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3D Object Classification Based on Volumetric Parts

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ABSTRACT

This article proposes a 3D object classification approach based on volumetric parts, where Superquadric-based Geon (SBG) description is implemented for representing the volumetric constituents of 3D object. In the approach, 3D object classification is decomposed into the constrained search on interpretation tree and the similarity measure computation. First, a set of integrated features and corresponding constraints are presented, which are used for defining efficient interpretation tree search rules and evaluating the model similarity. Then a similarity measure computation algorithm is developed to evaluate the shape similarity of unknown object data and the stored models. By this classification approach, both whole and partial matching results with model shape similarity ranks can be obtained; especially, focus match can be achieved, in which different key parts can be labeled and all the matched models with corresponding key parts can be obtained. Some experiments are carried out to demonstrate the validity and efficiency of the approach for 3D object classification.

Keywords: 3D object classification; interpretation tree; shape match; similarity measure; volumetric part

Cognitive informatics studies intelligent behavior from a computational point of view. It is the interdisciplinary study of cognitive and information sciences that investigates into the internal information processing mechanisms and processes of the natural intelligence in human brains and minds, such as reasoning, understanding, visual and auditory perception, and so forth (Wang, 2003, 2007; Wang & Kinsner, 2006). The work in this article mainly focuses on 3D object classification by intelligent computation, which is one of the basic research topics of visual information representation and interpretation.

Specifically, the problem considered in this article is how to classify 3D object into one of the known object classes based on volumetric parts and obtain the 3D models in the library with shape similarity measures. It is well known that complete and precise description of 3D objects and elaborate matching are essential to the 3D object classification. Volumetric representation has been used popularly in 3D object recognition (Krivic & Solina, 2004; Medioni & François, 2000; Pentland, 1987) because it is viewpoint independent, insensitive to local variations, and supported by extensive psychological evidence, most notably "Biederman (1987)."

Superquadric-based geon (SBG) description is implemented in this article for representing volumetric parts of 3D objects, which combines superquadric quantitative parametric information and geon's qualitative geometrical attributes. There has been much research work focused on object recognition with superquadrics or geons (Borges & Fisher, 1997; Dickinson, 1997; Krivic & Solina, 2004; Pentland, 1987; Raja & Jain, 1992). Especially, in "Borges and Fisher (1997)," superquadrics and geons were used for volumetric representation, and interpretation tree (Grimson, 1990) was implemented for 3D recognition. The models were arranged by the qualitative shape information (geon types) of model's parts. The indexing stage selects a subset of the model library to be fully searched based on the geon type. However, only the obtained geon types are not precise to determine the search space of 3D models due to the possible classification error and the ambiguity of geon type comparison of two corresponding parts of models, which may lead to miss the correct recognition results. As well, "Csákány and Wallace (2003)" studied the 3D meshed object classification, in which the bounding surface of objects was segmented into patches that can be described by some shape properties. Learning by some examples and class generation are two key components of the system.

In this article, we present a volumetric part based 3D object classification approach, in which the classification problem is looked upon as two subproblems, the constrained search on interpretation tree and the shape similarity measure computation. The article mainly makes the following contributions:

1. A set of integrated shape features of 3D object are proposed based on the SBG description. These features not only reflect the individual parts' geometrical shape, but the models' topological information among volumetric parts, which have powerful representative and discriminative capability;
2. A shape similarity measure computation algorithm is developed to evaluate the similarity measure between the unknown object data and 3D models in the library;
3. Both whole and partial matches can be accomplished with model shape similarity ranks by the proposed classification approach. Particularly, focus match can be achieved, in which different key parts of interest are labeled and all the matched models including the corresponding parts are obtained with similarity measures. This is very significant for some application areas, such as the retrieval and assembly of industrial CAD parts.

PROBLEM DESCRIPTION

The specific problem we consider in this article is to classify 3D object into one of the known object classes and obtain models with shape similarity measures. We do not discuss how 3D data is segmented and fitted by superquadrics, which have performed well in much research work (Gupta & Bajcsy, 1993; Jaklic, Leonardis, & Solina, 2000; Liu & Yuan, 2001).

We are given a set of object data parts represented by SBGs, and the prestored models with object class labels. The classification of 3D objects can be regarded as the match between 3D object data and models, which is structured as an Interpretation Tree (Grimson, 1990). In Figure 1, let $\{m_1, m_2, ..., m_i, ..., m_p\}$ be a set of model parts and $\{d_1, d_2, ..., d_j, ..., d_q\}$, be the object data parts, starting at a root node, we construct a tree in a depth-first fashion, assigning one model part to different data parts at each level of the tree.

In order to deal with the possible nonexistence of a feasible match between the current model part and the data parts, the "wild card" (*) is introduced to match a null data part with a model part in the tree for improving the robustness. A path through this tree represents a set of feasible correspondences or matching pairs, that is, a consistent interpretation.

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