Mobile Perfusion Analysis

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Computer Integrated Surgery II, Spring 2015

INTRODUCTION

The aim of our project was to develop a mobile-phone based software tool to assess local blood flow. Our tool bases this assessment upon amplified changes in skin color in iPhone videos as a result of blood flow along with thermal-infrared data. Measures of perfusion can help characterize healing of chronic wounds and assist physicians in developing appropriate treatment plans for patients. Currently laser doppler imaging (LDI) is the standard method of assessing perfusion, but it is often expensive and inaccessible. Our goal was to create an inexpensive and portable alternative to this standard system.

BACKGROUND

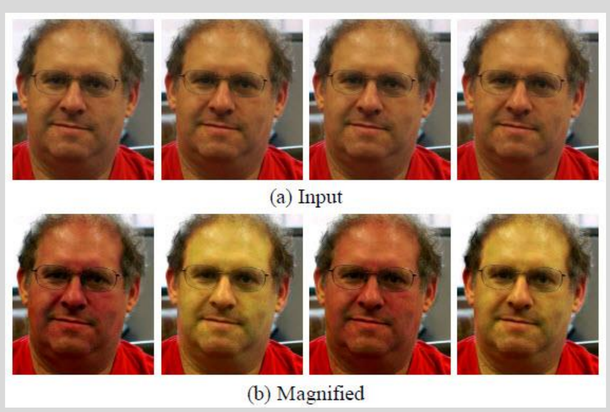

Figure 1. Example of EVM magnifying blood-flow induced changes in face color.

- The basis for the portability of our tool relied on the fact that the assessment could be made using only data collected via mobile phone.
- In particular, our approach relies on the information that can be extracted from standard iPhone videos and images taken by an infrared sensor attachment.
- The technique used to process our iPhone collected videos was Eulerian Video Magnification (EVM), an algorithm developed at MIT to amplify motion and color change in videos.
- A proposed application of this technique was to use the amplified color changes of the skin caused by underlying blood flow to determine a subject's heart rate. We validated this application first and then extended it to apply to the problem of perfusion assessment.

References

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3. Merla A, Di donato L, Romani GL, Proietti M, Salsano F. Comparison of thermal infrared and laser doppler imaging in the assessment of cutaneous tissue perfusion in scleroderma patients and healthy controls. Int J Immunopathol Pharmacol. 2008;21(3):679-86.
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EXPERIMENTAL METHODS

Data Collection

- iPhone captured video and thermal-infrared data (captured using a Flir ONE iPhone attachment) of human hands was collected from four subjects. Corresponding ground truth LDI data was collected from one of the four subjects.
- To mimic different blood flow conditions, we used a simple manual sphygmomanometer at low (0 mmHg), medium (60 mmHg), and high (120 mmHg) pressures to emulate good, medium, and poor perfusion respectively as three different samples during data collection.

Figure 2. Comparison of LDI images for low, med, and high pressure.

Data Analysis

- EVM was applied to all collected videos, with the same set of parameters that we found optimal for isolating heart rate.
- From these processed videos we selected and cropped out five smaller videos of just the fingertips as regions of interest.
- For averaged 5x5 pixel areas, we extracted features such as average intensity, rate of change in intensity, and time between peak intensities from these sample videos.
- The SVM (based on MATLAB built-in function) was then trained using the LDI ground truth to label our examples.
- We experimented with the SVM parameters of kernel, use/not use PCA and validation using 10-fold cross validation to find the optimal settings for accurate classification.

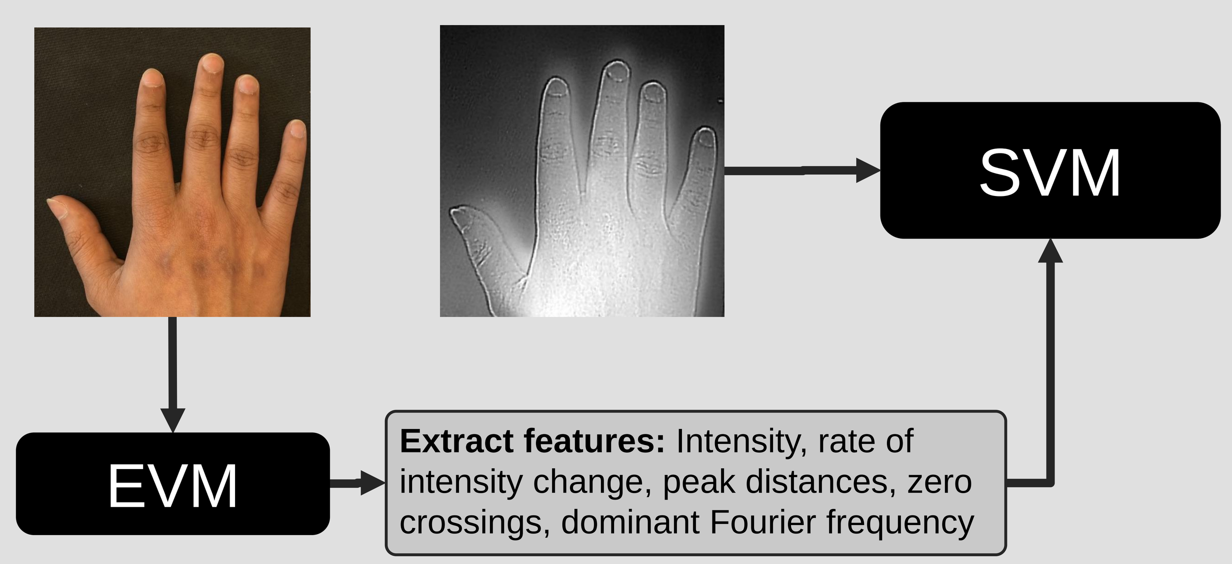

Figure 3. Visual description of the data analysis pipeline. Five features are extracted from the EVM processed video (across all 3 channels). These metrics and the corresponding IR data are then fed to the SVM algorithm which (after having been trained with ground truth), returns a classification for the perfusion.

RESULTS

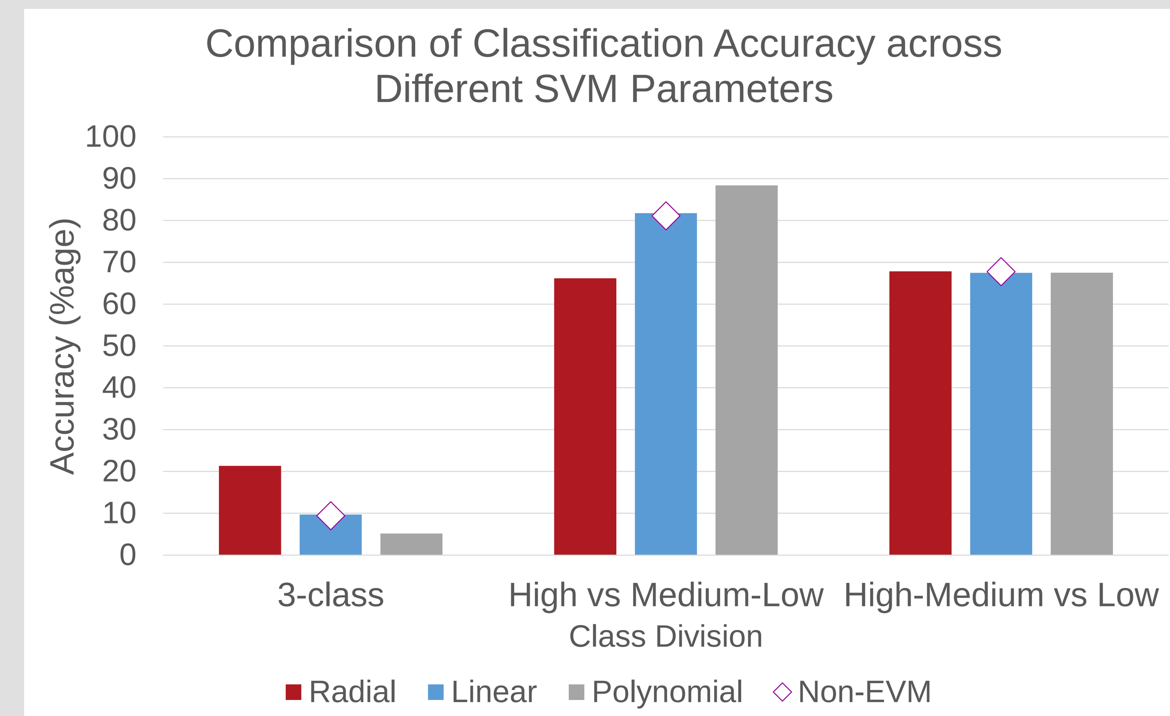

Figure 4. Comparison of Classification Accuracy across Different SVM Parameters

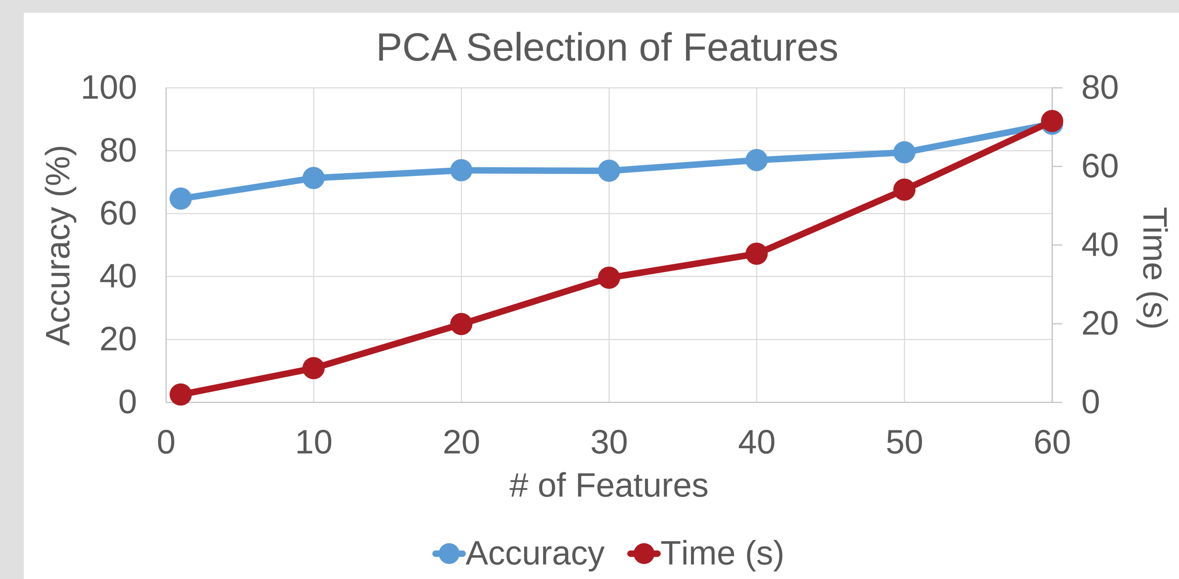

Figure 5. Performance of the SVM using PCA as number of features decreases. As expected, there is a tradeoff between accuracy and speed.

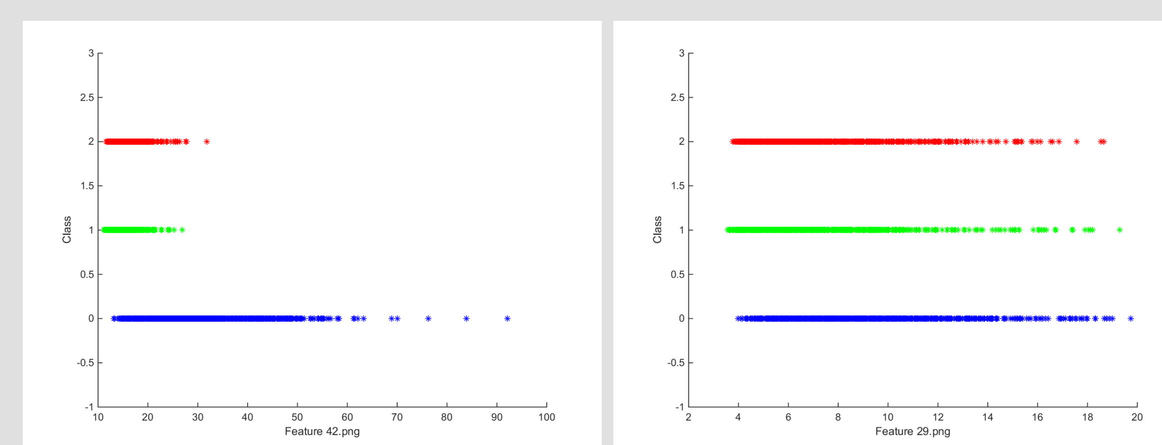

Figure 6. Comparison of the effectiveness of two different features (Max Zero Distance and Median Intensity for the red channel) in differentiating between the high, medium, and low perfusion classes.

Figure 7. Comparison of the 'heat map' outputs of the trained SVM on medium and high perfusion hands.

CONCLUSION

As shown in Fig. 4, there are promising results for two class classification, especially between cases of high-to-medium perfusion versus low perfusion, but there is still significant work needed to tune our algorithm for three-class classification or better.

Our experimentation with Principal Component Analysis (PCA) (see Fig. 5) showed that it resulted in faster classification at the cost of slightly lower accuracies in general, as expected. It also showed that no one feature was enough to achieve significant classification accuracy.

Indeed, in Fig. 6 we see that some features are very good at distinguishing between High-and-Medium flow and Low flow, however other features are relatively useless for the task.

We were however unable to show a significant advantage in using EVM to process the videos compared to just using the original video (Fig. 4), which may be a favorable result, because it implies that the final product could potentially be less computationally intensive than previously projected.

Future Work

- Conversion from MATLAB to mobile platform
- Inclusion of actual chronic wound data
- Use of non-contour detecting IR attachment

Lessons Learned

- Correlations using image and video data requires precise data collection to assure alignment (do not underestimate the difficulty of image processing!)
- Have organized, documented code from the start.
- Communication is key.

Credits

- *Azwad*: perfusion metric extraction, input-to-classifier pipeline development, and statistical analysis
- *Rohit:* data collection, SVM design and implementation, and SVM performance assessment
- *Yvonne:* pre-processing of video and image data, front end development, and source code control

Acknowledgements

Thank you to TissueAnalytics for sponsoring our project, Frank Lay for his access to the LDI system, and of course to both our mentors for guiding us all semester long.

TISSUEANALYTICS