



## IMPLEMENTATION OF MODIFIED CONTROL POINT IMAGE REGISTRATION METHOD

M.L. SHAHID and \*G. RAJA<sup>1</sup>

Electronic Engineering Department, University of Engineering and Technology, Taxila, Chakwal Campus, Chakwal, Pakistan

<sup>1</sup>Electrical Engineering Department, University of Engineering and Technology, Taxila, Pakistan

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Control Point Image Registration (CPIR) method is semi-automatic image registration technique in which control points are selected and matched manually. CPIR method is best suited for images that have distinct features; however, it needs highly skillful expert to select and match control points. This paper describes a modified CPIR method using fine tuning to register images which makes the control point selection and matching nearly independent of expert's skills. Fine tuning is achieved by applying normalized cross correlation which selects an 11x11 window around the input image control point and a 21x21 template across the reference image control point. The results of modified CPIR method are analyzed and it is found that modified method is more suitable and has low spatial dispersion values as compared to CPIR method.

**Keywords:** CPIR method, Control points, Landmarks, Spatial dispersion

### 1. Introduction

Image registration is the process of overlaying two or more images of the same scene taken at different times, from different viewpoints, and/or by different instruments [1-2]. It geometrically aligns two images—the input and reference images [3]. Image registration is often used as a preliminary step in other image processing applications. For example, we can use image registration to align satellite images or to align medical images captured with different diagnostic modalities (MRI and SPECT). Image registration allows us to compare common features in different images. For example, we might discover how a river has migrated, how an area became flooded, or whether a treatment is successful or not by comparing pre- and post-intervention images [4]. Different algorithms have been developed for image registration in MATLAB [5]. Control Point Image Registration (CPIR) method of MATLAB is semi-automatic image registration technique in which control points are selected and matched manually [6]. CPIR method is best suited for images that have distinct features; however, it needs highly skillful expert to select and match control points. Since control points are selected manually, therefore, quality of results mainly depends upon the expertise of control point selection expert. Results can be improved if we can make control point selection independent of expert's expertise.

The proposed research describes in depth modified CPIR method including fine tuning of control point selection. The main objective of proposed research is to implement a modified CPIR method. Modified CPIR method is semi-automatic image registration technique in which we use internal medical features as control points. This registration method can be used for monomodal and multimodal images. According to classifications presented by J.B.A. Maintz [4], this modified CPIR method is classified as semi-automatic intrinsic registration technique used for monomodal and multimodal images. The proposed research makes the results nearly independent of control point selection expert and error is minimized by using normalized cross correlation to fine tune the control points. Rest of paper is organized as follows: section 2 describes the brief working of modified CPIR method. The simulation results are analyzed and discussed in section 3 while section 4 concludes the paper.

### 2. Implementation of Modified CPIR Method

In CPIR method, control points are selected manually after reading input and reference images as shown in Figure 1. The image which is to be transformed to reach the geometry of other image called *input image* and the other image is called *reference image* [7-8]. In MATLAB environment, we open an interactive Control Points Selection Window and after that control points are chosen

\* Corresponding author : gulistan.raja@uettaxila.edu.pk

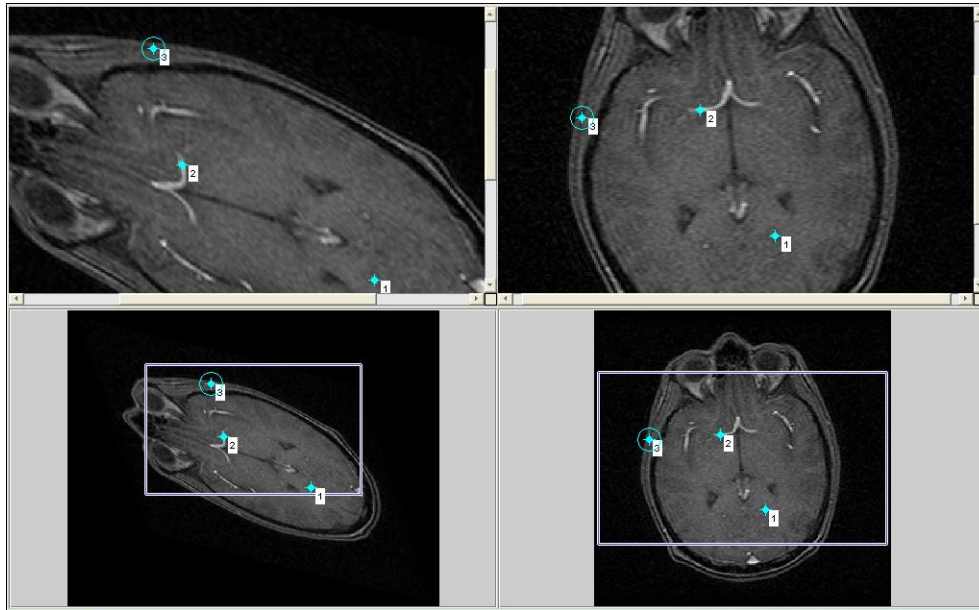


Figure 1. Control points selection window.

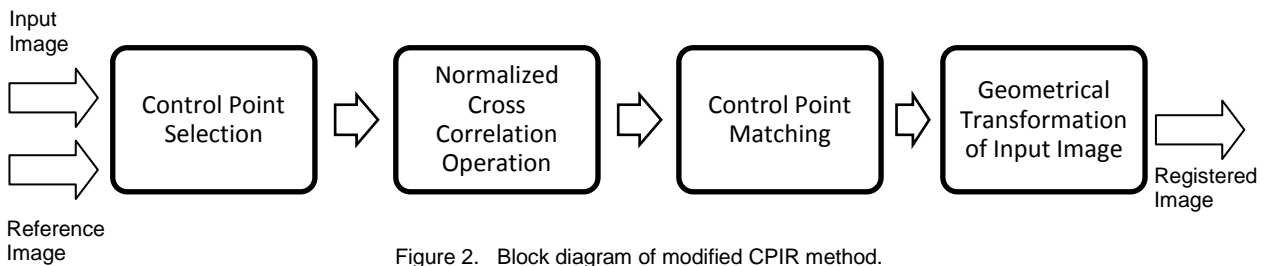


Figure 2. Block diagram of modified CPIR method.

manually by expert. They are detected and matched in both reference and input images manually. The method is completely described in Figure 2. In this method, three control points are selected from reference image and are matched with corresponding points in input image by an expert. Matching of these points is improved in modified CPIR method. This improvement is achieved by using normalized cross correlation to match the corresponding points. Normalization is used to make the matching independent of illumination variations of images [9]. This task is usually accomplished by subtracting the mean value and then dividing by the standard deviation. According to this definition, the normalized cross-correlation of a window,  $w(x, y)$  with a template  $t(x, y)$  is:

$$C = \frac{1}{n-1} \sum_{x,y} \frac{(w(x,y) - w_{avg})(t(x,y) - t_{avg})}{\sigma_w \sigma_t} \quad (1)$$

where  $n$  is the number of pixels in  $w(x, y)$  and  $t(x, y)$ ,  $w_{avg}$  is the average value of  $w(x, y)$  and  $\sigma_w$

is standard deviation of  $w(x, y)$ . Normalized cross correlation selects an 11 X 11 window around each input image control point and a 21 X 21 template across the corresponding reference image control point. In this way, best matched corresponding point is selected against the highest value of cross correlation operation.

After control points matching, input image is geometrically transformed to registered image by using geometrical mapping function. As the image is aligned, registered image is compared with reference image in two different ways. First, the results are compared visually and then quantitatively in terms of spatial dispersion and standard deviation. Spatial dispersion is a similarity metric which is used to measure the spatial difference between pixels in registered image and corresponding ones in reference image. It is measured in terms of Euclidean Distance. The formula for spatial dispersion is given by :

$$S_{disp} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (2)$$

Table 1. Abscissa coordinate values of registered and reference images.

No.	Image Name	Geometric Deformation	Landmarks of Registered Image using Modified CPIR Method (Abscissa-coordinates)			Landmarks of Reference Image (Abscissa-coordinates)		
			1st Landmark	2nd Landmark	3rd Landmark	1st Landmark	2nd Landmark	3rd Landmark
1	MRI Skull Side	Scaling	170.10	74.15	141.88	169.45	74.16	142.66
2			169.80	74.37	142.10	169.45	74.16	142.15
3			169.72	74.37	141.59	169.96	74.16	142.15
4			169.78	73.97	141.96	169.45	74.16	142.15
5			169.93	75.49	142.57	169.45	74.16	141.63
	Mean Value		169.86	74.47	142.02	169.55	74.16	142.15
6	MRI Skull Top	Translation	248.18	152.80	98.81	248.85	151.67	98.58
7			247.95	151.67	98.58	248.85	151.67	98.58
8			248.45	152.17	98.18	248.85	152.57	97.68
9			248.51	152.22	99.14	248.85	152.57	98.58
10			248.96	152.68	98.69	248.85	152.57	97.68
	Mean Value		248.41	152.31	98.68	248.85	152.21	98.22
11	MRI Skull Back	Reflection	125.80	176.06	54.83	125.67	177.18	53.55
12			125.38	176.21	53.07	125.67	176.66	53.55
13			123.97	177.25	53.25	125.67	176.66	53.55
14			126.09	176.19	54.23	125.15	177.18	53.55
15			125.89	176.66	52.33	124.64	177.18	53.55
	Mean Value		125.43	176.47	53.54	125.36	176.97	53.55
16	MRI Skull Top 1	Shearing	157.30	84.46	112.14	157.09	84.46	112.79
17			159.01	83.86	112.34	157.09	84.46	112.79
18			156.91	84.98	112.46	157.60	84.97	112.79
19			156.45	84.74	112.62	157.09	84.46	112.79
20			157.19	84.96	113.05	157.60	84.46	112.79
	Mean Value		157.37	84.60	112.52	157.29	84.56	112.79
21	MRI Skull Top 2	Rotation	307.45	225.50	238.11	305.54	225.00	238.00
22			305.30	224.99	237.59	305.00	225.00	238.00
23			306.53	225.89	238.79	306.00	224.00	238.00
24			306.30	226.17	237.17	306.00	225.00	238.00
25			308.76	226.43	238.86	306.00	225.00	238.00
	Mean Value		306.87	225.80	238.10	305.71	224.80	238.00

Hence spatial dispersion is used to measure the accuracy of the registration process. As small as the value of spatial dispersion, the results are better. The proposed research improves the results and minimizes the error by using normalized cross correlation to fine tune the control points.

### 3. Results and Discussions

MATLAB software is used to measure spatial dispersion and standard deviation for registration process. Spatial dispersion is a similarity metric which is used to measure the spatial difference between pixels in registered image and corresponding ones in reference image. It is measured in terms of Euclidean Distance [10]. The analysis conducted in proposed research is not platform dependent, therefore, the cost in terms of

time delay, hardware requirements and memory calls is not considered.

The difference between the coordinates of the corresponding points describes the misalignment of registered image. Larger differences indicate higher degree of misalignment of images. Hence, it is tried to minimize the difference as much as possible. We selected five different images MRI SKULL SIDE, MRI SKULL TOP, MRI SKULL BACK, MRI SKULL TOP1, MRI SKULL TOP2 and present results in tabular form. To determine spatial dispersion, three test points are selected and their abscissa and ordinate coordinate values are given in Tables 1 and 2. For each test point (landmark) we made five observations to get

Table 2. Ordinate Coordinate Values of Registered and Reference Images.

No.	Image Name	Geometric Deformation	Landmarks of Registered Image using Modified CPIR Method (Ordinate-coordinates)			Landmarks of Original Image (Ordinate-coordinates)		
			1st Landmark	2nd Landmark	3rd Landmark	1st Landmark	2nd Landmark	3rd Landmark
1	MRI Skull Side	Scaling	100.52	84.11	130.80	100.17	82.66	130.05
2			100.20	82.75	129.96	99.65	82.66	130.56
3			100.61	82.90	131.35	99.65	82.66	130.56
4			99.80	82.81	129.68	99.65	82.66	130.05
5			99.90	83.39	130.86	99.65	82.66	130.05
	Mean Value		<b>100.21</b>	<b>83.19</b>	<b>130.53</b>	<b>99.76</b>	<b>82.66</b>	<b>130.25</b>
6	MRI Skull Top	Translation	46.21	190.18	220.77	45.94	189.91	220.51
7			45.94	189.91	220.51	45.94	190.81	220.51
8			45.94	190.81	220.51	45.94	189.91	220.51
9			45.94	189.91	220.51	45.94	190.81	221.41
10			46.22	191.09	220.78	45.94	190.81	220.51
	Mean Value		<b>46.05</b>	<b>190.38</b>	<b>220.62</b>	<b>45.94</b>	<b>190.45</b>	<b>220.69</b>
11	MRI Skull Back	Reflection	63.88	121.39	114.65	63.60	121.29	113.56
12			63.31	122.52	113.62	63.60	121.80	114.08
13			66.76	120.54	114.07	63.60	122.32	114.08
14			65.60	121.77	113.68	63.60	121.80	114.08
15			63.81	120.80	115.10	63.60	121.29	114.08
	Mean Value		<b>64.67</b>	<b>121.40</b>	<b>114.22</b>	<b>63.60</b>	<b>121.70</b>	<b>113.97</b>
16	MRI Skull Top 1	Shearing	88.81	98.28	179.14	88.84	98.11	178.98
17			90.35	98.26	178.94	88.84	98.11	178.98
18			89.00	97.89	179.52	88.84	98.11	178.98
19			88.53	98.10	179.37	88.84	98.11	178.98
20			88.63	98.26	178.51	88.84	97.59	178.98
	Mean Value		<b>89.06</b>	<b>98.16</b>	<b>179.09</b>	<b>88.84</b>	<b>98.01</b>	<b>178.98</b>
21	MRI Skull Top 2	Rotation	188.12	199.15	333.09	186.31	199.00	332.00
22			187.32	198.34	332.20	186.00	198.00	331.00
23			187.10	198.39	333.87	187.00	199.00	332.00
24			188.28	199.28	332.83	186.00	199.00	332.00
25			188.78	199.66	330.14	186.00	198.00	332.00
	Mean Value		<b>187.92</b>	<b>198.96</b>	<b>332.43</b>	<b>186.26</b>	<b>198.60</b>	<b>331.80</b>

Table 3. Spatial Dispersion for the Proposed Registration Technique.

Image Name	Transformation Type	1 <sup>st</sup> Landmark	2 <sup>nd</sup> Landmark	3 <sup>rd</sup> Landmark
MRI Skull Side	Scaling	0.55	0.62	0.31
MRI Skull Top	Translation	0.45	0.12	0.46
MRI Skull Back	Reflection	1.08	0.58	0.25
MRI Skull Top 1	Shearing	0.24	0.15	0.29
MRI Skull Top 2	Rotation	2.02	1.06	0.63

average values. In this way we avoid errors in selecting landmark for calculating spatial dispersion and standard deviation. From the abscissa and ordinate coordinate values, spatial dispersion is calculated and given in Table 3. This tabular data is shown in the form of graphs in

Figure 3. It is clear from this chart that best results of registration are obtained for shearing transformation while relatively less improved results are observed in the case of rotation transformation. Spatial dispersion is also

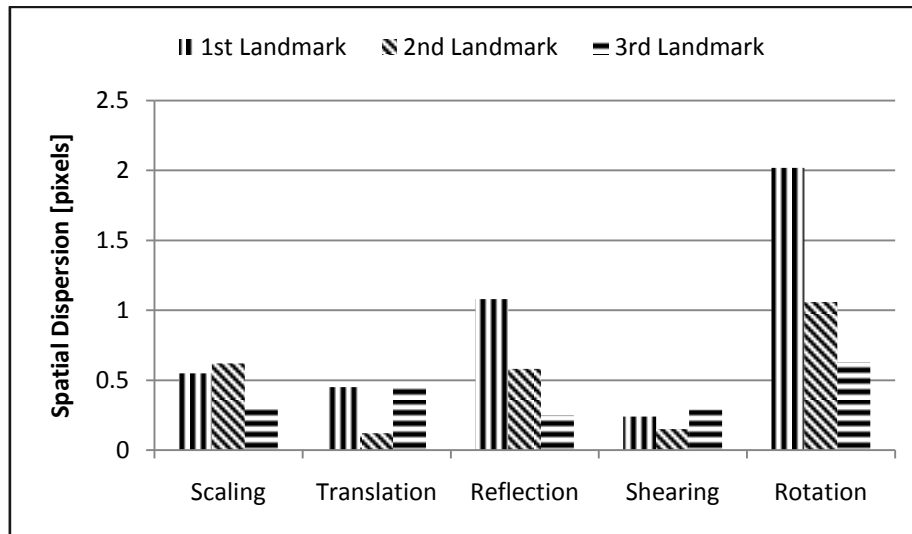


Figure 3. Spatial Dispersion for Modified CPIR Method.

Table 4. Spatial Dispersion for CPIR Method.

Image Name	Transformation Type	1st Landmark	2nd Landmark	3rd Landmark
MRI Skull Side	Scaling	0.95	1.02	1.11
MRI Skull Top	Translation	1.45	0.72	1.26
MRI Skull Back	Reflection	1.08	1.08	0.85
MRI Skull Top 1	Shearing	1.24	1.15	0.89
MRI Skull Top 2	Rotation	2.22	1.36	1.13

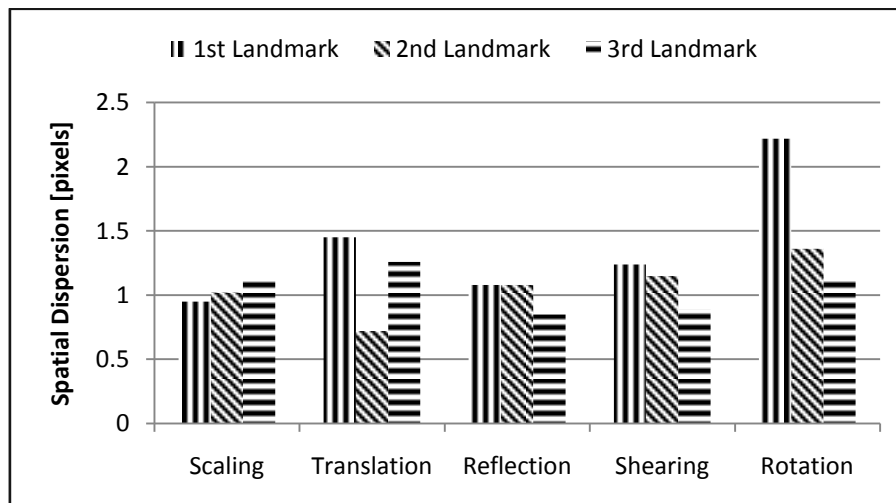


Figure 4. Spatial dispersion for CPIR method.

calculated for CPIR Method and is given in Table 4 and graphically shown in Figure 4. From Figures 3 and 4, it is clear that results are improved. Only in the case of rotation transformation, results are not improved too much.

The second similarity metric is standard deviation which indicates the exactness and success of repetition of registration process. If standard deviation has small value then it indicates that registration produces the same results on

Table 5. Standard deviation of abscissa and ordinate values for modified CPIR method.

Transformation Type	Abscissa-Coordinates			Ordinate-Coordinates		
	1st Landmark	2nd Landmark	3rd Landmark	1st Landmark	2nd Landmark	3rd Landmark
Scaling	0.15	0.59	0.36	0.36	0.57	0.69
Translation	0.38	0.45	0.35	0.15	0.54	0.15
Reflection	0.86	0.49	0.99	1.45	0.79	0.64
Shearing	0.97	0.46	0.34	0.74	0.17	0.39
Rotation	1.30	0.57	0.74	0.70	0.58	1.41

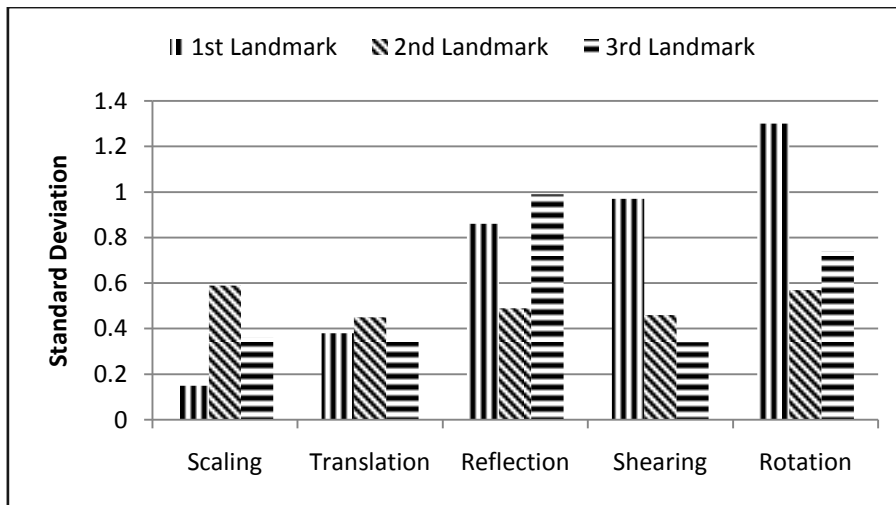


Figure 5. Standard deviation of abscissa coordinate values for modified CPIR method.

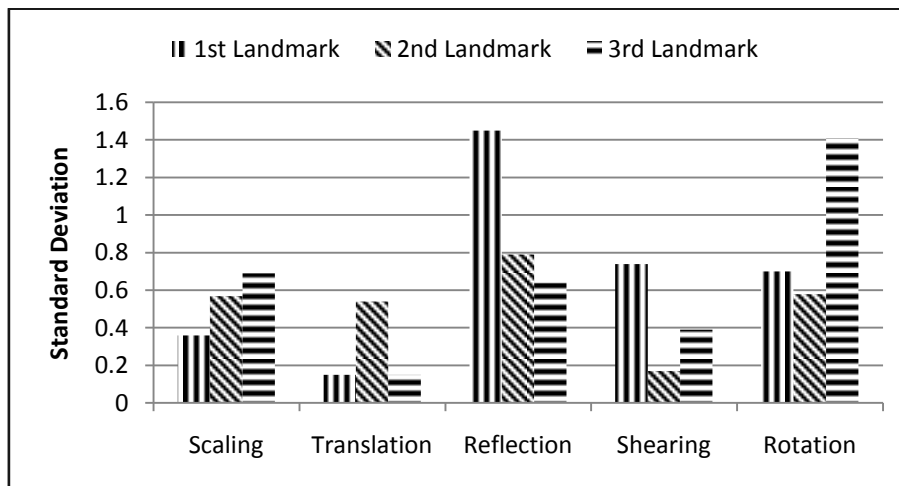


Figure 6. Standard deviation of ordinate coordinate values for modified CPIR method.

repeating this process again and again. The values of standard deviation for abscissa and ordinate coordinate values of three test points are given in Table 5 and graphically shown in Figures 5 and 6. It is clear from these charts of standard deviation

that best results of registration are obtained for translation transformation while less improved results are still observed in the case of rotation transformation. The values of standard deviation are also calculated for CPIR Method and its values

Table 6. Standard Deviation of Abscissa and Ordinate Values for CPIR Method.

Transformation Type	Abscissa-Coordinates			Ordinate-Coordinates		
	1st Landmark	2nd Landmark	3rd Landmark	1st Landmark	2nd Landmark	3rd Landmark
Scaling	0.95	1.29	0.89	1.23	2.06	0.97
Translation	1.18	1.23	1.76	0.56	0.98	0.45
Reflection	1.16	1.49	1.53	1.45	0.79	0.64
Shearing	0.97	0.87	0.59	0.74	0.37	0.39
Rotation	1.30	0.57	0.74	0.70	0.58	1.41

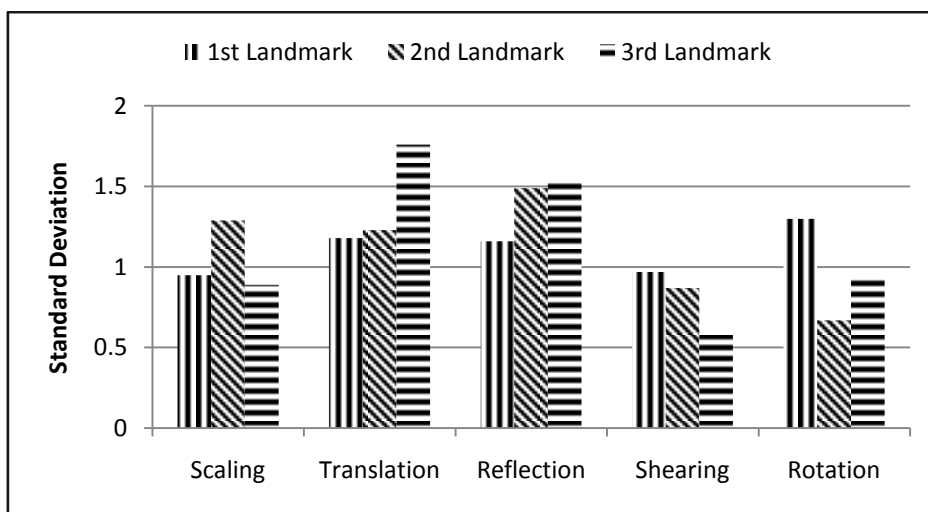


Figure 7. Standard deviation of abscissa coordinate values for CPIR method.

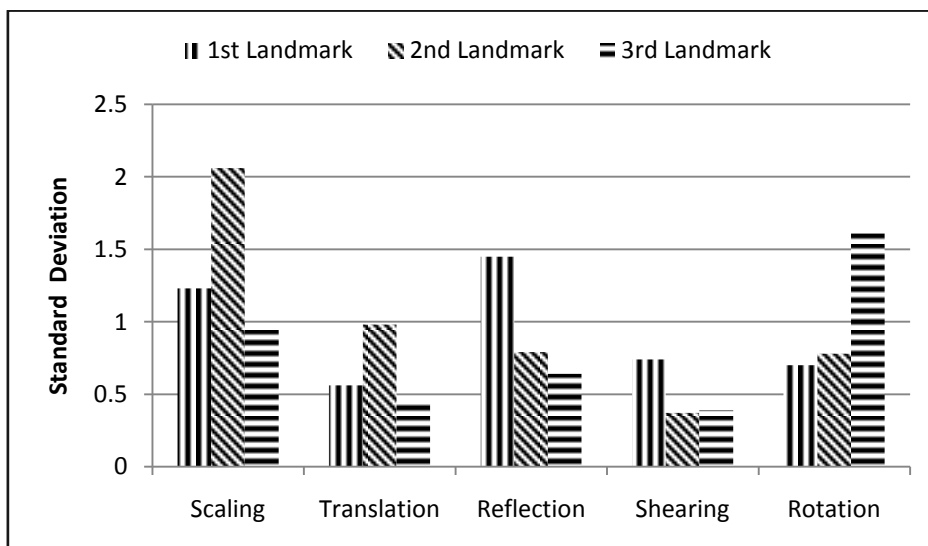


Figure 8. Standard deviation of ordinate coordinate values for CPIR method.

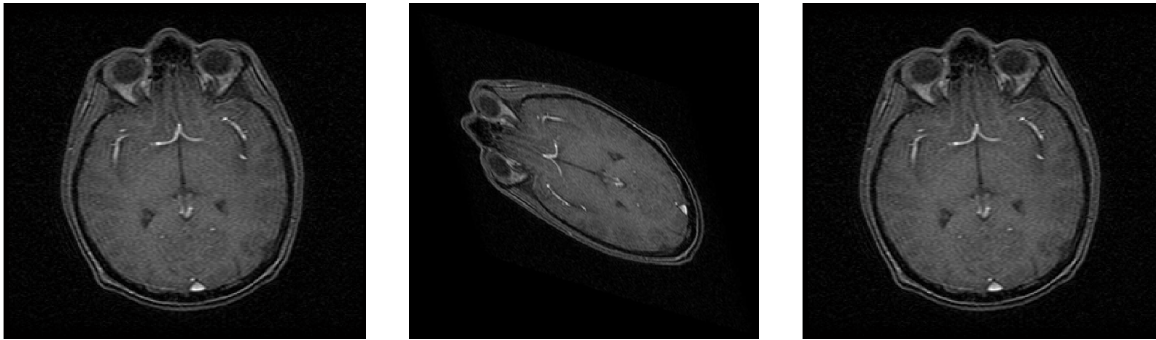


Figure 9. (a) Reference Image (b) Input Image (c) Registered Image

are presented in tabular form in Table 6 and graphically in Figure 7. Similarly the values of standard deviation of ordinate coordinates of three test points are shown graphically in Figure 8.

At the end, reference, input and registered images are shown in Figure 9 for visual comparison. These graphs show that registration in case of all transformations is improved but rotation transformation has minimum improvement. As a result, it has been found that Modified CPIR Method minimizes the error and improves the results.

#### 4. Conclusion

We analyzed Modified CPIR Method in-depth and it is concluded that overall results are improved by using fine tuning in the selection of control points. Modified CPIR method gives low spatial dispersion values as compared to CPIR method. It is also concluded that even if this implementation is specific for images having distinct features but this technique can be used for other images after some modifications or slight changes. Moreover, it is found that Modified CPIR Method is nearly independent of expertise of an expert.

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