Faculty of Science

UNIVERSITY OF TECHNOLOGY SYDNEY

Assignment Cover Sheet

Subject No: ________91403________

Subject Name: _______Medical Imaging_________

Student No: _____13758863______

Student Name: _____________Dhayaney Vijayan____________

Topic: _______Computer Lab Report 2- Image Registration_____________

I affirm that this assignment is my own work, that it has not been previously submitted for assessment, that all material which is quoted is accurately indicated as such, and that I have acknowledged all sources used fully and accurately according to the requirements. I am fully aware that failure to comply with these requirements is a form of cheating and could result in resubmission, loss of marks, failure and/or disciplinary action.

Signature: _____Dhayaney Vijayan_____ **Date: ______10/05/2020______**

91403 Medical Imaging
Computer Practical 2: Image Registration

Aim: To demonstrate mastery of disciplinary knowledge and its applications, problem solving, critical thinking and analysis, acquisition of operational skills with unfamiliar software, correlation of theoretical concepts and practical data, deriving conclusions from acquired data, and recognition of pros and cons of numerical simulation.

Specifically, this practical focuses on the examination of the image registration process and its clinical applications.

UTSOnline site: Assessment Task 1→ Practical 2: Image Registration. It will be referred to as the *Prac2 site*.

Assessment: The report is worth 10% of the total mark minus 1% for every day it is late. You are expected to complete all work and answer the numbered questions. The criteria comprise:

•application of the scientific method,

• skills in data analysis, and

• scientific communication skills in presenting and discussing conclusions based on acquired data.

Submission method: Upload to Prac2 site in a single document, including the cover sheet provided.

Due date: 10 May, 23:59. Past experience suggests it is unsafe to leave it until the last moment.

Venue: One of the Science Computer laboratories, as specified in your timetable.

Software: The computer practicals in this subject make use of *ImageJ*, an image processing pack- age, developed originally in the U.S. at the National Institutes of Health (NIH) and the University of Wisconsin. The software is bundled into Fiji[1], which contains ImageJ and the plugins needed for this practical. Access to the software is available in the Science Computer Laboratories, Monday to Friday, 8:00am-9:30pm, so long as the labs are not in use for a class. You can find Fiji shortcut from the Start menu in the Windows desktop. ImageJ is an open-source software package issued under BSD-2 licence that permits free download and use. It can be downloaded from Fiji and installed under any operating system that supports runtime Java environment. Note that no support is provided for private installations.

1 Background

Today's radiologists have access to a great variety of imaging modalities and acquisition regimes. A patient may undergo multiple imaging procedures as a part of the diagnostic work-up, with each procedure providing complementary diagnostic information. For example, a SPECT scan may reveal a hot spot indicative of a malignant nodal carcinoma in the chest, but it is not very good at depicting nearby anatomy while a CT scan provides detailed anatomical structure of the chest but may miss the pathology. A comparison of the SPECT and CT images can reveal the location of the pathology, for example, whether it is a bone tumour located in the rib or a lung tumour.

A patient may also undergo repeat imaging procedures over a period of time, with the aim of identifying often subtle changes in appearance of suspect lesions. The changes may be spontaneous or induced by treatment. For example, a child's MR scan reveals the presence of a teratoma. This is a benign tumour but because it has a potential to turn malignant, repeat MR is ordered. The question is: have the characteristics (size, shape, texture, boundary smoothness) of the lesion changed to suggest a malignancy?

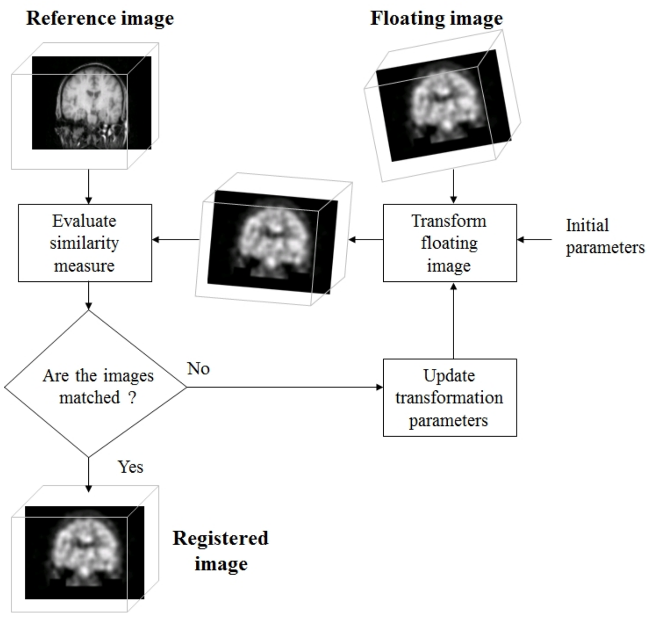
Images obtained at different times or with different machines cannot be assumed to be aligned. The misalignment could be due to different poses (e.g. prone and supine), different acquisition parameters, variations in spatial grid, and changes in anatomy/pathology. In order to extract reliable diagnostic information from a comparison of multiple images, these images must be aligned (registered).

There are many registration algorithms, but they all have the following elements in common:

• a set of transformations that can be applied to one image in order to align with another,

• a similarity measure to tell us how similar the transformed image is to its counterpart, and • a method of efficiently searching through all the possible transformations.

The general method illustrated below shows a positron emission tomography (floating) image of the brain being registered to a corresponding magnetic resonance (reference) image.



In terms of clinical applications, we distinguish several types of the registration problem:

- intra-subject intra-modality (same patient, same modality, e.g. annual breast screening),
- intra-subject inter-modality (e.g. chest SPECT and CT of the same patient),
- inter-subject intra-modality (e.g. in neurophysiological research, functional MR studies may need to be averaged over multiple subjects to detect subtle activity patterns),
- inter-subject inter-modality (again, may arise in research applications where different subjects were scanned with different modalities).

A review of image registration is available from Hutton et al. 2005. The link is also provided at Prac2 site under Background reading. Although the review focuses on registration of nuclear medicine images with other modalities, its analysis is broad enough to apply to other problems.

In this practical, you will investigate aspects of the registration problem and registration algorithms.

2 Registration of synthetic images Here we assume that the only difference between the fixed image (Fixed_rect.jpg) and the floating image (Float_rect1.jpg) is relative rotation.

1. Load the two images into ImageJ. Note that both images are binary (the pixel values are either 0 or 255).

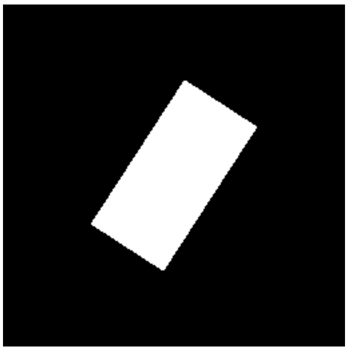


Figure 1: Fixed Rectangle Image

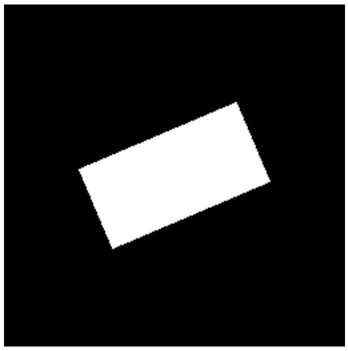


Figure 2: Float Rectangle Image 1

2. Guess by how much the floating image should be rotated. Now use command Image → **Transform→Rotate** to rotate the floating image by the estimated angle. Set Fill with background colour and Preview. Save the resulting floating image.
3. Display the absolute difference between the fixed image and the rotated floating image using command **Process → Image Calculator** and select **Difference**, which will compute the absolute difference between two images, $|\text{Image}_{Fixed} - \text{Image}_{Float}|$.

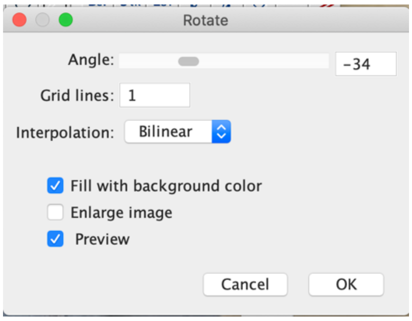
4. Vary the rotation angle and observe the absolute difference image until you are satisfied that you have obtained the best possible registration.

2.2 Rigid-body transformation

In a rigid body, the distance between any two points must not change. Accordingly, a rigid body transformation permits only rotations and translations. Here you will attempt to find the fixed float

Question 1 *Record your optimum rotation angle and the image of the absolute difference for that angle. Are there any residual registration errors? If so, how do you think they arose?*

Optimal Rotational Angle- (-34)° or counter-clockwise (-34)°



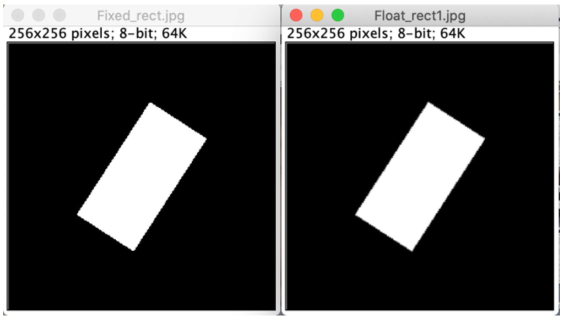
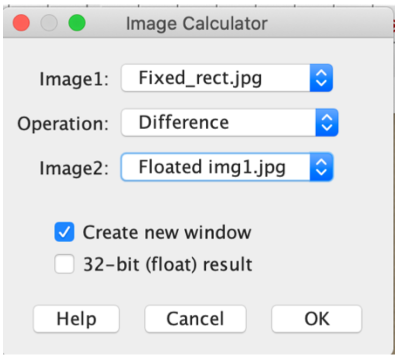


Figure 3: Rotational Angle for Float Rectangle img 1

Figure 4: Ater the Rotation- Fixed img (right) and Float img (left)



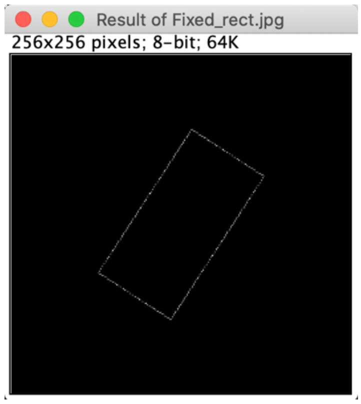


Figure 5: Dialogue box for image calculator

Figure 6: Image of absolute difference at (-34)°.

A small amount of pixelated residual registration errors is seen, and it could have been arisen due to the following reason:

According to Hutton *et al.,* if the **resolution is poor,** approximation to uniform rotation is coarser. Rotation of the rigid body which is a displacement field characterised by rapid change causes **temporal blurring** making the edges coarse and less defined. It is difficult to bring the two images to a common scale with a uniform spatial blur. Thus, the errors are obtained as the edges became rough and less detailed due to rotation, resulting in poor resolution of float image when compared to the fixed image.

parameters of a rigid-body transformation that will register the floating image (Float_rect2.jpg) to the fixed image (Fixed_rect.jpg). In addition to rotation, as in 2.1, use also **Image → Transform → Translate**.

2.3 Similarity transformation A similarity transformation is a rigid-body transformation plus zoom (overall magnification). Here you will attempt to find the parameters of a similarity transformation that will register the floating image (Float_rect3.jpg) to the fixed image (Fixed_rect.jpg). Use the preceding procedure but add the zoom factor with command **Image → Scale.** For ease of comparison, crop the image to the size of the reference image by means **of Image → Adjust → Canvas Size.**

2.4 A similarity measure

So far you have relied on visual perception to judge optimum transformation. However, your experience with the displayed absolute difference may suggest a way of quantifying a degree of similarity. Is there any one parameter provided by **Analyse → Set Measurement** applied to the absolute difference image that will quantify the dissimilarity between the two images**? The negative of such a parameter would act as the *similarity measure*.**

Here, once again, you will attempt to find the optimum rotational transformation that will register the floating image (Float_rect1.jpg) to the fixed image (Fixed_rect.jpg). Determine the value of the similarity measure for a range of rotation angles.

3 Registration of CT images

In this part, you will register two CT images of the thorax using the similarity measure you chose in the preceding section. The reference (fixed) image is Fixed_neck.jpg and the floating image is Float_neck.jpg, both available from Prac2 site. Assume that the two images are related by a rigid body transformation.

Question 2 *What is the optimum translation in the horizontal direction (width) and the vertical direction (height) and rotation in degrees? Show the image of the absolute difference. How does the accuracy of your result compare to the preceding registration result? Give an example of a clinical image where a rigid-body transformation can be expected to be a good approximation.*

For Float image 2 image,

- Translation,

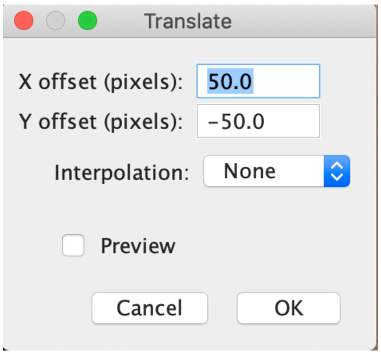


Figure 7: Dialogue box for translation

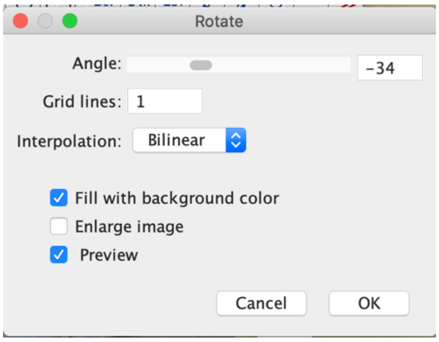
Figure 8: Translated Image

Optimal

X-Offset (Width) - **50 pixels**

Y-Offset (Height) - **(-50) pixels**

- Rotation,



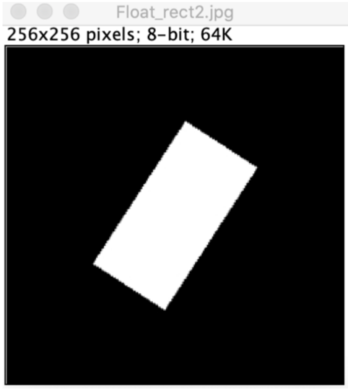


Figure 9: Dialogue box for Rotation **Figure 10: Rotated Image**

Optimal Rotational Angle- **(-34)° or counter-clockwise (-34)°**

- Image of absolute difference

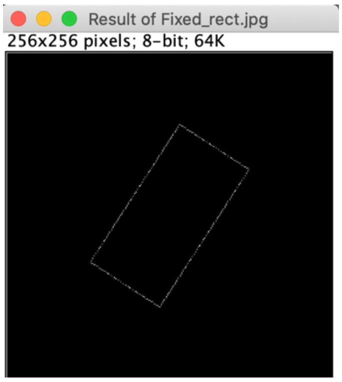


Figure 11: Image of absolute difference

- Difference between the preceding and current registration results.

  There is no much difference between the preceding and current registration results. According to Hutton *et al*., one of the characteristics feature of rigid-body translation is that it has uniform fine-scale displacement field where blurring is not perceivable. But the blurring caused by the rotation is in-evitable. That's why both results have no significant difference. This is also seen in the available registration results.

- Example of a clinical image where a rigid-body transformation can be expected to be a good approximation is the brain CT image of acute stroke

Question 3 *Determine the optimum transformation and state its parameters: horizontal and vertical translations, rotation, and magnification. Show the image of the absolute difference. How does the accuracy of your result compare to the two preceding registration results? Suggest clinical examples where a similarity transformation might not capture the misalignment between the corresponding images.*

For Float image 3 image,

- Rotation,

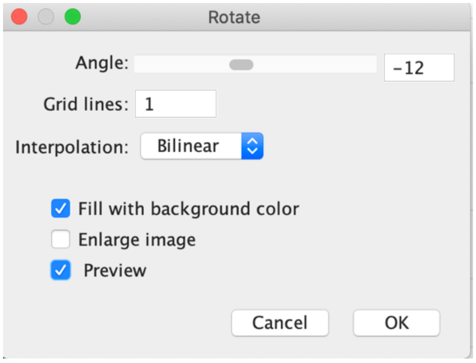


Figure 12: Dialogue box for rotation

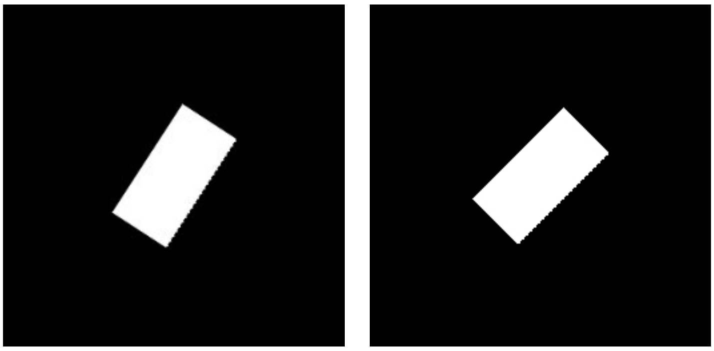


Figure 13: Rotated Image at -12°

  - Optimal Angle of Rotation- (-12)°
  - Gridline-1
  - Interpolation- Bilinear

- Translation

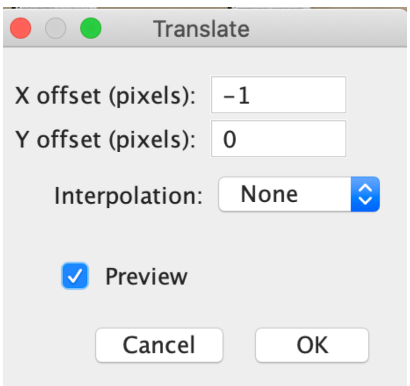


Figure 14: Dialogue box for translation

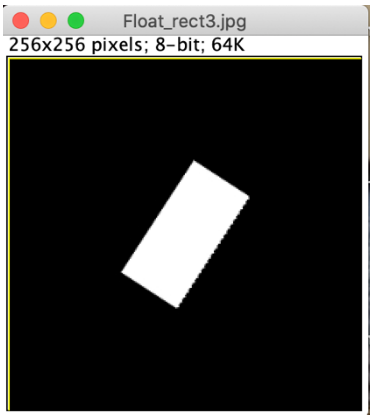
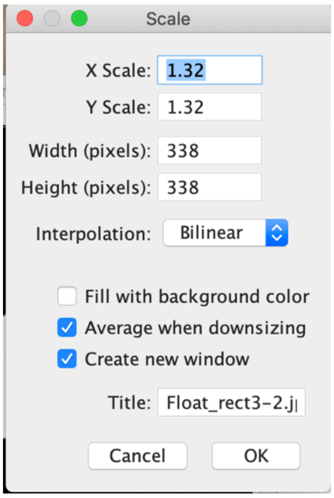


Figure 15: Translated Image

- X offset – (-1) pixel
- Y offset – 0 pixel
- Interpolation- None

- Scaling



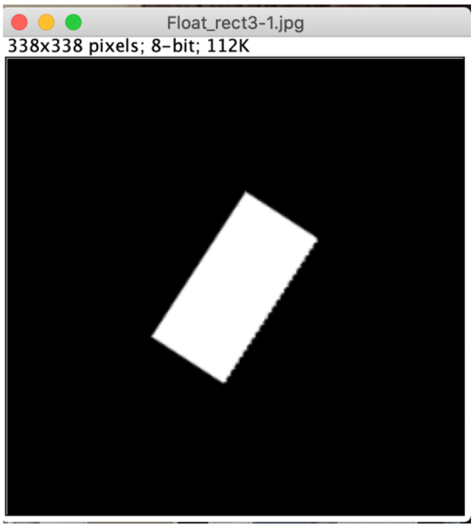
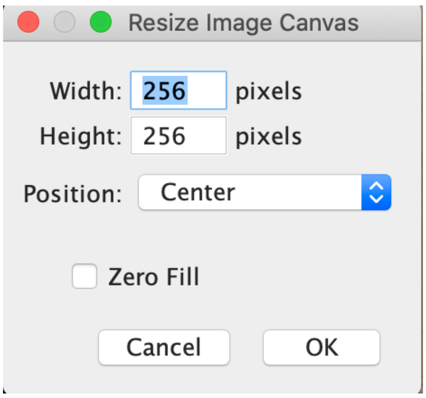


Figure 16: Dialogue box for Scaling **Figure 17: Enlarged Image**

- X Scale- 1.32
- Y Scale- 1.32
- Width- 338 Pixel
- Height- 338 Pixel

- Resizing with Canvas



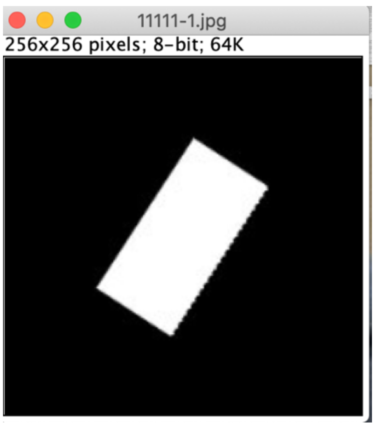


Figure 18: Dialogue box for resizing **Figure 19: Resized Image**

- ○ Width- 256 Pixel
- ○ Height- 256 Pixel

- Image of absolute difference

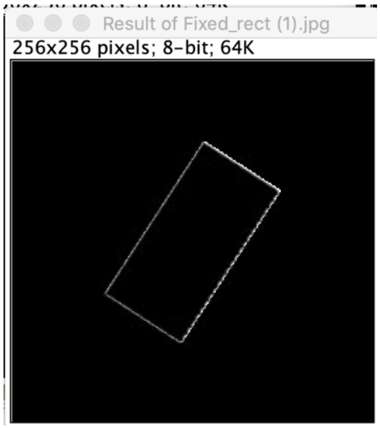


Figure 20: Image of absolute difference

- This is comparatively similar image as the previous Image of absolute differences and more or less has the same parameters as the previous registration methods. But this image has more defined pixelated edges when compared to the previous two images. As the variables applied increased the error has increased.
- Coronary CT angiography is one of the examples where similarity transformation cannot capture the location of stenosis.

Question 4 *Plot your chosen similarity measure for a range of rotation angles and demonstrate that it reaches the maximum value when the registration is optimum. What is the ideal value of that measure? Is it achieved? If not, why not? Suggest a method for automating the registration algorithm (draw a flowchart).*

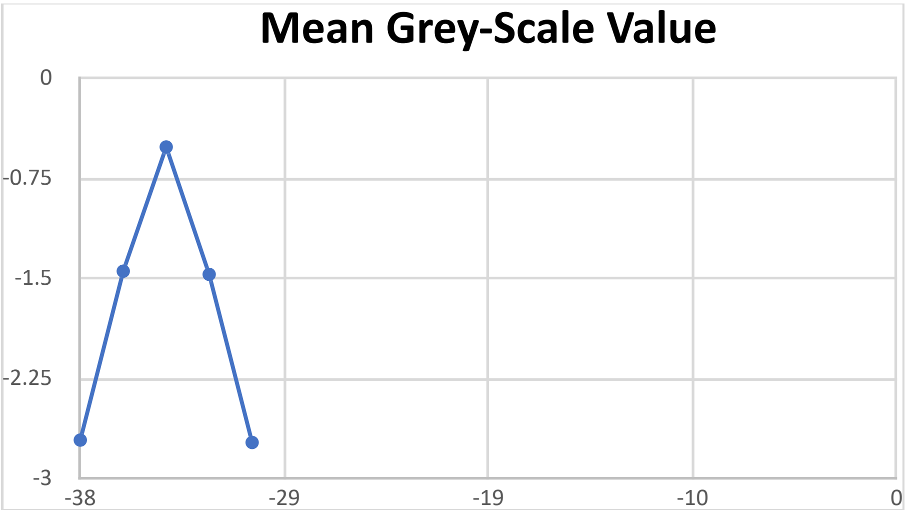
The chosen similarity measure for a range of rotation angles- Grey mean value

Following data of grey mean value was recorded for the angles of rotation -30°,-32°, -34°, -36°, -38° respectively. The negative values of mean grey-scale values are used as similarity measures.

Results

	Mean	StdDev
1	2.726	24.721
2	1.466	17.191
3	0.511	7.322
4	1.442	17.014
5	2.708	24.643

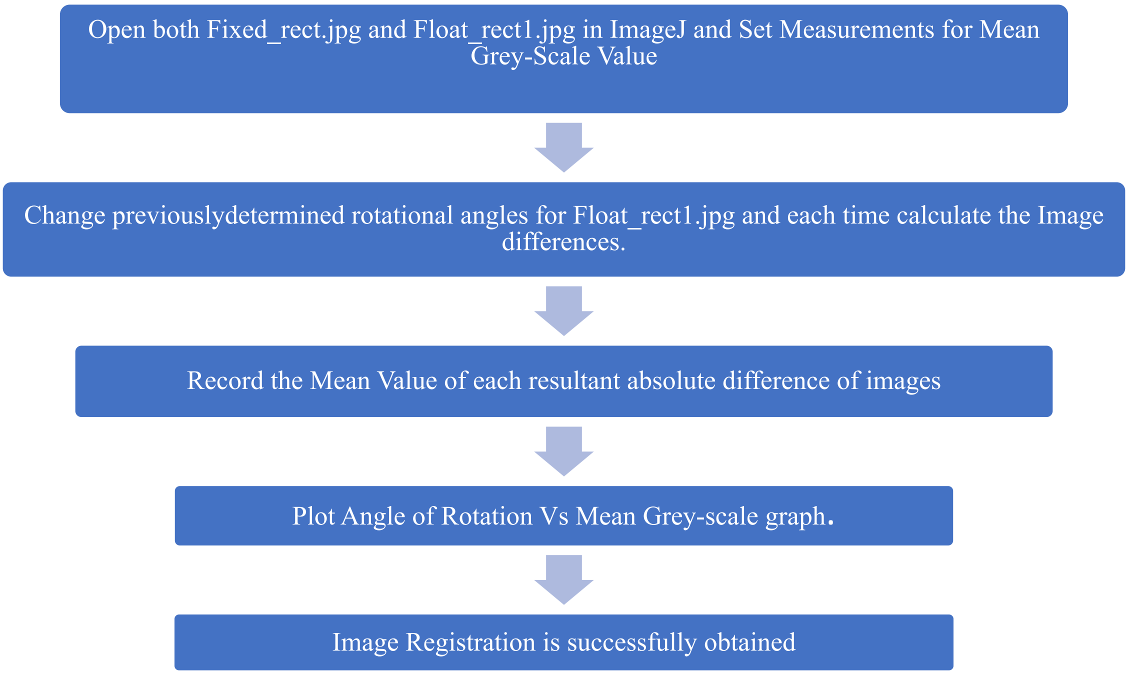
Figure 21: data of grey mean value



Graph 1: Angle of Rotation Vs Mean Grey Value, X-Axis- Angle of rotation and Y-Axis- Grey Mean Value

Mean Grey Value is maximum at the optimum Angle of rotation -34° where the registration error is at its least.

Flow-chart 1: Image registration

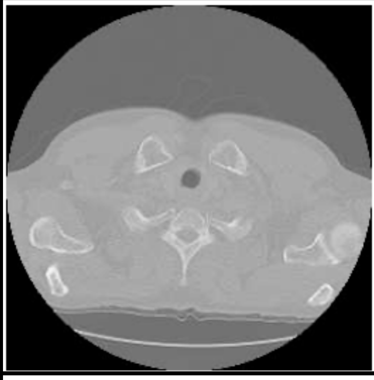
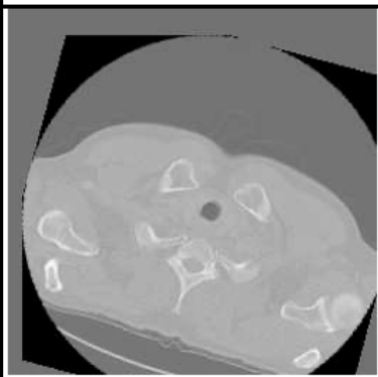


For anatomical orientation, look up the thorax CT at www.meddean.luc.edu -thorax. and select slice 1. Alternatively, examine the lowest section of the neck at www.meddean.luc.edu -head & neck. Another useful anatomy site based on MR images is at mrimaster.com.

1. In order to use the absolute difference, first convert each image to a binary form (black & white) by thresholding. Using **Image → Adjust → Threshold,** determine a convenient threshold value. One possibility may be to set the threshold to show just bones.

2. Transform the floating image while observing the absolute difference between the threshold images and recording the value of the similarity measure.

Question 5 *Determine the optimum transformation and show evidence for your conclusion. As evidence, provide a table showing the values of the three registration parameters (rotation angle, horizontal and vertical translations) and the resulting value of the similarity measure. Highlight the optimum value and display the corresponding difference image. How does your result compare to what you achieved with the simple synthetic images? If there is a significant difference between the results, what might account for it?*

	Fixed_neck image	Float_neck image
Original Images		
Rotational Parameters	Angle-0	Angle – (-16)°
	Grid line- 1	Grid line- 1
	Interpolation- Bilinear	Interpolation- Bilinear
Translation	Y-Offset- 0 Pixel	Y-Offset-(-15) Pixel
	X-Offset- 0 Pixel	X-Offset-(-15) Pixel
	Interpolation- None	Interpolation- None
Value of Similarity Measure of threshold images	Mean Grey-Value= 108.489	Mean Grey- Value= 108.555
Optimum Value	0	(-16)°
Threshold Values	133 &179	125&185

Threshold Images		

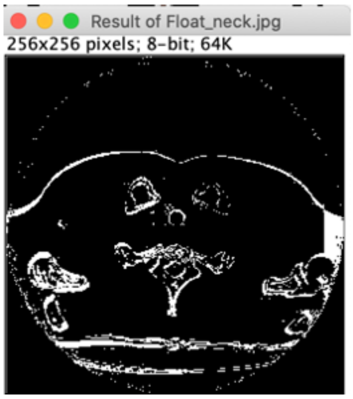


Figure 21: Image of Absolute Difference

Resultant Image Mean Grey Scale

Value= 17.778

The resultant image could be compared to the simple synthetic image where fewer operations are employed. And it has coarser pixelated edges making it less accurate and defined because the CT images are noisier compared to the simple synthetic image, Also, rotation contributes to the lesser contribution in resolution of the float image.

It is apparent that poor resolution and implication of many variability causes the residual registration errors. Thus, for better quality images, it is crucial that we select images with good resolutions and lesser variables are imposed.