Effect of Non-rigid Hybrid Demons registration on Medical Video Content

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled 'Effect of Non-rigid Hybrid Demons registration on Medical Video Content' has been envisaged, studied & carried out by ABHIJIT MONDAL (University Registration No: 111108 of 2016-2017) under my guidance and supervision and be accepted in the requirement for the Degree of Master of Technology in Intelligent Automation and Robotics of Jadavpur University.

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The thesis is hereby approved as a credible study of engineering subject and presented in satisfactory way to warrant acceptance as a prerequisite to the degree for which it has been yield to. It is understood that by this approval undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn there in but approve the thesis only for which it is submitted.

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis entitled 'Effect of Non-rigid Hybrid Demons registration on Medical Video Content' contains literature survey and original research work by the undersigned candidate, as part of his Degree of Master of Technology in Intelligent Automation and Robotics.

All information has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by these rules and conduct, I have fully cited and referenced all material when required and none of the work represented in this thesis is fabricated.

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Abstract

Image registration refers to transforming one image with reference to another. Image registration has become one of the key application in medical imaging, as medical images captured by different devices often leads to distortion. In our present work, we've studied the effect of different demon's registration techniques namely 1) Thirion's demons, 2) Wang's demon, 3) Tang's Demon on medical video content. We have also proposed a demon's algorithm derived from Sayan et al.'s work, with the optimized parameters and combining them with the best demon algorithm in order to extract the best Demon's registration result possible. Our proposed system broke a medical video content into multiple frames and applied registered consecutive frames. Later, the registration effects were observed with the help of Visual representation of registration frames, correlation value, Mean square error (MSE), Joint Entropy (MJE) and Mutual Information (MI) values between registered and unregistered frames. Our system also calculated the processing time for each registration technique in order to establish a comparative study among them.

Keywords—Transformation, Image registration, Rigid, Affine, B-Splines, Demons, MSE, MJE, NMI.

I. INTRODUCTION

In the area of image processing, image registration has introduced a large change. Image registration [1] has always played huge part in medical imaging such as multimodality fusion, functional mapping of brain images, surgeries which required image guidance etc. The main application of image registration is, it is capable of mapping pictures taken by two different devices. Such cases are known as multimodal image registration. But mapping the pictures which are taken by same image capturing devices, at different time, is known as mono-modal image registration [2].

The features used mainly in various image registration [3] algorithms are the surfaces, volumes, landmarks, contours or a combination of these features. To manually, semi-automatically or automatically bridge the gap between two images these features are used during image registration. Image registration [4] uses geometrical transformations as well. Geometrical transformations in image registration refer to aligning points in one object in an image corresponding to the other points of same object in another image. During mapping in image registration [5] spatial and temporal transformations are applied. To avoid distortion among the images and locate a particular point among them, image registration [6] is used. Apart from biomedicine, various image registration [7,8] algorithms are used to in various fields like military automatic target recognition, computer vision, and to analyze images and data from satellites as well.

There are four different image registration algorithms namely: (1) Rigid registration, (2) Affine registration, (3) B-Splines registration and (4) Demons registration. Rigid registration mainly depends on scaling, rotation or combination of these two techniques. Rigid transformation [9] was first proposed by O. Bottema and B. Roth. Later it was implemented into Rigid registration. Affine registration is mainly based on affine transformation, which is similar to rigid transformation. Although, Affine registration also applies the shear mapping. Affine transformations [10] were first described by M. Berger. In the year 2000, C. de Boor proposed a new transformation method based on splines [11]. Later this technique was further revised and modified into B-Splines registration. B-Splines registration uses unique features like control points, weighting function which leads to spline curves generation and grid build up. Demons algorithm [12] proposed by Thirion uses displacement deviator between two images for transformation.

Modality refers to image capturing devices. During registration capturing device can be same or different. According to modality image registration frameworks can be divided into two subsections (i) Monomodal Framework, (ii) Multimodal framework.

Monomodal Frameworks – During image registration process multiple image frames are processed. Often they are captured using same device. For eg. if an image of bouncing ball which is captured by a camera is registered by any of the image registration process then it is said to be monomodal registration. Mostly, during monomodal registration a video is broken into multiple image frames and those frames are further registered using image registration.

In 2008 Sassi et al. used SSIM (structure similarity index) in order to register MR images [13] using monomodal registration. In this work they used SSIM as similarity metric in image registration. The luminance and contrast component comparison helped them to develop this technique which was applied on MR images. Al-Azzawi et al. used nonsubsampled contourlet transform and mutual information to execute monomodal [14] registration on MR images. Efficiency of multi-resolution representation was used in order to extract salient edges (Al-Azzawi et al., 2010) from medical images. The MR images were decomposed using contourlet transform and the mutual information based image registration was done. Ghaffari and Fatemizadeh used correntropy (Ghaffari and Fatemizadeh, 2013) measure for mono-modal image registration. In this work correntropy [15,16] measure which is a measurement between two random variables based on information theoritic learning was used in order to register using monomodal registration. Mutual information and SSD (Systems, Signals and Devices) both were used during registration. Ghaffari and Fatemizadeh proposed monomodal registration based on sparse based similarity measure. In this work they combined SSD, CC, MI and CR similarity measures (Ghaffari and Fatemizadeh, 2013) in order to structure the image transformation [16] matrix.

Multimodal Frameworks - Multimodal registration refers to the image registration process where the images are captured using different devices are processed. For eg. if same medical image is captured using MRI and CT scan then using the image transformation matrix of MRI to CT scan can be used as multimodal registration technique. This process is very much effective in medical field as the transformation matrix can help to obtain different type of scanned images. Makrogiannis et al. proposed multimodal image registration [17] based fusion methodology (Makrogiannis et al., 2007) which was applied to drug discovery research. In this work, multimodal registration and fusion of PET and MRI was done. They also proposed optimization of this registration technique using genetic algorithm. In 2010, Reducindo et al. introduced multimodal registration (Reducindo et al., 2010) based on particle filter. This registration technique was based on Bayesian estimation [18] theory especially on particle filters. Using the method they managed to reduce the runtime of the multimodal registration technique. Pradeepa et al. proposed multimodal registration [19] using mutual information (Pradeepa &Vennila, 2012). The optimization of CT and MRI images were done by down sampling and image registration based on mutual information was applied on them. Recently, in 2015 Hernandez et al. used multimodal (Hernandez et al., 2015) registration on multiple retinal [20] images. This method was based on line structures. As the retinal images had several modality-invariant features, hence multimodal registration was needed to stabilize the framework. The registration process was based on salient line structures and was aligned to minimize the chamfer distance. Fig. 1 shows the image registration process according to image modality.

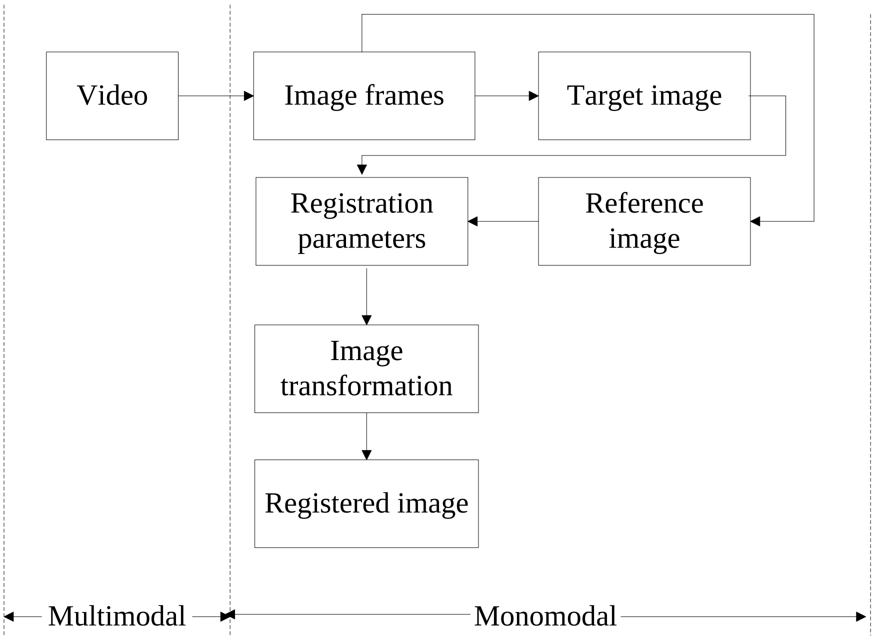


Fig. 1. Registration process according to modality

In the proposed work, we have used Demons registration, and taken three different variants of the demon's registration, namely, 1) Thirion's demons, 2) Wang's demon, 3) Tang's Demon.

Previously lot of research has been done in the area of image registration which has used these registration techniques. To our best knowledge, no previous work has compared the effect of these three demon's image registration techniques in order to identify the best possible demon's registration technique.

II. Literature Review

Huge amount of work has been done in the field of image registration. A brief literature review to significant image registration work is described in this section. Lucas and Kanade proposed an iterative image registration [21] technique with an application to stereo vision proposed a new image registration technique that makes use of the spatial intensity gradient of the images to find a good match using a type of Newton-Raphson iteration. Irani and Peleg proposed improving resolution [22] by image registration. They proposed the approach of back projection used in tomography. The improved resolution is given for gray level and color images when there is an unknown image displacement. Li et al. introduced a contour-based approach [23] to multi-sensor image registration proposed that they present two contour based method which use region boundaries and other strong edges as matching primitives.

In 2001, Christensen and He worked on a consistent nonlinear elastic image registration [24] method. In this work they described a new bidirectional image registration algorithm that estimates a consistent set of nonlinear forward and reverse transformations between two N dimensional images. Later in 2005, Hong and Zhang proposed an image registration technique[25] for high resolution remote sensing image in hilly area. In this work they used an automated image registration technique, which was based on the combination of feature-based and area-based matching. Wavelet-based feature extraction technique and relaxation-based image matching technique are employed in this research.

In the same year, Siu and Lau proposed image registration [26] based on IBR (Image-Based Rendering). In this paper, they analyzed the roles and requirements of an image registration technique for reducing the spatial sampling rate and based on those requirements they present a novel image registration technique to automatically recover the geometric proxy from reference images. They used chain-code correlation shape similarity criteria. Recently in 2013, Wahed et al. proposed automatic image registration [27] technique of Remote Sensing Images. In this work they proposed image registration technique of multi-view, multi-temporal and multispectral remote sensing images. Firstly, a pre-processing step is performed by applying median filtering to enhance the images. Secondly, the steerable pyramid transform is adopted to produce multi-resolution levels of reference and sensed images. Apart from the mentioned work, much work has been done in the field of image registration over the year.

In the following section (sec 3) different image registration techniques are discussed. In section 4 a comparative study of image registration framework is done. Section 5 presents a comparative study among the recent works in image registration field. Paper concludes in section 6.

III. METHODS AND MATERIALS

At first, the video is broken into multiple image frames. These images are registered using 1) Thirion's demons [12], 2) Wang's demon [29], 3) Tang's Demon registration [28]. The registered image qualities are checked with the help of correlation value and Mean square error (MSE), Joint Entropy (MJE), Mutual Information (MI) [30].

3.1 THIRION'S DEMONS REGISTRATION :

Thirion's basic Demons algorithm [12] is based on the principle of the optical flow formula. The reference image applies a displacement vector on the deformed image, which is called the Demons force, so that the pixels present in the deformed image are displaced in order to match with the reference image. Demons algorithm is an iterative process, and the optimization goal for each iteration is called the deformation field in this paper. As proven by Vercauteren et al.[31] the standard objective function of the nonrigid registration should include the similarity measure and the smoothness restriction of the alignment field:

$$E(\vec{u}) = \| R - F \otimes \vec{u} \|^2 + \sigma^2 \| \vec{u} \|^2$$

Here R and F are the reference image and the query image, respectively, $\vec{u}$ is the increment of the deformation field in each iteration, $\otimes$ stands for the deformation operation, and σ is a variable parameter.

Since the problem of non-rigid registration can be described by a minimum problem of $\vec{E}$, for $\nabla E(\vec{u}) = 0$, the solution of $\vec{u}$ can be obtained using the ESM (efficient second-order minimization) method. The increment of deformation displacement $\vec{u}$ can be presented by:

$$\vec{u} = (\| R - F \|)(\frac{\overrightarrow{\nabla R}}{\| \overrightarrow{\nabla R} \|^2 + \| R - F \|^2}$$

3.2 WANG'S DEMONS REGISTRATION

Since equation used in Thirion's basic Demons method only get the deformation field from the gradient information of the reference image, the model is only suitable for small deformed problems. Wang et al.[29] introduced the gradient information of the query image into the Demons force calculation formula. The parameter α was adopted to adjust the force strength in each iteration, and the Demons force in Wang's Demons is given as,

$$\vec{u} = (\| R - F \|)(\frac{\overrightarrow{\nabla R}}{\| \overrightarrow{\nabla R} \|^2 + \alpha^2 \| R - F \|^2} + \frac{\overrightarrow{\nabla F}}{\| \overrightarrow{\nabla F} \|^2 + \alpha^2 \| R - F \|^2}$$

3.3 TANG'S DEMONS REGISTRATION

Tang et al.[28] introduced a new factor *k* called the balance coefficient to adjust the force strength adaptively and analyzed the general range of the parameters. The Demons force expression in Tang's Demons is given as,

$$\vec{u} = (\| R - F \|)(\frac{\overrightarrow{\nabla R}}{k^2 \| \overrightarrow{\nabla R} \|^2 + \alpha^2 \| R - F \|^2} + \frac{\overrightarrow{\nabla F}}{k^2 \| \overrightarrow{\nabla F} \|^2 + \alpha^2 \| R - F \|^2}$$

3.4 SAYAN'S OPTIMIZED DEMONS REGISTRATION

Sayan et al. [32] introduced optimization into the demons registration. In this work they demons registration is optimized using Firefly algorithm (FA) to optimize the velocity smoothing kernels of the demons registration considering the correlation coefficient as a fitness function. Afterwards, the performance of proposed system using demons algorithm based FA is compared to the Particle Swarm Optimization (PSO). The experimental results proved that the proposed system based FA achieved correlation value of 0.6108 compared to demons registration [33, 34] with default parameters that provided 0.4468. Additionally, the FA based framework was more stable and produced superior results than the PSO based framework. Besides, the FA algorithm converged faster than PSO.

No of iteration(s)	***k_1***	***k_2***	***k_3***	**Obtained maximum fitness**
5	65	88	19	0.5914
10	72	82	20	0.6027
15	78	84	20	0.6051
20	96	76	20	0.604
25	98	98	20	**0.6108**
30	98	98	20	**0.6108**
35	98	98	20	**0.6108**

Data taken from Sayan et al.'s work shown in Table 1. Where k_1,k_2 were window size of Gaussian filter and k_3 was the sigma value.

IV. PROPOSED METHOD

In the current work firstly the medical content was broken into multiple frames. Then the two consecutive frames were registered with the higher frame set as target(/fixed) frame and previous one set as source (/moving) frame. The moving frame was then registered with 1) Thirion's demons [12], 2) Wang's demon [29], 3) Tang's Demon [28]. The resultant images were measured using correlation value and Mean square error (MSE), Joint Entropy (MJE), Mutual Information (MI) values between registered and unregistered frames. The registration having highest result were combined with Sayan et al.s [32] optimized parameters of Gaussian [35, 36] 2-d filter in demon's registration. This was done in order to extract the best of both sections (1) The Algorithm (2) It's parameters. The resultant algorithm was identified as Abhijit's demon (AD). The flowchart of the proposed work is shown below and the algorithm is discussed later.

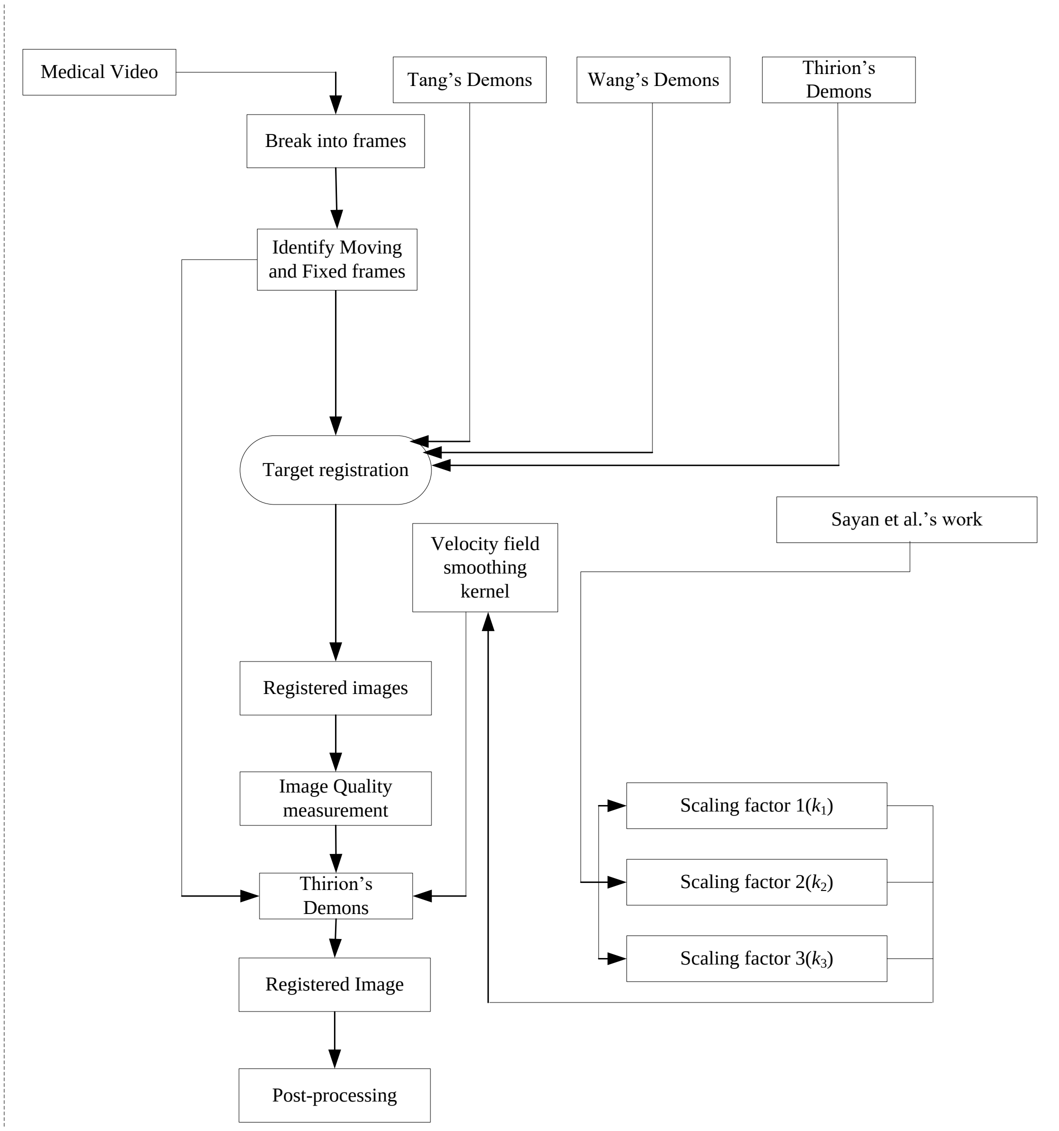


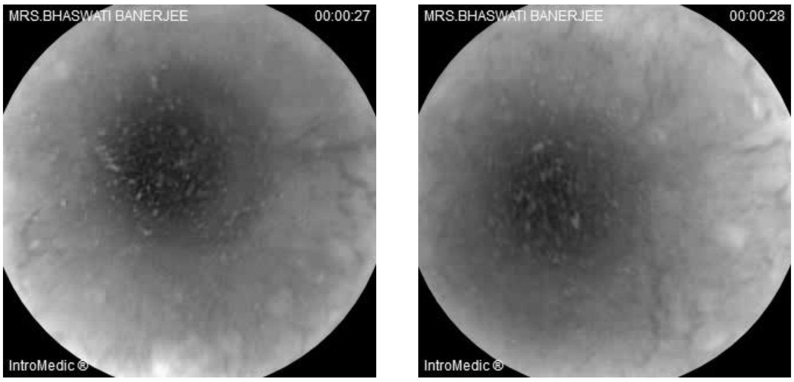
Fig. 2 Flowchart of the Proposed System

Algorithm:

Begin
For bin i=1:N, N =total no. of bins
    For image j=1:M, M = total number of images
        Read the source image;
        Read the target image;
        Apply alpha (noise) constant;
        Apply velocity field smoothing kernel (k_1,k_2,k_3);
        Begin
            Thirion's demons registration;
        End
    End for
End for
End

V.RESULTS AND DISCUSSION

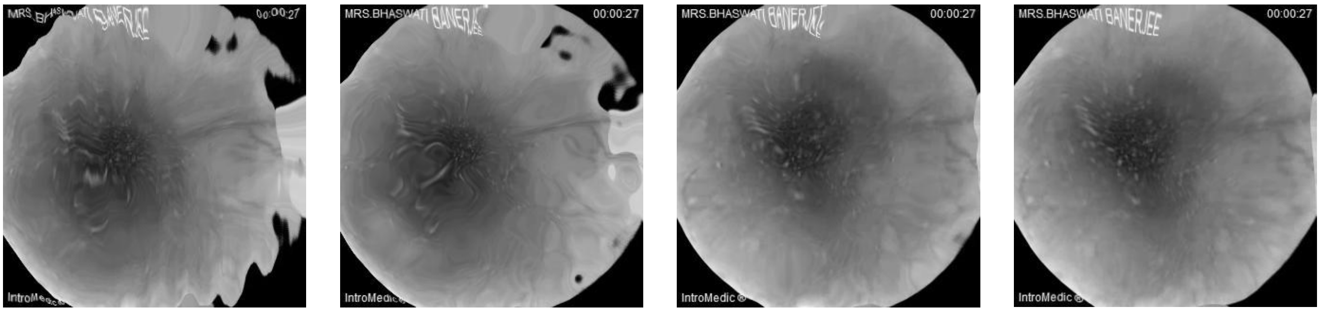
The complete study which includes different types of registration [37, 38] techniques were done on total 112 frames obtained from the video. For automated image registration process, we have used MATLAB R2018a software. From the previous discussion we've calculated the correlation, Mean square error (MSE) [30] , Joint Entropy (MJE) and Mutual Information (MI) between the frames before registration [39, 40] and after registration. Obtained registered images [41, 42] are shown below.



Frame 1 Frame 2

Fig 3. The moving (source) and fixed (target) frames obtained from video content.

Fig. 3 shows the obtained moving and fixed frames [43, 44, 45] extracted from medical video content. The video content was broken into multiple frames at first. Frame 1 was chosen as moving frame and frame 2 was chosen as fixed or target frame.



1. Frame 1 registered with reference to Frame 2 (Tang's Demon)

2. Frame 1 registered with reference to Frame 2 (Wang's Demon)

3. Frame 1 registered with reference to Frame 2 (Thirion's demons)

4. Frame 1 registered with reference to Frame 2 (Abhijit's demons)

Fig. 4. The effect of demon's registration with the help of 1. Tang's algorithm, 2. Wang's algorithm, 3. Thirion's algorithm, 4. The proposed System

Fig 4. shows the effect of image registration [46, 47, 48] as mentioned in the proposed system. The visualization clearly depicts that our proposed demons algorithm has performed better in terms of registration.

As previously discussed, the registered images' qualities are analyzed with the help of Mean Squared error, correlation, joint entropy and mutual information. The MSE is the cumulative [30] squared error between the registered and the original image

$$MSE = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y) - J(x,y)]^2$$

To calculate the joint entropy, you need to calculate the joint histogram between two images. The joint histogram is essentially the same as a normal 1D histogram but the first dimension logs intensities for the first image and the second dimension logs intensities for the second image. The joint entropy [30] of two images *X* and *Y* are calculated using the following equation.

$$MJE(X,Y) = -\sum_{x\in X}\sum_{y\in Y} P(x,y)\log_2[P(x,y)]$$

The mutual information [30] of the Image *X* and *Y* can be defined as

$$NMI = \text{entropy}(X) + \text{entropy}(Y) - MJE(X,Y)$$

The correlation coefficient [32] refers to the relationship between two image matrices; the correlation of two images can be calculated using the following equation

$$corr = \frac{\sum_m \sum_n (X_{mn} - X')(Y_{mn} - Y')}{\sqrt{(\sum_m \sum_n (X_{mn} - X')^2)(\sum_m \sum_n (Y_{mn} - Y')^2)}}$$

	No-register	Thirion Demons	Wang Demons	Proposed System	Tang Demons
MSE	78.5975	0.0032	0.0217	0.0055	0.0308
MJE	12.6538	7.3158	7.7372	7.4083	7.7871
NMI	1.4869	0.5116	0.2886	0.6198	0.2340
Correlation	0.8021	0.9147	0.7551	0.9377	0.6558
Time (sec)	-	3.487982	47.612281	7.467734	49.392287

Table 2. Comparative analysis between different demon's algorithm

As we can see from the above table it's visible our proposed system has performed better in terms of image quality. The following graph also supports the above mentioned claim of our proposed system being superior.

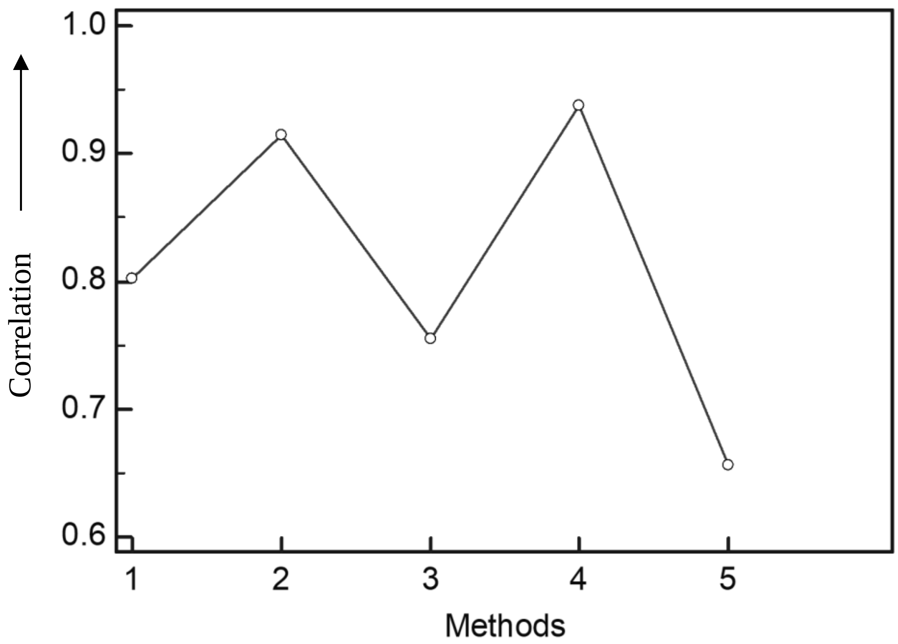


Fig 5. Correlation comparison for different methods, 1. No-register, 2.Thirion Demons 3. Wang Demons, 4. Proposed System, 5.Tang Demons

Although, the time taken for registration was quiet faster in Thirion's demons registration. The following graph also supports the previous statement.

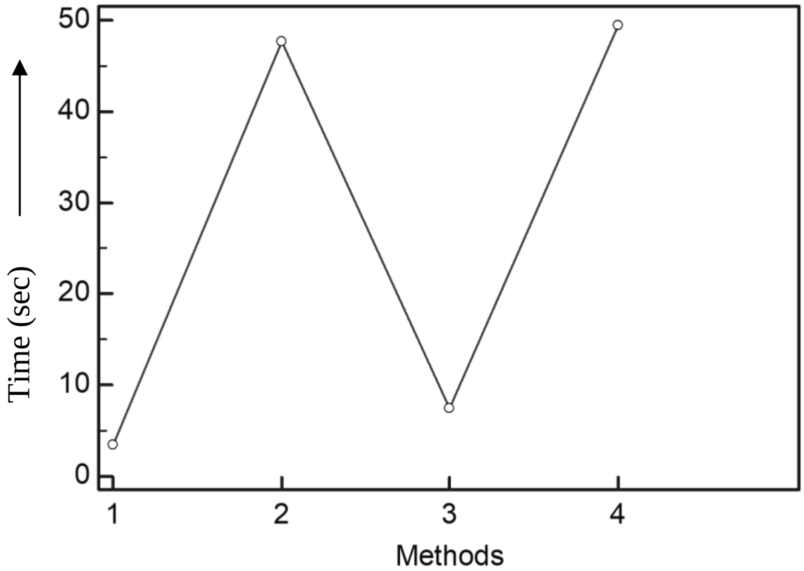


Fig. 6. Time comparison between 1.Thirion Demons 2. Wang Demons, 3. Proposed System, 4.Tang Demons

As we can see from the above discussion that our proposed system has managed to get best quality image among all four techniques. Although, the system failed to perform faster than other techniques, but that may happen due to bigger window size in 2-D filter (obtained from Sayan et al.'s work).

VI. CONCLUSION

The main objective of this study was to compare different demons registration techniques and to observe their effect on a medical video content. In order to compare different registration techniques, we used visual representation as well as the some quantification parameters like correlation factor, MJE, MSE and Mutual Information. Our study first, broke a medical video content and registered the frames, although the system remained focused on comparing the different demons registration method. The study showed Thirion's demons registration technique being faster and than other registration techniques. Hence, from Sayan et al.'s work the optimized parameters of demons registration were taken and combined them with Thirion's registration algorithm. The obtained results showed significant improve in the image quality. Further study may consist, various imaging operations like watermarking or compression combined with registration to observe the effect. Further study may include using more parameters or adjusting the consisting ones to establish the more optimized registration method. Our approach was a more realistic assessment of the relative merits of each registration method rather than categorically stating that any single method is superior in all situations.

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