Efficient Affine 2D-Image Registration using Evolutionary Strategies

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Abstract

We propose a new methodology to the general affine image registration problem that in two steps achieves near optimal results with high percentage of success using evolutionary strategies.

Principles

The image registration problem is *to find the mapping between two images* I_1 and I_2 that gives the best correspondence. Equation 1

$$I_2(x,y) = I_1(f(x,y)) \tag{1}$$

Approximations to f can be constructed by some transformations: affine and projective amongst several.

An affine transform is a linear transform composed of the following geometric transformations: translation, rotation, scaling, stretching, and shearing [2]. The general $2D$ affine transformation is expressed as shown in Equation 2.

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} a_{1,3} \\ a_{2,3} \end{bmatrix} + \begin{bmatrix} a_{1,1} & a_{1,2} \\ a_{2,1} & a_{2,2} \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} \tag{2}$$

Our approach to image registration uses a $(\mu + \lambda)$ Evolutionary Strategy for searching the six real variables described in Eq. 2. Crossover operation for control and object variables is generalized intermediate, mutation follows the standard formulation as explained in Bäck's book [1]. Our method uses only sample points equally spaced and distributed over the image. Thus, about 0.4% of image pixels are used for registration in our experiments. Fitness function is based on the similarity measure "absolute difference of intensities", as follows:

$$fitness = \frac{1}{1 + \sum_{\{x,y\}\in\Omega} |I_1(f(x,y)) - I_2(x,y)|} \tag{3}$$

Where Ω is the set of sample points. The fitness function takes values in $[0,1]$ to represent $[nomatch \rightarrow perfectmatch]$.

Methodology

The method consists of the following steps:
Step 1: Smooth both original images to be registered. Smooth procedure uses a convolution with a Gaussian kernel of $\sigma = 2$. Create the sample set of 256 pixels from smoothed image. Run the registration algorithm and stop it when fitness $f \geq 0.1$.
Step 2: Seed a new population with all individuals of the last generation of previous step.
Step 3: Load the original images and create a new sample set of 256 pixels. Run the registration algorithm and stop when condition is reached (for instance $f = 0.99$).

The goal is to apply our proposed method *stepwise refining affine image registration* to an affine transformation with gross distortion.

Results

We repeated 50 times the experiment using the same 256 x 256 pixels images and applying the same transformation. The initial population was created around the identity transformation. Values for μ and λ were 250 and 50. The correct transformation was found 92% of the times . In average 1468 generations were necessary in order to converge to the solution.

In the overall we have proposed a highly promising methodology. To the best of our knowledge no registration method based on affine transforms and evolutionary computation had accomplished this level of consistency and accuracy.

References

[1] T. Back. *Evolutionary Algorithms in Theory and Practice*. Oxford University Press, New York, 1996.
[2] B. Jahne. *Digital Image Processing: Concepts, Algorithms, and Scientific Applications*. Springer Verlag, Berlin, 1997.