Quality of different surface mapping techniques

Kvalitén hos olika textureringstekniker

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Author: Johanna Zhang
Supervisor: Lars Kjelldahl
Examiner: Lars Kjelldahl
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Abstract

Quality of Different Surface Mapping Techniques

Quality of different surface techniques was investigated in an experiment where eleven subjects evaluated the quality of pictures on a screen. The experiment consisted of three different scenes, three surface mapping techniques, two types of illumination, and two camera positions. The subjects were asked to rank the test images for realism and usefulness on a scale from 0 to 10. Results indicated an increased quality in the following order: ordinary texture mapping, bump mapping, displacement mapping. However, bump mapping were not superior to ordinary texture mapping in conveying realism. Results also showed that the type of illumination had significant effects on image quality and the surface techniques with directional light superior to ambient light. Camera position had no discernible effects on image quality.

Sammanfattning

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Preface

This Master’s project was carried out at NADA, KTH, and is aiming at completing a Master of Science degree in Computer Science at Stockholm University.

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Contents

1  Introduction............................................................................................................. 7
   1.1  Surface mapping techniques.......................................................................... 7
   1.2  Aim of this project ......................................................................................... 7
   1.3  Delimitations.................................................................................................. 8
2  Theories in Image Quality Assessment................................................................. 9
   2.1  Three dimensions of image quality assessment ........................................... 9
   2.2  Factors determining image quality ............................................................... 9
      2.2.1  The field of application ................................................................... 9
      2.2.2  The end user of the system ............................................................ 10
      2.2.3  The system parameters and characteristics.................................... 10
   2.3  Analytical methods or experimental methods............................................ 10
      2.3.1  Analytical methods........................................................................ 10
      2.3.2  Experimental methods................................................................... 10
3  Related Work ........................................................................................................ 11
4  Surface Mapping Techniques................................................................................ 13
   4.1  Ordinary texture mapping........................................................................... 13
   4.2  Bump mapping............................................................................................ 14
   4.3  Displacement mapping ............................................................................... 15
5  Method.................................................................................................................. 17
6  Images ................................................................................................................... 18
7  Experiment............................................................................................................. 26
   7.1  Subjects....................................................................................................... 26
   7.2  Equipment................................................................................................... 26
   7.3  Room conditions.......................................................................................... 26
   7.4  Image combinations.................................................................................... 27
   7.5  Questions.................................................................................................... 27
   7.6  Procedure .................................................................................................... 28
1 Introduction
Surface mapping is a technique that increases the quality in computer generated images. Three common surface mapping techniques are: ordinary texture mapping, bump mapping, and displacement mapping.

1.1 Surface mapping techniques
Texture mapping, introduced in the mid-1970s, is an important technique in computer graphics. It allows us to apply textures to a graphical object to increase surface details during the rendering process, without computing additional geometry during the modeling process. For example, rendering a brick wall without using texture mapping requires hundreds or thousands of rectangles to model the bricks. With texture mapping, only one big rectangle is needed for modeling the entire wall.

Texture mapping is useful in many cases, but not good enough when simulating rough surfaces. In the above example, the wall with wallpaper of bricks still appears artificial due to its smoothness. To cope with this problem, bump mapping was introduced by James Blinn [Blinn 1978] to perturb the surface normal to increase realism in simulating wrinkled surfaces. The wall now appears rough enough to convince people that it is made of bricks. However, there are two major problems with bump mapping. The first problem is that a bump mapped surface is actually flat and will not cast shadows correctly. The second problem is that the silhouette of the object will still be smooth.

The problems in bump mapping were solved by the introduction of displacement mapping [Cook 1984, Cook 1987] which is an extension of bump mapping. In bump mapping, only the surface normals are perturbed, while the geometry is not changed. In displacement mapping, not only the surface normals are perturbed, but also the geometry of the surface is changed since points are actually moved along their normals to create a new surface. This means that the geometry is actually changed but without complete usual modeling work.

1.2 Aim of this project
The aim of this project is to investigate the quality of different surface mapping techniques as perceived by users. The images are generated with a combination of varying parameters such as texture mapping techniques, illuminations and camera positions.
The main question at issue is: How does the image quality change when we change surface mapping techniques from ordinary texture mapping to bump mapping, and from bump mapping to displacement mapping?

At the same time, we will examine how the other parameters such as illuminations and camera positions affect the judgements of images. Interesting questions are:

- Does illumination change image quality? If so, in which way does it change it?
- Does the camera position influence on the image quality?

An experiment is performed where the subjects evaluate the quality of the images. The main application we have in mind for this investigation is computer games.

### 1.3 Delimitations

As mentioned earlier, the images are mainly designed for computer games. See also Appendix for text presented to participants. However, the images and test results are also interesting for such areas as scientific visualization, entertainment, art and commerce.

The images created for the project involve only three scenes: a brick wall, a signboard, and water with floating objects. They represent some common scenes in computer games. The images are created in such a way that they cover the combination of the interesting parameters (scene, surface mapping technique, illumination, camera position) that may affect image quality. There are many other interesting scenes that are not considered in this project.

The images are static and represent mainly still scenes in computer games. Moving scenes, which also frequently appear in games, have not been treated in this investigation. The results are therefore more applicable for static applications where still scenes dominate.

The experiment is rather judgement-oriented than task-oriented. The participants evaluate image quality through observing each static picture on the screen. There is no interaction between the subjects and the images. A task to be performed by a person may give a different result than an evaluation set by the participant.
2 Theories in Image Quality Assessment

In this chapter, we will first introduce dimensions of image quality assessment, and then explain factors determining image quality as well as different approaches to image quality assessment.

2.1 Three dimensions of image quality assessment

Huib de Ridder [de Ridder 2002] discusses three dimensions for image quality [Schenkman 2002]. They are: fidelity, naturalness, and usefulness. Fidelity is defined as match between the displayed image and the external reference, for example the original image. Naturalness is defined as match between the displayed image and the internal reference, for example the image the subject has in mind. Usefulness is defined as visibility/discrimination of details in the image.

Abdou and Dusaussoy [Abdou & Dusaussoy 1999] describe the usefulness of an image as the relevance of the information presented by the image to the task we seek to accomplish using this image. They describe image fidelity as measurement of the departure of a processed image from some standard image. They describe image intelligibility as denotation of the ability of man or machine to extract relevant information from an image.

2.2 Factors determining image quality

According to Abdou and Dusaussoy [Abdou & Dusaussoy 1999], image quality is determined by the following factors: the field of application, the end user of the system, and system parameters and characteristics.

2.2.1 The field of application

The field of application affects image quality judgement, because it determines the characteristics of the task of the image. These characteristics are specific to each field. An image suitable for computer games may be of no value for aerial simulation, and vice versa.
2.2.2 The end user of the system
For a human observer, image quality assessment should be based on a psychophysical model. On the other hand, if the images are processed by a computer, the image quality measurement can be based on the classification accuracy of the system.

2.2.3 The system parameters and characteristics
When the images are designed for a human end user, we need to define the display system, the viewing conditions, and the knowledge background of the end user.

2.3 Analytical methods or experimental methods
Approaches to image quality assessment can be categorized into two types of methods: analytical methods and experimental methods.

2.3.1 Analytical methods
In analytical methods, models are built to describe the interaction between the imaging device and some simple standard signals; these models are used to predict the performance in practical applications.

The advantage of this approach is that it is more general and does not require expensive equipment. The disadvantage is that the results may not accurately reflect the actual performance because of the approximation involved in applying the method. In many cases, the complexity of the system makes the analytical solution extremely difficult.

2.3.2 Experimental methods
In experimental methods, test models are built to represent various parameters of interest. Image quality is then measured by either rating the images using human observers or by introducing a figure of merit that takes the different imaging parameters into account.

The advantage of this approach is that it is more flexible and in many cases more accurate than the analytical method, because it can be made as close as possible to the actual application. Its disadvantage is that it is more costly, time consuming and usually involve multiple human observers.
3 Related Work

Studies with some relation to our work are reviewed in the following paragraphs.

Atherton and Caporael [Atherton & Caporael 1985] used the experimental method of multiple human observation ratings to examine the effectiveness of using polygon models to simulate curved surfaces. A total of nine polygon models were created with different polygon densities. For each polygon model, three test images were generated using flat shading, shade interpolation, and normal interpolation procedures. The subjects were asked to evaluate the image qualities by comparing each test image with two anchor images for lowest and highest quality representations. The test images were presented in random order, and the participants were asked to rank the images for form faithfulness and aesthetic appeal on a scale of 0 to 10. According to the figure of laboratory setting presented in the article, the active image region was approximately 30 cm wide and 25 cm high. The viewing distance was estimated to be 50 cm. Results indicated that the image quality changed very little using any of the shading techniques below the average polygon area of about 110 pixels per polygon for spheres of 95 pixel radii displayed on a 512x512 resolution monitor. The evaluations were close to ideal for shade and normal interpolation techniques. Atherton concluded that polygons were effective to produce smooth shaded imagery of curved surface models.

Barfield, Sandford, and Foley [Barfield, Sandford & Foley 1988] performed two experiments to investigate the effects of computer generated realism cues and to study the subjective perceived realism of computer-generated images. The first experiment, following the mental rotation paradigm, consisted of two levels of object complexity (simple, complex), four angles of rotation (0°, 60°, 120°, 180°), and two types of graphic images (wireframe, shaded). Under the shaded type of image are nested the number of light sources (one, two) and type of shading (flat, smooth). The subjects were asked to perform “same-different” discriminations for pairs of rotated three-dimensional images. Results showed that mean reaction times were faster for shaded images than for hidden-edge-removed images. In the second experiment, the subjects were asked to rate image realism. Results indicated that wireframe images were less realistic than shaded images. In addition, light sources were more important in conveying realism than surface shading, and there was no discernible effect between flat or smooth shading rendering methods on ratings of image realism.
Kjelldahl and Prime [Kjelldahl & Prime 1995] performed experiments to examine depth cues in perceiving 3D objects on static 2D scenes. The experiments consisted of two object types, two types of shading, four different depths, and four object configurations. The subjects were asked to estimate the depth of the objects and to rank certain objects for ease of depth determination. Results indicated that the placement was more important in depth estimates than the type of object and the type of shading.

Wanger, Ferwerda, and Greenberg [Wanger, Ferwerda, & Greenberg 1992] performed three experiments to study the influence of visual cues on perceived spatial relations in computer-generated images. The visual cues involved projection, shadow, object texture, ground texture, motion, and elevation. Results revealed that the effectiveness of different cues and the directions of their effects varied with the task. In the positioning task, shadow and perspective were significant. In the orienting task, perspective had negative effect, motion was effective, and shadow was a minor cue. In the scaling task, all cues were effective singly but interactions between cues accounted for most of the variation in performance. The experiments indicated that spatial manipulation on computer-generated images depended on both the nature of the task and the visual cues presented in the images.
4 Surface Mapping Techniques

Introduction of surface mapping techniques is a significant advance in the computer graphics. Surface mapping techniques increase image realism dramatically by adding interesting surface details without adding geometric modeling. In this thesis, we will examine three surface mapping techniques: ordinary texture mapping, bump mapping, and displacement mapping.

4.1 Ordinary texture mapping

Heckbert [Heckbert 1986] defines texture as a multidimensional image that is mapped to a multidimensional space. According to him, texture mapping is the process of mapping a function onto a surface in 3D. The domain of the function can be one, two, or three-dimensional, and it can be represented by either an array or a mathematical function. The most easy-to-understand type of textures is 2D texture, which can be thought of as decorative paper wrapping a colorless object. A 1D texture map is a one-dimensional array of colors that can be applied along any direction of an object. A 3D texture map is a 3D array of colors.

Texture maps can be obtained in two different ways. One way is getting an image as a texture map. Many people use images as texture maps to add surface details to the original object. For example, we can use scanned images or digital photographs of wood, sand, brick or grass as textures, and then map them or glue them to the model of these objects, thus achieve a more realistic look of them. We can also use a digital paint system to create textures such as flames or smoke. The other way is generating a texture map procedurally. Since a texture map is simply an array of color, it is possible to generate the values of the array by applying a computational process instead of reading a file. The usage of noise functions is a good example. A noise function is a single-valued function of one, two, or three variables that has no statistical correlation to any rotation or translation and that has a relatively limited amount of change in the value across a limited change in the domain. During procedural texturing, we can calculate the value of a noise function for each pixel in a textured object and use that value to determine the pixel color.

The major problem with the ordinary texture mapping technique is that it cannot simulate the irregularities on bumpy surfaces.
4.2 Bump mapping

Since ordinary texture mapping is not suitable for rendering winkled surfaces, James Blinn [Blinn 1978] presented a new mapping technique called bump mapping in 1978. Based on the observation that the light scattered from a diffuse surface depends only on the dot product of the surface normal and the light source direction, Blinn uses a texturing function to perform a small perturbation on the direction of the surface normal before using it in the intensity calculations.

The texturing function $F(u,v)$ is a two-dimensional height field called bump map. It represents some desired surface displacement. For a point $P(u,v)$ on a parameterized surface, the surface normal is defined as:

$$N = P_u \times P_v$$

Where $P_u$ and $P_v$ are the partial derivatives lying in the tangent plane to the surface at point $P$. The new surface point $P'(u,v)$ after displacement can be written as:

$$P' = P + FN$$

This process is shown in figure 1.

![Figure 1: Mapping bump function [Blinn 1978].](image)

The normal vector $N'$ to the new surface is derived as follows:

$$N' = P'_u \times P'_v$$

$$P'_u = P_u + F_u N + FN_u$$

$$P'_v = P_v + F_v N + FN_v$$


Because $F$ is small, we can ignore the final term in the equations for $P_u'$ and $P_v'$. We have:

$$N' = (P_u + F_uN) \times (P_v + F_vN)$$
$$= P_u \times P_v + F_uN \times P_v + F_vP_u \times N + F_uF_vN \times N$$

The first term is $N$ by definition. The last term is identically zero. Then we have:

$$N' = N + F_u (N \times P_v) + F_v (P_u \times N)$$
$$= N + F_u (N \times P_v) - F_v (N \times P_u)$$
$$= N + D$$

The perturbed normal vector is illustrated in figure 2.

![Perturbed normal vector](image)

**Figure 2: Perturbed normal vector [Blinn 1978].**

Although bump mapping achieve a certain degree of roughness by modifying the surface normal vectors before applying shading, it still has significant drawbacks since the surface is not "really" displaced. There are three major problems with bump mapping:

- High bumps do not cast shadows on other bumps.
- Hidden surface removal is not performed among the bumps.
- The silhouette of the object remains smooth.

### 4.3 Displacement mapping

Displacement mapping was first introduced by Cook [Cook 1984], and later described as part of the REYES algorithm [Cook 1987], where it was implemented by displacing vertices on micropolygons. Pharr and Hanrahan [Pharr & Hanrahan 1996] introduced geometry cache in a

The principle of displacement mapping is to permit a "real" third dimension to be added to the object by performing geometric perturbation as well as normal perturbation. It really created a new surface. Three basic components of a displaced surface are:

- A base surface function \( P(u,v) \) which is parameterized over a two dimensional domain and defines 3D points \((x,y,z)\) on the surface;
- A normal function \( N(u,v) \), and
- A displacement function \( D(u,v) \) that can be defined procedurally or interpolated from samples stored in an array.

The points on the new displaced surface \( P'(u,v) \) are defined as follows

\[
P'(u,v) = P(u,v) + D(u,v)N(u,v)
\]

where \( N(u,v) = N(u,v) / |N(u,v)| \)

A cross section of an example displacement mapped surface is shown in figure 3, where \( N'(u,v) \) is the normal to the displaced surface.

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*Figure 3: A cross section of a displaced surface [Doggett 2000].*
5 Method

For this project, we chose the experimental method. The test models are designed in such a way that the combination of interesting parameters are taken into consideration. After the test models are built, the method of multiple human observer ratings is used to examine the quality of the three surface mapping techniques.

Because of the involvement of human observers during the experiment process, the image quality will be measured based on a psychophysical model. Equipment, viewing conditions, and knowledge background of the observers will be recorded.

The test images will be presented individually in random order on the middle part of the screen. No anchor images will be used. The observers are supposed to refer to their experience for judging the image quality. The observer will be asked to rank the test images on a scale from 0 to 10. Test images will be presented in two rounds focusing on questions on realism and questions on usefulness respectively. Each observer will make a total of 72 judgements. Comments from the observers will also be recorded.

The data collected from the experiments will be examined using Excel diagrams. The results will be summarized through a study of the diagrams. Comments given by the observers will be structured and presented in order to give explanations and additional information.
6 Images

Three different scenes – a brick wall, a signboard, and water with floating objects – were created using Maya. They were supposed to represent some common game situations. Walls are often used to build up environment in games such as labyrinth exploring. A signboard gives text information in many different kinds of games. Water with floating objects is used in some navigation and adventure games.

Illuminations and camera positions are two other interesting parameters. For illumination, we chose ambient light and directional light. Ambient light simulates uniform illumination in an environment. Directional light simulates distant light sources for example sunlight.

The camera positions represent viewpoints of a scene. Observed from different angles, the scene may look different. Moving the camera position from front to side may result in the change of image quality.

Images were generated using Maya’s pre-defined surface mapping techniques for ordinary texture mapping, bump mapping, and displacement mapping. Figure 4 to figure 18 are a set of the most representative examples of the images in order to illustrate the different parameters used in the project.

*Figure 4: Brick wall, ordinary texture mapping, directional light, front camera position.*
Figure 5: Brick wall, bump mapping, directional light, front camera position.

Figure 6: Brick wall, displacement mapping, directional light, front camera position.
Quality of different mapping techniques

Figure 7: Brick wall, displacement mapping, ambient light, front camera position.

Figure 8: Brick wall, displacement mapping, directional light, side camera position.
Figure 9: Signboard, ordinary texture mapping, directional light, front camera position.

Figure 10: Signboard, bump mapping, directional light, front camera position.
Figure 11: Signboard, displacement mapping, directional light, front camera position.

Figure 12: Signboard, displacement mapping, ambient light, front camera position.
Figure 13: Signboard, displacement mapping, directional light, side camera position.

Figure 14–18 shows water with floating objects. (In this scene, front camera position means that the viewpoint is far away from the water plane, and side camera position means that the viewpoint is near the water plane.)

Figure 14: Water, ordinary texture mapping, directional light, front camera position.
Quality of different mapping techniques

Figure 15: Water, bump mapping, directional light, front camera position.

Figure 16: Water, displacement mapping, directional light, front camera position.
Figure 17: Water, displacement mapping, ambient light, front camera position.

Figure 18: Water, displacement mapping, directional light, side camera position.
7 Experiment
In this chapter, we explain in detail how the experiment was performed.

7.1 Subjects
Eleven subjects, eight male and three female, participated in the experiment. The average age of the subjects was 26.6 years. Ten subjects were students studying computer science at the Royal Institute of Technology and one was a teacher from the elementary school. Eight of the subjects had studied an introductory course in computer graphics. All of the subjects had experience in computer games. One of them had looked at children playing computer games. The other ten had played computer games themselves and six of them had even programmed computer games. One subject was red-green color-blind, which was irrelevant for the test results. The other ten had no defected color vision.

7.2 Equipment
The computer system Microsoft Windows 2000 was used. The hardware is x86 Family 6 Model 8 Stepping 1, AT/AT Compatible, 130 220 KB RAM, with a minitower of DELL, OptiPlex, GX300.

For the display system, a Plug and Play Monitor on NVIDIA RIVA TNT2 Model 64 (Dell) was applied. The monitor ran at a 75 Hz refresh frequency, with a 1024x768 pixel resolution, and with true color. The horizontal frequency was 60 KHz, and the vertical frequency was 75 Hz. The monitor’s contrast and brightness settings were both set to maximum.

7.3 Room conditions
The experiment was conducted in a room with white walls and light gray ceiling (figure 19). The surface of the walls is made of low reflecting fabric. The floor is dark gray. A white cotton curtain blocked most of the natural light from outside. Two fluorescent tube fittings are installed in the ceiling. One of them has two fluorescent tubes, the other has one tube. The fluorescent light sources are Philips TLD 36w/83. The light sources in the room do not cast shadows or reflections on the screen. The light source does not flicker.
The monitor is placed on a long wooden table of natural light brown color. Beside the table is a bookshelf. Between the monitor and the bookshelf is a minitower model system. It helps the end user to be less distracted by the bookshelf. On the wall behind the monitor and on the wall behind the end user there are two windows each. Gray ceiling, white walls, and Venetian blinds of neighboring labs can be seen through the windows. Reflection of fluorescent light sources from the neighboring labs can be seen slightly on the screen.

The atmosphere of the room is supposed to give the participants an impression of naturalness and help them to relax and be patient when they made their 72 judgements.

Figure 19: Experiment site.

7.4 Image combinations
The experiment consisted of three different scenes (a brick wall, a signboard, and water with floating objects), three surface mapping techniques (ordinary texture mapping, bump mapping, displacement mapping), two types of illumination (ambient light and directional light), and two different camera positions (front and side). A total of 36 images were presented for each session of the experiment (realism session and usefulness session).

7.5 Questions
Question one: How realistic do you think the image is?
Question two: How useful do you think the image could be applied in a computer game (for example, adventure, navigation, 3D feeling)?
7.6 Procedure

Before the subjects came, the author opened all images in Adobe Photoshop 6 according to the pre-prepared random sequences, and stacked up the images in such a way that only one image could be seen at one time. The author also stacked up four test images. See Figure 20.

![Figure 20: Screen layout.](image)

The subjects were welcomed and informed of the confidentiality of their personal data and judgements for the experiment. Personal data, knowledge background, and defect color vision were recorded.

The subjects were then given a leaflet introducing the purpose of the experiment. The main part of the leaflet reads as follows:

“In this experiment we will judge quality of different images that will eventually be applied in a computer game. You are supposed to rank the quality of those images. The images will be displayed in two rounds with two different questions. Your scores are picked from 0 to 10, i.e. 0, 1, 2, 3, …, 7, 8, 9, 10, where 0 indicates that the image is very bad according to the question, and 10 means that the image is very good according to the question. … Take your time and make your judgements in your own tempo. The experiment is estimated to take about one hour.”
The subjects were given the first question and made four test judgements according to the question. One half of the subjects have question number one as the first question, and the other half have question number two as the first question.

After the test judgements the subjects began with the first round of image quality assessment according to the question they had for the test judgements. They were asked to write down the scores on a form.

After the first round of 36 image judgements, the subjects were asked to take a short break. Then they were presented to the second question and began with the second round of 36 image judgements.

When all of the 72 judgements were completed, the subjects were asked to take a rest and give comments or ask questions.

The total time for the two main sessions were recorded. The subjects were informed that results from the experiment would be used in a Master’s thesis which would be found on NADA’s website.
8 Results
In this chapter, we present the results of the experiment. The results include the ranking results and the comments given by the participants.

8.1 Ranking results
Scores of the images were recorded during the experiment and entered into an Excel worksheet after the experiment. The scores were then sorted by different parameters such as texturing techniques, illuminations, camera positions, scenes, the combination of texturing techniques and illuminations, and the combination of texturing techniques and scenes. Interesting findings are presented as follows.

8.1.1 Evaluation of three texturing techniques
In the test images, displacement mapping has the best results considering both realism and usefulness assessment. Bump mapping has similar scores to ordinary texture mapping regarding the realism test, but has higher scores in the usefulness test. See figure 21.

Figure 21: Evaluation of texturing techniques.
8.1.2 Evaluation of two illuminations
In the tests on both realism and usefulness, directional illumination has better results than ambient illuminations. See figure 22.

![Figure 22: Evaluation of illuminations.](image)

8.1.3 Evaluation of camera positions
In the tests on both realism and usefulness, the side camera position has only a very tiny higher average score than the front camera position. Such tiny difference is estimated of no statistical significance. See figure 23.

![Figure 23: Evaluation of camera positions.](image)
8.1.4 Evaluation of three scenes
Among the three scenes, the signboard scene has the lowest average score. The brick wall scene and the water scene have similar scores for both realism and usefulness tests. See figure 24.

![Figure 24: Evaluation of the three scenes.](image)

8.1.5 Evaluation of texturing techniques in two illuminations
When using directional light, the image quality increases from ordinary texture mapping to bump mapping, and from bump mapping to displacement mapping. When using ambient light, the image quality remains the same for ordinary texture mapping and bump mapping, and has the best result for displacement mapping. This depends on that the normal vectors in bump mapping do not change when using ambient light. See figure 25 and figure 26.

In figure 25, bump mapping has a slightly lower score than ordinary texture mapping, which is estimated of no statistical significance. In both figure 25 and figure 26, ordinary texture mapping is not influenced by illuminations, while the evaluation of both bump mapping and displacement mapping increase from ambient light to directional light.
Quality of different surface mapping techniques

Figure 25: Evaluation of texturing techniques in two illuminations (realism appeal).

Figure 26: Evaluation of texturing techniques in two illuminations (usefulness appeal).
8.1.6 Evaluation of texturing techniques in three scenes

Regarding realistic assessment, displacement mapping has the best results for all three scenes. Bump mapping has similar results to ordinary texture mapping. See figure 27.

![Figure 27: Evaluation of texturing techniques in three scenes (realism appeal).](image)

Regarding usefulness assessment, image quality increases steadily from ordinary texture mapping to bump mapping, and from bump mapping to displacement mapping. See figure 28.

![Figure 28: Evaluation of texturing techniques in three scenes (usefulness appeal).](image)
8.1.7 Ranking time
The average response time was 8.6 minutes in the realism test and 8.8 minutes in the usefulness test. However, the average response time in the realism test was increased by one of the participants who completed the test in 18 minutes.

8.2 Comments made by the participants
Comments made by the participants can be classified into three categories: comments on the scenes, comments on the evaluation questions, and comments on the experiment method.

8.2.1 Comments on the scenes
The three scenes, the wall, the signboard, and the water, were commented on by the participants. A summary is given below.

The wall scene is considered as the most realistic one among the three scenes. “Some images of the wall scene give very strong 3D feeling. The bricks seem to stick out,” commented one participant.

The signboard scene is regarded as the least interesting scene. Firstly, the choice of the letters “KTH” was not practical. One participant said, “The letters ‘KTH’ are not likely to appear in a game.” Secondly, the letters were created too smooth, which gives a feeling of wrong material match. “The letters ‘KTH’ seem to be metal, but the background seems to be marble,” said one participant. Thirdly, shadows are important to interpret this scene. “With shadows the letters seem to be on the stone, while without shadows the letters are separated from the stone,” said one participant.

The water scene is considered as the most useful scene, but less realistic than the wall scene. Firstly, floating objects in the water make the scene less realistic. “The objects have too bright color and draw too much attention,” said one participant. Another participant said, “If you had chosen fish or a boat instead of a cube and a sphere, the scene would be more realistic.” Secondly, for the scenes using ordinary texture mapping and the scenes using bump mapping with ambient light, the water seems unrealistic. One participant said, “Some scenes do not look like water but smoke or fog.” Thirdly, the color of the water makes it less realistic. “The color is too blue, a grayer tone would have made the water more realistic,” said one participant. “The water is too dark to be tap water and too transparent to be a sea or a lake,” said another participant. Though the water scene is not regarded as very realistic, it is regarded as the most useful one in games thanks to
directional light and displacement mapping. “The light on the waves make the water very realistic”, said one participant. “This is the best computer-generated water I’ve ever seen”, said another participant. “I would give 2 or 3 for realism, but 10 for usefulness”, a third participant commented on the scene with displacement mapping.

The choice of the scenes could be improved. As one participant put it, “simulation of a human being could be more interesting”.

8.2.2 Comments on the evaluation questions
The question of realism is easily understood by all participants. The question of usefulness confused some participants. “I suppose that lower image quality is accepted in the usefulness test than in the realism test”, said one participant. “The question of usefulness is more difficult to judge”, said another participant. “For moving scenes in games, images of lower quality are still useful. But in still scenes, images are supposed to have high quality”, commented a third participant. One participant said, “Usefulness of images depends on the age of the player”.

8.2.3 Comments on the method
“With reference pictures, it will be easier to judge fidelity of the images”, said several participants, “otherwise it’s difficult to judge image qualities in the beginning. Don’t know what exactly to judge. Is it color, shape, or…? If given a survey of the images at first, the range of the scores could be broader”.

One participant has however a different opinion about the method, “Given reference pictures, the users would have compared the test images with that picture, not with reality”.
9 Discussion

In this chapter, we present the discussion on the experiment and the test results.

9.1 Image realism

The purpose of the realism test was easy for the subjects to understand. The term of realism used in this project corresponds to de Ridder’s term of naturalness, where internal reference is used rather than an external reference such as a photograph. The subjective ratings on realism indicated that displacement-mapped images were more realistic than bump-mapped or ordinary-texture-mapped images and that bump-mapped images were as realistic as ordinary-texture-mapped images. The effectiveness of displacement mapping complied with prediction before the experiment. However, it was surprising that bump mapping was not superior to ordinary texture mapping in conveying image realism. This might suggest that three-dimensional effects below a certain level are ignorable in realism judgement. Results also showed that images illuminated with directional light were perceived as more realistic than images illuminated with ambient light. The reason for this is probably that shadows are missing with just ambient light. In addition, there was no significant variation between images viewed from the two different camera positions (front and side).

Other interesting realism cues found during the experiment involved shadows, object representation, and tone of color. Images with shadows were viewed as more realistic than images without shadows. Shadows gave a feeling of irregularities on the surfaces. They also differed objects from their background. Objects represented by primitive shapes gave the feeling of a computer-generated regular geometric model. They were viewed less realistic than objects represented by modified shapes. According to one of the participants, bright color on far objects appeared closer than foreground objects with gloomy color. Such wrong depth perception reduced image realism. Images including colors with a high saturation were considered to be less realistic than images using colors with lower saturation.
9.2 Image usefulness
The purpose of the usefulness test was difficult for the subjects to understand. The results of usefulness test indicated an increase of usefulness from ordinary-texture-mapped images to bump-mapped images and from bump-mapped images to displacement-mapped images. Further, images using directional light were more useful than images using ambient light. Camera position was not a significant factor in usefulness judgement.

9.3 Discussion on the methods
We discuss some interesting aspects of the experimental approach used in this project.

9.3.1 Screen layout
The project used a small format for the image display. Each test image took approximately ten percent of the whole screen. The advantage of small format is that the image perceived on the screen is similar to the size used in games. The format we chose was enough to illustrate quality differences between the three surface mapping techniques. A major disadvantage of the screen layout is the distraction from irrelevant information on the screen. An alternative image display is full screen display. Full screen display will be more useful in task-oriented experiments where more information of the environment is necessary. Full screen display will also minimize the distraction from irrelevant information on the screen.

9.3.2 Anchor for realism test
An alternative design of a realism test is the use of a photograph as the anchor image for each scene. The advantage of using an anchor image is to make sure that all participants refer to the same reference image for realism judgement. By comparing test images with the anchor image, it will be easier for the subjects to make judgements. The range of scores will be broader. It will however set the photograph as the true and final answer, while many pictures in games appear realistic although they are very different from a photograph.
9.3.3 Task design for usefulness test
This project applied judgement-oriented design for the usefulness test. A more convincing design for a usefulness test would be task-oriented. In a task-oriented usefulness experiment, the subjects are asked to perform a task by interacting with the system. The usefulness of the test image will be estimated by, for instance, the time needed for completing the task or accuracy of the result. Task-oriented design is usually more complicated and needs more computer resources.

9.3.4 Subjects
The subjects of the experiment consisted of 11 people, eight male and three female. The average age was approximately 27, ranging between 21 and 40. To make the usefulness test more interesting, we can further study responses from different player groups (adults versus children, women versus men). The number of females can be increased to be the same as the number of male subjects. Young game players can also be introduced to the experiment.

9.4 Possible use of the results
The results may be useful for game developers in choosing surface mapping techniques. Displacement mapping yields the best image quality with the tradeoff of time consumption necessary for increasing geometric complexity during rendering time. If time is a big concern, displacement mapping may be saved to still scenes and the foreground where details are important. For moving scenes and the background where details are not very important, ordinary texture mapping and bump mapping are alternatives. In some computer games where images are pre-rendered and pre-loaded and thus rendering time is not a big concern, displacement mapping is preferable for its high image quality.
10 Conclusions

Subjective evaluation of realism and usefulness of three surface mapping techniques were undertaken. Three scenes, three mapping techniques, two illuminations, and two camera positions served as interesting parameters for image combination. Eleven subjects (eight male and three female) were asked to rate images for realism and usefulness on a scale of 0 to 10. Results indicated that displacement mapping was superior to bump mapping and that bump mapping was superior to ordinary texture mapping with respect to usefulness. Regarding realism, displacement mapping yielded still the highest average score, but bump mapping had similar quality to ordinary texture mapping. Results also revealed that directional light was more important in increasing image quality than ambient light, and that camera position had no significant effects on image quality.

Answers to questions in issue:

- How does image quality change when we change surface mapping technique from ordinary texture mapping to bump mapping, and from bump mapping to displacement mapping?

We examined image quality in two respects: realism and usefulness. In the realism test, ordinary texture mapping and bump mapping had similar scores, while displacement mapping had the highest average score. In the usefulness test, ordinary texture mapping had the lowest score, bump mapping had higher score, and displacement mapping had the highest score. Generally, we can say that image quality increases from ordinary texture mapping to bump mapping, and from bump mapping to displacement mapping.

- Does illumination change the image quality? If so, in which way does it change it?

Illumination had significant influence on the image quality. For both realism and usefulness assessments, directional light yielded better image quality than ambient light did. Of the three surface mapping techniques, bump mapping and displacement mapping were affected by illumination. With mere ambient light, bump mapping lost its effect because of the unchanged normal vector. The images had no 3D effects. With directional light, the normal vector was perturbed and the scene yielded more 3D feeling. Displacement mapping gave 3D effects using either ambient light or directional light. This was a big difference between displacement mapping and bump mapping when using ambient light. With ambient light, displacement-mapped images
appeared still as of being in 3D because displacement mapping had changed the surface geometry. However, directional light was superior to ambient light even for displacement mapping, because high bumps cast shadows on low bumps when using directional light.

- Does the camera position influence on the image quality?

The camera position had no discernible effect on the image quality.

- Are realistic images useful in computer games?

No. Image realism and image usefulness are two separate dimensions of image quality. A more realistic image does not automatically imply a more useful image. Image usefulness depends also on many other factors such as the characteristics (e.g. sex and age) of the player and the type of the game. On the other hand, a useful image may not be realistic at all, but still effective and functional in accomplishing tasks.
References


Quality of different surface mapping techniques


I denna undersökning vill vi bedöma kvalitén på olika bilder som skulle kunna användas i ett dataspel. Du kommer att få bedöma bildkvaliteten genom att ge betyg på bilderna. Bilderna kommer att visas i två omgångar med två olika frågor. Ditt betyg sker genom en poäng från 0 till 10, dvs 0, 1, 2, 3, ..., 7, 8, 9, 10, där 0 poäng betyder att bilden är mycket dålig enligt frågan och, 10 poäng betyder att bilden är mycket bra enligt frågan.

Det finns inte något rätt eller fel svar. Ditt svar är facit.

Gör bedömningarna i din egen takt. Vi räknar med att alla bedömningarna kommer att ta omkring en timme.

Provbedömningar enligt den första frågan:

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