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DESIGN REPORT
FOR THE
SCENE GRAPH EDITOR

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DESIGN OF HUMAN COMPUTER INTERFACE

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1. Abstract

The Scene Graph Editor is an application for viewing and editing 3D scenes created for the OpenSceneGraph software development toolkit. OpenSceneGraph is an open source 3D graphics toolkit designed for use with high performance, real-time 3D graphics applications. The Scene Graph Editor will provide a system for exploring and modifying the contents of a 3D scene through mouse based navigation and text based parameter display and entry systems. OpenSceneGraph will be employed by the Scene Graph Editor as a back-end module for 3D rendering. A set of front-end modules that define a user interface which provide access to the OpenSceneGraph functionality responsible for organizing and maintaining the elements of a 3D scene will serve as the main component of the Scene Graph Editor.

2. Functional Description

The Scene Graph Editor consists of a main application window containing one large canvas for 3D rendering. Capability to create additional picture-in-picture style viewports for the render surface by dragging the mouse or specifying dimensions through the keyboard are provided. Functionality for navigating the scene with the mouse and keyboard will also be available.

A group of list and text field widgets responsible for displaying parameters describing the contents of the 3D scene are contained within the main window, adjacent to the canvas. A tree style list widget is employed to represent the scene elements, complete with hierarchical structure, contained by the scene graph. Specialized icons and color coding are used to visually distinguish between different types of elements contained by the scene. Editable text fields provide a method for modifying the attributes of scene elements, and a color coding system is employed to identify scene elements that have been modified. A standard menu bar is also provided for basic application interaction.

3. Conceptual Design Model

The Scene Graph Editor provides a canvas and a set of tools for displaying and manipulating a 3D scene. The canvas displays a scene, which is specified by a file containing an existing scene graph, through one or more viewports. Viewports provide windows through which the scene is viewed. A camera controlled by the mouse and keyboard defines the point of view from which the scene is observed within a viewport. The tools provide access to the modifiable objects contained by the scene graph through a list to display the names and types of objects contained by the scene graph and a property sheet to display the attributes of the objects contained by the scene graph. Changes made to the scene graph with the tools are reflected by the scene depicted by the canvas.

3.1 Objects

The Scene Graph Editor is composed of the following objects:

- Canvas – Object to display/render one or more views of a scene.
- Viewport – Object defining the area for rendering a view of a scene.
- Camera – Object to define a view of a scene.
- Scene – A grouping of objects defining a 3D image, or scene.
- Scene Element – Graphical/state object that partially defines scene appearance.
- Element List – A hierarchical listing of objects contained by a scene.
- Property Sheet – A listing of properties and attributes for a scene object.

3.2 Role of Each Object

The objects composing the Scene Graph Editor have the following roles:

- Canvas – The canvas controls scene rendering and interaction. Canvas attributes affect the quality and performance of scene rendering. The canvas also controls the order with which each viewport is processed. Mouse and keyboard input, for camera manipulation, is received by the canvas and used to transform the view of the scene displayed by the viewport with the current focus.
- Viewport – The viewport defines an area within the canvas to be used for rendering a single view of a scene. Rendering of the scene view is constrained to the boundaries specified by the dimensions of the viewport.

- Camera – The camera defines the view of a scene. The position and orientation of the camera define the portion of the scene that is visible within a viewport.
- Scene – The scene contains a set of objects that define the 3D image to be rendered. The scene organizes objects as a tree-like structure, or graph, providing a hierarchical arrangement of the objects defining the scene.
- Scene Element – The scene element is a node contained by the scene graph which affects the appearance of the scene. Six distinct categories of scene element exist, with each type providing a different effect to scene appearance. The specific roles associated with the six scene object categories are:
 - Group Node – A basic node object with one or more children.
 - Switch Node – A specialized group node with multiple children, where only a single child is active at one time.
 - Transform Node – A specialized group node specifying a transformation to be applied to all child nodes.
 - Geode – A leaf node containing geometry objects.
 - State Set – An object specifying state attributes to be applied to geometry objects.
 - Geometry Object – A collection of vertices defining a 3D geometric object.
- Element List – The element list is a tree list widget that represents the scene graph as a collapsible tree structure. The names of each scene element are displayed by the list and the type of scene element is identified by a small icon appearing before the name.
- Property Sheet – The property sheet is a container widget that contains a set of editable text fields which display the values of the attributes for a scene element.

3.3 Object Attributes for each object

Each object contains the following attributes:

- Canvas Object Attributes

- Graphics Context – Information describing the 3D rendering capability of the canvas, which typically depends on the capability of the rendering hardware.
- Viewport Object Attributes
 - Position – The 2D coordinate specifying the position of the upper left hand corner of the viewport.
 - Size – The width and height of the viewport.
- Camera Object Attributes
 - Position – The 3D coordinate specifying the location of the camera within the scene.
 - Direction Vector – The 3D vector specifying the direction that the camera is pointing.
 - Up Vector – The 3D vector specifying the direction that the top of the camera is pointing.
- Scene Object Attributes
 - Background Color – The background color for the scene.
 - Ambient Light Color – The color of the ambient light for the scene.
- Scene Element Object Attributes
 - Attributes common to all six types of Scene Element:
 - Name – A unique string identifying the scene element.
 - Attributes of the Switch Node:
 - Active Node – The child node that is currently active.
 - Attributes of the Transform Node:
 - Translation – The translation transformation to apply to all children.
 - Rotation – The rotation transformation to apply to all children.
 - Scale – The scale transformation to apply to all children.
 - Attributes of the State Set:
 - Draw Style – The draw style for the geometry associated with the state set. Available draw styles are point, wireframe, and solid.

- Material Properties – The color of the geometry associated with the state set.
 - Texture Properties – The texture mapping settings for the geometry associated with the state set.
 - Light Emission Properties – The emissive properties for light emitting geometry associated with the state set.
 - Attributes of the Geometry Object:
 - Vertex Positions – The positions of the 3D vertices defining the geometry.
- Element List Object Attributes:
 - List Entries – Entries in the tree list that represent the scene elements contained by a scene graph.
- Property Sheet Attributes:
 - Text Fields – Text fields in the property sheet which display the attributes of a scene element.

3.4 Object Relationships

The objects composing the Scene Graph Editor have the following relationships:

- A canvas contains one or more viewport.
- A viewport contains exactly one camera.
- A camera exists within a scene.
- A scene contains one or more scene elements with exactly one scene element acting as the root of the scene graph.
- A scene element contains exactly one parent.
- A group node contains zero or more scene element children.
- A switch node contains zero or more scene element children.
- A transform node contains zero or more scene element children.
- A geode contains zero or more geometry objects.
- A state set attaches to exactly one scene element and modifies the geometric objects located at the end of the branches extending from the scene element.
- The element list contains a visual depiction of the scene graph hierarchy.

- The property sheet contains the values of the attributes for a scene element.

3.5 Actions on Objects

The following actions act upon the objects composing the Scene Graph Editor:

- Canvas Object Actions:
 - Render – Render a single frame.
- Viewport Object Actions:
 - Create – Create a viewport.
 - Delete – Delete a viewport.
 - Move – Move a viewport.
 - Resize – Resize a viewport.
 - Make Current – Make the viewport “current” for user interaction (camera manipulation).
- Camera Object Actions:
 - Move – Move the camera.
 - Orient – Orient the camera.
- Scene Object Actions:
 - Load – Load a scene from a file.
 - Save – Save a scene to a file.
- Scene Element Object Actions:
 - Delete – Delete a scene element.
 - Move – Change the parent of the scene element.
- Element List Object Actions:
 - Populate – Populate the tree list with scene elements.
 - Collapse – Collapse a branch of the tree list.
 - Expand – Expand a branch of the tree list.
- Property Sheet Object Actions:
 - Populate – Populate the property sheet with values of scene element attributes.

3.6 Actions on Object Attributes

The following actions act upon the attributes of the objects composing the Scene Graph Editor:

- Canvas Object Attribute Actions:
 - Configure – Specify graphics context settings at canvas creation.
- Viewport Object Attribute Actions:
 - Change Position – Set the viewport position.
 - Change Size – Set the viewport size.
- Camera Object Attribute Actions:
 - Change Position – Set the camera position.
 - Change Direction Vector – Set the camera direction vector.
 - Change Up Vector – Set the camera up vector.
- Scene Object Attribute Actions:
 - Change Background Color – Set the background color for the scene.
 - Change Ambient Light Color – Set the color of the ambient light for the scene.
- Scene Element Object Attribute Actions:
 - Attribute actions common to all six types of Scene Element:
 - Change Name – Set the unique string that identifies the scene element.
 - Attribute Actions for the Switch Node:
 - Select Active Node – Set the child node that is currently active.
 - Attribute Actions for the Transform Node:
 - Change Translation – Set the translation transformation value.
 - Change Rotation – Set the rotation transformation value.
 - Change Scale – Set the scale transformation value.
 - Attribute Actions for the State Set:
 - Change Draw Style – Set the draw style for the geometry associated with the state set.
 - Change Material Properties – Set the color of the geometry associated with the state set.

- Change Texture Properties – Set the texture mapping settings for the geometry associated with the state set.
 - Change Light Emission Properties – Set the emissive properties for light emitting geometry associated with the state set.
 - Attribute Actions for the Geometry Object:
 - Change Vertex Position – Set the position of a 3D vertex defining the geometry.
- Element List Object Attributes:
 - Select List Item – Click a list item with the mouse to make it the currently selected item, and cause the values of its attributes to be displayed by the property sheet.
 - Drag and Drop for List Item – Drag and drop a list item to change the parent of an item to the item on which it is dropped.
- Property Sheet Attributes:
 - Change Text Field Data – Set the value of a state element attribute displayed by the property sheet.

3.7 Actions on Object Relationships

The following actions act upon the relationships of the objects composing the Scene Graph Editor:

- Remove a viewport from a canvas.
- Add a viewport to a canvas.
- Find/retrieve a scene element contained by the scene.
- Remove a scene element from a scene.
- Change the parent of a scene element.
- Add a scene element to a group node for reparenting.
- Remove a scene element from a group node for deletion or reparenting.
- Add a scene element to a switch node for reparenting.
- Remove a scene element from a switch node for deletion or reparenting.
- Add a scene element to a transform node for reparenting.
- Remove a scene element from a transform node for deletion or reparenting.

- Remove a geometry object from a geode.
- Change the source of the scene element attribute values displayed by the property sheet to a different scene element.

4. Semantic Design

4.1 Semantic Design for Actions on Objects

4.1.1 Semantic specification for actions on Canvas Object:

- **Command:** Render
- **Information Required:** Scene
- **Description:** Render the 3D scene by traversing the scene graph, visiting each scene element, and drawing the geometry represented by the scene element to the canvas.
- **Side Effects:** The previous image displayed by the canvas is replaced when the new frame is rendered.
- **Feedback:** The user is presented with an image depicting the 3D scene contained by the Scene Object.

4.1.2 Semantic Specification for actions on Viewport Object:

- **Command:** Create
- **Information Required:** Viewport position, Viewport size
- **Description:** Create a viewport on the canvas to render a single view of the scene.
- **Side Effects:** The new viewport will obstruct portions of other viewports if it is positioned and sized such that it overlaps with any existing viewports.
- **Feedback:** The user is presented with a new viewport portraying a view of the scene.
- **Errors:**
 1. The position and size of the viewport may be specified such that a portion of the viewport is located outside of the canvas area.
 - **Solution 1:** User must specify position and size of viewport by drawing the viewport with the mouse which restricts valid draw area to the canvas.
- **Command:** Delete
- **Information Required:** Viewport identifier
- **Description:** Delete the existing viewport associated with the target identifier, removing it from the canvas.
- **Side Effects:** The target viewport will no longer exist.
- **Feedback:** The viewport will no longer be visible to the user.
- **Errors:**
 1. An identifier for a non-existing viewport is specified.
 - **Solution 1:** User must select the target viewport from a list of existing viewports; manual entry of the target viewport identifier is prohibited.
- **Command:** Move
- **Information Required:** Viewport identifier, Viewport position
- **Description:** Moves the viewport associated with the target identifier to the newly specified position.
- **Side Effects:** The old position is replaced with the new position.
- **Feedback:** The user is presented with the viewport drawn at the new location.
- **Errors:**

1. An identifier for a non-existing viewport is specified.
 - **Solution 1:** User must select the target viewport with the mouse.
 - **Solution 2:** User must select the target viewport from a list of existing viewports; manual entry of the target viewport identifier is prohibited.
 2. The position of the viewport may be specified such that a portion of the viewport is located outside of the canvas area.
 - **Solution 1:** User must specify the position of the viewport by dragging the viewport with the mouse which restricts valid draw area to the canvas.
 - **Solution 2:** The user is presented with an error message when specifying a position that is outside of the canvas area.
- **Command:** Resize
 - **Information Required:** Viewport identifier, Viewport size
 - **Description:** Resizes the viewport associated with the target identifier to the newly specified size.
 - **Side Effects:** The old size is replaced with the new size.
 - **Feedback:** The user is presented with the viewport drawn with the new size.
 - **Errors:**
 1. An identifier for a non-existing viewport is specified.
 - **Solution 1:** User must select the target viewport with the mouse.
 - **Solution 2:** User must select the target viewport from a list of existing viewports; manual entry of the target viewport identifier is prohibited.
 2. The size of the viewport may be specified such that a portion of the viewport is located outside of the canvas area.
 - **Solution 1:** User must specify the size of the viewport by dragging the viewport corners with the mouse which restricts valid draw area to the canvas.
 - **Solution 2:** The user is presented with an error message when specifying a size that is outside of the canvas area.
- **Command:** Make Current
 - **Information Required:** Viewport identifier
 - **Description:** Give focus to the viewport associated with the target identifier. The viewport with current focus is the only viewport to receive mouse input.
 - **Side Effects:** The previous viewport with focus will lose focus.
 - **Feedback:** The viewport with current focus is outlined by a thick border that distinguishes it from other viewports.
 - **Errors:**
 1. An identifier for a non-existing viewport is specified.
 - **Solution 1:** User must select the target viewport with the mouse.
 - **Solution 2:** User must select the target viewport from a list of existing viewports; manual entry of the target viewport identifier is prohibited.

4.1.3 Semantic Specification for actions on Camera Object:

- **Command:** Move
- **Information Required:** Camera position

- **Description:** Move the camera to a new position within the scene. Camera position is changed with the arrow keys and the mouse.
- **Side Effects:** The previous position is replaced, changing the view of the scene presented to the user.
- **Feedback:** The user is presented with a new view of the scene.

- **Command:** Orient
- **Information Required:** Camera orientation
- **Description:** Change the camera orientation to a new orientation within the scene. Camera orientation is changed with the mouse.
- **Side Effects:** The previous orientation is replaced, changing the view of the scene presented to the user.
- **Feedback:** The user is presented with a new view of the scene.

4.1.4 Semantic Specification for actions on Scene Object:

- **Command:** Load
- **Information Required:** Scene file name
- **Description:** Load the contents of a scene from the specified file to the hierarchical arrangement of the objects composing the scene.
- **Side Effects:** Previously existing scene data is replaced.
- **Feedback:** The user is presented with the loaded scene drawn on the canvas.
- **Errors:**
 1. An error occurs when opening the file because the file does not exist or the user does not have read permission.
 - **Solution 1:** The user may only select files from a list of existing files with read permission.
 - **Solution 2:** The user is presented with an error message indicating that the file can not be opened.
 2. An error occurs while reading the file.
 - **Solution 1:** The user is presented with an error message indicating that an error occurred while reading the file because the file may be corrupt.

- **Command:** Save
- **Information Required:** Scene filename
- **Description:** The content of the scene is written to the specified file.
- **Side Effects:** If the specified file already exists it will be overwritten.
- **Feedback:** The user is presented with a visual indication the file write has completed successfully.
- **Errors:**
 1. An error occurs when writing the file because the user does not have permission to write to the specified directory.
 - **Solution 1:** The user may only select directories for writing from a list of existing directories with write permission.
 - **Solution 2:** The user is presented with an error message indicating that the file can not be saved.

2. An error occurs while writing the file.
 - **Solution 1:** The user is presented with an error message indicating that an error occurred while writing the file.
3. An existing file is overwritten.
 - **Solution 1:** The user is asked if it is acceptable to overwrite the existing file before it is overwritten.

4.1.5 Semantic Specification for actions on Scene Element Object:

- **Command:** Delete
- **Information Required:** Scene Element identifier
- **Description:** Delete the scene element with the target identifier, removing it from the scene.
- **Side Effects:** The specified scene element will no longer exist.
- **Feedback:** The deleted element is no longer visible to the user.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.
- **Command:** Move
- **Information Required:** Scene Element identifier, Scene Element parent identifier
- **Description:** Move the scene element with the target identifier to a new location within the scene hierarchy. The scene element is moved by changing scene element's parent node.
- **Side Effects:** The scene element and all of its children are moved to a new position in the hierarchy.
- **Feedback:** The scene with altered appearance is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element or scene element parent is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.

4.1.6 Semantic Specification for actions on Element List Object:

- **Command:** Populate
- **Information Required:** Scene
- **Description:** Populate the element tree list with the names of the scene elements contained by the scene. The hierarchical arrangement of the scene mirrored by the hierarchical arrangement of the tree list.
- **Side Effects:** Previously existing content of the element list is replaced with the new scene element data.

- **Feedback:** The user is presented with a hierarchical listing of scene element names.
- **Command:** Collapse
- **Information Required:** Element List item identifier
- **Description:** An element list item with child items is collapsed so that the children are no longer visible.
- **Side Effects:** None.
- **Feedback:** The children of the collapsed element list item are no longer visible to the user.
- **Errors:**
 1. An identifier for a non-existing element list item is specified.
 - **Solution 1:** User must select the target element list item with the mouse; manual entry of the target element list identifier is prohibited.
 2. An identifier for a collapsed element list item is specified.
 - **Solution 1:** Collapsing and expanding of element list items are associated such that only expanded items are collapsed and only collapsed items are expanded.
- **Command:** Expand
- **Information Required:** Element List item identifier
- **Description:** An element list item with child items is expanded so that the children are visible.
- **Feedback:** The children of the expanded element list item are visible to the user.
- **Errors:**
 1. An identifier for a non-existing element list item is specified.
 - **Solution 1:** User must select the target element list item with the mouse; manual entry of the target element list identifier is prohibited.
 2. An identifier for a collapsed element list item is specified.
 - **Solution 1:** Collapsing and expanding of element list items are associated such that only expanded items are collapsed and only collapsed items are expanded.

4.1.7 Semantic Specification for actions on Property Sheet Object:

- **Command:** Populate
- **Information Required:** Scene element identifier
- **Description:** The property sheet is filled with the attribute values obtained from the scene element associated with the target identifier.
- **Side Effects:** Previously existing content of the property sheet is replaced with the new data.
- **Feedback:** The values for the attributes of the target scene element are visible to the user.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.

- **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.

4.2 Semantic Design for Actions on Attributes

4.2.1 Semantic Specification for actions on Canvas Object Attributes:

- **Command:** Configure
- **Information Required:** Canvas identifier, Canvas graphics context
- **Description:** Initialize the canvas to prepare for rendering.
- **Side Effects:** None.
- **Feedback:** Successful initialization of the canvas is not directly reported to the user; only failure is reported. The user will know that the canvas was successfully initialized if the scene is rendered correctly.
- **Errors:**
 1. Initialization fails because the canvas identifier is invalid or a valid graphics context could not be created because of hardware limitations.
 - **Solution 1:** The user is presented with an error message indicating that the canvas could not be initialized.

4.2.2 Semantic Specification for actions on Viewport Object Attributes:

- **Command:** Change Position
 - **Information Required:** Viewport identifier, Viewport position
 - **Description:** Changes the value of the position attribute from the viewport associated with the target identifier to the newly specified position value.
 - **Side Effects:** The old position value is replaced with the new position value.
 - **Feedback:** The user is presented with the viewport drawn at the new location.
 - **Errors:**
 1. An identifier for a non-existing viewport is specified.
 - **Solution 1:** User must select the target viewport with the mouse.
 - **Solution 2:** User must select the target viewport from a list of existing viewports; manual entry of the target viewport identifier is prohibited.
 2. The position of the viewport may be specified such that a portion of the viewport is located outside of the canvas area.
 - **Solution 1:** User must specify the position of the viewport by dragging the viewport with the mouse which restricts valid draw area to the canvas.
 - **Solution 2:** The user is presented with an error message when specifying a position that is outside of the canvas area.
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- **Command:** Change Size
 - **Information Required:** Viewport identifier, Viewport size
 - **Description:** Changes the value of the size attribute from the viewport associated with the target identifier to the newly specified size value.
 - **Side Effects:** The old size value is replaced with the new size value.
 - **Feedback:** The user is presented with the viewport drawn with the new size.
 - **Errors:**

1. An identifier for a non-existing viewport is specified.
 - **Solution 1:** User must select the target viewport with the mouse.
 - **Solution 2:** User must select the target viewport from a list of existing viewports; manual entry of the target viewport identifier is prohibited.
2. The size of the viewport may be specified such that a portion of the viewport is located outside of the canvas area.
 - **Solution 1:** User must specify the size of the viewport by dragging the viewport corners with the mouse which restricts valid draw area to the canvas.
 - **Solution 2:** The user is presented with an error message when specifying a size that is outside of the canvas area.

4.2.3 Semantic Specification for actions on Camera Object Attributes:

- **Command:** Change Position
- **Information Required:** Camera position
- **Description:** Change the value of the camera position attribute to the newly specified position value.
- **Side Effects:** The old position value is replaced with the new position value.
- **Feedback:** The user is presented with a new view of the scene.

- **Command:** Change Direction Vector
- **Information Required:** Camera direction vector
- **Description:** Change the value of the camera direction vector attribute to the newly specified direction vector value.
- **Side Effects:** The old direction vector value is replaced with the new direction vector value.
- **Feedback:** The user is presented with a new view of the scene.

- **Command:** Change Up Vector
- **Information Required:** Camera up vector
- **Description:** Change the value of the camera up vector attribute to the newly specified up vector value.
- **Side Effects:** The old up vector value is replaced with the new up vector value.
- **Feedback:** The user is presented with a new view of the scene.

4.2.4 Semantic Specification for actions on Scene Object Attributes:

- **Command:** Change Background Color
- **Information Required:** Color
- **Description:** Change the value of the background color attribute to the newly specified color value.
- **Side Effects:** The old background color value is replaced with the new background color value.
- **Feedback:** The background of the scene rendered to the canvas is now drawn with the new color.
- **Errors:**

1. An out of range color value is specified.
 - **Solution 1:** User must select the color with a slider widget that only allows valid color values to be specified.
 - **Solution 2:** The color value is clamped to the valid minimum/maximum value.
- **Command:** Change Ambient Light Color
- **Information Required:** Color
- **Description:** Change the value of the ambient light color attribute to the newly specified color value.
- **Side Effects:** The old ambient light color value is replaced with the new ambient light color value.
- **Feedback:** The scene is rendered with the new ambient light color.
- **Errors:**
 1. An out of range color value is specified.
 - **Solution 1:** User must select the color with a slider widget that only allows valid color values to be specified.
 - **Solution 2:** The color value is clamped to the valid minimum/maximum value.

4.2.5 Semantic Specification for actions on Scene Element Object Attributes:

- **Command:** Change Name (All Scene Element subtypes)
- **Information Required:** Scene Element identifier, Scene Element name
- **Description:** Change the value of the name attribute for the scene element associated with the target identifier to the new scene element name.
- **Side Effects:** The old name value is replaced with the new name value.
- **Feedback:** The new name is presented to the user through the element list.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.
- **Command:** Select Active Node (Switch Node subtype)
- **Information Required:** Scene Element identifier, Active child node identifier
- **Description:** Change the value of the active child node attribute to the new active child node.
- **Side Effects:** The old active child node value is replaced with the new active child node value.
- **Feedback:** The altered scene generated when visiting the new active child node during the rendering process is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element or active child node is specified.

- **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.
- **Command:** Change Translation (Transform Node subtype)
- **Information Required:** Scene Element identifier, Translation matrix
- **Description:** Change the value of the translation matrix attribute to the new translation matrix value.
- **Side Effects:** The old translation matrix value is replaced with the new translation matrix value.
- **Feedback:** The altered scene generated by the new translation is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.
- **Command:** Change Rotation (Transform Node subtype)
- **Information Required:** Scene Element identifier, Rotation matrix
- **Description:** Change the value of the rotation matrix attribute to the new transformation matrix value.
- **Side Effects:** The old rotation matrix value is replaced with the new rotation matrix value.
- **Feedback:** The altered scene generated with the new rotation matrix is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.
- **Command:** Change Scale (Transform Node subtype)
- **Information Required:** Scene Element identifier, Scale matrix
- **Description:** Change the value of the scale matrix attribute to the new scale matrix value.
- **Side Effects:** The old scale matrix value is replaced with the new scale matrix value.
- **Feedback:** The altered scene generated with the new scale matrix is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.

- **Command:** Change Draw Style (State Set subtype)
 - **Information Required:** Scene Element identifier, Draw style
 - **Description:** Change the value of the draw style attribute to the new draw style value.
 - **Side Effects:** The old draw style value is replaced with the new draw style value.
 - **Feedback:** The altered scene generated with the new draw style is presented to the user.
 - **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.
 2. An invalid draw style is specified.
 - **Solution 1:** User must select the draw style from a list of valid draw styles.
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- **Command:** Change Material Properties (State Set subtype)
 - **Information Required:** Scene Element identifier, Material property
 - **Description:** Change the value of the material property attribute to the new material property value.
 - **Side Effects:** The old material property value is replaced with the new material property value.
 - **Feedback:** The altered scene generated with the new material property is presented to the user.
 - **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.
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- **Command:** Change Texture Properties (State Set subtype)
 - **Information Required:** Scene Element identifier, Texture property
 - **Description:** Change the value of the texture property attribute to the new texture property value.
 - **Side Effects:** The old texture property value is replaced with the new texture property value.
 - **Feedback:** The altered scene generated with the new texture property is presented to the user.
 - **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.

- **Command:** Change Light Emission Properties (State Set subtype)
- **Information Required:** Scene Element identifier, Light color
- **Description:** Change the value of the light color attribute to the new light color value.
- **Side Effects:** The old light color value is replaced with the new light color value.
- **Feedback:** The altered scene generated with the new light color is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.
 2. An out of range color value is specified.
 - **Solution 1:** User must select the color with a slider widget that only allows valid color values to be specified.
 - **Solution 2:** The color value is clamped to the valid minimum/maximum value.

- **Command:** Change Vertex Position (Geometry Object subtype)
- **Information Required:** Scene Element identifier, Vertex position
- **Description:** Change the value of the vertex position attribute to the new vertex position value.
- **Side Effects:** The old vertex position value is replaced with the new vertex position value.
- **Feedback:** The altered scene generated with the new vertex position is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.

4.2.6 Semantic Specification for actions on Element List Object Attributes:

- **Command:** Select List Item
- **Information Required:** List Item identifier
- **Description:** Select an item in the element list.
- **Side Effects:** The previously selected item is no longer selected.
- **Feedback:** The selected item is visibly highlighted.
- **Errors:**
 1. An identifier for a non-existing list item is specified.
 - **Solution 1:** User must select the target list item from a list of existing list items; manual entry of the target list item identifier is prohibited.
- **Command:** Drag and Drop List Item
- **Information Required:** List Item identifier, Parent List Item identifier

- **Description:** A list item is selected with the mouse, dragged over a different list item, and dropped on the list item. The parent of the dragged and dropped list item is changed to the list item on which it was dropped.
- **Side Effects:** The parent of the dragged and dropped list item is changed to the new parent list item on which it was dropped.
- **Feedback:** The list item visually appears as a child of the new parent.
- **Errors:**
 1. An identifier for a non-existing list item or parent list item is specified.
 - **Solution 1:** User must select the target list item from a list of existing list items; manual entry of the target list item identifier is prohibited.

4.2.7 Semantic Specification for actions on Property Sheet Attributes:

- **Command:** Change Text Field Data
- **Information Required:** Scene Element identifier, Scene Element attribute values
- **Description:** The property sheet text fields are filled with the scene element attribute values from the scene element with the associated target identifier.
- **Side Effects:** Values currently displayed by the property sheet text field are replaced with the new values.
- **Feedback:** The user is presented with the data values from the scene element with the target identifier.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.

4.3 Semantic Design for Actions on Object Relations

4.3.1 Semantic Specification for actions on Canvas and Viewport Relationships:

- **Command:** Remove a viewport from a canvas
 - **Information Required:** Viewport identifier
 - **Description:** Remove the viewport with the target identifier from the canvas.
 - **Side Effects:** The removed viewport no longer exists.
 - **Feedback:** The removed viewport is no longer visible to the user.
 - **Errors:**
 1. An identifier for a non-existing viewport is specified.
 - **Solution 1:** User must select the target viewport from a list of existing viewports; manual entry of the target viewport identifier is prohibited.
-
- **Command:** Add a viewport to a canvas
 - **Information Required:** Viewport identifier, Viewport position, Viewport size
 - **Description:** Add a new viewport with the specified position and size to the canvas. The viewport identifier is specified by the user at creation time.
 - **Side Effects:** The new viewport will obstruct portions of other viewports if it is positioned and sized such that it overlaps with any existing viewports.

- **Feedback:** The user is presented with a new viewport portraying a view of the scene.
- **Errors:**
 1. The position and size of the viewport may be specified such that a portion of the viewport is located outside of the canvas area.
 - **Solution 1:** User must specify position and size of viewport by drawing the viewport with the mouse which restricts valid draw area to the canvas.
 2. A viewport identifier that already exists may be specified.
 - **Solution 1:** The user is presented with an error message when specifying a viewport identifier that already exists.

4.3.2 Semantic Specification for actions on Scene and Scene Element Relationships:

- **Command:** Find/retrieve a scene element from a scene
- **Information Required:** Scene Element identifier
- **Description:** Retrieves the scene element with the specified name/identifier from the scene.
- **Side Effects:** The retrieved scene element can be reparented or displayed by the property sheet.
- **Feedback:** None.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** The user is presented with an error message when a non-existing scene element identifier is specified.

- **Command:** Remove a scene element from a scene
- **Information Required:** Scene Element identifier
- **Description:** Removes the scene element associated with the target scene element identifier from the scene.
- **Side Effects:** The scene element no longer exists.
- **Feedback:** The altered scene with the removed scene element is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.

- **Command:** Change the parent of a scene element
- **Information Required:** Scene Element identifier, Parent Scene Element identifier
- **Description:** Set the parent scene element attribute of the scene element associated with the target scene element identifier to the new parent scene element.
- **Side Effects:** The scene element and all of its children are moved to a new position in the scene hierarchy.

- **Feedback:** The altered scene with the moved scene element is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element or parent scene element is specified.
 - **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.

4.3.3 Semantic Specification for actions on Scene Element Relationships:

- **Command:** Add a scene element to a group node
 - **Information Required:** Scene Element identifier, Group Node identifier
 - **Description:** Add the scene element associated with the target scene element identifier to the list of children contained by the group node with the specified identifier.
 - **Side Effects:** The scene element has a new parent and the group node has a new child.
 - **Feedback:** The altered scene with the relocated scene element is presented to the user.
 - **Errors:**
 1. An identifier for a non-existing scene element or non-existing group node is specified.
 - **Solution 1:** User must select the target scene elements from a list of existing scene elements; manual entry of the target scene element identifiers is prohibited.
-
- **Command:** Remove a scene element from a group node
 - **Information Required:** Scene Element identifier, Group Node identifier
 - **Description:** Remove the scene element associated with the target scene element identifier from the list of children contained by the group node with the specified identifier.
 - **Side Effects:** The scene element either has a new parent or has been deleted and the group node has lost a child.
 - **Feedback:** The altered scene with the relocated or removed scene element is presented to the user.
 - **Errors:**
 1. An identifier for a non-existing scene element or non-existing group node is specified.
 - **Solution 1:** User must select the target scene elements from a list of existing scene elements; manual entry of the target scene element identifiers is prohibited.
-
- **Command:** Add a scene element to a switch node
 - **Information Required:** Scene Element identifier, Switch Node identifier

- **Description:** Add the scene element associated with the target scene element identifier to the list of children contained by the switch node with the specified identifier.
- **Side Effects:** The scene element has a new parent and the switch node has a new child.
- **Feedback:** The altered scene with the relocated scene element is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element or non-existing switch node is specified.
 - **Solution 1:** User must select the target scene elements from a list of existing scene elements; manual entry of the target scene element identifiers is prohibited.

- **Command:** Remove a scene element from a switch node
- **Information Required:** Scene Element identifier, Switch Node identifier
- **Description:** Remove the scene element associated with the target scene element identifier from the list of children contained by the switch node with the specified identifier.
- **Side Effects:** The scene element either has a new parent or has been deleted and the switch node has lost a child.
- **Feedback:** The altered scene with the relocated or removed scene element is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element or non-existing switch node is specified.
 - **Solution 1:** User must select the target scene elements from a list of existing scene elements; manual entry of the target scene element identifiers is prohibited.

- **Command:** Add a scene element to a transform node
- **Information Required:** Scene Element identifier, Transform Node identifier
- **Description:** Add the scene element associated with the target scene element identifier to the list of children contained by the transform node with the specified identifier.
- **Side Effects:** The scene element has a new parent and the transform node has a new child.
- **Feedback:** The altered scene with the relocated scene element is presented to the user.
- **Errors:**
 1. An identifier for a non-existing scene element or non-existing transform node is specified.
 - **Solution 1:** User must select the target scene elements from a list of existing scene elements; manual entry of the target scene element identifiers is prohibited.

- **Command:** Remove a scene element from a transform node
 - **Information Required:** Scene Element identifier, Transform Node identifier
 - **Description:** Remove the scene element associated with the target scene element identifier from the list of children contained by the transform node with the specified identifier.
 - **Side Effects:** The scene element either has a new parent or has been deleted and the transform node has lost a child.
 - **Feedback:** The altered scene with the relocated or removed scene element is presented to the user.
 - **Errors:**
 1. An identifier for a non-existing scene element or non-existing transform node is specified.
 - **Solution 1:** User must select the target scene elements from a list of existing scene elements; manual entry of the target scene element identifiers is prohibited.
-
- **Command:** Remove a geometry object from a geode
 - **Information Required:** Geometry Object identifier, Geode identifier
 - **Description:** Remove the Geometry Object associated with the target identifier from the list of geometry objects contained by the geode with the specified identifier.
 - **Side Effects:** The geometry object no longer exists.
 - **Feedback:** The altered scene with the removed geometry object is presented to the user.
 - **Errors:**
 2. An identifier for a non-existing geometry object or non-existing geode is specified.
 - **Solution 1:** User must select the target scene elements from a list of existing scene elements; manual entry of the target scene element identifiers is prohibited.

4.3.4 Semantic Specification for actions on Property Sheet and Scene Element

Relationships:

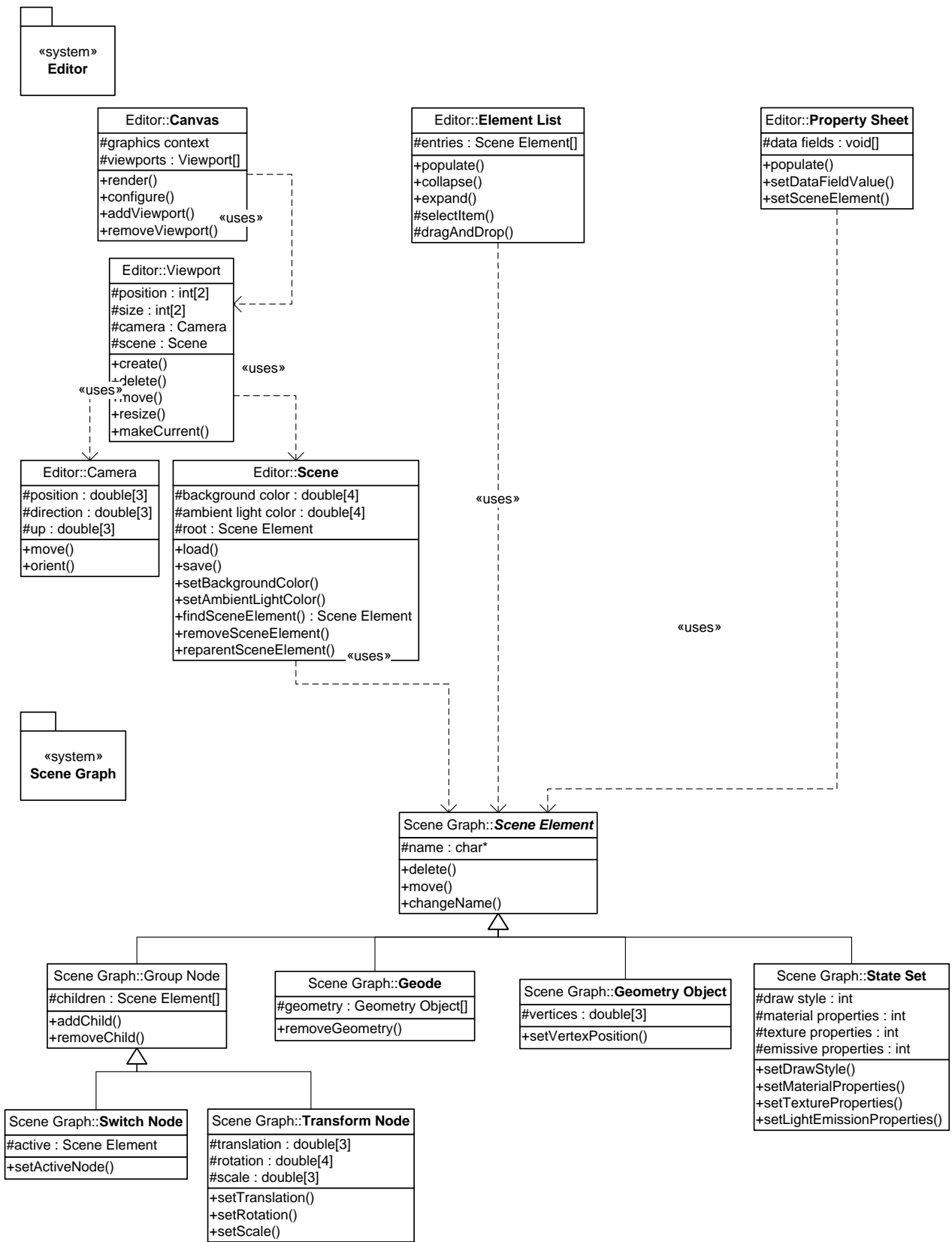
- **Command:** Change the source of the scene element attribute values displayed by the property sheet to a different scene element
- **Information Required:** Scene Element identifier, Scene Element attribute values
- **Description:** The scene element attribute values displayed by the property sheet are changed to the values of the scene element associated with the target scene element identifier.
- **Side Effects:** Values currently displayed by the property sheet are replaced with the new scene element attribute values.
- **Feedback:** The user is presented with the scene element attribute values.
- **Errors:**
 1. An identifier for a non-existing scene element is specified.

- **Solution 1:** User must select the target scene element from a list of existing scene elements; manual entry of the target scene element identifier is prohibited.

5. Component Diagram

The components comprising the Scene Graph Editor are organized as two separate sub-systems defining the editing capability and the rendering capability of the application. The Editor sub-system contains the Canvas, Viewport, Camera, Scene, Scene Element List, and Property Sheet objects which control user interaction. The Scene Graph sub-system contains the Scene Element and Scene Element sub-type objects which control the rendering of the scene that is displayed to the user with the Canvas. The Editor sub-system interacts with the Scene Graph sub-system through a one-way inter-subsystem communication interface.

The Editor sub-system displays and alters the attributes of objects contained by the Scene Graph sub-system. The Scene, Element List, and Property Sheet objects display and modify the attribute values of the Scene Element objects contained by the Scene Graph sub-system. The Canvas object interacts with the Viewport object and the Viewport object interacts with both the Camera and Scene objects within the Editor sub-system. Communication among components contained by the editor sub-system is also one-way. The following Component Diagram illustrates the attributes, actions, and relationships available for each component defining the Scene Graph Editor:



6.0 Visual Design

The visual design for the main application window, with property sheet for the basic scene element object and visible file menu, is depicted by Figure 1.

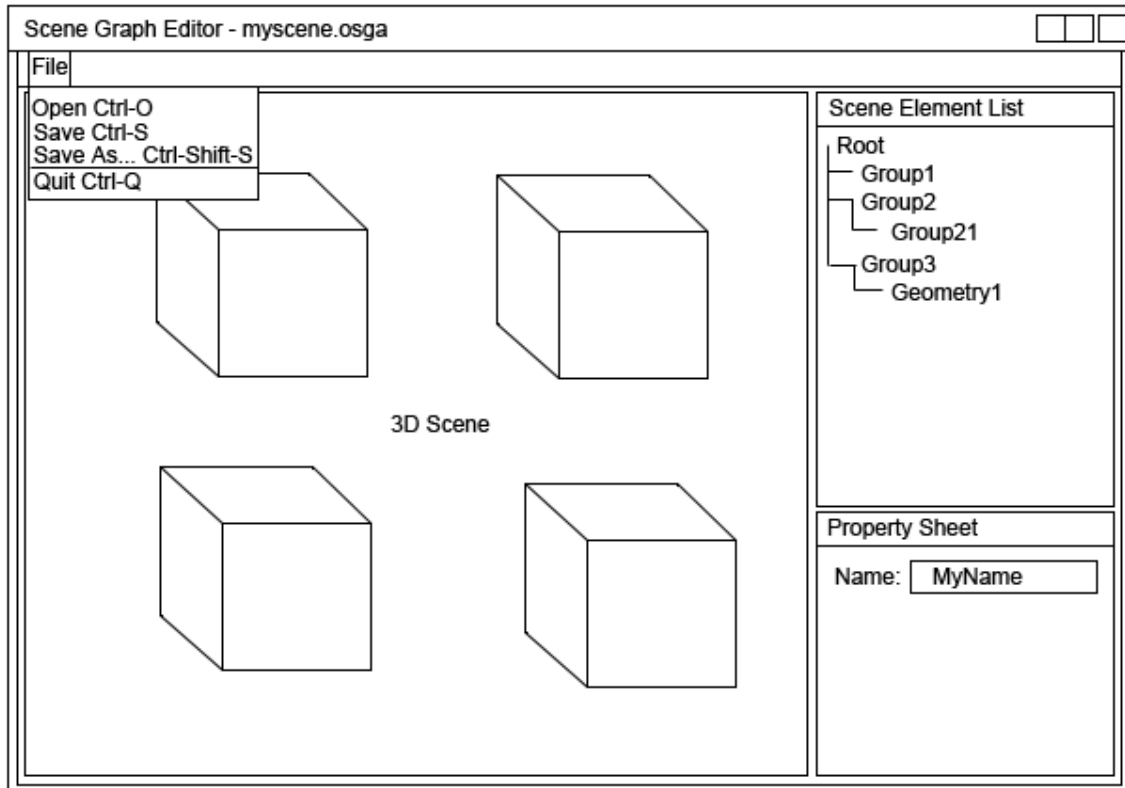


Figure 1 – Main Application Window

The visual design for the property sheets specific to the different scene element object types is depicted by Figure 2. From left to right, the first diagram depicts the basic property sheet associated with the Group Node and Geode, the second diagram depicts the property sheet associated with the Switch Node, the third diagram depicts the property sheet associated with the Transform Node, the fourth diagram depicts the property sheet associated with the Geometry Object, and the fifth diagram depicts the property sheet associated with the State Set Object.

The figure shows five 'Property Sheet' windows arranged in two rows. Each window has a title bar 'Property Sheet' and a 'Name' field containing 'MyName'.

- Top-left:** Only the 'Name' field is visible.
- Top-middle:** Includes an 'Active Node' list with three items: 'Child 1', 'Child 2' (highlighted in black), and 'Child 3'.
- Top-right:** Includes 'Trans' (X, Y, Z), 'Rot' (θ, X, Y, Z), and 'Scale' (X, Y, Z) fields.
- Bottom-left:** Includes a 'Vertices' table with 3 rows and 4 columns (headers: #, X, Y, Z).
- Bottom-right:** Includes 'Draw' (Style), 'Material' (Property), 'Texture' (Property), and 'Light' (Property) dropdown menus.

Figure 2 – Property Sheets for Each Scene Element Object Type

The visual design for the viewport manipulation dialog window is depicted by Figure 3.

The 'Viewport Dialog' window has a title bar with standard window controls. It features a list box on the left labeled 'Viewports' containing 'Viewport 1' and 'Viewport 2'. To the right are four input fields for 'X', 'Y', 'Width', and 'Height'. At the bottom are 'OK' and 'Cancel' buttons.

Figure 3 – Viewport Manipulation Dialog Window

The visual design for the color selection dialog window is depicted by Figure 4.

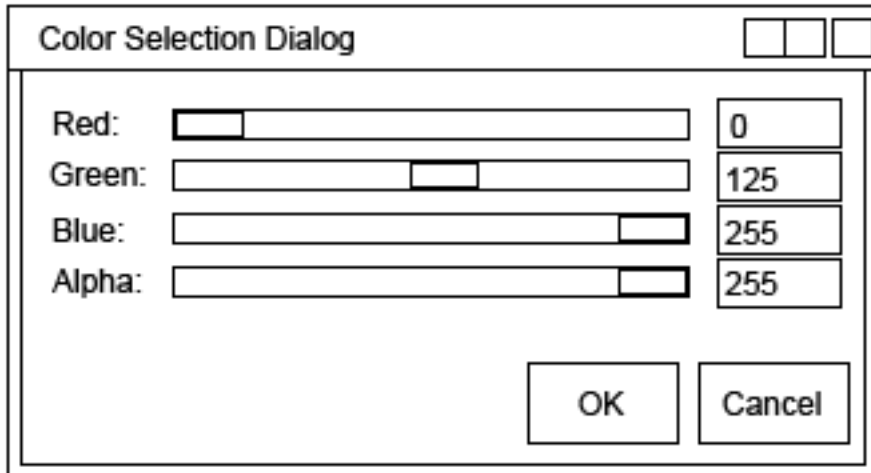


Figure 4 – Color Selection Dialog Window

7.0 Keyboard Functions

The Scene Graph Editor recognizes the following keyboard functions:

- Ctrl-Q – Quit/Exit the application.
- Ctrl-O – Open a Scene Graph file.
- Ctrl-S – Save the current Scene Graph file.
- Ctrl-Shift-S – Save the current Scene Graph file with a new name.
- V – Initiate the procedure to create a new viewport with the mouse.
- Shift-V – Display a dialog window to create and resize viewports.
- R – Reset the camera to the default position.
- B – Display a dialog to set the background color of the scene.
- A – Display a dialog to set the ambient light color of the scene.