

ShapeGen 2-D Graphics Library

User's Guide

Jerry R. VanAken

May 9, 2023

This user's guide provides an overview of the ShapeGen 2-D graphics library, reference pages for the functions in the library, and numerous code examples.

Table of Contents

ShapeGen overview	3
Introduction	3
Programming interface	5
A lightweight and portable graphics library.....	5
Paths and figures	7
Current point	8
ShapeGen coordinates.....	8
Device clipping rectangle.....	9
Scan conversion	10
Creating a ShapeGen object	11
Ellipses and elliptic arcs	13
Renderers included in this project.....	16
ShapeGen-renderer interface.....	16
Enhanced renderer pixel format.....	19
Compositing and filtering with layers	20
ShapeGen types and structures	24
SGCoord type	24
SGPoint structure.....	25
SGRect structure	26
ShapeGen functions	27
ShapeGen::BeginPath function	27
ShapeGen::Bezier2 function	28

ShapeGen::Bezier3 function	30
ShapeGen::CloseFigure function	31
ShapeGen::Ellipse function	33
ShapeGen::EllipticArc function	35
ShapeGen::EllipticSpline function.....	38
ShapeGen::EndFigure function	40
ShapeGen::FillPath function	41
ShapeGen::GetBoundingBox function	42
ShapeGen::GetCurrentPoint function.....	46
ShapeGen::GetFirstPoint function.....	47
ShapeGen::InitClipRegion function.....	48
ShapeGen::Line function.....	49
ShapeGen::Move function	50
ShapeGen::PolyBezier2 function	51
ShapeGen::PolyBezier3 function	53
ShapeGen::PolyEllipticSpline function.....	55
ShapeGen::PolyLine function.....	57
ShapeGen::Rectangle function	58
ShapeGen::ResetClipRegion function	60
ShapeGen::RoundedRectangle function.....	61
ShapeGen::SaveClipRegion function.....	63
ShapeGen::SetClipRegion function	65
ShapeGen::SetFixedBits function.....	67
ShapeGen::SetFlatness function	68
ShapeGen::SetLineDash function	69
ShapeGen::SetLineEnd function	71
ShapeGen::SetLineJoin function	73
ShapeGen::SetLineWidth function.....	75
ShapeGen::SetMaskRegion function	76
ShapeGen::SetMiterLimit function	78
ShapeGen::SetRenderer function	80
ShapeGen::SetScrollPosition function	82
ShapeGen::StrokePath function	84
ShapeGen::SwapClipRegion function	85

EnhancedRenderer functions.....	86
EnhancedRenderer::AddColorStop function	87
EnhancedRenderer::GetPixelBuffer.....	89
EnhancedRenderer::ResetColorStops function	90
EnhancedRenderer::SetColor function	91
EnhancedRenderer::SetConstantAlpha function.....	91
EnhancedRenderer::SetLinearGradient function.....	94
EnhancedRenderer::SetPattern function.....	97
EnhancedRenderer::SetRadialGradient function.....	102
EnhancedRenderer::SetTransform function	105
Appendix: Simple renderer code examples	111

ShapeGen overview

Introduction

[This GitHub project](#) contains the C++ source code for the ShapeGen 2-D graphics library. ShapeGen draws both filled and stroked shapes. It is lightweight and highly portable.

Some 2-D graphics libraries achieve portability by sitting atop a portable graphics library such as OpenGL. Or perhaps they run on Cairo, which in turn runs on PixMan. The resulting dependencies complicate the build process and create bloated executables.

The ShapeGen library code has only two dependencies. The library requires

- (1) a C++ compiler
- (2) the Standard C Library

To achieve portability, the library renders directly to pixel memory, with absolutely no reliance on intermediaries to do the actual rendering.

Of course, an operating system such as Linux or Windows does not allow an application program to draw directly to the on-screen memory for a windowed display that is shared with other applications. To run in these systems, a small amount of platform-dependent code is required to copy an image to on-screen memory after the image has been rendered by the ShapeGen library. All such platform-dependent code in this project is isolated in the `winmain.cpp` and `sdlmain.cpp` files.

The user of this graphics library calls ShapeGen functions to create arbitrarily complex geometric shapes that are then rendered and shown on a graphics display device. The user constructs shape boundaries by connecting geometric primitives such as line segments, spline curves, and circular or elliptic arcs. The library *flattens* the curves and arcs by approximating them with a series of straight polygonal edges. The resulting shapes are rendered as filled polygons.

Naturally, these shapes can be painted with solid colors. But for graphics systems with true-color displays, the ShapeGen library provides antialiasing and alpha blending, and can paint shapes with tiled patterns, linear gradients, and radial gradients.

The ShapeGen library additionally supports clipping regions of arbitrary shape and complexity.

This project includes the source code for a demo program that shows off the capabilities of the ShapeGen library. Also included is a simple ShapeGen-based SVG file viewer. Make files are included to build these example applications in Linux and Windows. Both applications require a true-color graphics display and run in a 1280x960 window.

The core of the library is the ShapeGen class, which implements a relatively simple but powerful 2-D *polygonal shape generator*. The functions implemented by the ShapeGen class are described in detail in the [ShapeGen functions](#) reference section in this user's guide. The polygonal shape generator is the part of a 2-D graphics system that maps mathematically defined shapes onto an x-y coordinate grid that represents the positions of pixels on a graphics display.

However, the shape generator stops short of actually touching the pixels, which is the job of a separate component: the *renderer*. The shape generator tells the renderer what shapes to draw but leaves all platform-specific and device-dependent operations on pixels to the renderer. Thus, the shape generator remains free of all such dependencies.

But even a renderer can be designed in such a way that the bulk of its code is free of platform and device dependencies. For example, the source code for this project includes example renderers that enable the ShapeGen demo program to run in Linux and Windows. To minimize the amount of platform-dependent code, the example renderers draw shapes directly to a *back buffer* – an off-screen, window-backing buffer in memory. After the image in the back buffer has been completely rendered, it is copied by a [BitBlit](#) (bit-block transfer) operation to the target window in the on-screen memory. Although the code that renders shapes to the back buffer is platform-independent, this BitBlit must be implemented by the underlying platform.

To further simplify renderer design, renderers are *not* responsible for clipping. All shapes that the ShapeGen object passes to the renderer have already been clipped.

Two example renderers are included in this project. The first is a *simple renderer* that does simple solid-color fill operations, but with no antialiasing. Second, an *enhanced renderer* is provided that performs antialiasing and alpha blending. An enhanced renderer works exclusively with true-color graphics display devices. In addition to filling shapes with solid colors, this renderer can fill them with tiled patterns, linear gradients, and radial gradients. However, the simple renderer is faster for filling large regions with solid colors.

An application calls the [ShapeGen::SetRenderer](#) function to switch from one renderer to the other.

For a system whose graphics display device has limited color capabilities and does not support true-color pixel formats, a standalone simple renderer is sufficient. As shown in the [appendix](#) to this user's guide, just a few lines of code are required to implement this type of renderer. Thus, the ShapeGen library can be ported to such a system with minimal effort.

Also included in this project is the source code for a set of *paint generators* to assist an enhanced renderer in filling shapes with tiled patterns, linear gradients, and radial gradients. During these fill operations, the paint generators do most of the heavy lifting for the renderer. Additionally, they contain no platform-specific or device-dependent code, although they are, of course, intended for use with true-color graphics displays.

For detailed descriptions of the functions implemented by the enhanced renderer and paint generators in this project, see the [EnhancedRenderer functions](#) reference section in this user's guide.

Well-defined interfaces connect the renderer to the library's shape-generator and paint-generator objects. For more information, see the [ShapeGen-renderer interface](#) topic in this user's guide.

Programming interface

The programming interface for ShapeGen library users is similar to that of other 2-D graphics software systems, such as [PostScript](#).

The PostScript page description language is the archetypical 2-D graphics interface. For comparison, the following table lists a number of ShapeGen library functions and the corresponding PostScript path-construction operators.

ShapeGen function	PostScript operator	ShapeGen function	PostScript operator
BeginPath	newpath	Move	moveto
Bezier3	curveto	SetClipRegion	clip
CloseFigure	closepath	SetFlatness	setflat
EllipticArc	arc	SetLineDash	setdash
FillPath	fill	SetLineEnd	setlinecap
GetBoundingBox	pathbbox	SetLineJoin	setlinejoin
GetCurrentPoint	currentpoint	SetLineWidth	setlinewidth
InitClipRegion	initclip	SetMiterLimit	setmiterlimit
Line	lineto	StrokePath	stroke

The PostScript path-construction operators are described in chapter 8 of the [PostScript Language Reference Manual](#), Second Edition, 1990. For detailed descriptions of the functions implemented by the ShapeGen class, see the [ShapeGen functions](#) reference section.

A lightweight and portable graphics library

The ShapeGen 2-D graphics library in this GitHub project is lightweight and portable. The platform-independent source code for the ShapeGen class consists of six well-commented C++ source files and two header files, which are listed in the following table.

File name	File size (bytes)	Description
<code>arc.cpp</code>	15K	Constructs paths for ellipses, elliptic arcs, and elliptic splines
<code>curve.cpp</code>	12K	Constructs paths for cubic and quadratic Bezier curves
<code>edge.cpp</code>	30K	Manages lists of polygonal edges, does clipping, and drives renderer
<code>path.cpp</code>	25K	Performs basic path-management functions
<code>stroke.cpp</code>	32K	Converts paths into stroked lines and curves
<code>thinline.cpp</code>	8K	Converts paths into <i>thin</i> stroked lines and curves
<code>shapegen.h</code>	10K	Header file for ShapeGen public interface
<code>shapepri.h</code>	12K	Header file for ShapeGen internal interfaces

The files in this table implement all the functions described in the [ShapeGen functions](#) reference section.

This project includes example renderers that are used by the ShapeGen demo program and SVG file viewer. These renderers use a 32-bit pixel format (see the [Enhanced renderer pixel format](#) topic) and are augmented with paint generators that fill shapes with solid colors, tiled patterns, linear gradients, and radial gradients. The platform-independent source code for the renderers implemented in this project consists of three well-commented C++ source files and one header file, which are listed in the following table.

File name	File size (bytes)	Description
gradient.cpp	26K	Implements paint generators for linear-gradient and radial-gradient fills
pattern.cpp	13K	Implements a paint generator for tiled-pattern fills
renderer.cpp	24K	Implements a pair of example renderers that are used by the ShapeGen demo program and SVG file viewer
renderer.h	8K	Header file for renderer and paint generator interfaces

The files in this table implement all the functions described in the [EnhancedRenderer functions](#) reference section.

Also included in this project is example application code that demonstrates the graphics capabilities of the ShapeGen library. The following table lists the source files for the ShapeGen demo program and SVG file viewer.

File name	File size (bytes)	Description
demo.cpp	142K	Contains source code for the ShapeGen demo program and for the code examples in the <i>ShapeGen User's Guide</i>
textapp.cpp	62K	Implements TextApp graphical text application and provides glyphs for all printing ASCII characters
bmpfile.cpp	13K	Implements a rudimentary BMP file reader used by the demo program to do pattern fills
svgview.cpp	10K	Source code for a simple SVG file viewer
nanosvg.h	96K	Modified version of M. Mononen's single-header SVG file parser
alfablur.cpp	12K	Implements an alpha-blurring filter used to render drop shadows
demo.h	7K	Header file for interfaces used in demo and SVG viewer programs

The ShapeGen demo program and SVG file viewer are designed to run on a system with a true-color graphics display with 24-bit or 32-bit pixels, but are otherwise platform-independent. The programs render to a 1280x960 window. Every pixel displayed in the demo program – including all geometric shapes and text – is drawn by the ShapeGen 2-D graphics library.

Although most of the code in this GitHub project is platform-independent, a relatively small amount of platform-dependent code is required to run the ShapeGen demo program and SVG file viewer in Windows and Linux. Specifically, these programs run on the Win32/GDI API in Windows, and on the [SDL2](#) (Simple DirectMedia Library, version 2) API in Linux and Windows. The following table lists all the source files that contain platform-dependent code.

File name	File size (bytes)	Description
winmain.cpp	8K	Implements all the platform-dependent functions needed to run the ShapeGen library on the Win32/GDI API in Windows

<code>sdlmain.cpp</code>	8K	Implements all the platform-dependent functions needed to run the ShapeGen library on the SDL2 API in Linux and Windows
--------------------------	----	---

Because nearly all the source code in the ShapeGen graphics library is free of platform or device dependencies, it is easily ported to any computer for which a C++ compiler is available. To drive a color-limited graphics display on low-cost or compact hardware, the ShapeGen source code can be paired with a standalone simple renderer that consists of just a few lines of code (see the [appendix](#)). A simple renderer fills shapes with solid colors but does no antialiasing.

Additionally, ShapeGen can take advantage of computers with true-color displays to do antialiasing, alpha blending, pattern fills, linear gradient fills, and radial gradient fills.

In comparison with larger and more complex open-source graphics software, the small size and relative simplicity of the source code for the ShapeGen library makes it relatively easy to modify and build upon. The clean separation of the ShapeGen library and renderer implementation enables developers to more easily add new rendering capabilities and to port the library to new platforms and hardware.

Last but not least, developers may find this GitHub project's ShapeGen library and example renderers to be sufficient, without modification, for many graphics applications.

For a high-level overview of ShapeGen capabilities and internal operation, see the article titled [ShapeGen: A lightweight, open-source 2-D graphics library written in C++](#) at the ResearchGate website.

Paths and figures

In both ShapeGen and PostScript, the programmer describes a shape by constructing a *path* to specify the boundary of the shape. For example, a simple path might consist of three points that describe a triangle.

However, a composite path is required to describe a more complex shape. For example, to describe a complex polygonal shape that contains holes and disjoint regions, a path is composed of several plane figures (the term used by ShapeGen) or subpaths (the PostScript term). Each figure or subpath contains a list of points that describes a sequence of connected boundary segments.

A path is implemented as a simple display list.

In PostScript, a path is a sequence of `lineto` and `curveto` segments. (Circular arcs are approximated with `curveto` segments.) Before a PostScript path can be rendered, it must be flattened – that is, each `curveto` segment must be replaced with a sequence of `lineto` segments that approximates the ideal curve.

ShapeGen paths, on the other hand, consist only of line segments. A `ShapeGen::EllipticArc` function call, for example, immediately flattens an arc before adding it to the path.

The ShapeGen approach is simpler but a PostScript path might take less time to transfer over a communications link, or better adapt to a target display device whose resolution is not known in advance. The PostScript scheme is less compelling if the path is to be constructed and then immediately rendered on the same computer.

The PostScript `fill` and `stroke` operators implicitly perform a `newpath` operation after filling or stroking the current path. The path can be preserved across a `fill` or `stroke` operation only by explicitly saving a copy of the path before the operation and then restoring the path afterward. In contrast, ShapeGen paths are reusable: a `ShapeGen::FillPath` or `ShapeGen::StrokePath` function call leaves the path intact. To begin a new path after a `FillPath` or `StrokePath` call, a ShapeGen user calls the `ShapeGen::BeginPath` function.

Current point

A number of ShapeGen path-construction functions rely on the concept of a *current point*. For example, the `ShapeGen::Line` function constructs a line segment that starts at the current point. The line segment ends at the point specified as an input parameter to the function, and this point becomes the new current point when the function returns. PostScript also defines a current point, but with subtle differences.

In ShapeGen, the current point is defined as the point most recently added to the current *figure* (subpath) in the current path. The current point is undefined if the current *figure* is empty. PostScript, on the other hand, defines the current point to be the point most recently added to the current *path*. The current point is undefined if the current *path* is empty.

A ShapeGen user can start a new, empty figure in a composite path that already contains several completed (or finalized) figures. Because the new figure is empty, the current point is undefined.

In contrast, a PostScript user encounters an empty subpath only after starting a new, empty path. This is the only time that the current point is undefined.

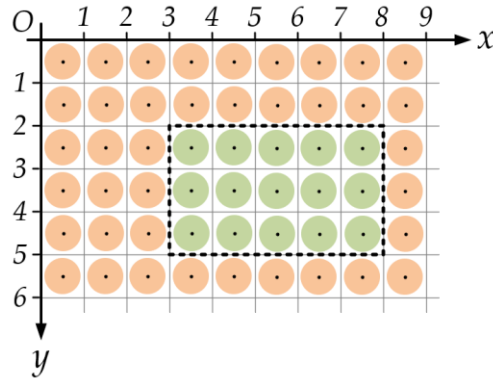
For example, both the `ShapeGen::EllipticArc` function and PostScript `arc` operator can draw a circular arc that starts at a specified angle. These primitives operate under similar rules. Namely, if the current point is defined, then a line segment is constructed from the current point to the starting point of the arc. Otherwise, the arc starting point becomes the first point in the new figure (in ShapeGen) or new path (in PostScript).

To draw a series of unconnected arcs without preceding line segments, a PostScript user must start a new path for each arc. A ShapeGen user, however, can construct all the arcs in a single, composite path.

In addition to the *current point*, ShapeGen defines a *first point*, which is the initial point in the current figure. A user calls the `ShapeGen::GetFirstPoint` and `ShapeGen::GetCurrentPoint` functions to retrieve the first point and current point, respectively. For example, after calling the `EllipticArc` function to add an arc to an empty figure, the user can retrieve the arc starting and ending points by calling the `GetFirstPoint` and `GetCurrentPoint` functions.

ShapeGen coordinates

The ShapeGen coordinate system maps x-y coordinates directly to pixels on the graphics display. As shown in the following diagram, the boundaries between pixels always fall on integer x-y coordinates; x coordinate values increase to the right and y coordinate values increase in the downward direction.



As shown in the diagram, pixel centers (shown as black dots) are located halfway between integer x - y coordinates. Because the boundaries between pixels always fall on integer coordinates, users don't need to worry about which pixels would get drawn if the boundaries of simple shapes like rectangles were to pass through pixel centers.

For example, in the preceding diagram, a filled green rectangle is rendered over an orange background. The x - y coordinates at the top-left corner of the rectangle are (3, 2). The width of the rectangle is 5 pixels, and the height is 3 pixels.

By default, application programs use *integer* coordinate values to describe shapes to ShapeGen drawing functions. However, some programs might require subpixel precision in the coordinates they supply to ShapeGen functions. For example, a program that needs to smoothly plot a special curve can specify the curve as a sequence of short line segments. But if these line segments are forced to start and end on integer coordinates, the curve will, on close inspection, appear irregular rather than smooth.

To address this issue, ShapeGen users can call the [ShapeGen::SetFixedBits](#) function to switch from the default, integer coordinate format to a fixed-point coordinate format. In a call to `SetFixedBits`, the caller specifies the number of bits to use for the *fractional* part of a coordinate value – that is, the number of bits to the right of the binary point in the fixed-point representation. For example, an argument value of 8 specifies a fixed-bit format with 8 bits of fraction. An argument value of 16 specifies 16 bits of fraction. Calling `SetFixedBits` with an argument value of 0 restores the default, integer coordinate format.

Device clipping rectangle

ShapeGen confines all drawing to the interior of a *device clipping rectangle*. This rectangle is a mapping from ShapeGen's x - y coordinates to the drawing area on the graphics display. The device clipping rectangle might represent the client drawing area in the target window (or viewport) on the screen. Or it might encompass the entire screen of a dedicated graphics display device.

The device clipping rectangle is specified by four integers, (x, y, w, h) . The x and y values specify the horizontal and vertical displacements, in pixels, of the rectangle's top-left corner from the ShapeGen coordinate origin. The w and h values are the width and height, in pixels, of the device clipping rectangle; these are typically the dimensions of the window or viewport on the graphics display. Thus, the device clipping rectangle specifies the region of the ShapeGen coordinate space that the viewer sees on the display.

Typically, the device clipping rectangle's x and y coordinates are both zero, in which case the origin of the ShapeGen coordinate system coincides with the top-left corner of the window. However, this rectangle's x and y coordinates can be specified as nonzero values to enable scrolling and panning through a virtual 2-D image that is larger than the window (see the [ShapeGen::SetScrollPosition](#) reference page).

ShapeGen's automatic clipping prevents drawing from occurring outside the window.

The viewer might find this method of scrolling and panning to be convenient for inspecting images that are larger than the drawing area on the screen. But because the image must be redrawn each time the position of the device clipping rectangle changes, this method is not by itself sufficient to provide smooth animation.

The user can call the [ShapeGen::SetClipRegion](#) and [ShapeGen::SetMaskRegion](#) functions to modify the shape of the clipping region inside the device clipping rectangle, but no clipping region ever extends beyond the bounds of the device clipping rectangle. To restore the clipping region to the current device clipping rectangle, the user calls the [ShapeGen::ResetClipRegion](#) function.

The device clipping rectangle is never undefined during the lifetime of a ShapeGen object. The ShapeGen class constructor requires a device clipping rectangle as an input parameter, so that an initial clipping region can be set when a ShapeGen object is created. The width and height of the device clipping rectangle can later be changed, if necessary, by calling the [ShapeGen::InitClipRegion](#) function. The position in ShapeGen x - y coordinate space of the top-left corner of the device clipping rectangle can be changed by calling the [ShapeGen::SetScrollPosition](#) function.

Scan conversion

ShapeGen paths can specify the boundaries of arbitrarily complex polygonal shapes. These shapes can contain holes and disjoint regions. Boundaries can self-intersect. Paths can be filled or stroked.

Each pair of adjacent points in a path specifies a polygonal edge. The edge has a direction. The direction arrow points from the edge's first point to its second point.

ShapeGen supports the same two polygon-fill rules as PostScript:

- nonzero winding number
- even-odd

In both PostScript and ShapeGen, the user can choose either of these rules to construct a *filled* path. *Stroked* paths are always constructed using the nonzero winding number rule.

ShapeGen's scan conversion rules are different from PostScript's. First, if the ShapeGen library is connected to a simple renderer (with no antialiasing), a pixel is treated as part of the interior of a polygon if the center of the pixel lies inside the polygon boundary. If the boundary passes precisely through the center of a pixel, the pixel belongs to the filled region below and to the right of the pixel center.

If the ShapeGen library is instead connected to an enhanced renderer, each pixel is partitioned into subpixels to enable antialiasing. In this case, the scan conversion rules are the same as before, except that they are applied to subpixels rather than pixels.

Creating a ShapeGen object

The programming interface for the ShapeGen 2-D graphics library is defined in this project's public header files `shapegen.h` and `renderer.h`.

An object of the ShapeGen class is created by calling the `CreateShapeGen` function, which is declared in `shapegen.h`, as follows:

```
ShapeGen* CreateShapeGen(Renderer *renderer, const SGRect& cliprect);
```

The second parameter, `cliprect`, is an [SGRect](#) structure that specifies the [device clipping rectangle](#), as previously described.

The first parameter is a pointer to a renderer, which is an object that accepts simple drawing commands from the ShapeGen object and then renders shapes into a two-dimensional array of pixels. A renderer is an instance of a class, such as `SimpleRenderer` or `EnhancedRenderer`, that is derived from the `Renderer` base class. For more information, see the [Renderer](#) topic.

For detailed descriptions of the functions implemented by the ShapeGen class, see the [ShapeGen functions](#) reference section.

To create a `SimpleRenderer` or `EnhancedRenderer` object, call the `CreateSimpleRenderer` function or `CreateEnhancedRenderer` function. These functions are declared in `renderer.h`, as follows:

```
SimpleRenderer* CreateSimpleRenderer(const PIXEL_BUFFER *bkbuf);  
EnhancedRenderer* CreateEnhancedRenderer(const PIXEL_BUFFER *bkbuf);
```

The `bkbuf` parameter points to a `PIXEL_BUFFER` structure that describes the two-dimensional array of pixels into which the renderer will draw shapes. Typically, this pixel array is the backing buffer for a graphics display. The `PIXEL_BUFFER` structure is defined in `renderer.h`, as follows:

```
struct PIXEL_BUFFER  
{  
    COLOR *pixels; // pointer to 2-D array of pixels  
    int width;     // width of pixel buffer in pixels  
    int height;    // height of pixel buffer in pixels  
    int depth;     // number of bits per pixel  
    int pitch;     // pitch of pixel buffer in bytes  
};
```

The `SimpleRenderer` class is, well, simple — its application interface consists of a single function, `SetColor`, which specifies a solid color for filling shapes. The `EnhancedRenderer` interface provides a number of additional capabilities. For detailed descriptions of the functions implemented by the `EnhancedRenderer` class, see the [EnhancedRenderer functions](#) reference section.

The `CreateShapeGen` function requires, as a call parameter, a pointer to an existing `Renderer` object, which means that a renderer must be created before a ShapeGen object can be created.

In the following code example, assume that the `MyTest` function is called first. This function creates a `SimpleRenderer` object and a `ShapeGen` object and uses these objects to draw to the graphics display.

MyTest fills the background with white and then calls a second function, MySub, that draws a red rectangle over a portion of the background.

```
void MySub(ShapeGen *sg, SGRect& rect)
{
    sg->BeginPath();
    sg->Rectangle(rect);
    sg->FillPath(FILLRULE_EVENODD);
}

void MyTest(const PIXEL_BUFFER& bkbuf, const SGRect& clip)
{
    SimpleRenderer *rend = CreateSimpleRenderer(&bkbuf);
    ShapeGen *sg = CreateShapeGen(rend, clip);
    SGRect rect = { 100, 80, 250, 160 };

    sg->BeginPath();
    sg->Rectangle(clip);
    rend->SetColor(GBX(255,255,255)); // white
    sg->FillPath(FILLRULE_EVENODD);

    rend->SetColor(GBX(255,40,20)); // red
    MySub(sg, rect);

    delete rend;
    delete sg;
}
```

The MyTest function takes two input parameters. The first, bkbuf, is a structure describing the backing buffer for the graphics display and is required for the CreateSimpleRenderer function call. The second parameter, clip, is the device clipping rectangle that is required for the CreateShapeGen function call. The calling program must ensure that this clipping rectangle fits within the bounds of the backing buffer defined in bkbuf.

Just before the MyTest function returns, it deletes the SimpleRenderer and ShapeGen objects. Neglecting to do so would cause the memory allocated for these objects to leak.

Of course, it's easy enough for a programmer to forget to delete these objects. A straightforward way to reduce the risk of leaks is to use smart pointers. A smart pointer can encapsulate a ShapeGen or Renderer object, make this object available to an application program, and automatically delete the object when it is no longer needed.

In the following code example, a modified version of the MyTest function, MyTest2, uses smart pointers to encapsulate the SimpleRenderer and ShapeGen objects. The two smart pointer objects, rend and sg, are defined within the context of the MyTest2 function. Thus, when the MyTest2 function returns and the two smart pointers go out of scope, the smart pointers' destructors are automatically called. These destructors delete the encapsulated Renderer or ShapeGen object, thereby avoiding a potential leak.

```
void MySub(ShapeGen *sg, SGRect& rect)
{
    sg->BeginPath();
    sg->Rectangle(rect);
    sg->FillPath(FILLRULE_EVENODD);
}
```

```

void MyTest2(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<SimpleRenderer> rend(CreateSimpleRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*rend, clip));
    SGRect rect = { 100, 80, 250, 160 };

    sg->BeginPath();
    sg->Rectangle(clip);
    rend->SetColor(GBX(255,255,255)); // white
    sg->FillPath(FILLRULE_EVENODD);

    rend->SetColor(GBX(0,120,255)); // blue
    MySub(&*sg, rect);
}

```

The MyTest2 example uses the SmartPtr class template defined in shapegen.h. Of course, you might prefer to use another smart pointer, such as the unique_ptr class template in the C++ Standard Library. However, the SmartPtr template is used here to avoid introducing additional dependencies into the ShapeGen library build.

Here is the definition of the SmartPtr class template from shapegen.h:

```

template <class T> class SmartPtr {
    T* _ptr;
public:
    explicit SmartPtr(T* ptr = 0) { _ptr = ptr; }
    ~SmartPtr() { delete _ptr; }
    T* operator->() { return _ptr; }
    T& operator*() { return *_ptr; }
};

```

To serve as a smart pointer, the SmartPtr class overloads the -> operator so that a SmartPtr object (such as rend or sg in the previous code example) can be used as a pointer to the encapsulated (e.g., Renderer or ShapeGen) object. To enable a pointer to an encapsulated object (such as a ShapeGen object) to be passed as an argument to a function (such as MySub in the MyTest2 code example), the SmartPtr class overloads the * operator.

All the code examples in the remainder of this user's guide will use the SmartPtr class template.

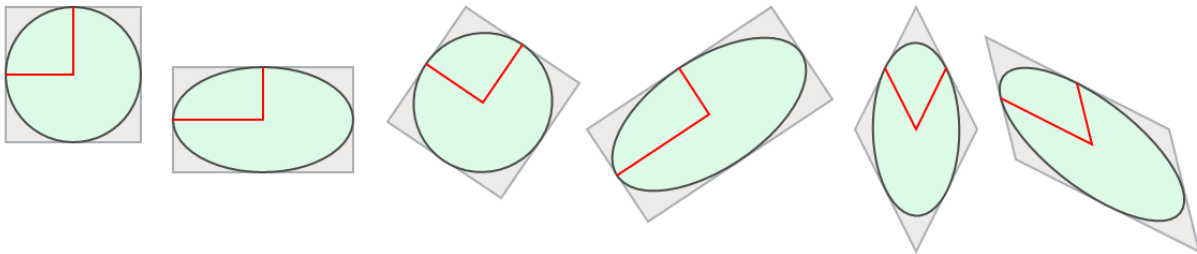
Ellipses and elliptic arcs

The paper titled [A Fast Parametric Ellipse Algorithm](#) on the arXiv.org website describes a fast algorithm for generating ellipses and elliptic arcs (and also, of course, circles and circular arcs).

The ShapeGen library uses this algorithm to construct ellipses and elliptic arcs of any shape and orientation. An ellipse is defined by three points: its center point plus the end points of two *conjugate diameters* of the ellipse. Other 2-D graphics libraries typically do not use conjugate diameters to describe their ellipses, so this brief explanation might be helpful:

The conjugate diameter end points are simply the midpoints of two adjacent sides of the square, rectangle, or parallelogram in which the ellipse is inscribed¹.

The following screenshot should clarify things a bit.

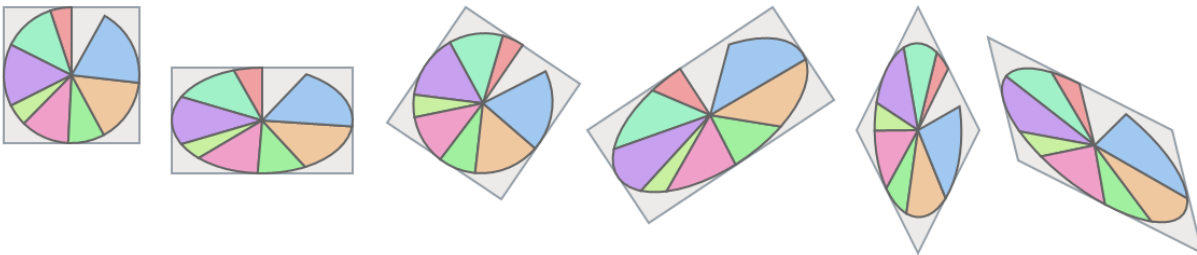


At the left edge of the screenshot, a circle is inscribed in a square. A circle is a special case of an ellipse. Red lines are drawn from the center of this particular ellipse to the end points of two conjugate diameters of the ellipse. (For the special case of a circle, any two perpendicular diameters are conjugate diameters.)

The other figures in the screenshot above are affine transformations of the initial figure at the left. In each case, the end points of the two conjugate diameters coincide with the midpoints of two adjacent sides of an enclosing square, rectangle, or parallelogram.

The preceding screenshot was rendered by a program that calls the `ShapeGen::Ellipse` function.

The following screenshot was rendered by a similar program that calls the `ShapeGen::EllipticArc` function to draw six different views of the same pie chart. The two screenshots share the same set of enclosing squares, rectangles, and parallelograms.



For more information, see the [Wikipedia article](#) on conjugate diameters, or see the paper titled [A rotated ellipse from three points](#) at the ResearchGate website.

In case you're curious, here's the function that created the pie chart screenshot:

```
void PieToss(const PIXEL_BUFFER& bkbuf, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&aarend, clip));
    float percent[] = {
        5.1, 12.5, 14.8, 5.2, 11.6, 8.7, 15.3, 18.7
    };
}
```

¹ You don't actually have to draw a square, rectangle, or parallelogram around your ellipse. That's done here just to help you visualize the underlying geometric principle.

```

};
COLOR color[] =
{
    RGBX(240,160,160), RGBX(160,240,200), RGBX(200,160,240), RGBX(200,240,160),
    RGBX(240,160,200), RGBX(160,240,160), RGBX(240,200,160), RGBX(160,200,240),
};
// Define three corner points of each square, rectangle,
// or parallelogram. We'll calculate the fourth point.
SGPoint xy[][4] = {
    { { 155, 29 }, { 29, 29 }, { 29, 155 }, },
    { { 353, 85 }, { 185, 85 }, { 185, 183 }, },
    { { 564, 100 }, { 458, 29 }, { 385, 136 }, },
    { { 743, 29 }, { 571, 143 }, { 628, 229 }, },
    { { 935, 143 }, { 878, 29 }, { 821, 143 }, },
    { { 1114, 143 }, { 943, 57 }, { 971, 171 }, },
};

sg->SetLineJoin(LINEJOIN_MITER);
for (int i = 0; i < ARRAY_LEN(xy); ++i)
{
    SGPoint v0, v1, v2;
    float astart = 0;

    // Use symmetry to calculate the fourth point of the
    // square, rectangle, or parallelogram. Then draw it.
    xy[i][3].x = xy[i][0].x - xy[i][1].x + xy[i][2].x;
    xy[i][3].y = xy[i][0].y - xy[i][1].y + xy[i][2].y;
    sg->BeginPath();
    sg->Move(xy[i][0].x, xy[i][0].y);
    sg->PolyLine(3, &xy[i][1]);
    sg->CloseFigure();
    aarend->SetColor(RGBX(237,235,233));
    sg->FillPath(FILLRULE_EVENODD);
    aarend->SetColor(RGBX(150,160,170));
    sg->SetLineWidth(2.0);
    sg->StrokePath();

    // The center point v0 of the ellipse is simply the center
    // of the enclosing square, rectangle, or parallelogram
    v0.x = (xy[i][0].x + xy[i][2].x)/2;
    v0.y = (xy[i][0].y + xy[i][2].y)/2;

    // The conjugate diameter end points are simply the
    // midpoints of two adjacent sides of the enclosing
    // square, rectangle, or parallelogram
    v1.x = (xy[i][0].x + xy[i][1].x)/2;
    v1.y = (xy[i][0].y + xy[i][1].y)/2;
    v2.x = (xy[i][1].x + xy[i][2].x)/2;
    v2.y = (xy[i][1].y + xy[i][2].y)/2;

    // Draw the pie chart inside the square, rectangle, or
    // parallelogram
    for (int j = 0; j < 8; ++j)
    {
        float asweep = 2.0*PI*percent[j]/100.0; // PI = 3.14159...

        sg->BeginPath();
        sg->EllipticArc(v0, v1, v2, astart, asweep);
        sg->Line(v0.x, v0.y);
        sg->CloseFigure();
        aarend->SetColor(color[j]);
        sg->FillPath(FILLRULE_EVENODD);
    }
}

```

```
        aarend->SetColor(GBX(100,100,100));
        sg->StrokePath();
        astart += asweep;
    }
}
```

Renderers included in this project

A ShapeGen object generates shapes that can be rendered on a graphics display. This object is paired with a renderer that draws the shapes to the back buffer. The contents of the back buffer can be copied to on-screen memory and shown on the graphics display.

This GitHub project includes the source code for example renderers that are platform-independent and that support true-color graphics displays. The ShapeGen demo program and SVG file viewer require a relatively small amount of additional, platform-dependent code to run in Linux and Windows.

The two example renderers are:

- A *simple renderer* that does solid-color fills with no antialiasing
- An *enhanced renderer* that does antialiasing and alpha blending

These renderers are implemented in the `renderer.cpp` file in the main directory of this project. Both renderers can fill shapes with solid colors. Additionally, the enhanced renderer provides antialiasing and alpha blending, and uses the paint generators in the project's `pattern.cpp` and `gradient.cpp` files to fill shapes with tiled patterns, linear gradients, and radial gradients.

The enhanced renderer works exclusively with true-color graphics displays.

The simple renderer is faster for filling large regions with solid colors.

To construct an image, the two example renderers write directly to a shared window-backing memory buffer, or *back buffer*. This buffer uses a 32-bit BGRA [pixel format](#) (that is `0xaarrggbb`). During construction of the image, a ShapeGen-based application can switch between from one renderer to the other by calling the [ShapeGen::SetRenderer](#) function. After the image has been rendered, a BitBlt operation copies the back buffer to a window or viewport in the on-screen memory.

The simple renderer can be easily modified to run on small computers that have limited graphics capabilities and cannot display true-color images. Just a few lines of code are required to implement a standalone simple renderer, which makes porting the ShapeGen library relatively simple. See the [appendix](#) for code examples of simple renderers that run on the Win32/GDI and SDL2 APIs.

The EnhancedRenderer class implementation in this GitHub project can be ported with minimal effort to a computer system with a true-color graphics display. The interface for this renderer implements a number of application-callable functions, which are described in the [EnhancedRenderer functions](#) section.

ShapeGen-renderer interface

Instead of passing a shape description directly to a renderer, a ShapeGen object embeds the shape information in a ShapeFeeder object. ShapeGen then passes this object to the renderer's `RenderShape` function, which performs the actual rendering. Each `RenderShape` call fills or strokes a shape that was

previously specified by a user-constructed path. During this call, the shape feeder acts as an iterator that supplies the renderer with pieces of the shape in line-by-line fashion, from top to bottom.

The shape feeder adapts its behavior to the type of renderer – simple or enhanced – that it's connected to.

For example, to support a simple renderer, the shape feeder breaks a shape into a series of rectangles with vertical and horizontal sides. Rectangle coordinates are specified as simple integers. For shapes with sharply curved or slanted sides, most of these rectangles might be just one or two pixels in height. However, a large, rectangular fill region can be specified as a single rectangle.

To support an enhanced renderer, the shape feeder breaks a shape into a series of *subpixel spans*², which the renderer uses to construct a coverage bitmask for each pixel in the shape. Each of these spans begins and ends on a *subpixel boundary*³. The x and y coordinates of a subpixel are expressed as *fixed-point* numbers. The integer part of an x or y coordinate identifies a pixel, and the fractional part identifies the subpixel column or row within the pixel.

For example, the example enhanced renderer in this project uses a 32-bit coverage bitmask (4 rows, and 8 bits per row) for alpha blending and antialiasing. For this renderer, the two fractional bits of a span's y coordinate, as supplied by the shape feeder, specify the subpixel row. An x coordinate supplied by the shape feeder is always in 16.16 fixed-point format, and the example renderer uses the three most-significant bits of the 16-bit fraction to determine the starting subpixel column.

To enable an enhanced renderer to conserve memory, the shape feeder always supplies spans in y-ascending order so that the portion of a shape that falls on a scan line can always be rendered in its entirety before construction of the next line begins.

The simplicity of a *simple* renderer makes it easy to port to any processor for which a C++ compiler is available. A simple renderer might be all that's needed to support a graphics display device that has limited color capabilities. The ShapeGen object calls this renderer's `RenderShape` function to do all of the drawing. For example, a simple renderer that runs on SDL2 can implement the `RenderShape` function as follows:

```
void BasicRenderer::RenderShape(ShapeFeeder *feeder)
{
    SDL_Rect rect;

    while (feeder->GetNextSDLRect(reinterpret_cast<SGRect*>(&rect)))
        SDL_FillRect(_surface, &rect, _pixel);
}
```

The `BasicRenderer` class in this code example is derived from the `SimpleRenderer` class, which defines a simple renderer. Both simple and enhanced renderers derive from the same base class, `Renderer`, which will be described shortly.

This implementation of the `RenderShape` function in the preceding example uses the `SDL_FillRect` function to fill the rectangles and thus runs on platforms, such as Linux and Windows, for which the SDL2 API

² Just as the term *span*, by itself, describes a horizontal row of pixels that spans the distance between the left and right edges of a filled region in a shape, a *subpixel span* is a row of *subpixels* that spans the region.

³ Analogous to a *pixel* boundary, which is located halfway between horizontally and vertically adjacent *pixel* centers, a *subpixel* boundary is located halfway between *subpixel* centers. For more information, see the [Scan conversion](#) section.

is available. An implementation that runs on the Win32/GDI API can call the [FillRect](#) function instead. For more information, see the simple renderer code examples in the [appendix](#).

The `RenderShape` function implemented by an *enhanced* renderer is necessarily more complex than this – it requires the exchange of additional information between the renderer and ShapeGen object. To support antialiasing and alpha blending, the `Renderer` interface definition includes `QueryYResolution` and `SetMaxWidth` functions. A fourth function, `SetScrollPosition`, supports scrolling of shapes painted with patterns and gradients.

The following `Renderer` base class definition is taken from the `shapegen.h` header file:

```
class Renderer
{
public:
    virtual void RenderShape(ShapeFeeder *feeder) = 0;
    virtual int QueryYResolution() { return 0; }
    virtual bool SetMaxWidth(int width) { return true; }
    virtual bool SetScrollPosition(int x, int y) { return true; }
};
```

The four functions in the `Renderer` class are called exclusively by the ShapeGen object. The last three of these functions are provided specifically to support enhanced renderers. Note that a simple renderer simply uses the versions of these three functions that are implemented in the preceding `Renderer` class definition.

When a new renderer is installed (for example, if the user calls the `ShapeGen::SetRenderer` function), ShapeGen immediately calls the renderer's `QueryYResolution`, `SetMaxWidth`, and `SetScrollPosition` functions. Additionally, ShapeGen calls `SetMaxWidth` to notify the renderer when the application program calls the [ShapeGen::InitClipRegion](#) function to change the width and height of the device clipping rectangle. ShapeGen calls the renderer's `SetScrollPosition` function when the application calls the [ShapeGen::SetScrollPosition](#) function to change the x-y scrolling coordinates.

An enhanced renderer implements a `QueryYResolution` function that returns the number of fractional (subpixel) bits the renderer requires in the fixed-point y coordinates for the spans it receives from the `ShapeFeeder`. For example, the example enhanced renderer in `renderer.cpp` requires two fractional bits in its y coordinates. (The x coordinates supplied by the shape feeder are always in a 16.16 fixed-point format.)

An enhanced renderer also implements a `SetMaxWidth` function that receives, as an input parameter, the maximum width (in pixels) of any shape it will be asked to draw.

The `SetScrollPosition` function supports horizontal and vertical scrolling of complex paint (that is, patterns and gradients) so that they remain in sync with painted shapes when the window is scrolled.

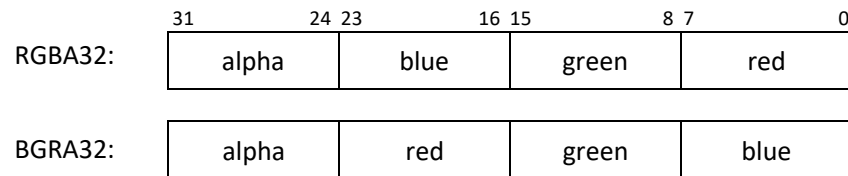
In addition to the four functions in the `Renderer` class above, a renderer is expected to provide functions that can be called by ShapeGen-based applications. Applications call these functions to specify, for example, the solid color, tiled pattern, or color gradient to use to render shapes. Either of the two example renderers in this GitHub project can do solid-color fills and must therefore provide an application-callable `SetColor` function. The example enhanced renderer implements a number of additional application-callable functions, and these are described in detail in the [EnhancedRenderer functions](#) section of this user's guide.

Enhanced renderer pixel format

The ShapeGen class generates the geometric outlines of shapes and maps the shapes onto a two-dimensional array of pixels. ShapeGen delegates all processing of pixel color and transparency data to the renderer.

The EnhancedRenderer class implementation in this GitHub project deals exclusively with 32-bit pixels that contain 8-bit red, green, blue, and alpha components. EnhancedRenderer member functions assume that, by default, ShapeGen-based application programs specify pixel values in RGBA32 format. On the other hand, this renderer draws to pixel buffers that are in BGRA32 format. Translation between the two formats requires swapping the red and blue components.

The names RGBA32 and BGRA32 mean different things to big-endians and little-endians, so the following figure is necessary to avoid confusion:



Little-endian naming conventions are used here because most readers will compile and run the ShapeGen demo programs on a PC, and the processors in most PCs have x86 or x64 instruction set architectures, which are little-endian.

The motivation for using the RGBA32 format for the application programming interface and the BGRA32 format for rendering is to conform to de facto standards that were established early in the history of Microsoft Windows. For example, the following RGB macro from the `wingdi.h` header file in Windows allows application programs to construct a 32-bit `COLORREF` (unsigned int) value from 8-bit r, g, and b components:

```
#define RGB(r,g,b) ((COLORREF)((((BYTE)(r)|((WORD)((BYTE)(g))<<8))|(((DWORD)(BYTE)(b))<<16)))
```

Note that this macro places the r, g, and b values in the same byte positions as the RGBA32 pixel format shown in the preceding figure.

In contrast, the Windows BMP file format, which was borrowed from IBM's OS/2, uses the following `RGBQUAD` structure (defined in `wingdi.h`) to specify the ordering of color components in the 32-bit pixels that comprise a true-color bitmapped image⁴:

```
typedef struct tagRGBQUAD {
    BYTE    rgbBlue;
    BYTE    rgbGreen;
    BYTE    rgbRed;
    BYTE    rgbReserved;
} RGBQUAD;
```

⁴ The `RGBQUAD` structure was initially used to describe 32-bit color palette entries. It was later used to specify the default pixel format for "uncompressed RGB" (true-color images). Later yet, the structure was extended (sort of) to support alpha blending, as described in this MSDN article: [Alpha Blending \(Windows GDI\) - Win32 apps](#).

On a little-endian machine, this structure places the r, g, and b values in the same byte positions as the BGRA32 format shown in the preceding figure. The C++ compiler for a big-endian machine will, of course, reverse the order of the RGBQUAD members in a 32-bit pixel.

The Windows RGB macro has the virtue of being consistent for both big- and little-endian machines.

In the ShapeGen library, the `renderer.h` header file defines the following two macros, which are similar to the Windows RGB macro:

```
#define RGBX(r,g,b)    (COLOR)(((r)&255)|(((g)&255)<<8)|(((b)&255)<<16)|0xff000000)
#define RGBA(r,g,b,a) (COLOR)(((r)&255)|(((g)&255)<<8)|(((b)&255)<<16)|((a)<<24))
```

These macros build an RGBA32 pixel from three or four 8-bit components. The RGBX macro sets the color components to the caller-specified r, g, and b values, and it sets the alpha (a) component to 255, which makes the pixel fully opaque.

The RGBA macro is similar to RGBX but allows the caller to set the alpha component to a custom value between 0 and 255. For either macro, the alpha component controls the opacity of the pixel. Setting the alpha component to zero makes the pixel completely transparent (bug alert: it will be invisible).

The COLOR type in the RGBX and RGBA macros is an unsigned int that the enhanced renderer uses to represent a 32-bit pixel value. By default, the EnhancedRenderer interface assumes that a user-supplied COLOR variable is in RGBA32 pixel format. However, the caller to the [EnhancedRenderer::SetPattern](#) function can set the FLAG_IMAGE_BGRA32 flag to indicate that the pixels in the pattern image are in BGRA32 format rather than RGBA32 format.

By default, the enhanced renderer assumes that a COLOR variable supplied by an application program is in straight (non-premultiplied) alpha format. However, the caller to the `EnhancedRenderer::SetPattern` function can set the FLAG_PREMULTALPHA flag to indicate that the pattern pixels are in premultiplied-alpha format.

Pixel buffers managed by the enhanced renderer are always in premultiplied-alpha format.

Compositing and filtering with layers

ShapeGen application programs typically draw to a back buffer, whose contents are then copied to the on-screen memory and displayed. By making use of the enhanced renderer's alpha-blending capabilities, users can render arbitrarily complex images by compositing layers of graphics elements into the back buffer.

However, if a complex image is to be used multiple times, the image can be rendered to a separate pixel buffer and preserved; doing so avoids discarding and then rendering the image again each time it is needed.

This separate pixel buffer is frequently referred to as a compositing layer, or simply *layer*. The pixel buffer for a layer typically has the same 32-bit pixel format as the back buffer. Depending on the application, a layer buffer may or may not have the same dimensions as the back buffer.

To create a pixel buffer that is to be used as a layer, the buffer is initially filled with a background color of transparent black. In a transparent black pixel, the 8-bit red, green, blue, and alpha components are all set to zero. After an image has been rendered over this background, any pixels in the layer buffer that have not been painted remain transparent. Thus, when the completed image in the layer is composited into the back

buffer, any part of the back buffer's original background that is covered by a transparent part of the layer remains fully visible.

An EnhancedRenderer object can work equally well with a back buffer or a layer buffer. The renderer doesn't even need to know whether it's drawing to a layer buffer or a back buffer. To use the renderer with a layer, it is only necessary to fill the layer buffer with transparent black at the time it is allocated. In contrast, a newly allocated back buffer's background should be fully opaque; that is, the alpha component in every pixel in the buffer should be initially set to 255.

Typically, it's most convenient to create separate EnhancedRenderer objects to work with the back buffer and layer buffer. Each of these renderer objects can then be managed by a dedicated ShapeGen object. Assigning separate renderer and ShapeGen objects to the back buffer and layer buffer avoids having to switch graphics contexts each time an application program's focus changes from the back buffer to the layer, and vice versa.

In the following code example, the DropShadow function creates a layer buffer, into which the function renders a composite image consisting of five connected shapes of different colors. Next, the alpha components from this image are Gaussian-blurred to form a drop shadow of the image. Finally, the original image and drop shadow are composited together into the back buffer. A detailed description follows the code example.

```
void DropShadow(const PIXEL_BUFFER& bkbuf, const SGRect& clip)
{
    // 1. Dedicate a renderer and ShapeGen object to the back buffer
    //
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));

    // 2. Create dedicated renderer and ShapeGen objects to manage a
    //     layer buffer, which is initialized to transparent black
    //
    SGRect clip2 = { 0, 0, 640, 480 }; // device clipping rect
    PIXEL_BUFFER layerbuf;
    layerbuf.pixels = 0; // renderer will allocate pixel memory
    layerbuf.width = clip2.w;
    layerbuf.height = clip2.h;
    layerbuf.depth = 32;
    SmartPtr<EnhancedRenderer> aarend2(CreateEnhancedRenderer(&layerbuf));
    SmartPtr<ShapeGen> sg2(CreateShapeGen(&*aarend2), clip2));

    // 3. Render OlympicRings image into layer, and get image's bbox
    //
    SGRect bbox;
    OlympicRings(&*sg2), &*aarend2), &bbox);

    // 4. Get subregion of layer that contains original, unblurred image
    //
    PIXEL_BUFFER subbuf;
    bool status = aarend2->GetPixelBuffer(&layerbuf);
    assert(status);
    DefineSubregion(subbuf, layerbuf, bbox);

    // 5. Apply Gaussian blur to alpha values in OlympicRings image
    //
    float stddev = 4.2f;
    AlphaBlur ablur(stddev);
    ablur.SetColor(RGBA(0,0,0,160));
```

```

status = ablur.BlurImage(subbuf);
assert(status);

// 6. Get the expanded bounding box for the blurred image
//
SGRect blurbbox;
ablur.GetBlurredBoundingBox(blurbbox, bbox);

// 7. Use blurred image as pattern for rendering to back buffer
//
blurbbox.x += 6, blurbbox.y += 8;
aarend->SetPattern(&ablur, blurbbox.x, blurbbox.y,
                  blurbbox.w, blurbbox.h, 0);
sg->BeginPath();
sg->Rectangle(blurbbox);
sg->FillPath(FILLRULE_EVENODD);

// 8. Use the original, unblurred image as the next fill pattern
//
aarend->SetPattern(subbuf.pixels, bbox.x, bbox.y,
                  bbox.w, bbox.h, subbuf.pitch/sizeof(COLOR),
                  FLAG_IMAGE_BGRA32 | FLAG_PREMULTALPHA);
sg->BeginPath();
sg->Rectangle(bbox);
sg->FillPath(FILLRULE_EVENODD);
}

```

The DropShadow function is taken from the demo.cpp source file in this project. The step-by-step description of this code example is as follows:

1. The DropShadow function starts by creating an enhanced renderer and ShapeGen object, which are accessed through the sg and aarend pointers, as was done in the [Creating a ShapeGen object](#) topic. These objects are dedicated for use with a back buffer that was allocated by the caller. Assume that this buffer has a width of 1280 pixels and a height of 960 pixels and was initially filled with an opaque background color.
2. Next, the example code creates a second enhanced renderer and ShapeGen object, which will be dedicated for use with a layer buffer. These objects are accessed through the aarend2 and sg2 pointers. In the call to the CreateEnhancedRenderer function, the layerbuf argument provides a null pointer value for the pixels member, which prompts the renderer to allocate a block of memory for the pixels and fill it with zeroes (transparent black). (Because the renderer allocated this memory, the renderer's destructor will delete it.)
3. The example code calls the OlympicRings function (in the demo.cpp source file in this project) to render an image to the layer buffer. This image is composed of five stroked shapes (interlocked circles) of different colors. The sg2 and aarend2 object pointers are passed as arguments in the OlympicRings function call. After rendering the image, this function retrieves the bounding box, bbox, for the image.
4. The DefineSubregion function (in the renderer.cpp source file) generates a concise description of the piece of the layer buffer that corresponds to the bounding box for the OlympicRings image.
5. To generate a Gaussian-blurred drop shadow for the OlympicRings image, an instance of the AlphaBlur class (defined in demo.h; implemented in alfablur.cpp) is created. The stddev argument passed to the AlphaBlur constructor is the standard deviation to use for the Gaussian filter.

The `AlphaBlur::BlurImage` function call takes the `OlympicRings` image as input, generates a blurred image (the drop shadow) from the alpha components in the input image, and allocates memory in which to store the blurred image. In this filtering process, which is referred to as *alpha blurring*, the color components in the input image are discarded and replaced by a fill color in the output image. The preceding call to the `AlphaBlur::SetColor` function specifies the fill color as partially opaque black.

To be suitable for alpha blurring, the source image must reside in a layer buffer so that any surrounding pixels that are not part of the image are transparent. If the source image were instead taken from the back buffer, which contains only fully opaque pixels, the alpha-blurred version of the image would be a very boring solid black rectangle.

6. The example code calls the `AlphaBlur::GetBlurredBoundingBox` function to retrieve the bounding box for the blurred image.

The bounding box for a Gaussian-blurred image is an expanded version of the bounding box for the original image. If r is the radius of the Gaussian filter kernel, the blurred image's bounding box is calculated by extending the four sides of the original image's bounding box outward by $r = \text{floor}(w/2)$ pixels, where w is the filter kernel width. The `AlphaBlur` constructor allows the caller to specify a custom kernel width (always an odd integer) but this example code simply relies on the constructor to calculate a default width.

7. From here on, the example code will be drawing to the back buffer and will use the `sg` and `aarend` pointers instead of `sg2` and `aarend2`.

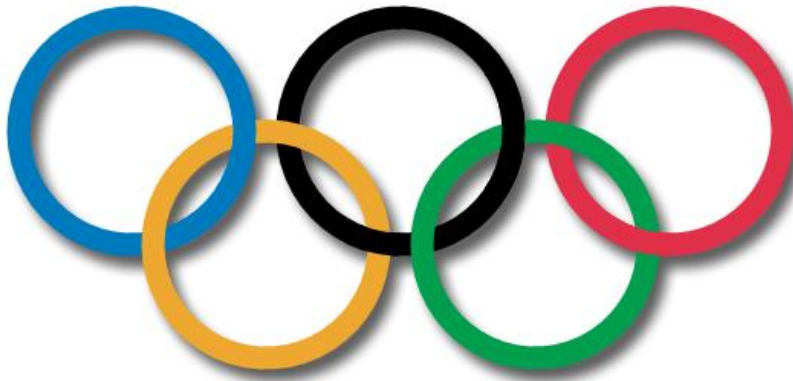
To achieve a shadow effect, the blurred image is composited into the back buffer first, after which the original image is composited over the blurred image. A small offset is added to the bounding box for the blurred image to push it a few pixels downward and to the right relative to the original image.

To alpha-blend the blurred image into the back buffer, the example code sets the blurred image to be the current fill pattern and then uses the pattern to fill the rectangle described by the bounding box for the blurred image. In the initial call to the `EnhancedRenderer::SetPattern` function, the first argument is a pointer to the `AlphaBlur` object, which implements an `ImageFeeder` interface, as described in the [EnhancedRenderer::SetPattern](#) reference topic. The `SetPattern` function uses this interface to load the blurred image to serve as the next pattern.

At first glance, using the blurred image as a fill pattern might not seem to be the most straightforward way to move this image into the back buffer. But fill patterns have these advantages:

- they are automatically clipped
 - they use the current [constant alpha](#) for blending
 - they use the transformation set by the [EnhancedRenderer::SetTransform](#) function
 - they can fill shapes other than rectangles
 - they can be automatically converted to premultiplied-alpha format, if needed
8. To blend the original, unblurred image into the back buffer, the example code again calls the `SetPattern` function to designate the original image as the fill pattern and then fills the rectangle described by this image's bounding box. In this version of the overloaded `SetPattern` function, the first argument is a two-dimensional pixel array, as described in the [EnhancedRenderer::SetPattern](#) topic.

The output produced by this code example is shown in the following screenshot.



For more information, the following websites have helpful descriptions of layers:

- Wikipedia.org — see [https://en.wikipedia.org/wiki/Layers_\(digital_image_editing\)](https://en.wikipedia.org/wiki/Layers_(digital_image_editing))
- Lifewire.com — see <https://www.lifewire.com/what-is-a-layer-140867>.

ShapeGen types and structures

The following types and structures are used by the functions in the ShapeGen programming interface. These types and structures are defined in the `shapegen.h` header file included in this GitHub project.

The `SGPoint` and `SGRect` structures are essentially identical to the SDL2 structures `SDL_Point` and `SDL_Rect` but are renamed here to enhance portability and to avoid naming conflicts in SDL2-based implementations.

SGCoord type

The `SGCoord` type is used to store an *x* or *y* coordinate value.

Syntax

C++

```
typedef int SGCoord;
```

Remarks

By default, ShapeGen functions treat the user's `SGCoord` values as 32-bit integers. However, the user can call the `ShapeGen::SetFixedBits` function to specify that ShapeGen functions are to treat `SGCoord` values as fixed-point numbers instead.

The `SGPoint` and `SGRect` structures contain coordinate values of type `SGCoord`. The interpretation of the *x-y* coordinate values in these structures is affected by calls to the `SetFixedBits` function.

For information about the mapping of ShapeGen x-y coordinates to the pixels on a graphics display, see [Scan conversion](#).

Header

`shapegen.h`

See also

[ShapeGen::SetFixedBits](#)

[SGPoint](#)

[SGRect](#)

SGPoint structure

The `SGPoint` structure specifies the position of a point in the x-y coordinate space used by the ShapeGen path-construction functions.

Syntax

C++

```
struct SGPoint {  
    SGCoord x;  
    SGCoord y;  
};
```

Members

x

The x coordinate value.

y

The y coordinate value.

Remarks

Parameters `x` and `y` specify horizontal and vertical displacements, in pixels, from the origin of the coordinate space used by the ShapeGen path-construction functions. In the ShapeGen coordinate system, `x` values increase to the right, and `y` values increase in the downward direction.

By default, ShapeGen functions treat the user's [SGCoord](#) values as 32-bit integers. However, the user can call the [ShapeGen::SetFixedBits](#) function to specify that ShapeGen functions are to treat `SGCoord` values as fixed-point numbers.

For information about the mapping of ShapeGen x-y coordinates to a graphics display, see [Scan conversion](#).

Header

`shapegen.h`

See also

[SGCoord](#)

[ShapeGen::SetFixedBits](#)

SGRect structure

The `SGRect` structure specifies a rectangle in terms of its width and height, in pixels, and the *x-y* coordinates at its top-left corner.

Syntax

C++

```
struct SGRect {  
    SGCoord x;  
    SGCoord y;  
    SGCoord w;  
    SGCoord h;  
};
```

Members

x

The *x* coordinate at the left edge of the rectangle.

y

The *y* coordinate at the top edge of the rectangle.

w

The width, in pixels, of the rectangle.

h

The height, in pixels, of the rectangle.

Remarks

The top and bottom sides of the rectangle are horizontal. The left and right sides of the rectangle are vertical.

Parameters *x* and *y* specify horizontal and vertical displacements, in pixels, from the origin of the coordinate space used by the ShapeGen path-construction functions. In the ShapeGen coordinate system, *x*

values increase to the right and *y* values increase in the downward direction. Thus, the minimum *x* and *y* coordinates for a rectangle are located at the rectangle's top-left corner.

By default, [SGCoord](#) values are 32-bit integers. However, the user can call the [ShapeGen::SetFixedBits](#) function to specify that ShapeGen functions are to treat SGCoord values as fixed-point numbers.

For information about the mapping of ShapeGen *x-y* coordinates to a graphics display, see [Scan conversion](#).

Header

`shapegen.h`

See also

[SGCoord](#)

[ShapeGen::SetFixedBits](#)

ShapeGen functions

The following reference topics describe the functions that comprise the ShapeGen programming interface. This interface is defined in the `shapegen.h` header file included in this GitHub project.

[ShapeGen::BeginPath](#) function

The `BeginPath` function begins a new path.

Syntax

C++

```
void ShapeGen::BeginPath();
```

Parameters

None

Return value

None

Remarks

This function discards any existing path, starts a new path, and starts a new, empty figure (or subpath) in this path.

After a new path is created, it persists until another `BeginPath` function call discards the path and creates a new one. A path is *not* destroyed by calls to [ShapeGen::FillPath](#), [ShapeGen::StrokePath](#), or the ShapeGen clipping functions.

Header

`shapegen.h`

See also

[ShapeGen::FillPath](#)

[ShapeGen::StrokePath](#)

ShapeGen::Bezier2 function

The `Bezier2` function constructs a quadratic Bezier spline curve (a parabolic arc), starting at the current point.

Syntax

C++

```
bool ShapeGen::Bezier2(  
    const SGPoint& v1,  
    const SGPoint& v2  
);
```

Parameters

v1

An [SGPoint](#) structure that specifies the x-y coordinates at the Bezier control point for the spline.

v2

An [SGPoint](#) structure that specifies the x-y coordinates at the end point of the spline.

Return value

Returns true if the function succeeds in constructing the spline. If the current point is undefined (because the current figure is empty), the function fails and immediately returns false. Before returning false, the function faults if the `NDEBUG` macro (used in `assert.h`) is undefined.

Remarks

The current point is the starting point for the spline. Parameters `v1` and `v2` specify the control point and end point of the spline.

The [ShapeGen::PolyBezier2](#) function constructs a set of connected quadratic Bezier splines in a single function call.

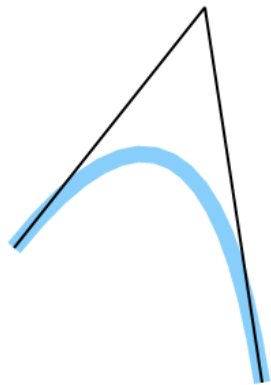
Example

This example uses the `Bezier2` function to draw a quadratic Bezier spline (in blue) and its control polygon (in black). (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example01(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip);
    SGPoint v0 = { 100, 200 }, v1 = { 200, 75 }, v2 = { 230, 270 };

    // Draw quadratic Bezier spline in blue
    aarend->SetColor(RGBX(135,206,250));
    sg->SetLineWidth(12.0);
    sg->BeginPath();
    sg->Move(v0.x, v0.y);
    sg->Bezier2(v1, v2);
    sg->StrokePath();

    // Outline control polygon in black
    aarend->SetColor(RGBX(0,0,0));
    sg->SetLineWidth(2.0);
    sg->BeginPath();
    sg->Move(v0.x, v0.y);
    sg->Line(v1.x, v1.y);
    sg->Line(v2.x, v2.y);
    sg->StrokePath();
}
```



The output produced by this code example is shown in the screenshot at left.

In the code example above, points `v0`, `v1`, and `v2` define the control polygon for the spline curve. The starting point, `v0`, is on the left side of the screenshot, the control point, `v1`, is at the top, and the end point, `v2`, is on the bottom right. The curve is tangent to side `v0·v1` at the starting point and is tangent to side `v1·v2` at the end point.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::PolyBezier2](#)

ShapeGen::Bezier3 function

The Bezier3 function constructs a cubic Bezier spline curve, starting at the current point.

Syntax

C++

```
bool ShapeGen::Bezier3(  
    const SGPoint& v1,  
    const SGPoint& v2,  
    const SGPoint& v3  
);
```

Parameters

v1

An [SGPoint](#) structure that specifies the x-y coordinates at the first Bezier control point for the spline.

v2

An [SGPoint](#) structure that specifies the x-y coordinates at the second Bezier control point for the spline.

v3

An [SGPoint](#) structure that specifies the x-y coordinates at the end point of the spline.

Return value

Returns `true` if the function succeeds in constructing the spline. If the current point is undefined (because the current figure is empty), the function fails and immediately returns `false`. Before returning `false`, the function faults if the `NDEBUG` macro (used in `assert.h`) is undefined.

Remarks

The current point is the starting point for the spline. Parameters `v1`, `v2`, and `v3` specify the two control points and end point of the spline.

The [ShapeGen::PolyBezier3](#) function constructs a set of connected cubic Bezier splines in a single function call.

Example

This example uses the Bezier3 function to draw a cubic Bezier spline (in orange) and its control polygon (in black). (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example02(const PIXEL_BUFFER& bkbuff, const SGRect& clip)  
{  
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));  
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip);  
    SGPoint v0 = { 140, 308 }, v1 = { 210, 70 },
```

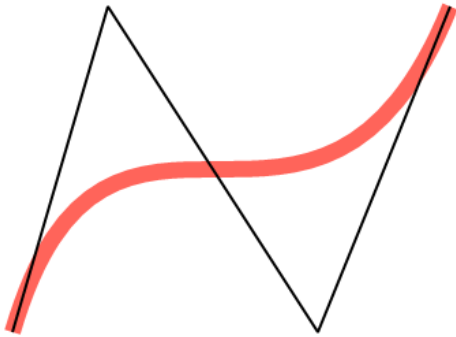
```

v2 = { 364, 308 }, v3 = { 461, 70 };

// Draw cubic Bezier spline in red
aarend->SetColor(RGBX(255,100,90));
sg->SetLineWidth(12.0);
sg->BeginPath();
sg->Move(v0.x, v0.y);
sg->Bezier3(v1, v2, v3);
sg->StrokePath();

// Outline control polygon in black
aarend->SetColor(RGBX(0,0,0));
sg->SetLineWidth(2.0);
sg->BeginPath();
sg->Move(v0.x, v0.y);
sg->Line(v1.x, v1.y);
sg->Line(v2.x, v2.y);
sg->Line(v3.x, v3.y);
sg->StrokePath();
}

```



The output produced by this code example is shown in the screenshot at left.

In the code example above, points v_0 , v_1 , v_2 , and v_3 define the control polygon for the spline curve. The starting point, v_0 , is at the lower-left corner of the screenshot. The end point, v_3 , is at the top-right corner. In between are the two control points, v_1 and v_2 . The curve is tangent to side $v_0 \cdot v_1$ at the starting point and is tangent to side $v_2 \cdot v_3$ at the end point.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::PolyBezier3](#)

ShapeGen::CloseFigure function

The `CloseFigure` function closes a figure (or subpath) by adding a line segment connecting the current point to the first point in the figure.

Syntax

C++

```
void ShapeGen::CloseFigure();
```

Parameters

None

Return value

None

Remarks

This function finalizes the current figure and starts a new, empty figure in the same path. After a figure is finalized, it cannot be modified or added to. Any finalized figure not explicitly closed by `CloseFigure` is open; that is, the first and last points in the figure are not connected. A `CloseFigure` call has no effect on a figure that has already been finalized.

`CloseFigure` affects the appearance of stroked paths drawn by the [ShapeGen::StrokePath](#) function but has no effect on the appearance of filled paths. Shapes filled by the [ShapeGen::FillPath](#) function are always constructed as though the first and last points in each figure are connected, regardless of any previous calls to `CloseFigure`. Similarly, clipping regions specified by the [ShapeGen::SetClipRegion](#) and [ShapeGen::SetMaskRegion](#) functions are always constructed as though the first and last points in each figure are connected.

The `StrokePath`, `FillPath`, `SetClipRegion`, and `SetMaskRegion` functions finalize the last figure in the path, if it has not already been finalized. When this occurs, the ends of the finalized figure are left open and cannot subsequently be closed.

If `CloseFigure` is called to finalize a figure that contains a single point, the point is discarded, which leaves the figure empty and ready to receive its first point.

In contrast to `CloseFigure`, the [ShapeGen::EndFigure](#) function finalizes a figure without closing it – that is, the start and end points are left unconnected.

Header

`shapegen.h`

See also

[ShapeGen::StrokePath](#)

[ShapeGen::FillPath](#)

[ShapeGen::CloseFigure](#)

[ShapeGen::SetClipRegion](#)

[ShapeGen::SetMaskRegion](#)

[ShapeGen::EndFigure](#)

ShapeGen::Ellipse function

The Ellipse function adds an ellipse to the current path.

Syntax

C++

```
void ShapeGen::Ellipse(  
    const SGPoint& v0,  
    const SGPoint& v1,  
    const SGPoint& v2  
);
```

Parameters

v0

An [SGPoint](#) structure that specifies the x-y coordinates at the center of the ellipse.

v1

An [SGPoint](#) structure that specifies the x-y coordinates at an end point of the first of a pair of conjugate diameters of the ellipse.

v2

An [SGPoint](#) structure that specifies the x-y coordinates at an end point of the second of a pair of conjugate diameters of the ellipse.

Return value

None

Remarks

This function can construct an ellipse of arbitrary shape and orientation. The ellipse is defined by its center point and two additional points that lie on the ellipse. The two additional points are the end points of two conjugate diameters of the ellipse.

If the two conjugate diameters are perpendicular and of the same length, the ellipse is a circle. To construct an ellipse in standard position, align the two conjugate diameters to be parallel with the x and y axes.

An ellipse constructed by the Ellipse function is added to the current path as a complete, closed figure. If, on entry to the Ellipse function, the current figure has not already been finalized, the function finalizes the figure by leaving it open (that is, in the same manner as the [ShapeGen::EndFigure](#) function) and then starts a new figure in the same path. After adding the points in the ellipse to the new figure, the Ellipse function finalizes this new figure by closing it (in the same manner as the [ShapeGen::CloseFigure](#) function) before starting a newer, empty figure in the same path.

On return from the Ellipse function, the current point is undefined.

For more information about conjugate diameter end points, see [Ellipses and Elliptic Arcs](#).

Example

It's straightforward to use the `Ellipse` function to inscribe an ellipse in a parallelogram so that the ellipse's center coincides with the center of the parallelogram, and the ellipse touches the parallelogram at the midpoint of each of its four sides. If we are given three consecutive corner points, *A*, *B*, and *C*, of the parallelogram, set parameter *v0* to the point midway between *A* and *C*, set *v1* to the point midway between *A* and *B*, and set *v2* to the point midway between *B* and *C*. This technique works for any parallelogram, rhombus, rectangle, or square.

The following example uses the `Ellipse` function to draw two ellipses inscribed in parallelograms. (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example03(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend, clip));
    SGPPoint xy[2][4] = {
        { { 100, 275 }, { 100, 75 }, { 300, 75 }, },
        { { 354, 309 }, { 380, 139 }, { 618, 37 }, },
    };

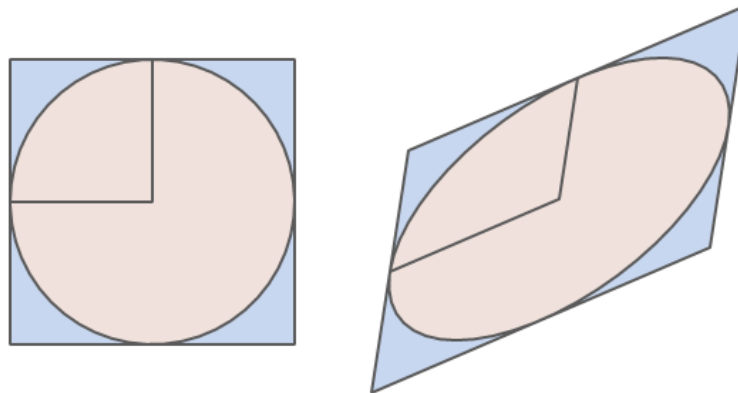
    sg->SetLineWidth(2.0);
    for (int i = 0; i < 2; ++i)
    {
        SGPPoint v0, v1, v2;

        // Use symmetry to calculate the fourth vertex of the
        // enclosing square or parallelogram
        xy[i][3].x = xy[i][0].x - xy[i][1].x + xy[i][2].x;
        xy[i][3].y = xy[i][0].y - xy[i][1].y + xy[i][2].y;

        // Calculate ellipse center and two conjugate diameter
        // end points
        v0.x = (xy[i][0].x + xy[i][2].x)/2;
        v0.y = (xy[i][0].y + xy[i][2].y)/2;
        v1.x = (xy[i][0].x + xy[i][1].x)/2;
        v1.y = (xy[i][0].y + xy[i][1].y)/2;
        v2.x = (xy[i][1].x + xy[i][2].x)/2;
        v2.y = (xy[i][1].y + xy[i][2].y)/2;

        // Render parallelogram and inscribed ellipse
        sg->BeginPath();
        sg->Ellipse(v0, v1, v2);
        aarend->SetColor(RGBX(240,225,220));
        sg->FillPath(FILLRULE_EVENODD);
        sg->Move(xy[i][0].x, xy[i][0].y);
        sg->PolyLine(3, &xy[i][1]);
        sg->CloseFigure();
        aarend->SetColor(RGBX(200,215,240));
        sg->FillPath(FILLRULE_EVENODD);
        sg->Move(v1.x, v1.y);
        sg->Line(v0.x, v0.y);
        sg->Line(v2.x, v2.y);
        aarend->SetColor(RGBX(90,90,90));
        sg->StrokePath();
    }
}
```

The output produced by this code example is shown in the following screenshot.



The figure on the left is a circle (a special kind of ellipse) inscribed in a square (a special kind of parallelogram). The circle touches the square at the midpoint of each side. Lines are drawn from the center of the circle to the end points of a pair of conjugate diameters, which in this case are simply perpendicular radii.

An affine transformation has been applied to the square on the left to produce the parallelogram on the right. The ellipse's center point and conjugate diameter end points have also been transformed. The resulting ellipse is inscribed in the parallelogram and touches the parallelogram at the midpoint of each of its four sides.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::EndFigure](#)

[ShapeGen::CloseFigure](#)

ShapeGen::EllipticArc function

The `EllipticArc` function constructs an elliptic arc in the current figure.

Syntax

C++

```
void ShapeGen::EllipticArc(  
    const SGPoint& v0,  
    const SGPoint& v1,  
    const SGPoint& v2,
```

```
float astart,  
float asweep  
);
```

Parameters

v0

An [SGPoint](#) structure that specifies the x-y coordinates at the center of the ellipse.

v1

An [SGPoint](#) structure that specifies the x-y coordinates at an end point of the first of a pair of conjugate diameters of the ellipse.

v2

An [SGPoint](#) structure that specifies the x-y coordinates at an end point of the second of a pair of conjugate diameters of the ellipse.

astart

The starting angle, in radians, of the elliptic arc.

asweep

The sweep angle, in radians, of the elliptic arc.

Return value

None

Remarks

Point **v0** is the center of the ellipse, and **v1** and **v2** are the end points of a pair of conjugate diameters of the ellipse. Parameter **astart** is the starting angle of the arc, and parameter **asweep** is the angle traversed by the arc. Both angles are specified in radians of elliptic arc, and both can have positive or negative values.

The starting angle is specified relative to point **v1**, and is positive in the direction of point **v2**. The sweep angle is positive in the same direction as the start angle.

If, on entry to this function, the current point is undefined (because the current figure is empty), the starting point of the arc becomes the first point in the figure. Otherwise, the function inserts a line segment connecting the current point to the starting point of the arc. On return from this function, the current point is set to the end point of the arc.

Arcs plotted by the `EllipticArc` function share an important property with Bezier curves: both are *affine-invariant*. For a Bezier curve, applying any affine transformation to the vertexes of the control polygon produces the same transformed curve as does directly transforming the points on the curve. Similarly, for an arc constructed by the `EllipticArc` function, application of any affine transformation to the ellipse center point **v0** and the two conjugate diameter end points **v1** and **v2** has the same effect as directly transforming the points on the arc. In particular, transformation of the arc does not require modification of the **astart** and **asweep** parameter values supplied to the function (see Example).

For more information about conjugate diameter end points, see [Ellipses and Elliptic Arcs](#).

Example

This example uses the `EllipticArc` function to draw two affine-transformed views of the same pie chart. (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

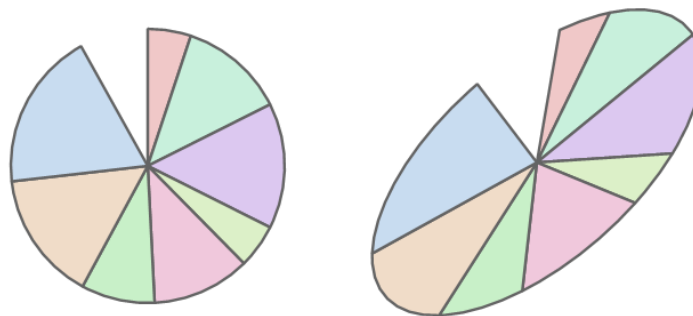
```
void example04(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));
    float percent[] = {
        5.1, 12.5, 14.8, 5.2, 11.6, 8.7, 15.3, 18.7
    };
    COLOR color[] = {
        RGBX(240,200,200), RGBX(200,240,220), RGBX(220,200,240), RGBX(220,240,200),
        RGBX(240,200,220), RGBX(200,240,200), RGBX(240,220,200), RGBX(200,220,240),
    };
    SGPoint v[2][4] = {
        { { 240, 210 }, { 240, 90 }, { 360, 210 }, },
        { { 581, 207 }, { 601, 91 }, { 724, 140 }, },
    };

    sg->SetLineWidth(2.4);
    for (int i = 0; i < 2; ++i)
    {
        float astart = 0;

        for (int j = 0; j < 8; ++j)
        {
            float asweep = 2.0*PI*percent[j]/100.0;

            sg->BeginPath();
            sg->EllipticArc(v[i][0], v[i][1], v[i][2], astart, asweep);
            sg->Line(v[i][0].x, v[i][0].y);
            aarend->SetColor(color[j]);
            sg->CloseFigure();
            sg->FillPath(FILLRULE_EVENODD);
            aarend->SetColor(RGBX(100,100,100));
            sg->StrokePath();
            astart += asweep;
        }
    }
}
```

The output produced by this code example is shown in the following screenshot.



The two pie charts in this screenshot differ only in values of the parameters v_0 , v_1 , and v_2 that are passed to the `EllipticArc` function. The `astart` and `asweep` parameter values that delimit the arcs in the two pie charts are identical. In essence, an affine transformation is applied to the v_0 , v_1 , and v_2 parameter values for the pie chart on the left to produce the pie chart on the right.

Should the caller need to obtain the x-y coordinates at the starting and ending points of each arc in the preceding code example, calls to the [ShapeGen::GetFirstPoint](#) and [ShapeGen::GetCurrentPoint](#) functions could be inserted immediately after the `EllipticArc` call.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::GetFirstPoint](#)

[ShapeGen::GetCurrentPoint](#)

ShapeGen::EllipticSpline function

The `EllipticSpline` function constructs an elliptic spline curve (an elliptic arc spanning $\pi/2$ radians), starting at the current point.

Syntax

C++

```
bool ShapeGen::EllipticSpline(  
    const SGPoint& v1,  
    const SGPoint& v2  
);
```

Parameters

v1

An [SGPoint](#) structure that specifies the x-y coordinates at the control point for the spline.

v2

An `SGPoint` structure that specifies the x-y coordinates at the end point of the spline.

Return value

Returns `true` if the function succeeds in constructing the spline. If the current point is undefined (because the current figure is empty), the function fails and immediately returns `false`. Before returning `false`, the function faults if the `NDEBUG` macro (used in `assert.h`) is undefined.

Remarks

The current point is the starting point for the spline. Parameters `v1` and `v2` specify the control point and end point of the spline. On return from this function, `v2` is the new current point.

The `ShapeGen::PolyEllipticSpline` function constructs a set of connected elliptic splines in a single function call.

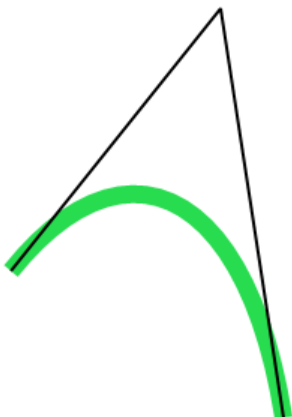
Example

This example uses the `EllipticSpline` function to draw an elliptic spline curve (in green). The spline's control polygon is outlined in black. (Parameter `bdbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example05(const PIXEL_BUFFER& bdbuf, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bdbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend, clip));
    SGPPoint v0 = { 140, 250 }, v1 = { 280, 75 }, v2 = { 322, 348 };

    // Draw elliptic spline in green
    aarend->SetColor(RGBX(40,220,80));
    sg->SetLineWidth(12.0);
    sg->BeginPath();
    sg->Move(v0.x, v0.y);
    sg->EllipticSpline(v1, v2);
    sg->StrokePath();

    // Outline control polygon in black
    aarend->SetColor(RGBX(0,0,0));
    sg->SetLineWidth(2.0);
    sg->BeginPath();
    sg->Move(v0.x, v0.y);
    sg->Line(v1.x, v1.y);
    sg->Line(v2.x, v2.y);
    sg->StrokePath();
}
```



The output produced by this code example is shown in the screenshot at left.

In the preceding code example, points `v0`, `v1`, and `v2` define the control polygon for the spline curve. The starting point, `v0`, is on the left side of the screenshot, the control point, `v1`, is at the top, and the end point, `v2`, is on the bottom right. The curve is tangent to side `v0·v1` at the starting point and is tangent to side `v1·v2` at the end point.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::PolyEllipticSpline](#)

ShapeGen::EndFigure function

The `EndFigure` function finalizes a figure (or subpath) by leaving the figure open; that is, the starting and ending points of the figure are left unconnected.

Syntax

C++

```
void ShapeGen::EndFigure();
```

Parameters

None

Return value

None

Remarks

This function finalizes the current figure and starts a new, empty figure in the same path. After a figure is finalized, it cannot be modified or added to. A figure that is finalized by the `EndFigure` function is open and cannot subsequently be closed. If this figure is later stroked by the [ShapeGen::StrokePath](#) function, no line segment is added to connect the starting and ending points of the figure.

The `EndFigure` and [ShapeGen::CloseFigure](#) functions affect the appearance of stroked paths but have no effect on the appearance of filled paths. Shapes filled by the [ShapeGen::FillPath](#) function are always constructed as though the first and last points in each figure are connected, regardless of any previous calls to `EndFigure` or `CloseFigure`. Similarly, clipping regions specified by the [ShapeGen::SetClipRegion](#) and [ShapeGen::SetMaskRegion](#) functions are always constructed as though the first and last points in each figure are connected.

Calls to `EndFigure` have no effect on a figure that has already been finalized.

If `EndFigure` is called for a figure that contains a single point, the point is discarded, which leaves the figure empty and ready to receive its first point.

Header

`shapegen.h`

See also

[ShapeGen::StrokePath](#)

[ShapeGen::CloseFigure](#)

[ShapeGen::FillPath](#)

[ShapeGen::SetClipRegion](#)

[ShapeGen::SetMaskRegion](#)

ShapeGen::FillPath function

The `FillPath` function fills the area enclosed by the current path according to the fill rule specified by the caller.

Syntax

```
C++

bool ShapeGen::FillPath(
    FILLRULE fillrule = FILLRULE_EVENODD
);
```

Parameters

fillrule

The fill rule to use for filling the path. Specify one of the following values for this parameter:

- `FILLRULE_EVENODD` – Even-odd (or parity) fill rule
- `FILLRULE_WINDING` – Nonzero winding number fill rule

If the caller does not explicitly supply a `fillrule` argument, the default value, `FILLRULE_EVENODD`, is automatically assigned to the `fillrule` parameter.

Return value

Returns `true` if the path, after being clipped, is not empty – in this case, the function has sent a description of the clipped path to the renderer to be filled. Otherwise, the function returns `false` to indicate that the clipped path was empty and that nothing has been sent to the renderer.

Remarks

The [ShapeGen::EndFigure](#) and [ShapeGen::CloseFigure](#) functions affect the appearance of stroked paths but have no effect on the appearance of filled paths. Shapes filled by the `FillPath` function are always constructed as though the first and last points in each figure are connected, regardless of any previous calls to `EndFigure` or `CloseFigure`.

If the final figure in the path has not already been finalized, `FillPath` finalizes this figure in the same manner as the `EndFigure` function. If, for example, a path is to be filled first and then stroked, and the final

figure in the path needs to be closed for the [ShapeGen::StrokePath](#) call, be sure to call `CloseFigure` before calling `FillPath`.

Header

`shapegen.h`

See also

[ShapeGen::EndFigure](#)

[ShapeGen::CloseFigure](#)

[ShapeGen::StrokePath](#)

ShapeGen::GetBoundingBox function

The `GetBoundingBox` function retrieves the minimum bounding box for the shape defined by the current path.

Syntax

C++

```
int ShapeGen::GetBoundingBox(  
    SGRect *bbox,  
    int flags = 0  
);
```

Parameters

bbox

A pointer to a caller-supplied [SGRect](#) structure. The function writes the x-y coordinates, width, and height of the minimum bounding box to this structure. The `bbox` argument can be null (zero) if the caller simply wants a count of the number of points in the path.

flags

The following flag bits are defined for this function:

- `FLAG_BBOX_STROKE` – Take the current stroked-line attributes into account
- `FLAG_BBOX_CLIP` – Clip the bounding box to the device clipping rectangle
- `FLAG_BBOX_ACCUM` – Accumulate bounding box data from multiple paths

Two or more of these flag bits can be used in combination in the same function call by bitwise-ORing them together.

If the caller does not explicitly supply a `flags` argument, the default value, 0, is automatically assigned to the `flags` parameter.

Return value

Returns a count of the number of points in the current path. If the path is empty, the function immediately returns a value of zero without writing to the structure pointed to by `bbox`. If the `FLAG_BBOX_CLIP` flag is set, and the bounding box lies completely outside the device clipping rectangle, the function returns a value of zero without writing to the `bbox` structure.

Remarks

The bounding box is determined by all the points in the current path. The path can be empty, or can contain one or more points. If the path contains multiple figures (or subpaths), the bounding box takes into account the points in all the figures.

Unless the `FLAG_BBOX_STROKE` flag bit is set, the `GetBoundingBox` function calculates the bounding box with the assumption that the path is to be filled by the `ShapeGen::FillPath` function.

If the `FLAG_BBOX_STROKE` flag bit is set, the `GetBoundingBox` function calculates the bounding box with the assumption that the path is to be stroked by the `ShapeGen::StrokePath` function. In this case, the `GetBoundingBox` function takes into account the current set of stroked-path attributes. These attributes are the line width, the line-end-cap style, the line-join style, and the miter limit. `GetBoundingBox` does not actually construct the stroked path. Instead, it first calculates the simple bounding box for the points in the path and then expands the box to encompass the features of the stroked path. For example, if rounded end caps and joins are currently selected, the function extends the simple bounding box outward by half the linewidth on each of its four sides.

The `GetBoundingBox` function's handling of the `FLAG_BBOX_STROKE` flag is conservative and can lead to an oversized bounding box if the current miter limit is excessively long. For example, if the joins in the stroked path are all formed by pairs of lines that meet at obtuse angles, a smaller miter limit would suffice without affecting the appearance of the rendered shape.

If the `FLAG_BBOX_CLIP` flag bit is set, the `GetBoundingBox` function clips the bounding box to the device clipping rectangle. If only part of the shape defined by the path lies inside the clipping rectangle, the function still returns the full count of points in the path. But if the shape lies entirely outside the clipping rectangle, the function returns zero and does not write to the `bbox` structure.

Unless the `FLAG_BBOX_ACCUM` flag bit is set, the `GetBoundingBox` function ignores the original contents of the `bbox` structure and overwrites them with the bounding box data for the current path.

The `FLAG_BBOX_ACCUM` flag enables a bounding box to be cumulatively assembled from multiple paths. If this flag is set, then instead of simply overwriting the initial contents of the `bbox` structure, the `GetBoundingBox` function treats these contents as valid bounding box data accumulated from previous paths. In this case, after constructing the bounding box for the new path, the function merges this bounding box with the existing contents of `bbox`. The result is a bounding box that encompasses multiple paths.

However, the `GetBoundingBox` function ignores the `FLAG_BBOX_ACCUM` flag if the original `bbox` contents specify a width or height that is less than or equal to zero and is therefore invalid. This behavior provides a convenient way to initialize a `bbox` structure before making the first in a series of `GetBoundingBox` function calls that will all use the `FLAG_BBOX_ACCUM` flag. For example, initialize the `bbox` width and height to zero.

The `GetBoundingBox` function does not alter the path in any way.

The bounding-box coordinates retrieved by this function are converted to the user's [SGCoord](#) format. By default, SGCoord values are integers, but the user can call the [ShapeGen::SetFixedBits](#) function to switch to a fixed-point format.

The four sides of the bounding box generated by the `GetBoundingBox` function are always adjusted to fall on the boundaries between pixels. These boundaries align with integer *x* and *y* coordinates in the coordinate system used by the ShapeGen drawing functions.

If the path contains a single point, the width and height values calculated for the bounding box can be small but are always greater than zero.

Example

This example uses the `GetBoundingBox` function to get the minimum bounding boxes for three similar shapes. The first shape is filled, the second is stroked with round joins, and the third is stroked with miter joins. (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example06(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));
    SGPoint xy[] = {
        { 130, 97 }, { 308, 265 }, { 326, 181 },
        { 100, 257 }, { 158, 312 }, { 206, 73 }
    };
    SGRect bbox;

    // Fill the shape with solid blue
    aarend->SetColor(RGBX(0,190,255)); // blue
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyLine(5, &xy[1]);
    sg->GetBoundingBox(&bbox, 0);
    sg->FillPath(FILLRULE_EVENODD);

    // Overlay the bounding box on the filled shape
    aarend->SetColor(RGBA(200,180,160,90)); // beige
    sg->BeginPath();
    sg->Rectangle(bbox);
    sg->FillPath(FILLRULE_EVENODD);

    // Move the shape to the right
    for (int i = 0; i < 6; ++i)
        xy[i].x += 320;

    // Stroke the shape with round joins
    aarend->SetColor(RGBX(0,190,255)); // blue
    sg->SetLineJoin(LINEJOIN_ROUND);
    sg->SetLineWidth(28.0);
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyLine(5, &xy[1]);
    sg->CloseFigure();
    sg->GetBoundingBox(&bbox, FLAG_BBOX_STROKE);
    sg->StrokePath();

    // Overlay the bounding box on the stroked shape
```

```

aarend->SetColor(rgba(200,180,160,90)); // beige
sg->BeginPath();
sg->Rectangle(bbox);
sg->FillPath(FILLRULE_EVENODD);

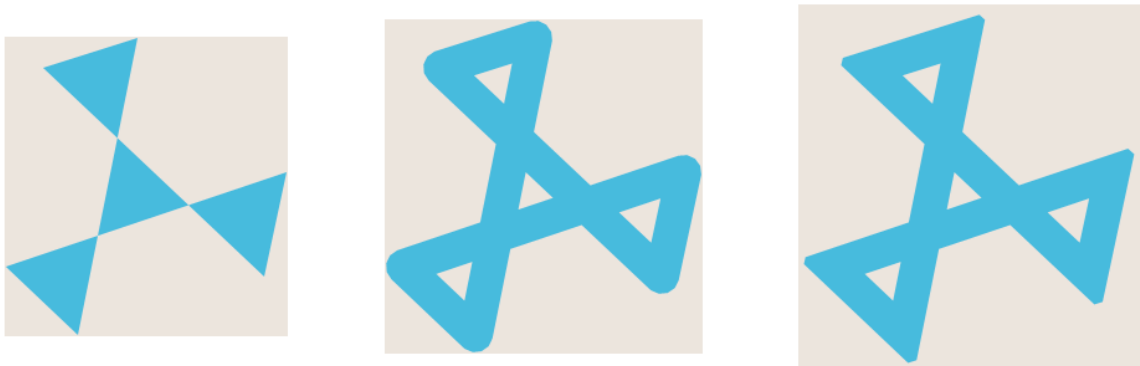
// Move the shape to the right
for (int i = 0; i < 6; ++i)
    xy[i].x += 345;

// Stroke the shape with mitered joins
aarend->SetColor(rgb(0,190,255)); // blue
sg->SetLineJoin(LINEJOIN_MITER);
sg->SetMiterLimit(1.6);
sg->BeginPath();
sg->Move(xy[0].x, xy[0].y);
sg->PolyLine(5, &xy[1]);
sg->CloseFigure();
sg->GetBoundingBox(&bbox, FLAG_BBOX_STROKE);
sg->StrokePath();

// Overlay the bounding box on the stroked shape
aarend->SetColor(rgba(200,180,160,90)); // beige
sg->BeginPath();
sg->Rectangle(bbox);
sg->FillPath(FILLRULE_EVENODD);
}

```

The output produced by this code example is shown in the following screenshot.



In this screenshot, three shapes are filled or stroked in blue. The bounding box that `GetBoundingBox` calculates for each shape is shown in beige. The path coordinates for the three shapes are identical, except for being shifted horizontally.

The shape on the left is filled by the `ShapeGen::FillPath` function. The middle shape is stroked by the `ShapeGen::StrokePath` function with round line joins and the line width set to 28 pixels. The shape on the right is stroked by the `StrokePath` function with the same line width, but with miter joins and a miter limit of 1.8.

The bounding boxes at the left and middle of the screenshot tightly circumscribe the enclosed shapes.

However, the bounding box on the right more loosely circumscribes the shape that is stroked with miter joins. That's because `GetBoundingBox` has to make worst-case assumptions about the extent of stroked shapes with miter joins. In the worst case, the two line segments that connect at a join are parallel or nearly

parallel but point in opposite directions. Clipping this join to the miter limit leaves two roughly square corners that push the sides of the bounding box further outward as the line width increases.

Header

`shapegen.h`

See also

[SGRect](#)

[SGCoord](#)

[ShapeGen::SetFixedBits](#)

ShapeGen::GetCurrentPoint function

The `GetCurrentPoint` function retrieves the current point.

Syntax

C++

```
bool ShapeGen::GetCurrentPoint(  
    SGPoint *cpoint  
);
```

Parameters

cpoint

A pointer to a caller-supplied [SGPoint](#) structure. The function writes the current point's x-y coordinates to this structure. This pointer can be null (zero) if the caller simply wants to know whether the current point is defined.

Return value

Returns true if the current point is defined. If the current point is undefined (because the current figure is empty), the function immediately returns a value of false without writing to the structure pointed to by `cpoint`.

Remarks

The current point is the point most recently added to the current figure (or subpath).

The x-y coordinates retrieved by this function are converted to the user's [SGCoord](#) format – integer or fixed-point – and rounded off as appropriate. By default, `SGCoord` values are integers, but the user can call the [ShapeGen::SetFixedBits](#) function to switch to a fixed-point format.

Header

`shapegen.h`

See also

[SGPoint](#)

[SGCoord](#)

[ShapeGen::SetFixedBits](#)

ShapeGen::GetFirstPoint function

The `GetFirstPoint` function retrieves the first point in the current figure.

Syntax

C++

```
bool ShapeGen::GetFirstPoint(  
    SGPoint *fpoint  
);
```

Parameters

fpoint

A pointer to a caller-supplied [SGPoint](#) structure. The function writes the first point's x-y coordinates to this structure. This pointer can be null (zero) if the caller simply wants to know whether the first point is defined.

Return value

Returns true if the first point is defined. If the first point is undefined (because the current figure is empty), the function immediately returns a value of false without writing to the structure pointed to by fpoint.

Remarks

The first point is the initial point in the current figure (or subpath).

This function can be used to retrieve the starting point of an elliptic arc with a nonzero starting angle, as constructed by the [ShapeGen::EllipticArc](#) function.

The x-y coordinates retrieved by this function are converted to the user's [SGCoord](#) format – integer or fixed-point – and rounded off as appropriate. By default, `SGCoord` values are integers, but the user can call the [ShapeGen::SetFixedBits](#) function to switch to a fixed-point format.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::EllipticArc](#)

[SGCoord](#)[ShapeGen::SetFixedBits](#)

ShapeGen::InitClipRegion function

The InitClipRegion function sets the [device clipping rectangle](#) to the specified width and height.

Syntax

C++

```
bool ShapeGen::InitClipRegion(  
    int width,  
    int height  
);
```

Parameters

width

The width, in pixels, of the new device clipping rectangle.

height

The height, in pixels, of the new device clipping rectangle.

Return value

Returns true if the width and height parameters are both greater than zero. Otherwise, the function fails and immediately returns false. Before returning false, the function faults if the NDEBUB macro (used in `assert.h`) is undefined.

Remarks

In addition to changing the dimensions of the device clipping rectangle, this function sets the current clipping region to the updated device clipping rectangle.

ShapeGen always interprets the width and height parameter values in this function call as integers and never as fixed-point numbers. Only parameters of type [SGCoord](#) are affected by [ShapeGen::SetFixedBits](#) function calls.

The InitClipRegion function changes only the width and height of the device clipping rectangle – it has no effect on the position of the top-left corner of the device clipping rectangle relative to the ShapeGen coordinate origin. To change this position, call the [ShapeGen::SetScrollPosition](#) function.

The [ShapeGen::SetClipRegion](#) and [ShapeGen::SetMaskRegion](#) functions can modify the clipping region inside the device clipping rectangle. However, when an InitClipRegion or SetScrollPosition function call changes the size or position of the device clipping rectangle, the current clipping region is replaced by the new device clipping rectangle, and any previous clipping region set by the SetClipRegion and SetMaskRegion functions is discarded.

An `InitClipRegion` or `SetScrollPosition` function call discards any copy of a clipping region that was previously saved by the [ShapeGen::SaveClipRegion](#) function or swapped out by the [ShapeGen::SwapClipRegion](#) function.

The current path is not altered in any way by an `InitClipRegion` or `SetScrollPosition` function call.

Header

`shapegen.h`

See also

[SGCoord](#)

[ShapeGen::SetFixedBits](#)

[ShapeGen::SetScrollPosition](#)

[ShapeGen::SetClipRegion](#)

[ShapeGen::SetMaskRegion](#)

[ShapeGen::SaveClipRegion](#)

[ShapeGen::SwapClipRegion](#)

ShapeGen::Line function

The `Line` function constructs a straight line from the current point to the specified end point.

Syntax

C++

```
bool ShapeGen::Line(  
    SGCoord x,  
    SGCoord y  
);
```

Parameters

x

The x coordinate of the end point for the line.

y

The y coordinate of the end point for the line.

Return value

Returns `true` if the function succeeds in constructing the line. If the current point is undefined (because the current figure is empty), the function fails and immediately returns `false`. Before returning `false`, the function faults if the `NDEBUG` macro (used in `assert.h`) is undefined.

Remarks

The current point is the starting point for the line. Parameters *x* and *y* specify the end point of the line.

On return from a `Line` call, the current point is set to the coordinates specified by parameters *x* and *y*.

The [ShapeGen::PolyLine](#) function can construct a list of connected line segments in a single function call.

Header

`shapegen.h`

See also

[ShapeGen::PolyLine](#)

ShapeGen::Move function

The `Move` function lifts the pen and moves it to a new starting point.

Syntax

C++

```
void ShapeGen::Move(  
    SGCoord x,  
    SGCoord y  
);
```

Parameters

x

The *x* coordinate of the first point in the new figure.

y

The *y* coordinate of the first point in the new figure.

Return value

None

Remarks

This function starts a new figure (or subpath) and adds the first point to this figure. On return from a `Move` call, the current point is set to the coordinates specified by parameters *x* and *y*.

If, on entry to the `Move` function, the current figure has not already been finalized, the function finalizes the figure in the same manner as the [ShapeGen::EndFigure](#) function before starting the new figure.

If a `Move` call is followed by another `Move` call, with no intervening path-construction calls, the second `Move` call overwrites (that is, discards and replaces) the point specified by the first `Move` call.

Header

`shapegen.h`

See also

[ShapeGen::EndFigure](#)

ShapeGen::PolyBezier2 function

The `PolyBezier2` function constructs one or more connected quadratic Bezier spline curves, starting at the current point.

Syntax

C++

```
bool ShapeGen::PolyBezier2(  
    int npts,  
    const SGPoint xy[]  
);
```

Parameters

npts

The number of points in the `xy` array.

xy

An [SGPoint](#) array containing two points for each quadratic Bezier spline. For example, an array of length `npts = 10` describes five splines.

Return value

Returns `true` if the function succeeds in constructing the splines. If the current point is undefined (because the current figure is empty), the function fails and immediately returns `false`. Before returning `false`, the function faults if the `NDEBUG` macro (used in `assert.h`) is undefined.

Remarks

The current point is the starting point for the first spline. The first two elements in array `xy` specify the control point and end point of the first spline. If the array contains more than two points, the end point of the first spline becomes the starting point for the second spline, and so on.

Whereas the [ShapeGen::Bezier2](#) function constructs a single quadratic Bezier curve, the `PolyBezier2` function can construct multiple quadratic Bezier curves in a single call.

On return from this function, the end point of the final spline in the array is the new current point.

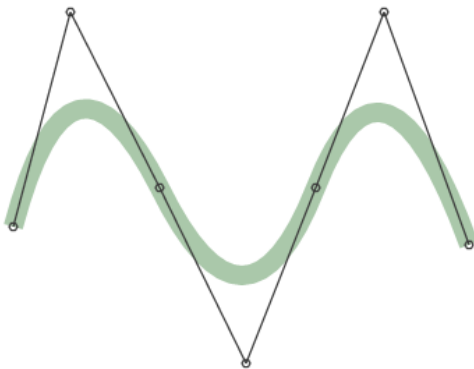
Example

This example uses the PolyBezier2 function to draw three connected quadratic Bezier spline curves. (Parameter bkbuff is a PIXEL_BUFFER structure that contains a description of the backing buffer for the graphics display, and parameter clip specifies the device clipping rectangle.)

```
void example07(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));
    SGPoint xy[] = {
        { 84, 224 }, { 125, 70 }, { 189, 196 }, { 251, 322 },
        { 301, 196 }, { 350, 70 }, { 411, 237 },
    };

    // Stroke the three connected quadratic Bezier splines in green
    aarend->SetColor(RGBX(170,200,170));
    sg->SetLineWidth(14.0);
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyBezier2(6, &xy[1]);
    sg->StrokePath();

    // Outline the spline skeleton in black
    aarend->SetColor(RGBX(60,60,60));
    sg->SetLineWidth(1.25);
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyLine(6, &xy[1]);
    for (int i = 0; i < 7; ++i)
    {
        // Mark the knots and control points
        SGPoint v0 = xy[i], v1 = v0, v2 = v0;
        v1.x += 3;
        v2.y += 3;
        sg->Ellipse(v0, v1, v2);
    }
    sg->StrokePath();
}
```



The output produced by this code example is shown in the screenshot at left.

The three connected splines are stroked in green, starting from the left. The spline skeleton is outlined in black, and the knots and control points are marked.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::Bezier2](#)

ShapeGen::PolyBezier3 function

The `PolyBezier3` function constructs one or more connected cubic Bezier spline curves, starting at the current point.

Syntax

C++

```
bool ShapeGen::PolyBezier3(  
    int npts,  
    const SGPoint xy[]  
);
```

Parameters

npts

The number of points in the `xy` array.

xy

An [SGPoint](#) array containing three points for each quadratic Bezier spline. For example, an array of length `npts = 6` describes two splines.

Return value

Returns `true` if the function succeeds in constructing the splines. If the current point is undefined (because the current figure is empty), the function fails and immediately returns `false`. Before returning `false`, the function faults if the `NDEBUG` macro (used in `assert.h`) is undefined.

Remarks

The current point is the starting point for the first spline. The first three elements in array `xy` specify the two control points and end point of the first spline. If the array contains more than three points, the end point of the first spline becomes the starting point for the second spline, and so on.

Whereas the [ShapeGen::Bezier3](#) function constructs a single cubic Bezier curve, the `PolyBezier3` function can construct multiple cubic Bezier curves in a single call.

On return from this function, the end point of the final spline in the array is the new current point.

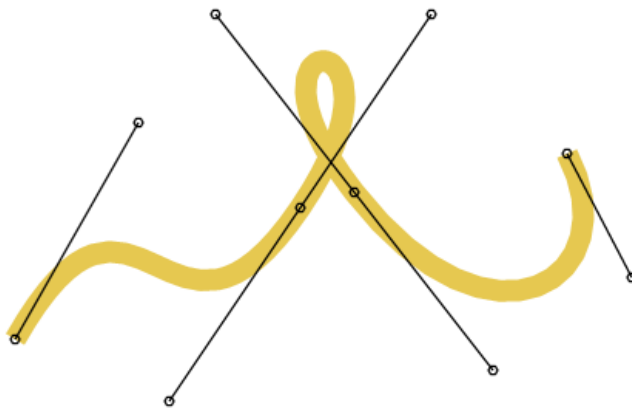
Example

This example uses the `PolyBezier3` function to draw three connected cubic Bezier spline curves. (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example08(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));
    SGPoint xy[] = {
        { 50, 270 }, { 130, 130 }, { 150, 310 }, { 235, 185 }, { 320, 60 },
        { 180, 60 }, { 270, 175 }, { 360, 290 }, { 450, 230 }, { 408, 150 }
    };

    // Stroke the three connected cubic Bezier splines in yellow
    aarend->SetColor(RGBX(230,200,80));
    sg->SetLineWidth(14.0);
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyBezier3(9, &xy[1]);
    sg->StrokePath();

    // Draw the spline handles in black
    aarend->SetColor(RGBX(0,0,0));
    sg->SetLineWidth(1.25);
    sg->BeginPath();
    for (int i = 0; i < 9; i += 3)
    {
        sg->Move(xy[i].x, xy[i].y);
        sg->Line(xy[i+1].x, xy[i+1].y);
        sg->Move(xy[i+2].x, xy[i+2].y);
        sg->Line(xy[i+3].x, xy[i+3].y);
    }
    for (int j = 0; j < 10; ++j)
    {
        SGPoint v0 = xy[j], v1 = v0, v2 = v0;
        v1.x -= 3;
        v2.y -= 3;
        sg->Ellipse(v0, v1, v2);
    }
    sg->StrokePath();
}
```



The output produced by this code example is shown in the screenshot at left.

The three connected splines are stroked in yellow, starting from the left edge of the screenshot. The spline handles are drawn in black.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::Bezier3](#)

ShapeGen::PolyEllipticSpline function

The `PolyEllipticSpline` function constructs one or more elliptic spline curves, starting at the current point.

Syntax

C++

```
bool ShapeGen::PolyEllipticSpline(  
    int npts,  
    const SGPoint xy[]  
);
```

Parameters

npts

The number of points in the `xy` array.

xy

An [SGPoint](#) array containing two points for each elliptic spline. For example, an array of length `npts = 4` describes two splines.

Return value

Returns true if the function succeeds in constructing the splines. If the current point is undefined (because the current figure is empty), the function fails and immediately returns false. Before returning false, the function faults if the NDEBUG macro (used in `assert.h`) is undefined.

Remarks

The current point is the starting point for the first spline. The first two elements in array `xy` specify the control point and end point of the first spline. If the array contains more than three points, the end point of the first spline becomes the starting point for the second spline, and so on.

Whereas the [ShapeGen::EllipticSpline](#) function constructs a single elliptic spline, the `PolyEllipticSpline` function can construct multiple elliptic splines in a single call.

On return from this function, the end point of the final spline in the array is the new current point.

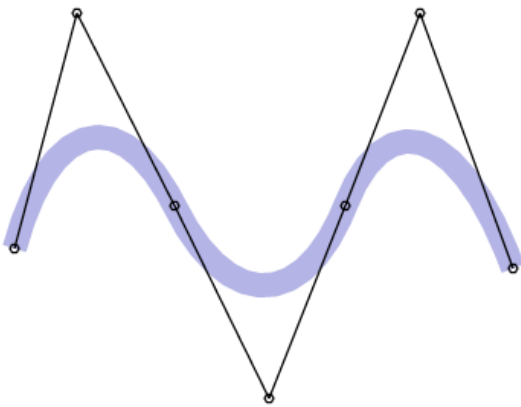
Example

This example uses the `PolyEllipticSpline` function to draw a series of connected elliptic spline curves. (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example09(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend, clip));
    SGPoint xy[] = {
        { 84, 224 }, { 125, 70 }, { 189, 196 }, { 251, 322 },
        { 301, 196 }, { 350, 70 }, { 411, 237 },
    };

    // Stroke the three connected elliptic splines in blue
    aarend->SetColor(GBX(180,180,230));
    sg->SetLineWidth(16.0);
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyEllipticSpline(6, &xy[1]);
    sg->StrokePath();

    // Outline the spline skeleton in black
    aarend->SetColor(GBX(0,0,0));
    sg->SetLineWidth(1.25);
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyLine(6, &xy[1]);
    for (int i = 0; i < 7; ++i)
    {
        // Mark the knots and control points
        SGPoint v0 = xy[i], v1 = v0, v2 = v0;
        v1.x -= 3;
        v2.y -= 3;
        sg->Ellipse(v0, v1, v2);
    }
    sg->StrokePath();
}
```

The output produced by this code example is shown in the screenshot at left.

The three connected splines are stroked in blue, starting from the left edge of the screenshot. The spline skeleton is outlined in black, and the knots and control points are marked.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::EllipticSpline](#)

ShapeGen::PolyLine function

The PolyLine function constructs one or more connected line segments, starting at the current point.

Syntax

C++

```
bool ShapeGen::PolyLine(  
    int npts,  
    const SGPoint xy[]  
);
```

Parameters

npts

The number of points in the xy array.

xy

An [SGPoint](#) array containing a point for each line segment. For example, an array of length `npts = 5` describes five lines.

Return value

Returns `true` if the function succeeds in constructing the lines. If the current point is undefined (because the current figure is empty), the function fails and immediately returns `false`. Before returning `false`, the function faults if the `NDEBUG` macro (used in `assert.h`) is undefined.

Remarks

The current point is the starting point for the first line segment. The first element in the `xy` array specifies the end point of this line segment. If the array contains more than one point, the end point of the first line segment becomes the starting point for the second line segment, and so on.

Whereas the [ShapeGen::Line](#) function constructs a single line, the `PolyLine` function can construct multiple lines in a single call.

On return from this function, the end point of the last line segment is the new current point.

Header

`shapegen.h`

See also

[SGPoint](#)

[ShapeGen::Line](#)

ShapeGen::Rectangle function

The `Rectangle` function adds a rectangle to the current path.

Syntax

C++

```
bool ShapeGen::Rectangle(  
    const SGRect& rect  
);
```

Parameters

rect

An [SGRect](#) structure that specifies the rectangle to add to the path.

Return value

None

Remarks

A rectangle constructed by the `Rectangle` function is added to the current path as a complete, closed figure. If, on entry to the `Rectangle` function, the current figure has not already been finalized, the

function finalizes the figure by leaving it open (that is, in the same manner as the [ShapeGen::EndFigure](#) function) and then starts a new figure in the same path. After adding the points in the rectangle to the new figure, the `Rectangle` function finalizes this new figure by closing it (in the same manner as the [ShapeGen::CloseFigure](#) function) before starting a newer, empty figure in the same path.

On return from the `Rectangle` function, the current point is undefined.

Example

Construction of a rectangle by the `Rectangle` function proceeds in a clockwise direction if we assume the following:

- `rect.w > 0` and `rect.h > 0`
- `rect.x` is the rectangle's left edge, and `rect.y` is the top edge

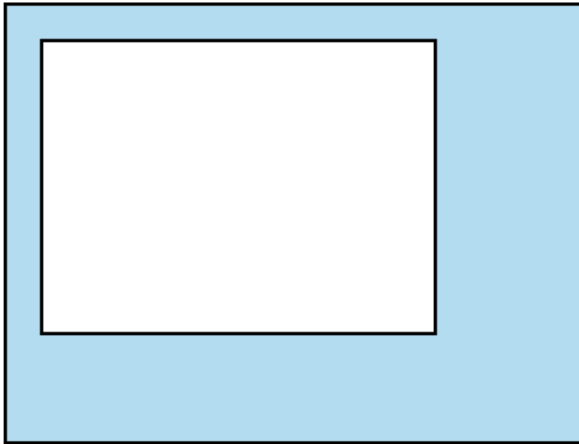
However, it's possible to modify the input parameters to the function so that the direction is reversed. In the following code example, the first (outer) rectangle is constructed in the CW direction, and the second in the CCW direction. (Parameter `bkbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example10(const PIXEL_BUFFER& bkbuf, const SGRect& clip)
{
    SmartPtr<SimpleRenderer> rend(CreateSimpleRenderer(&bkbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&(*rend), clip));
    SGRect rect = { 100, 75, 350, 265 };

    // Construction of the outer rectangle proceeds in the
    // clockwise direction (as seen on the display)
    sg->BeginPath();
    sg->Rectangle(rect);

    // Make the second rectangle smaller than the first
    rect.x += 22;
    rect.y += 22;
    rect.w -= 111;
    rect.h -= 88;

    // Modify the second rectangle's parameters so that its
    // construction proceeds in the counterclockwise direction
    rect.y += rect.h;
    rect.h = -rect.h;
    sg->Rectangle(rect);
    rend->SetColor(GBX(180,220,240));
    sg->FillPath(FILLRULE_WINDING); // <-- winding number fill rule!
    sg->SetLineWidth(2.0);
    sg->SetLineJoin(LINEJOIN_MITER);
    rend->SetColor(GBX(0,0,0));
    sg->StrokePath();
}
```



The output produced by this code example is shown in the screenshot at left.

Header

`shapegen.h`

See also

[SGRect](#)

[ShapeGen::EndFigure](#)

[ShapeGen::CloseFigure](#)

ShapeGen::ResetClipRegion function

The `ResetClipRegion` function sets the current clipping region to the [device clipping rectangle](#).

Syntax

C++

```
void ShapeGen::ResetClipRegion();
```

Parameters

None

Return value

None

Remarks

The device clipping rectangle is never undefined. When a `ShapeGen` object is created, the constructor sets the initial clipping region to the device clipping rectangle it receives as an input parameter. Thereafter, any

changes made by the [ShapeGen::SetClipRegion](#) and [ShapeGen::SetMaskRegion](#) functions to the shape of the clipping region are always confined to the interior of the device clipping rectangle.

The `ResetClipRegion` function discards any changes to the clipping region that were made by previous calls to the `SetClipRegion` and `SetMaskRegion` functions.

Any changes made by previous calls to the [ShapeGen::InitClipRegion](#) and [ShapeGen::SetScrollPosition](#) functions are retained in the device clipping rectangle that is restored by the `ResetClipRegion` function. The `InitClipRegion` function changes the width and height of the device clipping rectangle. The `SetScrollPosition` function changes the position of the top-left corner of the device clipping rectangle in ShapeGen coordinate space.

The `ResetClipRegion` function preserves any copy of a clipping region that was previously saved by the [ShapeGen::SaveClipRegion](#) function or that was previously swapped out by the [ShapeGen::SwapClipRegion](#) function.

Header

`shapegen.h`

See also

[ShapeGen::SetClipRegion](#)

[ShapeGen::SetMaskRegion](#)

[ShapeGen::InitClipRegion](#)

[ShapeGen::SetScrollPosition](#)

[ShapeGen::SaveClipRegion](#)

[ShapeGen::SwapClipRegion](#)

ShapeGen::RoundedRectangle function

The `RoundedRectangle` function adds a rectangle with rounded corners to the current path.

Syntax

C++

```
bool ShapeGen::RoundedRectangle(  
    const SGRect& rect  
    const SGPoint& round  
);
```

Parameters

rect

An [SGRect](#) structure that specifies the rectangle to add to the path.

round

An [SGPoint](#) structure that specifies the *x* (horizontal) and *y* (vertical) displacements of the elliptical arc starting and ending points from each corner of the rectangle.

Return value

None

Remarks

A rounded rectangle is a rectangle with rounded corners. The corners of the rectangle specified by the `rect` parameter are replaced with elliptic arcs. The `round` parameter specifies the horizontal and vertical dimensions of each arc.

To use circular arcs for the corners of the rectangle, set both components (that is, *x* and *y*) in the `round` parameter to the circle radius.

A rounded rectangle constructed by the `RoundedRectangle` function is added to the current path as a complete, closed figure. If, on entry to the `RoundedRectangle` function, the current figure has not already been finalized, the function finalizes the figure by leaving it open (that is, in the same manner as the [ShapeGen::EndFigure](#) function) and then starts a new figure in the same path. After adding the points in the rounded rectangle to the new figure, the `RoundedRectangle` function finalizes this new figure by closing it (in the same manner as the [ShapeGen::CloseFigure](#) function) and starting a newer, empty figure in the same path.

On return from the `RoundedRectangle` function, the current point is undefined.

Example

Construction of a rounded rectangle by the `RoundedRectangle` function proceeds in a clockwise direction if we assume the following:

- `rect.w > 0` and `rect.h > 0`
- `rect.x` is the rectangle's left edge, and `rect.y` is the top edge
- `round.x > 0` and `round.y > 0`

However, it's possible to modify the input parameters to the function so that the direction is reversed. In the following code example, the first (outer) rounded rectangle is constructed in the CW direction, and the second in the CCW direction. (Parameter `bdbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example11(const PIXEL_BUFFER& bdbuf, const SGRect& clip)
{
    SmartPtr<SimpleRenderer> rend(CreateSimpleRenderer(&bdbuf));
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bdbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&(*rend), clip));
    SGRect rect = { 100, 75, 350, 265 };
    SGPoint round = { 35, 35 };

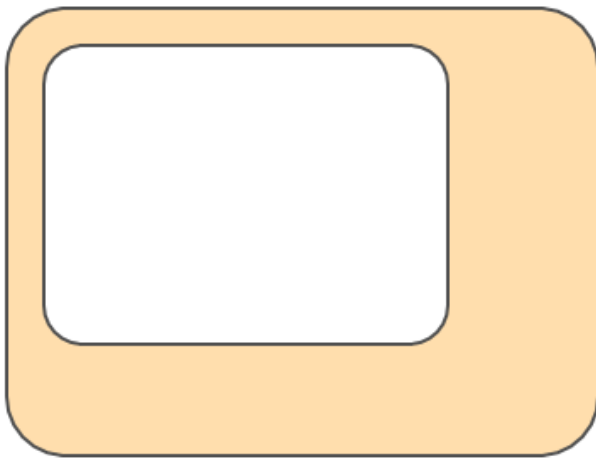
    // Construction of the outer rounded rectangle proceeds
    // in the clockwise direction (as seen on the display)
    sg->BeginPath();
    sg->RoundedRectangle(rect, round);

    // Make the second rectangle smaller than the first
```

```
rect.x += 22;
rect.y += 22;
rect.w -= 111;
rect.h -= 88;
round.x = round.y -= 12;

// Modify the second rectangle's parameters so that its
// construction proceeds in the counterclockwise direction
rect.y += rect.h;
rect.h = -rect.h;
round.y = -round.y;
sg->RoundedRectangle(rect, round);
rend->SetColor(GBX(255,222,173));
sg->FillPath(FILLRULE_WINDING); // <-- winding number fill rule!

// Switch to antialiasing renderer and stroke boundaries
sg->SetRenderer(aarend);
aarend->SetColor(GBX(80,80,80));
sg->SetLineWidth(2.0);
sg->StrokePath();
}
```



The output produced by this code example is shown in the screenshot at left.

Header

`shapegen.h`

See also

[SGRect](#)

[SGPoint](#)

[ShapeGen::EndFigure](#)

[ShapeGen::CloseFigure](#)

ShapeGen::SaveClipRegion function

The `SaveClipRegion` function saves a copy of the current clipping region.

Syntax

C++

```
bool ShapeGen::SaveClipRegion();
```

Parameters

None

Return value

Returns true if the current clipping region is not empty, in which case the saved copy of this clipping region is also not empty. Otherwise, the function returns false.

Remarks

A clipping region that is copied and saved by this function can be restored at a later time by calling the [ShapeGen::SwapClipRegion](#) function. Only one such copy exists at a time. Any previously existing copy of a clipping region is overwritten by a call to `SaveClipRegion`, or is swapped in by a `SwapClipRegion` call.

The saved copy of a clipping region is preserved through calls to the [ShapeGen::ResetClipRegion](#), [ShapeGen::SetClipRegion](#), and [ShapeGen::SetMaskRegion](#) functions.

A call to the [ShapeGen::InitClipRegion](#), [ShapeGen::SetScrollPosition](#), or [ShapeGen::SetRenderer](#) function causes any saved copy of a clipping region to be discarded and replaced with an empty clipping region.

ShapeGen clips all shapes, before they are rendered, to the interior of the current clipping region. An empty clipping region, which has no interior, effectively disables all drawing.

For example, if a `SetClipRegion` function call intersects the current clipping region with a path whose interior lies entirely outside the region, the resulting clipping region is empty.

Immediately after the ShapeGen object is created, the saved clipping region is, by default, empty.

Header

`shapegen.h`

See also

[ShapeGen::SwapClipRegion](#)[ShapeGen::ResetClipRegion](#)[ShapeGen::SetClipRegion](#)[ShapeGen::SetMaskRegion](#)[ShapeGen::InitClipRegion](#)[ShapeGen::SetScrollPosition](#)[ShapeGen::SetRenderer](#)

ShapeGen::SetClipRegion function

The SetClipRegion function sets the new clipping region to the intersection of the current clipping region and the interior of the current path.

Syntax

C++

```
bool ShapeGen::SetClipRegion(  
    FILLRULE fillrule  
);
```

Parameters

fillrule

The fill rule to use for converting the path to a filled region, which is then intersected with the current clipping region to form the new clipping region. Specify one of the following values for this parameter:

FILLRULE_EVENODD – Even-odd (or parity) fill rule

FILLRULE_WINDING – Nonzero winding number fill rule

Return value

Returns true if the new clipping region is not empty; otherwise, returns false. Drawing occurs only in the interior of the clipping region. Thus, if a clipping region is empty, it has no interior and no drawing can occur.

Remarks

This function confines drawing to the interior of an arbitrarily shaped area.

In contrast to the [ShapeGen::SetMaskRegion](#) function, which constructs a new clipping region that is the intersection of the current clipping region with the *exterior* of the current path, the SetClipRegion function constructs a new clipping region that is the intersection of the current clipping region with the *interior* of the current path

The SetClipRegion and SetMaskRegion functions can modify the clipping region inside the [device clipping rectangle](#) but cannot expand the clipping region beyond the bounds of the device clipping rectangle.

Example

This example uses the SetClipRegion function to set the clipping region to the interior of a star-shaped path. (Parameter bkbuf is a PIXEL_BUFFER structure that contains a description of the backing buffer for the graphics display, and parameter clip specifies the device clipping rectangle.)

```
void example12(const PIXEL_BUFFER& bkbuf, const SGRect& clip)  
{  
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuf));
```

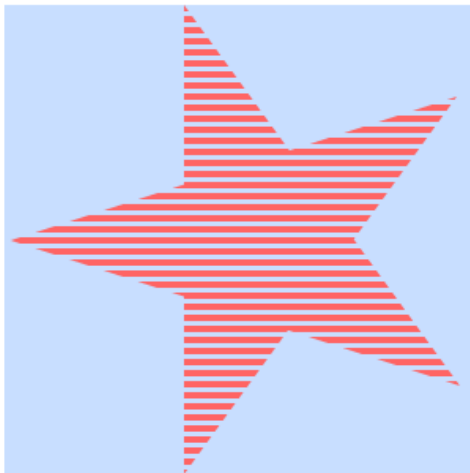
```
SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));
const float t = 0.8*PI;
const float sint = sin(t);
const float cost = cos(t);
const int xc = 212, yc = 199;
const SGRect rect = { 50, 50, 298, 298 };
int xr = -158, yr = 0;

// Set the clipping region to a 298x298-pixel square
sg->BeginPath();
sg->Rectangle(rect);
sg->SetClipRegion(FILLRULE_EVENODD);

// Do background fill with solid light blue
sg->BeginPath();
sg->Rectangle(clip);
aarend->SetColor(RGBX(200, 222, 255));
sg->FillPath(FILLRULE_EVENODD);

// Set the clipping region to a star-shaped area inside the square
sg->BeginPath();
sg->Move(xc + xr, yc + yr);
for (int i = 0; i < 4; ++i)
{
    int xtmp = xr*cost + yr*sint;
    yr = -xr*sint + yr*cost;
    xr = xtmp;
    sg->Line(xc + xr, yc + yr);
}
sg->SetClipRegion(FILLRULE_WINDING);

// Draw a series of horizontal red lines through the square
aarend->SetColor(RGBX(255,100,100));
sg->SetLineWidth(4.0);
sg->BeginPath();
for (int y = rect.y+2; y <= rect.y+rect.h; y += 7)
{
    sg->Move(rect.x, y);
    sg->Line(rect.x+rect.w, y);
}
sg->StrokePath();
}
```



The output produced by this code example is shown in the screenshot at left.

The code example starts by filling a blue square that lies entirely within the initial, rectangular clipping region. Next, a star-shaped path is constructed, and the clipping region is intersected with this path to form a new, star-shaped clipping region. Finally, a series of horizontal red lines is drawn through the blue square, but only the part of each line that lies inside the new clipping region is drawn.

Header

`shapegen.h`

See also

[ShapeGen::SetMaskRegion](#)

ShapeGen::SetFixedBits function

The `SetFixedBits` function specifies the new [fixed-point](#) format that the caller will use for [SGCoord](#) values in subsequent calls to ShapeGen functions.

Syntax

C++

```
int ShapeGen::SetFixedBits(  
    int nbits = 0  
);
```

Parameters

nbits

The number of bits of fraction in the fixed-point format for the caller's coordinate values. To specify that coordinate values are integers rather than fixed-point numbers, set this parameter to zero. Values for this parameter should be in the range 0 to 16.

If the caller does not explicitly supply an `nbits` argument, the default value, 0, is automatically assigned to the `nbits` parameter.

Return value

Returns the previous `nbits` value, if the function succeeds. If the new `nbits` parameter value is outside the range 0 to 16, the function fails and immediately returns a value of -1. Before returning -1, the function faults if the `NDEBUG` macro (used in `assert.h`) is undefined.

Remarks

By default, ShapeGen functions assume that all `SGCoord` values supplied by the caller are integers. The caller can opt to use fixed-point coordinates by calling the `SetFixedBits` function. At any time, the caller can switch back to using integer coordinates by calling `SetFixedBits` with `nbits = 0`.

The [SGPoint](#) and [SGRect](#) structures contain `SGCoord` members whose interpretation by ShapeGen is affected by `SetFixedBits` function calls.

To improve accuracy, the ShapeGen object uses 16.16 fixed-point coordinates rather than integer coordinates for its internal calculations. A 16.16 fixed-point number is stored as a 32-bit signed integer, but the 16 least-significant bits are assumed to lie to the right of the binary point and represent a fractional value.

Example

For example, the parameter value `nbits = 16` specifies that the caller's `SGCoord` values are to be interpreted as 16.16 fixed-point numbers.

Header

`shapegen.h`

See also

[SGCoord](#)

[SGPoint](#)

[SGRect](#)

ShapeGen::SetFlatness function

The `SetFlatness` function sets the ShapeGen flatness attribute, which specifies the maximum the chord-to-curve error tolerance.

Syntax

C++

```
float ShapeGen::SetFlatness(  
    float flatness = FLATNESS_DEFAULT  
);
```

Parameters

flatness

The maximum chord-to-curve distance (in pixels) that can be tolerated. Set this parameter to a value in the range 0.2 to 100.0.

If the caller does not explicitly supply a `flatness` argument, the default value, 0.5, is automatically assigned to the `flatness` parameter.

Return value

Returns the previous flatness setting.

Remarks

ShapeGen approximates curves and arcs with connected straight line segments; that is, with chords. The `flatness` parameter specifies how flat a curve segment must be before it can be satisfactorily approximated with a chord. Smaller `flatness` values result in smoother-looking curves and arcs but do so at the cost of shorter and more numerous chords.

The default flatness attribute value is 0.5 pixels.

If the caller specifies a `flatness` parameter value that is outside the range 0.2 to 100.0 pixels, the function quietly clamps the value to this range.

Header

`shapegen.h`

See also

[ShapeGen::FillPath](#)

[ShapeGen::StrokePath](#)

[ShapeGen::SetClipRegion](#)

[ShapeGen::SetMaskRegion](#)

ShapeGen::SetLineDash function

The `SetLineDash` function specifies the dash pattern to use for stroked paths.

Syntax

C++

```
bool ShapeGen::SetLineDash(  
    char *dash = 0,  
    int offset = 0,  
    float mult = 1.0  
);
```

Parameters

dash

A zero-terminated byte array that specifies, in alternating fashion, the lengths of the dashes and of the gaps between dashes in the pattern. The first array element specifies a dash length, the second specifies a gap length, and so on. The effective length of a dash or gap, in pixels, is the product of the corresponding dash array element value and the dash-length multiplier, `mult`.

If the caller does not explicitly supply a `dash` argument, the default value, 0, is automatically assigned to the `dash` parameter.

offset

The starting offset into the dash pattern. The effective offset, in pixels, is the product of the `offset` and `mult` parameters. Should be greater than or equal to zero or the function fails.

If the caller does not explicitly supply an `offset` argument, the default value, 0, is automatically assigned to the `offset` parameter.

mult

The dash-length multiplier. Should be greater than zero or the function fails.

If the caller does not explicitly supply a `mult` argument, the default value, 1.0, is automatically assigned to the `mult` parameter.

Return value

Returns `true` if the function successfully updates the dash pattern. Otherwise, it returns `false`. Before returning `false`, the function faults if the `NDEBUG` macro (used in `assert.h`) is undefined.

Remarks

The dash pattern affects the appearance of stroked paths constructed by the [ShapeGen::StrokePath](#) function.

For each figure constructed by the `StrokePath` function, the function begins at the specified offset into the pattern and repeats the pattern as many times as needed to reach the end of the figure.

The maximum length of the dash array is 32 elements, not counting the terminating zero. A dash array longer than this maximum is quietly truncated to 32 elements.

The `SetLineDash` function treats each element of the dash array as an unsigned, 8-bit integer regardless of whether the compiler defines the `char` type to be signed or unsigned.

By default, stroked paths are constructed as solid lines (that is, with no dash pattern). To restore this default, call `SetLineDash` with `dash = 0` (that is, a null pointer value). In this case, the `offset` and `mult` parameters are ignored.

Example

This example uses the `SetLineDash` function to construct stroked paths with four different line dash patterns. (Parameter `bkbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```

void example13(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));
    SGPoint xy[] = {
        { 127, 251 }, { 127, 203 }, { 72, 251 }, { 206, 299 },
        { 206, 203 }, { 109, 130 }, { 164, 58 },
    };
    float linewidth = 8.43;
    char dot[] = { 2, 0 };
    char dash[] = { 5, 2, 0 };
    char dashdot[] = { 5, 2, 2, 2, 0 };
    char dashdotdot[] = { 5, 2, 2, 2, 2, 2, 0 };
    char *pattern[] = { dot, dash, dashdot, dashdotdot, 0 };

    aarend->SetColor(RGBX(205, 92, 92));
    sg->SetLineWidth(linewidth);
    sg->SetLineJoin(LINEJOIN_MITER);
    for (int i = 0; i < 5; ++i)
    {
        sg->SetLineDash(pattern[i], 0, linewidth/2.0);
        sg->BeginPath();
        sg->EllipticArc(xy[0], xy[1], xy[2], 0, PI); // PI = 3.14159...
        sg->PolyBezier3(3, &xy[3]);
        sg->Line(xy[6].x, xy[6].y);
        sg->StrokePath();
        for (int j = 0; j < 7; ++j)
            xy[j].x += 170;
    }
}

```

The output produced by this code example is shown in the following screenshot.



Header

`shapegen.h`

See also

[ShapeGen::StrokePath](#)

ShapeGen::SetLineEnd function

The `SetLineEnd` function sets the ShapeGen line-end attribute, which specifies how to cap the ends of stroked paths.

Syntax

C++

```
LINEEND ShapeGen::SetLineEnd(  
    LINEEND capstyle = LINEEND_FLAT  
);
```

Parameters

capstyle

The type of cap to use at the ends of stroked lines and curves. This parameter should be set to one of the following line-end attribute values:

- LINEEND_FLAT – Flat line end (or butt cap)
- LINEEND_ROUND – Rounded line end (or round cap)
- LINEEND_SQUARE – Squared line end (or projecting cap)

If the caller does not explicitly supply a `capstyle` argument, the default value, `LINEEND_FLAT`, is automatically assigned to the `capstyle` parameter.

Return value

Returns the previous line-end attribute value.

Remarks

The line-end attribute affects the appearance of stroked paths subsequently constructed by the [ShapeGen::StrokePath](#) function.

The default value for the line-end attribute is `LINEEND_FLAT`.

Example

This example uses the `SetLineEnd` function to set different line-end attributes for three stroked paths. (Parameter `bkbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example14(const PIXEL_BUFFER& bkbuf, const SGRect& clip)  
{  
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuf));  
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip);  
    LINEEND cap[] = { LINEEND_FLAT, LINEEND_ROUND, LINEEND_SQUARE };  
    SGPoint vert[] = { { 84, 288 }, { 204, 114 }, { 264, 324 } };  
  
    for (int i = 0; i < 3; ++i)  
    {  
        sg->BeginPath();  
        sg->Move(vert[0].x, vert[0].y);  
        sg->PolyLine(2, &vert[1]);  
        sg->SetLineWidth(48.0);  
        sg->SetLineEnd(cap[i]);  
        aarend->SetColor(RGBX(135,206,235));  
    }
```



```
sg->StrokePath();
sg->SetLineWidth(2.0);
aarend->SetColor(RGBX(0,0,0));
sg->StrokePath();
for (int j = 0; j < 3; ++j)
    vert[j].x += 295;
}
```

The output produced by this code example is shown in the following screenshot.



From left to right, the stroked paths are drawn with line-end attributes of LINEEND_FLAT, LINEEND_ROUND, LINEEND_SQUARE. The path skeletons are outlined in black.

Header

`shapegen.h`

See also

[ShapeGen::StrokePath](#)

ShapeGen::SetLineJoin function

The SetLineJoin function sets the ShapeGen line-join attribute, which specifies how two connecting line segments in a stroked path are to be joined.

Syntax

C++

```
LINEJOIN ShapeGen::SetLineJoin(
    LINEJOIN joinstyle = LINEJOIN_BEVEL
);
```

Parameters

joinstyle

The way in which connecting line segments are to be joined. Set this parameter to one of the following join-style attribute values:

- LINEJOIN_BEVEL – Beveled join style
- LINEJOIN_ROUND – Rounded join style
- LINEJOIN_MITER – Mitered join style
- LINEJOIN_SVG_MITER – SVG default join style

If the caller does not explicitly supply a `joinstyle` argument, the default value, `LINEJOIN_BEVEL`, is automatically assigned to the `joinstyle` parameter.

Return value

Returns the previous line-join attribute value.

Remarks

The line-join attribute affects the appearance of stroked paths constructed by the [ShapeGen::StrokePath](#) function.

The default value for the line-join attribute is `LINEJOIN_BEVEL`.

The `LINEJOIN_SVG_MITER` line-join attribute value is provided for compatibility with the SVG 2-D graphics standard.

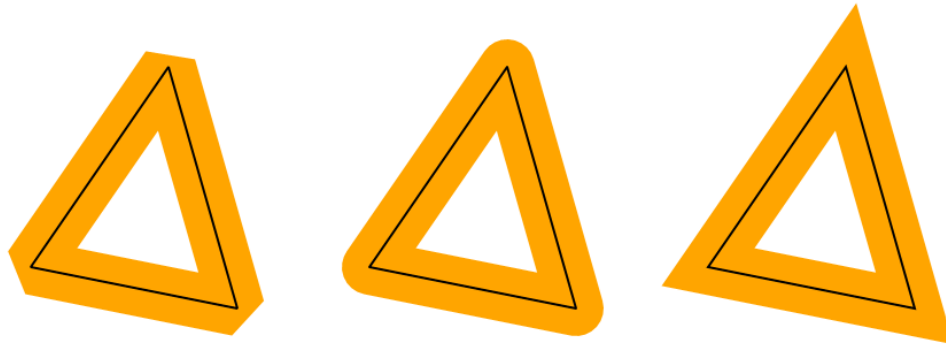
Example

This example uses the `SetLineJoin` function to set different line-join attributes for three stroked paths. (Parameter `bdbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example15(const PIXEL_BUFFER& bdbuf, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bdbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend, clip));
    LINEJOIN join[] = { LINEJOIN_BEVEL, LINEJOIN_ROUND, LINEJOIN_MITER };
    SGPoint vert[] = { { 84, 288 }, { 204, 114 }, { 264, 324 } };

    for (int i = 0; i < 3; ++i)
    {
        sg->BeginPath();
        sg->Move(vert[0].x, vert[0].y);
        sg->PolyLine(2, &vert[1]);
        sg->SetLineWidth(48.0);
        sg->SetLineJoin(join[i]);
        sg->CloseFigure();
        aarend->SetColor(RGBX(255,165,0));
        sg->StrokePath();
        sg->SetLineWidth(2.0);
        aarend->SetColor(RGBX(0,0,0));
        sg->StrokePath();
        for (int j = 0; j < 3; ++j)
            vert[j].x += 295;
    }
}
```

The output produced by this code example is shown in the following screenshot.



From left to right, the stroked paths are drawn with line-join attributes of `LINEJOIN_BEVEL`, `LINEJOIN_ROUND`, and `LINEJOIN_MITER`. The path skeletons are outlined in black.

Header

`shapegen.h`

See also

[ShapeGen::StrokePath](#)

ShapeGen::SetLineWidth function

The `SetLineWidth` function sets the width of stroked paths.

Syntax

C++

```
float ShapeGen::SetLineWidth(  
    float width = LINEWIDTH_DEFAULT  
);
```

Parameters

width

The line width (in pixels) of a stroked path.

If the caller does not explicitly supply a width argument, the default value, 4.0, is automatically assigned to the width parameter.

Return value

Returns the previous line-width attribute value.

Remarks

The line-width setting determines the width of stroked paths constructed by the [ShapeGen::StrokePath](#) function.

The default line-width setting is 4.0 pixels.

In addition to the line-width setting, the appearance of a stroked path is affected by the following attributes:

- Dashed-line pattern
- Line-join style
- Line-end cap style
- Miter limit

However, these attributes do not apply to a stroked path constructed with a line-width setting of zero, which is a special value that is typically used in conjunction with a simple renderer (no antialiasing).

If the line width is zero, a stroked line is constructed as a thinly connected string of pixels that mimic the appearance of a line drawn by the [Bresenham line algorithm](#). With this special line-width setting, stroked paths are always appear as solid lines (that is, with no dashed-line pattern). These stroked paths have beveled joins and triangular line-end caps, although these features might be difficult to discern due to their small size.

Header

`shapegen.h`

See also

[ShapeGen::StrokePath](#)

ShapeGen::SetMaskRegion function

The `SetMaskRegion` function sets the new clipping region to the intersection of the current clipping region and the exterior of the current path.

Syntax

C++

```
bool ShapeGen::SetMaskRegion(  
    FILLRULE fillrule = FILLRULE_EVENODD  
);
```

Parameters

fillrule

The fill rule to use for converting the path to a filled region, which is then masked off from the current clipping region to form the new clipping region. Specify one of the following values for this parameter:

- `FILLRULE_EVENODD` – Even-odd (or parity) fill rule
- `FILLRULE_WINDING` – Nonzero winding number fill rule

If the caller does not explicitly supply a `fillrule` argument, the default value, `FILLRULE_EVENODD`, is automatically assigned to the `fillrule` parameter.

Return value

Returns `true` if the new clipping region is not empty; otherwise, returns `false`. Drawing occurs only in the interior of the clipping region. Thus, if a clipping region is empty, it has no interior and no drawing can occur.

Remarks

This function masks off an arbitrarily shaped area so that drawing can occur only outside this area.

In contrast to the [ShapeGen::SetClipRegion](#) function, which constructs a new clipping region that is the intersection of the current clipping region with the *interior* of the current path, the `SetMaskRegion` function constructs a new clipping region that is the intersection of the current clipping region with the *exterior* of the current path

The `SetMaskRegion` and `SetClipRegion` functions can modify the clipping region inside the [device clipping rectangle](#) but cannot expand the clipping region beyond the device clipping rectangle.

Example

This example uses the `SetMaskRegion` function to exclude a star-shaped path from the interior of the clipping region. (Parameter `bdbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

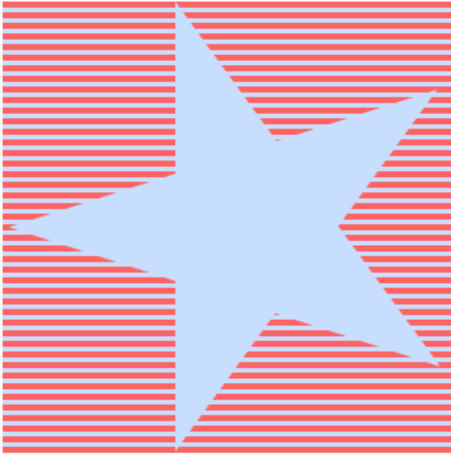
```
void example16(const PIXEL_BUFFER& bdbuf, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bdbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));
    const float t = 0.8*PI;
    const float sint = sin(t);
    const float cost = cos(t);
    const int xc = 212, yc = 199;
    const SGRect rect = { 50, 50, 298, 298 };
    int xr = -158, yr = 0;

    // Fill the rectangle with solid light blue
    sg->BeginPath();
    sg->Rectangle(rect);
    aarend->SetColor(RGBX(200, 222, 255));
    sg->FillPath(FILLRULE_EVENODD);

    // Mask off a star-shaped area from the clipping region
    sg->BeginPath();
    sg->Move(xc + xr, yc + yr);
    for (int i = 0; i < 4; ++i)
    {
        int xtmp = xr*cost + yr*sint;
        yr = -xr*sint + yr*cost;
        xr = xtmp;
        sg->Line(xc + xr, yc + yr);
    }
    sg->SetMaskRegion(FILLRULE_WINDING);

    // Draw a series of horizontal, red lines through the square
    aarend->SetColor(RGBX(255,100,100));
```

```
sg->SetLineWidth(4.0);
sg->BeginPath();
for (int y = rect.y+2; y <= rect.y+rect.h; y += 7)
{
    sg->Move(rect.x, y);
    sg->Line(rect.x+rect.w, y);
}
sg->StrokePath();
}
```



The output produced by this code example is shown in the screenshot at left.

The code example starts by filling a blue square that lies entirely within the initial, rectangular clipping region. Next, a star-shaped path is constructed, and the clipping region is intersected with the *exterior* of this path to form a new clipping region. Finally, a series of horizontal red lines is constructed through the blue square, but only the part of each line that lies inside the new clipping region (which lies *outside* the masked-off area) is drawn.

Header

`shapegen.h`

See also

[ShapeGen::SetClipRegion](#)

ShapeGen::SetMiterLimit function

The `SetMiterLimit` function sets the value of the ShapeGen miter-limit attribute, which specifies the maximum length that a mitered join can reach before the point is automatically beveled off.

Syntax

C++

```
float ShapeGen::SetMiterLimit(
    float mlim = MITERLIMIT_DEFAULT
);
```

Parameters

mlim

The new miter-limit setting. Set this parameter to a value greater than or equal to 1.0.

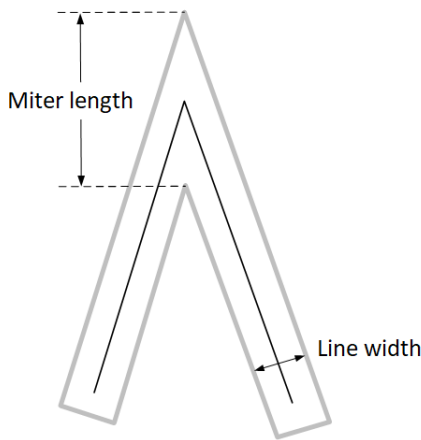
If the caller does not explicitly supply an `mLim` argument, the default value, 10.0, is automatically assigned to the `mLim` parameter.

Return value

Returns the previous miter-limit attribute value.

Remarks

This function specifies the miter limit, which determines the maximum length of a mitered join in a stroked path. This length, the *miter length*, is shown in the following figure.



For a given miter limit value, `mLim`, the maximum miter length is calculated as

$$\text{max_miter_length} = \text{mLim} * \text{line_width}$$

The [ShapeGen::StrokePath](#) function automatically snips off the sharp point of a mitered join that exceeds this limit, turning it into a beveled join whose length matches the `max_miter_length` value calculated above.

The default miter-limit setting is 10.0.

The minimum miter-limit setting is 1.0. A miter limit of 1.0 specifies that mitered joins at all angles are to be beveled. If the caller specifies an `mLim` parameter value less than 1.0, the function quietly clamps the miter limit to 1.0.

To specify that stroked paths are to be constructed with mitered joins, call the [ShapeGen::SetLineJoin](#) function with `joinstyle = LINEJOIN_MITER`. By default, stroked paths are constructed with beveled joins.

Example

This example uses the `SetMiterLimit` function to set different miter limits for two mitered joins. (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example17(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
```

```

SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));
SGPoint vert[] = { { 120, 300 }, { 204, 114 }, { 252, 324 } };

sg->SetLineEnd(LINEEND_SQUARE);
sg->SetLineJoin(LINEJOIN_MITER);
sg->SetMiterLimit(4.0);
for (int i = 0; i < 2; ++i)
{
    sg->BeginPath();
    sg->Move(vert[0].x, vert[0].y);
    sg->PolyLine(2, &vert[1]);
    sg->SetLineWidth(48.0);
    aarend->SetColor(RGBX(173,215,87));
    sg->StrokePath();
    sg->SetLineWidth(2.0);
    aarend->SetColor(RGBX(0,0,0));
    sg->StrokePath();
    sg->SetMiterLimit(1.4);
    for (int j = 0; j < 3; ++j)
        vert[j].x += 255;
}
}

```



The output produced by this code example is shown in the screenshot at left.

The stroked path on the left side of the screenshot is drawn with a miter-limit setting of 4.0. The stroked path on the right side is drawn with a miter-limit setting of 1.4.

Header

`shapegen.h`

See also

[ShapeGen::StrokePath](#)

[ShapeGen::SetLineJoin](#)

ShapeGen::SetRenderer function

The `SetRenderer` function sets the [Renderer](#) object that ShapeGen uses to render filled and stroked shapes on the display device.

Syntax

C++


```
bool ShapeGen::SetRenderer(
    Renderer *rend
);
```

Parameters

rend

A pointer to a [Renderer](#) object.

Return value

Returns true if the function call is successful. If `rend = 0` (null pointer), the function fails and returns false. Before returning false, the function faults if `NDEBUG` (used in `assert.h`) is undefined.

Remarks

A [ShapeGen](#) object is always paired with a [Renderer](#) object. A nonnull [Renderer](#) object pointer is a required [ShapeGen](#) constructor parameter. At any time, the user can call [SetRenderer](#) to change the [Renderer](#) object associated with the [ShapeGen](#) object.

The [SetRenderer](#) call has these side effects:

- The current clipping region is reset to the device clipping rectangle. The effect is the same as a call to the [ShapeGen::ResetClipRegion](#) function.
- Any clipping region previously saved by the [ShapeGen::SaveClipRegion](#) function or swapped out by the [ShapeGen::SwapClipRegion](#) function is discarded.

For more information, see [Renderer](#).

Example

This example uses the [SetRenderer](#) function to switch from one renderer to another. (Parameter `bkbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example18(const PIXEL_BUFFER& bkbuf, const SGRect& clip)
{
    SmartPtr<SimpleRenderer> rend(CreateSimpleRenderer(&bkbuf));
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*rend), clip);
    SGRect rect = { 100, 110, 400, 240 };
    SGPoint v0 = { 360, 170 }, v1 = { 360+160, 170 }, v2 = { 360, 170+110 };

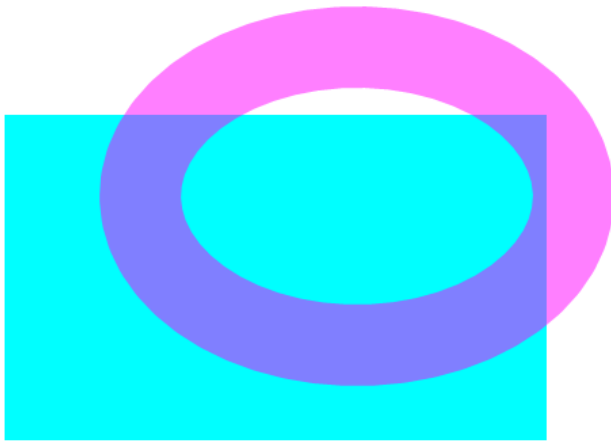
    // Use the simple renderer to fill a cyan rectangle
    sg->BeginPath();
    sg->Rectangle(rect);
    rend->SetColor(GBX(0,255,255)); // cyan (100% opaque)
    sg->FillPath(FILLRULE_EVENODD);

    // Switch to the enhanced renderer
    sg->SetRenderer(aarend);

    // Alpha-blend a stroked magenta ellipse over the rectangle
```

```
sg->BeginPath();
sg->Ellipse(v0, v1, v2);
aarend->SetColor(RGBA(255,0,255,128)); // magenta (50% opaque)
sg->SetLineWidth(60.0);
sg->StrokePath();
}
```

The output produced by this code example is shown in the following screenshot.



This example uses smart pointers to create a simple renderer, `rend`, and an enhanced renderer, `aarend`. Next, `rend` is installed as the initial renderer for the ShapeGen object, which is made accessible through another smart pointer, `sg`. The ShapeGen object then uses `rend` to draw a cyan rectangle. This rectangle is completely opaque, as are all shapes painted by a simple renderer.

Next, a `SetRenderer` function call installs the enhanced renderer, `aarend`, in place of the simple renderer. Using the new renderer, a partially transparent ellipse is stroked in magenta over the cyan rectangle.

This example uses the `RGBA` macro (defined in `renderer.h`) to construct a 32-bit RGBA pixel value with an 8-bit alpha component value of 128, which makes the pixel 50.2 percent opaque.

Header

`shapegen.h`

See also

[ShapeGen::ResetClipRegion](#)

[ShapeGen::SaveClipRegion](#)

[ShapeGen::SwapClipRegion](#)

ShapeGen::SetScrollPosition function

The `SetScrollPosition` function enables a viewer to scroll and pan through a “virtual” 2-D image that is larger than the available drawing area on the screen.

Syntax

```
C++
```

```
void ShapeGen:: SetScrollPosition(  
    int x,  
    int y  
);
```

Parameters

x

The horizontal scrolling displacement, in pixels, from the origin of the ShapeGen x-y coordinate space.

y

The vertical scrolling displacement, in pixels, from the origin of the ShapeGen x-y coordinate space.

Return value

None

Remarks

The `SetScrollPosition` function changes the position of the top-left corner of the [device clipping rectangle](#) relative to the ShapeGen x-y coordinate origin. The device clipping rectangle is a mapping of a rectangular portion of ShapeGen x-y coordinate space to a window (or viewport) on the graphics display device. Thus, if the user program constructs a path containing a virtual 2-D image that is larger than the window, the `SetScrollPosition` function can be used to scroll and pan through the image. Clipping prevents drawing from occurring outside the window.

If input parameters `x` and `y` are both zero, the top-left corner of the target window on the graphics display coincides with the ShapeGen x-y coordinate origin. Increasing the value of `x` causes the window to pan to the right. Increasing the value of `y` causes the window to scroll downward.

ShapeGen always interprets parameter values `x` and `y` as integers. Note that only parameters of type [SGCoord](#) are affected by [ShapeGen::SetFixedBits](#) function calls.

The `SetScrollPosition` function changes only the *position* of the device clipping rectangle – it has no effect on its width or height. To change the width and height of the device clipping rectangle, call the [ShapeGen::InitClipRegion](#) function.

The [ShapeGen::SetClipRegion](#) and [ShapeGen::SetMaskRegion](#) functions can modify the clipping region inside the device clipping rectangle. However, when a `SetScrollPosition` or `InitClipRegion` call changes the position or size of the device clipping rectangle, the current clipping region is replaced by the new device clipping rectangle, and any previous clipping region set by the `SetClipRegion` and `SetMaskRegion` functions is discarded.

Also, a `SetScrollPosition` or `InitClipRegion` function call discards any copy of a clipping region that was previously saved by the [ShapeGen::SaveClipRegion](#) function or swapped out by the [ShapeGen::SwapClipRegion](#) function.

The current path is not altered in any way by a `SetScrollPosition` or `InitClipRegion` function call.

A ShapeGen user program can construct a path containing a shape that is larger than the available drawing area on the screen. In this case, a viewer can use the `SetScrollPosition` function to inspect all parts of the shape by scrolling and panning through it. However, this function is not meant to provide smooth animation. Note that the shape must be redrawn after each `SetScrollPosition` call. Additionally, using this function with a shape that is much larger than the device clipping rectangle might incur significant clipping overhead.

To observe the effect of the `SetScrollPosition` function, run either the ShapeGen demo program or the SVG file viewer included in this GitHub project. Then, while holding the control key down, press any arrow key to generate calls to this function.

Header

`shapegen.h`

See also

[SGCoord](#)

[ShapeGen::SetFixedBits](#)

[ShapeGen::InitClipRegion](#)

[ShapeGen::SetClipRegion](#)

[ShapeGen::SetMaskRegion](#)

[ShapeGen::SaveClipRegion](#)

[ShapeGen::SwapClipRegion](#)

ShapeGen::StrokePath function

The `StrokePath` function strokes the current path.

Syntax

C++

```
bool ShapeGen::StrokePath();
```

Parameters

None

Return value

Returns `true` if the path, after being stroked and clipped, was not empty – in this case, the function sent a description of the resulting path to the renderer to be filled. Otherwise, the function returns `false` to indicate that the resulting path was empty and that nothing was sent to the renderer.

Remarks

The appearance of a stroked path is affected by several stroked-path attributes. The following table contains a list of stroked-path attributes, the default settings of these attributes, and the functions that change the attribute values.

Attribute	Default setting	Function
Line dash pattern	No dash pattern (solid line)	ShapeGen::SetLineDash
Line end cap style	Flat (or butt) cap	ShapeGen::SetLineEnd
Line join style	Beveled join	ShapeGen::SetLineJoin
Line width	4.0	ShapeGen::SetLineWidth
Miter limit	10.0	ShapeGen::SetMiterLimit

The values held by these attributes during the time the path is being constructed are irrelevant. The appearance of a stroked path is affected only by the attribute values at the time of the `StrokePath` call.

The [ShapeGen::EndFigure](#) and [ShapeGen::CloseFigure](#) functions affect the appearance of stroked paths but have no effect on the appearance of filled paths. Shapes filled by the [ShapeGen::FillPath](#) function are always constructed as though the first and last points in each figure are connected, regardless of any previous calls to `EndFigure` or `CloseFigure`.

Header

`shapegen.h`

See also

[ShapeGen::SetLineDash](#)
[ShapeGen::SetLineEnd](#)
[ShapeGen::SetLineJoin](#)
[ShapeGen::SetLineWidth](#)
[ShapeGen::SetMiterLimit](#)
[ShapeGen::EndFigure](#)
[ShapeGen::CloseFigure](#)
[ShapeGen::FillPath](#)

ShapeGen::SwapClipRegion function

The `SwapClipRegion` function swaps the current clipping region with a previously saved copy of a clipping region.

Syntax

C++

```
bool ShapeGen:: SwapClipRegion();
```

Parameters

None

Return value

The function returns true if the new clipping region is not empty. Otherwise, it returns false.

Remarks

This function exchanges the current clipping region with the copy of a clipping region that was previously saved or swapped out. Only one such copy exists at a time. This copy was either swapped out by an earlier call to `SwapClipRegion`, or was previously saved by a `ShapeGen::SaveClipRegion` function call.

The saved copy of a clipping region is preserved through calls to the `ShapeGen::ResetClipRegion`, `ShapeGen::SetClipRegion`, and `ShapeGen::SetMaskRegion` functions.

A call to the `ShapeGen::InitClipRegion`, `ShapeGen::SetScrollPosition`, or `ShapeGen::SetRenderer` function causes any saved copy of a clipping region to be discarded and replaced with an empty clipping region.

ShapeGen clips all shapes, before they are rendered, to the interior of the current clipping region. An empty clipping region, which has no interior, effectively disables all drawing.

For example, if a `SetClipRegion` function call intersects the current clipping region with a path whose interior lies entirely outside the region, the resulting clipping region is empty.

Immediately after the ShapeGen object is created, the saved clipping region is, by default, empty.

Header

`shapegen.h`

See also

[ShapeGen::SaveClipRegion](#)

[ShapeGen::ResetClipRegion](#)

[ShapeGen::SetClipRegion](#)

[ShapeGen::SetMaskRegion](#)

[ShapeGen::InitClipRegion](#)

[ShapeGen::SetScrollPosition](#)

[ShapeGen::SetRenderer](#)

EnhancedRenderer functions

The following reference topics describe the functions that comprise the EnhancedRenderer programming interface. This interface is defined in the `renderer.h` header file included in this GitHub project.

Some of the functions in this section take pixel values as input parameters. These pixel values are specified to be of type `COLOR`, which is defined in `renderer.h` to be an unsigned 32-bit integer. The function descriptions that follow contain more information about pixel formats.

EnhancedRenderer::AddColorStop function

The `AddColorStop` function adds a new color stop to the renderer's internal color stop table.

Syntax

C++

```
void EnhancedRenderer::AddColorStop(float offset, COLOR color);
```

Parameters

offset

A float value in the range 0 to 1.0 that specifies the offset of the new color stop in the color stop table.

color

A `COLOR` value that specifies the color at the new color stop.

Return value

None

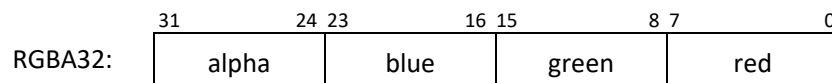
Remarks

The renderer's color stop table contains the list of color stops that are used to generate linear gradients and radial gradients.

To create a new color stop table, first call the [EnhancedRenderer::ResetColorStops](#) function to delete any previously added color stops. Next, through a series of calls to `AddColorStop`, add two or more color stops to the table. Color stops should be added in order of increasing offsets, starting with `offset = 0` and ending with `offset = 1.0`.

To enable gradients to have abrupt changes in color, two successive color stops are allowed to have the same offset. If the abruptness of the color change results in objectionable aliasing, you can move the two offsets slightly apart to achieve a smoother transition.

The `color` parameter is a `COLOR` (unsigned 32-bit integer) value that contains 8-bit red, green, blue, and alpha components. These components are specified in RGBA32 pixel format, as follows:



To supply a color stop table for a linear gradient or radial gradient, construct the table *before* calling the [EnhancedRenderer::SetLinearGradient](#) or [EnhancedRenderer::SetRadialGradient](#) function.

Immediately after the `EnhancedRenderer` object is created, the renderer's color stop table is empty.

Example

This example uses the `AddColorStop` function to add three color stops to an initially empty color stop table. (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example19(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip);
    int i0, j0, i1, j1;
    float x0 = 300.0, y0 = 190.0;
    float x1 = 400.0, y1 = 190.0;
    char dash[] = { 1, 0 };

    // Add three color stops
    aarend->AddColorStop(0, RGBX(0,255,255));    // cyan
    aarend->AddColorStop(0.33, RGBX(240,255,22)); // yellow
    aarend->AddColorStop(1.0, RGBX(255,100,255)); // magenta

    // Set up the linear gradient
    aarend->SetLinearGradient(x0,y0, x1,y1, SPREAD_REPEAT,
                             FLAG_EXTEND_START | FLAG_EXTEND_END);

    // Use the gradient to fill a wide, stroked horizontal line
    i0 = x0 - 150, j0 = y0;
    i1 = x1 + 150, j1 = y0;
    sg->SetLineWidth(100.0);
    sg->SetLineEnd(LINEEND_ROUND);
    sg->BeginPath();
    sg->Move(i0, j0);
    sg->Line(i1, j1);
    sg->StrokePath();

    // Draw a dashed vertical black line through the
    // linear gradient's starting point at (x0,y0)
    sg->SetLineDash(dash, 0, 8.07);
    sg->SetLineWidth(2.0);
    aarend->SetColor(RGBX(0,0,0));
    i0 = x0, j0 = y0 - 85;
    i1 = x0, j1 = y0 + 85;
    sg->BeginPath();
    sg->Move(i0, j0);
    sg->Line(i1, j1);
    sg->StrokePath();

    // Draw a dashed vertical red line through the
    // linear gradient's ending point at (x1,y1)
    aarend->SetColor(RGBX(240,40,40));
    i0 = x1, j0 = y1 - 85;
    i1 = x1, j1 = y1 + 85;
    sg->BeginPath();
    sg->Move(i0, j0);
    sg->Line(i1, j1);
    sg->StrokePath();
}
```

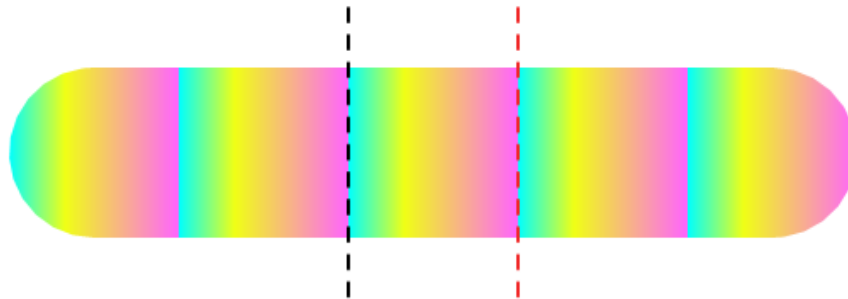

The first color stop in this example is set to cyan, and the last color stop is set to magenta. In between these two color stops, a third color stop, at offset = 0.33, is set to yellow. As required, the three color stops are added in order of increasing offsets, with the first and last offsets set to 0 and 1.0, respectively.

Next, an [EnhancedRenderer::SetLinearGradient](#) function call sets up the renderer to do linear gradient fills in *repeat* mode (spread = SPREAD_REPEAT). These gradient fills will use the new color stop table.

A wide horizontal line with rounded end caps is then stroked with the gradient pattern.

Finally, a dashed vertical black line is drawn through the linear gradient starting point (x0,y0), and a dashed vertical red line is drawn through the linear gradient ending point (x1,y1).

The output produced by this code example is shown in the following screenshot.



Header

`renderer.h`

See also

[EnhancedRenderer::ResetColorStops](#)

[EnhancedRenderer::SetLinearGradient](#)

[EnhancedRenderer::SetRadialGradient](#)

EnhancedRenderer::GetPixelBuffer

The `GetPixelBuffer` function retrieves a description of the pixel buffer that is managed by this renderer.

Syntax

C++

```
bool GetPixelBuffer(PIXEL_BUFFER *pixbuf);
```

Parameters

pixbuf

A pointer to a caller-supplied `PIXEL_BUFFER` structure into which the function writes a description of the renderer's pixel buffer.

Return value

If the renderer has a valid pixel buffer, the function returns `true` after writing a description of the buffer to the caller-supplied `PIXEL_BUFFER` structure. Otherwise, the function immediately returns `false`.

Remarks

A pixel buffer that is described by the `PIXEL_BUFFER` structure is a two-dimensional array of 32-bit pixels. These pixels are typically in either `RGBA32` or `BGRA32` format. These two formats are described in the [Enhanced renderer pixel format](#) topic. The `GetPixelBuffer` function enables the caller to retrieve a description of the pixel buffer that is managed by the renderer.

For more information about the `PIXEL_BUFFER` structure, see the [Creating a ShapeGen object](#) topic.

Code example

For a code example that uses the `GetPixelBuffer` function, see the [Compositing and filtering with layers](#) topic.

Header

`renderer.h`

EnhancedRenderer::ResetColorStops function

The `ResetColorStops` function deletes all color stops from the renderer's internal color stop table.

Syntax

C++

```
void EnhancedRenderer::ResetColorStops();
```

Parameters

None

Return value

None

Remarks

Before using the [EnhancedRenderer::AddColorStop](#) function to construct a new color stop table, call the `ResetColorStops` function to delete any previously added color stops from the table.

Header

`renderer.h`

See also

[EnhancedRenderer::AddColorStop](#)

EnhancedRenderer::SetColor function

The `SetColor` function creates a solid-color paint generator for the renderer to use for subsequent fill and stroke operations. The new paint generator replaces any previously created paint generator.

Syntax

C++

```
void EnhancedRenderer::SetColor(COLOR color);
```

Parameters

color

A `COLOR` value that specifies the solid color to use for subsequent fill operations.

Return value

None

Remarks

The `color` parameter is a `COLOR` (unsigned 32-bit integer) value that contains 8-bit red, green, blue, and alpha components. These components are specified in RGBA32 pixel format, as follows:

	31	24	23	16	15	8	7	0
RGBA32:	alpha		blue		green		red	

Immediately after the `EnhancedRenderer` object is created, the renderer has been configured to fill with solid opaque black.

Header

`renderer.h`

See also

None

EnhancedRenderer::SetConstantAlpha function

The `SetConstantAlpha` function sets the *source constant alpha* value that the renderer is to use for subsequent fill and stroke operations.

Syntax

C++

```
void EnhancedRenderer::SetConstantAlpha(COLOR alpha);
```

Parameters

alpha

A COLOR value in the range 0 (fully transparent) to 255 (fully opaque) that specifies the source constant alpha value to use for subsequent fill operations. Place this value in the 8 least-significant bits of the 32-bit alpha parameter; set the other 24 bits to zero.

Return value

None

Remarks

During fill or stroke operations, the renderer's source constant alpha is mixed with the paint generated for solid-color, pattern, and gradient fills. That is, the renderer combines the source constant alpha with the per-pixel alpha values from the current paint generator.

When a solid-color, pattern, or gradient paint generator is created, it takes a snapshot of the current source constant alpha value. For example, when an [EnhancedRenderer::SetLinearGradient](#) function call creates a linear-gradient paint generator, the generator captures the source constant alpha value that is in effect when the call occurs and then continues to use this value for fill operations until the paint generator is replaced.

Immediately after the EnhancedRenderer object is created, the source constant alpha has been set to its default value, which is 255 (fully opaque).

Example

This example uses the SetConstantAlpha function to change the opacity of four rectangles filled with a linear gradient. (Parameter bkbuff is a PIXEL_BUFFER structure that contains a description of the backing buffer for the graphics display, and parameter clip specifies the device clipping rectangle.)

```
void example20(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend, clip));
    COLOR checker[4] = {
        RGBX(90,90,90), RGBX(255,255,255),
        RGBX(255,255,255), RGBX(90,90,90),
    };
    SGRect bkgd = { 40, 40, 525, 275 };
    SGRect rect = { 53, 30, 107, 295 };
    float xform[6] = { 0.040, 0, 0, 0.040, 0, 0 };

    // Draw checkerboard background pattern
    aarend->SetTransform(xform);
    aarend->SetPattern(checker, 1.6,1.6, 2,2, 2, 0);
    sg->BeginPath();
    sg->Rectangle(bkgd);
    sg->FillPath(FILLRULE_EVENODD);
    aarend->SetTransform(0);

    // Set up color stop table
    aarend->AddColorStop(0, RGBX(0,255,255)); // cyan
    aarend->AddColorStop(0.7, RGBX(255,0,0)); // red
    aarend->AddColorStop(1.0, RGBA(0,0,0,0)); // transparent
```

```
// Fill four rectangles with linear gradient
for (int alpha = 255; alpha > 60; alpha -= 60)
{
    aarend->SetConstantAlpha(alpha);
    aarend->SetLinearGradient(0,30, 0,173, SPREAD_REFLECT,
                             FLAG_EXTEND_START | FLAG_EXTEND_END);

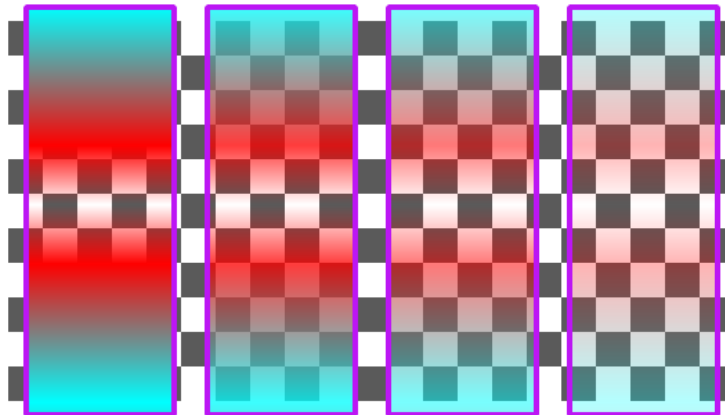
    sg->BeginPath();
    sg->Rectangle(rect);
    sg->FillPath(FILLRULE_EVENODD);
    aarend->SetConstantAlpha(255);
    aarend->SetColor(RGBX(188,22,244));
    sg->StrokePath();
    rect.x += 131;
}
}
```

In this example, the background is first filled with a black-and-white checkerboard pattern.

Next, a three-entry color stop table is set up with a gradient-fill pattern consisting of cyan, red, and fully transparent color stops.

Four rectangles (outlined in purple) are then filled with identical linear gradients, all of which use the same color stop table. The gradient is inherently opaque at the top and bottom of each rectangle and is transparent in the middle. The only difference among the four rectangles is the source constant alpha value that is applied to the gradient fill. For the rectangle on the left, the source constant alpha value is 255 (fully opaque), which means the only non-opaque part of the rectangle is due to the transparent pixel value in the color stop table. The source constant alpha values in the other three rectangles are, from left to right, 195, 135, and 75.

The output produced by this code example is shown in the following screenshot.



In the rectangle furthest to the right, even the fully opaque parts of the gradient pattern are nearly transparent when combined with the source constant alpha value.

Header

renderer.h

See also

[EnhancedRenderer::SetLinearGradient](#)

EnhancedRenderer::SetLinearGradient function

The `SetLinearGradient` function creates a linear-gradient paint generator for the renderer to use for subsequent fill and stroke operations. The new paint generator replaces any previously created paint generator.

Syntax

C++

```
void EnhancedRenderer::SetLinearGradient(  
    float x0,  
    float y0,  
    float x1,  
    float y1,  
    SPREAD_METHOD spread,  
    int flags  
);
```

Parameters

x0

A float value that specifies the x-coordinate at the starting point.

y0

A float value that specifies the y-coordinate at the starting point.

x1

A float value that specifies the x-coordinate at the ending point.

y1

A float value that specifies the y-coordinate at the ending point.

spread

A `SPREAD_METHOD` enum value that specifies whether the linear gradient is to spread according to the *repeat*, *reflect*, or *pad* method. The following enum values are defined for this parameter:

- `SPREAD_PAD` – Use the padding colors to fill pixels that lie outside the region between the starting and ending isolines (the pair of gradient isolines that pass through the starting and ending points; see Remarks below).

- `SPREAD_REPEAT` – Repeat the gradient pattern to fill pixels that lie outside the region between the starting and ending isolines.
- `SPREAD_REFLECT` – Alternately repeat and reflect the gradient pattern to fill pixels that lie outside the region between the starting and ending isolines.

flags

The following flag bits are defined for this parameter:

- `FLAG_EXTEND_START` – Extend the gradient fill beyond the starting isoline (the gradient isoline that passes through the starting point; see Remarks below).
- `FLAG_EXTEND_END` – Extend the gradient fill beyond the ending isoline.

If neither of these flags is set, gradient fills are confined to the region between the starting isoline and ending isoline. In this case, pixels outside this region are not filled, and, thus, the spread parameter has no effect.

Return value

None

Remarks

The color intervals in the linear-gradient fill pattern are specified in the renderer's color stop table. A linear-gradient paint generator takes a snapshot of the current color stop table during the `SetLinearGradient` function call and then uses these color stops for gradient-fill operations until the paint generator is replaced. For more information, see [EnhancedRenderer::AddColorStop](#) and [EnhancedRenderer::ResetColorStops](#).

Linear-gradient fill operations use the renderer's current constant alpha, which is set by the [EnhancedRenderer::SetConstantAlpha](#) function.

Linear-gradient fill operations use the renderer's affine transformation matrix (set by the [EnhancedRenderer::SetTransform](#) function). A linear-gradient paint generator takes a snapshot of the matrix during the `SetLinearGradient` function call and then continues to use this matrix for linear-gradient fill operations until the paint generator is replaced.

Internally, the linear-gradient paint generator uses a parameter t to designate the gradient at a point in the gradient pattern. Parameter t has the value 0 at starting point (x_0, y_0) and has the value 1.0 at ending point (x_1, y_1) . Isolines of constant $t = 0$ and $t = 1.0$ pass through the starting and ending points, respectively, and are normal to the vector from (x_0, y_0) to (x_1, y_1) . Gradient t increases linearly from 0 to 1.0 over the interval from the starting isoline to the ending isoline, and the color stop table specifies the color changes over this interval.

Outside this interval, the spread and flags parameters specify the gradient fill behavior. If the `FLAG_EXTEND_START` flag is set, the gradient fill extends beyond the starting isoline, into the region for which $t < 0$. If the `FLAG_EXTEND_END` flag is set, the gradient fill extends beyond the ending isoline, into the region for which $t > 1.0$.

The `SPREAD_PAD` spread method uses solid colors to pad areas outside the region between the starting and ending isolines. The padding color for pixels that lie beyond the starting isoline is taken from the first entry in the color stop table (at `offset = 0`). The padding color for pixels that lie beyond the ending isoline is taken from the last entry in the color stop table (at `offset = 1.0`).

The SPREAD_REPEAT and SPREAD_REFLECT spread methods use the fractional part of gradient t to look up colors in the color stop table. The SPREAD_REFLECT method additionally uses the integer part of t to determine whether to repeat (if $[t]$ is even) or reflect (if $[t]$ is odd) the gradient pattern.

Example

This example uses the SetLinearGradient function to imitate the color gradients of sunrise over the ocean. (Parameter bkbuff is a PIXEL_BUFFER structure that contains a description of the backing buffer for the graphics display, and parameter clip specifies the device clipping rectangle.)

```
void example21(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend, clip));
    SGRect bkgd = { 40, 40, 400, 300 };
    SGRect light = { 200, 190, 80, 150 };
    SGPoint v0 = { 240, 191 }, v1 = { 200, 191 }, v2 = { 240, 151 };

    // Fill background with ocean horizon gradient colors
    aarend->AddColorStop(0, RGBX(90,100,160));
    aarend->AddColorStop(0.5, RGBX(250,170,110));
    aarend->AddColorStop(0.5, RGBX(30,40,50));
    aarend->AddColorStop(1.0, RGBX(50,155,180));
    aarend->SetLinearGradient(0,40, 0,340, SPREAD_PAD, 0);
    sg->BeginPath();
    sg->Rectangle(bkgd);
    sg->FillPath(FILLRULE_EVENODD);

    // Show sun rising on horizon
    aarend->ResetColorStops();
    aarend->AddColorStop(0, RGBX(225,205,100));
    aarend->AddColorStop(1.0, RGBX(255,145,44));
    aarend->SetLinearGradient(0,150, 0,190, SPREAD_PAD, 0);
    sg->BeginPath();
    sg->EllipticArc(v0, v1, v2, 0, PI); // PI = 3.14159265...
    sg->FillPath(FILLRULE_EVENODD);

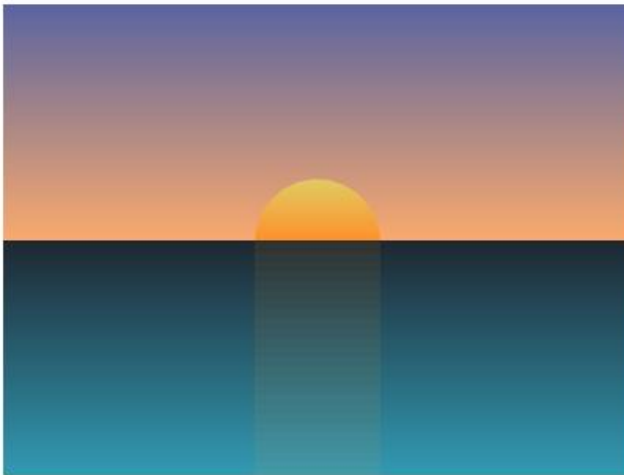
    // Show hazy reflection of sun on water
    aarend->ResetColorStops();
    aarend->AddColorStop(0, RGBA(255,160,44,16));
    aarend->AddColorStop(1.0, RGBA(255,160,44,24));
    aarend->SetLinearGradient(0,190, 0,193, SPREAD_REFLECT, FLAG_EXTEND_END);
    sg->BeginPath();
    sg->Rectangle(light);
    sg->FillPath(FILLRULE_EVENODD);
}
```

In this example, the color gradients are all oriented vertically. In the starting and ending points passed as arguments to each SetLinearGradient function call, the two x-coordinates are identical, which means that the two y-coordinates wholly determine the slope of the gradient.

The color stop table for the background is half sky colors and half ocean colors, with the abrupt color transition at the horizon occurring halfway through the table, at offset = 0.5. The first SetLinearGradient function call generates the fill colors for the background rectangle, with the gradient starting point set to the top of the rectangle and the ending point to the bottom.

Next, a new two-entry color stop table is constructed to represent the color gradient in the rising sun. The second `SetLinearGradient` function call generates the fill colors for the filled half circle, with the gradient starting point aligned with the top of the top of the circular arc and the ending point aligned with the center of the circle.

Finally, a new two-entry color stop table is constructed to represent the sun's reflection on the water. The RGB values in the two colors stops are identical, but their alpha values are slightly different. These alpha values are small (16 and 24) to make the reflection appear hazy. In the third `SetLinearGradient` function call, the `FLAG_EXTEND_END` flag is set to enable the gradient to extend beyond the region between the starting and ending points. The spread argument is set to `SPREAD_REFLECT` to give the reflection an undulating appearance.



The output produced by this code example is shown in the screenshot at left.

Header

`renderer.h`

See also

[EnhancedRenderer::AddColorStop](#)

[EnhancedRenderer::ResetColorStops](#)

[EnhancedRenderer::SetTransform](#)

[EnhancedRenderer::SetConstantAlpha](#)

EnhancedRenderer::SetPattern function

Either version of the `SetPattern` function creates a tiled-pattern paint generator for the renderer to use for subsequent fill and stroke operations. The new paint generator replaces any previously created paint generator.

Syntax

```
C++
```

```
void EnhancedRenderer::SetPattern(  
    const COLOR *pattern,  
    float u0,  
    float v0,  
    int w,  
    int h,  
    int stride,  
    int flags  
);  
  
void EnhancedRenderer::SetPattern(  
    ImageReader *imgrdr,  
    float u0,  
    float v0,  
    int w,  
    int h,  
    int flags  
);
```

Parameters

pattern

A pointer to a COLOR array that contains the image to use for tiled pattern fills. This parameter is used only by the first version of the SetPattern function listed in the Syntax section above.

imgrdr

A pointer to an ImageReader object (see Remarks below) that supplies the image to use for tiled pattern fills. This parameter is used only by the second version of the SetPattern function listed in the Syntax section above.

u0

A float value that specifies the horizontal offset of the left edge (minimum u -coordinate) of the pattern image from the origin of the u - v coordinate system in pattern space.

v0

A float value that specifies the vertical offset of the top edge (minimum v -coordinate) of the pattern image from the origin of the u - v coordinate system in pattern space.

w

An int value that specifies the width (in pixels) of the pattern image.

h

An int value that specifies the height (in pixels) of the pattern image.

stride

An int value that specifies the stride (in pixels) from the start of one row to the start of the next row in the image array pointed to by the pattern parameter. If successive rows in the image are separated in memory by padding (unused storage for one or more COLOR values), then `stride > w`. But if the rows are contiguous in memory, then `stride = w`. This parameter is used only by the first version of the `SetPattern` function listed in the Syntax section above.

flags

The following flag bits are defined for the flags parameter:

- `FLAG_IMAGE_BOTTOMUP` – The rows in the pattern image are stored in bottom-up rather than top-down order.
- `FLAG_IMAGE_BGRA32` – The pixels in the pattern image use BGRA32 format rather than RGBA32 format.
- `FLAG_PREMULTALPHA` – The pixels in the pattern image are already in premultiplied-alpha format.

These flags are used by both versions of the `SetPattern` function listed in the Syntax section above.

Return value

None

Remarks

The two versions of the `SetPattern` function listed in the Syntax section above are similar but differ in how the caller supplies the pattern image to the tiled-pattern object. In both versions, the image consists of 32-bit pixel values.

The first version supplies a pattern image in the form of an array of pixel values. Such an array is convenient for specifying simple patterns – for example, a checkerboard pattern specified by a four-pixel array. The pattern parameter points to an array of pixels, each of which is a COLOR (unsigned 32-bit integer) value. By default, each pixel is assumed to be in RGBA32 format, but the `FLAG_IMAGE_BGRA32` flag bit can be set to indicate that the pixels are in BGRA32 format, as will be described shortly.

The second version of the `SetPattern` function receives a pointer to an `ImageReader` object, which supplies the pattern image as a stream of pixel values. This version is convenient for reading a pattern image from an image file – for example, a BMP, PNG, or JPEG file. The `SetPattern` function requires the `ImageReader` object to support the following interface (see the `renderer.h` header file):

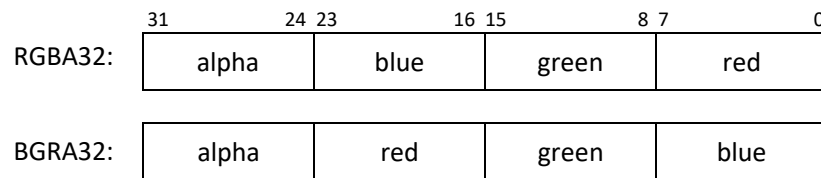
```
class ImageReader
{
public:
    virtual int ReadPixels(COLOR *buffer, int count) = 0;
};
```

Each successive `ReadPixels` function call copies the number of pixels specified by the count parameter to the location pointed to by the buffer parameter. The function returns the number of pixels copied. When

the supply of pixels is exhausted, the function continues to return zero. Two example implementations of the `ImageReader` class can be found in the source code for the ShapeGen demo program.

Three flag bits are defined for the `flags` parameter. The `FLAG_IMAGE_BOTTOMUP` flag indicates that the rows of the pattern image are stored in bottom-up order. By default, the `SetPattern` function expects images to be stored in top-down order. For example, images in BMP files are usually stored in bottom-up order and would appear upside down if used without the `FLAG_IMAGE_BOTTOMUP` flag.

The `FLAG_IMAGE_BGRA32` flag indicates that the 32-bit pixels in the pattern image are in BGRA32 format. By default, the `SetPattern` function expects the pixels to be in RGBA32 format. BGRA32 format is similar to RGBA32 format, except that the 8-bit red and blue fields are swapped, as shown in the following figure:



The `SetPattern` function requires its internal copy of the source image to be in *premultiplied-alpha format*, which means that each pixel's red, green, and blue color components have been multiplied by the pixel's alpha value. By default, the `SetPattern` function converts the pixels in the image to premultiplied-alpha format immediately after copying them. However, the caller can set the `FLAG_PREMULTALPHA` flag to indicate that the pixels in the input image are already in premultiplied-alpha format (so that no conversion is required).

Tiled-pattern fill operations use the renderer's current constant alpha, which is set by the [EnhancedRenderer::SetConstantAlpha](#) function.

Tiled-pattern fill operations use the renderer's affine transformation matrix (set by the [EnhancedRenderer::SetTransform](#) function). A tiled-pattern paint generator takes a snapshot of the matrix during the `SetPattern` function call and then continues to use this matrix for pattern-fill operations until the paint generator is replaced.

Example

This example uses the `SetPattern` function to fill an ellipse with a tartan pattern. (Parameter `bkbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example22(const PIXEL_BUFFER& bkbuf, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&aarend, clip));
    COLOR yel = RGBX(231,213,168), gry = RGBX(163,147,128),
        red = RGBX(211,76,73), mar = RGBX(146,74,77),
        blu = RGBX(79,78,88);
    COLOR tartan[7*7] = {
        yel, gry, gry, yel, gry, gry, gry,
        gry, red, red, gry, mar, mar, mar,
        gry, red, red, gry, mar, mar, mar,
        yel, gry, gry, yel, gry, gry, gry,
        gry, blu, blu, gry, blu, blu, blu,
        gry, blu, blu, gry, blu, blu, blu,
    }
```

```

    gry, blu, blu, gry, blu, blu, blu,
};
SGPoint v0 = { 260, 194 }, v1 = { 40, 194 }, v2 = { 260, 40 };
float xform[6] = { 0.055, 0.055, -0.055, 0.055, 0, 0 };

aarend->SetTransform(xform);
aarend->SetPattern(tartan, 0,0, 7,7,7, 0);
sg->BeginPath();
sg->Ellipse(v0, v1, v2);
sg->FillPath(FILLRULE_EVENODD);
}

```

In this example, the source image for the pattern is contained in a 49-element array consisting of 32-bit pixels. The image is 7 pixels wide and 7 pixels high.

The transform matrix, as specified by the xform array, scales up the image by a factor of 13 and then rotates the image by 45 degrees. This 2-D affine transformation can be factored into two 3x3 matrices, as follows:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} 0.71 & 0.71 & 0 \\ -0.71 & 0.71 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1/13 & 0 & 0 \\ 0 & 1/13 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

When the two 3x3 matrices above are multiplied together, the result is the xform array in the code example. As explained on the [EnhancedRenderer::SetTransform](#) reference page, the last row of a 3x3 transform matrix is always [0 0 1] and does not need to be explicitly included in the xform array.



The output produced by this code example is shown in the screenshot at left.

Header

`renderer.h`

See also

[EnhancedRenderer::SetConstantAlpha](#)

[EnhancedRenderer::SetTransform](#)

EnhancedRenderer::SetRadialGradient function

The `SetRadialGradient` function creates a radial-gradient paint generator for the renderer to use for subsequent fill and stroke operations. The new paint generator replaces any previously created paint generator.

Syntax

C++

```
void EnhancedRenderer::SetRadialGradient(  
    float x0,  
    float y0,  
    float r0,  
    float x1,  
    float y1,  
    float r1,  
    SPREAD_METHOD spread,  
    int flags  
);
```

Parameters

x0

A float value that specifies the x-coordinate at the center of the starting circle.

y0

A float value that specifies the y-coordinate at the center of the starting circle.

r0

A float value that specifies the radius of the starting circle.

x1

A float value that specifies the x-coordinate at the center of the ending circle.

y1

A float value that specifies the y-coordinate at the center of the ending circle.

r1

A float value that specifies the radius of the ending circle.

spread

A `SPREAD_METHOD` enum value that specifies whether the linear gradient is to spread according to the *repeat*, *reflect*, or *pad* method. The following enum values are defined for this parameter:

- `SPREAD_PAD` – Use the padding colors to fill pixels that lie outside the region between the starting and ending circles.
- `SPREAD_REPEAT` – Repeat the gradient pattern to fill pixels that lie outside the region between the starting and ending circles.
- `SPREAD_REFLECT` – Alternately repeat and reflect the gradient pattern to fill pixels that lie outside the region between the starting and ending circles.

flags

The following flag bits are defined for the `flags` parameter:

- `FLAG_EXTEND_START` – Extend the gradient fill beyond the starting circle.
- `FLAG_EXTEND_END` – Extend the gradient fill beyond the ending circle.

If neither of these flags is set, the gradient fill is confined to the region between the starting circle and ending circle. In this case, pixels outside this region are not filled, and, thus, the spread parameter has no effect.

Return value

None

Remarks

The color intervals in the radial-gradient fill pattern are specified in the renderer's color stop table. A radial-gradient paint generator takes a snapshot of the current color stop table during the `SetRadialGradient` function call and then continues to use these color stops for gradient-fill operations until the paint generator is replaced. For more information, see [EnhancedRenderer::AddColorStop](#) and [EnhancedRenderer::ResetColorStops](#).

Radial-gradient fill operations use the renderer's current constant alpha, which is set by the [EnhancedRenderer::SetConstantAlpha](#) function.

Radial-gradient fill operations use the renderer's affine transformation matrix (set by the [EnhancedRenderer::SetTransform](#) function). A radial-gradient paint generator takes a snapshot of the matrix during the `SetRadialGradient` function call and then continues to use this matrix for radial-gradient fill operations until the paint generator is replaced.

Internally, the radial-gradient paint generator uses a parameter t to designate the gradient at a point in the gradient pattern. Parameter t is 0 at the edge of the starting circle and is 1.0 at the edge of the ending circle. Either radius – r_0 or r_1 – can be zero, in which case the starting or ending circle shrinks to a point. The two radii cannot both be zero.

Along a line connecting corresponding points on the two circles, gradient t increases from 0 to 1.0, and the color stop table specifies the color changes over this interval.

Outside this interval, the `spread` and `flags` parameters specify the gradient fill behavior. If the `FLAG_EXTEND_START` flag is set, the gradient fill extends beyond the starting circle, into the region for which

$t < 0$. If the FLAG_EXTEND_END flag is set, the gradient fill extends beyond the ending circle, into the region for which $t > 1.0$.

The SPREAD_PAD spread method uses solid colors to pad areas outside the region between the starting and ending circle. The padding color for pixels that lie beyond the starting circle is taken from the first entry in the color stop table (at offset = 0). The padding color for pixels that lie beyond the ending circle is taken from the last entry in the color stop table (at offset = 1.0).

The SPREAD_REPEAT and SPREAD_REFLECT spread methods use the fractional part of gradient t to look up colors in the color stop table. The SPREAD_REFLECT method additionally uses the integer part of t to determine whether to repeat (if $[t]$ is even) or reflect (if $[t]$ is odd) the gradient pattern.

The two EXTEND flags defined for the flags parameter are fashioned after the Extend array defined for Type 3 (Radial) Shadings in the PDF specification*. The radial gradients defined in the SVG 2 standard encompass the subset of this functionality for which, in effect, the two EXTEND flags are always set.

Example

This example uses the SetRadialGradient function to fill a circle with a gradient that ranges in color from light yellow to dark red. (Parameter bkbuff is a PIXEL_BUFFER structure that contains a description of the backing buffer for the graphics display, and parameter clip specifies the device clipping rectangle.)

```
void example23(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend, clip));
    SGPoint v0 = { 200, 200 }, v1 = { 200-162, 200 }, v2 = { 200, 200-162 };

    aarend->AddColorStop(0, RGBX(255,255,224)); // light yellow
    aarend->AddColorStop(1.0, RGBX(139,0,0)); // dark red
    aarend->SetRadialGradient(140,140,19, 182,182,188, SPREAD_PAD, FLAG_EXTEND_START);
    sg->BeginPath();
    sg->Ellipse(v0, v1, v2);
    sg->FillPath(FILLRULE_EVENODD);
}
```

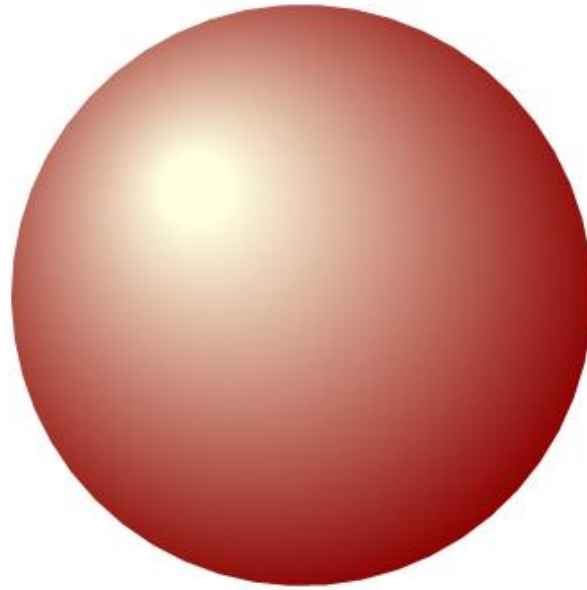
The goal in this example is to give the radial gradient an appearance similar to that of a glossy red sphere reflecting a yellowish light source.

The color stop table starts with light yellow (at offset = 0) and ends with dark red (at offset = 1.0). The ending circle for the radial gradient has a radius that's just a bit larger than that of the circular shape that's being filled, and its center is located 20 pixels to the left and above the shape's center. The effect is to lighten the top-left edge of the circular shape by shaving off the darkest part of the gradient there.

The starting circle for the radial gradient has a radius of 19 pixels and is padded with light yellow to give the appearance of a reflection from a light source. The center of the starting circle is offset from that of the ending circle by 42 pixels in both x and y.

The output produced by this code example is shown in the following screenshot.

* See section 8.7.4.5.4 of the PDF specification (ISO 32000-1 standard, first edition, 2008) at https://www.adobe.com/content/dam/acom/en/devnet/pdf/pdfs/PDF32000_2008.pdf.



Header

`renderer.h`

See also

[EnhancedRenderer::AddColorStop](#)

[EnhancedRenderer::ResetColorStops](#)

[EnhancedRenderer::SetConstantAlpha](#)

[EnhancedRenderer::SetTransform](#)

EnhancedRenderer::SetTransform function

The `SetTransform` function sets the affine transform matrix that the renderer will use for subsequent fill and stroke operations. Both pattern fills and gradient fills are transformed by this matrix.

Syntax

C++

```
void EnhancedRenderer::SetTransform(const float xform[]);
```

Parameters

xform

A six-element `float` array that specifies the affine transformation to use for subsequent pattern and gradient fill operations. Setting `xform` to zero (null array pointer) indicates that no transformation is to be performed on fill patterns or gradients (equivalent to specifying the identity matrix).

Return value

None

Remarks

The renderer's affine transform matrix specifies the mapping of the x-y coordinates of a pixel on the screen to the corresponding u - v coordinates in pattern (or texture) space. The renderer uses this mapping to copy the color of the pattern or gradient at coordinates (u,v) to the pixel at coordinates (x,y) .

If the `xform` array is defined as

```
float xform[6] = { a, b, c, d, e, f };
```

then the resulting affine transformation of a point (x,y) on the display to a point (u,v) in pattern space is defined as follows:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} a & c & e \\ b & d & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

The bottom row of the matrix is implicitly always $[0 \ 0 \ 1]$ and does not need to be explicitly included in the `xform` array supplied to the `SetTransform` function. The format of the `xform` array is the same as that of the 2-D affine transform array defined in the SVG 2 standard.

To apply an affine transformation to a tiled pattern, linear gradient, or radial gradient, call `SetTransform` to set the transformation matrix *before* calling one of the following:

- [EnhancedRenderer::SetPattern](#)
- [EnhancedRenderer::SetLinearGradient](#)
- [EnhancedRenderer::SetRadialGradient](#)

Immediately after the `EnhancedRenderer` object is created, the renderer's affine transform matrix has been set to its default value, which is the identity matrix (that is, no transformation).

Example 1

This first code example shows how to use the `SetTransform` function to apply a 2-D affine transformation to a radial gradient. (Parameter `bkbuff` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example24(const PIXEL_BUFFER& bkbuff, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuff));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend, clip));
    float xform[6] = { 0.375, -0.650, 1.083, 0.625, 364.3, 227.1 };
    SGPoint sc[3] = { { 200, 160 }, { 200-70, 160 }, { 200, 160-70 } };
    SGPoint ec[3] = { { 290, 215 }, { 290-100, 215 }, { 290, 215-100 } };
    SGRect rect = { 40, 40, 400, 300 };
    char dash[] = { 1, 0 };

    // Fill the left rectangle with background color gray
    aarend->SetColor(GBX(180,180,180));
    sg->BeginPath();
    sg->Rectangle(rect);
    sg->FillPath(FILLRULE_WINDING);
}
```

```

// Fill the left rectangle with a radial gradient
aarend->AddColorStop(0, RGBX(255, 215, 0)); // gold
aarend->AddColorStop(1.0, RGBX(135, 206, 235)); // skyblue
aarend->SetRadialGradient(200,160,70, 290,215,100, SPREAD_REPEAT,
                        FLAG_EXTEND_START | FLAG_EXTEND_END);
sg->FillPath(FILLRULE_WINDING);

// Stroke the outline of the starting circle in black
aarend->SetColor(RGBX(40,40,40));
sg->SetLineDash(dash, 0, 8.07);
sg->SetLineWidth(2);
sg->BeginPath();
sg->Ellipse(sc[0], sc[1], sc[2]);
sg->StrokePath();

// Stroke the outline of the ending circle in red
aarend->SetColor(RGBX(255,0,0));
sg->BeginPath();
sg->Ellipse(ec[0], ec[1], ec[2]);
sg->StrokePath();

// Fill the right rectangle with background color gray
rect.x += 420;
aarend->SetColor(RGBX(180,180,180));
sg->BeginPath();
sg->Rectangle(rect);
sg->FillPath(FILLRULE_WINDING);

// Set up a new transform for the radial gradient
aarend->SetTransform(xform);

// Fill the right rectangle with the transformed radial gradient
aarend->SetRadialGradient(200,160,70, 290,215,100, SPREAD_REPEAT,
                        FLAG_EXTEND_START | FLAG_EXTEND_END);
sg->FillPath(FILLRULE_WINDING);

// Transform the coordinates of the starting and ending circles.
// To improve resolution, convert the transformed coordinates to
// 16.16 fixed-point format.
for (int i = 0; i < 3; ++i)
{
    float xtmp = 65536*(xform[0]*sc[i].x + xform[2]*sc[i].y + xform[4]);
    sc[i].y = 65536*(xform[1]*sc[i].x + xform[3]*sc[i].y + xform[5]);
    sc[i].x = xtmp;

    xtmp = 65536*(xform[0]*ec[i].x + xform[2]*ec[i].y + xform[4]);
    ec[i].y = 65536*(xform[1]*ec[i].x + xform[3]*ec[i].y + xform[5]);
    ec[i].x = xtmp;
}

// Tell ShapeGen the coordinates are in 16.16 fixed-point format
sg->SetFixedBits(16);

// Outline the transformed starting circle in black
aarend->SetColor(RGBX(40,40,40));
sg->BeginPath();
sg->Ellipse(sc[0], sc[1], sc[2]);
sg->StrokePath();

// Outline the transformed ending circle in red
aarend->SetColor(RGBX(255,0,0));

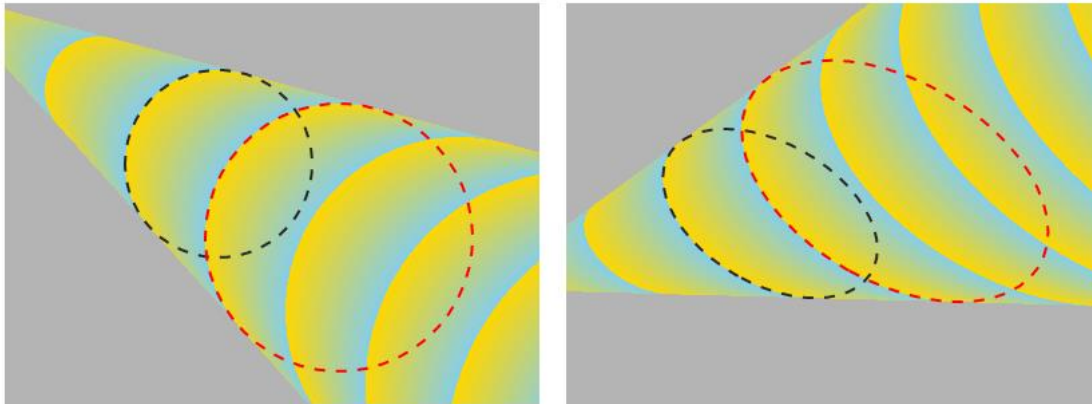
```

```

sg->BeginPath();
sg->Ellipse(ec[0], ec[1], ec[2]);
sg->StrokePath();
}

```

The output produced by this code example is shown in the following screenshot.



The rectangle on the left is filled with the original, untransformed radial gradient, after which the starting and ending circles that define this gradient are outlined by black and red dashed lines, respectively.

At the start of the code example, the `xform` array defines the 2-D affine transformation that is to be applied to the radial gradient. The transformed gradient will be used to fill the rectangle on the right side of the screenshot.

To transform the radial gradient, the `xform` array is first passed to the `SetTransform` function. The `SetTransform` call is followed by an `EnhancedRenderer::SetRadialGradient` function call, which loads the transformation matrix and radial gradient parameters into the radial-gradient paint generator. The `ShapeGen::FillPath` function call then fills the rectangle on the right with the transformed radial gradient.

To verify that the radial gradient has been precisely transformed, this same transformation is applied to the coordinates in the `sc` and `ec` arrays, which specify the starting and ending circles. The transformed circles, which are now ellipses, are stroked with black and red dashed lines over the transformed gradient pattern on the right side of the screenshot. Applying the transformation to the circle coordinates is straightforward – the required matrix multiplications are performed in the for-loop in the code example.

However, applying the transformation to the radial gradient parameters is a bit tricky. By handing off the transformation matrix to the `SetTransform` function, the programmer can ignore all the messy details.

The `xform` array in this example embodies the following transformation:

1. Translate the original, untransformed radial gradient from center coordinates (240, 190) of the rectangle on the left to the x-y origin.
2. To squash the circles into ellipses, scale the figure by a factor of 0.75 in the x dimension and by 1.25 in the y dimension.
3. Rotate the figure by $\pi/3$ radians in the counterclockwise direction.
4. Translate the figure from the x-y origin to center coordinates (660, 190) of the rectangle on the right.

The steps in this transformation are summarized in the following matrix equation:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \cos \frac{\pi}{3} & \sin \frac{\pi}{3} & 660 \\ -\sin \frac{\pi}{3} & \cos \frac{\pi}{3} & 190 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0.75 & 0 & 0 \\ 0 & 1.25 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -240 \\ 0 & 1 & -190 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Example 2

This next code example shows how to use the `SetTransform` function to map a rectangular image to a target shape that is a square, rectangle, or parallelogram. (Parameter `bkbuf` is a `PIXEL_BUFFER` structure that contains a description of the backing buffer for the graphics display, and parameter `clip` specifies the device clipping rectangle.)

```
void example25(const PIXEL_BUFFER& bkbuf, const SGRect& clip)
{
    SmartPtr<EnhancedRenderer> aarend(CreateEnhancedRenderer(&bkbuf));
    SmartPtr<ShapeGen> sg(CreateShapeGen(&*aarend), clip));
    int w = 7, h = 7; // width, height of test image
    COLOR c0 = RGBX(212,212,212), c1 = RGBX(255,40,0),
           c2 = RGBX(0,191,255), c3 = RGBX(100,100,100);
    COLOR image[] = {
        c0,c2,c0,c2,c0,c2,c0, // a 7x7 test image
        c1,c0,c3,c3,c3,c0,c2,
        c0,c0,c3,c0,c0,c0,c0,
        c1,c0,c3,c3,c0,c0,c2,
        c0,c0,c3,c0,c0,c0,c0,
        c1,c0,c3,c0,c0,c0,c2,
        c0,c1,c0,c1,c0,c1,c0,
    };
    SGPoint vert[][4] = { // 3 of 4 vertices
        { { 155, 29 }, { 29, 29 }, { 29, 155 }, },
        { { 353, 85 }, { 185, 85 }, { 185, 183 }, },
        { { 564, 100 }, { 458, 29 }, { 385, 136 }, },
        { { 743, 29 }, { 571, 143 }, { 628, 229 }, },
        { { 935, 143 }, { 878, 29 }, { 821, 143 }, },
        { { 1114, 143 }, { 943, 57 }, { 971, 171 }, },
    };
    char dash[] = { 9, 0 };

    sg->SetLineWidth(2.0);
    sg->SetLineJoin(LINEJOIN_MITER);
    sg->SetLineDash(dash, 3, 1.0);
    for (int i = 0; i < ARRAY_LEN(vert); ++i)
    {
        // Use symmetry to calculate the 4th vertex of the square,
        // rectangle, or parallelogram that is to be filled
        float x0 = vert[i][0].x, y0 = vert[i][0].y;
        float x1 = vert[i][1].x, y1 = vert[i][1].y;
        float x2 = vert[i][2].x, y2 = vert[i][2].y;

        vert[i][3].x = x0 - x1 + x2;
        vert[i][3].y = y0 - y1 + y2;

        // Construct the matrix that will transform points in the
        // square, rectangle, or parallelogram to the test image
        float xP = x0 - x1, yP = y0 - y1;
        float xQ = x2 - x1, yQ = y2 - y1;
```

```

float det = xP*yQ - xQ*yP;
float wdet = w/det, hdet = h/det;
float xform[6];

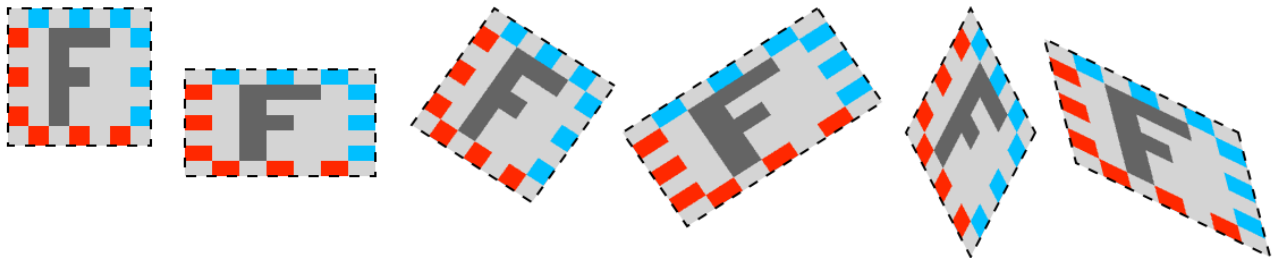
xform[0] = wdet*yQ, xform[2] = -wdet*xQ;
xform[1] = -hdet*yP, xform[3] = hdet*xP;
xform[4] = wdet*(xQ*y1 - yQ*x1), xform[5] = hdet*(yP*x1 - xP*y1);
aarend->SetTransform(xform);

// Map the test image onto the square, rectangle, or
// parallelogram that is to be filled
sg->BeginPath();
sg->Move(vert[i][0].x, vert[i][0].y);
sg->PolyLine(3, &vert[i][1]);
sg->CloseFigure();
aarend->SetPattern(image, 0,0, w,h,w, 0);
sg->FillPath(FILLRULE_EVENODD);

// Outline the square, rectangle, or parallelogram with a
// black dashed line
aarend->SetColor(RGBX(0,0,0));
sg->StrokePath();
}
}

```

The output produced by this code example is shown in the following screenshot.



The image array, which is defined near the start of the code example, contains a simple 7-by-7 test image.

The initializer for the `vert` array defines the first three vertices for each shape in a series of squares, rectangles, and parallelograms oriented at various angles. The fourth vertex for each of these shapes is later calculated using symmetry.

Each iteration of the `for`-loop in the code example calls the [EnhancedRenderer::SetPattern](#) function to specify the mapping of the test image to the next shape (square, rectangle, or parallelogram) in the `vert` array. In the code that precedes this call, a 2-D affine transformation matrix is constructed and loaded into the `xform` array. This matrix specifies the transformation from the x - y coordinates of a pixel in the shape to the corresponding u - v coordinates in the image. Later, during the pattern-fill operation, the image will be sampled at these u - v coordinates to determine the color value that is to be written to the pixel.

This transformation matrix is constructed from the first three vertices – (x_0, y_0) , (x_1, y_1) , (x_2, y_2) – of the shape and then scaled to the width w and height h of the test image. The transformation is described by the following matrix equation:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \frac{1}{x_P y_Q - x_Q y_P} \begin{bmatrix} w & 0 & 0 \\ 0 & h & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} y_Q & -x_Q & 0 \\ -y_P & x_P & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -x_1 \\ 0 & 1 & -y_1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

The rightmost 3x3 matrix above translates the vertex at (x_1, y_1) to the x-y origin and translates the first and third vertices to coordinates $(x_P, y_P) = (x_0 - x_1, y_0 - y_1)$ and $(x_Q, y_Q) = (x_2 - x_1, y_2 - y_1)$.

Before each `SetPattern` call, the `SetTransform` function is called to specify the new transformation matrix. The `SetPattern` function then loads the test image and transformation matrix into the pattern-fill paint generator. Finally, during the `ShapeGen::FillPath` function call, the pattern-fill paint generator fills the shape with the transformed test image.

To verify that the test image has been mapped precisely to the designated shape in the `vert` array, the `ShapeGen::StrokePath` function call outlines the shape boundary with a black dashed line.

Header

`renderer.h`

See also

[EnhancedRenderer::SetPattern](#)

[EnhancedRenderer::SetLinearGradient](#)

[EnhancedRenderer::SetRadialGradient](#)

Appendix: Simple renderer code examples

This GitHub project's `renderer.cpp` file implements both a simple renderer and an enhanced renderer, as explained in the [Renderer](#) section. These two example renderers can cooperatively render an image in a back buffer that has a 32-bit BGRA pixel format (that is `0xaarrggb`).

However, an enhanced renderer works exclusively with true-color graphics display devices. For devices that have more limited color capabilities, a standalone simple renderer is sufficient.

To draw a shape, the ShapeGen object embeds the description of the shape in a ShapeFeeder object. The shape feeder is then passed to the renderer's `RenderShape` function, which performs all rendering.

To support a simple renderer, the shape feeder breaks a shape into a series of rectangles with vertical and horizontal sides. Rectangle coordinates are specified as simple integers. For shapes with sharply curved or slanted sides, most of these rectangles might be just one or two pixels in height. However, a large, rectangular fill region can be specified as a single rectangle.

A simple renderer provides a `SetColor` function that a ShapeGen-based application calls to specify the color to use for filling the next shape. The application specifies the color as an RGB value, and the `SetColor` function maps this value as closely as possible to the pixel format in which the shape is to be rendered.

A simple way to design a standalone simple renderer that will handle an arbitrary pixel format is to allow the underlying platform do the required color mapping and rectangle filling.

This appendix provides complete C++ code examples for standalone simple renderers that run on the [SDL2](#) and Win32/GDI APIs. Modifying these examples to run on other platforms should be straightforward.

SDL2 API code example

The following is an implementation of a simple renderer that runs on the SDL2 API (for example, in Linux or Windows).

```
//-----
//
// BasicRenderer class: Fills a shape with a solid color but does _NOT_
// do antialiasing. This class is derived from the SimpleRenderer class
// in demo.h, which, in turn, is derived from the Renderer base class
// in shapegen.h. This BasicRenderer class implementation is platform-
// dependent -- it uses the SDL_FillRect function in SDL2 to fill the
// horizontal spans that comprise the shape.
//
//-----

class BasicRenderer : public SimpleRenderer
{
    friend ShapeGen;

    SDL_Surface* _surface;
    Uint32 _pixel;

protected:
    void RenderShape(ShapeFeeder *feeder);

public:
    BasicRenderer(SDL_Surface* screenSurface) : _surface(screenSurface), _pixel(0)
    {
        SetColor(RGBX(0,0,0));
    }
    ~BasicRenderer()
    {
    }
    void SetColor(COLOR color);
};

// Fills a series of horizontal spans that comprise a shape
void BasicRenderer::RenderShape(ShapeFeeder *feeder)
{
    SDL_Rect rect;

    while (feeder->GetNextSDLRect(reinterpret_cast<SGRect*>(&rect)))
        SDL_FillRect(_surface, &rect, _pixel);
}

// Selects the color to be used for subsequent fills and strokes
void BasicRenderer::SetColor(COLOR color)
{
    int r = color & 0xff;
    int g = (color >> 8) & 0xff;
    int b = (color >> 16) & 0xff;

    _pixel = SDL_MapRGB(_surface->format, r, g, b);
}
```


This renderer paints shapes with solid colors and performs no antialiasing. The BasicRenderer constructor receives, as an input parameter, the back buffer pointer that the calling program obtained from the [SDL_GetWindowSurface](#) function. The RenderShape member function performs all of the rendering. It iteratively calls the shape feeder's GetNextSDLRect function to receive the next rectangle (an [SDL_Rect](#) structure) and then calls the [SDL_FillRect](#) function to draw the filled rectangle into the back buffer. The SetColor member function calls the [SDL_MapRGB](#) function to map the caller's RGB color parameter to the nearest color value in the pixel format of the back buffer. The COLOR type and RGBX macro are defined in the renderer.h file in the ShapeGen project directory. After the rendered image in the back buffer is complete, the calling program calls the [SDL_UpdateWindowSurface](#) function to BitBlt the back buffer to the window.

Win32/GDI API code example

The following is an implementation of a simple renderer that runs on the Win32/GDI API in Windows.

```
//-----
//
// BasicRenderer class: Fills a shape with a solid color but does _NOT_
// do antialiasing. This class is derived from the SimpleRenderer class
// in demo.h, which, in turn, is derived from the Renderer base class
// in shapegen.h. This BasicRenderer class implementation is platform-
// dependent -- it uses the FillRect function in Windows GDI to fill
// the horizontal spans that comprise the shape.
//
//-----

class BasicRenderer : public SimpleRenderer
{
    friend ShapeGen;

    HDC _hdc;
    HBRUSH _hBrush;

protected:
    void RenderShape(ShapeFeeder *feeder);

public:
    BasicRenderer(HDC hdc) : _hdc(hdc), _hBrush(0)
    {
        SetColor(RGBX(0,0,0));
    }
    ~BasicRenderer()
    {
        DeleteObject(_hBrush);
    }
    void SetColor(COLOR color);
};

// Fills a series of horizontal spans that comprise a shape
void BasicRenderer::RenderShape(ShapeFeeder *feeder)
{
    RECT rect;

    while (feeder->GetNextGDIrect(reinterpret_cast<SGRect*>(&rect)))
        FillRect(_hdc, &rect, _hBrush);
}

// Selects the color to be used for subsequent fills and strokes
void BasicRenderer::SetColor(COLOR color)
{

```

```
DeleteObject(_hBrush);  
_hBrush = CreateSolidBrush(color & 0x00ffffff);  
SelectObject(_hdc, _hBrush);  
}
```

Unlike the SDL2 implementation previously discussed, this renderer can draw directly to a window in on-screen memory – *if* the input parameter is the handle to a display device context for the window. The calling program obtains this handle from the Win32/GDI [BeginPaint](#) function. Drawing directly to the window is slower than using a back buffer but is useful for debugging graphics software. By stepping through the rendering code on a debugger, you can watch as each shape is constructed in piecemeal fashion. When debugging is complete, the code can be sped up by rendering a complete image to a back buffer that is then copied to the window in a single Win32/GDI [BitBlt](#) operation.

The `RenderShape` member function performs all of the rendering. It iteratively calls the shape feeder's `GetNextGDIrect` function to receive the next rectangle (a Win32/GDI [RECT](#) structure) and then calls the Win32/GDI [FillRect](#) function to draw the filled rectangle into the back buffer. The `SetColor` member function calls the Win32/GDI [CreateSolidBrush](#) function to map the caller's RGB color parameter to the nearest color value in the target buffer's pixel format.