Evolutionary Computation Approaches for Shape Modelling and Fitting

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Abstract. This paper proposes and analyzes different evolutionary computation techniques for conjointly determining a model and its associated parameters. The context of 3D reconstruction of objects by a functional representation illustrates the ability of the proposed approaches to perform this task using real data, a set of 3D points on or near the surface of the real object. The final recovered model can then be used efficiently in further modelling, animation or analysis applications. The first approach is based on multiple genetic algorithms that find the correct model and parameters by successive approximations. The second approach is based on a standard strongly-typed implementation of genetic programming. This study shows radical differences between the results produced by each technique on a simple problem, and points toward future improvements to join the best features of both approaches.

1 Introduction

Shape modelling is a mature technology, extensively used in the industry for various applications (rapid prototyping, animation, modelling of cherubical prothesis, *etc*) [4]. Our purpose is to ease shape modelling of objects from the real world by fitting template shape models, defined by a functional representation (FRep) [17], to point data sets. The resulting model can later be modified and reused to fit the requirements of an application. An approach for modelling human body with template parameterized models was recently proposed [19]. Such a work underlines, in a different context, the importance to be able to later process and modify models from the real world.

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The traditional methods used in reverse engineering and shape recovery of constructive solids rely on a segmentation of scan data and fitting of some mathematical models. Usually, these mathematical models are parametric or algebraic surface patches [3,7]. They are then converted to a boundary representation model. In [3,7], the need of relations between parameters or objects is introduced. These relations intend to guarantee symmetry or alignment in the object, thus enforcing the accuracy of the recovery procedure. Fitting parametric and algebraic surfaces, using relations between the parameters and objects, is a difficult problem of non-linear constrained optimization. Robertson *et al.* [18] proposes an evolutionary method based on GENOCOP III [14,15] to efficiently resolve this hard problem. The drawback of such methods in shape recovery is that they suit only boundary representation with segmented point sets. Adding new primitives would require a corresponding segmentation of the point sets, which is difficult or even impossible in the case of complex blends or sweeps. Furthermore, it may be difficult for the resulting model available only as a BRep (*i.e.* Boundary Representation) to be reused in extended modelling, analysis or animation.

We have extended [5] the general idea of knowledge-based recovery (*i.e.* the use of relations between parameters and primitives) with a different interpretation and a different model, the function representation of objects [17]. In this approach, standard shapes and relations are interpreted as primitives and operations of a constructive model. The input information provided by the user is a template (sketch) model, where the construction tree contains only specified operations and types of primitives while the parameters of operations and primitives are not required and are recovered by fitting. Template models may exist in dedicated library for each domain of applications, available to be reused, or else they need to be created by the user. In [5], a method based on a genetic algorithm is proposed for fitting the template FRep model to point sets. The main problem of this method is that the FRep model has to be defined by the user.

In this paper, we propose different Evolutionary Computation (EC) [1] approaches to automatically determine both the model (shape modelling) and its best parameters (shape fitting). We use both Genetic Algorithm (GA) [10,8] and Genetic Programming (GP) [12,2] methodologies, and discuss the results, pros and cons, and possible improvements of each approach.

2 The FRep Model

In general, the shape recovery of objects follows a sequence of different steps, shown in Fig. 1. This paper is focused on the methods used to derive the FRep model and its parameters (modelling and model estimation).

2.1 The Function Representation

The function representation (FRep) [17] follows a constructive approach for modelling multidimensional objects. In the constructive modelling approach, a com-