Reliability of Computer Graphics Images As Visual Assessment Tool

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ABSTRACT

This paper analyzes the use of computer graphics images as an architectural assessment tool. The characteristics of such images as an architectural simulation tool are discussed and their reliability as an assessment tool is evaluated and compared with that of traditional hand-generated perspective drawings. An example application, architectural simulation of a city renewal plan, is presented.

Key words: reliability, montage image, assessment, architectural simulation, computer graphics system.

1 INTRODUCTION

Assessing the impact of new construction, such as bridges, buildings, and roads, on the local visual environment, is very important and should be considered in conjunction with their physical, chemical, and other environmental impacts. Traditionally, this evaluation has been carried out using hand-generated perspective drawings. However, the method is inevitably artificial, and this obstructs objective assessment of the visual impact of new construction. Moreover, hand drawings are very costly to prepare, and cannot be dynamically altered during the course of the design.

If highly realistic (or photographic) images are able to be created dynamically (from various view points), we can foretell what visual impact is followed due to the new constructions to the environments. The best planning that taking into account of the visual impact might be obtained by using these images. We could call the checking process by using the highly realistic images as the visual assessment of the new constructions to their environments.

The authors have proposed an image montage method to address this problem [Nakamae 86]. In this method, the computer combines a computer generated image of the proposed construction with a scanned in photograph of the visual background to create a composite image suitable for objective visual assessment. This technique produces highly realistic images with relatively short calculation times.

In the case of a large scale city renewal effort, however, little or none of the image area will be filled by a scanned in background. The image will consist almost entirely of computer-generated objects. This implies that long calculation times will be required to generate highly realistic images. In order to take best advantage of computer generated images, it is important to keep the calculation time low so that dynamic alterations of view point or view reference point are practical. Thus, for city planning, the utility for assessment purposes of computer generated images is less than that of montage images.

There has not been a comprehensive discussion of the reliability of drawings (including both hand and computer prepared drawings) as a visual assessment tool. Thus, we will first present an analysis of computer graphic images for assessment. In the following section we discuss the characteristics of computer images as an assessment tool, the possibility of using these images as a highly reliable assessment tool, and compare their reliability to that of traditional hand prepared drawings.

Section 2 describes a computer graphic based assessment method by using a set of images developed by the authors. In Section 3 the relative reliability of assessment using computer images compared to that using hand-drawn images is investigated, and the characteristics of our method are discussed. Section 4 provides an example of assessment using our images, and Section 5 gives a summary of results obtained.

2 VISUAL ASSESSMENT USING COMPUTER GRAPHIC DRAWINGS

As discussed in the previous section, the current application differs from montage images in that most of the image area is computer generated, with very little scanned-in background. Images are composed of many elements, which we will call image segments. We will further classify image segments into natural and artificial objects. In order to make possible objective visual assessment, the overall picture must exhibit a sort of "harmony of realisticness." While one wishes to render each image segment as realistically as possible, there is a competing desire to keep calculation times down in order to create a practical chain of image creation steps for dynamic assessment.

For artificial objects, calculation time can be reduced by reducing the rendering accuracy for objects distant from the viewpoint. Thus, distant objects are rendered with less, and nearby objects are rendered with more accuracy.

Natural objects have previously been displayed by using probabilistic algorithms [Reeves 85], botanical and rule-based methods [Aono 84], and fractals [Smith 84]. However, due to the wide variety of trees used in city planning, none of these methods are suitable for use in the computer image based assessment problem. Our method provides two methods for displaying natural objects. First, natural objects can be very roughly sketched using primitive shapes. Thus natural objects are treated identically with artificial objects. Second, natural objects can be displayed by the montage method. A natural object database is generated by extracting necessary objects from their backgrounds in scanned-in photographs. Each application can reference the most appropriate object from the natural object database. By choosing between the two methods on a case-by-case basis, our method generates highly realistic computer graphic images for visual assessment.

Figure 1 shows a block diagram of our image management system. The total operations are composed of three blocks, the data input step, the image creation step, and the representation step.

2.1 Data Input Step

In the data input step, operations are carried out to handle the input of 3D data, and the step allows the data to be verified using simple wire frame output. This step is implemented on microcomputers with a view to its simultaneous use by many operators.

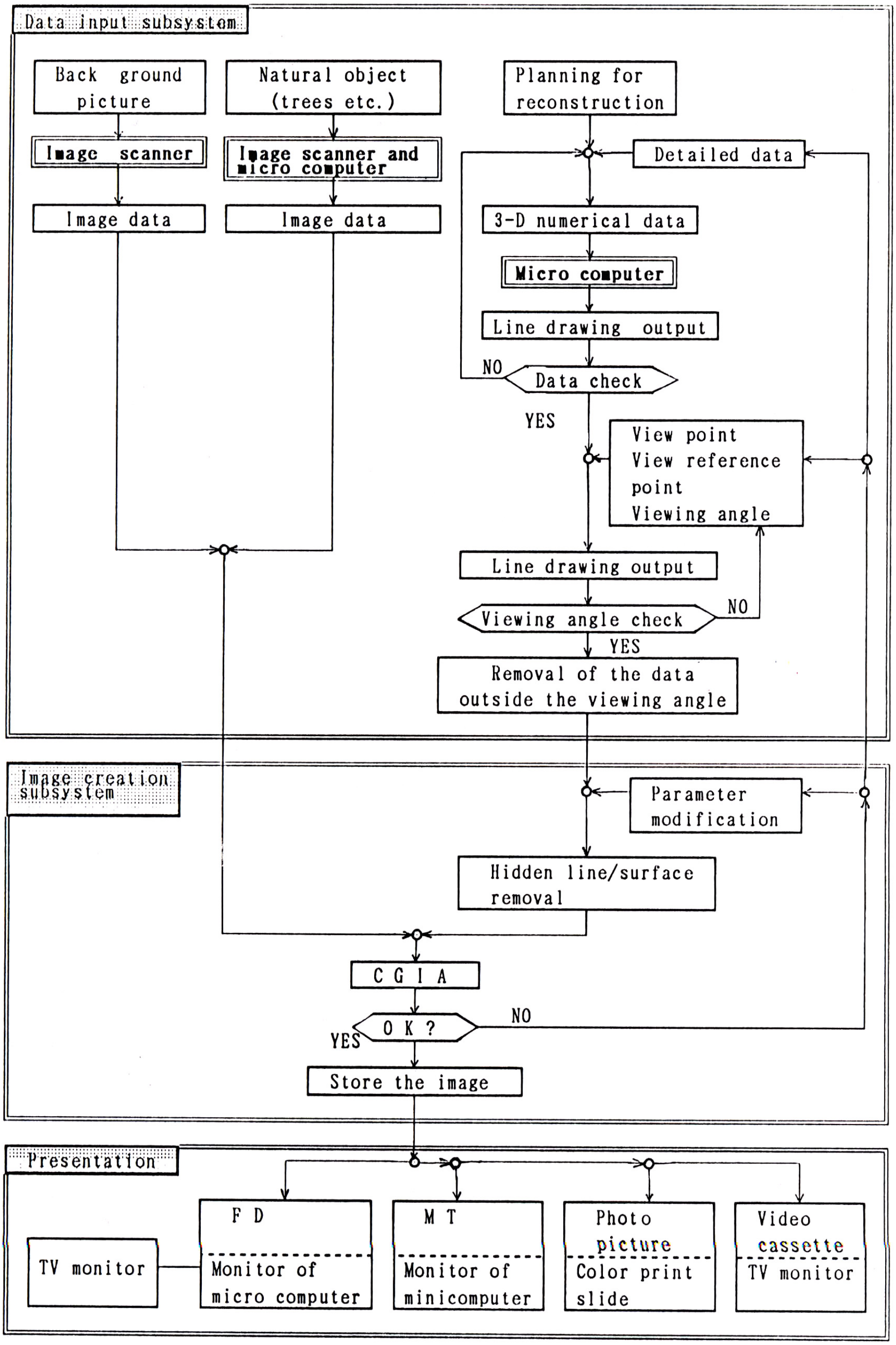


Figure 1: Block Diagram of our Assessment Image Creation. The total procedures are for creating computer graphic images for assessment (CGIA)

3D objects are represented as sets of primitives. Each object also has color and texture attributes. When an error is encountered in the input, it can be edited.

When data input and verification are completed, the view point, view reference point, and viewing angle can be set. For a constant view point and view reference point, varying the viewing angle produces very different images. With a wide viewing angle, a wide angle lens effect is produced, while a narrow viewing angle produces a telescopic lens effect. The viewing angle can be dynamically selected based on line drawing output.

2.2 Image Creation Step

The main merit of our method is inherent in the shading process. By properly adjusting the color and texture of each object, a computer image with very nearly photographic appearance can be generated. Data is transferred to the mini-computer based image creation step from the data input step. Here hidden line and surface removal, and shading with illumination maps are performed.

Artificial objects, such as buildings, can be adequately described numerically. However, natural objects, such as low brush thickets and roadside trees, cannot be easily described using geometric primitives. Our empirical work has yielded the following composite method for displaying natural objects.

2.2.1 Displaying low brush thickets

This class of natural objects is displayed using primitives such as parallelepipeds. The color and intensity of each surface of the resulting object are calculated as for artificial objects, based on the light source. The calculated color of each surface is then modulated by a prescribed, semi-random function. This produces realistic appearing low brush thickets. The method may also be applied to artificial objects such as walls of buildings or stone walls to increase the rendering quality.

2.2.2 Displaying tall roadside trees

Two methods are provided for displaying roadside trees. The first is the composite image montage method. A photograph of a real tree is scanned in and a microcomputer is used to extract the tree from its background. The tree image data is composited into the overall image by the image creation step, using intensity and position data.

A major drawback of this method is the difficulty of creating the database. Assembling photographs of a wide variety of trees and assembling them into a database is a formidable task. However, once the database is completed, it provides a very valuable source of realistic tree images, allowing realistic assessment images to be created using many different types of trees.

The second method is approximation with geometric primitives, similar to the method described for brush thickets above. Each roadside tree is approximated with appropriate primitives, and the obtained tree figures are stored in the database. When used, a randomizing function is applied to the surfaces as discussed for the brush thickets. This method is very simple, but unfortunately does not produce highly realistic trees. However, it can be useful as a first approximation for selecting the general shape of tree to be used.

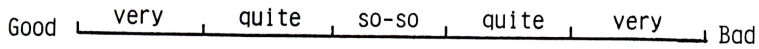


Figure 2: Preference Scale for the Category Method.

As shown in Figure 1, conversion of image data from the image scanner is carried out in the data input step. Our method also supports scanned-in background pictures for montage images, but that is beyond the scope of this paper.

3 COMPUTER GRAPHIC IMAGES FOR VISUAL ASSESSMENT

In actual assessment applications, the style of computer graphics used must be tailored carefully to the assessment purpose. For example, in the initial stages of renewal planning, it is important to keep calculation time low enough to facilitate very dynamic interaction with the required operations. Line drawings (with or without hidden line removal) are thus very valuable at this stage. The main objective here is to verify the basic plan. As planning proceeds, requirements move to more and more realistic images. The process moves through a progression from simple line drawings, through ever more realistic (and computationally expensive) drawings.

In order to ascertain that the computer graphic images are meeting the requirements, it is helpful to do some analysis of the human user's reaction to various images, and subjective preferences. Psychologists have developed the following types of methodology for quantifying a viewer's reaction to an image [Yasuda 77], [Wright 60].

a) Ordering Method.
Each viewer selects r objects out of n total objects, or orders the r objects.

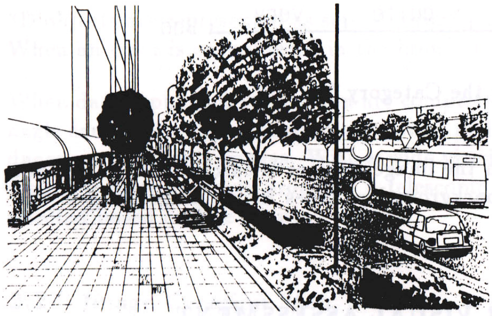
b) Pair Comparison Method.
Pairs of objects selected from the set are shown together to the viewer, who names a preference within each pair.

c) Category Method.
Some number of categories are defined over the preference scale, (Figure 2) and the viewer is asked to put each object into the most suitable category.

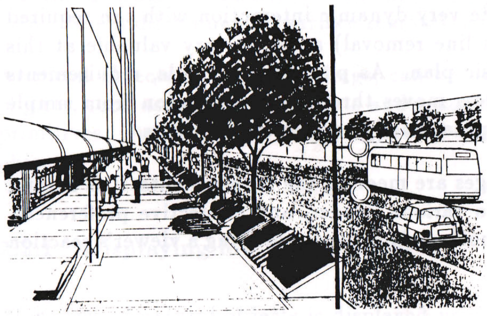
d) SD Method.
Pairs of adjectives of opposite meaning are set up, and the viewer rates each object on a linear scale between each pair of adjectives.

In this paper we focus on the use of highly realistic images for assessment, since they provide a basis for a wider range of use. One of the items to be evaluated using such images is the overall color design of the construction. This includes i) determining the basic color of the environment, and ii) comparing monotone colors against other color schemes. Highly realistic images are also very useful for evaluating the appearance from various view points. In the final step, these images are used to select the best of a number of reconstruction plans. Of the above listed psychological evaluation methods, b), c), and d) are useful for visual assessment using computer generated images.

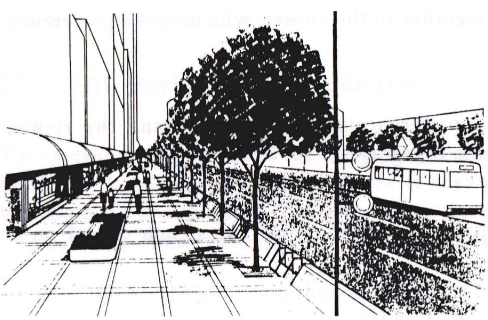
Please observe Figures 3 through 5 for a comparison of hand drawings with computer drawings. Figure 3 shows three hand prepared drawings from a view point 3.5 meters above the ground (a



A

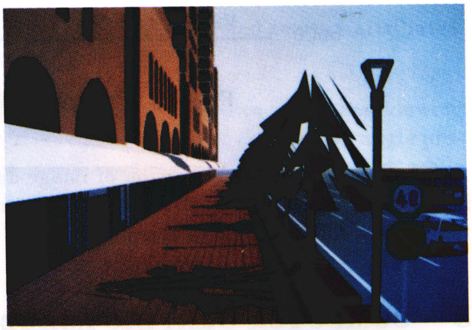


B

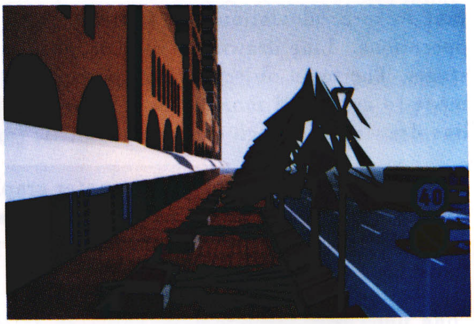


C

Figure 3: Example of Hand Prepared Perspective Drawing.



A



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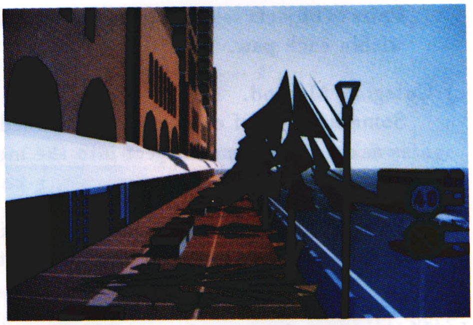

C

Figure 4: Example of Computer Prepared Perspective Drawing. Viewpoint is 3.5m above the ground.

height very commonly used in hand prepared architectural drawings). Figure 4 shows drawings from the same perspective, but prepared by computer. Figure 5 is also computer generated, but with the height now set to 1.6 meters above the sidewalk. This is approximately the eye height of a pedestrian. The trees along the sidewalk in Figures 4 and 5 were generated using the simple approximation by primitives described in 2.2.2. Slides of each of these images were presented to a number of testees. The testees consisted of 34 non-specialists and 31 engineers with responsibility for the reconstruction plan, for a total of 65 testees. The evaluation was carried out as described in the next section.

3.1 Application of Category Method

The testees were questioned on:

1) Total image impression.
2) Showiness.
3) Lightness.
4) Softness.
5) Color and texture of the sidewalk.
6) Flower pots and benches on the sidewalk.
7) Width of the sidewalk.

The testees were asked to place each image in one of five categories on a preference scale (Figure 2). Items 2) through 4) were phrased using adjectives, and thus the category method applied to these items is equivalent to the SD method. Tables 1, 2, and 3 summarize the result of applying the category method to images A, B, and C for Figures 3, 4, and 5. In each table, the first row contains the results for the non-specialists, and the second row for the engineer testees. The third row is the total result, and the number in parentheses is the variance.

We can discuss each image's reliability as a tool for the assessment by using the variance. If an image is presented to a group of people who are supposed to share the same aspect or preference for the plan, lower variance between each person's answer is derived only if the image shows the expected scene faithfully. Therefore, the results obtained from the specialist group in our test serve as the useful source to decide what is the better image for assessment. In the following discussions, we suppose that the variance is closely related to the reliability of the assessment, with small variance indicating that the testees gave largely similar answers. Thus, the media is considered to provide a reliable base for assessment.

The results in Tables 1 through 3 show that the variance was smaller for the engineers than for the non-specialists. This is a natural result, and verifies the accuracy of the image comparing method c).

On the other hand, comparing the hand and computer drawn images (drawn from the same viewpoint) in Figures 3 and 4, the variance is smaller for the hand drawn images in every case except that of B, that is, the hand drawn images are more reliable. This may be due to the fact that the height in Figures 3 and 4 is the standard height for hand prepared perspective drawings, giving a preferential bias to the hand drawings. In A, the viewpoint is set higher, and the test results for the engineers favor the computer drawings. As a final result, computer graphic images are judged to provide a more stable media for assessment (one with less variance), than hand prepared drawings.

Table 1: Category Method Applied to Image A of Figures 3, 4, and 5. First row of each block is the result for non-specialists, and second row is for engineer testees. The third row gives the total result. Variance is given in parentheses. X is results for hand drawings. Y and Z are results for computer drawings of the higher view point and of the lower view point, respectively.

Evalnation items	X	Y	Z
(1) Total evaluation	3.35 (0.96)	2.91 (1.54)	3.82 (1.06)
	3.20 (0.89)	2.27 (0.55)	3.26 (0.80)
	3.28 (0.90)	2.61 (1.16)	3.55 (1.00)
(2) Showiness	3.00 (1.52)	2.53 (1.35)	2.94 (0.91)
	2.97 (0.72)	2.40 (0.59)	2.87 (0.52)
	2.98 (1.13)	2.47 (0.98)	2.91 (0.71)
(3) Lightness	3.44 (1.16)	2.97 (1.12)	3.88 (0.77)
	3.00 (0.55)	2.45 (0.81)	3.55 (0.46)
	3.23 (0.91)	2.73 (1.02)	3.72 (0.64)
(4) Tenderness	3.00 (0.97)	2.24 (0.97)	2.94 (0.66)
	2.70 (0.63)	1.97 (0.52)	2.71 (0.55)
	2.86 (0.82)	2.11 (0.77)	2.83 (0.61)
(5) Color/texture of sidewalk	3.30 (1.18)	3.15 (1.46)	3.68 (0.77)
	2.60 (0.73)	2.30 (0.49)	2.94 (0.80)
	2.97 (1.08)	2.75 (1.18)	3.32 (0.91)
(6) Impression of flower pots and benches	3.06 (1.27)	2.82 (1.24)	3.44 (1.28)
	3.10 (1.06)	2.14 (0.62)	2.80 (0.58)
	3.08 (1.15)	2.51 (1.06)	3.14 (1.04)
(7) Width of sidewalk	4.21 (0.71)	3.71 (0.82)	3.91 (1.23)
	3.93 (0.62)	2.80 (0.86)	3.58 (0.65)
	4.08 (0.68)	3.28 (1.03)	3.75 (0.97)

Table 2: Category Method Applied to Image B of Figures 3, 4, and 5. Contents are as for Table 1.

Evalnation items	X	Y	Z
(1) Total evaluation	3.53 (1.05)	4.09 (0.39)	4.03 (0.82)
	3.60 (0.66)	3.45 (0.72)	3.68 (0.36)
	3.56 (0.85)	3.79 (0.64)	3.86 (0.62)
(2) Showiness	3.71 (0.94)	4.03 (0.45)	4.12 (0.59)
	3.57 (0.53)	3.19 (0.63)	3.71 (0.23)
	3.64 (0.74)	3.63 (0.71)	3.92 (0.45)
(3) Lightness	3.42 (0.56)	3.85 (0.68)	3.88 (0.59)
	3.67 (0.51)	3.36 (0.70)	3.55 (0.32)
	3.54 (0.54)	3.62 (0.74)	3.72 (0.49)
(4) Tenderness	3.03 (0.88)	3.59 (0.67)	3.68 (0.77)
	2.97 (0.65)	3.10 (0.82)	3.48 (0.46)
	3.00 (0.76)	3.35 (0.80)	3.59 (0.62)
(5) Color/texture of sidewalk	3.27 (1.53)	3.56 (0.80)	3.85 (0.61)
	3.12 (0.70)	3.07 (0.73)	3.19 (0.56)
	3.22 (1.13)	3.32 (0.82)	3.54 (0.69)
(6) Impression of flower pots and benches	3.44 (1.28)	3.74 (0.99)	4.00 (0.79)
	3.53 (0.74)	3.13 (1.18)	3.23 (0.91)
	3.48 (1.02)	3.45 (1.16)	3.63 (0.99)
(7) Width of sidewalk	3.85 (1.16)	3.77 (0.67)	3.44 (0.86)
	3.43 (0.74)	3.39 (0.51)	3.13 (0.32)
	3.66 (0.99)	3.59 (0.62)	3.29 (0.62)

Table 3: Category Method Applied to Image C of Figures 3, 4, and 5. Contents are as for Table 1.

Evalnation items	X	Y	Z
(1) Total evaluation	3.09 (1.13)	3.18 (0.88)	2.82 (1.06)
	3.20 (1.06)	2.42 (0.52)	2.55 (0.72)
	3.14 (1.08)	2.82 (0.84)	2.69 (0.90)
(2) Showiness	2.88 (0.83)	3.00 (0.85)	3.06 (0.72)
	2.83 (0.83)	2.65 (0.37)	2.71 (0.41)
	2.86 (0.82)	2.83 (0.64)	2.89 (0.60)
(3) Lightness	3.56 (0.92)	3.50 (0.44)	3.03 (1.09)
	3.30 (0.70)	2.81 (0.63)	2.97 (0.63)
	3.45 (0.82)	3.17 (0.64)	3.00 (0.86)
(4) Tenderness	2.97 (1.00)	2.97 (0.70)	2.44 (0.86)
	3.00 (0.83)	2.65 (0.70)	2.39 (0.51)
	2.98 (0.91)	2.82 (0.72)	2.42 (0.68)
(5) Color/texture of sidewalk	3.18 (1.12)	3.18 (0.70)	2.85 (1.22)
	3.20 (0.58)	2.58 (0.65)	2.97 (0.70)
	3.19 (0.85)	2.89 (0.75)	2.91 (0.96)
(6) Impression of flower pots and benches	3.00 (1.15)	3.09 (1.05)	2.59 (1.10)
	3.07 (1.10)	2.45 (0.66)	2.48 (0.73)
	3.03 (1.11)	2.79 (0.95)	2.54 (0.91)
(7) Width of sidewalk	3.74 (1.11)	3.68 (0.65)	3.29 (1.00)
	3.47 (0.95)	3.03 (0.43)	3.00 (0.53)
	3.61 (1.04)	3.37 (0.64)	3.15 (0.79)

3.2 Application of the Pair Comparison Method

The hand drawings of Figure 3 were compared to the computer drawings (with a lower viewpoint) of Figure 5, by the pair comparison method. Two images (for example, Figure 3A and Figure 3B) are shown to the testees, who are asked to judge which is preferable in some dimension (for instance, "showy"). Testees who answered neither were excluded from the results. The results were summarized using a comparison matrix P, where element P_{ij} (here indices i and j run from 1 to 3) is the normalized count of testees answering that image j is preferable ("showy", for instance) to image i. It is clear then that $P_{ij} + P_{ji} = 1$. The normalized values for the sum of each row of P, namely

$$Ps_i = \frac{1}{N}\sum_{j=1}^{3} P_{ij}$$

are plotted in Figure 6. Here N is the number of testees. Figure 6 gives separate results for engineers and for non-specialists. In both cases the images prepared by computer from the lower viewpoint show a larger range (difference between largest and smallest Ps_i). This indicates that assessment based on computer prepared drawings provides a more stable result than hand prepared drawings.

4 ASSESSMENT WITH COMPUTER GRAPHIC IMAGES

The results of Section 3 indicate that computer graphic drawings allow more stable assessment than hand prepared ones, justifying work to apply computer graphics techniques to architectural simulation. However, Figures 4 and 5 were generated using the artificially simple method for

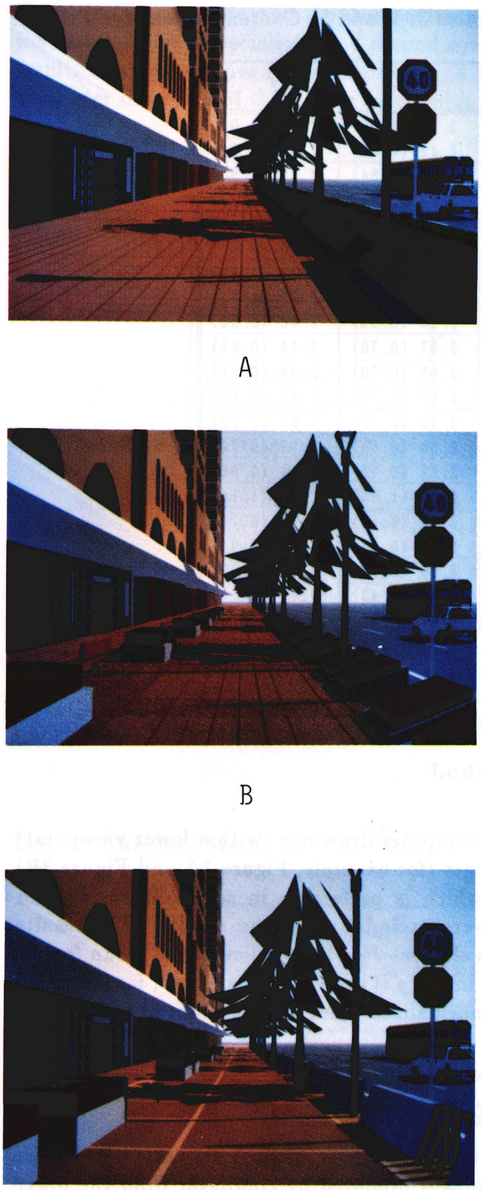

Figure 5: Example of Computer Prepared Drawing. Viewpoint at 1.6m above the ground.

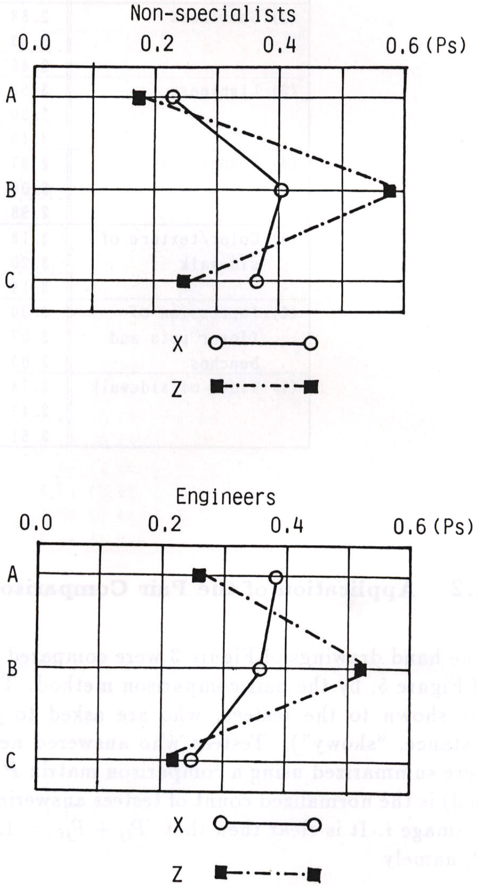

Figure 6: Sum of Rows of Comparison Matrix *P*. Engineer and non-specialist results are shown separately. X is results for hand drawings, and Z for computer drawings of the lower view point.

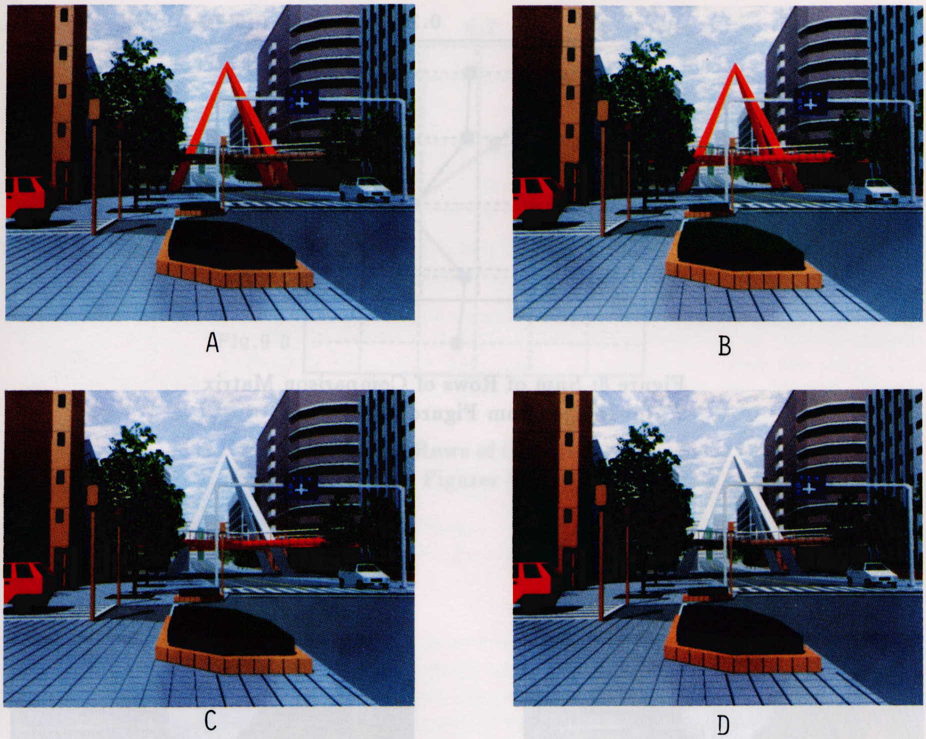

Figure 7: Computer Drawings for Selection of Bridge Color.

natural objects, leading to a fairly low level of realism. This problem was pointed out by many of the testees. The worst problem they pointed out was the representation quality of trees. Thus, we recognized the necessity of displaying trees by the more sophisticated method described in 2.2.2. The resulting, more realistic images were actually used in the further discussions. Since total image assessment is the goal, the pair comparison method was used.

Suppose that the objective of the assessment in the example is to determine the appropriate color and shape of a pedestrian bridge to be constructed near an intersection (a problem from an actual urban reconstruction application). Figure 7 shows a set of images used to select a harmonious color for the bridge. Roadside trees were generated using the cutting and montage method described in 2.2.2. The viewpoint is 1.6 meters above the ground.

The four images of Figure 7 were investigated via the pair comparison method, with the help of 89 testees, including 31 engineers. The results, in Figure 8, show a clear preference for D over the other plans. The next application, in Figure 9, is selection of the color and shape of the bridge. The results, in Figure 10, again show an overwhelming preference for the plan of Figure 7D.

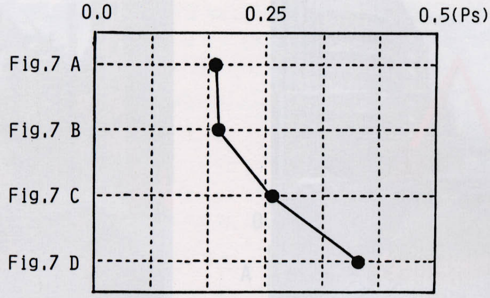

Figure 8: Sum of Rows of Comparison Matrix P, for Images from Figure 7.

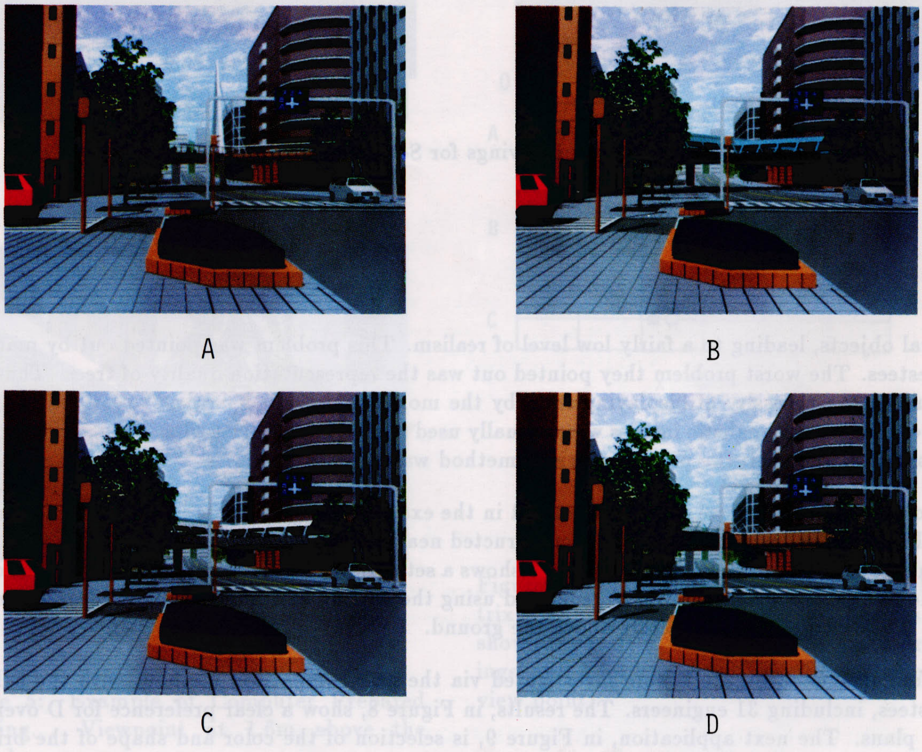

Figure 9: Computer Drawings for Selection of Bridge Color/Shape.

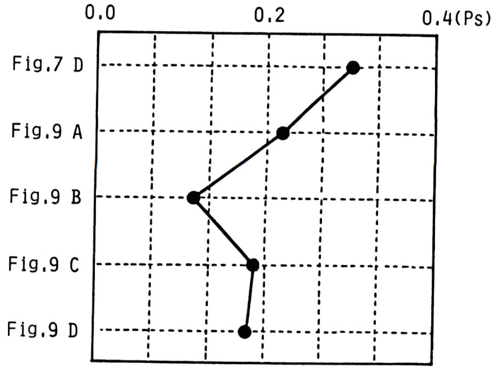

Figure 10: Sum of Rows of Comparison Matrix P for Images from Figures 9 and 7D.

5 CONCLUSIONS

The value of applying computer graphics techniques to assessment of the visual impact of new construction has already been appreciated, and some applications have been reported. However, no results had been reported with regard to the characteristics of using computer graphics images for architectural simulation, the reliability of the media, or a comparison of its reliability in comparison to traditional techniques. We have investigated these issues using the preference experiment with testees. The principal results of our investigations are:

a) computer drawings, in general, lead to a result with smaller variance. Hence, reliable assessments results are guaranteed.

b) The range of results obtained using computer drawings is larger than that using traditional hand drawings. Thus, more stable assessment results are possible.

c) Selection of the viewpoint is a dominating factor in the assessment results. The fact that the viewpoint may be easily, dynamically altered proved to be one of the greatest merits of using computer drawings.

To sum up, our results show that computer graphic images hold great promise for environmental assessment.

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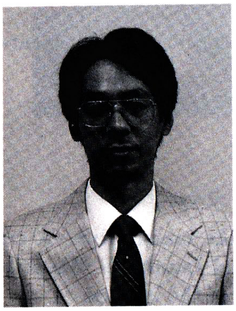

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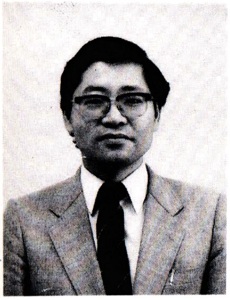

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