Modelling with Implicit Complexes

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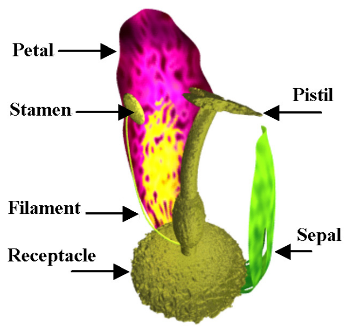

Figure 1. Components of a flower.

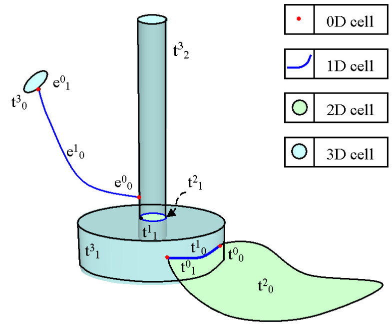

Figure 2. IC structure of the flower model.

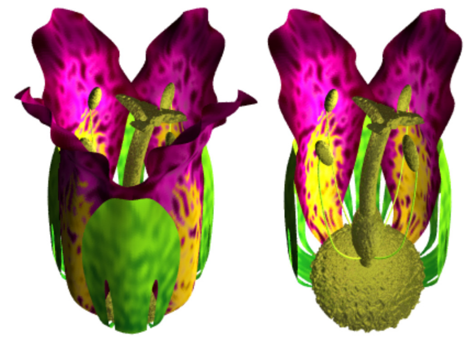

Figure 3. Rendered IC flower model.

1 Introduction

This sketch presents a novel method for modelling heterogeneous objects. Such objects can be heterogeneous from the point of view of their dimensionality and their internal structure. We have defined a hybrid model, called an Implicit Complex (IC) [Adzhiev et al. 2001], based on the concepts of cellular spaces and CW-complexes. We have extended CW-complexes with the implicit description of cells and allowed more sophisticated relations, between the cells, to be defined. A heterogeneous object represented by the hybrid model is considered as a single entity integrating different representation schemes with the ability to preserve and extract information about its components and independently process them while guaranteeing topologically correct definitions.

2 Hybrid Model Based on the Implicit Complex

We have proposed the hybrid IC-based cellular-functional model of heterogeneous objects in [Adzhiev et al. 2001]. For the description of an IC, it is necessary to specify its topology and its geometry. Geometrically an IC is a union of properly joined cells of different dimensionalities, where each cell has a homogeneous description, either explicit or implicit. IC topology is described by relations between its elements.

Explicit (e.g. parametric, BRep) cells e_i^q (where q is the cell dimension and i is its cell index) are defined by a characteristic map of a topological ball from a space of real parameters into the modelling space. Such a map can be described by a vector function of scalar parameters that are similar to those traditionally used in CAD and FEA for the representation of curve segments, surface patches and curvilinear polyhedrons.

Implicit cells t_j^s can be described in one of two ways: with an FRep *(function representation)* in E^3 by an inequality of the form $F(X) \geq 0$ (where $F(X)$ is a continuous real function of point X) or with an FRep in E^2 by a mapping of the form $h_j : E^2 \rightarrow E^3$. Cells of lower dimension can also be described using FReps. For instance, 0D points or 1D curves can be represented as intersections of implicit surfaces and 2D surface patches as implicit surfaces trimmed by FRep solids.

As to the IC topology, there are two main types of relations that establish connections between cells of different dimensionalities: the boundary relation and the "to contain" relation.

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In the IC model, cells can overlap and some cells can be located inside others. Topological correctness of an implicit complex is guaranteed by the proper restrictions imposed on the relationships between cells inside the implicit complex.

To describe the non-geometric properties of a heterogeneous object, represented by an IC, we use the cellular-function model of the attributes introduced in [Adzhiev et al. 2001]. In the hybrid model, the geometry and attributes are completely independent although they share the same modelling space. Each attribute A_i is defined by its set of values $N_i^{m_i}$ along with a map function $S_i : E^3 \rightarrow N_i^{m_i}$ (where m_i is the dimension of the attributes).

3 A Case Study

To illustrate the modelling process consider the following example (Fig. 1), where flower's the 3D receptacle, pistil and stamens are modelled using FReps. The 2D petals and sepals are first defined using FReps in a 2D space, and then mapped to a 3D space using an appropriate non-linear mapping. The 1D filaments are explicitly defined by spline curve segments in 3D space.

The IC model of the flower (Fig. 2) contains cells corresponding to its components (Fig. 1). Here the receptacle is described by the 3D cell t_1^3, the pistil by the 3D cell t_2^3, the stamen by the 3D cell t_0^3, the filament by the 1D cell e_0^1, and the petal by the 2D cell t_0^2. To assemble the listed components together we have to introduce the auxiliary cells $\left(e_0^0, e_1^0, t_0^0, t_1^0, t_0^1, t_1^1, t_1^2\right)$ describing their interconnections through the corresponding boundary relations.

The flower is considered as a heterogeneous object with colour attributes. To render implicit complexes (Fig. 3), existing polygonization and ray-tracing algorithms are used taking into consideration the dimensionality of the cells, their representation type and the relations between them.

From the above discussion we can see that ICs make it possible to combine cellular representations and constructive function representations in a uniform model. Future work directions include an extension of the model to time-dependent ICs, the development of specific operations applicable to entire IC, and the implementation of a specialized modelling and animation language which uses this novel modeling technique.

References

ADZHIEV, V., KARTASHEVA, E., KUNII, T., PASKO, A., SCHMITT, B. 2001. Cellular-functional Modeling of Heterogeneous Objects, In *Proceedings of 7th ACM Solid Modeling Symposium*, ACM Press, 192-203.