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Comparative study of digital texture mapping and analogue material

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Introduction

Digitalization has transformed design radically in the past few decades. In the early 60's, architect Utzon had to struggle to find a feasible structural solution for the free-form curved surface that he designed for the Sydney Opera house. Four decades later, Frank Gehry could create very complex geometric models with ease. It is clear that the digital revolution is producing a similar revolution in design by providing new intellectual tools (Mitchell, 1999). Nevertheless, it is always a challenge for designers to learn and employ the new technologies to their practice. Two groups of people are involved in this revolution: the developers (software engineers) and the users (designers). The revolution cannot exist if either one is not participating. However, often a disconnection exists between them that may slow down the process.

The disconnection can occur in three ways: vocabulary, concept and categorization. Software engineers have used vocabulary that is elusive to designers. Designers are familiar with materials, vinyl, carpet, plastic laminate and paint, yet very few know Raytrace, Blinn, Phong and Anosotropic. They also know form, shape, contour and volume, but not editable mesh, NURBS, normal, Boolean and polygon. Furthermore, not only the terms in the two professions are different, but also the fundamental concepts. For instance, the designer's concept of materials is more limited than the software engineer's concept of texture mapping. For software engineers, texture mapping is "a method of varying the surface properties from point to point in order to give the appearance of surface detail that is not actually present in the geometry of the surface" (Ebert, Musgrave, Peachey, et. al., 2002). It was "introduced as a method of adding to the visual richness of a computer generated image without adding geometry" (Turk, 1991). Software engineers employ texture mapping as a means to reduce the amount of time for computation. Lighting effect, shadow, even structure can all be applied to the surface as texture mapping. However, it is evident that treating lighting, shadow or structure as textures is a foreign concept for designers who have the tendency to think that textures can only mean materials as they normally do in the analogue world. As a result, many of the functions created by the engineers are not used by designers. In addition, many designers also encounter obstacles while choosing and learning new technologies due to the vast number of choices - AutoCAD, 3DS Max, Maya, Rhino, Form-Z, SketchUp, just to name a few. Therefore, comparative studies of the recent development in 3D visualization are needed in order for designers to take full advantage of those new technologies.

Objective of Study

The goal of this paper is to establish links between the two bodies of knowledge so that designers can utilize the new digital tools more effectively. The focus of this paper is on the commonalities and differences of material and texture mapping techniques among 3D rendering softwares, namely 3DS Max (including Viz), Maya, AutoCAD, Rhino, Revit and SketchUp. Three aspects of material mapping techniques can be compared among these 3D rendering products: vocabulary, concept and categorization. However, this paper will discuss only the vocabulary in material and texture mapping used among those softwares. Future study on the two other aspects of material and texture mapping among the current 3D softwares is recommended. The result of this comparative study may help software engineers to better understand how designers view and use computer graphic products.

The Concept of Texture Mapping vs. Material

The texture mapping technique has progressed dramatically since the beginning of 3D rendering products. It has become more complex as it continues to develop. However, the foundation of texture mapping has not changed. Paul Heckbert summarized the development on texture mapping in 1986. He stated "The possible uses for mapped texture are myriad. Some of the parameters that have been texture mapped to date are, in roughly chronological order:
surface color
specular reflection
normal vector perturbation (bump mapping)
specularity transparency
diffuse reflection
shadows, surface displacement
local coordinate system" (Heckbert, 1986)

These texture mapping techniques and terminologies are still used today. Software engineers in computer graphics are familiar with the development and terminologies. Nevertheless, it has not been easy for designers to understand the terminologies used in 3D software industry without taking lessons beyond the scope of design. Some terminologies coming from the name of a person who has had significant contribution to the software industry are especially unfamiliar to designers. For instance, "Phong" and "Blinn" are surnames of two important pioneers in computer graphics: Bui Tuong Phong (History of School of Computing at University of Utah) and Jim Blinn (Microsoft research). Designers could have guessed that those material balls they are struggling with are named after people; however, they would not have known any of computational methods and rendering properties. Some functions have never been fully understood by designers who are using those 3D graphic products. Designers classify 3D graphic products as intuitive and indirect. In general, high-end design softwares are more expensive and less intuitive. They can produce superior rendering results; however, they require numerous hours of training in order to operate properly. As a result, design firms are reluctant to purchase expensive commercial 3D packages and send their personnel for training; instead, they turn to less expensive

and intuitive 3D products (Acheson & Hardin, 2003). The question to ask is how intuitive are they? Why is one 3D rendering software package more intuitive than another? Merriam-Webster online defines the term "intuition" as "quick and ready insight," "immediate apprehension or cognition," and "the power or faculty of attaining to direct knowledge or cognition without evident rational thought and inference." Nevertheless, no previous research has compared the current 3D products in a sense of how intuitive they are and how they are designed in terms of vocabulary, concept and categorization. This paper is the foundation of research on intuitivism of current 3D graphic products. However, it will not directly answer the question of whether a given software is intuitive or not.

Research Methodology

This research is a descriptive study. It seeks to describe the commonalities and differences of vocabulary used among current 3D rendering softwares, namely 3DS Max 2009, Maya 8.5 personal learning edition, AutoCAD 2006, Rhinoceros 4.0, Revit Architecture 2008 and Google SketchUp 6 relevant to designing materials. The versions were chosen entirely based on the availability. However, the author believes that the different versions should not affect this research greatly. This paper also compares the complexity of material and texture mapping technique among those softwares.

Prior to this study, the author is familiar with how to design materials and apply textures to materials in 3DS Max (including Viz) and AutoCAD, but not in Maya, Rhino, Revit and SketchUp. For the purpose of this study, the author developed a systematic method of determining where to find information that is relevant to this research. The procedures are: 1) Go to Help (Help is available in every software) and type in three phrases relevant to this research: material, texture, mapping; 2) Count the number of topics found through search that are relevant to designing materials; 3) Read all the topics and learn how a basic material is designed; 4) Identify terms and find the common one shared by many softwares and the unique one used by one software; and 5) Identify terms shared by designers and software engineers.

The systematic procedure is comprised of two aspects of research: data collection (Step 1-3) and data analysis (Step 4-5).

Data Collection

The author followed the data collection procedure developed from research methodology and typed "material,""texture" and "mapping" into the search from Rhinoceros 4.0, Revit Architecture 2008, Google SketchUp 6, 3DS Max 2009, Maya 8.5 personal learning edition and AutoCAD 2006.

The results of data collection and methods of designing materials are:

Rhinoceros 4.0 evaluation

Through search, the author found four topics related to designing materials: Material mapping options, material properties, object properties, and texture mapping properties. The author found no unique terms in Rhino. In addition, all the terms and phrases used in Rhino are common in

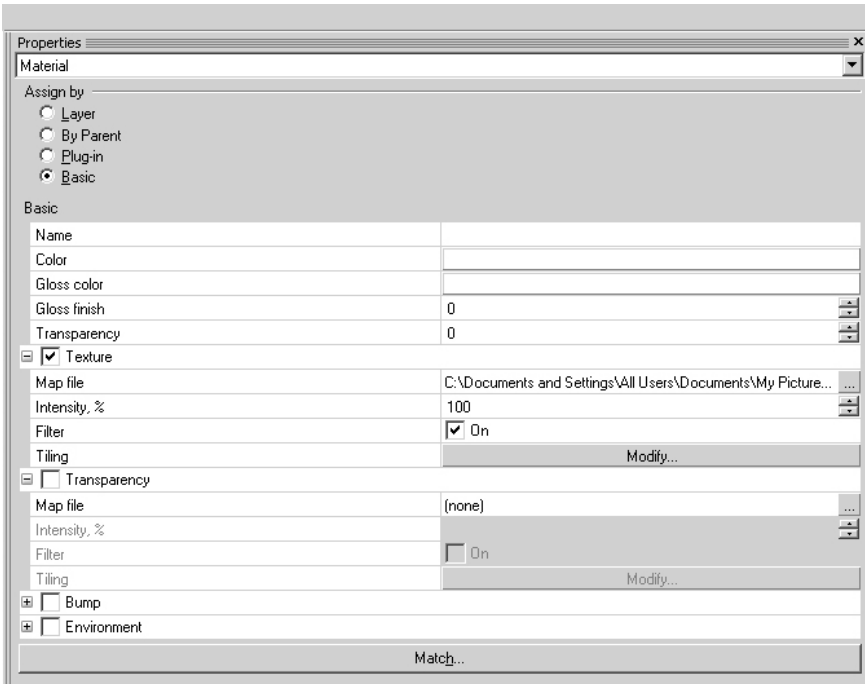

Figure 1
Basic Material Properties in **Rhinoceros 4.0**

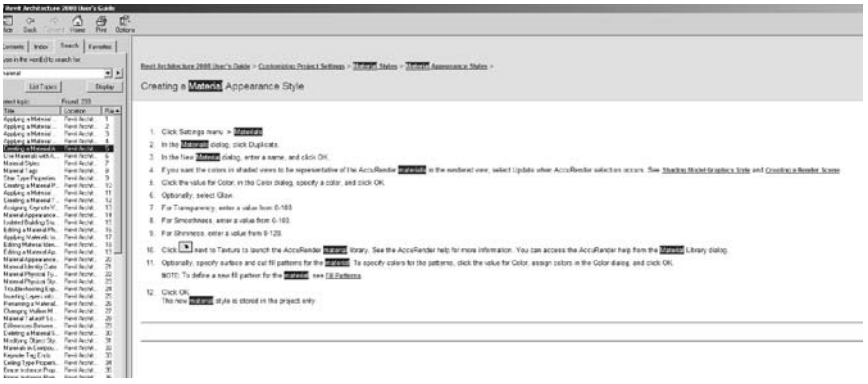

Figure 2
Explanation of creating a material appearance style in **Rhinoceros 4.0**

English and can be understood by designers without special training. For instance, gloss finish and transparency are common words and can be found from www.merriam-webster.com. The method of designing a basic material in Rhino is explained below.

"Basic Material Properties (see Fig. 1)
If you select the Basic option for assigning render properties, you can set the color, finish, transparency, texture, and bump for use by the built-in Rhino renderer.

1) Name
Names the material.
2) Color
The color used to render surfaces, polysurfaces, or polygon meshes. To change the render color, click the color swatch and select a color in the Select Color dialog box.
The color option does not affect the select wireframe display. To change the color of the wireframe display, change the color of the object's layer or set the color on the Object page.
3) Gloss color
Sets the highlight color. Note: Set the highlight color to match the base color for metallic materials. Set the gloss color to white for plastic materials.
4) Gloss finish
Adjusts the highlight from matte to glossy.
5) Texture
Defines the name of a bitmap file that will be mapped onto the surface when you render the scene.
6) Properties - Transparency
Adjusts the transparency of an object in the rendered image.
7) Properties - Bump bitmap
Defines the name of a bitmap file that will be mapped on the surface as a bumpmap when you render the scene.
8) Properties - Environment
Defines the name of a bitmap that will be mapped onto the surface as though it were being reflected." (This information was found from Rhinoceros Help)

Revit Architecture 2008

The author followed the research procedure and typed "material" into the search from Revit Architecture 2008 Help. 203 topics were found by Revit as relevant topics for material; however, the author investigated all 203 topics and found many are repeated topics. In fact only four topics are relevant to designing a material: creating a material appearance style, use materials with AccuRender Textures that reference Bitmaps, Raytrace, and specify Raytrace setting (see Fig. 2). Search for "texture" and "mapping" did not yield any new topics regarding designing a material.

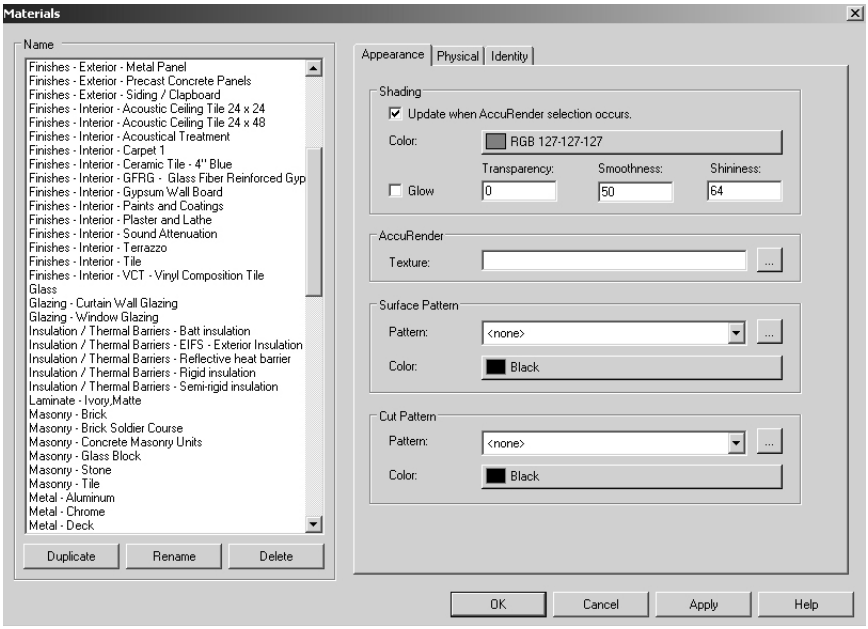

Figure 3
Design materials in **Revit**

The author found two unique terms in Revit through search procedure: AccuRender and Raytrace. They are not common words in English. It is possible that more unique terms exist in Revit but were not found through this search procedure. However, the number should be very limited. Further investigation led to a conclusion that AccuRender is unique to Revit, and Raytrace is a common term by shared many 3D rendering softwares. The method of designing a basic material in Revit is explained below (see Fig. 3).

"When you assign materials to elements, some material parameters are defined in Revit Architecture (such as color). Other material parameters (such as texture) are defined by AccuRender. If the AccuRender textures use bitmaps, then 3ds Max is able to successfully render the textures on assigned surfaces.
In Revit Architecture, click Settings menuMaterials to edit materials
More complex textures, however, may be defined using AccuRender procedures for combining materials. (For example, the marble procedure combines a Base material with a Vein material.) These are called procedural materials.
If the AccuRender materials are procedural, 3ds Max translates the material at the most basic level. It displays colors and other settings defined by Revit Architecture but ignores the AccuRender procedural texture.

After you bring a Revit 3D view into 3ds Max, you can use its Material Editor to refine the texture on objects whose materials are not translated properly. To minimize the number of objects that do not have the appropriate textures in 3ds Max, use materials with textures that use AccuRender bitmaps whenever possible." (This information was found from Revit Architecture 2008 Help –User's Guide).

Google SketchUp 6

The author followed the research procedure typed "material" into the search from Google SketchUp 6 Help – online User's Guide. 34 topics were found by SketchUP as relevant topics; however, the author only found two topics that are related to designing a material: Material Browser and Paint Bucket Tool (see Fig. 4).

The author also typed in "texture" and "mapping" and did not find new topics relevant to this research. The author found no unique terms. In addition, all the terms and phrases used in SketchUp are common in English and can be understood by designers without special training. The method of designing a basic material in SketchUp is explained below.

"SketchUp contains a library of predefined materials that you can apply to faces and edges in your model. The Material Browser is used to organize materials and colors into libraries and to select and to apply materials to your model.

Activate the Materials Browser either by clicking on the Paint Bucket Tool or by selecting Material Browser from the Window menu.

Applying Materials

There are multiple methods to apply a material to entities in your model. To apply materials using the Paint Bucket Tool:

Select the Paint Bucket Tool. The cursor will change to a paint bucket. The Materials Browser will open.
Click on the Select tab.
Locate and click on a material library within the drop-down list.
Click on the material you want to use.
Click on a entity to apply the color or material to the entity.

Editing Materials

Changes made a material will automatically apply to the entities in the model painted with that material. This behavior allows you to interactively experiment with color variations in your model. To edit a material:

Select the Materials menu item. The Materials Browser is displayed.
Click on the Select tab.

material Search

Rank	Title
1	Position Texture Tool
2	Material Browser
3	Paint Bucket Tool
4	Adding Detail to Your Models
5	3D Model (3DS) Export
6	Display Settings Dialog Box
7	Entity Info
8	3D Model (VRML) Export
9	Glossary
10	Context Menu Items
11	Group
12	Component
13	2D Vector File Formats
14	Model Info Dialog Box
15	Reorienting Materials
16	Tools Menu
17	Select Tool
18	Matching Photos and Models
19	Image
20	Window Menu
21	Context Menus
22	Model Settings and Managers
23	3D Model (FBX) Export
24	3D Model (XSI) Export
25	3D Model (OBJ) Export
26	Drawing Quickly
27	Application Preferences
28	3D Model (DAE) Export
29	What's New in this Release?
30	Layer Manager
31	Get Current View Button
32	2D Graphic Import
33	2D Graphic (Epix) Export
34	Color Pickers

Figure 4
Search results of "material" in **SketchUp**

Click on the In Model library drop-down list.
Click on one of the materials. The material appears in the material thumbnail.

Click on the Edit tab.
Modify settings in any of the material. Refer the Edit Panel for further information.
(optional) Save your changes to the edited material:

Click on the In Model button. The In Model library is displayed.
Context-click on the edited material. The In Model context-menu is displayed.
Select the Save As menu item.
Navigate to a directory (folder) where you want to save the style.
Type a name in the File name field and click the Save button. The file is saved. Refer to the Open or create a library context-menu item for information on how to retrieve this material for use in other SketchUp files." (This information was found from SketchUp User's Guide)

3DS Max 2009

"Material" was typed into the search of Autodesk 3DS Max Help, and 500 topics were found by Max as relevant topics. This is to be expected due to the complexity of Max. Because of the

large number of relevant topics, 20 random numbers were generated in order to reduce the time of reading all 500 topics (http://www.random.org/integers/, see Fig. 5). This number of randomly generated numbers should be increased for a more precise study. Twenty topics according to the randomly generated numbers were analyzed as whether or not they are relevant to designing materials. These are the topics found through random selection:

316 Blinn shader
163 3ds Max materials in mental ray renderings
71 Raytrace material
147 Using Multi/Sub-Object Materials with Particle Systems
407 Select By Material ID Dialog
22 Raytrace Maps Rollout
28 Materials and Linked Revit Objects
2083 D Displacement Shader (mental ray)
255 Put to Library Dialog
219 Schematic View Preferences Dialog
127 Tiles Map (Appeared twice from random selection)
268 Plastic/Vinyl ProMaterial (mental ray)
170 Cool
39 Clean MultiMaterial Utility
129 Make Material Copy
49 Render to Texture: Baked Material Rollout
270 Select Bitmap Image File Dialog
410 Coordinates Rollout (3D)
404 Lathe Modifier

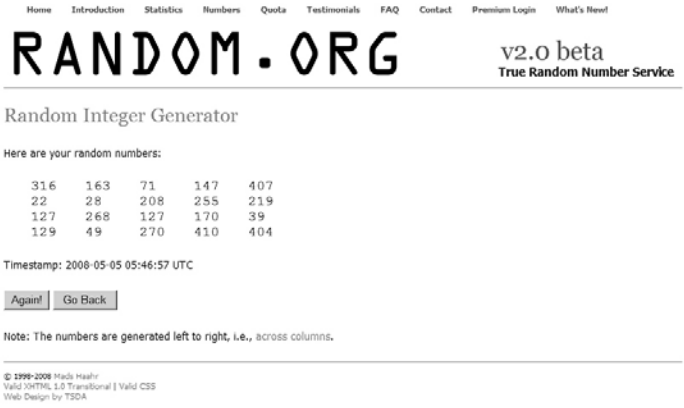

Figure 5
Random numbers generated by random.org

Among these twenty topics, the author only found six topics that are not related to designing a material. They are topic 28, 255, 219 170, 129 and 404. The other fourteen topics are relevant to designing material or applying texture mapping. The relevant topics consist of 70% of all randomly selected topics. If one applies this ratio to the total number of 500 topics resulted from the search, the number of topics that are relevant will be 350. When "texture" and "mapping" were typed into search, 312 and 500 topics were found respectively by Max. The author did count how many topics are repeated with the search results of "material;" however, she expected both repeated topics and new topics from the new search. Given the large number of search results, the author is not able to determine the accurate number of relevant topics at this stage. The assumed number of relevant topics is between 300 and 500.

From reading the titles of twenty randomly generated topics, the author found four terms that are not common English words: Blinn, Raytrace, Mental Ray and ProMaterial. Among these four unique terms, Blinn is unique to Max (can also be found in Maya, which is another high-end software, but not in other softwares from this research), and Raytrace and Mental Ray are shared terms by many 3D rendering softwares. ProMaterial is unique to Max; however, it is just another name for mental ray materials. The previous assumption is that there are a minimum of 300 and a maximum of 500 possible topics relevant to this research. Twenty out of the total of 300 to 500 were examined, and 4 unique terms were found. According to the law of probability, if there are 4 unique terms found out of 20 topics, there should be 60-100 of them existing in Max. However, it is expected that many of the unique terms resulting from different searches are repeated. The actual number should be smaller, but it is unknown at this stage.

This initial finding showed the complexity of Max. The method of designing a basic material in 3ds Max is too complex to be included in this paper.

Maya 8.5 personal learning edition

"Material," "texture" and "mapping" were typed into the search of a subcategory called "rendering and render setup" under Maya85 PLE Online Help. Many topics were found. The number is very large and has not been counted at the present time (see Fig. 6). However, it is apparent that the search result shares a lot of similarity with the search result of Max. The vocabulary found in the search results including "phong" and "Blinn," which also appeared in the search results from Max. The method of designing a basic material in Maya is also too complex to be included in this paper. Similar to Max, the actual number of unique terms is virtually unknown at this stage of research.

AutoCAD 2006

The author found 13 relevant topics through search of "material", "texture" and "mapping":
Materials Dialog Box
Define and Modify Material
Specify How to Apply the Map

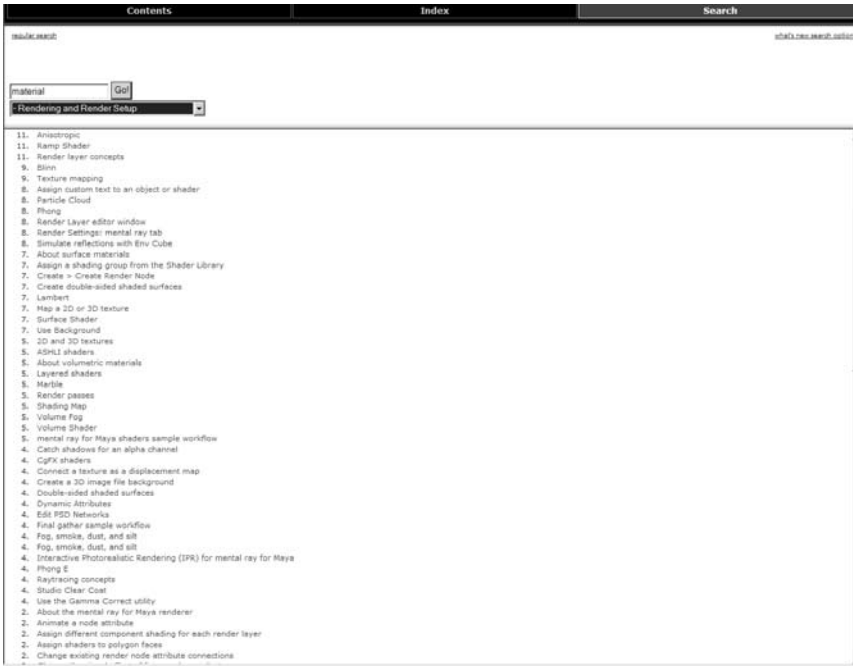

Figure 6
Search results of “material” in **Maya**

Specify a Type of Map
Adjust Material Bitmap Placement Dialog Box
New or Modify Granite Material Dialog Box
New or Modify Marble Material Dialog Box
New or Modify Wood Material Dialog Box
To change a material from matte to shiny
RMAT Command
Adjust UVW Coordinates Dialog Box
Mapping Dialog Box
Specify How to Apply the Map

Two unique terms in AutoCAD 2006 were found: RMAT and UVW. They are not common words in English. RMAT is unique to CAD. UVW is a common term shared by many 3D rendering software packages.

The method of designing a basic material in AutoCAD is explained below.

"To define a new material
Click View – Render- Materials
In the Materials dialog box, click New.
In the New Standard Materials dialog box, enter a name in the Material Name box.
The name must be unique and have no more than 16 characters.

Set the color and specify a value for each of the following material attributes: Color/Pattern, Ambient, and Reflection, or specify material attributes for Roughness, Transparency, Refraction, and Bump Map.

Set the color and value for Color/Pattern.
Color is the base color reflected by the object, also known as diffuse reflection. The main (diffuse) color of the material can be viewed in the sample image. You can adjust the color with the Value and Color controls.

Pattern is defined as a bitmap image that consists of an arrangement of pixels (picture elements). Patterns can include any bitmap file types supported by the program.

Set the color and value for Ambient.
The settings for Ambient adjust the material's shadow color. The Ambient settings also determine the color reflected from ambient light.

Set the color and value for Reflection.
The Reflection settings determine the color of the reflected highlights, also known as specular reflection.
.
For Photo Raytrace, Value specifies the material's coefficient of reflectivity. This is the amount of a reflected ray's color to add to a surface where the ray strikes.

For a shiny effect, set the value for Reflection to 0.7, and set the value for Color to 0.3. If you want the color of the highlight to be white, move the Red, Green, and Blue sliders until each has a value of 1.

Set the value for Roughness.
The Roughness setting determines the size of the reflected highlight.

Set the value for Transparency.
The Transparency setting can make all or part of an object transparent or translucent.
Set the value for Refraction.
The Refraction setting sets a refraction index for transparent materials. Refraction values have no effect unless you enter a nonzero value for Transparency.

Set the value for Bump Map.
The Bump Map setting determines the brightness of a bump map object. Bump Map values are translated into apparent changes in the height of the surface of an object.

Click Preview to see if the values you specified produce the effect you want.
Change the values and continue to preview your changes until you're satisfied with the material's appearance. Click OK.
Render toolbar

Command line: RMAT" (This information was found from AutoCAD 2006 Help)

Data Analysis

Three aspects of material, texture and mapping were compared:

A. Number of topics found to be relevant to designing materials through search;

B. Number of unique terms used by one software; and

C. Unique terms created by software engineers (These terms are not common English words and may appear to be elusive to designers).

Name of the software	A. Number of relevant topics found through search	B. Unique terms used only by this software	C. Unique terms used only by software engineers (not common English words)
Rhinoceros	4+	None or limited number	None or limited number
Revit Architecture	4+	2+	1+
Google SketchUp	2+	None or limited number	None or limited number
3DS Max	300-500	Unknown, expected to be a big number	Unknown, expected to be a big number
Maya	Unknown, expected to be a big number	Unknown, expected to be a big number	Unknown, expected to be a big number
AutoCAD	13	1+	2+

Table 1
Comparison of topics and unique terms relevant to material and texture among 3D rendering softwares

Conclusion

Given the focus of this research, the conclusions are only valid for the aspect of designing materials among those software packages included in this research. This table offers some insight into many aspects of those 3D software packages that are included in this research. It is evident that the bigger the number under category A is, the more complicated the software gets when it comes to designing materials. The figure in category A is the indicator of how complex the software is. Software packages rank from the most complex one to the simplest one: 1) 3ds Max and Maya, 2) AutoCAD, 3) Rhino and Revit, and 4) SketchUp. This paper suggests that the number under category C can be used as an indicator for how intuitive the software packages are to the designers. The reason behind it is that the more familiar the designers are with the vocabulary used in one software, the easier it is for them to use it. If a designer has to constantly go to Help and search for a definition of one particular word, the software will not be intuitive to the designer. If this assumption can be verified by research from other disciplines, the following statement can be made: SketchUp and Rhino are the most intuitive software packages to the designers, followed by Revit, then by AutoCAD. Max and Maya are the most difficult ones to learn. The conclusion drawn from column B is that if someone has prior experience with the more complex software packages such as Max or Maya, it should be easy for them to learn other software packages. Among those software packages, SketchUp and Rhino are the easiest to learn, followed by AutoCAD and Revit.

Future study

The result of this study can be used as the foundation for questionnaire to collect data from designers and design students regarding their learning experiences on various 3D graphic software packages. The hypothesis such as “the higher percentage of phrases shared by design and software development, the easier for designers to learn the software” can be tested and verified. The study of material and texture among various software packages can be further complicated by plug-ins that are commonly used for these computer graphic software packages. For instance, V-Ray is available for Max, SketchUp, Maya, Rhino and Revit. Future study regarding how V-ray is incorporated to those stand-alone software packages is suggested.

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