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Generic 3D Component-Based Model Synthesis from Mesh Segments

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***Abstract*—In this paper, we have proposed a component-based 3D model synthesis system. In the new system, the user is able to design a new models by simple composition of available mesh components from two or more models, which is often applied to variate the outlook of the characters or objects in a large scene. With our technique, we may create characters such as the legendary minotaur, centaur, mermaid, as well as some illusionary figures in science fictions, movies, or computer games.**

I. Introduction

The rapid advancements of the 3D technologies in recent years directly leads to the emerge of 3D applications and contents such as the computer games and animations, etc.. The digital content developments, especially the geometric design of 3D models is somehow tedious and time consuming, which usually takes up a lost of human resources and work hours in a project. While the application of 3D models are popularized recently, a lots of online repositories of 3D models are now readily seen on the internet.

A recent trend in the task of content creation advocate modeling by example parts to provide fast semi-automatic or automatic modeling, which usually provides a simple and useful authoring tool or facility for the artists to do fast model composition by reusing existing parts [1]–[8], [8]–[12]. However, these approaches usually require a meaningful decomposition and a semantic description over the example meshes. Moreover, to allow seamless and proper attachment, special care has to be taken on relocating, orienting, and stitching the selected part.

To address such issues, we proposed a simple yet effective approach to modeling by example parts. In our work, we have assumed that all the input models presented in the database are properly segmented into parts. If they are not segmented, we may either segment the input automatically by a part-type segmentation tool or cut it manually.

In our new system, we started presenting the user an option list to choose a base model from our test database. Afterward, the user may find a usable part from the database by selecting a model and one of its parts; then, he can replace a part of the base mesh with the selected part and form a variation of the base model. Modeling in this way saves a lots of works by reusing the parts from existing models. Hence, it has become a research trend and was intensively studied in these years.

II. Related Works

In [3], Funkhouser et. al. proposed an example-based modeling approach to create a model by replacing parts based on geometric similarity. In their approach, the user is able to select a candidate part from a collection of example parts, then locate, and scale the selected part to replace a replaceable part of a base mesh. In a later work, [4] proposed using contact relations prior to the part-level replacements so that the models can be consistently co-segmented.

Lately, [5] proposed an enhancement data-driven approach to rough 3D contents creation by using customized example parts. In which, the customized parts are recognized and retrieved by means of component matching and retrieval techniques. In followup efforts, a branch, called assembly-based modeling, proposed by [7], [8] suggested using probabilistic models in learning parts for assembling or generating shape variations from existing ones.

In addition, Xu et al. [6] proposed a photo inspired approach to the creation of 3D models by deforming parts according to the constraints set by the image silhouettes.

H. Huang et. al. proposed an automatic shape composition method to fuse two shape parts [9]. At its core of their approach is a field-guided shape registration guided by an ambient vector field to automatically align the input parts by conforming their sharp features. This approach guarantees natural continuation by interpolations between the stitched sub-parts. However, their approach is limited to the registration of only two parts of well-defined open boundaries at a time and the result may not be semantically desirable compositions.

Another method proposed by E. Kalogerakis et. al. focus on synthesizing shapes by identifying new plausible combinations of components from existing shapes [8]. In their work, a new generative model of component-based shape structure representing probabilistic relationships between properties of shape components is presented. Their approach assumes that the geometric features of components are linear correlated and normally distributed; hence, it is not capable of capturing more complex geometric variability and may fail to produce visually pleasing results. Furthermore, they did not consider optimizing the orientation of components and preventing intersections between the components.

A. Jain et.al. proposed a shape blending approach by re-combining parts from different shapes according to constraints deduced by shape analysis involving shape segmentation, contact analysis, and symmetry detection [10]. Their system can rapidly produce new visually pleasing blended variations of the database shapes with similar symmetry and adjacency structure.

III. Overview

In our approach, we have formulate our problem as follows. Given a based mesh $M(V, F)$, in which V represents the set of vertices and F the set of faces. We have assumed that the mesh can be segmented in to a set of m joined subparts S by a shape decomposition method D, with which

$$M \overset{D}{\rightarrow} S : S = \{C_0, C_1, \ldots, C_m\}, \tag{1}$$

where C_i represents the i-th subpart of M.

Provided that the user has found a replaceable subpart C'_j from another mesh M' from the database, which has been segmented by D into $S' = \{C'_0, C'_1, \ldots, C'_n\}$ and has selected a subpart C_i of the based mesh M to be replaced by C'_j. Furthermore, we assumed that the open boundary of a mesh subpart C can be successfully identified by $B(C)$, which is denoted as ∂C.

$$C \overset{B}{\rightarrow} \partial C, \tag{2}$$

IV. Our Method

The goal of our algorithm is to optimizing the orientation of C'_j and preventing intersections between $C'_j$and the other subparts of the base mesh M, i.e., $S - \{C_i\}$.

In other words, our algorithm is to replace C_i with and C_j and create a blended mesh model M''. On the basis of such concept, we can outline the algorithm of shape replacement as follows.

1) Segment base mesh M by algorithm D: $M \overset{D}{\rightarrow} S : S = \{C_0, C_1, \ldots, C_m\}$;
2) Remove $\{C_i\}$ from S;
3) Remove $\{C'_j\}$ from S';
4) Locate the boundaries of $S-\{C_i\}$ and $\{C'_j\}$, i.e., $B(S-\{C_i\})$ and $B(\{C'_j\})$;
5) Set corresponding feature points between $B(S - \{C_i\})$ and $B(\{C'_j\})$;
6) Orient $\{C'_j\}$ and stitch corresponding feature points between $B(S - \{C_i\})$ and $B(\{C'_j\})$ so that $S' = S - \{C_i\} \cup \{C'_j\}$;
7) Output the resulting mesh M'

We simply search for a rigid transformation that aligns the selected subpart then fuse the subpart into the based mesh. Prior to the removal of the selected part C_i from the base mesh M, we have to locate and refine the boundary between part C_i and the remaining part of the base mesh M, i.e., $B(S-\{C_i\})$ and $B(\{C'_j\})$ by smoothing the boundary curve similar to the way we have proposed earlier in [13].

Afterward, to properly align the subpart with the remaining of the base mesh, we have to compute the normal $\vec{n}(P)$ of the average planes P of the open boundaries $B(S - \{C_i\})$ and $B(\{C'_j\})$ and their center of the projected convex polygon $C(P)$ formed by the projection of the boundary vertices onto the average plane. Hence, the registration of C'_j to $S - \{C_i\}$ can be achieved by translating $C(P(B(C'_j)))$ to $C(P(B(S - \{C_i\})))$ followed a rotation aligning $\vec{n}(P(B(C'_j)))$ with $\vec{n}(P(B(S - \{C_i\})))$.

In the finale stage, we compute the least common multiple of the number of vertex between $B(S - \{C_i\})$ and $B(\{C'_j\})$ then refine the boundaries of $B(S - \{C_i\})$ and $B(\{C'_j\})$ until a one-to-one correspondence their vertices can be derived. The stitching of the boundary vertices is then can be trivially performed by choosing from nearest points or performing smooth interpolations.

V. Experimental Results

We have collected our test segmented/tagged meshes from the dataset of [14]. The results are shown in Figure 1. The left column shows the base mesh model. Note that in the resulting new mesh, the body, $S - C'_j$, is colored red, while the planted subparts from the mesh presented in the middle column is colored blue.

From the results shown in the figure, we have shown with our partial results that our novel approach can successfully create a new model by component-wise replacements for segmented meshes.

VI. Concluding Remarks and Future Works

In this paper, we have addressed the issues of modeling by example, in which, a new model can be created from example meshes that have been previously tagged or segmented. Instead of automatic generation, we choose a user-driven interactive approach that presented the user an intuitive user interface by which he can arbitrarily create a new mesh by replacing subparts of a user-selected base mesh with arbitrary subparts from other meshes. As we proved by the experimental results demonstrated in previous section, the new approach is simple and effective.

In the near future, we will try to apply techniques from shape understanding and image segmentation to allow a smart selection mechanism from screen space so that more freedom can be allowed for the user in choosing subparts from the mesh.

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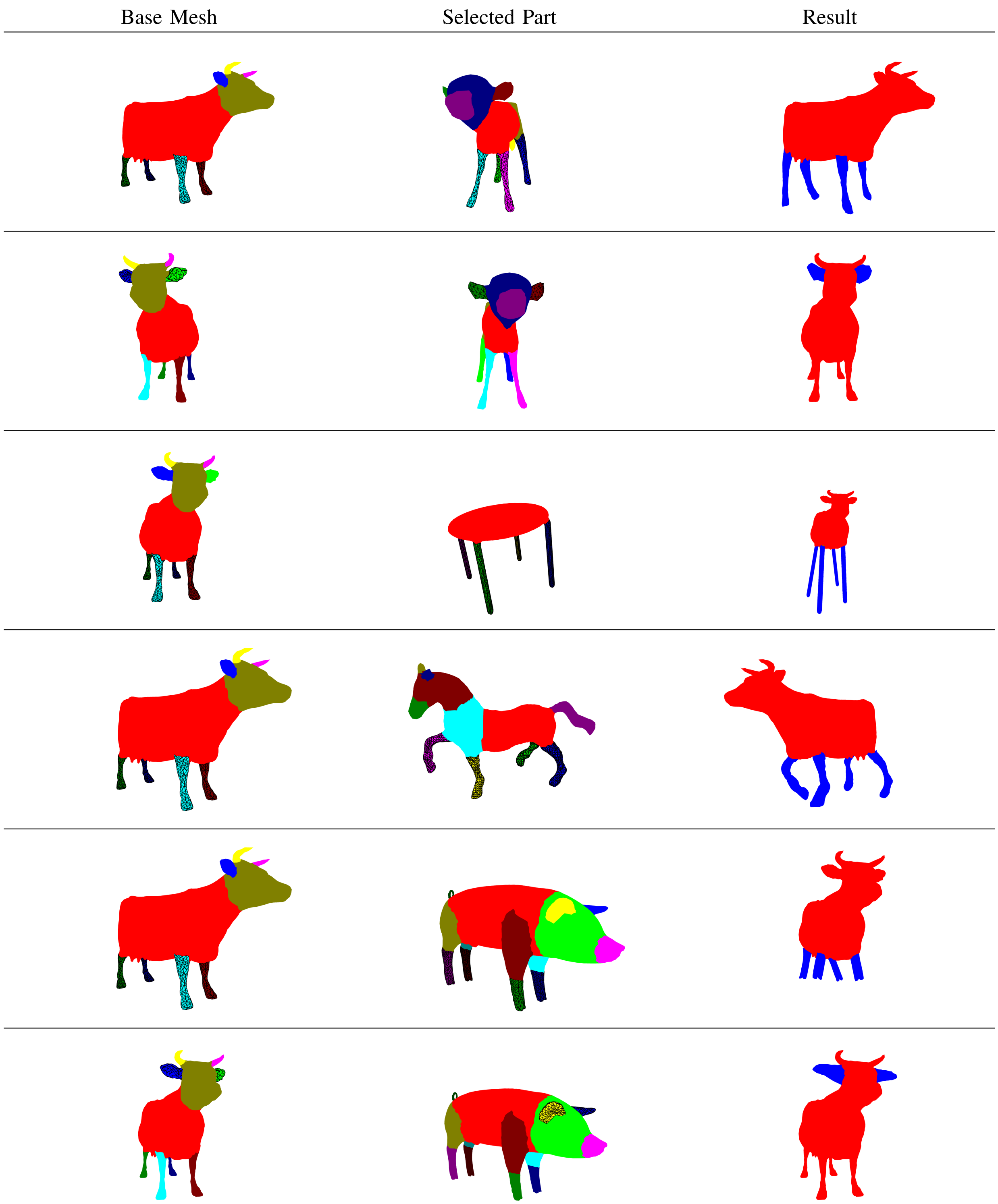

Fig. 1. The experimental results: the base mesh on the left, selected subparts are maked with black color in the middle, the blended result on the right.

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