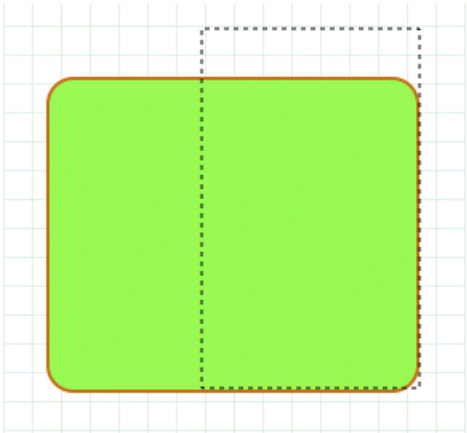
Using Overlay Windows

If you're trying to preserve the contents of a window so that you can do quick animation or editing without having to redraw complex window contents, you can use Mac OS X window compositing to your advantage. You can overlay a transparent window on top of an existing window and use the overlay for drawing new content or performing animation.

The performance using overlay windows on Quartz Extreme systems is much better than any caching and blitting scheme using QuickDraw. That's because Quartz puts the GPU to work for you. Using overlay windows is less CPU-intensive than having either Quartz or QuickDraw perform blending. On systems prior to Quartz Extreme, the performance is still acceptable.

The CarbonSketch application uses overlay windows in two ways: to indicate a user selection with "marching ants," as shown in Figure 7-1 (page 70), and to provide feedback on dragging and resizing an object, as shown in Figure 7-2 (page 71). Before continuing, you might want to run CarbonSketch, create a few shapes, and then see how selecting, dragging, and resizing work from the user's perspective. You can find the application in `/Developer/Examples/Quartz`.

Figure 7-1 Using "marching ants" to provide feedback about selected content

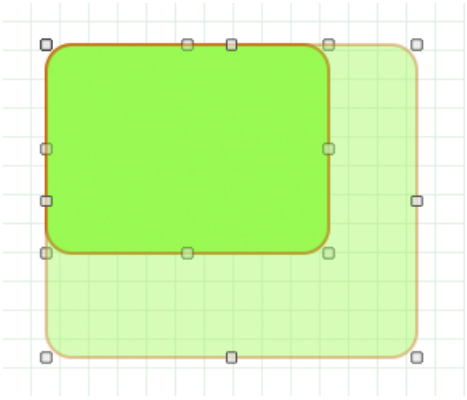


Note: CarbonSketch uses marching ants as an homage to QuickDraw. See the *Apple Human Interface Guidelines* for details on the preferred visual feedback to provide to the users about a selection.

You'll want to study the CarbonSketch application to understand the implementation details, but the general idea of how it works is as follows. When there is a mouse-down event, a mouse-tracking routing creates a rectangle that is the same size as the document that the user is drawing in. Then, it clips the graphics context used for the document (referred to here as the drawing graphics context) and the graphics context used for an overlay window to the document rectangle. The overlay graphics context is now ready for drawing.

Before any drawing takes place in the overlay graphics context, the application simply sets the alpha transparency of the stroke and fill colors to an alpha value that ensures that the original drawing underneath shows through. In addition, the "faded" version of the drawing in the overlay window adds to aesthetics of the dragging effect. The transparency also provides feedback to the user that indicates an action is occurring (dragging, selecting, resizing) but has not yet been completed.

Figure 7-2 Using an overlay window to provide feedback on dragging and resizing



Now that you understand the overall approach to using an overlay window, let's take a look at mouse tracking in Quartz for a simple sketching application. Suppose that this simple sketching application lets a user draw a path in a view by clicking and dragging the pointer. The code in Listing 7-1 shows the routines that are key to handling mouse tracking for this simple sketching application.

The `CanvasViewHandler` routine is a Carbon event handler that processes the `kEventControlTrack` Carbon event. The `ConvertGlobalQDPointtoViewHIPoint` routine converts global Quick Draw points to HIView coordinates, which are local, relative to the HIView. Also shown in the listing is the `CanvasData` structure that keeps track of the HIView object associated with the view, the origin of the view, and the current path that's drawn in the view. Note that the path is mutable.

The `CanvasViewHandler` routine is incomplete; it handles just the one event. The ellipses indicate where you would insert code to handle other events. The routine first gets the mouse location (provided as global coordinates) and resets the CGPath object by releasing any non null path. Then, as long as the mouse button is down, the routine tracks the mouse location, converting each global coordinate to a view-relative coordinate, adding a line to the path, and updating the display. When the user releases the mouse, the routine sends pat the control part upon which the mouse was released.

Listing 7-1 Code that handles mouse tracking for a simple drawing application

```
struct CanvasData {
```

```
    HIViewRef           theView;
    HIPoint             canvasOrigin;
    CGMutablePathRef    thePath;
};
typedef struct CanvasData   CanvasData;

// ---------------------------------------------
static HIPoint  ConvertGlobalQDPointToViewHIPoint (
                            const Point inGlobalPoint,
                            const HIViewRef inDestView )
{
    Point       localPoint = inGlobalPoint;
    HIPoint     viewPoint;
    HIViewRef   contentView;

    QDGlobalToLocalPoint (GetWindowPort(GetControlOwner(inDestView)),
                             &localPoint );

    // convert the QD point to an HIPoint
    viewPoint = CGPointMake(localPoint.h, localPoint.v);

    // get the content view (which is what the local point is relative to)
    HIViewFindByID (HIViewGetRoot(GetControlOwner(inDestView)),
                         kHIViewWindowContentID, &contentView);

    // convert to view coordinates
    HIViewConvertPoint (&viewPoint, contentView, inDestView );
    return viewPoint;
}

// ---------------------------------------------- -
static OSStatus CanvasViewHandler (EventHandlerCallRef inCallRef,
                            EventRef inEvent,
                            void* inUserData )
{
    OSStatus        err = eventNotHandledErr;
    ControlPartCode part;
    UInt32          eventClass = GetEventClass( inEvent );
    UInt32          eventKind = GetEventKind( inEvent );
    CanvasData*     data = (CanvasData*)inUserData;

// (...)
        case kEventControlTrack:
            {
                HIPoint  where;
                MouseTrackingResult mouseResult;
                CGAffineTransform   m = CGAffineTransformMakeTranslation (
                            data->canvasOrigin.x,
                            data->canvasOrigin.y);

                // Extract the mouse location (global coordinates)
                GetEventParameter( inEvent, kEventParamMouseLocation,
                                    typeHIPoint, NULL,
                                    sizeof( HIPoint ),
                                    NULL, &where );

                // Reset the path
                if (data->thePath != NULL)
```

```
                CGPathRelease(data->thePath);

            data->thePath = CGPathCreateMutable();
            CGPathMoveToPoint(data->thePath, &m, where.x, where.y);

            while (true)
            {
                Point qdPt;

                // Watch the mouse for change
                err = TrackMouseLocation ((GrafPtr)-1L, &qdPt,
                                  &mouseResult );

                // Bail out when the mouse is released
                if ( mouseResult == kMouseTrackingMouseReleased )
                    break;

                // Need to convert from global
                where = ConvertGlobalQDPointToViewHIPoint(qdPt,
                                            data->theView);
                fprintf(stderr, "track:  (%g, %g)\n", where.x,
                                          where.y);
                CGPathAddLineToPoint(data->thePath, &m, where.x,
                                          where.y);

                part = 0;
                SetEventParameter(inEvent, kEventParamControlPart,
                                typeControlPartCode,
                                sizeof(ControlPartCode),
                                &part);

                HIViewSetNeedsDisplay(data->theView, true);
            }

            // Send back the part upon which the mouse was released
            part = kControlEntireControl;
            SetEventParameter(inEvent, kEventParamControlPart,
                                typeControlPartCode,
                                sizeof(ControlPartCode),
                                &part);
        }
        break;
// (...)
```

Relevant Resources

For information on programming with HIView, see:

- *HIView Programming Guide*
- *Upgrading to the Mac OS X HIToolbox*

See these reference documents:

- *HIView Reference*

Hit Testing

Hit testing is a generic term for any procedure that determines whether a mouse click occurs inside a shape or area. Quartz provides two solutions for hit testing:

- A path-oriented solution, which checks to see if the area enclosed by a path contains the hit point. See "Using a Path for Hit Testing" (page 75).
- A pixel-oriented solution, which involves drawing into a 1x1 bitmap context with the appropriate transform. This solution is used in the CarbonSketch sample application that's available in `/Developer/Examples/Quartz`. See "Using a 1x1 Bitmap Context for Hit Testing" (page 75).

When you are hit-testing, you may need to know the transform that Quartz uses to map between user and device space. The function `CGContextGetUserSpaceToDeviceSpaceTransform`, introduced in Mac OS X v10.4, returns the affine transform that maps user space to device space in a graphics context. There are other convenience functions for transforming points, sizes, and rectangles between these two coordinate spaces. For example, `CGContextConvertPointToUserSpace` transforms a point from the device space of a context to its user space.

Using a Path for Hit Testing

In Mac OS X v10.4 and later, you can use the function `CGPathContainsPoint` to find out if a point is inside a closed path. A direct replacement for `PtInRgn`, this function is useful when you have a corresponding path for each shape being tested. Here's the prototype:

```
bool CGPathContainsPoint (CGPathRef path, const CGAffineTransform *m,
                          CGPoint point, bool eoFill);
```

`CGPathContainsPoint` returns true if the point is inside the area that's painted when the path is filled using the specified fill rule. You can also specify a transform that's applied to the point before the test is performed. (Assuming the point is in local view coordinates and the path uses the same coordinate space, a transform is probably not needed.)

Using a 1x1 Bitmap Context for Hit Testing

Here's the idea behind the pixel-oriented solution:

1. Create a 1x1 bitmap context that contains a single pixel. (The bitmap you provide for this context consists of a single, unsigned 32-bit integer.) The coordinates of this pixel are (0, 0).
2. Initialize the bitmap to `0`. Effectively, this means the pixel starts out having no color.

3. If necessary, convert the coordinates of the hit point from window space into user space for the Quartz context in which you are drawing.

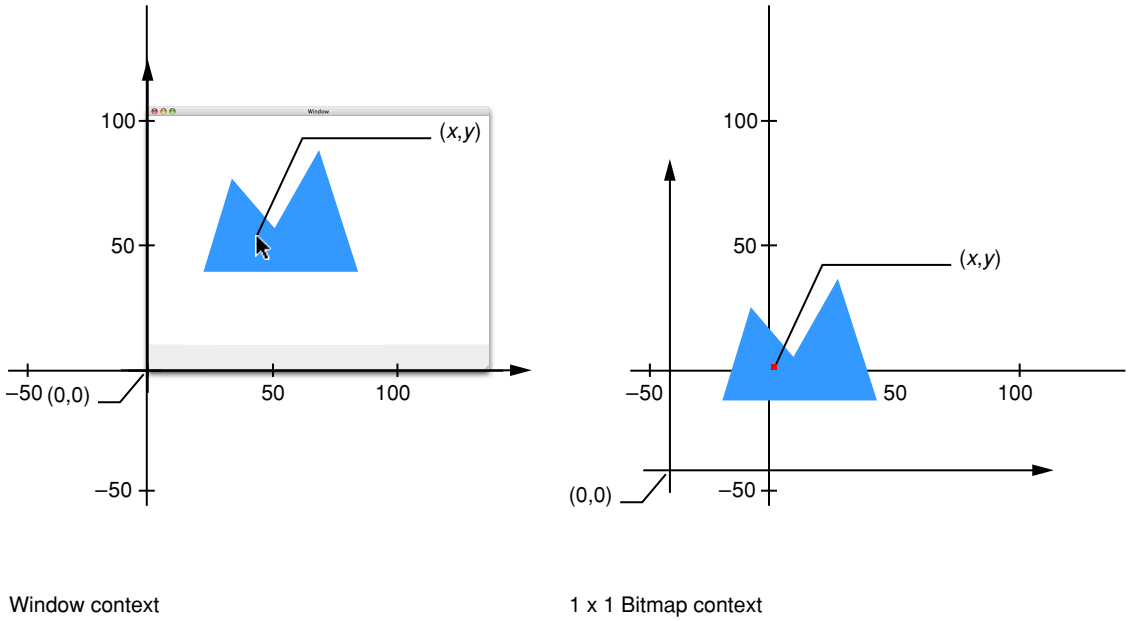
4. Translate the current transformation matrix (CTM) in the bitmap context such that the hit point and the bitmap have the same coordinates. If the coordinates of the hit point are (*x*, *y*), you would use the function `CGContextTranslateCTM` to translate the origin by (–*x*, –*y*).

   Figure 8-1 illustrates how translation is used to position the hit point in a shape directly over the pixel in a 1x1 bitmap context.

5. Iterate through your list of graphic objects. For each object, draw the object into the bitmap context and check the bitmap to see whether the value of the pixel has changed. If the pixel changes, the hit point is contained in the object.

This solution is very effective but may require some calibration. By default, all drawing in a window or bitmap context is rendered using anti-aliasing. This means the color of pixels located just outside the border of a shape or image may change, and this could affect the accuracy of hit testing. (The path-oriented solution doesn't have this concern, because it is purely mathematical and doesn't require any rendering.)

Figure 8-1 Positioning the hit point in the bitmap context



For this method to work properly, each graphic object must be drawn at the same location in both the user's window context and the bitmap context.

Listing 8-1 shows how to write a function that returns a 1x1 bitmap context suitable for hit-testing. In this implementation, the context is created once and cached for later reuse. A detailed explanation for each numbered line of code follows the listing.

Listing 8-1 A routine that creates a 1x1 bitmap context

```
CGContextRef My1x1BitmapContext (void)
{
```

```
    static CGContextRef context = NULL;
    static UInt32 bitmap[1];                                                    // 1

    if (context == NULL)                                                        // 2
    {
        CGColorSpaceRef cs = MyGetGenericRGBColorSpace();                       // 3

        context = CGBitmapContextCreate (                                       // 4
            (void*) bitmap,
            1, 1,   // width & height
            8,      // bits per component
            4,      // bytes per row
            cs,
            kCGImageAlphaPremultipliedFirst
        );
        CGContextSetFillColorSpace (context, cs);                               // 5
        CGContextSetStrokeColorSpace (context, cs);                             // 6
    }
    return context;
}
```

Here's what the code does:

1. Reserves memory for the 1-pixel bitmap.
2. Checks to see if the context exists.
3. Creates a GenericRGB color space for the bitmap context. For more information on creating a GenericRGB color space, see "Creating Color Spaces" (page 42). Note that this is a get routine, which means that you do not release the color space.
4. Creates a 1x1 bitmap context with a 32-bit ARGB pixel format. The context is created once and saved in a static variable.
5. Sets the fill color space to ensure that drawing takes place in the correct, calibrated color space.
6. Sets the stroke color space.

Listing 8-2 shows how to write a simplified hit testing function. Given a hit point with user space coordinates, this function determines if anything drawn in the view contains the point. Additional code would be needed for hit-testing in a view with several graphic objects or control parts.

Listing 8-2 A routine that performs hit testing

```
ControlPartCode MyContentClick (MyViewData *data, CGPoint pt)
{
    CGContextRef ctx = My1x1BitmapContext();
    UInt32 *baseAddr = (UInt32 *) CGBitmapContextGetData (ctx);             // 1
    baseAddr[0] = 0;                                                        // 2

    CGContextSaveGState (ctx);                                              // 3
    CGContextTranslateCTM (ctx, -pt.x, -pt.y);                              // 4
    (*data->proc) (ctx, data->bounds);                                      // 5
    CGContextRestoreGState (ctx);                                           // 6
```

```
    if (baseAddr[0] != 0)                                                    // 7
        return 1;
    else
        return 0;
}
```

Here's what the code does:

1. Gets the address of the 1-pixel bitmap used for hit testing.
2. Clears the bitmap.
3. Saves the graphics state in the bitmap context. This is necessary because the context may be used again.
4. Makes the bitmap coordinates equal to the hit-point coordinates.
5. Draws the object being tested into the bitmap context.
6. Restores the graphics state saved in step 3.
7. Checks to see whether the pixel has changed, and returns a part code of 0 or 1 to indicate whether a hit occurred.

Listing 8-3 shows how a handler for the `kEventControlHitTest` event might detect a mouse click inside your drawing in a view that's embedded inside a composited window. A detailed explanation for each numbered line of code follows the listing.

Listing 8-3 A routine that handles a hit-test event in a composited window

```
OSStatus MyViewHitTest (EventRef inEvent, MyViewData *data)
{
    ControlPartCode partCode;
    OSStatus err = noErr;
    HIPoint point;

    (void) GetEventParameter (inEvent, kEventParamMouseLocation,
        typeHIPoint, NULL, sizeof(HIPoint), NULL, &point);                   // 1

    ControlPartCode partCode = MyContentClick (data,
        CGPointMake (point.x, data->bounds.size.height - point.y));          // 2

    (void) SetEventParameter (inEvent, kEventParamControlPart,               // 3
        typeControlPartCode, sizeof(ControlPartCode), &partCode);

    return err;
}
```

Here's what the code does:

1. Gets the hit point in local view coordinates.
2. Checks to see whether the hit point is inside the drawing. A part code of 1 indicates that a hit occurred. The hit-testing function expects a point of type `CGPoint` (y-axis pointing upwards), so this code flips the y-coordinate of the hit point.
3. Sets the part code parameter in the `kEventControlHitTest` event.

Relevant Resources

See these reference documents:

- *CGContext Reference*
- *CGGeometry Reference*

Offscreen Drawing

QuickDraw applications often draw in an offscreen graphics world and use `CopyBits` to blit the image to the screen in one operation. Prior to Mac OS X, this was the recommended way to prevent flicker during lengthy drawing operations. Windows in Mac OS X are double-buffered, and window buffers are flushed automatically inside the application event loop. Therefore the use of offscreen graphics worlds for this purpose should no longer be necessary.

There are occasions when it still makes sense to draw offscreen and move the offscreen image into a window in a single operation. In Mac OS X, the primary motivation for drawing offscreen is to cache content. For example, you may want to cache an image that's used more than once, or move selected areas of a large image into a window at different times. During rapid animation sequences, some applications prepare a background image offscreen, move the background to the window as a unit, and draw the animated parts of the scene over the background.

Quartz provides two offscreen drawing environments: bitmap graphics contexts and CGLayer objects (introduced in Mac OS X 10.4). The HIView function `HIViewCreateOffscreenImage` is also worth considering if your application is HIView based. This function creates a CGImage object for the HIView passed to it.

If your application runs in Mac OS X v10.4 and later, you should consider using CGLayer objects for offscreen drawing. Prior to that version, offscreen drawing is done to a bitmap graphics context.

Using a Bitmap Context for Offscreen Drawing

A bitmap graphics context in Quartz is analogous to an offscreen graphics world with user-supplied storage for the pixel map (`NewGWorldFromPtr`). You can create bitmap contexts with many different pixel formats, including 8-bit gray, 16-bit RGB, and 32 bit RGBA, ARGB, and CMYK.

You create a bitmap context by calling the function `CGBitmapContextCreate` and passing in a specific set of attributes, including a bitmap into which Quartz renders your drawing. You're free to use the bitmap for other purposes—for example, you could create a bitmap context and a graphics world that share the same memory.

After drawing in a bitmap context, you can easily transfer the bitmap image to another Quartz context of any type. To maintain device independence, copying an image is a drawing operation and not a blitting operation. There are two steps:

1. Create a Quartz image from the bitmap. In Mac OS X v10.4 and later, you can use the function `CGBitmapContextCreateImage`.
2. Draw the image in the destination context using the function `CGContextDrawImage`.

For detailed information about creating and using bitmap contexts, see Graphics Contexts in *Quartz 2D Programming Guide*.

Using a CGLayer Object for Offscreen Drawing

Starting in Mac OS X 10.4, the recommended way to draw offscreen is to create a CGLayer object and draw to it. CGLayers are opaque types that provide a context for offscreen drawing. A CGLayer object is created from an existing graphics context by calling the function `CGLayerCreateWithContext`. The resulting CGLayer object has all the characteristics of the graphics context that the layer is created from. After the layer object is created, you pass it to the function `CGLayerGetContext` to get a graphics context for the layer. It is this graphics context that you draw to using the function `CGLayerDrawAtPoint` and `CGLayerDrawInRect`. You cannot access layer drawing directly.

CGLayer objects are cached by the operating system whenever possible, which greatly improves drawing performance. One important feature of CGLayers is that you do not need to know the device characteristics of the destination context.

It's best to use a CGLayer when you need to:

- Reuse your drawing, as in the background scene for a game.
- Draw the same image multiple times, as in a game sprite.

To use CGLayer, follow these steps:

1. Call the function `CGLayerCreateWithContext` to create a CGLayer object from an existing graphics context. The resulting CGLayer object has all the characteristics of the graphics context that the layer is created from. Carbon applications can use the context provided in the `kEventControlDraw` event for this purpose.
2. After the layer object is created, pass it to the function `CGLayerGetContext` to get a graphics context for the layer. It is this graphics context that you draw to.
3. To draw to the layer graphics context, use any of the Quartz drawing functions (such as `CGContextDrawPath`, `CGContextFillRect`, and so forth), passing the layer graphics context as the context parameter. Note that you cannot access the drawing in the layer directly.
4. To draw the contents of a CGLayer to a destination graphics context (possibly the same graphics context used to create the layer, but it doesn't need to be). Use the functions `CGLayerDrawAtPoint` and `CGLayerDrawInRect`.

For a code example that shows how to draw using CGLayer objects, see CGLayer Drawing in *Quartz 2D Programming Guide*.

Relevant Resources

In *Quartz 2D Programming Guide*, see:

- CGLayer Drawing
- Graphics Contexts

See these reference documents:

- *CGContext Reference*
- *CGBitmapContext Reference*
- *CGLayer Reference*

Performance

Performance is important to all graphics programs, whether they are based on QuickDraw or Quartz. When you rewrite your application to use only Quartz, you'll want to pay particular attention to performance issues. Although Quartz optimizes its operations "under the hood," there are coding practices you can adopt to ensure that your code works in concert with Quartz optimization strategies.

As you develop your application, you can analyze its performance using the debugging tools (Shark, Quartz Debug, Sampler, and so on) provided with Mac OS X. In particular, Quartz Debug is useful for identifying issues related to drawing performance.

Adopting Good Coding Practices

Part of adopting good coding practices is to understand how Quartz works. Your code may be performing some task that either isn't necessary or is working at cross-purposes with Quartz.

Consider following these guidelines:

- Don't overdraw. Mac OS X v10.4 introduces a coalesced update feature. Quartz draws at a set rate (1/60 sec.) for optimal results. Don't try to draw faster by flushing or synchronizing. In fact, Quartz enforces deferred updating to prevent you from drawing too fast.
- Make your code cache-friendly. If you keep any Quartz object that you reuse, such as images, layers, colors,and patterns, Quartz notices and caches that object. Cached objects are drawn faster than those that aren't. Make sure you are not creating, disposing, and recreating the same thing over and over again.
- Use CGLayers for offscreen rendering. They are a better choice from a performance standpoint than bitmap graphics contexts.
- Be kind to the window server by not overflushing. It's important to understand the difference between the function `CGContextFlush` and the function `CGContextSynchronize`. The function `CGContextFlush` performs the flush immediately by calling into the window server. (It is not equivalent to `CGContextSynchronize` + `QDFlushPortBuffer`.)

  The purpose of `CGContextSynchronize` is to delay flushing. Synchronizing allows you to draw to the window backing store multiple times using multiple contexts. Given that each flushing operation is synchronized with the beam, you want to minimize the number of flushes (which is what calling the function `CGContextSynchronize` achieves).

Relevant Resources

For more information, see:

- *Drawing Performance Guidelines*, which describes some basic ways to improve drawing performance in your code, contains specific tips for Carbon and Cocoa, describes how to measure performance, and discusses other issues, such as flushing.
- Quartz Performance: A Look Under the Hood, in *Quartz 2D Programming Guide*.
- *CGLayer Reference*, which provides a complete reference to the functions that create and manage CGLayer objects.

Document Revision History

This table describes the changes to *Quartz Programming Guide for QuickDraw Developers*.

Date	Notes
2006-09-05	Fixed typographical errors.
2006-07-24	Corrected a function name and a typographical error.
2005-08-11	Made numerous technical improvements throughout.
2005-04-29	Updated for Mac OS X v10.4.
	Changed the title from *Transitioning to Quartz 2D* to make it more consistent with the titles of similar documentation.
2005-01-11	Added a new article on replacing QuickDraw regions.
2004-06-28	First version of *Transitioning to Quartz 2D*.

Document Revision History

Glossary

blitting The process of moving bits from a back buffer to an onscreen location. Blitting is not necessary (not recommended) when using Quartz.

bitmap In Quartz, any two-dimensional array of pixel data in a standard format. Not to be confused with the `BitMap` data type in QuickDraw, which is a 1-bit pixel array.

bitmap graphics context A bit-based offscreen drawing destination.

CG The prefix used for functions in the Quartz API. See also Core Graphics.

CGLayer An offscreen graphics context, introduced in Mac OS X v10.4, suited for high-quality offscreen rendering of content that you plan to reuse.

clipboard See pasteboard.

Core Graphics The name of the framework in which the Quartz API resides—CoreGraphics.framework. The Quartz API is sometimes referred to as the Core Graphics API.

CopyBits A QuickDraw function that has no direct replacement in Quartz, primarily because Quartz does not use a bit-based graphics model, as QuickDraw does.

filling A drawing operation that paints an area contained within a path, using either a solid color or a pattern. Quartz has two rules that it can use to determine whether a point should be filled—the winding number rule and the even-odd rule. See Quartz 2D Programming Guide for a detailed discussion of these rules.

framing See stroking.

grafport See graphics context.

graphics context In Quartz, an abstraction for a drawing destination. There are different flavors—window, printing, PDF, OpenGL, and bitmap.

graphics state Defines the drawing parameter settings (line width, fill color, and many other parameters) for a specific graphics context.

GWorld An offscreen drawing context. In Quartz, see bitmap graphics context and CGLayer.

ImageIO A framework, introduced in Mac OS X v10.4, that provides functions for moving image data into and out of Quartz. Image IO functions are in the ImageIO framework. They use the CG prefix.

pasteboard A standardized mechanism for exchanging data within applications or between applications. The most familiar use for pasteboards is handling copy and paste operations.

painting For the Quartz equivalent of the QuickDraw painting operation (such as that used for the QuickDraw function `PaintOval`), see filling.

pixel manipulation The process of operating on bits. Quartz does not provide functions that operate on a pixel-by-pixel bases. Core Image provides support for image processing on a per-pixel basis.

Quartz Compositor An advanced windowing system that manages the onscreen presentation of Quartz, OpenGL, and QuickTime content, much as a video mixer does.

resolution independence A feature that supports drawing to an abstract space such that drawing is the same size when rendered for raster devices of any native resolution.

stroking A drawing operation which paints a line that straddles a path.