Affine Image Registration Transformation Estimation Using a Real Coded Genetic Algorithm with SBX

Mosab Bazargani
CENSE and DEEI-FCT
Universidade do Algarve
Campus de Gambelas
8005-139 Faro, Portugal
mbazargani@gmail.com

António dos Anjos
Departamento de Ciências e Tecnologias
ISMAT - Instituto Superior Manuel Teixeira Gomes
8500-508 Portimão, Portugal
antoniodosanjos@gmail.com

Fernando G. Lobo
CENSE and DEEI-FCT
Universidade do Algarve
Campus de Gambelas
8005-139 Faro, Portugal
fernando.lobo@gmail.com

Ali Mollahosseini
ILab 2.57, DEEI-FCT
Universidade do Algarve
Campus de Gambelas
8005-139 Faro, Portugal
ali.mollahosseini@gmail.com

Hamid Reza Shahbazkia
ILab 2.57, DEEI-FCT
Universidade do Algarve
Campus de Gambelas
8005-139 Faro, Portugal
hshah@ualg.pt

ABSTRACT

We describe the application of a real coded genetic algorithm (GA) to align two or more 2-D images by means of image registration. The proposed search strategy is a transformation parameters-based approach involving the affine transform. The real coded GA uses Simulated Binary Crossover (SBX). In addition, we propose a new technique for matching points between a warped and static images by using a randomized ordering when visiting the points during the matching procedure. The results confirm the usefulness of the proposed noisy objective function and the suitability of SBX as a recombination operator for this type of problem.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods, and Search; I.4.8 [**Image Processing and Computer Vision**]: Scene Analysis

General Terms

Algorithms, Performance

Keywords

Image registration, affine transform, point-pattern matching, genetic algorithms, simulated binary crossover

1. INTRODUCTION

Image Registration (IR) is the process of aligning two or more images of the same scene taken at different times, from different directions, and/or by different sensors, by finding the best mapping function between them [4] based in the images' features (e.g. point positions). This paper addresses the design of the mapping function for 2-D image registration using the affine transform. The affine transform has six parameters: θ_0, θ_1, θ_2, θ_3, θ_4, and θ_5. θ_2 and θ_5 specify the translation and θ_0, θ_1, θ_3, and θ_4 aggregate rotation, scaling, stretching, and shearing. A geometric operation transforms the coordinates (x, y) of a deformed image D into (x', y') of a warped image W as follows:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \theta_0 & \theta_1 & \theta_2 \\ \theta_3 & \theta_4 & \theta_5 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} . \quad (1)$$

The warped image W should be as close as possible to the static image S. To solve this problem we use an elitist real coded GA with SBX and Gaussian mutation.

2. A REAL CODED GA WITH SBX FOR IMAGE REGISTRATION

For the 2-D case, the affine transformation is defined by six parameters, $\theta_0 \dots \theta_5$. A candidate solution for the GA is therefore represented by a chromosome vector with six genes, each a real number.

To compute the objective function value of a candidate solution, we start by warping the deformed image according to the parameters of the affine transformation specified in the representation of a candidate solution, yielding a new point-set. Then the matching of points is modeled using a correspondence binary matrix based on the closest-point rule. The closest-point is measured using the Euclidean distance between matched points. Each point in any set corresponds, at most, to one point in the other set. To find the correspondence for each point, the closest point in the other set is chosen. If the nearest point has already been assigned to another point, the next non-assigned nearest point is chosen. This procedure is performed twice, once for each direction (warped to static, and static to warped). The objective function is based on the weighed similarity of two point-sets using the Euclidean distance of the matched points. The points that are connected exclusively from one direction are penalized, and those that are connected in both directions are given half weight in terms of Euclidean distance.

A match-order vector is proposed to specify the order in

GECCO'12 Companion, July 7–11, 2012, Philadelphia, PA, USA.
ACM 978-1-4503-1178-6/12/07.

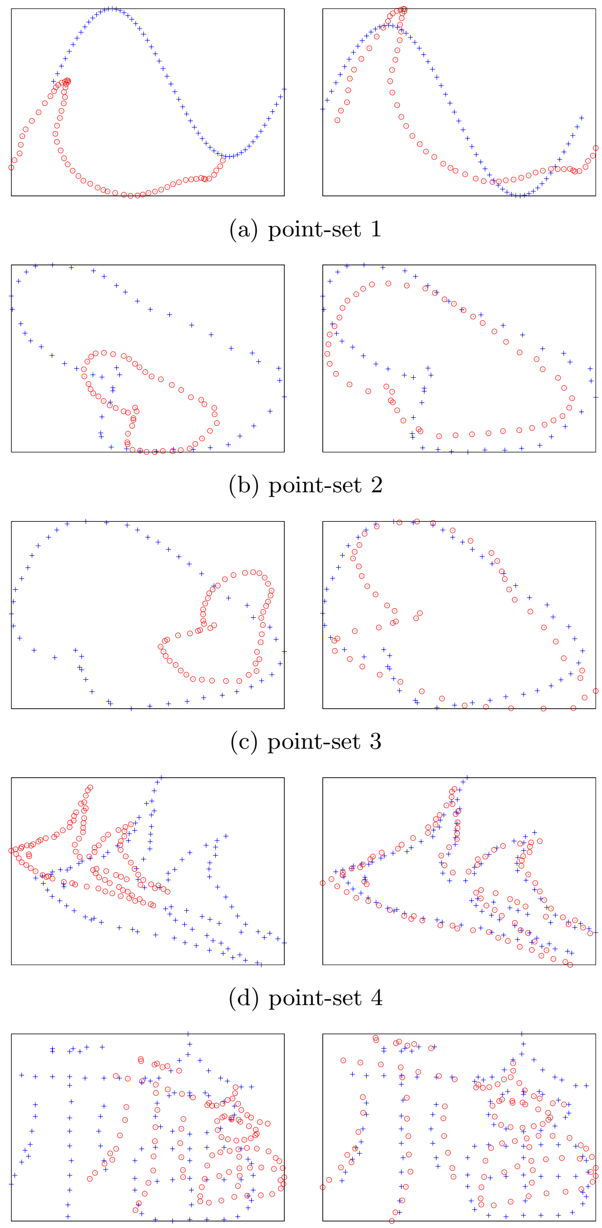
which the points of a given set are visited when finding its closest-point match. For different orderings, different correspondences may be found. Therefore, the match-order vector is randomly created in each generation. This makes the evaluation of a candidate solution a somewhat noisy process.

The proposed GA was tested on the five point-sets available at `http://noodle.med.yale.edu/~chui/rpm/TPS-RPM.zip`. They include the deformed and static points' locations. The deformed points were generated from the static ones by a non-affined (i.e. free-form) transform. The GA setup was the same for all data sets. Most parameter settings were tuned beforehand, and held fixed for all experiments. We use tournament selection without replacement of size 5, SBX crossover with distribution index 2 [2], and Gaussian mutation for all the genes. The crossover probability was set to 1.0 and each gene undergoes SBX with probability 0.5. The experiments were performed with populations of size 30, 60, 120, 240, and 480. Larger populations gave better solution quality but the improvements were negligible for sizes larger than 120. We use a *replace worst* strategy, with the worst half of the current population being replaced by the best half of the newly generated solutions.

Figure 1 illustrates the five point-sets before and after warping. These are sets where deformations are non-affine, therefore the resulting warped images will never match perfectly. Nevertheless, they present a very good approximation. When compared to the approach from [3] it is possible to observe that our results are more precise. Additional details about the proposed GA can be found in [1].

3. CONCLUSIONS

This paper proposed a real coded GA for 2-D image registration using the affine transform. As opposed to previous evolutionary computation approaches for solving IR, our method uses Simulated Binary Crossover, a parent-centric recombination operator that has been giving good results on a variety of continuous real world optimization problems within a GA framework. The use of a randomized ordering when visiting points during the point-matching procedure was also proposed, and although this technique yields a noisy fitness function evaluation, the results obtained show that the GA is capable of dealing with it quite well.



(a) point-set 1

(b) point-set 2

(c) point-set 3

(d) point-set 4

(e) point-set 5

Figure 1: Non-affine distorted point-sets (left, blue dots for static image points, red dots for deformed image points) and GA affine image registration (right, red dots are the warped image points) results obtained after 500 generations using population size 120. The warped images are zoomed for better visualization.

4. REFERENCES

[1] M. Bazargani, A. dos Anjos, F. G. Lobo, A. Mollahosseini, and H. R. Shahbazkia. Affine image registration transformation estimation using a real coded genetic algorithm with SBX, 2012. arXiv eprint No. 1204.2139.

[2] K. Deb and R. B. Agrawal. Simulated binary crossover for continuous search space. *Complex Systems*, 9:115–148, 1995.

[3] F. L. Seixas, L. S. Ochi, A. Conci, and D. M. Saade. Image registration using genetic algorithms. In *Proceedings of the 10th Annual Conference on Genetic and Evolutionary Computation*, GECCO'08, pages 1145–1146, New York, USA, 2008. ACM.

[4] B. Zitová and J. Flusser. Image registration methods: a survey. *Image and Vision Computing*, 21:977–1000, 2003.