A 3D Modeler Using Genetic Algorithm

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Abstract We propose a new approach to easily creating 3D geometric models from real objects. *Genetic algorithm* (GA) is used as a framework for the acquisition of approximated models and the creation of new 3D geometries from the real objects. We use the implicit method for 3D geometric representation. A set of model parameters to approximate a real object's shape are explored by GA. Then, the approximated model is evolved to various 3D geometries by the proposed modeler using interactive GA. The user can easily create novel 3D models through subjective evaluation.

遺伝的アルゴリズムを用いた３次元モデル生成法

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あらまし 現実物体から新しい３次元モデルを容易に生成するための１つの手法を提案する．この手法では，現実物体の形状を近似した変形可能な３次元モデルの獲得とそれを基にした新しい３次元モデルの生成に遺伝的アルゴリズム（以下ＧＡ）を用いる．また，３次元モデルの表現法には変形可能である陰関数モデルを用いる．まず，ＧＡを用いて陰関数モデルのパラメータを探索し，現実物体を近似した形状をもつ３次元モデルを生成する．そして，インタラクティブＧＡを用いたモデラにより，近似モデルから様々な形状をした３次元モデルを生成する．利用者は生成された３次元モデルを主観的に評価し，この評価を基にシステムが３次元モデルを進化させる．このことにより，利用者が芸術的センスに乏しくても斬新な３次元モデルを簡単に造りあげることができる．

1. Introduction

Computer graphics (CG) becomes a popular technology in many fields such as games, medicine, product design, and art. However, an enormous amount of time and efforts is required to create 3D models from scratch. One solution is to capture a real object's shape with the 3D scanner, produce a deformable model from the scanned object data (called a point cloud), and produce new geometries by deforming the model. This method relies on a fact that a new product tends to be produced by modifying the current design rather than inventing a new one from scratch. Because a point cloud consists of many discrete 3D vertices, it is difficult to use as a base model for deformation.

Therefore, a method to automatically convert the point cloud to a deformable 3D model is desired. Moreover, the user need a good design sense to create appealing shapes. Consequently, a mechanism to support easy creation of new 3D geometries from the deformable model also is a critical requirement.

There are many published methods to convert a point cloud to some types of 3D model[1][2]. However, they do not consider to automatically create new shapes from the acquired model after the conversion. Other research groups focus on the modeling interface to realize easy deformation[3][4]. They cannot, however, effectively support the user's cut and try process to create new models.

Our proposed method is to make a deformable 3D model from a point cloud with GA and to create new 3D geometries based on the deformable model with interactive GA. It represents the deformable model by using the implicit method[5]. An implicit model has a set of deforma-

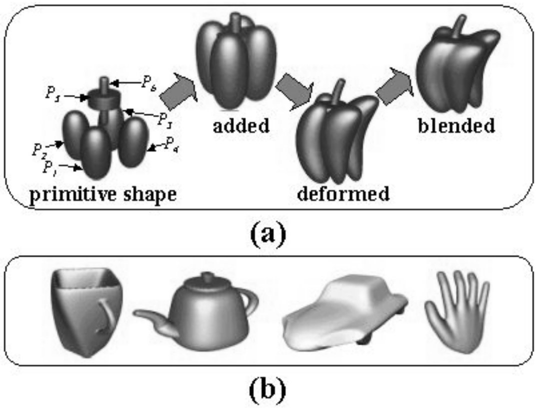

Figure 1: Implicit models.
(a)deformation and blending of primitive shapes
(b)implicit model example

tion parameters to define its geometry.

Because the modification of these parameters intuitively deforms its model shape, a set of optimum parameters to approximate a point cloud can be found by using an appropriate optimization method. The dimension is generally more than fifty. We adopt GA as a unified optimization method for these problems. Additionally, a set of parameters to represent new and innovative 3D shapes can also be explored by such an optimization method. GA is an excellent method at finding an optimum solution in a very broad search space.

Finding a set of implicit model parameters to approximate a specific point cloud is a very difficult problem because the search space of model parameters is a very high dimensional space. While other optimization methods can easily find local optimum solution in such high dimensional space, the proposed GA-based search method can efficiently find a globally optimum solution.

The interactive GA-based deformation method creates various 3D shapes from the approximated model. A group of models, the so called a generation, is exhibited to the user and the user subjectively

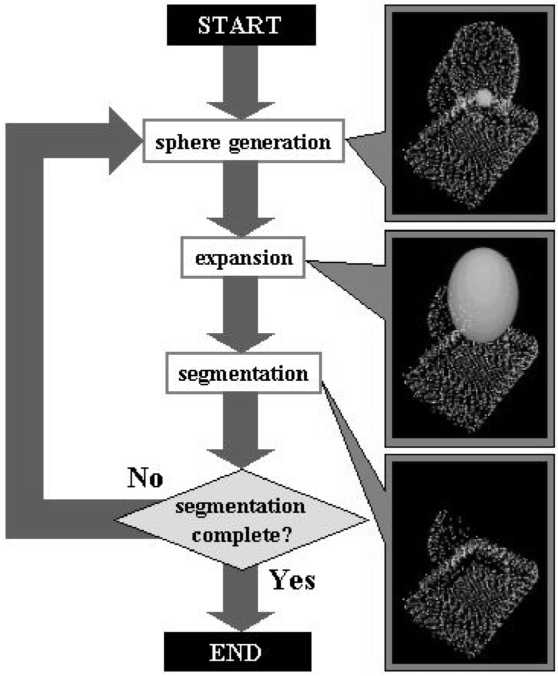

Figure 2: Superquadrics expansion method for segmentation.

evaluates these models in the generation. The system produces a new set of models based on the user's evaluation using GA and exhibits them again. This process is repeated until the user get a desirable model. Because this process demands no skills and knowledge on CG modeling, even novice user can easily create new models. Various shapes including unexpected ones can intuitively be produced because of GA's randomness.

2. GA-base 3D Modeling

2.1. Implicit Model

The implicit method blends multiple primitive shapes to generate a complex geometry as shown in figure 1[5]. A primitive shape is represented by using a superquadric function, being defined by a set of deformable parameters. The implicit model can intuitively be deformed by changing the parameter values.

2.2. Deformable Model Generation Using GA

A point cloud taken from a real object needs to be segmented before the approximation. We introduce a segmentation method, what is called the superquadrics expansion method[6]. This method swells a superquadric sphere in the point cloud until the sphere matches the point cloud's surface. All vertices matched with the swelled sphere is segmented as a part. Figure 2 shows how this method work. The process is iterated until all vertices in the point cloud are segmented. Finally, the point cloud is converted to a set of parts and each part is used to generate a deformable model.

GA is used to explore an optimum set of parameters to approximate each part in a segmented point cloud separately. Figure 3 illustrates the shape approximation process. Each segmented point cloud is approximated one superquadrics primitive shape by GA operations. Each primitive shape, the so called an individual, is encoded as a chromosome and a chromosome in genotype consists of model parameters of a primitive shape. A group of individuals, what is called a generation, is created for the parameter optimization by GA.

The process of optimizing model parameters is as follows.

1. Create the first generation by randomizing model parameters.
2. The fitness value of each individual is calculated by a predefined evaluation function.
3. The next generation is created by the simulation of natural evolutionary processes such as selection, crossover, and mutation based on each individual's fitness value.

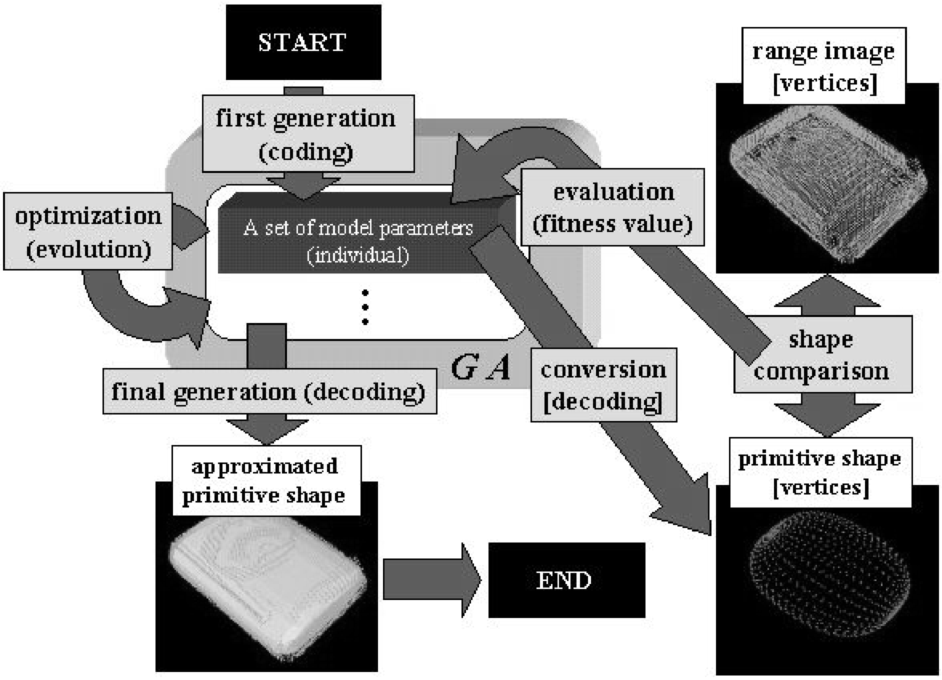

Figure 3: Approximation process of one primitive shape by GA.

4. Return to step 2 until an optimum set of primitive parameters is found.

A set of vertices is generated from the primitive parameters to calculate the fitness value for each individual. Next, a pair of nearest vertices is spotted between the segmented point cloud and the primitive shape, and the distance of the vertices pair is calculated. The distance calculation is executed for all vertices in the segmented point cloud and the primitive shapes. Then, the fitness value F is computed as follows:

$$F = Ave \times \omega_1 + SD \times \omega_2$$

where Ave is the average distance between the segmented point cloud and the primitive shape, SD is the standard deviation, and ω_1 and ω_2 are the weight values. Because smaller fitness value means better model parameters, the set of optimum parameters is detected when F becomes smaller than a predefined threshold.

As the approximation process is executed for all segmented parts, a deformable model approximating the captured point cloud is acquired by blending all primitives with the implicit method.

2.3. Model Deformation Using Interactive GA

A deformable model acquired in the previous approximation process is used as an initial shape and deformed to produce new models by interactive GA.

First of all, this process randomly vibrates the model parameters to create a set of varied models as an initial generation. Up to twenty models are simultaneously displayed as shown in figure 4. Next, the user intuitively select their preferable shapes in the display and give them higher fitness values. Then, the system produces a new set of models (a new generation) based on the given fitness values and displays them again. This process is repeated until the user gets a satisfactory model.

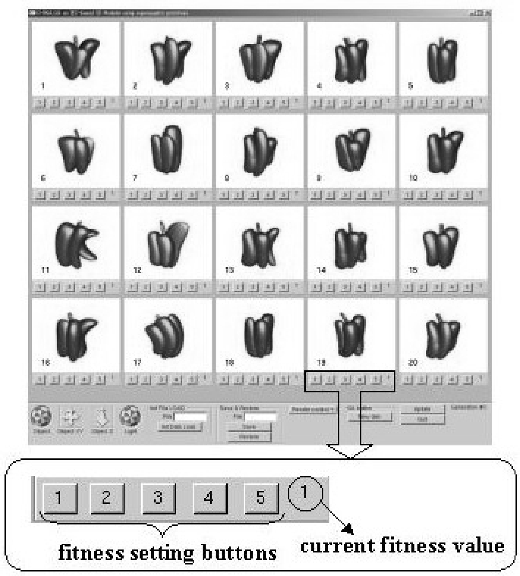

Figure 4: Interface of interactive GA-based modeler.

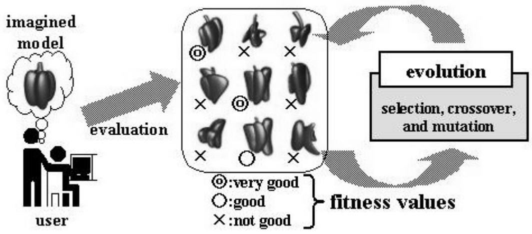

Figure 5: Interactive GA-based modeling.

A difference between the interactive GA-based deformation and the GA-based shape approximation is how to set the fitness value. While the fitness value is calculated by a predefined evaluation function in the shape approximation, it is set by the user based on their subjective preference in the model deformation. A set of models in a population is evolved by simulating the GA operations such as selection, crossover, and mutation as described in the previous section. Figure 5 shows the process of the interactive GA-based modeling.

3. Preliminary experiment

We conducted a preliminary experiment

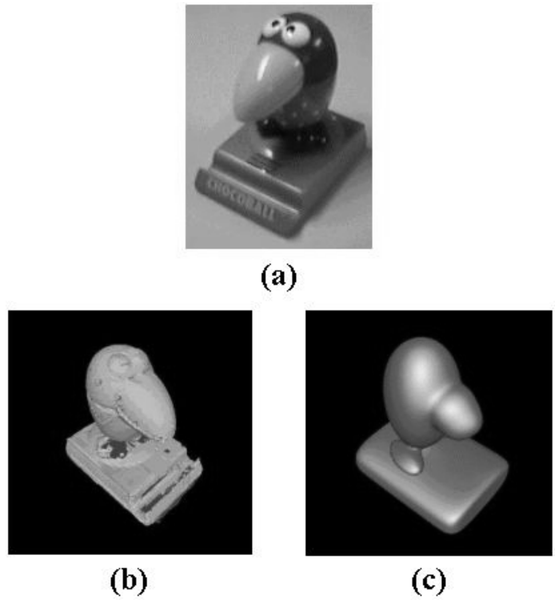

Figure 6: Experimental result of shape approximation.

(a)character merchandise used in experiment
(b)point cloud with surface rendering
(c)approximated model

to test the effectiveness of our proposed method. We used a character merchandise, as shown in figure 6(a), as an original model, and tried to create different shapes from it. Figure 6(b) shows a point cloud with surface rendering captured by a 3D scanner, the Minolta's VIVID 700, and figure 6(c) is an approximated deformable model derived from the point cloud. The shape approximation is performed under the following conditions:

- Population count is 100,
- Selection rate is 80 %,
- Crossover method is one-point crossover,
- Mutation rate is 1 %.

The deformable model is approximated by using five primitive shapes and deformed by the interactive GA modeler. As a result, some interesting character shapes

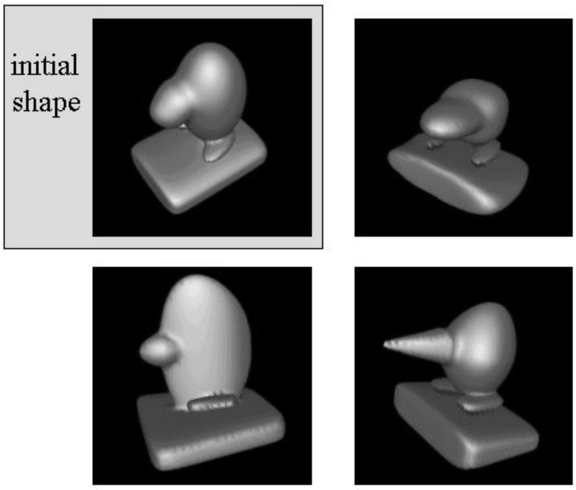

Figure 7: Experimental results of deformation.

are acquired as shown in figure 7. The approximated model is not so accurate one as found in other proposed methods[1][2]. It catches, however, enough features of the original shape and provides a good start in the following model deformation process.

4. Conclusions

We proposed a modeling method to easily creating 3D geometries from real objects. It allows the user to create new 3D shapes without depend on any expertise in 3D modeling techniques.

The approximation, however, sometimes generates an inappropriate shape from the point cloud, because the GA parameters are not sufficiently tuned. We need to optimize the GA parameters for selection, crossover, and mutation operations. We also need to conduct further experiments using more realistic objects to prove the effectiveness of our method.

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