Extrusion Editor 1.0

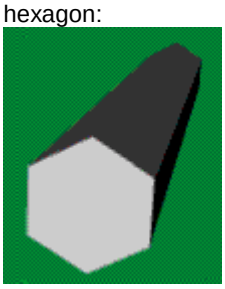
User's Guide

Contents

About Extrusion Editor

Extrusion Editor is a VRML97-compliant pluggable application for ParallelGraphics' VrmlPad and it provides the opportunity to create geometric shapes based on the Extrusion node in developing virtual worlds written in VRML.

An Extrusion node is something like a more general version of a cylinder. It consists of a 2D polygon, defined in the *crossSection* field, which is extruded along a three dimensional spine in the local coordinate system to define a surface in three dimensions. The following picture shows an extruded hexagon:



The Extrusion node in VRML provides a compact format for describing a wide variety of shapes.

Extrusion Editor Features

Extrusion Editor includes features that help you create extruded geometric shapes conveniently and quickly. Take a look at Extrusion Editor's capabilities:

Editing – Visual support for the creation of extrusions, a customizable plan view, and multiple undo/redo.

Texture – Advanced interactive texture mapping (Cortona VRML client must be installed).

Material – Built-in Material Editor that provides functions to create and edit materials.

Smoothing technique – The ability to create the cross-section and spine based on the smooth Bezier curves (spline curves for generating trajectory).

Shapes – Combines a set of extrusions into a single group.

Library – This contains the library of the already created extrusions. Adding the created extrusion to the library and inserting its code into VrmlPad.

Preview – All manipulations with extrusion parameters are dynamically displayed in the 3D window (Cortona VRML client must be installed).

Hardware and system requirements

- Operating system: Microsoft® Windows® 95/98/ME/2000 or Windows NT® 4.0, Internet Explorer 4.0 or a later version.
- Computer: Pentium® 90 MHz or better.
- Random Access Memory (RAM): minimum of 16 MB.
- Display: The 800x600, high color mode is recommended.
- Input devices: Mouse and keyboard.
- Free disk space: 0.5 MB of hard disk space for program files.
- ParallelGraphics' VrmlPad must be installed on your computer.

- To use texture mapping and previewing you will need to install Cortona 3.1 or a later version. You can find cortvrml.exe self-extracting installation program at http://www.parallelgraphics.com/products/cortona/download/

Installing and Starting Extrusion Editor

Extrusion Editor is delivered as a downloadable package or on CD-ROM. The Setup program provided with each package looks for the folder where the VrmlPad is installed and copies all necessary software components along with content Libraries to the AddIns folder.

To install *Extrusion Editor*:

1. Start Windows.
2. Run the setup program received from ParallelGraphics or simply double-click extegold.exe from the CD-ROM.
3. Follow Setup instructions.
4. To start the program, run your VrmlPad and choose "Extrusion Editor..." from the "Tools" menu. Please note that the texture mapping and previewing in the Perspective View are available only if Cortona VRML client is installed on your computer.

Getting assistance

You can get help without interrupting your work.

For a brief description of a menu command or a toolbar button:

- Position the pointer over the command or button – the description appears below the command or button

Technical support

We are interested in receiving your feedback about *Extrusion Editor*. For product support, you can send an e-mail to support@parallelgraphics.com. Before posting your message, please follow these simple instructions:

1. Check the online Help.
2. Include in your message any information that could help answer your question or solve the problem.
3. Document the system configuration: OS version, CPU type, memory, graphics card, monitor, etc.
4. When error messages occur, please document the complete message including sub dialog details and provide step-by-step instructions for recreating the problem.

Working with Extrusion Editor

This tool allows you to create impressive models from scratch and provides an efficient way to edit an existing extrusion (VRML code).

To start the program:

In the VrmlPad program, click **Extrusion Editor…** from the **Tools** menu or click the  *Extrusion Editor* toolbar button.

To edit an existing extrusion:

Open the VRML file that contains the extrusion you want to edit in the VrmlPad program.
Position the pointer over the *Extrusion* node or over its field, data or one of the curly braces.
Press the right mouse button and select the **Edit Extrusion…** command. The selected extrusion appears in the *Extrusion Editor.* You can also right-click the *Extrusion* node or its icon in the Scene Tree.

To insert the created shape into VrmlPad:

1. Select the Insert As and Placement options to specify the method to be used when you add a ready extrusion model to the file currently opened in VrmlPad.

   Insert As

   Insert As list box. This allows you to select whether the created shape will be inserted into VrmlPad as an *Extrusion* or *IndexedFaceSet* node. Please note that only the selected shape will be inserted if you select Extrusion or IndexedFaceSet for a group of shapes. You can also insert the *Extrusion* node within *Transform* or *Group* node. This allows you to insert the set of shapes listed at Shapes as a single model.
   Reuse identical nodes. This technique allows you to reuse, if possible, the identical objects (nodes) in the VRML file by giving the object a name the first time it is used (with DEF) and then refer to the object by name (with USE). Select this checkbox if you want to capitalize on the economy of modeling an object and consequently to reduce a VRML file.

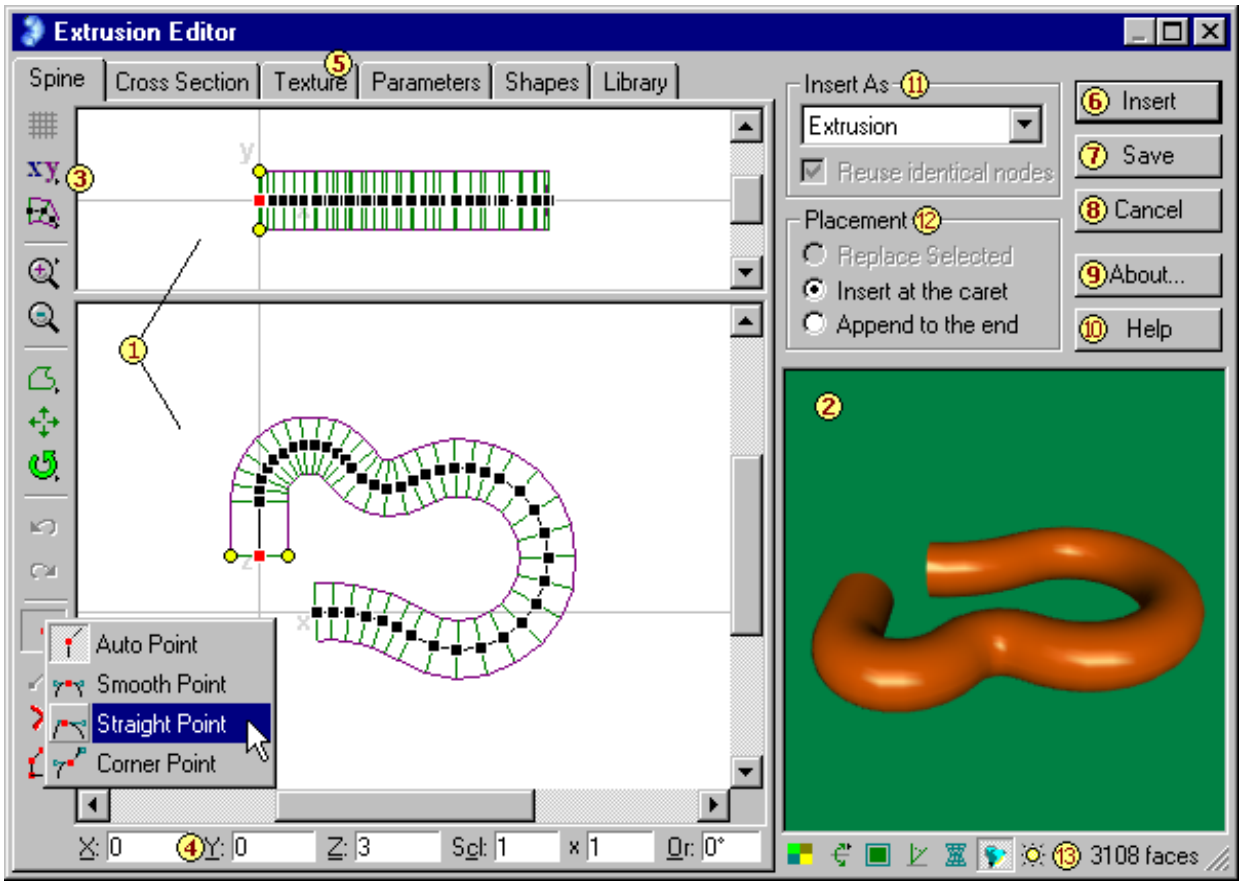
   Placement

   Replace Selected. Replaces the currently selected extrusion. This option is available only if you have opened an extrusion using the Edit Extrusion command from the right-button pop-up menu of VrmlPad.
   Insert at the caret. Inserts the code of the created extrusion at the caret's position of the VrmlPad window.
   Append to the end. Adds the code of your extrusion to the end of the VRML file.

2. To add an extrusion, click Insert. Please note that the extrusion may have several specific parameters originated from the Bezier spline smoothness technique that will be lost after inserting the extrusion into VrmlPad. Therefore it is recommended to save the created extrusion for further editing.

Screen Layout

When you start *Extrusion Editor* you see an arrangement of screen elements, which is described below.



① Plan window
By default, the front and bottom views of the spine 3D path is shown. You can change the view using the Top Plan Orientation button.

② Perspective View window
3D extrusion is viewed here. You may navigate the camera using the mouse or keyboard. ParallelGraphics Cortona VRML client should be used as a viewer in the Perspective View window.

③ Menu bar
This contains the function buttons. Some buttons may have the additional commands in the sub-menu.

These buttons are marked with the tiny triangle to the right, for example,  . To display the sub-menu, press and hold the corresponding function button. The selected button appears on the toolbar instead the default button. To activate the button, just click it.

④ Parameters bar
You can manually specify the vertex coordinates, cross-section scale and orientation by typing the corresponding values in the X, Y, Z, Scl, and Or boxes.

⑤ Switch bar
This allows you to enter the required mode: Spine, Cross Section and Texture. The Parameters tab allows you to specify extrusion attributes, crease angle, material and hints on how to generate vertices for the spline paths. The Library contains a ready made and saved by the user extrusions.

⑥ Isert button
Inserts the generated Shape node into VrmlPad.

⑦ **Save button**
Saves an extrusion in the Library.

⑧ **Quit button**
Quits Extrusion Editor.

⑨ **About button**
Displays Extrusion Editor copyright and version number.

⑩ **Help button**
Displays help topics for Extrusion Editor.

⑪ **Insert As list box**
This allows you to select whether the created shape will be inserted into VrmlPad as an *Extrusion* or *IndexedFaceSet* node. Please note that only selected shape will be inserted if you select Extrusion or IndexedFaceSet for a group of shapes. You can also insert the *Extrusion* node within *Transform* or *Group* node. This allows you to insert the set of shapes listed at Shapes as a single model.

⑫ **Placement**
Specifies the method to be used when you add a ready extrusion to the file currently opened in VrmlPad. To add an extrusion, click Insert.

> **Replace Selected.** Replaces the currently selected extrusion. This option is available only if you have opened an extrusion using the Edit Extrusion command from the right-button pop-up menu of VrmlPad.
> **Insert at the caret.** Inserts the code of the created extrusion at the caret's position of the VrmlPad window.
> **Append to the end.** Adds the code of your extrusion to the end of the VRML file.

⑬ **View toolbar**
Controls for headlight and directional light, wireframe mode, background color in the Perspective View window and navigation. There is also a *pop-up menu*, which you access by pressing the right mouse button while the pointer is over the Perspective View window.

Spine

Spine is the piecewise linear 3D path along which the cross-section is extruded and it is described as a series of vertices in the coordinate system. This section contains a description of the basic operations in the Spine editing mode.

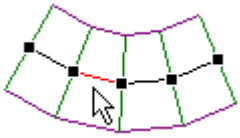
To create a new spine:

1. Make sure you are in the Spine mode (click the Spine tab to enter).
2.  In the Snap to Grid dialog box, specify the grid cell in Plan (in metres).
3.  In the New Line or Form group on the toolbar select one of the function buttons. This allows you to choose the drawing algorithm for the spine path (see “Spine and Cross Section toolbar buttons” for details).

To select the vertex:

- Make sure that none of the following buttons are active:  ,  or  and then click the vertex in the Plan window. It becomes red. To cancel the selection, click in a blank area of the window. You can move the selected vertex, scale and change the orientation of the cross-section in the Spine editing mode, and change the Point Style (the ability to control smoothness for a curve).

To select the segment:

-  Make sure that none of the following buttons are active:  ,  or  and then click the segment in the Plan window. It becomes red. To cancel the selection, click in a blank area of the window. You can change the segment style of the selected segment to transform from a straight line to a curve, or vice versa.

To move the vertex:

1. Position the pointer over the vertex, the pointer changes to  .
2. Drag the vertex to the desired location in Plan. Note: The ALT key if pressed when moving changes the snap-to-grid option to its opposite meaning.

To change the vertex parameters manually:

- Click the vertex in the Plan window to select it. The Parameters bar below the Plan is activated. This allows you to manually specify the vertex coordinates, cross-section scale and orientation by typing the corresponding values in the X, Y, Z, Scl, and Or (orientation of the cross-section curve along the spine, in degrees) boxes. The values you specify are considered as absolute values.

To add the vertex:

- Position the pointer anywhere in a vacant place of the Plan window or over the segment, CTRL-click.

To delete the vertex:

1. Select the vertex by clicking it, the selected vertex turns red.
2. Click the  button on the toolbar, or press the Delete key.

To change the segment style:

1. Click a segment to select it.
2.  Choose the Curved Segment or Straight Segment to transform it from a straight line to a curve, or vice versa.

To move the plan views:

1. Position the pointer anywhere in a vacant place of the Plan window and press the ALT key. The pointer looks like a hand  .
2. Move the mouse while holding the left mouse button to move the plan.

Note:

For a short description of all function buttons that can be used in the Spine mode, see “Spine and Cross Section toolbar buttons”.

Cross Section

Cross-section is a 2D piecewise linear curve described as a series of connected vertices that are extruded though space.

Click the Cross Section tab to enter. The functionality of the user’s interface in the Cross Section editing mode looks like the one for the Spine mode but some function buttons are not available in this mode.

Texture

To open texture in the Texture Mapper:

- Click the Browse button on the toolbar or type the path to resource file in the URL field and press ENTER. This applies the texture to the currently selected shape.

To remove the texture from the current shape:

- Click the Clear button.

To move a texture:

- Click the Move button and drag the texture in the Texture window in any direction. If you drag while the CTRL key is pressed, the texture movement is limited to the horizontal or vertical direction (this depends on the first mouse move).

To stretch or shrink a texture relative to the pivot point:

- Click Scale on the Texture toolbar, the pivot point appears in the window. Drag the texture to stretch or shrink it. To resize a texture proportionally from the center, hold down SHIFT while moving.
  Note: You can move the pivot point in the window by dragging.

To rotate a texture around the pivot point:

- Click Rotate on the Texture toolbar, the pivot point appears in the window. Drag the texture in the direction you want to rotate it. The minimal angular step equals 15 degrees. To achieve smooth rotation and scaling, SHIFT-drag the texture.

To stretch or shrink a texture:

- Click the Expand or Shrink button, respectively.

To flip the texture horizontally or vertically:

- Click the Flip Horizontal or Flip Vertical button, respectively.

To rotate the texture 90 degrees to the left or right:

- Click Rotate Right or Left.

To make a texture seem a little blurred:

- Click the Blur Texture button.

To brighten or darken a texture image:

- Click the More Brightness or Less Brightness button.

To return a texture to default state:

- Click Reset Default on the Texture toolbar – the texture reverts to its original state.

Note:
You can manually specify the translation, scale and rotation fields of the TextureTransform node by typing the corresponding values in the S, T, Scl, and Rot boxes on the bar below.

Parameters

Extrusion attributes

Begin cap – indicates whether or not to place a planar capping polygon at the starting point of the extrusion.
End cap – indicates whether or not to place a planar capping polygon at the other end of the extrusion.
Solid – indicates whether the back faces of the geometry (the inner surface of the extrusion) are invisible (checked) or visible (clear).
Convex – indicates whether all faces in the shape are convex. If your cross-section is not convex and you have Begin cap or End cap checked, clear the Convex checkbox (this sets *convex* to FALSE).
Normals follow the right hand rule – indicates whether the vertices of the cross-section are listed in counterclockwise order or not when viewed from above (from the +Y axis)

Crease angle

To achieve a smooth look for your model, you can tune the crease angle. If the angle between the geometric normals of two adjacent faces is less than or equal to the specified value for the crease angle parameter, the edge between the two adjacent faces is smooth-shaded. Otherwise, the appearance of rendered surface is calculated so that a lighting discontinuity across the edge is produced.

Material

You can preview the material on the sample sphere and define a custom color.

Bezier spline smoothness

Spine – specifies the number of edges (segments along a spline path). This indicates how many points in the *spine* field will be generated according to what's drawn in the Plan curve.
Cross section – specifies the number of points in the *crossSection* field that will be generated according to what's drawn in the Plan curve.

Floating point precision (FP Precision)

This specifies the number of digits after the decimal point to be inserted in the corresponding field of VRML file.

Shapes

The Shapes option lets you group extrusions so that they move together or separately. It combines a set of shapes (extrusions) into a single group. When you create a new model, you can treat this set of shapes as a single object in your scene. You can transform the group as a single object, and you can apply modifications as if it were a single object. When you create a new or open an existing extrusion, it appears automatically in the list at the Shapes tab.

To select an extrusion:

- Click the row that contains the extrusion. The  icon appears.
- Or in the Spine editing mode, right-click an extrusion and choose Select Shape from the pop-up menu.

To add an extrusion to the Shapes list:

- Select an extrusion in the Library and click the Add button. Note: You can also hold down SHIFT and double-click its thumbnail.

To display or hide a shape in the Perspective View and Spine windows:

- Select or clear the check mark at the  column.

To group or ungroup shapes with the selected shape:

- Select or clear the check mark at the  column. This icon marks all of shapes that are linked to the currently selected shape. You can move or scale a set of linked shapes by using the Move or Scale command in the Spine editing mode and manipulating with the selected shape.

Using the right-button pop-up menu

- Some useful commands in Shapes can be accessed by pressing the right mouse button while the pointer is over the row that contains the extrusion. This pop-up menu duplicates the command from the Shapes toolbar and enables the additional commands such as Copy and Paste the extrusion parameters and Clear Material and Texture. The Paste command sets the corresponding parameters for the shape which is currently selected by the right mouse click. This command is available only if you have copied parameters of the extrusion.

Toolbar buttons:

New. Creates a new "empty" shape for further editing.
Clone. Duplicates the selected extrusion.
Rename. Select the shape you want to rename, click Rename, type the new name, and then press ENTER. Note: You can also press F2 or click its name twice.
Save. Saves the selected extrusion in the Library.
Delete. Removes the selected extrusion from the Shapes list.
Undo. Reverses the last action.
Redo. Reverses the action of the Undo command.

Library

The Library window contains a ready made and saved by the user extrusions. To save the created extrusion in the Library, just click the Save button. Its name is generated automatically and the corresponding image as a thumbnail appears in the Library window. Please note that the extrusion may have several specific parameters originated from the Bezier spline smoothness technique that will be lost after inserting the extrusion into VrmlPad. Therefore it is recommended that you save the created extrusion for further editing.

Open To open an extrusion object in *Extrusion Editor* and display it in the installed VRML browser, select it by clicking its thumbnail and click Open. You can also open an object by double-clicking its thumbnail.

Add This adds the selected extrusion to the Shapes list.

Rename This enables you to changes the name of an extrusion in the library. Select the shape you want to rename, click Rename, type the new name, and then press ENTER. You can also press F2 or click its name twice.

Delete Deletes the selected extrusion from the library.

Overwrite Replaces the selected extrusion with the currently opened one in the *Extrusion Editor*.

Undo Reverses the last command in the Library mode.

Arrange Lines up thumbnails in the Library window automatically.

Spine and Cross Section toolbar buttons

 **Grid** – opens the Snap to Grid dialog box and sets the snap-to-grid option that you can use to easily align the vertices of a spine and cross-section. Select or clear the Snap to grid checkbox to activate or disable the snap-to-grid option. You can also specify the grid cell in Plan, in metres.

 **Top Pane Orientation** – allows you to select the planes in which the projection of the extrusion's spine will be shown at the top and down windows of Plan. The XY or YZ planes correspond accordingly to the top part of the Plan window. The VRML coordinate system is assumed.

Show details
This group of commands allows you to select a viewing mode in Plan:
 **Spine Only** – this displays only the spine path in Plan.
 **Base SCPs** – shows both the spine path and *spine-aligned cross-section plane* (SCP).
 **SCPs Bound** – this adds the bounding lines to the Base SCPs view.
 **Wireframe** – the extruded object appears to be outlined with wires in Plan.

 **Zoom In** – increases the view magnification in the Plan window. You can also use Gray Plus on the numeric keypad.
 **Zoom Out** – decreases the view magnification in the Plan window. You can also use Gray Minus on the numeric keypad.
 **Default Zoom** – returns the view of Plan to its original (default) size.
 **Fit to Window** – makes the object view fully visible in the Plan window. You can also use the HOME key.
 **Free Zoom** – expands the selected area of a plan to be fully visible. To select an area, hold the left mouse button anywhere in the Plan window, draw a corresponding rectangle and then release the button. The area is immediately magnified in both views. When this mode is active, the pointer changes to  .

New Line or Form
This group of commands enables a variety of drawing algorithms for the spine and cross-section path.
 **Freeform** – use this tool to draw series of connected vertices of a 3D spine or cross section one by one. Click where you want to set up the vertex in the Plan window, then move the pointer to another place and click again, and so on. When you decide to finish, double-click at the last vertex position, or right-click or press ESC. When this mode is active, the pointer changes to  .

 **Curve** – use this tool to draw the Bezier curve that is used to generate vertices of a 3D spine or cross section to be positioned closely to the drawn curve. To draw a Bezier curve, position the pointer on the Plan where you want the line to begin, click the primary mouse button, drag the pointer to where you want the next control point, and so on. A smooth line appears as you drag. When you decide to stop the curve, double-click at the last control point position, or right-click or press ESC.


Use these tools to draw a rectangle, diamond, octagon, triangle, oval, hexagon, or pentagon plane figure. Press the left mouse button where you want the shape to start, and then continue to move the mouse and release wherever you want to add a shape. To maintain the proportions of a drawing shape, hold down SHIFT while moving. To resize a shape from the point where you have pressed the mouse button outwards, hold down CTRL while moving. To resize a shape proportionally from the center outwards, hold down CTRL+SHIFT while moving.

Move or Scale
Use this tool to move or scale the spine in the Plan window. When you click this button, sizing handles appear at the corners and along the edges of the rectangle that surrounds the spine. You can resize an object by dragging its sizing handles. To achieve smooth scaling, ALT-drag a sizing handler. To move an object, position the pointer over the object, the pointer changes to , press the left mouse button, and then move the mouse and release wherever you want to place an object.
Note: You can manually specify the numerical values to move the spine or cross-section and resize the spine along the vertical or horizontal axes on the top plan. Choose the Spine or Cross Section editing mode, click the Move or Scale button, type the corresponding values in the X, Y, Z, or Scl (first value scales in horizontal axis) boxes, and then press ENTER. The values you specify are considered as relative values and measured in metres for moving.

Rotate or Flip
Contains buttons for rotating and flipping operations.
Free Rotate – use this tool to rotate the spine or cross section to any degree in the Plan window. When you click this button, the rotation handles (green dots) appear at the corners of the rectangle that surrounds the spine or cross section. You can rotate an object by dragging its rotation handles. The minimal angular step equals 15 degrees. To achieve a smooth rotation, ALT-drag a handler. If you hold the CTRL key, the object in Plan rotates about the opposite handler you drag. You can also move an object. Position the pointer over the object, the pointer changes to , press the left mouse button, and then move the mouse and release wherever you want to place an object.
Rotate Left – rotates the spine or cross section 90 degrees to the left in Plan.
Rotate Right – rotates the spine or cross section 90 degrees to the Right in Plan.
Flip Horizontal – flips an object horizontally (symmetrically about the vertical line in Plan).
Flip Vertical – flips an object vertically (symmetrically about horizontal line in Plan).
Add Reflection – mirrors the spine or cross section about the vertical or horizontal line in Plan (this depends of the pointer position relative to the object) and combines these two objects together. To add the reflected object, position the pointer on an empty place in Plan. If it is possible to create the mirrored object, the pointer changes to cross, press the left mouse button – the mirrored object appears in dashed. Move the pointer to position the mirrored object and release the mouse button to combine objects. This allows you to create symmetrical figures. To disable the Snap to grid option, hold ALT when moving.

Undo command – reverses the last editing operation.
Redo command – recreates the last undone operation.

Point Style
These tools give you the ability to control smoothness for a curve.
Auto Point – draws the Bezier curve automatically. This command is activated by default when you have created a curve in Plan and selected one of the control points.
Smooth Point – displays manipulators for the selected control point. You can change the direction vector (tangent) at that point by dragging the manipulator.
Straight Point – unlike the Smooth Point tool, this also allows you to change the value of the direction vector separately for both directions of a curve around the selected control point.
Corner Point – unlike the Straight Point tool, this also allows you to change the direction vector separately for both directions of a curve around the selected control point. Using this technique, you can create curves when the direction vector suddenly jumps from one direction to another at this point.

Segment Style – allows you to choose the Curved Segment or Straight Segment to transform from the straight line to a curve, or vice versa.

 **Delete** – deletes the selected vertex, control point, or segment if the cross-section or spine form the closed curve.

 **Close Curve** – connects the ends of a curve in the plan.

 **Open Curve** – removes any segment of a closed figure. If the segment is selected, this removes it.

Extrusion, algorithmic description

This section provides a detailed algorithmic description of the Extrusion node from The Virtual Reality Modeling Language Node reference (ISO/IEC 14772).

The Extrusion node specifies geometric shapes based on a two dimensional cross-section extruded along a three dimensional spine in the local coordinate system. The cross-section can be scaled and rotated at each spine point to produce a wide variety of shapes.
An Extrusion node is defined by:
a 2D *crossSection* piecewise linear curve (described as a series of connected vertices);
a 3D *spine* piecewise linear curve (also described as a series of connected vertices);
a list of 2D *scale* parameters;
a list of 3D *orientation* parameters.

Shapes are constructed as follows. The cross-section curve, which starts as a curve in the Y=0 plane, is first scaled about the origin by the first *scale* parameter (first value scales in X, second value scales in Z). It is then translated by the first spine point and oriented using the first *orientation* parameter (as explained later). The same procedure is followed to place a cross-section at the second spine point, using the second scale and orientation values. Corresponding vertices of the first and second cross-sections are then connected, forming a quadrilateral polygon between each pair of vertices. This same procedure is then repeated for the rest of the spine points, resulting in a surface extrusion along the spine.
The final orientation of each cross-section is computed by first orienting it relative to the spine segments on either side of point at which the cross-section is placed. This is known as the *spine-aligned cross-section plane* (SCP), and is designed to provide a smooth transition from one spine segment to the next (see Figure 6.6). The SCP is then rotated by the corresponding *orientation* value. This rotation is performed relative to the SCP. For example, to impart twist in the cross-section, a rotation about the Y-axis (0 1 0) would be used. Other orientations are valid and rotate the cross-section out of the SCP.

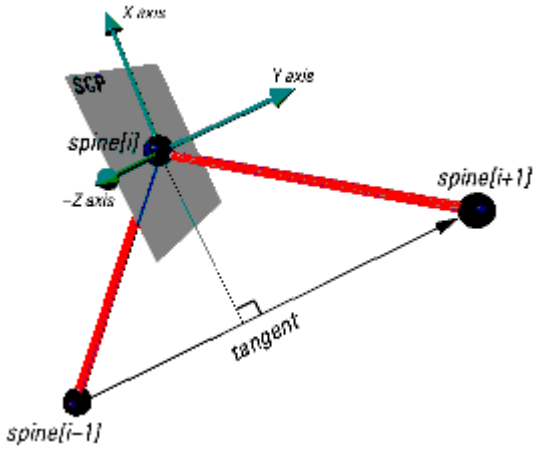


Figure 6.6 -- Spine-aligned cross-section plane at a spine point.

The SCP is computed by first computing its Y-axis and Z-axis, then taking the cross product of these to determine the X-axis. These three axes are then used to determine the rotation value needed to rotate the Y=0 plane to the SCP. This results in a plane that is the approximate tangent of the spine at each point, as shown in Figure 6.6. First the Y-axis is determined, as follows:
Let n be the number of spines and let i be the index variable satisfying 0 <= i < n:

a) *For all points other than the first or last:* The Y-axis for *spine*[i] is found by normalizing the vector defined by (*spine*[i] - *spine*[i -1]).
b) *If the spine curve is closed:* The SCP for the first and last points is the same and is found using (*spine*[1] - *spine*[n -2]) to compute the Y-axis.
c) *If the spine curve is not closed*: The Y-axis used for the first point is the vector from spine[0] to spine[1], and for the last it is the vector from spine[n -2] to spine[n -1].

The Z-axis is determined as follows:

d) *For all points other than the first or last:* Take the following cross-product:
Z = (spine[i+1] - spine[i]) x (spine[i-1] - spine[i])

e) *If the spine curve is closed:* The SCP for the first and last points is the same and is found by taking the following cross-product:
Z = (spine[1] - spine[0]) x (spine[n-2] - spine[0])
f) *If the spine curve is not closed:* The Z-axis used for the first spine point is the same as the Z-axis for spine[1]. The Z-axis used for the last spine point is the same as the Z-axis for spine[n-2].
g) After determining the Z-axis, its dot product with the Z-axis of the previous spine point is computed. If this value is negative, the Z-axis is flipped (multiplied by -1). In most cases, this prevents small changes in the spine segment angles from flipping the cross-section 180 degrees.

Once the Y- and Z-axes have been computed, the X-axis can be calculated as their cross-product.