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Interactive Evolution of 3D Models based on Direct Manipulation for Video Games

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Abstract

Interactive evolutionary computation (IEC) is an effective solution for problems of user subjectivity. However, a significant problem with IEC is user fatigue. IEC requires direct evaluation, and so increasing the number of generations results in increased fatigue. We previously reported a method for building a three-dimensional (3D) model using interactive evolution. Here, we propose a method of direct manipulation (DM) using IEC to reduce user fatigue, whereby direct encoding is applied to the final results during post-processing. This allowed instant changes to the shape of the final model, reducing user fatigue. This method can manipulate several parameters of 3D models in real-time. Test results show that IEC with DM is superior to IEC alone.

Keywords: Interactive Evolutionary Computation; 3D Model; Direct Manipulation; Video Game;

1. Introduction

Evolutionary computation (EC) is a useful method to account for user subjectivity [1]. However, it requires control of an evaluation function, which can be inconvenient. Interactive EC (IEC), on the other hand, does not use an evaluation function but rather aesthetic selection to solve problems. However, IEC can lead to user fatigue during the course of an experiment. A number of studies on IEC have attempted to reduce this fatigue [6,7]. Previously, we researched the generation of three-dimensional (3D) models for videogames using IEC, and proposed a method that alters the results using post-processing [2]. In this paper, we describe a new method,

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based on our previous work, that reduces user fatigue through direct manipulation (DM). The scheme is illustrated in Figure 1.

2. Background

We previously reported a method for generating 3D models using IEC [2]. With this tool, amateur gamers can create 3D models that can be directly exported into videogames. However, the use of IEC can require a large number of generations, which can lead to user fatigue. A method that provides an interface that allows users to change the most recent results would allow direct encoding, which would improve the results without fatiguing users. We propose such a method using DM.

Cho et al. showed that evolution can be accelerated using DM [3]. They evolved fashion designs using IEC, and the number of generations decreased when they used DM. Similarly, we can expect to reduce user fatigue using DM.
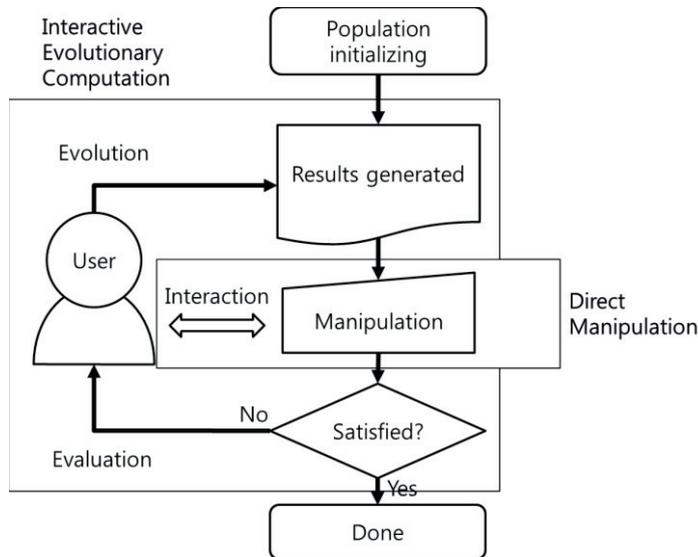

Fig. 1. Overview of direct manipulation based on interactive evolutionary computation.

3. Method for 3D Building Generation using Direct Encoding

In this section, we describe a method for generating 3D models using direct encoding (DE). First, to provide an intuitive method for users, we developed a tool for combining several simple 3D objects to generate complex 3D shapes. Using it, users can change the results intuitively by modifying each object. The changes should have a one-to-one correspondence. If not, then if, for example, one block is changed to two different blocks, the user may become confused.

3.1. Method to Generate 3D Shapes

Our method generates shapes by combining circular, rectangular, and polygonal pillars with three types of end sections, and the objects can be of variable size (Fig. 2). These features are necessary not only for crossover and mutation, but also for changing the size of objects. This method allows users to create complex shapes, particularly because it is not limited to objects of fixed size.
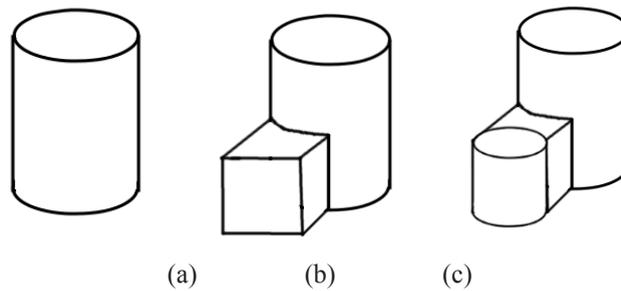
(a)   (b)   (c)

Fig. 2. (a) A single object. (b) Two objects of different size.
(c) A compound model of three objects of different size.

3.2. Objects for Direct Manipulation

In our method, all elements of an object have the same size for DM. A polygonal block requires more information than a circular or rectangular block. However, we do not need using a lot of memory for only polygonal blocks with GA. Therefore, we used a reproducible random number generator to make each block the same size. This generator, which provides a reproducible random number [4], can produce objects of various shape but the same size. Table 1 shows the structure of each segment in an object, an important aspect of which is seeding using the random number generator. Four seeds can result in a number of circular, rectangular, and polygonal shapes, and these can be converted into other shapes without additional bytes. The feature is based on DE, and an object with a given parameter consists of eight bytes.

Table 1. Structure of each segment in each object.

Name	Size of parameter	Value
Type of wall	4 bits	0: Rectangle
		1: Circle
		2,3: Polygon
Type of end	4 bits	0: Flat
		1: Bevel
		2: Spire
Position X	1 byte	$0 \sim 255$
Position Y	1 byte	$0 \sim 255$
Height	1 byte	$0 \sim 255$
Seed for Generator	4 bytes	$0 \sim 0x7FFFFFFF$
Total	8 bytes	

4. DM with IEC

We can generate 3D models that can be applied to DM. Here, we describe how we can apply DM to an interactive interface. The Web-based interactive interface that we used utilizes WebGL for graphics [5]. This interface generates 3D models with fixed textures. The 3D model can be manipulated on the screen.

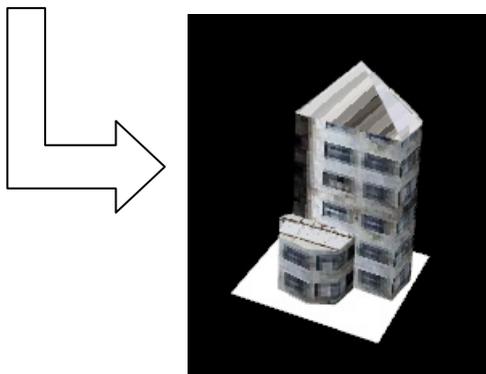| 34 | 54 | 47 | 91 | 34 | 89 | 190 | 185 | 2 | 27 | 34 | 32 | 16 | 220 | 127 | 79 |

Fig. 3. Example of a 16-byte model.

4.1. DM

DM is a method that allows users to directly manipulate parameters of an object during evolution. It can reduce the total number of evolutionary steps, and hence reduce the amount of user input required to make 3D models. Figure 4 illustrates the process of manipulation using DM. It is similar to DE, but in addition to adding new features, it can manipulate existing objects. In this way, IEC with DM can change the direction of evolution based on users' subjective manipulation.
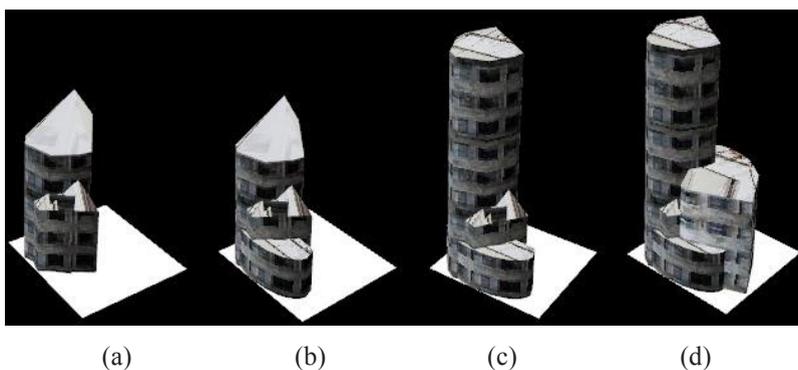

(a)   (b)   (c)   (d)

Fig 4. (a) Base result. (b) Adding a segment. (c) Modifying the segment. (d) Adding another segment. All processes are conducted on a single object.

4.2. Web-based IEC Interface

We added a DM function to the Web-based 3D building generation interface. Figure 5 (left) shows the basic screen of the interface used for IEC. The user can evolve objects by selection. If users want to manipulate an

object, they can edit the result on the publish screen, as shown in the right panel. In this screen, the user can publish a result or provide feedback on the manipulated result via the menu.
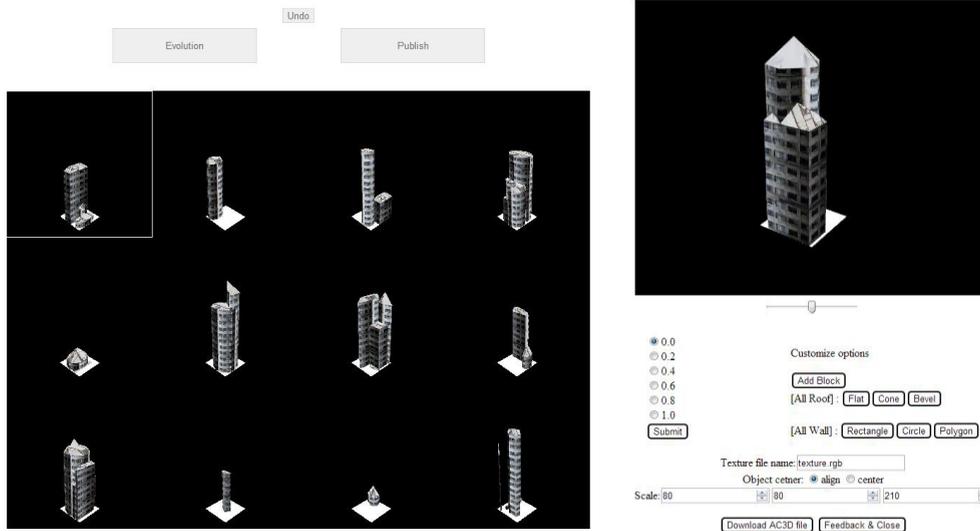

Fig. 5. (Left) Main screen. (Right) Publish (manipulation) screen.

5. Results

We gave two themes to seven participants with no previous 3D modeling experience. Participants generated 3D building models using three methods: IEC only, DM only, and IEC with DM. We collected 'satisfaction' and 'fatigue' results from the users based on two themes: 'a livable building for the upper class' and 'a livable building for the middle class.' The results were integers between 1 and 10, where a larger number for satisfaction is better and a lower number for fatigue is better. Some of the resulting structures are shown in Figure 6.

Tables 2 and 3 show the results of a Scheffe test. As shown in Table 2, IEC only and DM only had clearly different results (p-value < 0.05). IEC with DM was positioned between IEC only and DM only, as expected. As shown in Table 3, participants were most satisfied with the IEC with DM method. The associated fatigue was greater than that of IEC only but less than that of DM only. IEC may have shown low fatigue in our tests because the number of selection was limited. DM was associated with high satisfaction because users have more control over the results. This indicates that merging IEC and DM may be expected to combine the benefits of both techniques.

Table 2. Result of a Scheffe test with user's satisfactions and fatigues

Comparison of two methods	p-value
IEC only – DM only	0.000398
IEC only – IEC with DM (proposed method)	0.076993
DM only – IEC with DM	0.211616

Table 3. Mean values of satisfaction and fatigue and group by Scheffe test

Type of method	Mean of satisfaction	Mean of fatigue	Group
IEC only	6.50	4.00	A
DM only	7.14	5.84	B
IEC with DM	7.71	5.04	AB

6. Conclusion

We have described a method for generating 3D shapes iteratively and interactively; we found reduced user fatigue compared to DM and improved user satisfaction compared to IEC. However, participants reported that the user interface of DM was not satisfactory, and thus it should be improved. Nevertheless, our results show that problems with IEC can be overcome by providing a DM interface, and users are able to achieve satisfactory results with less fatigue.
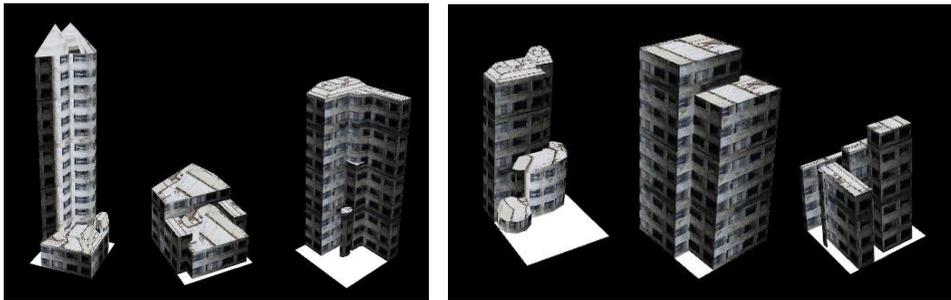

Fig. 6. Selected user-generated shapes from the experiments.
(Left) A livable building for the upper class. (Right) A livable building for the middle class.

Acknowledgments

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