Entropy-based metrics for joint image alignment

Report Name	Outline Project Specification
Author (User Id)	Laura Collins (lac32)
Supervisor (User Id)	Neil MacParthalain (ncm)
Module	CS39440
Degree Scheme	GH7P (Artificial Intelligence And Robotics)
Date	February 3, 2016
Revision	0.2
Status	Draft

1 Project description

The Project builds upon the Congealing code developed by Erik Learned-Miller from the University of Massachusetts [4]. In the paper Learned-Miller utilises the Congealing algorithm to align both MNIST handwriting data and MRI Scans by reducing the variability between each pixel within a stack of images. For example, the algorithm will analyse the properties of the upper-leftmost pixel in image 1, then in image 2 and through each image in the set. This variation between pixels is known as Entropy, and thus the objective of Congealing is to minimise the Entropy across a set of images.

The aim of this project will be to implement the Congealing algorithm using not only standard Entropy, as in Learned-Miller's application, but using other metrics, as discussed in Section 2.1. Mammography scans are the image of choice for this project as aligning these scans would help build an average of the image set. With this is in mind it is possible to build an average for the 4 breast tissue composition categories outlined by BI-RADS (Breast Imaging-Reporting and Data System) - with 1 being fatty tissue (lowest risk) and 4 being dense tissue (highest risk) [5]. Approaching this alignment of images using different metrics would output different a range of output results, and further investigation could be undertaken to ascertain the best alignment metric.

Finally, the resulting software tool could be used by Radiologists in assessing the tissue variation between the 4 categories and could also be used to build a classifier model to help categorise new, unseen mammography scans by tissue density.

An adapted-XP (Extreme Programming) approach has been selected for the software methodology on this Project. Some early investigation will go into how to best overcome the lack of Pair-Programming practice. Daily stand-ups will take in the formal of daily meet-ups with peers to discuss individual progress.

2 Proposed tasks

2.1 Research into alternative metrics

The original Congealing algorithm implemented by Learned-Miller uses standard Entropy and thus research into different alignment metrics will be needed. This led me on to the paper by Al-Sharhan et al [1] about different Fuzzy Entropy implementations. Each one is implemented with slight variation, and thus each gives a different output.

2.2 Installing MATLAB

A MATLAB license will need to be obtained and then MATLAB installed and properly configured on my MacBook Pro. Learned-Miller's Congealing code will need to be imported. Research will have to be undertaken as to how to how to run tests in MATLAB.

2.3 Development

The development is likely to be split into 2 major sections:

2.3.1 Graphical User Interface

From here the User will be able to input their sets of images, select the alignment metric and the output will be displayed. This is vital for the easy comparison between images for clinicians.

2.3.2 Algorithm Implementation

Each Algorithm will be implemented in the original Congealing code, swapping out the standard Entropy algorithm for each Fuzzy Entropy version.

2.4 Dataset

Choosing to align Mammography scans causes some issues, the main one being the file size of the images. For example, the Digital Database for Screening Mammography (DDSM) has approximately 4400 pixels per line, with each pixel approximately 1900bits [3]. The dataset of choice will be the 'Mini-MIAS database of mammograms' as their image size has been specifically reduced to 1024x1024 pixels [6].

2.5 Project Meetings & Blog

Weekly supervisor meetings will be conducted throughout the project. A blog will also be kept throughout the duration of the project, covering a wide range of topics such as weekly updates, hurdles, progress made and other news worth noting. Ghost will be used as the blogging platform of choice, located at: `lauramcollins.co.uk/blog`.

3 Project deliverables

Through the duration of the Project, the following deliverables are to be expected.

3.1 Short Report per Alignment implementation

At the end, or at a suitable time during development should it arise, a short report will be created to outline the implementation of each Entropy-based metric. This report will cover resources used, progress made, any hurdles overcome and any extra notes that may be of use in the Final Report. This will be an ongoing process, to conclude once development has ceased.

3.2 Mid-Project Demonstration Notes

A set of notes will be created to accompany the mid-project demonstration. This will be a summary of what was presented, and will be discussed with the project supervisor prior to the demonstration. This will be included in the appendices of the Final Report as a marker of technical improvement since the mid-project demonstration.

3.3 Technical Deliverable & Test Scripts

The final Technical Deliverable package will include all necessary files to run the software. This package will be submitted for assessment and also will be stored upon a version control system.

3.4 Test Scripts

Exact tools for testing the technical deliverable will be assessed as the project progresses. It is likely that these will include MATLAB's xUnit automated testing framework and JUnit (if Java is utilised), along with some required manual testing. These will be submitted as part of the technical deliverable.

3.5 Story Cards and CRC Cards

As this project will be following an adapted-XP methodology, the defining stories and design will fall within the Story Cards and CRC Cards respectively. These are likely to be included in the Final Report appendices.

3.6 Final Report

This will be the final evaluative report, acknowledging any third-party libraries, frameworks and tools used along with other associated appendices. This will be completed and submitted at the end of the Project.

3.7 Final Demonstration

No formal documentation will be needed for this stage of the Major Project, however due to it's importance to the final grade, and the work needed to prepare for it, it is worth noting here.

3.8 Possible Publication

If the average image outputs are found to be of use to clinicians there is the possibility of writing a scientific paper on the original algorithm, research, alterations to the algorithm(s) and final conclusions. This would be work completed at the end of the Project cycle.

Annotated Bibliography

[1] S. Al-Sharhan, F. Karray, W. Gueaieb, and O. Basir, "Fuzzy entropy: a brief survey," in *Fuzzy Systems, 2001. The 10th IEEE International Conference on*, vol. 3. IEEE, 2001, pp. 1135–1139. [Online]. Available: http://dx.doi.org/10.1109/fuzz.2001.1008855

Paper outlining the different implementations of Fuzzy Entropy, of which 3 will be selected and focused on during this Project.

[2] M. Cox, S. Sridharan, S. Lucey, and J. Cohn, "Least squares congealing for unsupervised alignment of images," in *Computer Vision and Pattern Recognition, 2008. CVPR 2008. IEEE Conference on*. IEEE, June 2008, pp. 1–8. [Online]. Available: http://dx.doi.org/10.1109/cvpr.2008.4587573

Futher builds upon Learned-Miller's Congealing approach with faster convergence and no pre-defined step size. Results are presented on both the MNIST handwriting data set (as in the original Learned-Miller paper) and the MultiPIE face database. However the project would most benefit from a narrow entropy-only based approach, staying in-line with the original Major Project title.

[3] M. Heath, K. Bowyer, D. Kopans, R. Moore, P. Kegelmeyer, and C. Processing, "The digital database for screening mammography," 2001, accessed: February 2016. Available: http://marathon.csee.usf.edu/Mammography/Database.html. [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.216.6553

Due to the large nature of the DDSM dataset, this is not the dataset of choice. However it may be useful for further work on this project in the future - however it will have to be assessed as to how to acquire the necessary computational power.

[4] E. G. Learned-Miller, "Data driven image models through continuous joint alignment," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 28, no. 2, pp. 236–250, Feb. 2006. [Online]. Available: http://dx.doi.org/10.1109/tpami.2006.34

Learned-Miller's original Congealing method is the basis for this Project. This paper was extremely useful for understanding of the basic concepts behind it, and will be a good reference guide throughout the project.

[5] A. C. Society, "Understanding your mammogram report BI-RADS categories," http://www.cancer.org/treatment/understandingyourdiagnosis/examsandtestdescriptions/mammogramsandotherbreastimagingprocedures/mammograms-and-other-breast-imaging-procedures-mammo-report, 2015, accessed January 2016.

Website outlining Mammography scan result guidelines and the 4 tissue density composition categories. Particularly important for understanding the differences between the 4 sets of images, and how best to name them.

[6] J. Suckling, J. Parker, D. Dance, S. Astley, I. Hutt, C. Boggis, I. Ricketts, E. Stamatakis, N. Cerneaz, S. Kok, *et al.*, "The mammographic image analysis society digital mammogram database," in *Exerpta Medica. International Congress Series*, vol. 1069, 1994, pp. 375–378, accessed: February 2016. Available: http://peipa.essex.ac.uk/info/mias.html.

Chose to use this dataset as it has taken the original MIAS database, and reduced the pixel edge size.