Project 2: Image Registration by Fourier Methods

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Abstract

The objective of image registration is to take a set of distorted images, and to construct them in a manner that makes a recognizable, less distorted image. In MATLAB, this is accomplished by shifting images about fixed points, and then averaging them together. The performance of image registration is quantified by the signal-to-noise (SNR) ratio. Overall, the images are transformed to the frequency domain, the phases are analyzed and aligned, and then the image is shifted back to reconstruct the image.

Background

"Image Registration based on Neural Network and Fourier Transform," by A. B. Abche, F. Yaacoub, A. Maalouf and E. Karam discusses an image registration method implemented with feed forward neural network and Fourier transform techniques. This involves acquiring the spectrums of the input images, and selecting the Fourier coefficients as the inputs to the neural network. This neural network estimates the transformation, in terms of translation, rotation, and magnification, and then performs the operation to best align the corresponding images. Because this approach does not estimate the various registration parameters separately, instead estimating them all simultaneously, this leads to a better optimized set of registration parameters. This approach ultimately yields higher results than other Fourier based methods, and has been validated on 2D images.

"Motion-based, multi-modality image registration for cardiac imaging", by A. T. Cebula, D. R. Gilland, J. G. Parker and Y. Chen discusses how to best align images for moving 3D applications, such as the heart. This approach utilizes 3D vector fields that are estimated using optical flow methods. These 3D vector fields are also assumed to be similar and are rigidly aligned by minimizing a sum-of-squares error objective function. This method leads to a 1-5 mm precision for an anatomical point, and was compared to a mutual information (MI) based method.

"Fast and efficient image registration based on gradient orientations of minimal uncertainty," by T. Arbel and D. De Nigris discusses the methodologies for how to have fast and efficient image registration. The objective of time sensitive contexts for image registration is an engineering problem being faced by many in the medical field. This paper describes a fast and accurate multi-model registration framework that is based on matching gradient orientations at locations of minimal gradient magnitude uncertainties in a coarse-to-fine manner. Doing so in this manner performed with accuracies below 2 mm using 2% of the total voxels. This approach has been validated using a publicly available dataset, and achieved comparable accuracy to that of the other top performing methods, but with only one sixth of the processing time. Despite this, there are still challenges with implementing this method in the field.

Method

Image registration is necessary because when multiple images are taken, they show distortion from each other, and none may show a clear and complete full image. Because of this, the images must be averaged together, and this was accomplished in MATLAB. There are also many libraries that make it easier to manipulate and automate this image processing.

Firstly, the collection of images was indexed and looped through so each image could be processed individually. Then, the images were normalized such that all of the details of each image appear in approximately the same location across the images. From this, the mean of all the images were taken and averaged together for the final result.

Results

The top left image shows the original image in the collection of images called "undergraduate_data.mat". The bottom left image is post centralizing, and is the image that gets put in a collection to be ultimately averaged into the image on the right. This final image (right) is the culmination of the image processing of all the individual, offset, blurred images. All of this is showcased in the figure below.

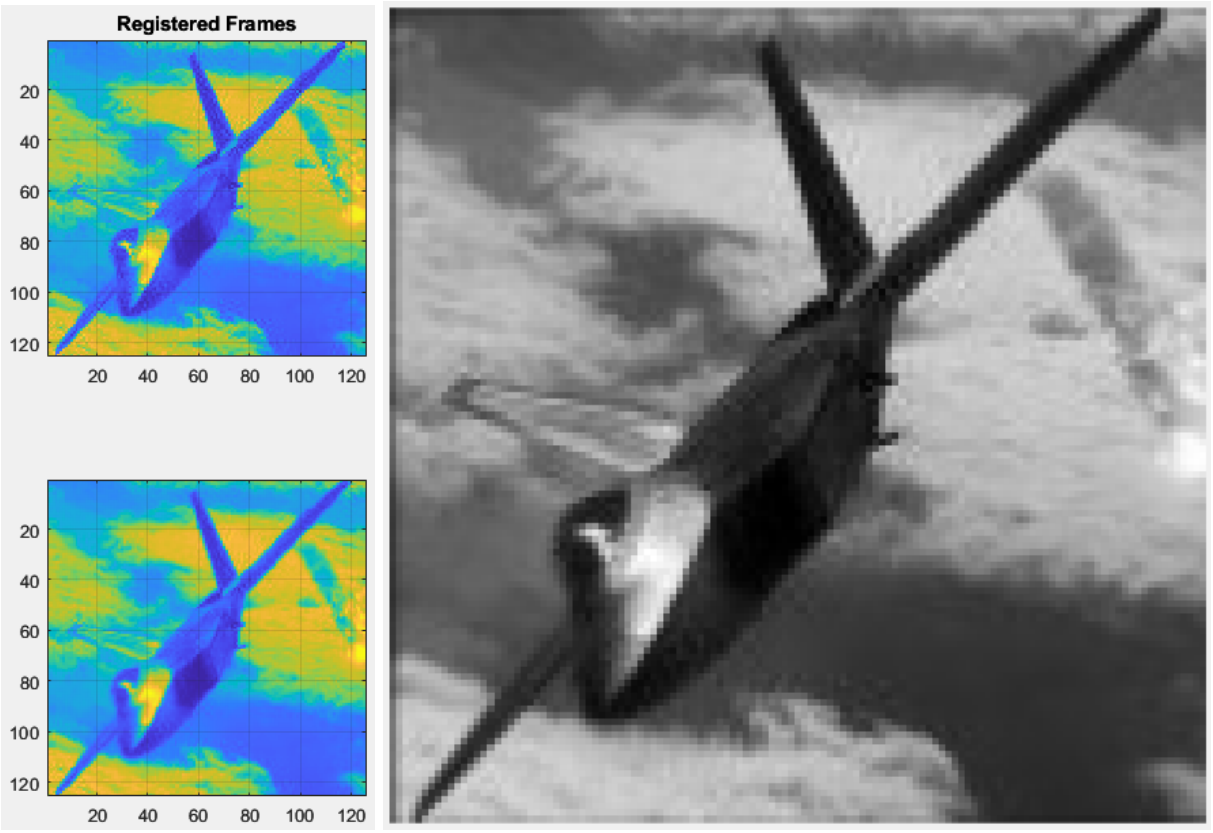

Figure 1: Registered Frames (Left) and Reconstructed Image (Right)

Discussion of Results

An alternative method to image analysis and reconstruction involves using the Fast Fourier Transform (FFT). This method involves taking the 2 dimensional FFT of the image, shifting it to its midpoint, and then performing a logarithmic transformation to determine the magnitude of the image. The figure below shows the performance of the FFT on an image.

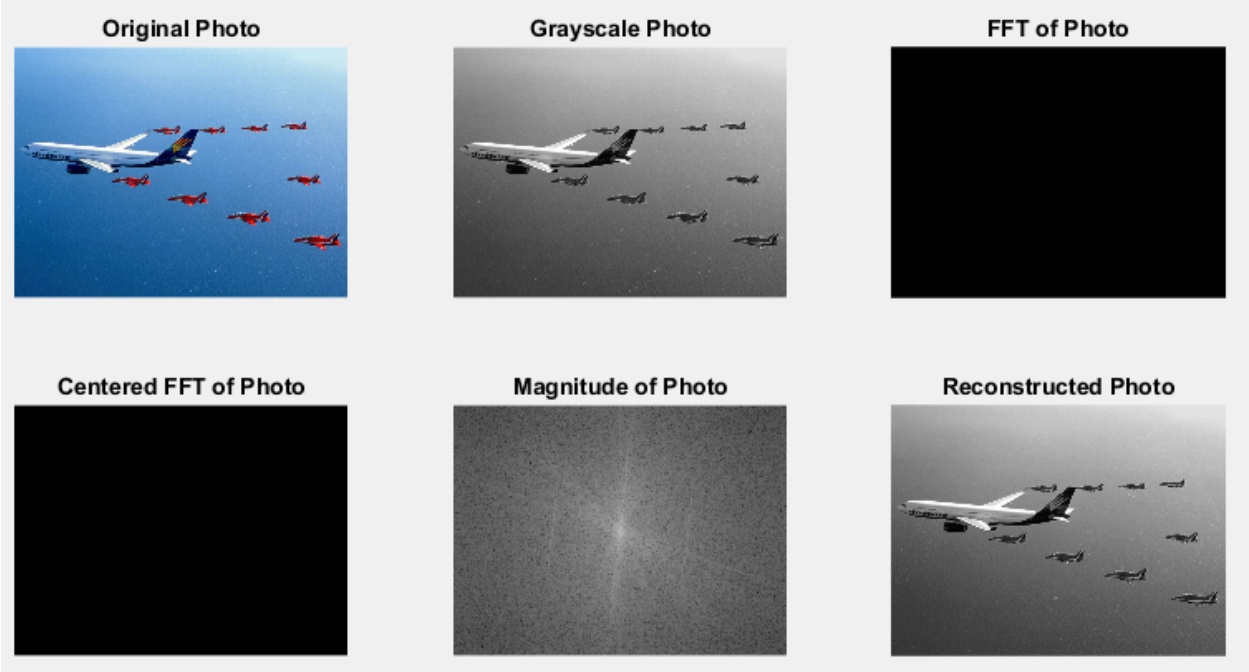

Figure 2: FFT of an Image

Comparing the FFT method to the image registration method, there are some key similarities and differences. The biggest difference between the two is that the FFT is much less computationally intensive than that of the image registration algorithm. The biggest benefit for the image registration is the MATLAB libraries that drastically improve the ease of usability. Despite this, both have similar methods of reading, aligning, and processing images, with the FFT having slightly higher image resolution over that of the image registration.

Conclusion

Overall, the images were read through transforming them to the spatial frequency domain, aligning the frequencies, and shifted back to their original state. The goal of doing this was to be able to take a collection of images, all of which were slightly distorted from each other, and average them together to create one cohesive image. Additionally, noise averaging methods were implemented to reduce the signal-to-noise (SNR) ratio, such that the image is as crisp as possible. In conclusion, an image registration algorithm was created to align a collection of distorted frames and average them together into one clear image.

Appendix

References

A. B. Abche, F. Yaacoub, A. Maalouf and E. Karam, "Image Registration based on Neural Network and Fourier Transform," 2006 International Conference of the IEEE Engineering in Medicine and Biology Society, 2006, pp. 4803-4806, doi: 10.1109/IEMBS.2006.260342.

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