Comparative analysis of different optimized structural feature extraction algorithm for estimation of parameters in image registration

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ABSTRACT

Proficient image registration is evaluated by optimizing the differences between two or more images taken from distinct modality, in terms of time and viewpoints. In this paper, we investigated the registration efficiency by extracting features using various feature extraction methods and selecting the optimum features set to estimate the various transformation parameters. HOG (Histogram of Oriented Gradients), KLT (Kanade Lucas Tomasi), and SIFT (Scale Invariant Feature Transform) feature extraction techniques are applied. To choose the discriminated features extracted by SIFT, the optimization algorithms PSO (Particle Swarm Optimization), EO (Equilibrium Optimization), and AOA (Arithmetic Optimization Algorithm) are used. The transformation parameters are estimated using a back propagation neural network based prediction model. The experiment is run on multiple of medical images, conventional benchmark images, and SAR (Synthetic Aperture Radar) images, and the accuracy of parameter estimation is reported in average MSE.

Keywords - **Feature extraction, Feature selection, Parameter estimation, Optimization algorithms.**

I. INTRODUCTION

The purpose of image registration is to match or align two or more images captured at different times or in different modalities. Image registration is used in areas such as correlation between various types of medical imaging such as MRI, CT, PET, and SPET, remote sensing imaging, astronomical imaging, and image mosaicing, among others. The aim of image registration is to determine transformation from the input image to the target image through affine transformations such as scaling, rotation, and translation.

Although image registration can be categorized in a variety of ways, feature-based approaches are commonly used in this area. The steps involved in feature-based image registration are feature extraction, feature selection, training the prediction model, and feature matching. Robust Independent Elementary Features (BRIEF) [16], Oriented Fast and Rotated BRIEF (ORB) [10], Scale Invariant Feature Transform (SIFT) [15], Kanade Lucas Tomasi (KLT) [6], [20], Speed Up Robust Feature (SURF) [12] , Histogram of Oriented Gradients (HOG) [18], and geometric invariants with local features [21] are some of the efficient algorithms used to extract the features. The feature vector's dimension, on the other hand, is quite huge. Any feature extraction algorithm that extracts a large number of features raises the computational cost.

Feature selection, or optimizing the amount of features, is used to decrease redundancy in the feature vector and to find the right balance between computational cost and registration accuracy. For feature selection, various optimization approaches are explored, including GA (Genetic Algorithm) [11], ACO (Ant Colony Optimization) [9], [8], PSO (Particle Swarm Optimization) [5], [17], [7], EO (Equilibrium Optimization) [3], and AOA (Arithmetic Optimization Algorithm) [4]. Due to the efficiency of feature-based matching, we refined the features set acquired by the SIFT methodology. To estimate the different transformation parameters, the selected features are used to train the BPNN based prediction model. In terms of MSE, the experimental results demonstrated a comparison of estimated values of rotate, translation, and scale factors.

II. METHODOLOGY

This section includes the following structural feature extraction algorithms, as well as the various optimization strategies employed in this paper.

1.1 HISTOGRAM OF ORIENTED GRADIENTS (HOG)

Histogram of Oriented Gradients (HOG) [18] is a well-known structural feature extraction method in image processing. The image is divided into overlapping blocks called a cell and compute HOG descriptor from each cell to compute the final feature vector. This method is similar to other scale invariant feature extraction methods. HOG computes the shape or structural features of an image. It extracts the gradients and calculates the orientation from locally contrasting normalized cells. Steps of the HOG feature extraction algorithm as follows:

Step -1: Compute Horizontal (G_X) and vertical (G_Y) difference of an image, I(x, y), using (1) and (2).

$$G_X=I(x,y)-I(x+1,y) \quad (1)$$

$$G_Y=I(x,y)-I(x,y+1) \quad (2)$$

Step-2: Calculate gradient (G), of each location using (3).

$$G=\sqrt{(G_X^2+G_Y^2)} \quad (3)$$

Step-3: Compute the orientation (D) of each pixel using (4).

$$D = \tan^{-1}(G_Y/G_X) \quad (4)$$

1.2 KANADE-LUCAS-TOMASI (KLT)

Kanade-Lucas-Tomasi (KLT) [6], [20], is a feature-tracking and extraction method used in multimedia image registration techniques. It uses spatial information of the pixels to find the best match position. KLT uses partial derivatives to find the gradient of an image.
KLT calculates the gradient matrix, G with using (5), for an image using both horizontal and vertical directions can be calculated using (6) and (7), respectively.

$$C= \begin{matrix} C_1 & C_2 \\ C_3 & C_4 \end{matrix} \quad (5)$$

Where, C_1, C_2, C_3 and C_4 are coefficients of G.

$$\Delta X\ (X,Y)=\delta/\delta X\ G(X,Y) \quad (6)$$

$$\Delta Y\ (X,Y)=\delta/\delta Y\ G(X,Y) \quad (7)$$

Next, eigenvalues (λ_1 and λ_2) of G are calculated. For uniform intensity regions, the values of λ_1 and λ_2 are small however for corners, edges, or any high and low intensity based textures, the values λ_1 and λ_2 are both large, for obvious reasons. A small and large eigenvalue represent unidirectional patterns. Equation (8) is used to keep all the largest eigenvalues (λ_m) for every pixel of an image. In the feature selection step, KLT considers all the pixels having an eigenvalue greater than a predefined threshold λ_t as in (9).

$$\lambda_m=Max(\lambda_1, \lambda_2) \quad (8)$$

$$\lambda_m > \lambda_t \quad (9)$$

1.3 SCALE INVARIANT FEATURE TRANSFORM (SIFT)

The extraction of unique features from images is always an important preposition. These are features that will remain unaltered after even application of transformations. There are several prepositions to achieve this, however, the use of Scale Invariant Feature Transformation or SIFT algorithm has been found as an efficient technique. This algorithm was proposed by David G. Lowe in the year 2004 in his scholarly article titled “Distinctive Image Features from Scale-Invariant Keypoints” [15]. SIFT is capable to detect a sufficiently large number of distinctive features spread across the whole image. The extracted features are invariant of change of scale, rotation of the image, and to some extent capturing the device's position change and change of lightness of the image. These extracted features are sufficiently localized in both frequency and spatial domain and are least affected by the obstruction, noise, and clutter. The SIFT algorithm follows several steps to extract the desired result. It starts with Scale-Space extrema detection [19] where on different scales the Gaussian blur of the image is computed using Difference-of-Gaussian (DoG) function to find out potentially important points which still remains stable after blurring over scale-space. This is the first approach to find out scale-invariant features as given in (10) for an input image P(x, y).

$$DoG(x,y,\sigma) = [G(x,y,i\sigma)-G(x,y,\sigma)]*P(x,y) = S(x,y,i\sigma)-S(x,y,\sigma) \quad (10)$$

where, scale space (S) of an image P is given as convolution of Gaussian function (G) as given in (11).

$$G(x,y,\sigma) = 1/(2\pi\sigma^2)e^{-(x2+y2)/2\sigma 2} \quad (11)$$

where, σ refers to the present scale and i represents i^{th} scale. The key- points are generally the maxima and minima of all DoG values. From the selected key points, the next step is to eliminate border region key-points and low-contrast area key-points, as these do not add to the effectiveness of the algorithm. After this, in the next step, an orientation is calculated for each key-point to make them stable even after rotation. There may be more than one orientation assigned to a key-point and they are calculated based on the image gradient's orientation. For each image key-point K(x,y), the gradient g(x,y) and orientation o(x,y) can be computed by using (12) and (13) respectively.

$$g(x,y) = \sqrt{([K(x+1,y)-K(x-1,y)]^2+[K(x,y+1)-K(x,y-1)]^2)} \quad (12)$$

$$o(x,y) =\tan^{-1}([K(x,y+1)-K(x,y-1)]/[K(x+1,y)-K(x-1,y)]) \quad (13)$$

Finally, the image gradients are computed locally for specific scale around every key-point to guard them against significant amount of modification in shape and brightness of the image.

1.4 ARITHMETIC OPTIMIZATION ALGORITHM

The basic arithmetic operations of addition, subtraction, multiplication, and division inspired the Arithmetic Optimization Algorithm (AOA) [4]. Exploration, or the agent exploring the search space to avoid local extrema, and exploitation, or reaching the closest solutions as much as feasible, are both part of the optimization process. Division and Multiplication operators are employed to explore the search space due to the high distributed value, however they are unable to obtain the nearest solutions due to the high dispersion. Due to the limited dispersion, Addition and Subtraction, on the other hand, can reach the desired answer.

Division and Multiplication operations in AOA explore the search space randomly. For any value $r_1 > A$, the AOA explores the search space otherwise it performs exploitation, where A is the acceleration function of particular iteration. The division operation is performed to explore the search space if $r_2 < 0{:}5$ else multiplication is performed as indicated in (14).

$$x_{i,j}(r+1) = \begin{cases} best(x_j) \div (P+\varepsilon)*((U_i-L_j)*\mu+L_j), & r_2<0.5 \\ best(x_j) *P* ((U_i-L_j)*\mu+L_j), & \text{otherwise} \end{cases} \quad (14)$$

In exploitation phase of AOA, operators like subtraction and addition focusing for the better outcome. For a random value r_3, the subtraction is performed if the value of r_3 is less than 0:5, otherwise addition is performed as indicated in (15).

$$x_{i,j}(r+1) = \begin{cases} best(x_j) - P *((U_i-L_j)*\mu+L_j), & r_3<0.5 \\ best(x_j) + P * ((U_i-L_j)*\mu+L_j), & \text{otherwise} \end{cases} \quad (15)$$

1.5 EQUILIBRIUM OPTIMIZATION

Equilibrium Optimization [3] is a physics-based meta-heuristic optimization process that is motivated by dynamic mass balance in a control volume. When all of the forces acting on the particle are balanced, it is said to be in equilibrium. The EO method is motivated by the aforementioned equilibrium law. The mass equilibrium equation is represented by (16), a first order ordinary differential equation.

$$V\delta C = Q * C_e - Q * C + M \quad (16)$$

where $V\delta C$ represents the mass change rate in V (Control Volume), C represents the concentration inside the V, Q represents the in and out volumetric flow rate of the V and M represents the generation of mass inside the V.

At first, the population sets are generated at random from the individuals. To build an equilibrium pool, the fittest particle based on the objective function is used. Each population of the equilibrium pool is updated using (17) in each iteration.

$$E_n = P_E + (Cn - P_E)*ET+(G_F/rv)*(1-ET) \quad (17)$$

where E_n is the concentration in the control system, P_E represents random particle, ET is the exploration in the search space, G_F is the final generation rate, r is the turnover rate, v is the in and out flow rate of the control system.

1.6 PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization, or PSO [5], [7] , [17] is a natural-inspired optimization algorithm based on flocking behaviour of birds. Initially a swarm of birds is randomly looking for food in a certain area without any idea about the meal or how far away from the food. Each bird follows the bird that is closest to the food.

The particles are updated by two values in every iteration of PSO. The best fitness value or best solution of every given particle is referred to as P_b. Another best fitness value, G_b, is obtained from all the particles in the search space. After determining the two values, each particle uses (18) and (19) to update its velocity and position.

$$V_i(k+1)=I*v_p(k)+\alpha_1*rand(0,1)*(P_b-present_p) + \alpha_2*rand(0,1)*(G_b-present_p) \quad (18)$$

$$Position_i(k+1)=Position_i(k)+V_i(k+1) \quad (19)$$

Where V_i is the velocity of the ith particle, I is the inertia coefficient, and rand(0,1) is a random number between 0 and 1. The local optimum and global optimum learning rates, respectively, are α_1 and α_2.

III. RESULT ANALYSIS

Different types of datasets, such as remote sensing dataset (SAR) [14], medical images [1], [2], and standard benchmark dataset, are used in this research to assess the predicted value of different transformation parameters for image registration, as shown in Fig. 1, Fig. 2, and Fig. 3, respectively. The transformation parameters are limited to a specified range, such as rotational angle (-300° to 300°), scaling along the X and Y axes (0 to 3), and translation along the X and Y axes (1 to 10).

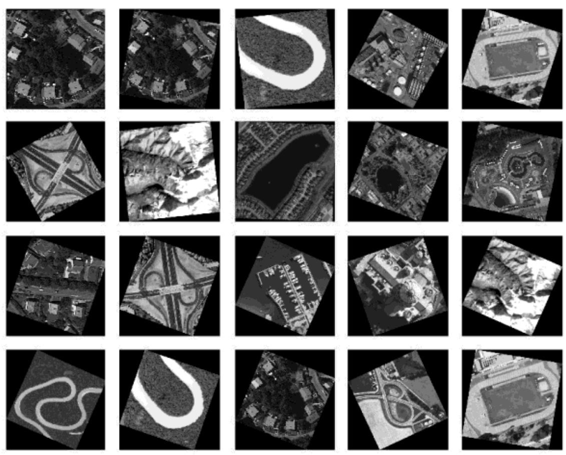

Fig 1: Sample SAR images.

Table 1: MSE calculation on various image datasets

Image Datasets	SAR Dataset			Medical Dataset			Standard Images		
Methods	R_{MSE}	S_{MSE}	T_{MSE}	R_{MSE}	S_{MSE}	T_{MSE}	R_{MSE}	S_{MSE}	T_{MSE}
SIFT	0:1202	0:1052	0:0217	0:1760	0:1845	0:0349	0:2742	0:1751	0:0289
KLT	0:146	0:2419	0:2127	0:3214	0:4142	0:1211	0:8933	0:4468	0:0311
HOG	0:066	0:1106	0:1174	0:4118	0:3343	0:0355	0:9843	0:2483	0:0359
SIFT-EO [13]	0:0346	0:0902	0:0194	0:2185	0:2863	0:0182	0:2298	0:1448	0:0194
SIFT-AOA	0:0724	0:0747	0:0607	0:0967	0:0905	0:0738	0:0788	0:0847	0:0764
SIFT-PSO	0:0631	0:0911	0:0461	0:3167	0:2831	0:0637	0:2164	0:0961	0:0346

This study compares the structural feature extraction techniques SIFT, KLT, and HOG, as well as optimization algorithms such as EO, AOA, and PSO, to choose discriminant features from SIFT and estimate transformational parameters for image registration. The comparison is based on an average MSE with ten evaluations for Rotation (RMSE), Scaling (SMSE), and Translation (TMSE). The BPNN based predictive model is for this experiment. Table 1, shows how different methods compare in terms of MSE between the original transformation parameters and the anticipated parameters value.

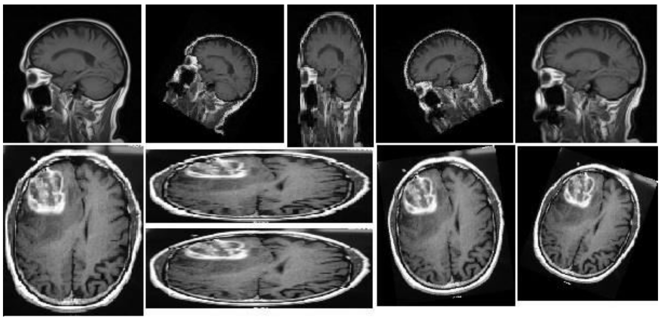

Fig. 2: Sample medical images.

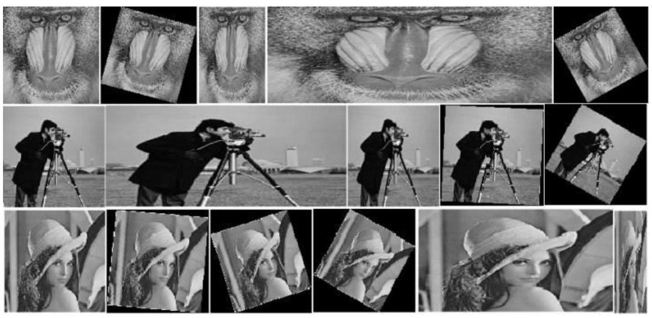

Fig. 3: Sample standard images.

IV. CONCLUSION

The structural feature-based transformational parameter estimation approach for picture registration is investigated in this work. For extracting a high number of features, traditional structural feature extraction techniques like HOG, KLT, and SIFT have a significant processing overhead. Apply PSO, EO, and AOA optimization methods to the SIFT feature vector to reduce the number of features and select the most significant ones. The neural network-based predictions are trained using the reduced feature vector. We will try to consider other predictors in the future to get a more accurate estimate of the various transformation parameters.

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