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New Image Registration Techniques: Development and Comparative Analysis

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Abstract:

Design and Development of new Image Registration Techniques by using complex mathematical transformation functions are attempted in this research work as there is a requirement for the performance measurement of image registration complexity. The design and development of new image registration techniques are carried out with complex mathematical transformations of Radon and Slant functions due to their importance. And the rotation and translation geometric function are considered for better insight into the complex image registration process. The newly developed image registration techniques areevaluated and analyzed with openly available images of Lena, Cameraman and VegCrop. The accuracy as a performance measure of the newly developed image registration techniques are attempted to measure with popularly known metrics of RMSE, PSNR and Entropy. And the results obtained after successful image registration process are compared are presented. It is observed from the results that the developed new image registration techniques using Radon and Slant transformation functions with rotation and translation are superior and useful for the requirement and purpose in the digital image processing domain. Finally a research effort is made to development of new image registration techniques that are useful to extract intelligence embedded in the images with complex transformation function and an attempt is made to measure its performance also.

Keywords: I_R-Reference Image; I_S-Sensed Image; I_{RS}-Registered Image; E-Entropy value; PSNR-Peak Signal to Noise Ratio; RMSE-Root Mean Square Error.

I. INTRODUCTION

Image Registration is defined as a processby considering two spatially different images of same scene that are collected at different - (i) times; (ii) sensors; (iii) views; (iv) spaces [2,3,11]. The images of same scene so acquired are - (i) without any modifications is called as I_R and (ii) collected at different time/sensor/view/space is called as I_S.These I_R and I_S are used in the image registration process to achieve I_{RS} in order to interpret for required valuable information embedded in them.

Image registration is already identified as the most critical and important pre-processing task in the image processing domain where two or more images are overlayed to extract the required valuable information. Also, it is identified that the image registration techniques are complex, unique and application dependent [6,7,24]. In order to visualize images to meet variety of requirements and complex applications, it is found that there is a basic need for thedevelopment of more number of image registration techniques in the digital image processing domain, even though there are many image registration techniques available in the literature.

Intensity based image registration techniques are developed by choosing pixel values of reference and sensed images, and are directly considered for various similarity criteria. The similarity measures, correlation techniques and transformation functions are few popular approaches that are used to design and development of image registration techniques [5,12,15,21].

The reminder of this paper work is organized as ch. 2 to 6. Critical set of reasons in ch-2, mathematical background theory in ch-3, strategy of research methodology in ch-4, analysis andcomparative results in ch-5, and finally the research work is concluded in ch-6.

II. RATIONALE

The design and development of new image registration techniques is an open and challenging research area because there are unimaginable number of variety of applications in the image processing domain. There are many approaches available for the design and development of wide variety of image registration techniques by considering (i) similarity measures; (ii) correlation techniques; (iii) transformation functions,etc. Also, there are many sophisticated and complex mathematical transformation functions are available in the literature for the design anddevelopment of new image registration techniques. Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), Haar Transform, Walsh Transform, Hadamard Transform, Slant Transform, KL Transform, Hough Transform, Contourlet Transform, Ridgelet Transform, and Radon Transform are few such transformation functions [1,4,7,9,14,16,18,20,22]. In order to carryout

this research study Radon and Slant transformation functions are chosen with rotation and translation as geometrical functions.

III. BACKGROUND THEORY

Radon Transformation Function, Slant Transformation Function, Entropy, PSNR and RMSE are the mathematical background [8,13,14,16,18,19,20,24], in addition to the image registration process in order to carryout this research study for the design and development of new image registration techniques.

3.1 Radon Transformation Function

Radon transform[14,20] over the line ρ is represented as R (ρ, θ), and is mathematically representedas given in eq. (1) & (2) below:

$$\rho = x\cos\theta + y\sin\theta \quad (1)$$

$$R(\rho,\theta) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\,\delta\,(\rho - x\cos\theta - y\sin\theta)\,dx\,dy \quad (2)$$

Where, δ(.) is Dirac delta function, g(s,θ) is the radon transform, f(x,y) is the 1-D projection of (x,y), $-\infty < s < \infty$ and $0 \le \theta \le \pi$, θ in degrees = 0 to 180.

3.2 Slant Transformation Function

The Slant transformation function [14,18] is given below:

$$[V] = \sum_{i=1}^{N}\sum_{j=1}^{N}[S_n]\ [U]\ [S_n]^T \quad (3)$$

Where, [U] be the reference image of size N * N, $[S_n]$ is the N * N unitary slant matrix.

3.3 Performance Measures

The RMSE, PSNR & Entropy are three metrics are chosen as performance measures to evaluate the accuracy of the new image registration techniques, and their mathematical computations are given in the equations below:

$$MSE = \left(\frac{1}{MN}\right)\sum_{i}^{M}\sum_{i}^{N}\left(I_R(i,j) - I_S(i,j)\right)^2 \quad \text{and RMSE} = \sqrt{MSE} \quad (4)$$

Where, I_R is the reference image, I_S is the sensed image, MN is the size of the image, i and j is the intensity of the pixel in row i and column j. RMSE should be near to zero for best match between two images.

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \quad (5)$$

Where, R is the maximum possible pixel value of the image. Maximum value of PSNR indicates good match between two images.

$$E = \sum_{i=1}^{m}\left(p_i * \log_2\left(\frac{1}{p_i}\right)\right) \quad (6)$$

Where, m is events with p_1, p_2, ….., p_n known probabilities. The smaller the E, the better the registration will be.

IV. RESEARCH METHODOLOGY

The research work is structured by defining - (i) problem statement; (ii) objective; (iii) Design and Development; (iv) image data; (v) performance measures.

4.1 Statement

Design and Development of new Image Registration Techniques using Radon and Slant Transformation Functions.

4.2 Objective

Accuracy as a performance evaluation indicator of the new successful image registration techniques with measurement and comparison of most popularly used metrics of (i)RMSE; (ii) PSNR; (iii) Entropy;

4.3 Design and Development

The Design and Development is carried out for successful image registration with Radon and Slant transformation functions, and by choosing Rotation and Translation as two geometric functions. The design, development, implementation, analysis and data presentations are carried out with Matlab R2013a and its tools on a personal computer in the Windows environment.

4.4 Image Data

Cameraman, Lena and VegCrop are chosen with rotation angle of 45 degrees, and translation of 1 0 0; 0.1 1 0; 15 -12 1; as three image data sets, and are denoted as set-1, set-2, and set-3 respectively in order to develop and evaluate new image registration techniques.

4.5 Performance Measures

Even though there are many performance measures for the evaluation of image registration techniques, the RMSE; PSNR; and Entropy; are three most popular metrics those are considered to evaluate the accuracy of the new image registration techniques in this research work.

V. ANALYSIS AND RESULTS

The new image registration techniques are developed using Radon and Slant transformation techniques, and results are obtained with Cameraman, Lena and VegCrop images by considering rotation and translation. After successful image registration with matched features, the results are compared and displayed in table-1,4,7&10 for all the three sets of images with reference, sensed, registered and matched feature images. The table-2,5,8&11 indicates magnitude & phase, Radon spectrum (only for Radon transformation) and peak plots for all three sets images that shows the confirmation of successful image registration with rotation and translation for both Radon and Slant transforms. The RMSE, PSNR and Entropy results are shown in Table-3,6,9&12, and the better performance results are indicated with arrows, which indicates the better accuracy for set-3 images comparatively. The comparative analysis results obtained from RMSE, PSNR and Entropy as performance measure for Image registration techniques with rotation & translations for three sets of images using Radon and Slant transforms are displayed in the Graphs-1-6. All the analysis and comparative results displayed in Tables-1-12 and Graphs-1-6 are mostly self explanatory as they are prepared in tabular and graphical formats for the presentation purpose (all images are screen shots taken for display purpose only, where visibility and resolution varies due to printing and other limitations).

Finally, it is observed from the research study that the new image registration techniques are accurate, efficient and unique. And, it is found that the new image registration techniques using Radon and Slant transformation are superior and useful. The research studies are required to be continued with more transformation techniques because there are many variety of application requirements for image registration with multiple transformation techniques in order to obtain information embedded in the acquired images.

Table-1: Images with matched features-Radon Transform with rotation

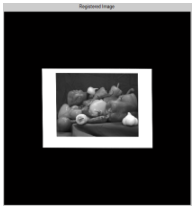
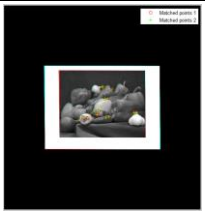
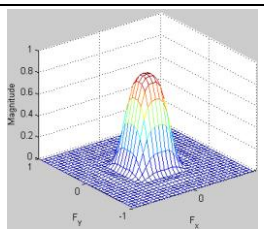
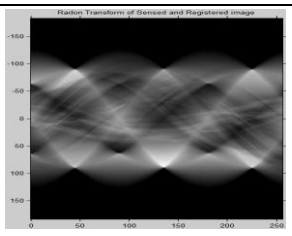
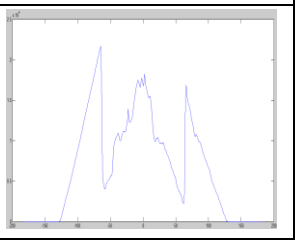
Images	I_R	I_S	I_{RS}	Matched Features
Set-1				
Set-2				
Set-3				

Table-2: Plots and Spectrum-Radon Transform with rotation

Images	Magnitude & Phase Plots	Radon Spectrum	Peak Plots
Set-1			

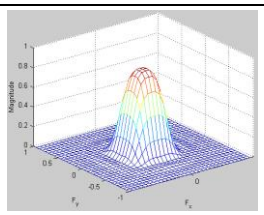
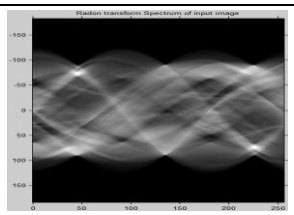
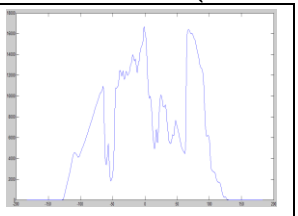
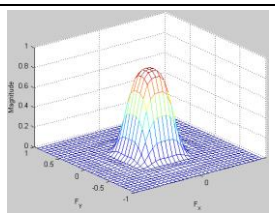
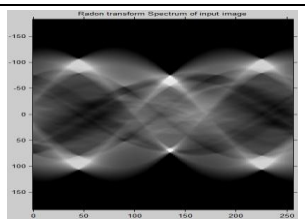
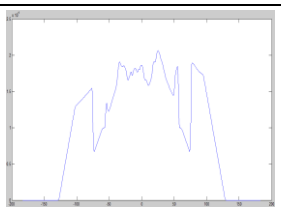
Set-2			
Set-3			

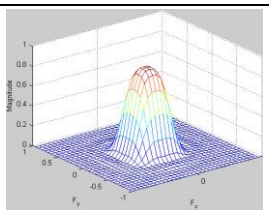
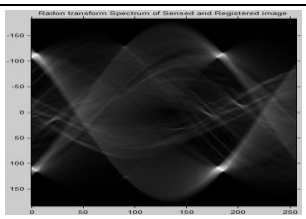
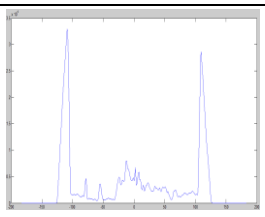
Table-3: Performance measures-Radon Transformation with rotation

Images	**Entropy**			**PSNR**	**RMSE**
	I_R	**I_S**	**I_{RS}**		
Set-1	7.0097	4.4651	2.5683	52.6816	0.3507
Set-2	7.5683	4.7423	2.6980	54.9837	0.2064
Set-3	5.1456	3.4851	2.0736 ↓	72.3940 ↑	0.0037 ↓

Table-4: Images with matched features-Radon Transform with translation

Images	**I_R**	**I_S**	**I_{RS}**	**Matched Features**
Set-1				
Set-2				
Set-3				

Table-5: Plots and Spectrum-Radon Transform with translation

Images	**Magnitude & Phase Plots**	**Radon Spectrum**	**Peak Plots**
Set-1			

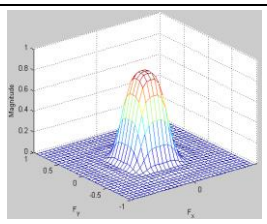
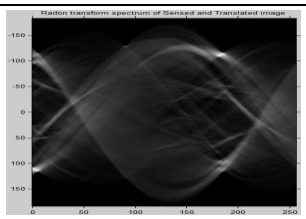
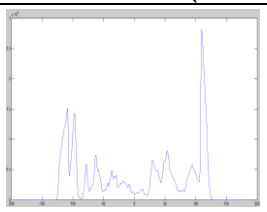
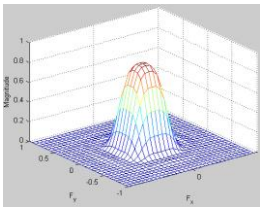
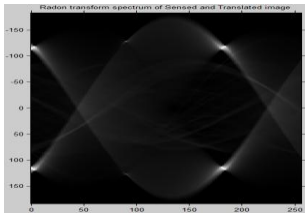
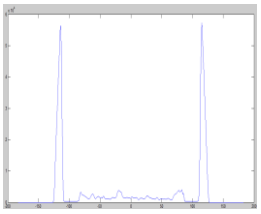
Set-2			
Set-3			

Table-6: Performance measures-Radon Transformation with translation

Images	**Entropy**			**PSNR**	**RMSE**
	I_R	**I_S**	**I_{RS}**		
Set-1	7.0097	6.8352	6.4754	52.7936	0.3418
Set-2	7.5683	7.3192	6.9592	51.5641	0.4536
Set-3	5.1456	5.1838	5.1466 ↓	52.9133 ↑	0.3325 ↓

Table-7: Images with matched features-Slant Transform with rotation

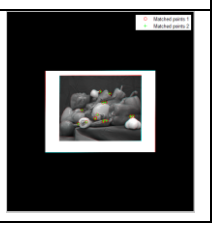
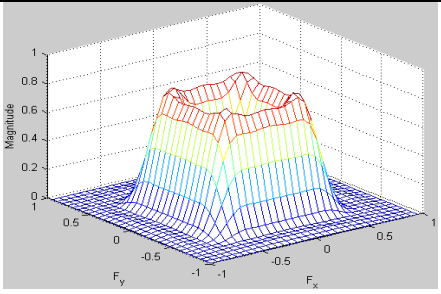
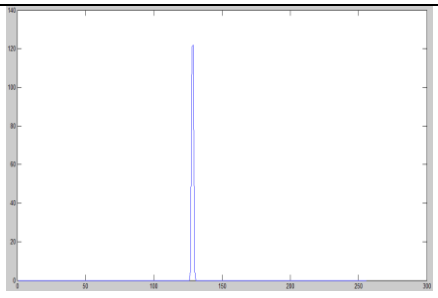
Images	**I_R**	**I_S**	**I_{RS}**	**Matched Features**
Set-1				
Set-2				
Set-3				

Table-8: Plots-Slant Transform with rotation

Images	**Magnitude & Phase Plots**	**Peak Plots**
Set-1		

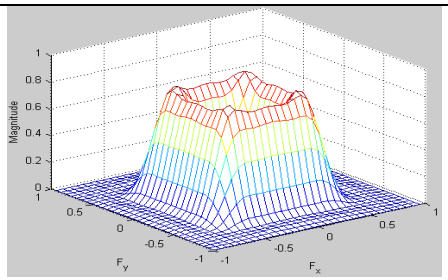
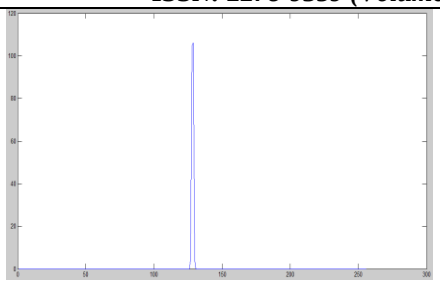
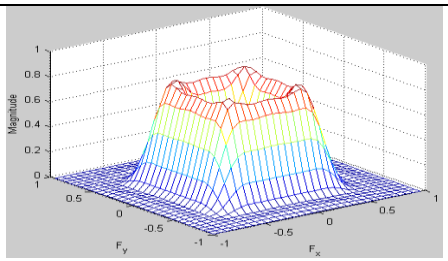
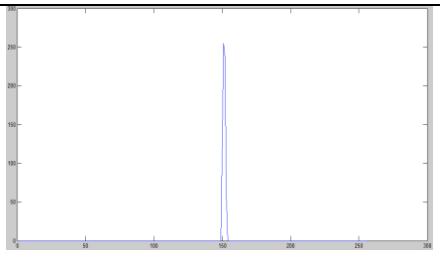
Set-2		
Set-3		

Table-9: Performance measures-Slant Transformation with translation

Images	**Entropy**			**PSNR**	**RMSE**
	I_R	**I_S**	**I_{RS}**		
Set-1	7.0097	4.4651	2.6124	66.6805	0.0140
Set-2	7.5683	4.7423	2.7266	66.3446	0.0151
Set-3	5.1456	3.4851	2.1561 ↓	68.0670 ↑	0.0101 ↓

Table-10: Images with matched features-Slant Transform with translation

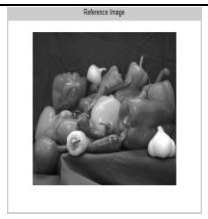
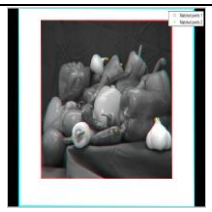
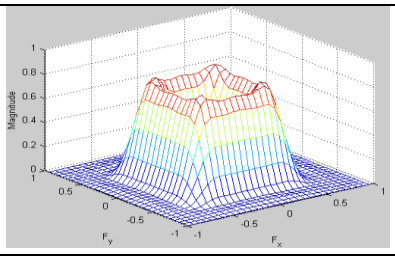
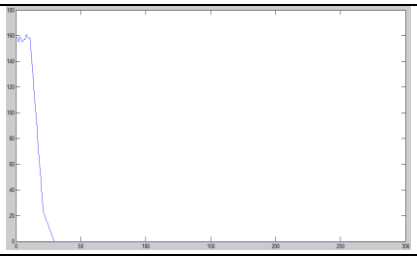
Images	**I_R**	**I_S**	**I_{RS}**	**Matched Features**
Set-1				
Set-2				
Set-3				

Table-11: Plots-Slant Transform with translation

Images	**Magnitude & Phase Plots**	**Peak Plots**
Set-1		

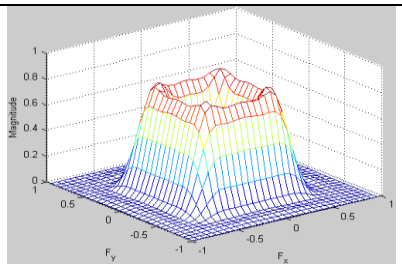
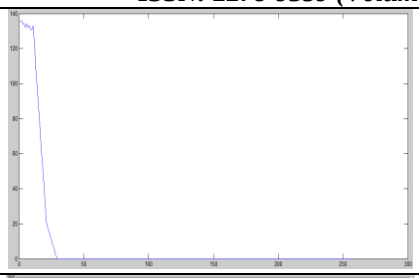
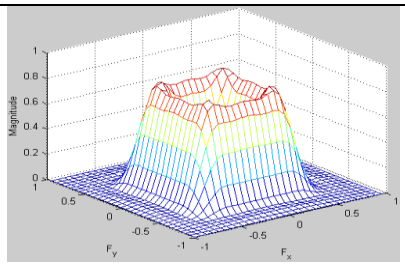
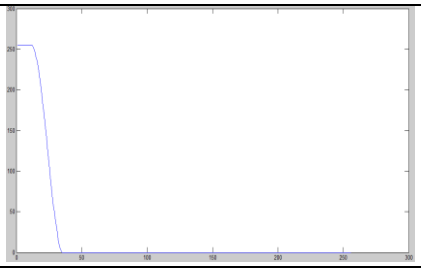
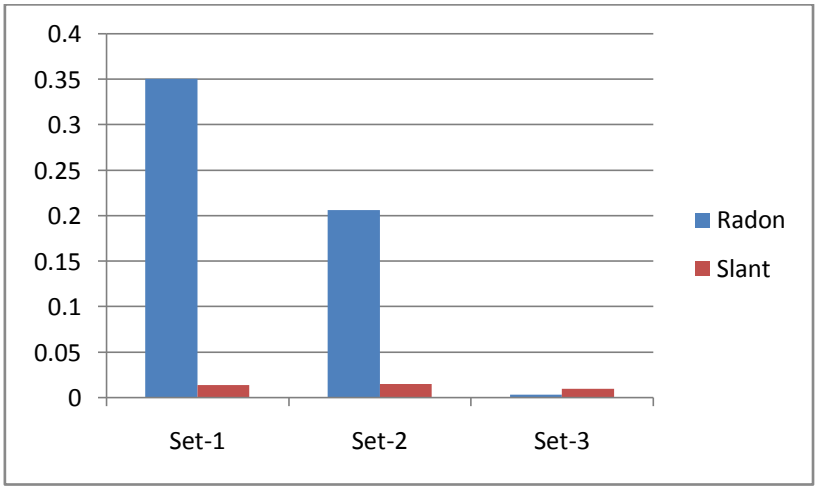
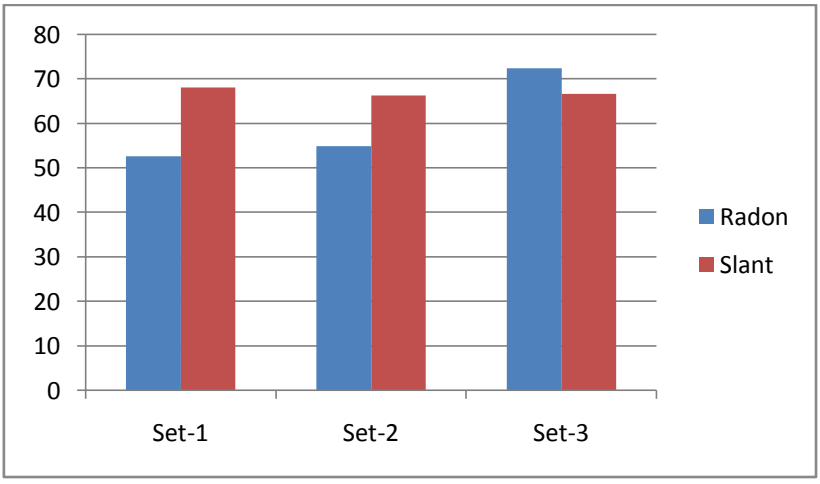
Set-2		
Set-3		

Table-12: Performance measures-Slant Transformation with translation

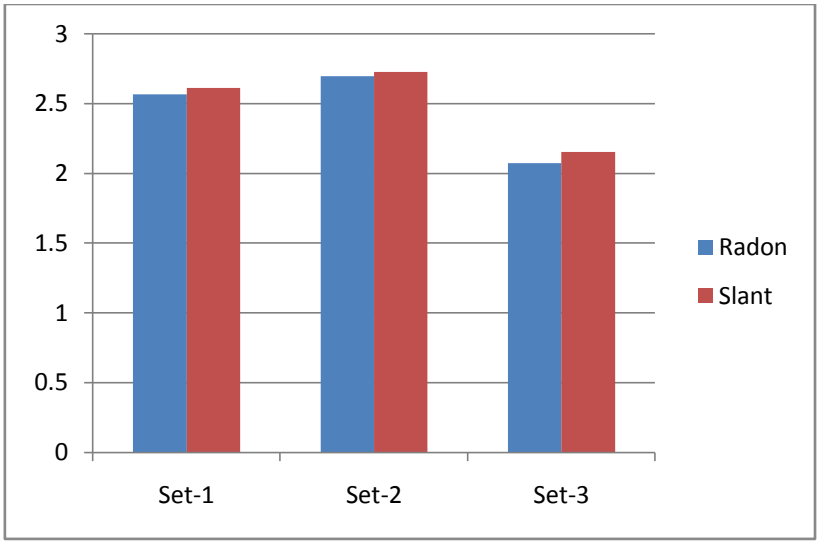
Images	**Entropy**			**PSNR**	**RMSE**
	I_R	**I_S**	**I_{RS}**		
Set-1	7.0097	6.8352	6.5653	66.3563	0.0150
Set-2	7.5683	7.3192	6.9347	65.8881	0.0168
Set-3	5.1456	5.1838	5.3010 ↓	72.7534 ↑	0.0009 ↓



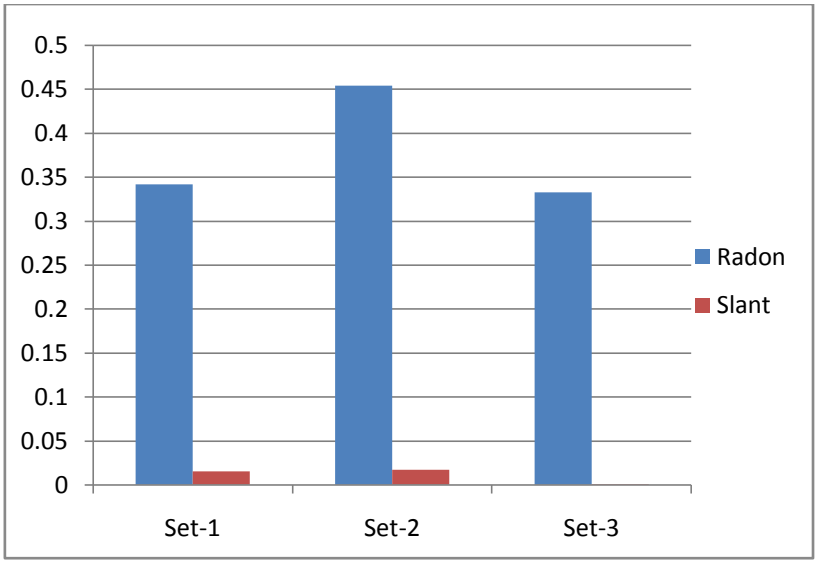
Graph-1: RMSE-performance comparison of IR technique using Radon and Slant Transformations with rotation: Set-3 better result.



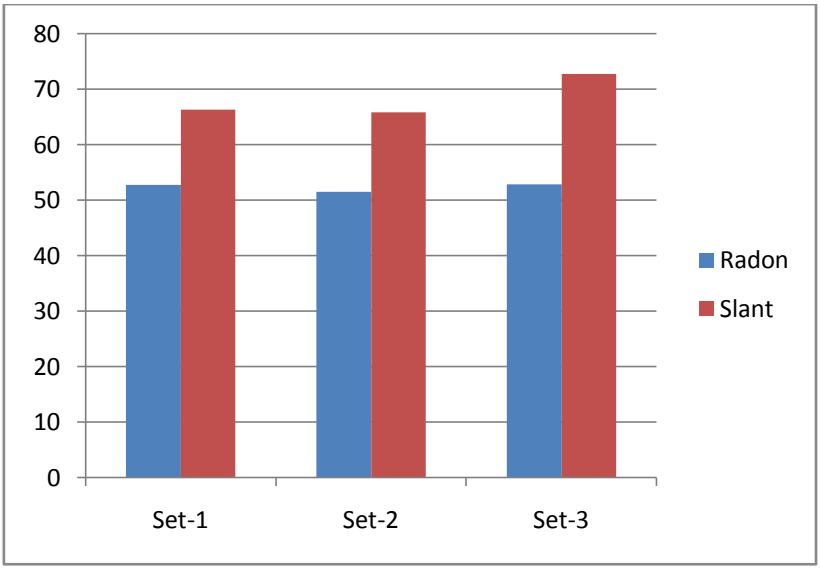
Graph-2: PSNR-performance comparison of IR technique using Radon and Slant Transformations with rotation: Set-3 better result.



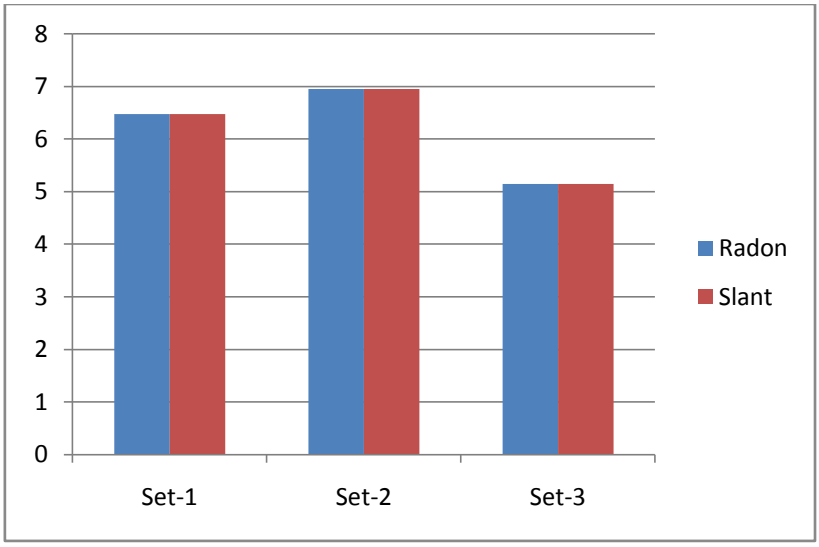
Graph-3: Entropy-performance comparison of IR technique using Radon and Slant Transformations with rotation: Set-3 better result



Graph-4: RMSE-performance comparison of IR technique using Radon and Slant Transformations with translation: Set-3 better result



Graph-5: PSNR-performance comparison of IR technique using Radon and Slant Transformations with translation: Set-3 better result.



Graph-6: Entropy-performance comparison of IR technique using Radon and Slant Transformations with translation: Set-3 better result.

VI. CONCLUSIONS

The basic need, importance, requirement, complexity, unimaginable number of variety of applications, and application dependency nature of image registration process are all well understood in this limited research study. This enabled to attempt for the design & development of new registration techniques using Radon and Slant transformation functions with rotation and translation as geometrical transformation functions, and the overall research work as utilization with many transformation functions, and as an unique application for image registration. It is observed that the research efforts of Radon transformation gives better performance results and unique for successful image registration[23,24]. Also observed that there is a basic need and requirement for further studies and extension on this research work. Hence, the authors would like to extend their scope of research work towards the design and development of image registration techniques for different domain of image sets, viz., satellite images, computer vision, medical imaging, etc., where the research efforts could be highly useful for the scientific research and education purposes of the world community.

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