Comparing Paired Comparison-based Interactive DE and Tournament Interactive GA on Stained Glass Design

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ABSTRACT

Tournament Interactive Genetic Algorithm (T-IGA) and Paired Comparison-based Interactive Differential Evolution (PC-IDE) are applied to the design of stained glass windows and the two algorithms with variable length genotype are compared in a context of interactive evolutionary computation. For both methods, stained glass windows are represented by colored 2D Voronoi diagrams, and a specific phenotypic crossover operator allows offspring to inherit visual features from both parents. The two algorithms have been evaluated by two professional stained-glass artists whom use them to create original designs in a controlled experimental setting. The results indicate superiority of PC-IDE, thus confirming previous theoretical results.

Categories and Subject Descriptors

I.2.8 [**Problem Solving, Control Methods, and Search**]: Heuristic methods; I.3.5 [**Computational Geometry and Object Modeling**]: Curve, surface, solid, and object representations

General Terms

Algorithms

Keywords

Interactive Differential Evolution, Tournament Interactive Genetic Algorithm, Paired Comparison, Stained Glass Window, Voronoi diagram

1. INTRODUCTION

A stained glass window is made of small pieces of stained glass, i.e., glass colored by adding metallic salts during its manufacture, arranged to form patterns or pictures, traditionally held together by strips of lead and supported by a rigid frame.

Our aim is to propose a tool for computer-aided creative design of stained glass windows. Such a tool might be used by an artist (the user) in order to create abstract stained glasses according to his/her tastes and preferences.

Interactive Evolutionary Computation (IEC), is an evolutionary technique whereby the fitness of individuals could be obtained thanks to interactions with human users [3]. Such a technique is used when an expert is able to evaluate subjectively an individual of the population but it is hard or impossible to formalize efficiently such evaluation. In image processing domain, Brooks proposed to re-style an image so as to approximate a stained glass by integrating in its algorithm user's preferences as another image [2]. But, it was not allowing the user to interact with the algorithm in order to refine the design. In a design context, it is useful to use IEC techniques in order to propose to the user several solutions that mix several previous pleasing visual features. We propose and compare two IEC frameworks for creating stained glass designs.

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2. PROPOSED METHODS

Tournament-IGA is a Interactive GA in which individuals are evaluated according to a method of competitive fitness called single-elimination tournament. Individuals are paired at random, and one game is played per pair. Losers of games are eliminated from the tournament. This process continues until only the champion remains. The fitness of an individual is the number of games played.

Paired Comparison based Interactive Differential Evolution is based on Differential Evolution, a population based and continuous function optimizer where distance and direction information from the current population is used to guide the search process [4] and adapted in an interactive case.

In both methods, two individuals are presented to the user who is asked to choose the best among the paired, simply by clicking the mouse. We have adapted and compared both algorithms to deal with stained glass design. An elegant solution for representing such designs, based on the use of Voronoi Diagrams (VD), has been suggested a few years ago by Ashlock and colleagues [1].

Genotype of each individual is designed as a variable length vector of floating-point values. For uniformity, all the floating-point values are in the $[0, 1]$ interval. Tile shapes are encoded by means of the generating points for the VD that represents the design, with their associated color. The genotype is made up of genes, each encoded by a triplet (x, y, c) of floating-point values.

The recombination operator we use is a problem-specific **phenotypic crossover**, devised so that offsprings have a better chance to inherit high-level visual features from both parents. Indeed, four random values in $[0, 1]$ are randomly generated, which are interpreted as coordinates of two points (x_1, y_1) and (x_2, y_2) and define a straight line that divides the unit square and by the same way the stained glass into two halves. The idea is to split genotypes of both parents according to that crossover line. Therefore, the parent 's genes are divided into two subsets: those that encode points that lie on the left (named L_1 for the first parent and L_2 for the second) and on the right of the crossover line (R_1 and R_2). In principle, the first child should inherit the genes in $L_1 \cup R_2$, while second child should inherit $L_2 \cup R_1$. However, it is possible that the crossover line does not separate the same number of points in both parents. That is why we deal with variable length genotype. Original DE algorithm has been designed to deal with fixed genome length only. Yuan and He [5] suggested a mutation strategy that consists in making an expanding operation with zero padding on all vectors participating in this operator, hence solving previous problem. As DE algorithm is based on a difference between vectors of float values, we propose to previously sort genes according to the distance of each point from the origin $(0, 0)$ so as to compare functionally similar points.

For our experiment, first population has been **initialized randomly**. However, in the future, it should be done using genotypes of existing stained glass design in which the user could be interested in.

When applying T-IGA, **Gaussian mutation** with a standard deviation of 0.2 is used. The mutation rate has been set to 0.05.

3. RESULTS AND DISCUSSIONS

To obtain an informed evaluation of the two proposed approaches, we contacted a couple of professional stained-glass artists, Mrs. and Mr. Valenti, who were so kind to accept to volunteer their creativity and take part in a test under controlled conditions.

After familiarizing them with the interactive evolutionary tool implementing the proposed stained glass design methods, written in Java on top of the ECJ [1] API, we asked our subjects to use each algorithm during one session of 15 minutes. In order to avoid biases due to the random initialization of the population made of 9 individuals, we fixed the seed of the random number generator to have all experimental sessions start with the same identical initial population. Both subjects were asked to use T-IGA first, and then PC-IDE. After testing both algorithms, each subject was asked to compare the design results.

Mrs. Valenti evaluated 36 generations during one run of T-IGA and 25 generations during one run of PC-IDE. With the same protocol, Mr Valenti evaluated 14 generations of individuals using T-IGA and 13 generations using PC-IDE. Asked whether of the two designs the couple of expert was most satisfied with, they were no doubt in indicating individuals obtained with PC-IDE.

Interviewed on his impressions using the tool, Mr. Valenti told us that he had the impression that the T-IGA method did not respond to his feedback the way he expected. He had difficulties to see the difference between some individuals that he had described as "messy". At a certain point, while he was working on refining a motif that had emerged and that he liked, evolution took a sudden bend and led him astray, without his being able to recover a satisfactory design. He did not understand where the algorithm wanted to go. On the other hand, he and she found PC-IDE much easier to control. They appreciated PC-IDE because they can refine quicly a desired motif; generated individuals by PC-IDE fits quite well the intended design which was not formally expressed.

[1]URL: `http://cs.gmu.edu/~eclab/projects/ecj/`

Both subjects of our experiment have agreed on judging the PC-IDE version of the tool more sensitive to their feedback and, thus, easier to control. This clear tendency of users toward preferring PC-IDE to T-IGA and may be regarded as an experimental confirmation of previous theoretical results obtained by Takagi and Pallez [4].

Both subjects appeared to be quite satisfied of the designs obtained, at least with PC-IDE, which is a further confirmation that the interaction with the user provides an effective guidance of the evolution. The subjects even went to the point, while commenting on their experience, of saying that they had the impression the PC-IDE-based tool "understood" the type of design they were trying to create.

4. CONCLUSION AND FUTURE WORK

We have proposed and compared two IEC frameworks for personalizing stained glass designs. The stained glass designs composition is guided by the user, that is, the compositions evolve in order to adapt them to the user tastes and preferences. The results indicate superiority of PC-IDE, thus confirming previous theoretical results obtained in [4]. We plan on incorporating ideas from [1] to allow the initialization of the population from existing designs and to allow curved edges. Another idea is to extend user interaction by allowing the manual editing of designs.

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6. REFERENCES

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