

Image Registration Using Genetic Algorithms

Flávio Luiz Seixas
IC/UFF
Computer Science Dept.
fseixas@ic.uff.br

Luiz Satoru Ochi
IC/UFF
Computer Science Dept.
satoru@ic.iff.br

Aura Conci
IC/UFF
Computer Science Dept.
aconci@ic.uff.br

Débora C. M. Saade
TET/UFF
Telecomm. Eng. Dept.
debora@midia.com.uff.br

ABSTRACT

This paper addresses the image registration problem applying genetic algorithms. The image registration's objective is the definition of a mapping that best matches two set of points or images. In this work the point matching problem was addressed employing a method based on nearest-neighbor. The mapping was handled by affine transformations. Experiments were conducted using three 2D synthetic point-sets with different affine transformations and noise. The results were compared against other optimization techniques. The similarity of two point-sets is measured using the Euclidean distance between matched points.

Categories and Subject Descriptors

I.4.8 [Image Processing and Computer Vision]: Scene Analysis – motion, object recognition, time-varying imagery, tracking.

General Terms

Algorithms, Measurement, Performance, Verification.

Keywords

Image registration, genetic algorithm, point matching, affine transformations.

1. INTRODUCTION

Registration is a fundamental task in image processing used to match two images taken at different times, from different sensors or from different viewpoints. Image registration (IR) is defined as the search for the best mapping used to align two or more images of the same scene [1]. It has been applied in a number of research areas, including medical imaging analysis [2], computer vision and pattern recognition [3].

There are different approaches to the IR problem from the metaheuristics point of view, especially considering genetic algorithms (GAs) and evolutionary algorithms [4, 5]. GAs are computational models of natural evolution in which stronger individuals are more likely to be the winners in a competitive environment. GAs are a stochastic method and provide a good behavior in parameters learning. However, the main advantage of the GA approach for range image registration is that a pre-alignment between views is not necessary to guarantee good results [6]. This paper proposes the use of GA to IR.

2. EXPERIMENT

Let X and Y be two set of 2D points-set. We named X the source

set and Y the template set. Let us consider the space of possible transformation function to be the affine transformation defined by Equation 1. The IR search space is composed by (i) linear combinations of affine transformation, (ii) a similarity measurement and (iii) an optimizer.

$$X' = A \cdot X + T \Leftrightarrow \begin{bmatrix} x'_1 \\ x'_2 \end{bmatrix} = \begin{bmatrix} a_1 & a_2 \\ a_3 & a_4 \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} t_1 \\ t_2 \end{bmatrix} \quad (1)$$

where: X is the 2D coordinate of data points-set, X' is its new coordinate, A is an affine transformation matrix and T is the translation vector.

The matching problem was modeled using a correspondence matrix M ($N \times K$) based on closest-point rule. The matching algorithm has a sequence as following:

- (1) Set $M' \leftarrow 0$ and $M'' \leftarrow 0$;
- (2) For each point from source set $X(x_i')$, search the closest point from template set $Y(y_j)$. Then $m_{ij}' \leftarrow 1$;
- (3) For each point from template set $Y(y_j)$, search the closest point from source set $X(x_i')$. Then $m_{ij}'' \leftarrow 1$;
- (4) Compute $m_{ij} \leftarrow \frac{m_{ij}' + m_{ij}''}{2}$.

One point in set Y must correspond to one point in set X , and vice versa. If the correspondence occurs in a two-way constraint, $m_{ij} = 1$. Despite one point in set Y corresponding to one point in set X , if the opposite is not true, $m_{ij} = 0.5$. Finally, $m_{ij} = 0$ if there is not correspondence between the mentioned points. The fitness function is:

$$fitness = \frac{1}{N \cdot K} \left(\sum_{i=1}^N \sum_{j=1}^K \frac{1}{m_{ij}} (x_i' - y_j)^2 \right) \cdot v \quad (2)$$

where: x_i' , $i = 1, 2, \dots, N$ is the source point after the transformation function, y_j , $j = 1, 2, \dots, K$ is the template point, m_{ij} is the point matching matrix M and v is the variance of mean-square error (MSE) values.

Figure 1a represents the fitness evaluation sequence, where x_i' , $i = 1, 2, \dots, N$, is the source point achieved by the spatial transformation defined by affine matrix parameters and M_{ij} is the matching matrix. We represent the possible solutions as a chromosome vector defined by six genes, reproducing translation ($t1$, $t2$), skewing (sk), squeezing (sq), rotation (r) and scaling (s) effects, as showed in Figure 1b. These spatial transformations are parameterized in the affine matrix showed in Equation 1. The GA's objective is to find out the best spatial transformation (chromosome) in a population of individuals.

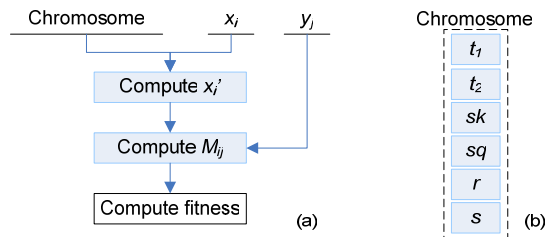


Figure 1. Fitness computing scheme

The GA selection was based on a stochastic uniform method [7]. The stochastic uniform method describes a line in which each parent corresponds to a section of the line of length proportional to its expectation. The algorithm moves along the line in steps of equal size, one step for each parent. At each step, the algorithm allocates a parent from the section it lands on. The first step is a uniform random number less than the step size. Regarding reproduction options, we set a number of individuals that are guaranteed to survive to the next generation randomly choosing 2 and a crossover fraction of 80%. The mutation function is composed by a Gaussian distribution centered on zero. It is then added to each vector entry of an individual. The crossover function creates a random binary vector. Then it selects the genes where the vector is 1 from the first parent and the genes where the vector is 0 from the second parent. It is then combined to form the child. We defined as the stopping criterion the maximum number of iterations the genetic algorithm performs to 50 generations.

Our experimental tests were performed using different source and template points-sets defined by (a), (b) and (c) as showed in Figure 2. The first column of Table 1 is the best fitness value achieved from the GA. The second one shows the values achieved by the algorithm proposed by Chui *et al.* [8]. Chui uses a deterministic annealing framework in order to regularize the warping components and reject a fraction of points as outliers through a soft-assign approach. We can notice similar results on both, despite using distinct methods. The GA proposed here uses an affine transformation model, while Chui uses thin-plate spline non-linear based approach.

Table 1. Comparison.

Points-set	Our best fitness value ($\cdot 10^{-4}$)	Fitness evaluation using Chui <i>et al.</i> (2000) ($\cdot 10^{-4}$)
(a)	7.1	2.9
(b)	1.3	1.4
(c)	1.7	0.6

3. CONCLUSION

The IR problem is a very complex problem in the field of image processing. The study of recent search and optimization algorithms applied to IR has offered new perspectives to handle this challenge. The contribution of this paper is addressing the use of a GA framework to solve the matching and mapping problem considering two point-sets. GA offers a number of configuration parameters and functions. We notice that the definition of the initial population, which is usually initialized with random entries, is critical to the GA searching progress. As future works, we are evaluating the use of GA considering a real-world application.

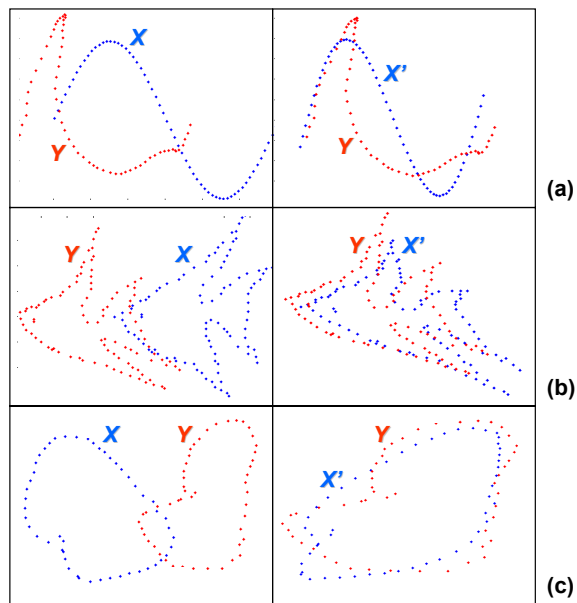


Figure 2. Template Y and source point-sets X , before (left) and after (right) IR performing

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