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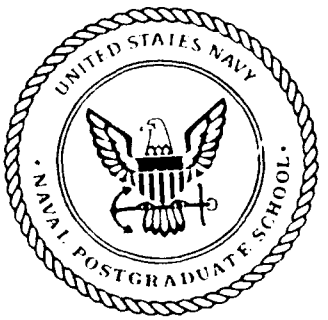

THESIS

NPSME - AN INTERACTIVE TOOL FOR MATERIAL CHARACTERISTICS SPECIFICATION

by

Wilhelm Friedrich Anderson

December 1990

Thesis Advisor: Michael J. Zyda

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NPSME - AN INTERACTIVE TOOL FOR MATERIAL CHARACTERISTICS SPECIFICATION

by

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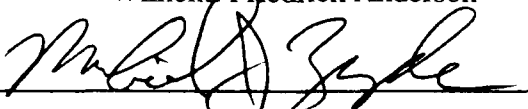
Approved By: 

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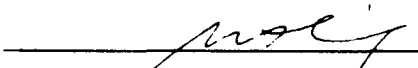

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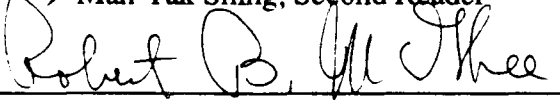

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ABSTRACT

A general tool capable of interactively creating, displaying, modifying, and managing lists of material specifications is required for the display of 3D icons on the Silicon Graphics Inc. IRIS 4D workstation. The Naval Postgraduate School Material Editor (NPSME) fulfills these requirements using an interactive interface and provides direct support for the Naval Postgraduate School's Command and Control Workstation of the Future project.

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ACKNOWLEDGEMENTS

I would like to thank Lieutenant David King, USN, and Lieutenant Commander Richard Prevatt, USN, for continually putting up with my pestering questions, David Pratt, for providing constant encouragement, and most significantly my principle advisor, Dr. Michael Zyda, who believed in me and accepted me as part of his team.

I. INTRODUCTION

A general tool capable of interactively creating, displaying, modifying, and managing lists of material specifications is required for the display of 3D icons on the Silicon Graphics Inc. IRIS 4D workstation. The Naval Postgraduate School Material Editor (NPSME) fulfills these requirements using an interactive interface and provides direct support for the Naval Postgraduate School's Command and Control Workstation of the Future project.

A. BACKGROUND

Material specification is the definition of the color of an object in terms that allow a computer to properly represent that color on a graphics display. Previously, material specification had been accomplished by the use of in-line code in a graphics program's source. The use of in-line code material specification has several drawbacks. First, a modification to the graphics program's source code is required whenever a change to the graphics program's 3D icon material specification is desired. This results in numerous compilations of the source code in a trial and error search for the right color display. Second, materials specified by in-line code are not readily available to multiple graphics program authors. In fact, multiple users may not even be aware of all the material specifications that do exist, and so be limited in their 3D icon color selection. Third, materials specified in one application and later used in a new application must be tediously written into the new application's source file.

The use of 3D Object File Format (OFF) was a start to solving this problem. A 3D icon, including all its material specifications, is defined in a single ASCII text file. The graphics program reads the desired 3D icon's file using the appropriate OFF command and then the 3D icon can be displayed as desired. If the 3D icon's material specifications are to be changed, then the change can be done in that 3D icon's OFF file using a text editor without requiring a change to the graphics program's source file and a subsequent compilation (Zyda, *Graphics and Video Laboratory*, Book Number 7, 1990, pp. 3-46). This simple 3D

icon definition method spawned a host of OFF files, each with its various material specifications. The problem of any user accessing the full range of materials that had been specified was magnified. In addition, a material management issue now arose as the same material specification name appeared repeatedly throughout various OFF files but specified different material characteristics each time. A separate material management problem surfaced with the same material specification appearing repeatedly throughout various OFF files but under different material names.

Both the in-line coding and the use of OFF for material specification have the limitation that the material specification can not be previewed until the graphics program is executed. This forces wasted effort as 3D icon material specifications are changed and the 3D icon is displayed repeatedly in the search for the proper color representation. Material specifications should be available for preview prior to their use. A better method than the OFF text editing should be employed to modify existing material specifications. The numerous defined material specifications residing in various files must be efficiently handled with regard to duplicate names, multiple identical definitions, and the creation of a material library allowing access to all defined materials.

The Naval Postgraduate School Material Editor (NPSME) resolves these issues. Using NPSME with its interactive user interface, material specifications can be created, chosen from a master library, chosen from a specific material specification file, previewed and modified interactively, then saved to the desired individual material specification file. New material specification files can be created for specific applications. Existing material specification files can be edited, duplicate material names identified, and duplicate material definitions removed. A master material specification library can be maintained and easily accessed.

B. THESIS ORGANIZATION

Chapter II presents a summary of the Silicon Graphics Inc. IRIS 4D workstation color model and defines the elements formulating a material specification. Chapter III is an overview of NPSME capabilities and use. Chapter IV is a discussion on NPSME limitations and future enhancements. Appendix A is a sample material specification file. Appendix B is a sample file created by the NPSME filter material list capability.

II. IRIS 4D MATERIAL SPECIFICATION

Before explaining how to use the Naval Postgraduate School Material Editor (NPSME) a discussion of how the Silicon Graphics Inc. IRIS 4D workstation displays color is necessary. Background information on the IRIS 4D workstation monitor and graphics lighting capabilities is introduced in this chapter. The presentation of the lighting equation is reproduced from *Graphics and Video Laboratory* written by Dr. Michael J. Zyda (Zyda, *Graphics and Video Laboratory*, Book Number 6, 1990, pp. 47-58) except as otherwise noted.

A. RGB

The color receptors in the human eye are called cones. There are three types of cones. One is sensitive to red light, another green light, and the last to blue light. The color perceived by the brain is determined by the number and type of cones excited around the spot on the retina of the eye struck by a ray of light. Monitors take advantage of this fact and use red, green, and blue phosphors to display colors. The phosphors are part of the display screen. The monitor has red, green, and blue electron guns which sweep the display screen. As the stream of electrons from a gun hits the phosphors of that gun's color only those phosphors become excited and emit that color of light. This in turn will excite the cones of that color in the eye. In order to produce other colors then red, green, and blue the monitor is divided into pixels. Each pixel has red, green, and blue phosphors in it. The stream of electrons from the electron guns can range from zero (black) to full intensity (bright) and is varied from pixel to pixel. Each electron gun sweeps every pixel on the screen numerous times a second. The color of the pixel then becomes the resultant color of the combination of red, green, and blue phosphors excited.

The range of intensity of each electron gun varies from 0 to 255 allowing 256 settings per gun. A color is represented by a red, green, and blue (RGB) triple indicating the intensity each gun is to be set to display that color. The color black is the RGB triple [0, 0, 0] and the color white is the RGB triple [255, 255, 255]. A neutral color is a color that has

an equal value for each gun and represents a shade of gray between the colors black and white. Other colors are achieved by unequal values for each gun such as red [255, 0, 0], green [0, 255, 0], blue [0, 0, 255], yellow [255, 255, 0], magenta [255, 0, 255], and cyan [0, 255, 255]. These colors are fully saturated (bright) since the electron guns are either at full intensity or off. Less bright colors have a value between 0 and 255 such as a less bright shade of red [200, 0, 0].

Since the monitor phosphors are the same color as the cones in the eye, the monitor can display almost the full range of colors the eye perceives in the real world. The eye also has rods which are mainly sensitive to the intensity of the color allowing the eye to have a slightly higher range of color perception than that presented by the monitor. Still the monitor can represent 256 x 256 x 256 which equals 16,777,216 different colors (Silicon Graphics Inc., 1987, pp. 4.1-4.3).

B. LIGHTING EQUATION

The color of an object is determined by several factors and the relationships between them. The surface material of an object has emission, ambient, diffuse, and specular properties. Consider a point on the surface of an object that is illuminated by a light source. The color of the point depends on the material surface properties at that point as affected by the following:

- The color of the light source.
- The location of the light source with respect to the point.
- The direction of light from the light source with respect to the point.
- The color of the material at the point.
- The location of the viewer with respect to the point.
- The viewer's direction of view with respect to the point.

In order to show the interrelationships between the above factors and incorporate the RGB capabilities of the monitor to realistically display color certain definitions must be made prior to presenting the lighting equation:

- r Red component of RGB color triple.
- g Green component of RGB color triple.
- b Blue component of RGB color triple.

- C — Color represented as an RGB color triple:

  $C = [r, g, b]$

  Addition of two colors:

  $C_1 = [r_1, g_1, b_1]$

  $C_2 = [r_2, g_2, b_2]$

  $C_1 + C_2 = [(r_1 + r_2), (g_1 + g_2), (b_1 + b_2)]$

  One color amplifying a second color:

  $C_1 = [r_1, g_1, b_1]$

  $C_2 = [r_2, g_2, b_2]$

  $C_1 \times C_2 = [(r_1 \times r_2), (g_1 \times g_2), (b_1 \times b_2)]$

- M — RGB color triple from the material specification:

  $M = [r, g, b]$

- M_e — Material specification emission color:

  $M_e = [r_{me}, g_{me}, b_{me}]$

- M_a — Material specification ambient color:

  $M_a = [r_{ma}, g_{ma}, b_{ma}]$

- M_d — Material specification diffuse color:

  $M_d = [r_{md}, g_{md}, b_{md}]$

- M_s — Material specification specular color:

  $M_s = [r_{ms}, g_{ms}, b_{ms}]$

- C_{me} — Color of emission light emitted by from material.
- C_{ma} — Color of ambient light reflecting off material.
- C_{md} — Color of diffuse light reflecting off material.
- C_{ms} — Color of specular light reflecting off material.

- C_p — Color of point p on surface of an object as seen by the viewer.

The lighting equation follows:

- $C_p = C_{me} + C_{ma} + C_{md} + C_{ms}$ (Eq. 2.1)

Each of the terms in equation 2.1 determining the color of point p will now be defined.

C. EMISSION

The emission surface property of a material is usually caused by "elevated surface temperature and the resultant molecular activity. In a general sense, emissivity is the result of absorbed energy being radiated or emitted from the surface as visible light" (Hall,1989, p. 40). Emitted light is independent of the color, location, and direction of light sources, and is also independent of the location and view direction of the viewer. Emitted light depends only on the surface properties of the material and will not affect the color of any other object (Silicon Graphics Inc., 1987, p. 9.17). Therefore,

- $C_{me} = M_e$ (Eq. 2.2)

D. AMBIENT

Ambient light is light that arrives at the object indirectly by reflecting off other surfaces. It is assumed to have no specific originating direction but rather to be simultaneously arriving from all directions, thus causing the light to be reflected uniformly in all directions. Ambient light is independent of the location and direction of light sources and is independent of the location and view direction of the viewer. Ambient light reflected off a material is dependent only on the color and intensity of ambient light in the scene and the color and surface properties of the material (Silicon Graphics Inc., 1987, p. 9.3).

Ambient light arriving at the object originates from two sources, the amount of ambient light in the scene, and the contributions from light sources. The amount of ambient light in the scene is considered to be independent of light sources and is of constant color and intensity everywhere, whereas light sources have a specific ambient light color and intensity component. More definitions,

- C_{as} Color of ambient light in the scene.
- C_{al} Color of ambient light from a light source in scene.
- t Total number of light sources in the scene.

Then,

- $C_{ma} = (C_{as} \times M_a) + \sum_{i=1}^{t} C_{al_i} \times M_a$ (Eq. 2.3)

E. DIFFUSE

Diffuse light is light from a light source that is reflected uniformly in all directions by a material with a rough surface. Rough surfaces cause light to be reflected evenly in all directions. Diffuse light depends on:

- The color of the light source.
- The angular relationship between the light source and the reflecting surface at the point of incidence.
- The reflectance properties of the material at the point of incidence.

Diffuse light does not depend on the location of the viewer. The amount of diffuse light reflected at the point of incidence is determined by the cosine of the angle Θ formed by a line drawn from the point of incidence to the light source and a line normal (perpendicular) to the surface at the point of incidence (see Figure 2.1) (Silicon Graphics Inc., 1987, p. 9.2).

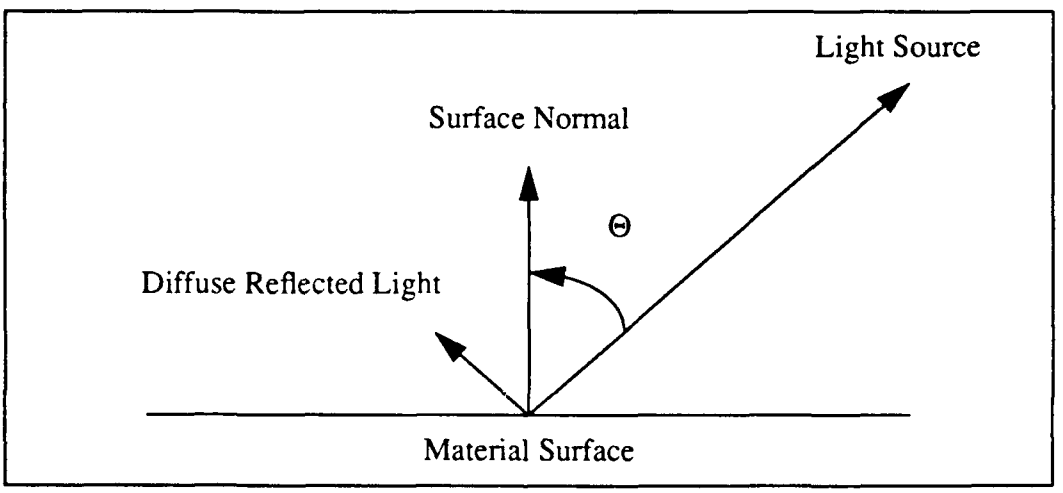

Figure 2.1 Diffuse Light Reflection

More definitions,

- Positions are three dimensional locations (x, y, z).
- V Vectors which are unit vectors.

  Vector at point p is $[x, y, z]$ and is interpreted as $xi + yj + zk$.

- N Normals which are unit vectors.

  Normal at point p is $[x, y, z]$ and is interpreted as $xi + yj + zk$. Surface normals point away from the front side of the surface. The cosine of the angle between two normals is the dot product of the normals.

- V_{pl} Vector from point p to light source.
- N_p Surface normal at point p.
- C_l Color of light from a light source in scene.
- t Total number of light sources in the scene.

Then,

- The $\cos \Theta = V_{pl} \bullet N_p$
- If $V_{pl} \bullet N_p \leq 0$ then the surface is self-shadowing and $C_{md} = 0$

Otherwise,

- $$C_{md} = \sum_{i=1}^{t} C_{li} \times M_d \times (V_{pli} \bullet N_p) \qquad \text{(Eq. 2.4)}$$

Notice that this means diffuse light will be greatest when the surface normal points directly at the light source $(\cos\Theta = 1)$ and decreases to zero as the surface normal points away from the light source.

F. SPECULAR

Specular light is light from a light source that is reflected non-uniformly depending on the smoothness of a material's surface. The smoother the surface the more directional the reflected light will be and the shinier the material will appear. The smoothest surface is a perfect reflector or mirror. Specular highlights are evident when the view direction is into the reflecting light rays and appear as a glare such as the glare produced by a flashlight shining off a polished automobile hood (Silicon Graphics Inc., 1987, p. 9.9-9.11). Specular light depends on:

- The color of the light source.
- The angular relationship between the light source, the surface normal, and the viewer at the point of incidence.
- The reflectance properties of the material at the point of incidence.

Specular light depends on the location of the viewer. The amount of specular light reflected at the point of incidence is determined by the cosine of the angle ϕ. One side of angle ϕ is the bisector of the angle formed by a line drawn from the point of incidence to the light source and a line drawn from the point of incidence to the viewer. The other side is a line normal (perpendicular) to the surface at the point of incidence (see Figure 2.2).

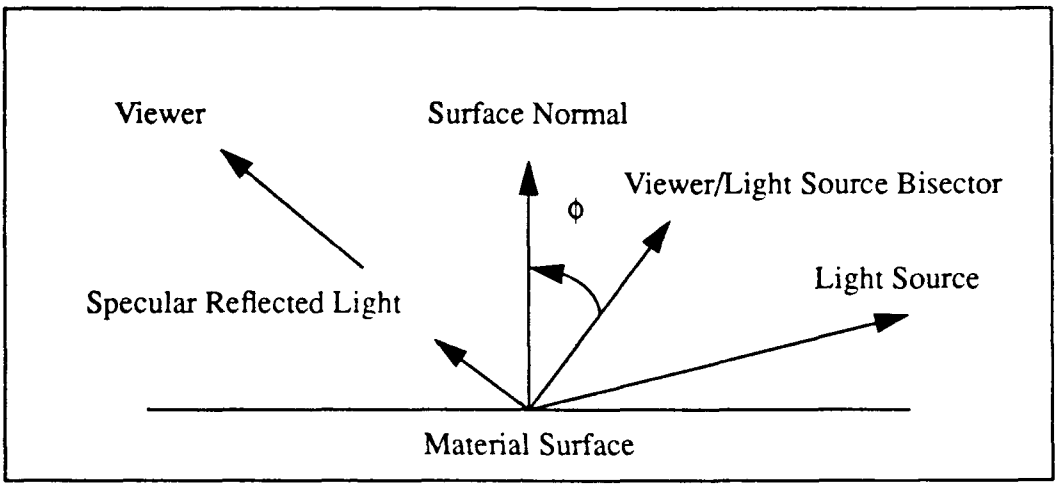

Figure 2.2 Specular Light Reflection

More definitions,

- V_{pl} Vector from point p to light source.
- V_{pv} Vector from point p to viewer.
- N_p Surface normal at point p.
- V_b Vector which is the bisector of the angle between the light source and the viewer.
- E_{mss} Material's specular scattering exponent (Phong number).

  E_{mss} is used to create a sharper specular highlight in the material display. This is accomplished by the term:

  $$(\cos\phi)^{E_{mss}}$$

  As E_{mss} is increased the $\cos\phi$ curve will become steeper and more like a spike.
- C_l Color of light from a light source in scene.

- t Total number of light sources in the scene.

Then,

- If $(V_{pl} \bullet N_p) \leq 0$ then the surface is self-shadowing and $C_{ms} = 0$
- If $(V_{pv} \bullet N_p) \leq 0$ then the surface shadows the viewer and $C_{ms} = 0$

Otherwise,

- $$C_{ms} = \sum_{i=1}^{t} (C_{li} \times M_s) \times (V_{bi} \bullet N_{pi})^{E_{mss}} \qquad \text{(Eq. 2.5)}$$

G. ALPHA

There is one further characteristic of a material to discuss, how opaque the material is. This is the material's alpha value. The Silicon Graphics Inc. IRIS 4D workstation allows for a full range of alpha values from fully transparent to fully opaque.

H. MATERIAL SPECIFICATION

The color and surface properties of a material are quantified into fourteen values. These are:

$Emission_{red}$	$Emission_{green}$	$Emission_{blue}$
$Ambient_{red}$	$Ambient_{green}$	$Ambient_{blue}$
$Diffuse_{red}$	$Diffuse_{green}$	$Diffuse_{blue}$
$Specular_{red}$	$Specular_{green}$	$Specular_{blue}$
E_{mss}		
Alpha		

The range of values for emission, ambient, diffuse, and specular RGB triples is normalized from an integer value between 0 and 255 into a float value between 0.0 and 1.0. Alpha values also range from 0.0 to 1.0. E_{mss} has an integer range from 0 (no specular highlighting) to 128 (sharp specular highlighting). Appendix A is a sample file showing material specifications.

III. NPSME CAPABILITIES AND USE

The Naval Postgraduate School Material Editor (NPSME) is comprised of two editors, an RGB material specification editor and an image editor. NPSME is the first application to make use of the Panel Designer and Toolbox user interface developed at the Naval Postgraduate School by Lieutenant David King, USN, and Lieutenant Commander Richard Prevatt, USN (King and Prevatt, 1990). NPSME was designed with ease of use in mind. The displays are intuitive and actions are simply executed by mouse commands.

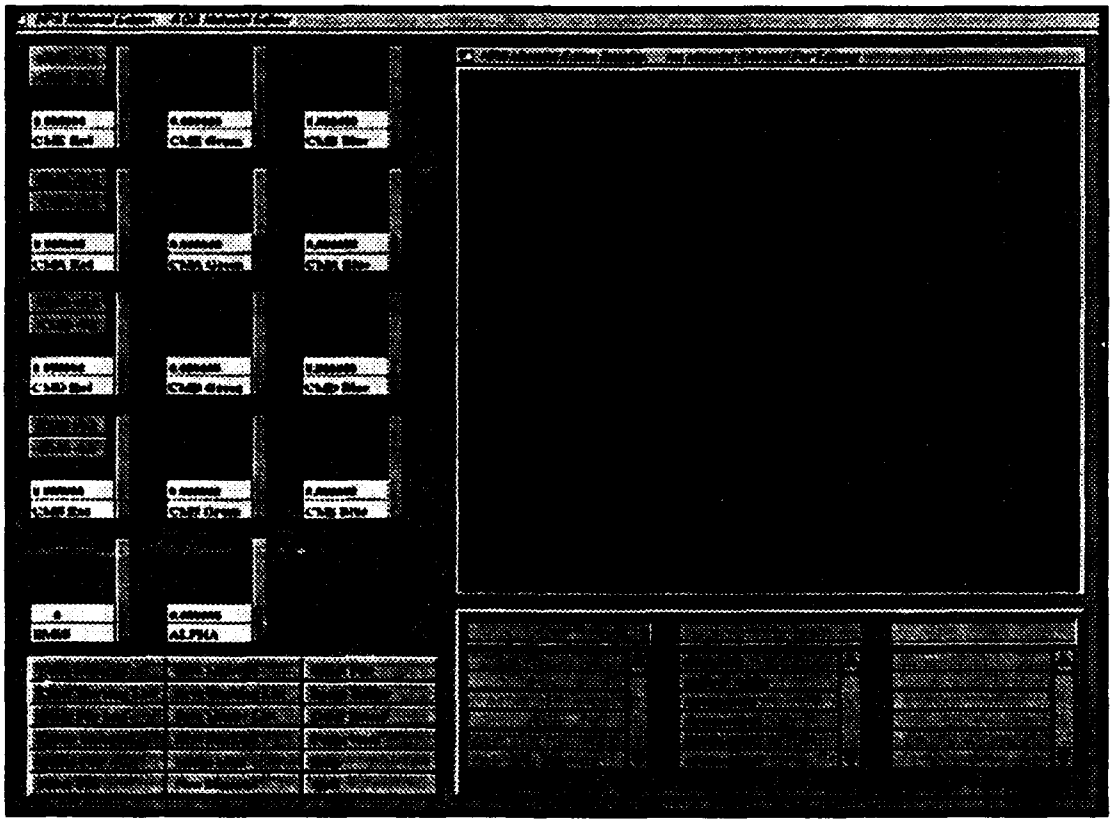

Figure 3.1 NPSME Opening Display

A. STARTING NPSME

To start NPSME type "npsme" followed by a carriage return. There will be a short pause as NPSME is initialized. NPSME always presents the user with the RGB material editor upon start-up (see Figure 3.1).

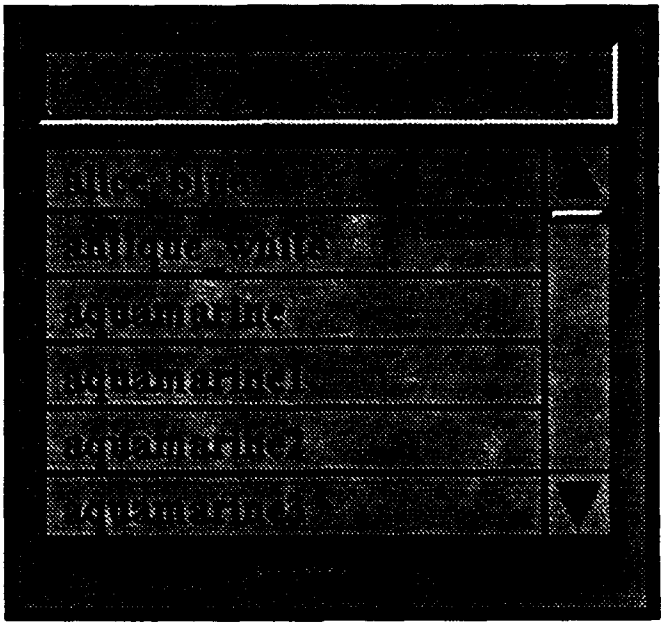

Figure 3.2 Menu Group

B. MENU GROUPS

A menu group consists of a menu, an up button, a slider, a down button, and a typein box (see Figure 3.2). To scan the choices available, use the left mouse to select the up button to move up the list or the down button to move down the list. The choices displayed in the menu will scroll appropriately. The slider's slider bar will move in the direction of the selected button and its relative position on the slider will indicate where in the list the relative position of the choices displayed in the menu are located. Alternately, to quickly move up or down the list, use the left mouse to select the slider's slider bar and move it up or down. The choices displayed in the menu will be those of the slider's position in the list. Use the left mouse to select the desired choice from the menu. To quickly access a specific item in the list use the menu's typein box.

C. TYPEIN BOXES

To use a typein box, select the typein box with the left mouse. The typein box will change color to light brown to indicate that it has been selected. Use the keyboard to type the desired name to be selected in the typein box. When the desired name has been typed in, press the carriage return key or use the left mouse to click in the typein box. If there is a name in the typein box when initially selected, use the backspace key to move to the desired typein start point or use control u to completely delete the old name, and then type in the new name.

D. RGB MATERIAL EDITOR

The title bar of NPSME will display the name of the editor NPSME currently has active. For the RGB material editor (see Figure 3.1) the title will read as follows:

- NPS Material Editor: RGB Material Editor

Located in the upper left hand corner of the display screen is the RGB slider group consisting of a set of fourteen sliders that control the material specification settings. There are three sliders grouped together for the red, green, and blue settings for each material surface characteristic of emission, ambient, diffuse, and specular. The last two sliders are for E_{mss} and alpha settings. The values of the fourteen sliders set the material characteristics for the material in the display window. Under the slider group is a set of eighteen option buttons to execute specific material editor utilities. To the right of the option button group are three material list menus. The left list is the working material list for building new material specification files, the center list is the master list of all materials entered into the master material list library, and the right list is for editing specific material list files. The material display window is located above the material list menus. The material display window is a red and white checkerboard background over which the material that is being edited is displayed on the surface of a half cylinder. The effects of using the sliders to change the material specification settings can immediately be seen. When NPSME is executed, a material has not yet been selected for editing and so the material display window will show the background checkerboard without displaying the half cylinder. The material display window title bar will read:

- NPS Material Editor Display: No Material Selected For Editing

1. RGB Material Editor Mouse Controls

In the RGB Material Editor, the left mouse button is used to select options from menus, select buttons to execute button functions, and manipulate sliders to change slider values. The middle mouse button is not connected and so has no effect. The right mouse button calls a pop up menu for selecting either the RGB Material Editor, the Image Editor or to quit NPSME.

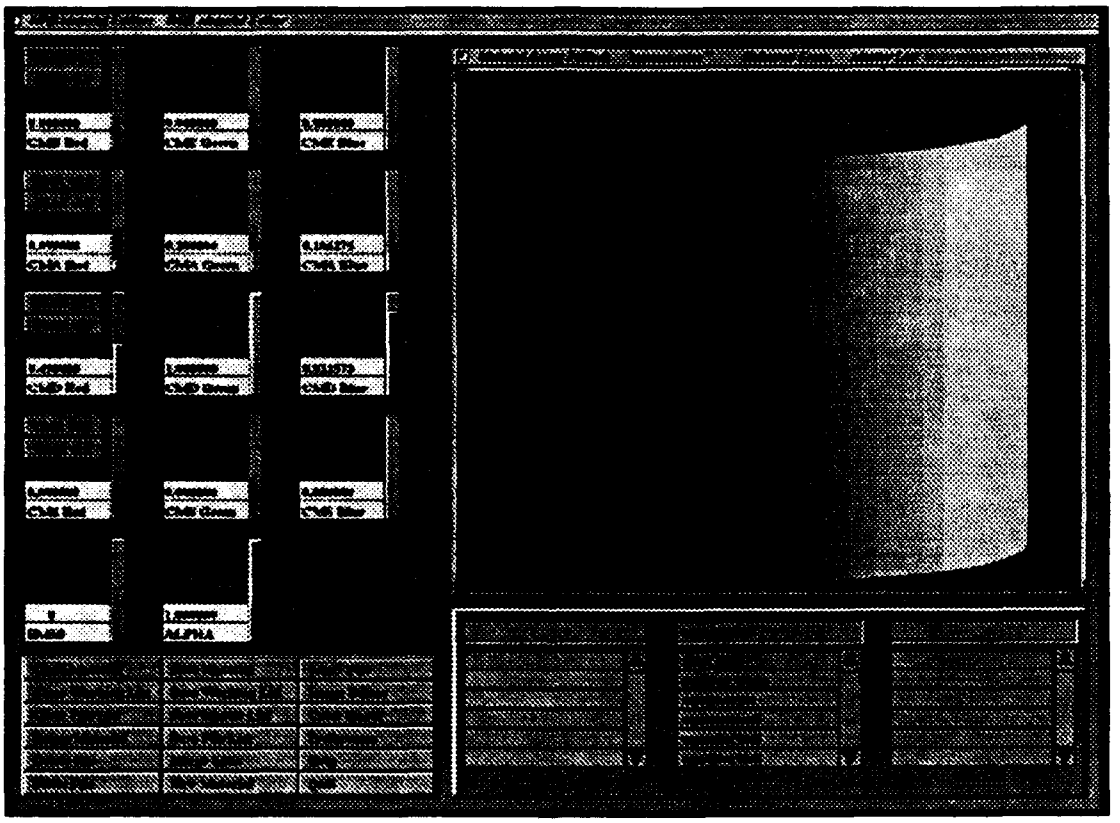

Figure 3.3 RGB Editor

2. Selecting A Material For Editing

There are three material list menus located under the material display window (see Figure 3.3). The left list is the working material list for building new material specification files, the center list is the master list of all materials entered into the master material list library, and the right list is for editing specific material list files. Using the option buttons

to the left of the working list menu, materials can be selected from, edited, saved to, or deleted from each list. New materials can be created and added to each list. Each list can be filtered of materials having the same material specification or merged with any other list. Changes made to the working list can be saved to any file name. Changes made to the master list can be saved to the master material list library. Changes made to the file list can be saved to that file name or to any other file name.

To select a material, use the left mouse to select the desired material name from the menu choices. The material will then be displayed on the half cylinder in the material display window, the RGB slider group will be set to that material's specification values, and the selected material name will appear in the typein box above the menu choices (see Figure 3.3). To quickly access a specific material use the menu's typein box.

3. Material Display Window

The background of the material display window is a red and white checkerboard (see Figure 3.3). The selected material is displayed on a half cylinder located over the checkerboard. The checkerboard background is provided as a reference for the selected material's alpha value (transparency). As the alpha value decreases, the material becomes more transparent and the checkerboard background can be seen through the material until the alpha value reaches zero. At this point the material is fully transparent and the half cylinder disappears. There is one white light source in the display window to interact with the material's ambient, diffuse, and specular surface properties. The half cylinder is three dimensional to display the material on a curved surface As any one of the sliders in the RGB slider group is changed to change the material's specification properties, the change in the material is immediately displayed on the half cylinder to provide the user with immediate interactive feedback. The title bar of the material display window provides information on the material name and what list the material was selected from. A sample title bar would be:

- Material Being Edited: "aquamarine" Selected From: Master List

Under certain conditions, such as start-up or when the list from which the selected material was selected is cleared, the material display window is reset and the half cylinder will not be visible. After the next material selection the half cylinder will again be displayed.

4. Editing A Material

After a material has been selected, it can be edited using one of the fourteen sliders in the RGB slider group (see Figure 3.3). The fourteen sliders are sub grouped into four rows of three and one row of two. The four rows of three slider groups represent the material surface properties of emission, ambient, diffuse, and specular with an individual slider for each of their red, green, and blue values. The row of two sliders represent the material's E_{mss} and alpha values. To edit a material, use the left mouse to select the desired slider's slider bar and move the slider bar up or down to increase or decrease that slider's value. The value of the slider is displayed just above the slider's label box located immediately to the left of the slider. The changes made to the slider's value will immediately be seen in the material displayed on the half cylinder in the material display window. To achieve a fine value adjustment for a slider, hold down the control key when the slider bar is selected. The slider bar will now adjust the slider's value over a range of 0.1 instead of the normal full range of 1.0.

Located just to the left of each of the four slider sub groups are two buttons labeled "+ 0.1" and "- 0.1". These buttons are provided to uniformly increase or decrease the RGB values of that individual material property by 0.1. Use the left mouse to select either of these buttons. The slider values are clipped after a maximum value of 1.0 or a minimum value of 0.0 is reached.

5. Undoing Changes Made To A Material

Changes made to a material can be undone by using the left mouse to select the "Undo Material" button from the options button group. The RGB sliders will be reset to the material's values prior to editing and the material displayed on the half cylinder in the material display window will be reset to the original material. The "Undo Material" button only affects editing since the material's selection or the last time the material was saved.

6. Clearing The Working List

The Working List can be cleared by using the left mouse to select the "Clear Working List" button from the options button group. If the selected material came from the

Working List, the Working List's typein box will be cleared as well, the RGB sliders will be set to zero, and the material display window will be reset.

7. Clearing The File List

The File List can be cleared by using the left mouse to select the "Clear File List" button from the options button group. If the selected material came from the File List, the File List's typein box will be cleared as well, the RGB sliders will be set to zero, and the material display window will be reset.

8. Deleting A Material

After a material has been selected, it may be deleted from any list by using the left mouse to select the "Delete Material" button from the options button group. This selection causes the delete material panel to be displayed. The selected material can be deleted from any list by selecting that list from the choices displayed in the delete material panel. The "Cancel" choice stops the delete material process.

9. Deleting A File

The "Delete File" option button has not been implemented.

10. Filtering A Material List

Any of the three material lists may be filtered of duplicate material specifications by using the left mouse to select the "Filter List" button from the options button group. This selection causes the filter list panel to be displayed (see Figure 3.4). The accuracy of the filter can be set by using the left mouse to select one of the accuracy levels which range from the first to the sixth decimal place. The list to be filtered is then selected by using the left mouse. The "Cancel" choice stops the filter list process. When a list is filtered, each material in the list is compared to every other material in the list. If all fourteen material specification values of the comparison material are equal to their counterparts in the material being checked, to the accuracy level selected, then the material being checked is deleted from the list. A file is generated with the file name being "X.#fl" where X is the original file name and # is the number of lists filtered since NPSME was executed. For each group of duplicated materials this file will contain the materials deleted from the list and

the single material left in the list that duplicates them. Appendix B is a sample of a file generated using the filter list option.

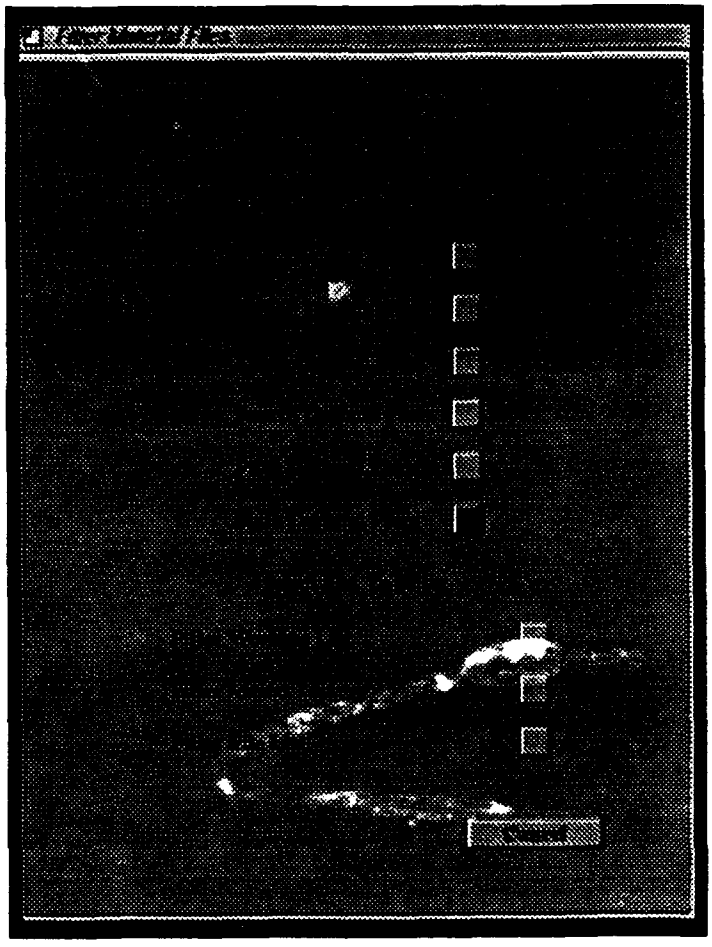

Figure 3.4 Filter Material File Menu

11. Saving A Material

An edited material can be saved to any list by using the left mouse to select the "Save Material" button from the options button group. This selection causes the save material panel to be displayed. The name the selected material is to be saved under can be changed by changing the name displayed in the save material typein box. The selected material can be saved to any list by selecting that list from the choices displayed in the save material panel. The "Cancel" choice stops the save material process. If a material having

the chosen name is in the selected list a warning panel will be displayed to query if the old material in the list should be replaced by the new material. Use the left mouse to select the "Save" button to overwrite the old material or the "Cancel" button to return to the save material panel in order to choose another name to save the material to.

12. Saving The Working List

The Working List can be saved to a file by using the left mouse to select the "Save Working List" button from the options button group. This selection causes the save list panel to be displayed. The new file will be saved in the current directory. If the file is to be saved to a different directory, use the left mouse to select the "Change Directory" button. The select file panel will then be displayed to allow the directory to be changed. When the desired directory is selected, the select file "Cancel" button will return to the save list panel. Enter the file name to save the Working List to in the save list panel typein box. The "Cancel" choice stops the save list process. If a file having the chosen name is all ready in the current directory, a warning panel will be displayed to query if the old file should be replaced by the new file. Use the left mouse to select the "Save" button to overwrite the old file or the "Cancel" button to return to the save list panel in order to choose another name. The Working List can only be saved to a directory in which the user has write permission.

13. Saving The Master List

The Master List can be saved by using the left mouse to select the "Save Master List" button from the options button group. This selection causes the master list to be saved and a message panel to be displayed to state that the master list has been saved. Use the left mouse to select the "Continue" button to resume using the RGB Editor.

14. Saving The File List

The File List can be saved to a file by using the left mouse to select the "Save File List" button from the options button group. This selection causes the save list panel to be displayed. The new file will be saved in the current directory. If the file is to be saved to a different directory, use the left mouse to select the "Change Directory" button. The select file panel will then be displayed to allow the directory to be changed. When the desired directory is selected, the select file "Cancel" button will return to the save list panel. Enter

the file name to save the File List to in the save list panel typein box. The "Cancel" choice stops the save list process. If a file having the chosen name is in the current directory a warning panel will be displayed to query if the old file should be replaced by the new file. Use the left mouse to select the "Save" button to overwrite the old file or the "Cancel" button to return to the save list panel in order to choose another name to save the File List to. The File List can only be saved to a directory in which the user has write authority.

15. Merging Material Lists

Any two lists can be merged together by using the left mouse to select the "Merge Lists" button from the options button group. This selection causes the merge list panel to be displayed. Select the merge list option desired to merge two lists together. The "Cancel" choice stops the merge list process. What the merge list option does is to add every material in the first list to the second list. This is a fast way to combine two lists. If a material name in the first list appears in the second list that material will be added to the second list under the new name "X_DUP" where X is the original material name. This prevents the possibility of losing one of two different materials having the same name.

16. Creating A New Material

A new material can be created by using the left mouse to select the "New Material" button from the options button group. This selection causes a new material with default values to be created and displayed. When the new material has been edited it may be saved to any list by using the left mouse to select the "Save Material" button from the options button group.

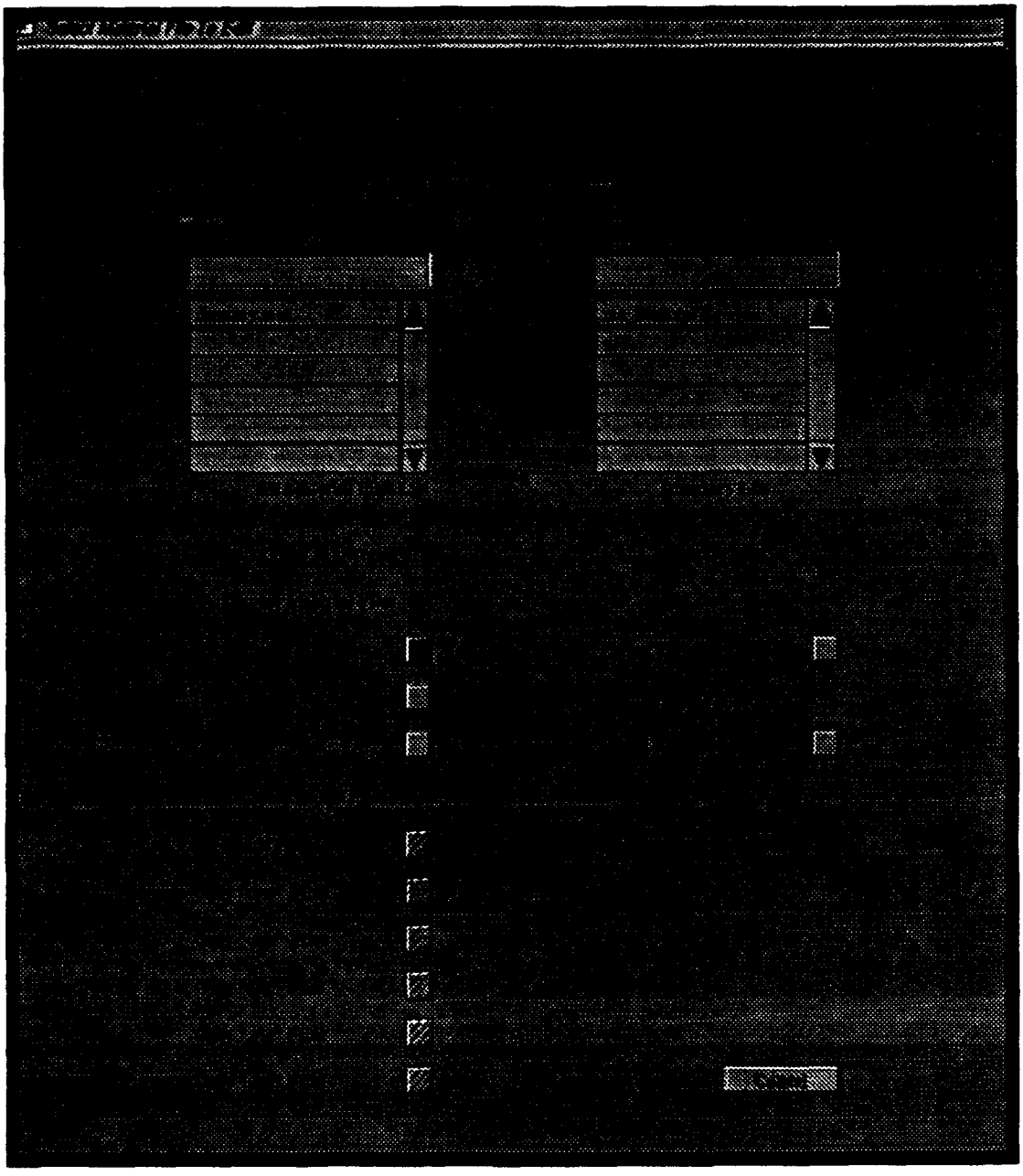

Figure 3.5 Select File Menu

17. Selecting A Material File To Edit

Any material file may be selected for editing by using the left mouse to select the "Select File" button from the options button group. This selection causes the select file

panel to be displayed (see Figure 3.5). At the top of the select file panel, the current directory path is displayed along with the home directory path (which is the directory NPSME was in when executed). There are two menus. The right menu displays all the sub directories in the current directory. Use the left mouse to select a sub directory to search or use the typein box to choose a sub directory to search. To search the parent directory, use the left mouse to select the "Parent Directory" button. To return to the home directory from any directory, use the left mouse to select the "Home Directory" button. Select a file to edit from the left menu. The only files in the current directory available for editing are those files that have the suffix ".mat" or ".off". The files displayed for selection can be filtered by using the left mouse to select the appropriate file display button under the file menu. When a file is selected for editing, the File List is cleared and the materials in that file are added to the File List. Use the left mouse to chose the "Cancel" button to stop the select file process.

18. Selecting The Image Editor

To move to the image editor, use the left mouse to select the "Image Editor" button from the options button group or use the right mouse to access the pop up menu and select the "Open Image Editor" option. The image editor will then be displayed.

19. Selecting The Color Smear Editor

The "Color Smear" option button has not been implemented.

20. Setting Preferences

The "Preferences" option button has not been implemented.

21. Help

The "Help" option button has not been implemented.

22. Quitting NPSME From RGB Editor

To quit NPSME, use the left mouse to select the "Quit" button from the options button group or use the right mouse to access the pop up menu and select the "Quit" option.

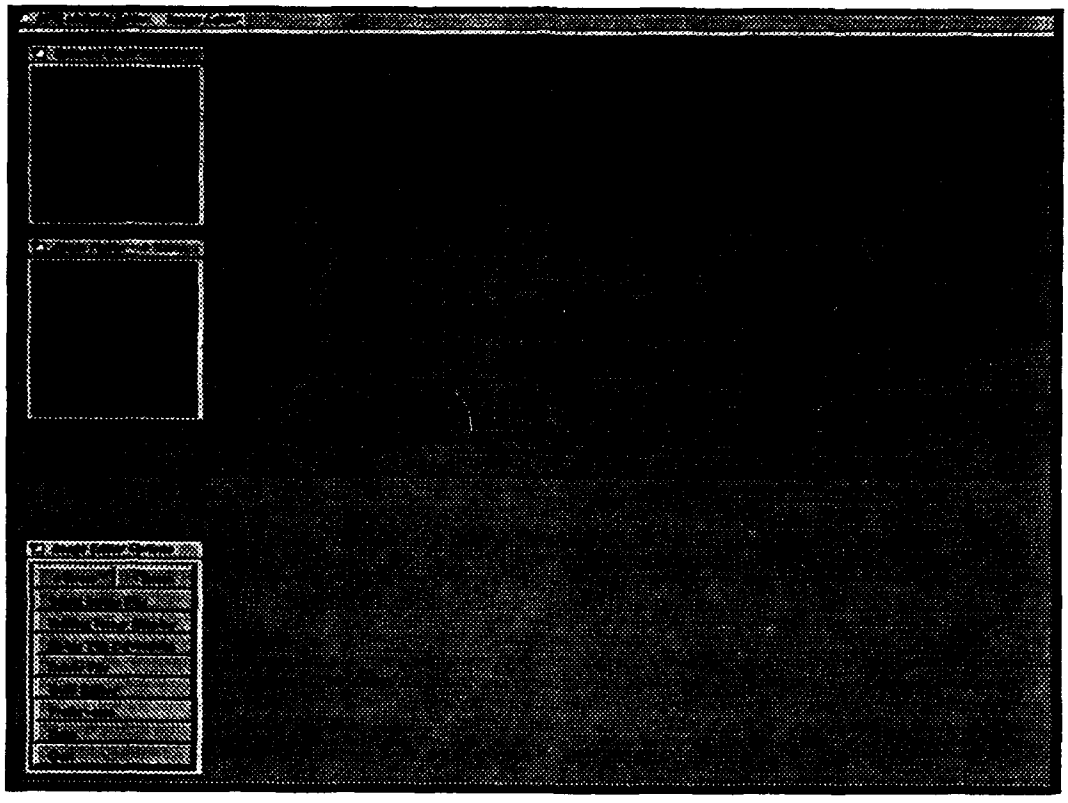

Figure 3.6 Image Editor Opening Display

E. Image Editor

The title bar of NPSME will display the name of the editor NPSME currently has active (see Figure 3.6). For the image editor the title will read as follows:

- NPS Material Editor: Image Editor

The image editor is provided to enable the display of images and then to pick a desired color from that image. The selected color will be converted to a material specification format. Diffuse RGB values will be set to be the same as those of the selected color. Ambient RGB values will be twenty percent of those of the selected color. Emission RGB, specular RGB, and E_{mss} will be set to zero. Alpha will be set to 1.0. This will provide a baseline from which the selected color may then be edited. A color selected from an image may be added to any of the three lists in the RGB material editor.

In the upper left hand corner of the display screen is the selected color display window which is a small version of the material display window. Directly below that is the zoom display window. Below the zoom display window is the image editor options button group. When an image has been selected for editing, it will be displayed in the center of the image editor.

1. Image Editor Mouse Controls

In the Image Editor the left mouse button is used to select buttons to execute and to select colors from displayed images. The left mouse will only be enabled to select colors when an image is displayed and the left mouse is located over the image. One click on the middle mouse button is used to freeze the zoom window display and enable the left mouse to select colors from the zoom window. When the zoom window display is frozen, the left mouse will be disabled from selecting colors from the image display window. To unfreeze the zoom window and enable the left mouse for color selection from the image display window, click the middle mouse a second time. The right mouse button calls a pop up menu for selecting either the RGB Material Editor, the Image Editor or to quit NPSME.

2. Selected Color Display Window

The selected color display window is a small version of the material display window in the RGB editor. When the left mouse is enabled for color selection the color of the pixel that is pointed to by the mouse will be displayed on the half cylinder in the selected color display window. When the left mouse is not enabled for color selection, only the background checkerboard will be displayed in the selected color display window.

3. Zoom Display Window

The zoom display window is 200 pixels wide and 200 pixels high. The zoom display will show an enlargement of the area in the image display window located around the pixel pointed to by the mouse (see Figure 3.7). The enlargement or zoom factor default is 4. This means a box from the image display window 50 pixels wide and 50 pixels high centered around the mouse will be enlarged to fill the zoom window. The zoom factor may be adjusted using the "+ Zoom" or "- Zoom" buttons from the options button group. The zoom factors are not sequential, but are specified to smoothly display the selected area from

the image display window in the zoom display window. The zoom factors available are 1, 2, 4, 5, 10, 20, 50, and 100. Above a zoom factor of 10 the portion of the image display window enlarged in the zoom window becomes distorted and unrecognizable as part of the image. The zoom window was included to allow the selecting of the color of any pixel in the image display window.

4. Changing The Zoom Factor

To change the zoom factor use the left mouse to select either the "+ Zoom" or "- Zoom" buttons from the options button group. The zoom factor will be increased or decreased to the next zoom factor available. The zoom factors available are 1, 2, 4, 5, 10, 20, 50, and 100. Above a zoom factor of 10 the portion of the image display window enlarged in the zoom window becomes distorted and unrecognizable as part of the image.

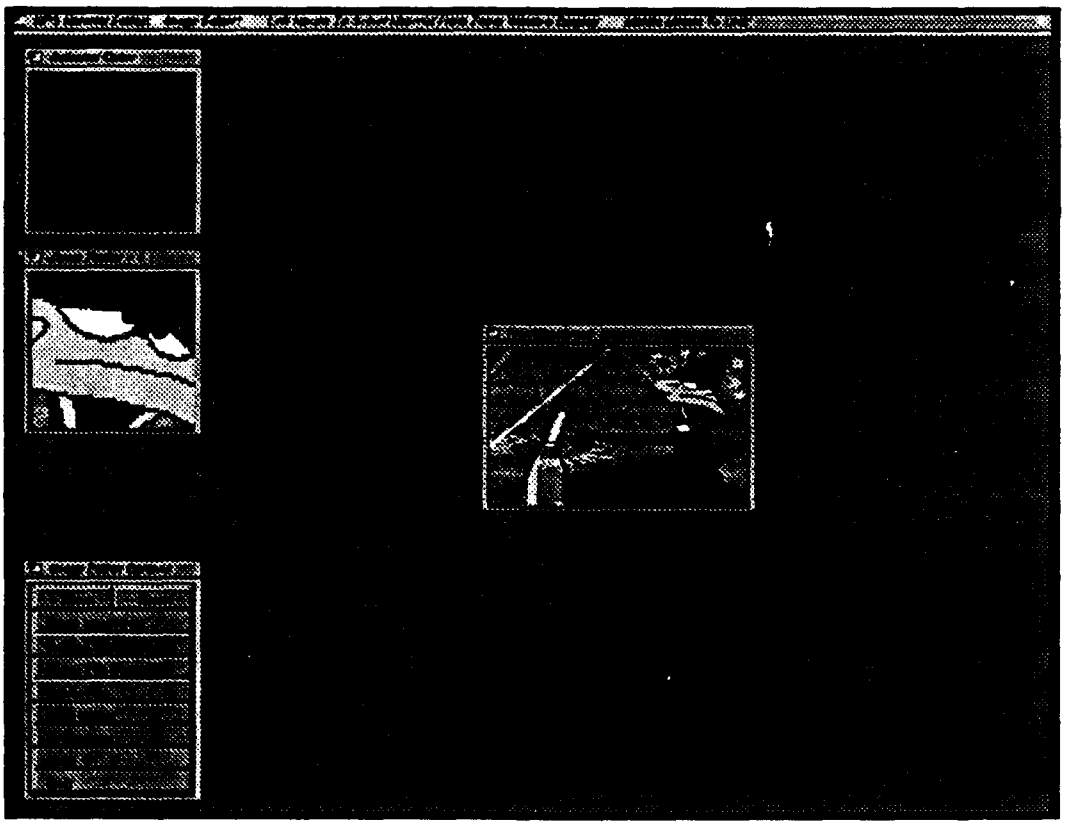

Figure 3.7 Image Editor

5. Selecting An Image For Display

To chose an image for display and editing, use the left mouse to select the "Select Image" button from the options button group. The select file panel will be displayed. Select a file to display from the left menu. The files in the current directory that will be available in the left menu are those files that have the suffix ".bw", ".eps", ".gif", "rle", or "sgi". The files displayed for selection can be filtered by using the left mouse to select the appropriate file display button under the file menu. The chosen image file will be displayed in the image editor and the left mouse will be enabled for color selection (see Figure 3.7). Currently, only ".gif" files can be displayed by the image editor. The routines to display ".bw", ".eps", ".rle", and ".sgi" files have not yet been implemented. Use the left mouse to choose the "Cancel" button to stop the select file process.

6. Rolling Image Display

The rolling image display will show each ".gif" file in a directory, one at a time, for approximately three seconds each. This allows the user to review all the ".gif" files in a directory. When an interesting image is found, the rolling image display can be halted, color selections made, and then the rolling image display restarted. To review all the ".gif" files in a directory, use the left mouse to select the "Rolling Image" button from the options button group. The image review panel will be displayed.

a. Selecting Start Image For Rolling Image Display

To choose the start image for the rolling image display use the left mouse button to select the "Select Start File" button from the image review panel. The select file panel will be displayed. Only ".gif" files can be currently displayed by the image editor, so ensure the ".gif" file filter button is on. Select a file to start the rolling display from the left menu. The select file panel will then be closed and the rolling image display started. Each image in the current directory will be displayed for approximately three seconds before the next image in the list displayed. The left mouse will not be enabled for color selection until the "Edit Image" button on the image review panel is chosen.

b. Starting The Rolling Image Display

The rolling image display will automatically be started when the start file is chosen from the select file menu. If the rolling image display has been halted for color selection, it can be restarted by using the left mouse to select the "Start Review" button from the image review panel.

c. Stop The Rolling Image Display For Editing

To halt the rolling image display and enable the left mouse for color selection use the left mouse to select the "Edit Image" button from the image review panel. The middle mouse can now be used for freezing the zoom window for zoom window display color selection. The current image will remain displayed for editing until the rolling image display is started again or a new image selected.

d. Stop The Rolling Image Display

To stop the rolling image display, use the left mouse to select the "Cancel" button from the image review panel. This will halt the rolling image display and close the image review panel.

7. Converting Image Formats

The "Image Conversion" option button has not been implemented.

8. Deleting A File

The "Delete File" option button has not been implemented.

9. Selecting The Image Editor

To move to the RGB material editor use the left mouse to select the "RGB Editor" button from the options button group or use the right mouse to access the pop up menu and select the "Open RGB Editor" option. The RGB material editor will then be displayed.

10. Setting Preferences

The "Preferences" option button has not been implemented.

11. Help

The "Help" option button has not been implemented.

12. Quitting NPSME From Image Editor

To quit NPSME use the left mouse to select the "Quit" button from the options button group or use the right mouse to access the pop up menu and select the "Quit" option.

IV. NPSME LIMITATIONS

The Naval Postgraduate School Material Editor (NPSME) provides the means to create, edit, and manage material specifications and their files on the Silicon Graphics Inc. IRIS 4D workstation. The material specifications edited using NPSME appear correct when displayed on the IRIS 4D workstation. There is a great need in computer graphics to make video recordings of executed programs. Here a problem arises that NPSME does not solve. Video recordings are typically made for display on a National Television System Committee (NTSC) monitor. The IRIS 4D workstation has an RGB monitor. The display color becomes distorted when the output signal from a RGB monitor is converted to an NTSC signal. This is caused by the red, green, and blue phosphors having different values on NTSC and RGB monitors. "You can not critically preview imagery intended for NTSC using RGB imagery" (Hall, 1989, p. 139). This effect can be dramatic for the color red. The present solution to this problem is to view the NTSC monitor while using NPSME to edit material specifications on the IRIS 4D workstation. Materials defined this way will appear as desired when displayed on a NTSC monitor, even though they will not look quite right on the IRIS 4D workstation.

V. FUTURE RESEARCH

There are several Naval Postgraduate School Material Editor (NPSME) features that were not implemented due to time constraints. These are presented for further NPSME development. Suggestions for future research are also included.

A. DELETE FILE OPTION

Implement a feature to delete ".mat", ".off", ".bw", ".eps", ".gif", ".rle", and ".sgi" files. This will aid directory maintenance while running NPSME.

B. COLOR SMEAR DISPLAY OPTION

Implement a color smear display. This would be a three dimensional RGB color cube from which to select colors. The coordinate axis would be red, green, and blue. The cube would exist in the positive octant with the black (0, 0, 0) corner being the origin. The opposite corner would be white (1, 1, 1). The other corners would be red (1, 0, 0), green (0, 1, 0), blue (0, 0, 1), cyan (0, 1, 1), magenta (1, 0, 1), and yellow (1, 1, 0). Gouraud shading would be used on the faces of the cube. The cube could be rotated to allow viewing of all its faces. When an interesting color is seen, a slice perpendicular to the cube face could be taken at that point. These slices would be squares. Gouraud shading would be used in the slice. A desired color could then be picked off the slice display.

Alternately, instead of taking slices through the cubes faces, slices would be taken perpendicular to the neutral color axis which runs from the black (0, 0, 0) corner to the white (1, 1, 1) corner. A slider could be used to change the value on the neutral axis through which the slice is taken. A desired color could then be picked off the slice display.

C. PREFERENCES OPTION

Implement a preferences option to allow the user to change the colors of the material display checkerboard. The ability to change the half cylinder background would provide a means to check color contrast compatibility with the materials being edited.

D. HELP OPTION

Implement a help option to provide users with on line help. Use the Panel Designer and Toolbox (King and Prevatt) file view to display a help text file.

E. IMAGE CONVERSION OPTION

Implement an image conversion option in the image editor to allow users to access the full capabilities of the image processing programs. These would provide for converting an image from one format to another while running NPSME instead of having to do the image conversion before executing NPSME.

F. SAVING MATERIAL ".off" FILES

NPSME will read a ".off" file and extract all its materials. The materials from the ".off" file are sent to the File List. After editing, these materials can be saved to a file, but they can not be saved back to the ".off" file. Saving the materials back to the ".off" file would save user effort in text editing the ".off" file to incorporate the new material changes.

G. FILTERED MATERIAL REPLACEMENT

Implement a routine for the filter material list function that would conduct a complete directory search of material files and replace the duplicated material names with the single remaining material from the duplicated group. This would save user effort, as presently the user would have to look at the deleted material file generated by the filter material list function and then manually search files and replace materials.

H. 3D ICON EDITOR

Add a new editor to NPSME that would allow for the display and editing of the materials on a 3D icon. The 3D icon could be displayed in the editor and viewed from all angles. Each polygon forming the 3D icon could be selected and the material of that polygon edited. Then the resulting changes to the 3D icon could be saved to a file.

I. ALTERNATE COLOR SPACES

Add to NPSME the capability to convert to, display, and edit materials in alternate color spaces such as HSV (Hue, Saturation, Value) hexcone and HSL (Hue, Saturation,

Lightness) double hexcone, double cone, and cylinder. These color spaces are "intended for ease of color selection" (Hall, 1989, p. 47).

J. RGB AND NTSC COMPATABILITY

Implement color space conversion functions (Hall, 1989). This will not solve the RGB to NTSC problem presented in chapter 4, but would provide information on which RGB colors could be converted to valid NTSC colors.

APPENDIX A

A sample material specification file looks as follows:

```
defmaterial black
    emission      0.000000 0.000000 0.000000
    ambient       0.000000 0.000000 0.000000
    diffuse       0.000000 0.000000 0.000000
    specular      0.000000 0.000000 0.000000
    shininess     0.000000
    alpha         1.000000
defend

defmaterial blue
    emission      0.000000 0.000000 0.000000
    ambient       0.000000 0.000000 0.200000
    diffuse       0.000000 0.000000 1.000000
    specular      0.000000 0.000000 0.000000
    shininess     0.000000
    alpha         1.000000
defend

defmaterial gold
    emission      0.000000 0.000000 0.000000
    ambient       0.400000 0.200000 0.000000
    diffuse       0.900000 0.500000 0.000000
    specular      0.700000 0.700000 0.000000
    shininess    10.000000
    alpha         1.000000
defend

defmaterial yellow
    emission      0.000000 0.000000 0.000000
    ambient       0.200000 0.200000 0.000000
    diffuse       1.000000 1.000000 0.000000
    specular      0.000000 0.000000 0.000000
    shininess     0.000000
    alpha         1.000000
defend
```

APPENDIX B

The following is a sample file created by the NPSME filter material list capability:

```
Fri Dec 14 02:40:55 1990

dummy.mat

Filter Setting:  First Decimal Place

Deleted Material                    Duplicated By Material

alice_blue_0_2                      alice_blue_0_1
alice_blue_0_3                      alice_blue_0_1
alice_blue_0_4                      alice_blue_0_1
alice_blue_0_5                      alice_blue_0_1
alice_blue_0_6                      alice_blue_0_1
```

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