ShapeGen User's Guide

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Introduction

The 2-D 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 to draw, but leaves all device-dependent operations on pixels to the renderer. Thus, the shape generator remains free of all such device dependencies.

This GitHub project contains the C++ source code for a ShapeGen class that implements a 2-D polygonal shape generator. The ShapeGen programming interface is similar to that of other 2-D graphics software systems.

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

ShapeGen function	PostScript operator
`BeginPath`	newpath
`Bezier3`	curveto

ShapeGen function	PostScript operator
`Move`	moveto
`SetClipRegion`	clip

CloseFigure	closepath
EllipticArc	arc
FillPath	fill
GetBoundingBox	pathbbox
GetCurrentPoint	currentpoint
InitClipRegion	initclip
Line	lineto

SetFlatness	setflat
SetLineDash	setdash
SetLineEnd	setlinecap
SetLineJoin	setlinejoin
SetLineWidth	setlinewidth
SetMiterLimit	setmiterlimit
StrokePath	stroke

The PostScript path construction operators are described in chapter 8 of the *PostScript Language Reference Manual*, Second Edition, 1990.

Paths and figures

In both ShapeGen and PostScript, a shape is described by a path. 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 disjointed regions, a path is composed of several plane figures (the term used by ShapeGen) or subpaths (the PostScript term). Each figure or subpath consists of a list of points that describes a sequence of connected polygonal edges.

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. But 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 must call the `ShapeGen::BeginPath` function.

Renderer

A ShapeGen object must be paired with a renderer so that shapes constructed by the 2-D polygonal shape generator can be drawn on a graphics display. This GitHub project includes the source code for renderers that run in Linux and Windows. Two classes of renderer are provided for either operating system. A *basic*

renderer, which does no antialiasing, is paired with an *antialiasing renderer*, which can additionally do alpha blending. The user calls the `ShapeGen::SetRenderer` function to switch between these two renderers.

For Linux, these two renderers run on the Simple DirectMedia Library (SDL2). For Windows, one version of the two renderers runs on Windows GDI; the other version runs on SDL2, and is essentially identical to the SDL2 version that runs in Linux.

The class definitions for both basic renderers and antialiasing renderers are derived from the following Renderer base class, which is defined in header file shapegen.h:

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

All three of these functions are called exclusively by the ShapeGen object. Additionally, a renderer derived from the base class is expected to provide user-callable functions to, for example, specify the solid color, repeating pattern, or color gradient to be used to render shapes. The example renderers included in this GitHub project do solid color fills and provide a user-callable SetColor function.

The Renderer::RenderShape function receives a pointer to a ShapeFeeder object, which operates as an iterator to supply a series of either rectangles or spans (horizontal rows of pixels) to be filled. Each RenderShape call fills or strokes a shape defined by a user-constructed path.

The Renderer::QueryYResolution and Renderer::SetClipWidth functions are provided for the benefit of antialiasing renderers. An antialiasing renderer implements a QueryYResolution function that returns the number of fractional (subpixel) bits the renderer requires in the y coordinates it receives from the ShapeFeeder. This renderer also implements a SetMaxWidth function that receives the maximum width (in pixels) of any shape it will be asked to draw. When the renderer is installed (for example, if the user calls the ShapeGen::SetRenderer function), ShapeGen immediately calls both QueryYResolution and SetMaxWidth. Note that a basic renderer, which does no antialiasing, simply uses the versions of these two functions defined in the base class above.

Internally, ShapeGen constructs a path to describe a polygonal shape, and then decomposes this path into a list of non-overlapping trapezoids with horizontal top and bottom sides. For consumption by a basic renderer, ShapeGen further decomposes these trapezoids into rectangles with integer width and height. (Because the trapezoids frequently have slanted rather than vertical left and right sides, the resulting rectangles are often just one pixel in height.) For an antialiasing renderer, the trapezoids are decomposed into spans with fixed-point starting and ending x coordinates.

The implementation of a basic renderer is quite simple, which makes it easy to port to any processor for which a C++ compiler is available. For example, the basic renderer that runs on SDL2 implements 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);
}
```

This version of the RenderShape function (see source file sdlmain.cpp) uses the `SDL_FillRect` function to fill the rectangles, and therefore runs on platforms, such as Linux, on which SDL2 is available. The version that runs on Windows GDI (see winmain.cpp) calls the `FillRect` function instead.

The RenderShape functions implemented by the antialiasing renderers in this GitHub project are necessarily more complex than this.

Either version of the antialiasing renderer constructs an 8x4 coverage bitmask for each pixel in the shape that is being rendered. However, only enough memory to store one scanline of pixels is needed. To this end, the spans supplied by the ShapeFeeder to the renderer's RenderShape function are always provided in ascending-y order. Thus, the renderer finishes constructing a shape's contribution to one scanline before starting on the next scanline. These renderers rely on the alpha-blending capabilities of the underlying platform. The SDL2 version calls the `SDL_BlitSurface` function, and the Windows GDI version calls the `AlphaBlend` function.

The Windows GDI versions of the RenderShape functions in this project write "directly" to the window on the screen, which you might find useful if you're debugging a graphics program. That's because you can single-step through the RenderShape function in a debugger, and inspect each rectangle or span as it is drawn. Of course, Windows doesn't allow a user to write directly to screen memory, and so every rectangle or span undergoes bounds checking before it is drawn. After you finish debugging your graphics program, though, it will run faster if you modify it to first draw everything to an offscreen buffer and then blit the completed image to the window. That's how the SDL2 version of the RenderShape function in this project works.

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 target window (aka viewport) on the graphics display. The device clipping rectangle might span the entire screen of a dedicated graphics display.

After constructing a shape, and before any drawing occurs, ShapeGen automatically clips any part of the shape that lies outside the current device clipping rectangle. All such clipping occurs before ShapeGen passes the shape to the renderer.

The user can call the `ShapeGen::SetClipRegion` and `ShapeGen::SetMaskRegion` functions to modify the interior of the current clipping region, but no clipping region ever extends beyond the bounds of the device clipping rectangle.

The device clipping rectangle is specified by four integers, (*x*,*y*,*w*,*h*), where *x* and *y* are the coordinates at the top-left corner of the rectangle, and *w* and *h* are its width and height, in pixels. X coordinate values increase to the right, and y coordinate values increase in the downward direction. The *x* and *y* values specify the horizontal and vertical displacements, in pixels, of the rectangle's top-left corner from the origin of the

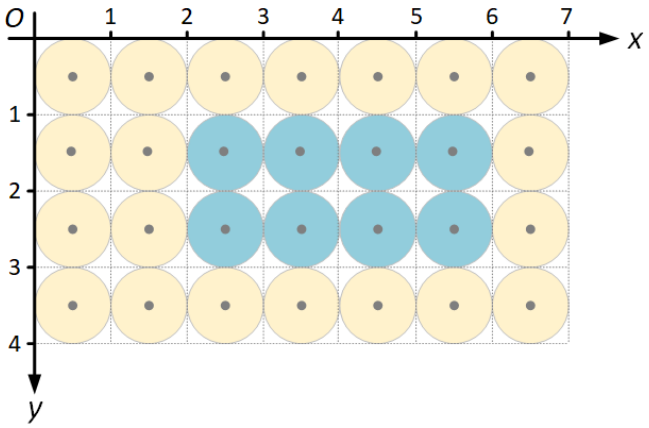
coordinate system used by the ShapeGen functions. The *w* and *h* values match the width and height of the window. Thus, the device clipping rectangle specifies the region of the ShapeGen coordinate space that the viewer sees in the window.

Typically, (*x*,*y*) = (0,0), in which case the origin of the coordinate system coincides with the top-left corner of both the device clipping rectangle and the window.

However, the device clipping rectangle's *x* and *y* coordinates can be specified as nonzero values to enable horizontal and vertical scrolling through the user's coordinate space. If a ShapeGen user's program constructs a "virtual" image that is larger than the window, scrolling enables the window to pan across the image.

The ShapeGen class constructor requires a device clipping rectangle as an input parameter, so that an initial clipping region is defined from the moment 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 of the top-left corner of the rectangle can be changed by calling the `ShapeGen::SetScrollPosition` function.

The following figure shows how ShapeGen maps its x-y coordinate space to the pixels on the graphics display. Integer x and y coordinates lie on the boundaries between pixels. In this example, the device clipping rectangle has width *w* = 7 and height *h* = 4. This particular rectangle's position is specified as (*x*,*y*) = (0,0), so that its top-left corner coincides with the user's x-y coordinate origin.



The background in this example is painted yellow. Inside the device clipping rectangle, a smaller rectangle is filled with blue paint. The top-left corner of the blue rectangle is at coordinates (2,1) and the bottom-right corner is at coordinates (6,3).

The rule for filling a region defined by a polygonal boundary is that a pixel belongs to the region if the center of the pixel lies inside the boundary. Otherwise, the pixel is not part of the region.

In the event that the boundary between two filled regions passes precisely through the center of a pixel, the pixel belongs to the region just below and to the right of the pixel center.

Creating a ShapeGen object

The ShapeGen programming interface is defined in the public header file shapegen.h. The internal implementation of the ShapeGen interface is encapsulated by the SGPtr class, which is defined at the bottom

of this header file. An instance of the SGPtr class operates as a smart pointer that creates a ShapeGen object and provides access to this object's public interface. When the SGPtr object goes out of scope and is automatically deleted, the SGPtr destructor deletes the ShapeGen object.

The constructor for the internal ShapeGen implementation takes two input parameters:

- A pointer to a Renderer object
- The device clipping rectangle

The SGPtr constructor takes the same two input parameters, which it passes to the ShapeGen constructor.

The following code example shows how to use an SGPtr object to create a ShapeGen object. Briefly, the `MyTest` function sets the background color in the device clipping rectangle to white. Then it calls the `MySub` function to fill a blue rectangle that's 250 pixels wide and 160 pixels high.

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

void MyTest(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(rend, clip);
    SGRect rect = { 100, 80, 250, 160 };

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

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

The `MyTest` function's first call parameter, `rend` is a pointer to a basic renderer. The second parameter, `aarend`, points to an antialiasing renderer, which is not used in this example. The interface for the SimpleRenderer class (see header file demo.h) is derived from the Renderer base class (see header file shapegen.h), but contains an additional function, `SetColor`, that sets the color to be used for color-fill operations. The BasicRenderer class, mentioned previously (see Renderer), implements the SimpleRenderer interface. The `rend` parameter in this example, in fact, points to a BasicRenderer object.

The MyTest function's third parameter, `clip`, specifies the device clipping rectangle.

As an automatic variable, the SGPtr object, `sg`, resides in the program stack and is deleted when it goes out of scope at the end of the `MyTest` function.

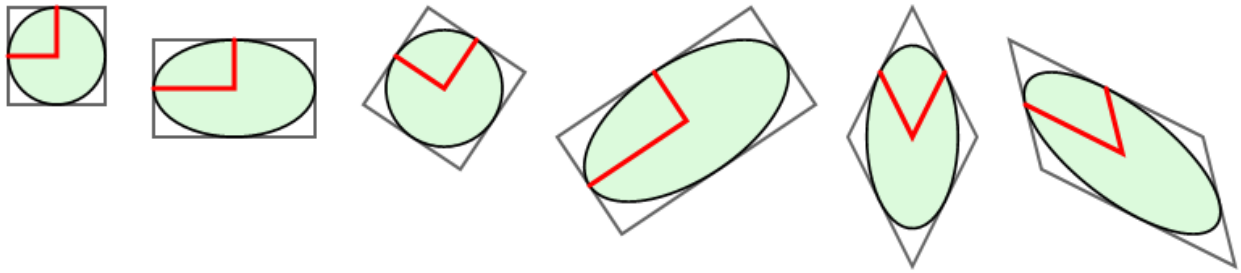
To serve as a smart pointer, the SGPtr class overloads the -> operator so that an SGPtr object, such as `sg`, can be used as a pointer to the encapsulated ShapeGen object. To enable a ShapeGen object pointer to be passed to a function (such as `MySub` in the preceding code example) as a call parameter, the SGPtr class overloads the * operator.

Ellipses and elliptic arcs

The ShapeGen interface can construct ellipses and elliptic arcs of any shape and orientation. An ellipse is defined by three points: its center point, and the end points of two *conjugate diameters* of the ellipse. Other 2-D graphics systems 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 inscribed.

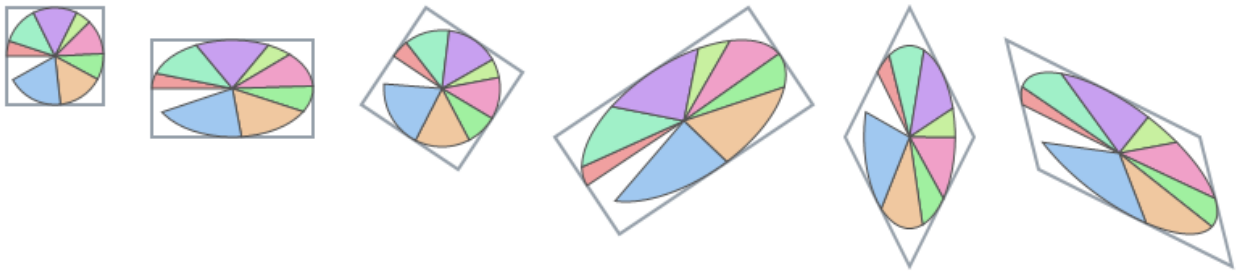
The following screenshot should clarify things a bit.



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 preceding screenshot 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 this article at the ResearchGate site.

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

```
void PieToss(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
```

```
{
    SGPtr sg(aarend, clip);
    const float PI = 3.14159265;
    float percent[] = {
        5.1, 12.5, 14.8, 5.2, 11.6, 8.7, 15.3, 18.7
    };
    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] = {
        { {  20,  80 }, {  20,  20 }, {  80,  20 } },
        { { 110, 100 }, { 110,  40 }, { 210,  40 } },
        { { 240,  80 }, { 280,  20 }, { 340,  60 } },
        { { 400, 160 }, { 360, 100 }, { 480,  20 } },
        { { 540, 100 }, { 580,  20 }, { 620, 100 } },
        { { 660, 120 }, { 640,  40 }, { 760, 100 } },
    };

    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. 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(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;

            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(RGBX(80,80,80));
            sg->SetLineWidth(1.0);
            sg->StrokePath();
            astart += asweep;
        }
    }
}
```

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 virtually 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 integers. However, the user can call the ShapeGen::SetFixedBits function to specify that ShapeGen functions are to treat SGCoord values as fixed-point numbers.

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 Device clipping rectangle.

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. 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 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 Device clipping rectangle.

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. 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 integers. However, the user can call the `ShapeGen::SetFixedBits` function to specify that ShapeGen functions are to treat SGCoord values as fixed-point numbers.

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 (aka subpath or contour) in this path.

After a new path is created, it exists 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

The x-y coordinates at the Bezier control point for the spline.

V2

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 a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

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 call.

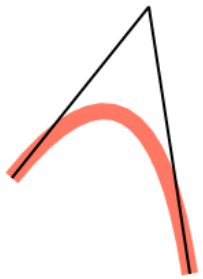
Example

This example uses the `Bezier2` function to draw a quadratic Bezier spline (in red) and its control polygon (in black). (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.) (Variable `sg` is the ShapeGen object pointer, `rend` points to the basic renderer, and `aarend` points to the antialiasing renderer.)

```
void example01(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);

    SGPoint v0 = { 100, 200 }, v1 = { 200, 75 }, v2 = { 230, 270 };

    // Draw quadratic Bezier spline in red
    aarend->SetColor(RGBX(255,120,100));
    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 result is shown in the following screenshot.



In the 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 end point, `v2`, is on the right. The control point, `v1`, is at the top. 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

`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

The x-y coordinates at the first Bezier control point for the spline.

V2

The x-y coordinates at the second Bezier control point for the spline.

V3

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 a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

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 call.

Example

This example uses the `Bezier3` function to draw a cubic Bezier spline (in red) and its control polygon (in black). (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example02(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    SGPoint v0 = { 100, 200 }, v1 = { 150, 30 },
            v2 = { 260, 200 }, v3 = { 330, 30 };

    // Draw cubic Bezier spline in red
    aarend->SetColor(RGBX(255,120,100));
    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 result is shown in the following screenshot.

In the code example, points `v0`, `v1`, `v2`, and `v3` define the control polygon for the spline curve. The starting point, `v0`, is at the lower-left corner of the screenshot. The end point, `v3`, is at the top-right corner. In between are the two control points, `v1` and `v2`. The curve is tangent to side `v0`·`v1` at the starting point, and is tangent to side `v2`·`v3` at the end point.

Header

`shapegen.h`

See also

`ShapeGen::PolyBezier3`

ShapeGen::CloseFigure function

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

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.

Any figure not explicitly closed by `CloseFigure` is open; that is, the first and last points in the figure are not connected.

`CloseFigure` affects the appearance of stroked paths, 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`.

A path might contain a combination of closed and open figures. If a figure is to be closed, then after adding the final point to the figure, call `ShapeGen::CloseFigure` to finalize the figure before calling `StrokePath`, `FillPath`, or the `ShapeGen::Move` function. Otherwise, the figure is left open and cannot subsequently be closed.

A `CloseFigure` call has no effect on a figure that has already been finalized.

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.

The `PathMgr::SetClipRegion` and `PathMgr::SetMaskRegion` functions automatically finalize the last figure in the path, if it has not already been finalized. In this case, the ends of the finalized figure are left open.

In constrast to `CloseFigure`, the `PathMgr::EndFigure` function finalizes a figure without closing it—that is, the start and end points are left unconnected.

Header

`shapegen.h`

See also

`ShapeGen::FillPath`

`ShapeGen::CloseFigure`

`ShapeGen::Move`

`PathMgr::SetClipRegion`

`PathMgr::SetMaskRegion`

`PathMgr::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`

The x-y coordinates at the center of the ellipse.

V1

The x-y coordinates at an end point of the first of a pair of conjugate diameters of the ellipse.

V2

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 in the same manner as the `ShapeGen::EndFigure` function before starting a new figure in the same path. After adding the points in the rectangle to the new figure, the `Ellipse` function finalizes this figure 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.

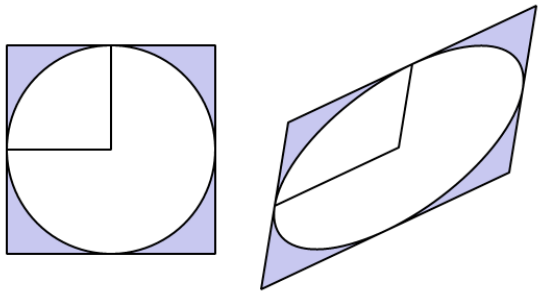
Example

This example uses the `Ellipse` function to draw two ellipses inscribed in parallelograms. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example03(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    SGPoint u[4] = { { 100, 275 }, { 100, 75 }, { 300, 75 }, };
    SGPoint du[3] = { { 244, 34 }, { 270, 74 }, { 308, -38 }, };
    SGPoint v0, v1, v2;

    sg->SetLineWidth(2.0);
    for (int i = 0; i < 2; ++i)
    {
        u[3].x = u[0].x - u[1].x + u[2].x;
        u[3].y = u[0].y - u[1].y + u[2].y;
        v0.x = (u[0].x + u[2].x)/2;
        v0.y = (u[0].y + u[2].y)/2;
        v1.x = (u[0].x + u[1].x)/2;
        v1.y = (u[0].y + u[1].y)/2;
        v2.x = (u[1].x + u[2].x)/2;
        v2.y = (u[1].y + u[2].y)/2;
        sg->BeginPath();
        sg->Move(u[0].x, u[0].y);
        sg->PolyLine(3, &u[1]);
```

```
            sg->CloseFigure();
            sg->Ellipse(v0, v1, v2);
            aarend->SetColor(RGBX(200,200,240));
            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(0,0,0));
            sg->StrokePath();
            for (int j = 0; j < 3; ++j)
            {
                u[j].x += du[j].x;
                u[j].y += du[j].y;
            }
        }
    }
```

The result 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.

In the figure on the right, an affine transformation has been performed on the original points in the figure on the left. The parallelogram on the right is the transformed version of the square on the left. The center point and conjugate diameter end points are also transformed. The resulting ellipse is inscribed in the parallelogram and touches the parallelogram at the midpoint of each side.

Header

`shapegen.h`

See also

`ShapeGen::EndFigure`

`ShapeGen::CloseFigure`

ShapeGen::EllipticArc function

The `EllipticArc` function adds an elliptic arc to the current path.

Syntax

C++

```
void ShapeGen::EllipticArc(
   const SGPoint& v0,
   const SGPoint& v1,
   const SGPoint& v2,
   float astart,
   float asweep
);
```

Parameters

V0

The x-y coordinates at the center of the ellipse.

V1

The x-y coordinates at an end point of the first of a pair of conjugate diameters of the ellipse.

V2

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 swept out 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.

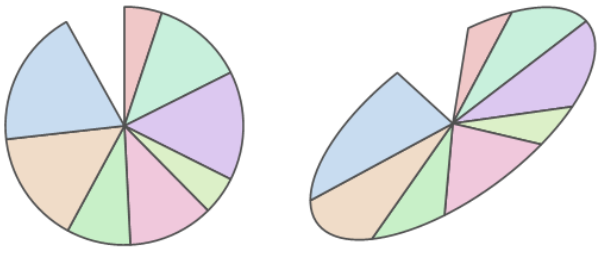
If, on entry to this function, the current point is undefined (because the current figure is empty), the starting point of the arc becomes the first point in the figure. Otherwise, the function inserts a line segment connecting the current point to the starting point of the arc. On return from this function,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

Example

This example uses the `EllipticArc` function to draw two affine-transformed views of the same pie chart. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example04(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    const float PI = 3.14159265;
    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 v0[] = { { 200, 175 }, { 476, 173 } };
    SGPoint v1[] = { { 200,  75 }, { 489,  93 } };
    SGPoint v2[] = { { 300, 175 }, { 595, 117 } };

    sg->SetLineWidth(1.7);
    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(v0[i], v1[i], v2[i], astart, asweep);
            sg->Line(v0[i].x, v0[i].y);
            aarend->SetColor(color[j]);
            sg->CloseFigure();
            sg->FillPath(FILLRULE_EVENODD);
            aarend->SetColor(RGBX(80, 80, 80));
            sg->StrokePath();
            astart += asweep;
        }
    }
}
```

The result is shown in the following screenshot.



The two ellipses in the screenshot differ only in the three points—v0, v1, and v2—that are passed to the EllipticArc function. The astart and asweep angles are identical. That's because these angles remain invariant to affine transformations of v0, v1, and v2.

If we needed obtain the x-y coordinates at the starting and ending points of each arc in the preceding code example, we could insert calls to the ShapeGen::GetFirstPoint and ShapeGen::GetCurrentPoint functions immediately after the EllipticArc call.

Header

shapegen.h

See also

ShapeGen::GetFirstPoint

ShapeGen::GetCurrentPoint

ShapeGen::EllipticSpline function

The EllipticSpline function constructs an elliptic spline curve (an elliptic arc of π/2 radians), starting at the current point.

Syntax

C++

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

Parameters

V1

The x-y coordinates at the control point for the spline.

V2

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 a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

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.

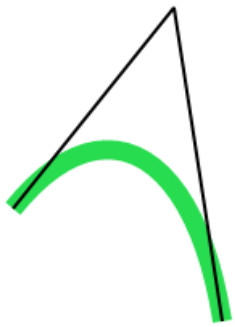
The `ShapeGen::PolyEllipticSpline` function constructs a set of connected elliptic splines in a single call.

Example

This example uses the `EllipticSpline` function to draw an elliptic spline curve (in green). The spline's control polygon is outlined in black. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example05(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    SGPoint v0 = { 100, 200 }, v1 = { 200, 75 }, v2 = { 230, 270 };

    // 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 result is shown in the following screenshot.



In the 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 end point, `v2`, is on the right. The control point, `v1`, is at the top. 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

ShapeGen::PolyEllipticSpline

ShapeGen::EndFigure function

The EndFigure function finalizes a figure (aka subpath or contour) 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. If the finalized 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.

A path might contain a combination of closed and open figures. If a figure is to be closed, then, after adding the figure to the path, call CloseFigure to finalize the figure before calling StrokePath, FillPath, or the ShapeGen::Move function. Otherwise, the figure is left open and cannot subsequently be closed.

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::Move

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
);
```

Parameters

fillrule

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

FILLRULE_EVENODD – Even-odd (aka parity) fill rule

FILLRULE_WINDING – Nonzero winding number fill rule

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 points in the current path.

Syntax

C++

```
bool ShapeGen::GetBoundingBox(
   SGRect *bbox
);
```

Parameters

bbox

A pointer to an SGRect structure. The function writes the minimum bounding box coordinates to this structure.

Return value

Returns true if the function succeeds in retrieving the bounding box. If the current path is empty, the function fails and immediately returns a value of false.

Remarks

The bounding-box 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.

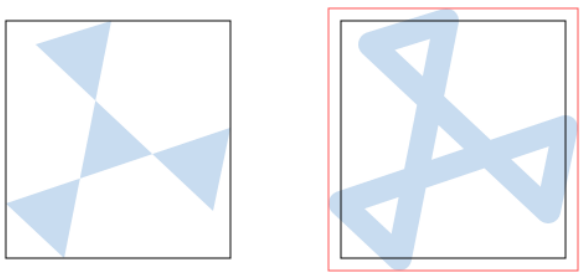
Example

This example uses the GetBoundingBox function to get the minimum bounding boxes for two shapes: one that is filled, and one that is stroked. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example06(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    SGPoint xy[] = {
        { 104, 62 }, { 247, 196 }, { 261, 129 },
        { 80, 190 }, { 127, 234 }, { 165, 43 }
    };
    float linewidth = 20.0;
    SGRect bbox;

    // Fill shape in blue
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyLine(5, &xy[1]);
```

```
    aarend->SetColor(RGBX(200,220,240));
    sg->FillPath(FILLRULE_EVENODD);

    // Get bounding box and outline it in black
    sg->GetBoundingBox(&bbox);
    sg->SetLineWidth(1.0);
    sg->SetLineJoin(LINEJOIN_MITER);
    sg->BeginPath();
    sg->Rectangle(bbox);
    aarend->SetColor(RGBX(0,0,0));
    sg->StrokePath();

    // Move the shape to the right
    for (int i = 0; i < 6; ++i)
        xy[i].x += 270;

    // Stroke the figure in blue
    sg->SetLineJoin(LINEJOIN_ROUND);
    sg->SetLineWidth(linewidth);
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyLine(5, &xy[1]);
    sg->CloseFigure();
    aarend->SetColor(RGBX(200,220,240));
    sg->StrokePath();

    // Get the bounding box and outline it in black
    sg->GetBoundingBox(&bbox);
    sg->SetLineWidth(1.0);
    sg->SetLineJoin(LINEJOIN_MITER);
    sg->BeginPath();
    sg->Rectangle(bbox);
    aarend->SetColor(RGBX(0,0,0));
    sg->StrokePath();

    // Expand each side of the bounding box by half the line width
    bbox.x -= linewidth/2;
    bbox.y -= linewidth/2;
    bbox.w += linewidth;
    bbox.h += linewidth;

    // Outline the modified bounding box in red
    sg->BeginPath();
    sg->Rectangle(bbox);
    aarend->SetColor(RGBX(255,80,80));
    sg->StrokePath();
}
```

The result is shown in the following screenshot.



First, the code example constructs a path and fills it to produce the shape shown on the left side of the screenshot. The GetBoundingBox function is called on the path, and the resulting bounding box is outlined in black.

Next, the code example constructs a similar path, shifted to the right, and strokes it to produce the shape on the right side of the preceding screenshot. The GetBoundingBox function is called on the path, and the resulting bounding box is outlined in black. In this case, the edges of the stroked path extend beyond the bounding box. To address this problem, the code example expands the original bounding box by half the stroked line width on all four sides. This expanded bounding box (outlined in red) successfully encloses the entire shape. Of course, this trick might not work as well for mitered joints.

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 an SGPoint structure. The function writes the current point's x-y coordinates to this structure.

Return value

Returns true if the function succeeds in retrieving the current point. If the current point is undefined (because the current figure is empty), the function fails and immediately returns a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

Remarks

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 (aka subpath or contour).

Syntax

C++

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

Parameters

`fpoint`

A pointer to an `SGPoint` structure. The function writes the first point's x-y coordinates to this structure.

Return value

Returns true if the function succeeds in retrieving the first point. If the first and current points are undefined (because the current figure is empty), the function fails and immediately returns a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

Remarks

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::InitClipRegion function

The InitClipRegion function updates the device clipping rectangle, and sets the current clipping region to this rectangle.

Syntax

C++

```
void 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

None

Remarks

This function sets the device clipping rectangle to the dimensions specified by the parameters width and height. Pixel grid coordinates in the range 0 ≤ x < width and 0 ≤ y < height lie within the new device clipping rectangle.

The ShapeGen object, working in association with a Renderer object, confines all drawing to the interior of the device clipping window.

Calls to the ShapeGen::SetClipRegion and ShapeGen::SetMaskRegion functions can modify the clipping region inside the device clipping rectangle, but cannot expand the clipping region beyond the device clipping window.

The clipping region is never undefined. When the ShapeGen object is created, an initial device clipping rectangle is a required constructor parameter. ShapeGen always stores a copy of the current device clipping rectangle so that it can be restored at any time by a call to the ShapeGen::ResetClipRegion function.

The InitClipRegion function discards any copy of a clipping region that was previously saved by the ShapeGen::SaveClipRegion function. Other ShapeGen functions, including ResetClipRegion, SetClipRegion, and SetMaskRegion, preserve any copy of a clipping region previously saved by SaveClipRegion.

Header

shapegen.h

See also

ShapeGen::SetClipRegion

ShapeGen::SetMaskRegion

ShapeGen::ResetClipRegion

ShapeGen::SaveClipRegion

ShapeGen::Line function

The Line function constructs a 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 a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

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 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 (aka subpath or contour) and adds the first point to this figure.

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 deletes and replaces the point specified by the first Move call.

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

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 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 a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

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.

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

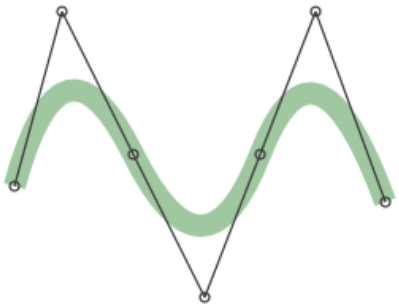
Example

This example uses the PolyBezier2 function to draw three connected quadratic Bezier spline curves. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example07(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
```

```
    SGPtr sg(aarend, clip);
    SGPoint xy[] = {
        { 40, 140 }, { 70, 30 }, { 115, 120 }, { 160, 210 },
        { 195, 120 }, { 230, 30 }, { 274, 150 }
    };
    SGPoint v0, v1, v2;

    // Stroke three connected quadratic Bezier splines in green
    aarend->SetColor(RGBX(160,200,160));
    sg->SetLineWidth(14.0);
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyBezier2(6, &xy[1]);
    sg->StrokePath();

    // Outline spline skeleton in black; mark knots & control points
    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)
    {
        v0 = v1 = v2 = xy[i];
        v1.x -= 3;
        v2.y -= 3;
        sg->Ellipse(v0, v1, v2);
    }
    sg->StrokePath();

    //-----  Label the output of this code example -----
    TextApp txt;
    COLOR crText = RGBX(40,70,110);
    char *str = "Output of code example from ShapeGen::"
                "PolyBezier2 reference topic in userdoc.pdf";
    SGPoint xystart = { 24, 400 };
    float scale = 0.3;
    txt.SetTextSpacing(1.1);
    sg->SetLineWidth(3.0);
    aarend->SetColor(crText);
    txt.DisplayText(&(*sg), xystart, scale, str);
}
```

The result is shown in the following screenshot.



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

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 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 a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

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.

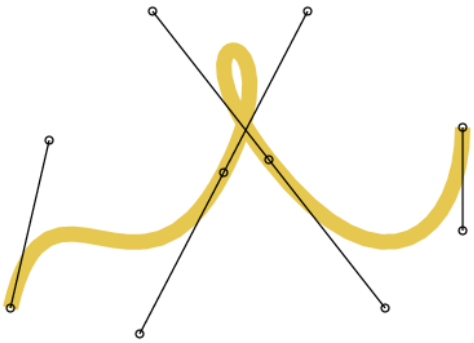
On return from this function, the end point of the final spline in the array is the new current point.

Example

This example uses the PolyBezier3 function to draw three connected cubic Bezier spline curves. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example08(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    SGPoint xy[] = {
        { 30, 250 }, { 60, 120 }, { 130, 270 }, { 195, 145 }, { 260, 20 },
        { 140, 20 }, { 230, 135 }, { 320, 250 }, { 380, 190 }, { 380, 110 }
    };
    SGPoint v0, v1, v2;
    int i;

    // Stroke three connected cubic Bezier splines in yellow
    aarend->SetColor(RGBX(230,200,80));
    sg->SetLineWidth(12.0);
    sg->BeginPath();
    sg->Move(xy[0].x, xy[0].y);
    sg->PolyBezier3(9, &xy[1]);
    sg->StrokePath();

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

The result is shown in the following screenshot.



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

Header

shapegen.h

See also

ShapeGen::Bezier3

ShapeGen::PolyEllipticSpline function

The PolyEllipticSpline function constructs one or more elliptic spline curves (π/2-radian elliptic arcs), 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 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 a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

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.

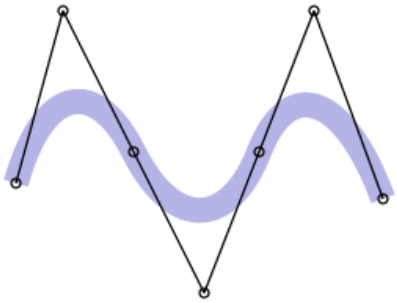
On return from this function, the end point of the final spline in the array is the new current point.

Example

This example uses the PolyEllipticSpline function to draw a series of connected elliptic spline curves. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example09(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    SGPoint xy[] = {
        { 40, 140 }, { 70, 30 }, { 115, 120 }, { 160, 210 },
        { 195, 120 }, { 230, 30 }, { 274, 150 }
    };
    SGPoint v0, v1, v2;

    // Stroke three connected elliptic splines in blue
    aarend->SetColor(RGBX(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 spline skeleton in black; mark knots & control points
    aarend->SetColor(RGBX(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)
    {
        v0 = v1 = v2 = xy[i];
        v1.x -= 3;
        v2.y -= 3;
        sg->Ellipse(v0, v1, v2);
    }
    sg->StrokePath();

    //-----  Label the output of this code example -----
    TextApp txt;
    COLOR crText = RGBX(40,70,110);
    char *str = "Output of code example from ShapeGen::"
                "PolyEllipticSpline reference topic";
    SGPoint xystart = { 24, 400 };
    float scale = 0.3;
    txt.SetTextSpacing(1.1);
    sg->SetLineWidth(3.0);
    aarend->SetColor(crText);
    txt.DisplayText(&(*sg), xystart, scale, str);
}
```

The result is shown in the following screenshot.



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

Header

`shapegen.h`

See also

`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 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 a value of false. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning false.

Remarks

The current point is the starting point for the first line segment. The first element in array xy 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.

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

Header

`shapegen.h`

See also

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

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 in the same manner as the ShapeGen::EndFigure function before starting a new figure in the same path. After adding the points in the rectangle to the new figure, the Rectangle function finalizes this figure 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:

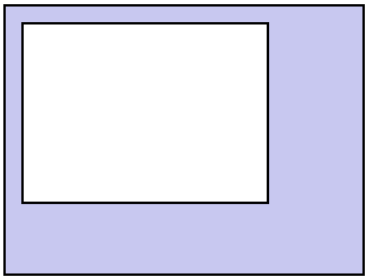
- rect.w > 0 and rect.h > 0
- rect.x is the rectangle's left edge, and rect.y is the top edge

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. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example10(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
```

```
{
    SGPtr sg(rend, clip);
    SGRect rect = { 100, 75, 300, 225 };

    sg->BeginPath();
    sg->Rectangle(rect);

    // Make the second rectangle smaller than the first
    rect.x += 15;
    rect.y += 15;
    rect.w -= 95;
    rect.h -= 75;

    // Modify the parameters so that construction
    // of the second rectangle proceeds in the
    // CCW direction
    rect.y += rect.h;
    rect.h = -rect.h;
    sg->Rectangle(rect);
    rend->SetColor(RGBX(200,200,240));
    sg->FillPath(FILLRULE_WINDING);  // <-- winding number fill rule
    sg->SetLineWidth(2.0);
    sg->SetLineJoin(LINEJOIN_MITER);
    rend->SetColor(RGBX(0,0,0));
    sg->StrokePath();
}
```

The result is shown in the following screenshot.



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. The device clipping rectangle is a required parameter for the ShapeGen constructor. The user can update device clipping rectangle by calling the `ShapeGen::InitClipRegion` function.

Header

`shapegen.h`

See also

`ShapeGen::InitClipRegion`

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`

The rectangle to add to the path.

`round`

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 replace the corners of the rectangle with circular arcs, set `round.x` = *r* and `round.y` = *r*, where *r* is 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 in the same manner as the `ShapeGen::EndFigure` function before starting a new figure in the same path. After adding the points in the rounded rectangle to the new figure, the `RoundedRectangle` function finalizes this figure in the same manner as the `ShapeGen::CloseFigure` function before 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 `Rectangle` function proceeds in a clockwise direction if we assume the following:

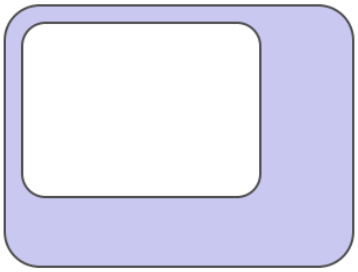
- `rect.w > 0 and rect.h > 0`
- `rect.x is the rectangle's left edge, and rect.y is the top edge`
- `round.x > 0 and round.y > 0`

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. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example11(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(rend, clip);
    SGRect rect = { 100, 75, 300, 225 };
    SGPoint round = { 30, 30 };

    // Construct outer rounded rectangle
    sg->BeginPath();
    sg->RoundedRectangle(rect, round);

    // Make the second rectangle smaller than the first
    rect.x += 15;
    rect.y += 15;
    rect.w -= 95;
    rect.h -= 75;
    round.x = round.y -= 10;

    // Modify the parameters so that construction
    // of the inner rounded rectangle proceeds
    // in the CCW direction
```

```
    rect.y += rect.h;
    rect.h = -rect.h;
    round.y = -round.y;
    sg->RoundedRectangle(rect, round);
    rend->SetColor(RGBX(200,200,240));
    sg->FillPath(FILLRULE_WINDING);  // <-- winding number fill rule

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

The result is shown in the following screenshot.



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 to indicate that 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 replaced by a call to `SaveClipRegion`, or swapped out 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` function causes any previously 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 the current clipping region lies entirely inside an area that is then masked off by a `SetMaskRegion` function call, the resulting clipping region is empty.

Header

`shapegen.h`

See also

`ShapeGen::SwapClipRegion`

`ShapeGen::ResetClipRegion`

`ShapeGen::SetClipRegion`

`ShapeGen::SetMaskRegion`

`ShapeGen::InitClipRegion`

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 that is then intersected with the current clipping region. Specify one of the following values for this parameter:

FILLRULE_EVENODD – Even-odd (aka 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 device clipping rectangle.

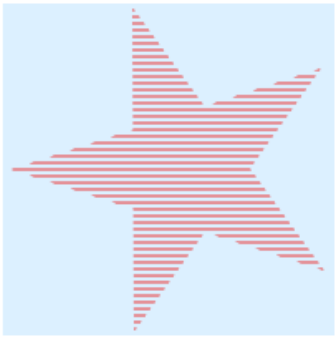
Example

This example uses the `SetClipRegion` function to set the clipping region to the interior of a star-shaped path. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example12(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(rend, clip);
    const float PI = 3.14159265;
    const float t = 0.8*PI;
    const float sint = sin(t);
    const float cost = cos(t);
    const int xc = 160, yc = 150;
    int xr = -105, yr = 0;
    SGRect rect = { 50, 50, 200, 200 };

    // Draw a square filled with a light blue color
    sg->BeginPath();
    sg->Rectangle(rect);
    rend->SetColor(RGBX(220,240,255));
    sg->FillPath(FILLRULE_EVENODD);

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

    // 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(238,50,50));
    sg->SetLineWidth(1.0);
    sg->BeginPath();
    for (int y = 50; y < 254; y += 4)
    {
        sg->Move(50, y);
        sg->Line(250, y);
    }
    sg->StrokePath();
}
```

The result is shown in the following screenshot.



The code example starts by filling a blue square that lies entirely within the current 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 lines (shown in red) are constructed 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 future calls to ShapeGen functions.

Syntax

C++

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

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.

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. If the macro NDEBUG (used by assert.h) is undefined, the function faults before returning -1.

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.

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. (A 16.16 fixed-point number is a 32-bit value in which the 16 LSBs are interpreted as a fraction.) ShapeGen uses 16.16 fixed-point numbers in its internal calculations.

Header

`shapegen.h`

See also

`SGCoord`

`SGPoint`

`SGRect`

ShapeGen::SetFlatness function

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

Syntax

C++

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

Parameters

`flatness`

The maximum curve-to-chord distance, measured in pixels. Set this parameter to a value in the range 1.0/16.0 to 16.0.

Return value

Returns the previous flatness setting.

Remarks

ShapeGen approximates curves and arcs with connected straight line segments, or 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, more accurate approximations to curves and arcs, but do so at the cost of shorter and more numerous chords.

The default flatness attribute value is 0.6 pixels.

If the caller specifies a `flatness` parameter value that is outside the range 1.0/16.0 to 16.0 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 lines and curves.

Syntax

C++

```
void ShapeGen::SetLineDash(
   char *dash,
   int offset,
   float mult
);
```

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`.

offset

The starting offset into the dash pattern. The effective offset, in pixels, is the product of the `offset` and `mult` parameters.

mult

The dash-length multiplier.

Return value

None

Remarks

For each figure constructed by the `ShapeGen::StrokePath` function, the function begins at the starting 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 15 elements, not counting the terminating zero. A `dash` array longer than this maximum is quietly truncated to 15 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.

Example

This example uses the `SetLineDash` function to construct stroked paths with four different line dash patterns. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example13(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
```

```
    const float PI = 3.14159265;
    SGPoint xy[] = {
        {  86, 192 }, {  86, 153 }, {  40, 192 }, { 140, 230 },
        { 140, 184 }, { 140, 153 }, {  71,  92 }, { 117,  32 }
    };
    float linewidth = 6.0;
    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 };

    aarend->SetColor(RGBX(205, 92, 92));
    sg->SetLineWidth(linewidth);
    for (int i = 0; i < 4; ++i)
    {
        sg->SetLineDash(pattern[i], 0, linewidth/2.0);
        sg->BeginPath();
        sg->EllipticArc(xy[0], xy[1], xy[2], 0, PI);
        sg->PolyEllipticSpline(4, &xy[3]);
        sg->Line(xy[7].x, xy[7].y);
        sg->StrokePath();
        for (int j = 0; j < 8; ++j)
            xy[j].x += 150;
    }
}
```

The result 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++

```
bool ShapeGen::SetLineEnd(
   LINEEND capstyle
);
```

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 values:

LINEEND_FLAT -- Flat line end (aka butt cap)

LINEEND_ROUND -- Rounded line end (aka round cap)

LINEEND_SQUARE -- Squared line end (aka projecting cap)

Return value

None

Remarks

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. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example14(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    LINEEND cap[] = { LINEEND_FLAT, LINEEND_ROUND, LINEEND_SQUARE };
    SGPoint vert[] = { { 70, 240 }, { 170, 95 }, { 220, 270 } };

    for (int i = 0; i < 3; ++i)
    {
        sg->BeginPath();
        sg->Move(vert[0].x, vert[0].y);
        sg->PolyLine(2, &vert[1]);
        sg->SetLineWidth(40.0);
        sg->SetLineEnd(cap[i]);
        aarend->SetColor(RGBX(200,200,240));
        sg->StrokePath();
        sg->SetLineWidth(1.7);
        aarend->SetColor(RGBX(0,0,0));
        sg->StrokePath();
        for (int j = 0; j < 3; ++j)
            vert[j].x += 230;
    }
}
```

The result 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`

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++

```
void ShapeGen::SetLineJoin(
   LINEJOIN joinstyle
);
```

Parameters

`joinstyle`

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

LINEJOIN_BEVEL -- Beveled joint

LINEJOIN_ROUND -- Rounded joint

LINEJOIN_MITER -- Mitered joint

Return value

None

Remarks

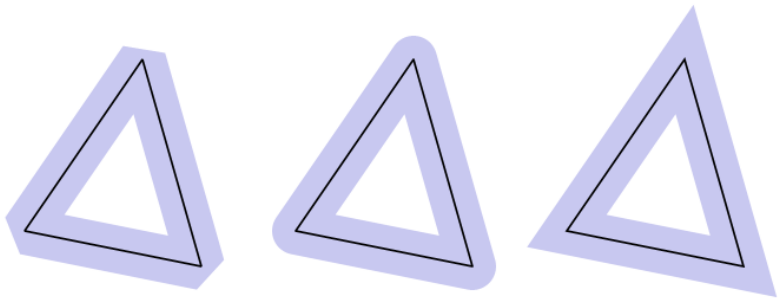
The default value for the line-join attribute is LINEJOIN_BEVEL.

Example

This example uses the `SetLineJoin` function to set different line-join attributes for three stroked paths. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example15(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    LINEJOIN join[] = { LINEJOIN_BEVEL, LINEJOIN_ROUND, LINEJOIN_MITER };
    SGPoint vert[] = { { 70, 240 }, { 170, 95 }, { 220, 270 } };

    for (int i = 0; i < 3; ++i)
    {
        sg->BeginPath();
        sg->Move(vert[0].x, vert[0].y);
        sg->PolyLine(2, &vert[1]);
        sg->SetLineWidth(40.0);
        sg->SetLineJoin(join[i]);
        sg->CloseFigure();
        aarend->SetColor(RGBX(200,200,240));
        sg->StrokePath();
        sg->SetLineWidth(1.7);
        aarend->SetColor(RGBX(0,0,0));
        sg->StrokePath();
        for (int j = 0; j < 3; ++j)
            vert[j].x += 230;
    }
}
```

The result 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`

ShapeGen::SetLineWidth function

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

Syntax

```
C++

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

Parameters

width

The width, in pixels, of a stroked path.

Return value

Returns the previous line-width setting.

Remarks

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

- Dashed-line pattern
- Line joint 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.

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 (i.e., no dashed-line pattern) with beveled joints and triangular line-end caps (although these features might be difficult to discern due to their small size).

The default line-width setting is 4.0 pixels.

Header

`shapegen.h`

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
);
```

Parameters

`fillrule`

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

FILLRULE_EVENODD – Even-odd (aka 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 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. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example16(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(rend, clip);
    const float PI = 3.14159265;
    const float t = 0.8*PI;
    const float sint = sin(t);
    const float cost = cos(t);
    const int xc = 160, yc = 150;
    int xr = -105, yr = 0;
    SGRect rect = { 50, 50, 200, 200 };

    // Draw a square filled with a light blue color
    sg->BeginPath();
    sg->Rectangle(rect);
```

```
    rend->SetColor(RGBX(220,240,255));
    sg->FillPath(FILLRULE_EVENODD);

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

    // Mask off 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->SetMaskRegion(FILLRULE_WINDING);

    // Draw a series of horizontal, red lines through the square
    aarend->SetColor(RGBX(234,50,50));
    sg->SetLineWidth(1.0);
    sg->BeginPath();
    for (int y = 50; y < 254; y += 4)
    {
        sg->Move(50, y);
        sg->Line(250, y);
    }
    sg->StrokePath();
}
```

The result is shown in the following screenshot.

The code example starts by filling a blue square that lies entirely within the current 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 lines (shown in red) are constructed through the blue square, but only the part of each line that 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 joint can reach before the point is automatically beveled off.

Syntax

C++

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

Parameters

`mlim`

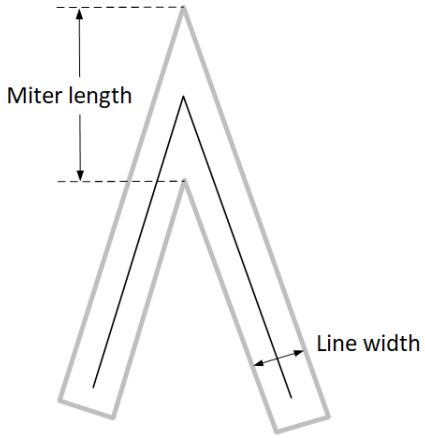
The new miter-limit setting. Set this parameter to a value in the range 1.0 to 100.0.

Return value

Returns the previous miter-limit setting.

Remarks

This function specifies the miter limit, which determines the maximum length of a mitered joint. 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

max_miter_length = `mlim` * line_width

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

The default miter-limit setting is 10.0.

A miter-limit setting of 1.0 specifies that miter joints at all angles are to be beveled.

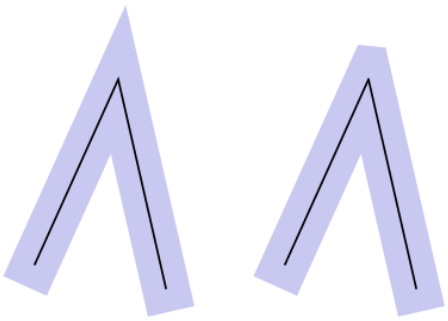
If the caller specifies an `mlim` parameter value that is outside the range 1.0 to 100.0, the function quietly clamps the value to this range.

Example

This example uses the `SetMiterLimit` function to set different miter limits for two mitered joints. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

```
void example17(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(aarend, clip);
    SGPoint vert[] = { { 100, 250 }, { 170, 95 }, { 210, 270 } };

    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(40.0);
        aarend->SetColor(RGBX(200, 200, 240));
        sg->StrokePath();
        sg->SetLineWidth(1.7);
        aarend->SetColor(RGBX(0,0,0));
        sg->StrokePath();
        sg->SetMiterLimit(1.4);
        for (int j = 0; j < 3; ++j)
            vert[j].x += 210;
    }
}
```

The result is shown in the following screenshot.



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

Header

`shapegen.h`

See also

ShapeGen::StrokePath

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++

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

Parameters

rend

A pointer to a Renderer object. This parameter must be nonnull. If the rend parameter is zero and the macro NDEBUG (used by assert.h) is undefined, the function faults.

Return value

None

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 a call to the ShapeGen::SaveClipRegion function is discarded.

Example

This example uses the SetRenderer function to switch from one renderer to another. (Variable sg is the ShapeGen object pointer, rend points to the basic renderer, and aarend points to the antialiasing renderer.)

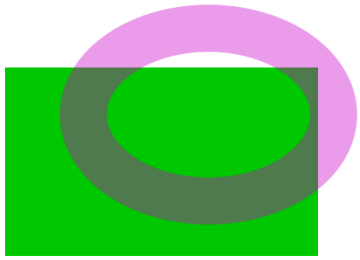
```
void example18(SimpleRenderer *rend, SimpleRenderer *aarend, const SGRect& clip)
{
    SGPtr sg(rend, clip);
    SGRect rect = { 100, 80, 400, 240 };
    SGPoint v0 = { 360, 140 }, v1 = { 360+160, 140 }, v2 = { 360, 140+110 };
```

```
    // Use the basic renderer to fill a green rectangle
    sg->BeginPath();
    sg->Rectangle(rect);
    rend->SetColor(RGBX(0,200,0));  // green (opaque)
    sg->FillPath(FILLRULE_EVENODD);

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

    // Alpha-blend a magenta, stroked ellipse with the rectangle
    sg->BeginPath();
    sg->Ellipse(v0, v1, v2);
    aarend->SetColor(RGBA(200,0,200,100));  // magenta + alpha
    sg->SetLineWidth(60.0);
    sg->StrokePath();
}
```

In this example, the basic renderer, `rend`, is passed as an input parameter to SGPtr constructor, which creates a ShapeGen object and installs `rend` as this object's initial renderer. Using this renderer, a rectangle is painted green. This rectangle is completely opaque, as are all shapes painted by the basic renderer.

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

The result is shown in the following screenshot.



This example uses the RGBA macro (defined in demo.h) to construct a 32-bit RGBA pixel value with an alpha channel value of 100.

Header

`shapegen.h`

ShapeGen::SetScrollPosition function

This function enables horizontal and vertical scrolling of a window (aka viewport) across ShapeGen's x-y coordinate space.

Syntax

C++

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

Parameters

x

The horizontal scrolling displacement, in pixels, from the origin of the ShapeGen user's x-y cooordinate space.

y

The vertical scrolling displacement, in pixels, from the origin of the ShapeGen user's x-y cooordinate space.

Return value

None

Remarks

If parameters x and y are both zero, the top-left corner of the target window coincides with the origin of the x-y coordinate space used by the ShapeGen path construction functions. Increasing the value of x causes the window to scroll to the right. Increasing the value of y causes the window to scroll downward.

If a ShapeGen user constructs a "virtual" image that is larger than the target window on the graphics display, vertical or horizonal scrolling can be used to select the part of the image that is visible in the window.

The device clipping rectangle defines the region of the ShapeGen user's x-y coordinate space that the viewer sees in the target window on the graphics display. For more information, see Device clipping window.

Header

`shapegen.h`

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 joint style	`Beveled joint`	`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 to indicate that 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 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.

Header

shapegen.h

See also

ShapeGen::SaveClipRegion

ShapeGen::ResetClipRegion

ShapeGen::SetClipRegion

ShapeGen::SetMaskRegion

ShapeGen::InitClipRegion