# An Automated Image Registration Methodology Using a Hybrid Genetic Algorithm Strategy

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## Introduction

Aligning multiple medical image volume sets for a composite fMRI analysis is a time consuming process. [1] Conventional gradient-search registration strategies are foiled frequently due to the presence of numerous local minima. In this article an automatic registration algorithm based upon a genetic algorithm (GA) is presented. It eliminates the local minima/maxima traps of conventional optimization techniques. A preprocessing stage normalizes the intensities of each volume set and the images intensity centroids are automatically translated to the origin prior to application of the GA. This strategy facilitates the automated application of masks. It increases the speed and accuracy of registration. The method was applied to fMRI data for Sprague-Dawley rat brains.

## Method

Based upon the principles of Darwinian natural selection, a typical GA approach has a few basic steps: 1) generate a random initial population; then iteratively 2) rank the population based upon fitness criterion; 3) mate individuals as a function of their fitness and 4) account for the possibility of mutation. The genetic make-up consists of translation, rotation, and scaling chromosomes. The genetic recombination (crossover) is a random percentage from each chromosome of one parent and a complementary weight from the other parent. For medical image data the ranking (or evaluation) process can be computationally expensive. To streamline and accelerate the registration process several processes were employed. The image volumes were normalized for intensity and an intensity centroid and standard deviation were calculated. The image intensity centroids were translated to the origin. A mask was applied about this origin. The extent of the mask was the minimum of 1/2 the pixel span or ½ the standard deviation. This mask reduced the evaluation process by a minimum factor of 4 but typically an order of magnitude. The uniformity of SD rat brains allowed other streamlining processes. The GA evaluation was based upon the masked region of the centroid slice only. The chromosomes were $\Delta x$, $\Delta y$, and rotation angle $\theta$ about the z-axis initially. A subsequent application of the GA used x and y scaling chromosomes. These parameters were applied to the entire volume. The volume set was rotated 90 degrees out of plane. The GA was applied a third time with only two chromosomes, rotations about the y-axis and x-axis, which were applied to the volume set. The sequential application of the GA for reduced parameter (or chromosome) sets substantially reduced the computational time and enhanced the final result. Our implementation was restricted to MR images of SD rat brains using a fast-spin echo on a 4.7T Bruker magnet system. In these situations the imaging strategy and tissue properties strongly support predominantly rigid body registrations. For each of the transformation parameters (or GA "chromosomes"), the search space is user-specified. The cost function for these registration processes was the sum of absolute difference (SAD) of pixel intensities between the subject and reference volume sets within the masked regions.

## Results

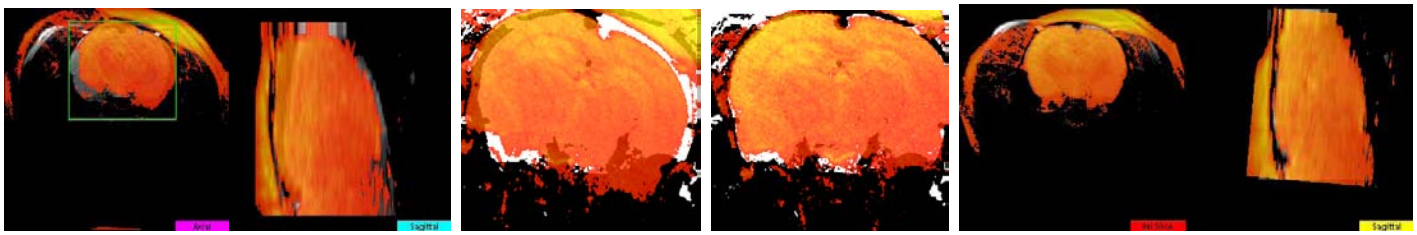
GA parameter constraints were automatically assigned based upon the image resolution and intensity. For the examples listed in this work, the parameter constraints used for our particular examples were: a) In-plane [-20, 20] pixels for translation, [-30, 30] degrees for $\theta$, [.95, 1.05] for scaling factor Sx and Sy, and b) Out-of-plane [-5, 5] degrees for rotation $\alpha$ and $\beta$. Figure 1(a) (b) (c) and (d) display the initial misalignment, masked slices, registered masks using GA and the registered subjects with 2D transformation matrix applied, respectively. Based on numerous test examples, GA approach attained 98% or greater agreement with manual registration which was defined as the gold standard (GS). Table 1 lists the registration quality results based on the reduction of intensity errors (SAD) using the GA approach compared to that of the manual alignment. The GA registration quality was 98% or greater.

## Conclusion

An image registration using optimization of voxel similarities was presented. This voxel similarity measurement was coupled with a hybrid genetic algorithm and shown to be a robust and accurate registration strategy. The registration quality was superior to the conventional alignment techniques. Significantly, the GA was not strongly sensitive to the initial start location nor was it susceptible to local minima/maxima. Non rigid body transform (scaling) had marginal enhancements to the registration due to the repeatability of the SD rat brain subjects. One of the greatest benefits of this hybrid GA procedure was the lack of a required quality start location. The automated centroid mask coupled with the sequential application of GA alignments mimicked manual registration sequences. The reduced evaluation space accelerated the registrations by multiple orders of magnitude compared to a simultaneous affine parameter space alignment. The hybrid GA demonstrated excellent alignments, frequently surpassing that of manual registration.

| Subject | GA1 ($\Delta x$, $\Delta y$, $\theta$) | GA2 (Sx, Sy) | GA3 ($\alpha$, $\beta$) |
|---|---|---|---|
| A | 98.2% | 98.3% | 99.4% |
| B | 98.1% | 98.5% | 99.6% |
| C | 99.2% | 99.2% | 100.3% |

**Table 1:** Relative registration accuracy of GA compared to Gold Standard: |orig-GA|/|orig-GS|x100%



(a) Original Volumes with Masked Regions (b) Masks (c) GA Aligned Masks (d) Aligned 3D Volumes

**Figure 1:** Initial misalignment, GA alignment of Masked Slices and Registered Volumes

## References

[1] Karin Kneöaurek, Marija Ivanovic, Josef Machac and David A. Weber, Medical image registration, Europhysics News (2000) Vol. 31 No. 4