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Research Article

Medical Image Registration by GSA Optimized Matching Algorithm

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Abstract

The primary contribution of this research is the development of computational frameworks that tackle in a general and principled way the problems arising in the construction of an image registration system. A novel algorithm for image features matching is used in terms of evolutionary algorithms. We have efficiently used the gravitational search algorithm (GSA) to match image features by tuning the rotational angle of image. The complete work is divided into three modules: edge detection, features extraction and features matching. After studying previous work on this, we used the effective phase congruency method for the edge detection to avoid non uniform illumination problem occurred in detection of edges. The requirement of features extraction is that matching points which don't change even after change in angle of rotation of image. So we used scale invariant features transform (SIFT) method to extract features and finally we purposed the tuned matching algorithm which can work for almost every type of image. Our features matching using GSA algorithm tune the rotational angle of test image and set it to an optimum angle so that it can best match with the reference image.

Keywords: *Gravitational search algorithm etc.*

Introduction

Registration is a fundamental task in image processing used to match two or more pictures taken, for example, at different times, from different sensors, or from different viewpoints. Virtually all large systems which evaluate images require the registration of images, or a closely related operation, as an intermediate step. Specific examples of systems where image registration is a significant component include matching a target with a real time image of a scene for target recognition, monitoring global land usage using satellite images, matching stereo images to recover shape for autonomous navigation, and aligning images from different medical modalities for diagnosis. Image registration, sometimes called image alignment, is an important step for a great variety of applications such as remote sensing, medical imaging and multi-sensor fusion based target recognition. It is a prerequisite step prior to image fusion or image mosaic. Its purpose is to overlay two or more images of the same scene taken at different times, from different viewpoints and/or by different sensors. It is a fundamental image processing technique and is very useful in integrating information from different sensors, finding changes in images taken at different times, inferring three-dimensional information from stereo images, and recognizing model-based objects. Registration can be performed either manually or automatically.

In literature many features based image registration algorithm is widely used as due to contrast variation in image, pixel intensity varies and in these kind of cases features based extraction is efficient. Besides these the need of feature extraction in image registration requires the technique which is scale and affine transformation invariant. SIFT has been widely used in literature but the data length is quite big which requires more computational time. Iteratively matching algorithm have been used in literature which generally used genetic algorithm which suffers from falling into local maxima, so a more comprehensive method has to be proposed for iterative optimization. For these we have proposed a global optimization algorithm named gravitational search algorithm (GSA) along with SIFT features. A rotated image by 20^o angle is used as a test image and to avoid the edge variation due to intensity change, phase congruency algorithm is used followed by SIFT algorithm and GSA respectively. Next sections discuss the proposed algorithm and results.

Proposed Methodology

This work is related to image registration applied to almost every type of image. We have used phase congruency model discussed in previous chapter for edge detection. The selection of this model lies with the fact that images can vary in illumination of light and that poses threat to unidentified edges in image,

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resulting in skipping of that part in feature extraction. The complete work can be divided into three main modules as diagrammatically represented below:

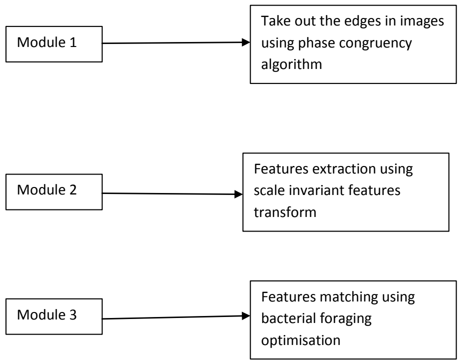


Figure 1: Modules of proposed work

Module 1: The edge detection in test image is done using PC algorithm which performs well over widely used canny edge detection doesn't perform well in case of non uniform illuminated image. The difference can be visible in the example pictures given below picked up from the Peter Koveski's home page.

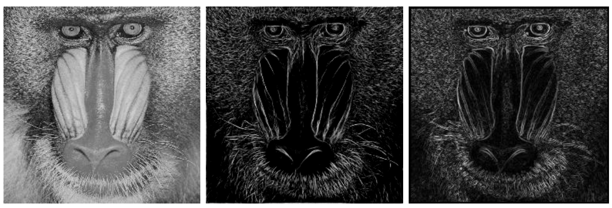


Figure 2 (a): input test image (b) PC edge detected map, Step and line features are marked equally well. Note how each whisker has been marked as a single feature. (c) canny edge detected map, Note how edges are marked on each side of each whisker.

The mathematical formulation of 2-D image PC for our work is given as:

first step is to convolve the normalized iris image I (x,y) with a bank of 2D log-Gabor filters with different orientations and scales. The Log-Gabor has a transfer function of the following form:

$$G(\omega) = \exp(\frac{-(\log(\omega/\omega_0))^2}{2(\log(k/\omega_0))^2})$$

where ω_0 is the filter's center frequency. k/ω_0 should be aconstant for vary ω_0. The 2D log-Gabor is constructed with the cross-section of the transfer function in the angular direction being a Gaussian function:

$$G(\theta) = \exp(\frac{-(\theta-\theta_0)^2}{2\sigma_\theta{}^2})$$

where θ_0 represents the orientation of the filter, σ_θ is the standard deviation of this Gaussian function. Here we choose 6 orientations and 4 scales. Let M_{so}^{even} and M_{so}^{odd} denote the even-symmetric and odd symmetric filter at scale s and orientation o. The response vector can be got by:

$$[e_{so}(x,y), o_{so}(x,y)] = [I(x,y) * M_{so}^{even}, I(x,y) * M_{so}^{odd}]$$

The amplitude of the response at a given scale and orientation can be computed by:

$$A_{so} = \sqrt{e_{so}(x,y)^2 + o_{so}(x,y)^2}$$

And the phase angle is:

$$\emptyset_{so}(x,y) = a\tan(o_{so}(x,y)/e_{so}(x,y))$$

Let $\emptyset_{so}(x,y)$, denotes the mean phase angle at orientation o, it can be estimated by:

$$\overline{\emptyset}_0^{even}(x,y), \overline{\emptyset}_0^{odd}(x,y) = \frac{(\sum_s e_{so}(x,y), \sum_s o_{so}(x,y),)}{\sqrt{\sum_s e_{so}(x,y)^2 + \sum_s o_{so}(x,y)^2}}$$

A sensitive phase deviation measure $\Delta\emptyset_{so}(x,y)$, is used.

$$\Delta\emptyset_{so}(x,y) = \cos\left(\emptyset_{so}(x,y) - \overline{\emptyset_0}(x,y)\right) - \left|\sin\left(\emptyset_{so}(x,y) - \overline{\emptyset_0}(x,y)\right)\right|$$

Then the 2D phase congruency is calculated as follows:

$$PC_0(x,y) = \frac{\sum_o \sum_s A_{so}(x,y)(\Delta\emptyset_{so}(x,y))}{\sum_o \sum_s A_{so}(x,y) + \in}$$

$\in$ is a very small positive real number, used to prevent division of zero, its value set to be 0.0001. According to Kovesi, using the magnitude of dot and cross products, the phase deviation can be calculated directly from the filter outputs, as:

$$A_{so}(x,y)\Delta\emptyset_{so}(x,y) = A_{so}(x,y)\cos\left(\emptyset_{so}(x,y) - \overline{\emptyset_0}(x,y)\right) - \left|\sin\left(\emptyset_{so}(x,y) - \overline{\emptyset_0}(x,y)\right)\right| = \left(e_{so}(x,y).\overline{\emptyset}_0^{even}(x,y) + o_{so}(x,y).\overline{\emptyset}_0^{odd}(x,y)\right) - \left(e_{so}(x,y).\overline{\emptyset}_0^{odd}(x,y) + o_{so}(x,y).\overline{\emptyset}_0^{even}(x,y)\right)$$

By this formula the phase congruency of image is calculated. The outcome of this is

Module 2: Features extrication using shift invariant transform features is done in this module. The SIDT is explained in previous chapter so we won't discuss again here.

Module 3: Features mapping have equal importance as above steps. We have used a bio optimized matching algorithm i.e. bacterial foraging optimization. The reference image is rotated by some angle just for testing purpose. In gravitational search algorithm (GSA), we optimize the optimum angle of rotation of the test image on the basis of minimizing mean square error in features of reference image and test image.

The features descriptor obtained from the previous module for reference as well as test image is fed into matching module, so that a minimum difference between them can be reached. The fitness function to be minimized is the mean square error given as:

$$MSE = \frac{sum(diff^2)}{size(features)}$$

The flow chart for the proposed work is given in figure

Results

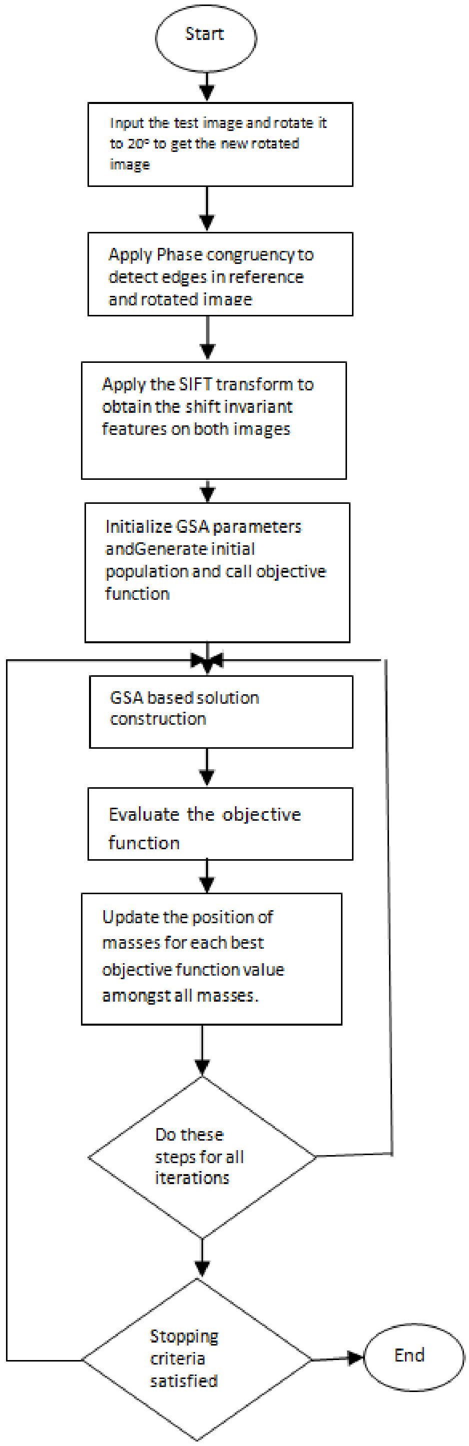


Figure 3: Flow chart of proposed work

The proposed work is implemented in MATLAB and we used medical DICOM images to test the image registration scheme. The input image is resized to 200* 200 pixels and is considered as the reference image which is rotated by 20° to make a test image. Features are extracted from both images and converted into 1 dimensional vector. In matching we are using GSA optimization. Gravitational search algorithm is used in our work and a total of 10 iterations for all 4 agents is done or in other words the objective function is called 10 times for an agent and the output of fitness function is plotted in figure 4.

This is the plot of mean square error which is calculated in objective function. Since it is error, so it should be decreasing which is so in plot. For a good tuning of GSA algorithm, the objective function plot must be decreasing and after few iterations it should settle to a minimum value with no further change. This condition is satisfied in our case which is validated in figure 4.

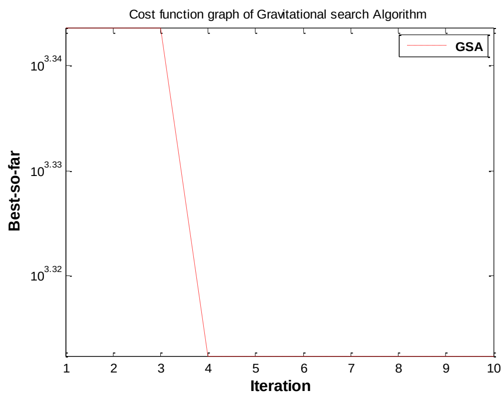


Figure 4: Objective function value plot for GSA tuning

Around 40000 features are extracted out of 200*200 images. Since after rotation the black space is left behind and usually that doesn't contain any information, so no feature points locations will be in that region. If any image is actually captured by rotating the lens of camera then this black space will not occur and a better features matching will also be visible. After using proposed matching algorithm the features points are matched more than simple matching algorithm whose result is shown in figure 5.

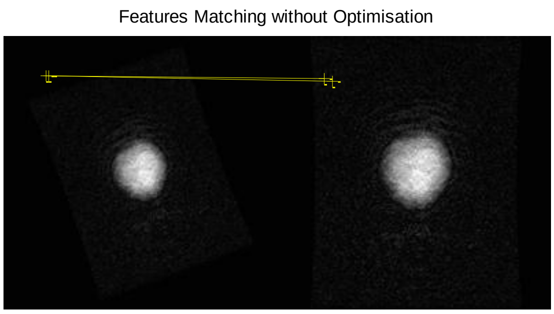


Figure 5: Features points matched in both images without optimization

Figure 6 shows the points matched in both images after rotating the image by optimized rotation angle and checking out points matching. After GSA tuning the angle of -155.6571° is achieved or 24.3439° almost, which gives best matching results. An error of 4.3439° from the rotation angle at input is there. The normalized matching value calculated by number of points at same location for both cases is 0.2141 and 0.7326. Proposed algorithm is also tested on images other than DICOM images. A comparison bar graph for these is shown in figure 7. this bar graph shows that for the proposed work, normalized matching value is higher for every type of image.

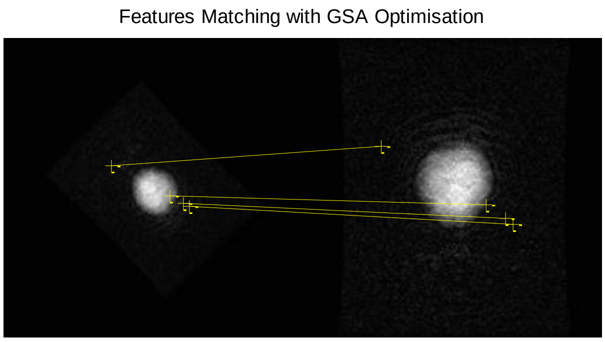
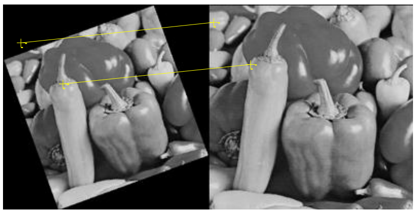
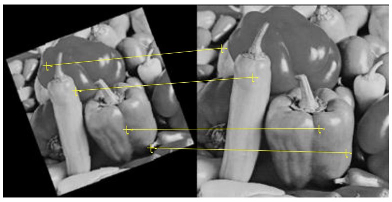
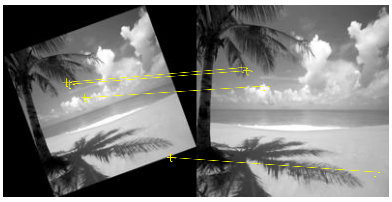
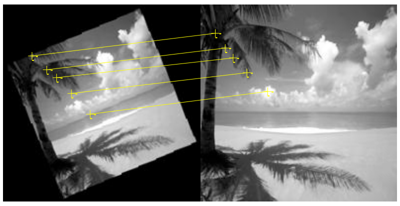


Figure 6: Points matched after GSA optimization

Pepper Image	 Without Optimization
	 With GSA Optimization
Beach image	 Without Optimization
	 With GSA Optimization

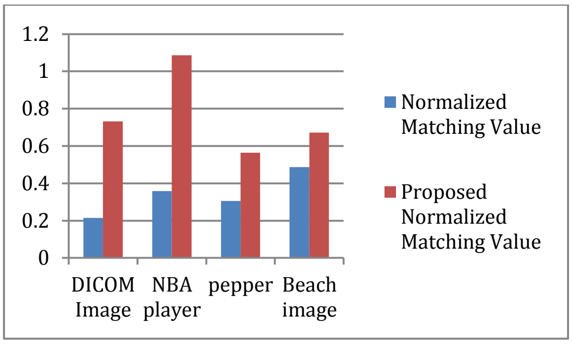


Figure 7: normalized Matching for different types of images

Conclusion

We have used DICOM images for testing purpose but this is a generalized algorithm and can work for any type of input image whether that can be medical or satellite images. Unsupervised learning in the form of GSA algorithm makes it generalize for every type of image. GSA is an optimization algorithm which changes its agent's position to find a place for minimum objective function value. In our case it will search for the optimum angle at which matching points between test and reference image are maximum. We considered mean square error between features points location extracted from the module 2 using SIFT. After optimization the rotational angle set to a minimum value for which more number of matching points exist and test image is aligned with the reference image by that optimum angle. The images used here are compressed to 200*200 so that execution time can be reduced. Comparison results with un-optimized solution shows that proposed work with GSA optimization is better.

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