3-D CG Lighting with an Interactive GA

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***Abstract*— This paper applies an interactive GA technique to support lighting design of 3-D CG. Five amateur CG designers decide the best types, ON/OFF, color attributions, and positions of three lights in 3-D CG for a given object to match different two given motives. They make the lighting by hand and by using the lighting support system based on the interactive GA. 20 subjects compare their lighting arts, and a subjective test is conducted to evaluate how the interactive GA is useful. From the subjective test, it has been shown that the CG lighting support system especially helps lighting designers who are beginners.**

1 Introduction

1.1 Background and motivation

According to decreasing price and increasing performance of computers, it is becoming inexpensive to use 3-dimensional computer graphics (3-D CG). This situation has allowed not only professional but also semi-professional or amateurs to create the 3-D CG easily. As the necessity and the market of multi-media in computer and communication business are growing up, people who create CG are widely spreading to non-professional level.

However, it is not easy for amateurs to create high-qualified CG arts. Although it is easy for non-professional users to use the 3-D CG environment, low cost and high speed of the environment do not help them in improving the quality of CG and developing their capability.

The objective of this research is to provide technology which helps human creative capability. We deal with a lighting problem of 3-D CG for this purpose. Figure 1 is an example of 3-D CG lighting.

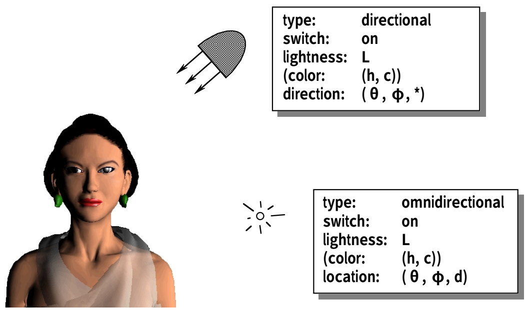


Figure 1: Lighting in 3-D CG. Two types of lights have several lighting parameters described in section 2.

Lighting plays an important role in the 3-D CG to give vivid impression to the viewers. Fundamentally speaking, the 3-D CG is a simulation of photographing, and lighting is one of the most important factors in photographing to set off objects. The lighting for CG has same importance as the photographing.

Deep experience and knowledge are required to set the optimal lighting parameters such as location, angle, type of light beam, color attributions, and combination of multiple lights. It is not easy for amateurs to optimize them even if good CG environment is provided. On the other hand, it is not difficult for amateurs to evaluate or compare multiple CG arts which have different lighting.

The idea to realize the objective mentioned above is to use interactive genetic algorithms (GA) and to combine the searching capability of computer and evaluating capability of human. The 3-D CG environment that involves the interactive GA shows multiple lighting CG arts to human, and the GA searches the optimal lighting parameters according to the scores evaluated by the human.

1.2 GA for design

Artistic design can be said to optimize many design parameters, such as color, lightness, shapes, positions, etc. Parameter optimization techniques can be introduced to support the design. GA is one of such techniques.

Subjective evaluation based on designer's intuition and interpretation of given design motif or concept should be used for GA design support systems. Since GA searches based on a fitness function, the GA can use the subjective evaluation by using the evaluation as fitness value itself.

This type of GA is called as an interactive GA. Human designers search the best design with the help of the design parameter optimization by GA.

The interactive GA has been applied to several artistic design fields. Some applications to creating images or figures are: montage face image generation [5], designing shapes of bug biomorphs [14], creating images, evolving expressions that specify particular sequences of image-processing functions [12, 13, 1], creating plants based on L-System Grammars [9] combining interactive evolution with constructive solid geometry techniques to create computer renderings of 3-D forms ("virtual sculptures") [19], general-purpose interactive graphic layout system based on GA [8], the design of a double curvature concrete arch dam [10], line drawing and application to face drawing [2], and the decision support system for aesthetic design of cable-stayed bridges [7]. The interactive GA has been also applied to music field. Some of them are: Jam session [4], generating rhythms of percussion instruments [6]. Besides these artistic design, it has been applied to engineering design [22], too.

The objective of this paper is to evaluate how the interactive GA is helpful for human designers, statistically. We use the lighting task in computer graphics (CG).

2 CG lighting with an interactive GA

We evaluate the interactive GA applied to two CG lighting tasks that have different lighting parameters with a little different GA operators. The reason why different tasks, GA operators, and design motives described in the next section are used is to demonstrate that the interactive GA is useful for CG lighting design regardless of these differences.

(a) CG lighting tasks

An lighting object, view angle, and the number of lights of both tasks are fixed as a woman's upper half body, front view of the woman, and three lights, respectively. Main difference between two tasks is that the second task has color lights, which increases the complexity of GA search.

The interactive GA searches the best combination of the types, locations, and lightness of the three lights for both tasks, and color of the lights for the second task.

(b) GA coding

The lighting parameters of the task 1 are encoded into a chromosome with 90 bits (see Figure 2(a)). Each light has six parameters: type of the light source, ON/OFF, lightness level, and the spherical coordinate of its location or direction in a 3-D space. The type of a light is either an infinite or omni-directional one that is distinguished by 1 bit. ON/OFF of the light uses 1 bit. The spherical coordinates of the three lights in 3-D space are given by 8 bits $\times$ 3. The coordinate means a light direction for an infinite light or a light location for an omni-directional light. The lightness of the light is given by 4 bits. Totally, a GA chromosome for the task 1 has 30 bits $\times$ 3 lights.

The lighting parameters of the task 2 are encoded into a chromosome with 114 bits (see Figure 2(b)). Each light has the parameters of hue (4 bits) and chroma (4 bits) as well as lightness (4 bits). Totally, a GA chromosome for the task 2 has 38 bits $\times$ 3 lights.

(c) GA operators

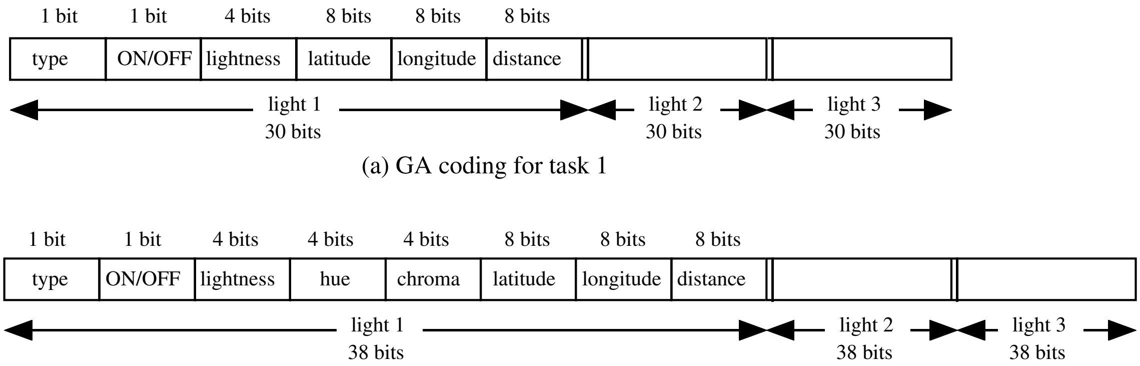
Interactive GA experiments for the two tasks use a little different GA operators.

Task 1 uses a simplex crossover [3] and asymmetrical mutation rates [21]. Half of populations is generated by the simplex crossover that uses better two parents and one worse parent and is copied to another half. The two population groups have 20 % and 0.2 % mutation rates respectively, which aims to balance the capabilities of global search and fast convergence. This mutation strategy is a little different from the reference of [21]. The population size is nine, and two of them are copies from the previous generation as elitists.

Task 2 uses more popular GA operations. Two-points crossover and a 2% mutation rate operation are used. The population size is nine, and one of them is copied as an elitist.

(d) Population size

Populations size, nine, is too small from the normal GA search point of view. This comes from the constraint



(b) GA coding for task 2

Figure 2: Parameters of three lights on a chromosome. 'Type' of a light is either an infinite or omni-directional, 'ON/OFF' and 'lightness' are of lighting, 'latitude', 'longitude', and 'distance' are spherical coordinate of a light position.

of an interactive GA. Since the human burden of interactive GA operators is serious problem for practical use, several dozen of populations cannot be shown on a display spatially or time sequentially. This interface design for the interactive GA is also an important research issue. We will describe this point in Conclusion again.

3 CG lighting experiment

To evaluate the performance of the interactive GA for 3-D CG lighting, five amateur designers are given design motives and make lighting CG arts with/without the interactive GA (see Figure 3). Lighting without the interactive GA means that they design the lighting manually based on their experience and knowledge. The experiences of the five designers on CG is up to two years.

When they design the lighting using an interactive GA, nine 3-D CG lighting arts created by GA are simultaneously displayed in each generation. The CG object and lighting conditions are described in section 2. The interactive GA operators evaluate how the displayed graphics are close to the given lighting motives and input their evaluation in five scales. The quantized score is used to reduce the burden of the operators [15].

Two sets of lighting motives are given to the tasks described in 2. Table 1 shows these motives. Five designers are requested to make lighting best matched to the given motives.

Further explanations to the motives of the task 2 are given before they design the task 2. They are: *tender-heated, pretty, cheerful, positive*, and *justice* for a movie heroine, and *nasty, persistent, sly, makeshift, evil*, and *devilish* for a movie villain.

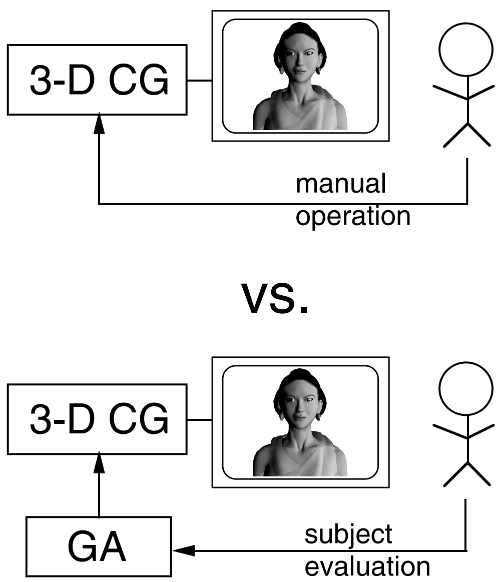


Figure 3: 3-D CG lighting arts made by amateurs with/without interactive GA.

The user interface for this experiment is designed not to tire CG designers seriously. Instead of numerical keyboard input, direct pointing in CG 3-D space is implemented using the Open Inventor, a X-Window tool kit for 3-D CG, for manual designing. For the design with the interactive GA, they input their 5-step evaluation by clicking one of five buttons attached to

Table 1: Lighting design motives.

given to task 1	*gloomy impression*
	cheerful impression
given to task 2	*heroine in a movie pamphlet*
	villain in a movie pamphlet

the each displayed CG object

Figure 4 shows some examples of designed in this experiment. Note that the original CG arts used in our experiment are color images on CRT display, and their quality is much better than these printed images on paper.

4 Subjective Test

The CG arts obtained in section 3 are evaluated by 20 subjects through the Ura's variation [20] of the Sheffé's method of paired comparisons [11].

The Sheffé's method of paired comparisons is a subjective test that requests subjects to give a score to the difference between a given pair of 3-D CG art, and it makes a psychological distance measure from the scores. The significance of differences among evaluated CGs is tested by the analysis of variance.

The number of comparing lighting images are 10: 5 images made by 5 amateurs manually, and 5 images made by 5 amateurs with the interactive GA. The number of pair of image used for the subjective test is ${}_{10}C_2 = 45$.

The lighting images are displayed in a same CRT display environment that 3-D experimental designers used in section 3. 20 subjects are divided into 4 groups of 4 or 6 subjects and evaluate the displayed CGs.

20 subjects are requested to give 5-step scores to the difference between a pair of image made in section 3 with considering (1) how the given lighting images are close to the given motif and (2) how they are qualified as CG arts.

The evaluation of the subjects for three 3-D CG arts are statistically tested. Figure 5 shows the statistical test results of lighting for two motives. The x-axis is a constructed psychological distance measure. Black and gray bars in the figures show confidence intervals of 95% and 99%, respectively. The distance between CG lighting arts whose confidence interval are not overlapped on the psychological distance measure in Figure 5 is significant.

5 Discussion

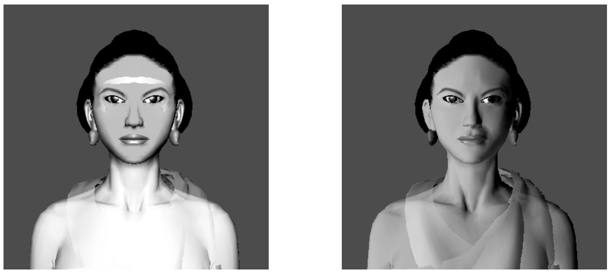
All designers whose manual lighting are poor (< 0) can significantly improve their lighting arts by using the

by hand　　with an interactive GA

(a) lighting design of *gloomy impression*

by hand　　with an interactive GA

(b) lighting design of *cheerful impression*



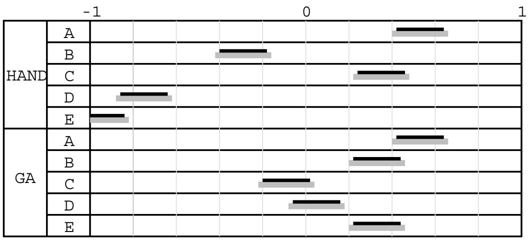
by hand　　with an interactive GA

(c) color lighting design of *heroine in a movie pamphlet*

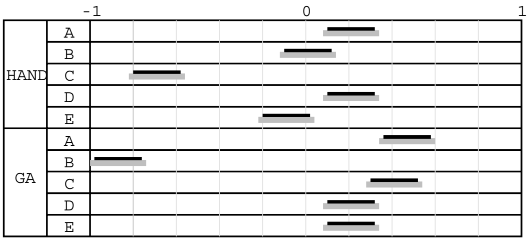
by hand　　with an interactive GA

(d) color lighting design of *villain in a movie pamphlet*

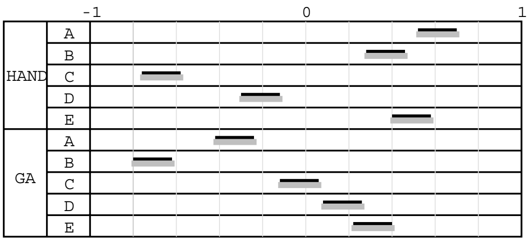
Figure 4: Examples of lighting arts made by hand and with the interactive GA for the given motive.



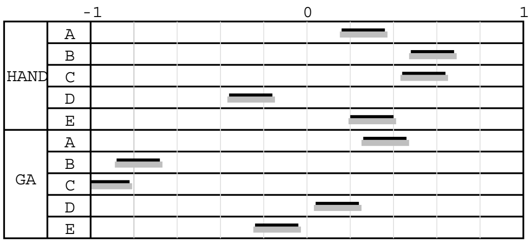
(a) lighting of gloomy impression



(b) lighting of cheerful impression



(c) lighting of heroine in a movie pamphlet



(d) lighting of villain in a movie pamphlet

Figure 5: Confidence interval of lighting arts made for four given motives on psychological scale. HAND and GA mean CG lighting made by hand and with with an interactive GA. A to E are five armature CG designers. Black and gray bars show confidence interval of 95% and 99%, respectively. Right side on the scale means better evaluation.

interactive GA. See operators: B, D, and E in Figure 5(a), C and E in Figure 5(b), C and D in Figure 5(c), and D in Figure 5(d). This result has not been depend on lighting tasks and GA operators used in this design experiment.

On the other hand, most of the operators whose manual lighting are evaluated better (> 0) have not been able to improve the lighting significantly by using the interactive GA, or even become worse. See operators: A and C in Figure 5(a), A, B, and D in Figure 5(b), A, B, and E in Figure 5(c), A, B, C, and E in Figure 5(d).

The designers whose manual lighting are evaluated better may be able to concretely imagine a good lighting combination for given concept. If so, they could set lighting to what they imagine easily by hand, but it took time till the GA searched out the lighting condition that they imagine. This estimation may be supported by the different evaluation between tasks 1 and 2; the task 2 that has wider GA searching space shows notably worse tendency than task 1.

Similarly, the designers whose manual lighting are evaluated poorly may not be able to concretely imagine a good lighting combination for given concept. Although they could not set lighting parameters easily by hand, the interactive GA might be able to search out better lighting conditions that they could evaluate better. This estimation may be supported by the different evaluation between tasks 1 and 2, too; the task 2 to which concrete and detail design concepts were given shows notably better tendency than task 1.

From these points of view, we can say that the interactive GA support system is more effective for less experienced armature designers. The combination of the global searching capability of GA and the evaluating capability of human is well-matched.

Note that this result does not directly mean that the interactive GA is useless for skilled designers. To evaluate if the interactive GA is useful for such designers, we need to conduct further two experiences: (1) whether the interactive GA whose initial condition is manual lighting design significantly becomes better than initial manual lighting, and (2) whether the interactive GA gives design hint which helps their manual design. They are the next research issues.

6 Conclusion

We have applied the interactive GA technique to the lighting task in 3-D CG. 3-D CG lighting arts created by amateur designers with/without the interactive GA have been evaluated through subjective tests. From subjective test, it has shown that the interactive GA effectively works on supporting amateur designers regardless of type of tasks and GA operators used in this paper, especially for designers whose experiences or capability is not high.

Though this paper has shown that the interactive GA is useful for skill-less designers, further experiments are need to evaluate the supporting effect of the interactive GA for the skilled designers. We have discussed this point as one of further research.

One of important points to make powerful CG supporting systems based on the interactive GA is a human interface. Besides applying the interactive GA to CG tasks, we are improving the input interface [15, 18] and presentation interface [16, 17]. These researches for several aspects of the interactive GA make it practical technology.

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