Mobile-Based Blood Flow Analysis of Chronic Wounds

CIS II: Project Proposal

Team 7

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Introduction

The goal of the project is to develop an integrated software-and-hardware solution that allows a clinician to use a mobile device to extract a usable metric that assesses local blood flow. Measures of local blood flow (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, inaccessible, and inefficient. Consequentially, wound prognosis is often poor in quality and can necessitate skin grafts, amputation of the limb or even death.

Technical Approach

Our first approach to the problem is to analyze video data collected via smartphone with Eulerian Video Magnification (EVM), an algorithm developed in MATLAB at MIT that detects and magnifies minute temporal changes in videos that are invisible to the naked eye. One theorized way of extracting perfusion information given EVM data is to determine the rate and magnitude of change in the intensity of the RGB channels of successive images produced by the algorithm. We can then compare this with the perfusion measured by Laser Doppler Imaging (LDI) in selected areas of interest and determine if there is a correlation. If there is good correlation between the two we will then work to build a classifier that can characterize areas in an image as having low, medium or high perfusion.

We are looking to use Support Vector Machines (SVMs) which are a form of supervised learning algorithms. The ground truth given to us in the LDI data presents several "labelled" examples for our SVM and we would be using a portion of these as our training set and setting others aside to be our test set. In order to prevent overfitting, we will assess our classifier's performance with cross validation wherein we randomize the data that we select to be our training and test sets each time we train it. The features that we are looking to feed our SVM include a measure of "average time derivative" i.e. average rate of change of intensity in the RGB channels of a particular data point, and given a steady pulse we could also use the magnitude of certain frequencies in the data after taking a Fourier transform. If all goes well, the classifier will be able to categorize perfusion with high accuracy (close to that shown by LDI) when presented with novel data.

If it performs not as well, in that it cannot distinguish between good and medium perfusion, perhaps, we will then attempt to incorporate single point velocimetry readings obtained via compact laser doppler probe to the classification system. We theorize that if these data points are used as an additional decision parameter for the SVM, classification may improve. We will be focusing on the usage of the additional information to improve perfusion assessment accuracy, given that we already know the approximate corresponding location in the EVM image that the laser doppler reading was acquired from—tracking and calibration of the laser using the smartphone camera is secondary and would be worked on only as a maximum deliverable. We postulate that, if necessary, tracking of the laser could be done with an IR attachment for the iPhone camera, which is readily available on the market.

Dependencies

The first period of the project requires us to have access to EVM and LDI data. Tissue Analytics has already provided us with enough to start working with and has promised us more by the end of February.

In the event that EVM does not give us near perfect correlation with LDI data we will require a compact laser doppler system. Preliminary research has confirmed the market availability of such a product at an estimated price range easily within our preassigned budget of $5,000 from Tissue Analytics. We are only planning to use this budget on the miniature LDI probe. Training for usage of the device will also be arranged by the company.

Milestones

Our timeline scheme is 4 periods of three weeks each, with a progress checkpoint at the end of each. Each three week period will generally focus on one goal, though due to branching contingency plans, there could be a few different paths taken.

The first major milestone in our timeline is at the end of the third week, and the completion criterion is the proof-of-concept of the EVM approach at assessing perfusion. Working up to this, in the first week we will be thoroughly researching the literature listed in our references, and focusing on identifying parameters (brightness, color, etc) that can be gleaned from videos after applying the EVM algorithm that may correlate to blood perfusion. Following this, in the second and third weeks, we will evaluate the values of the selected metrics on a set of images, and compare to the relative perfusion units on the corresponding laser dopper images. If there is moderate or strong correlations between certain metrics and the relative perfusion of the corresponding area, we will move forward with the EVM classifier approach. If not, we will focus on the laser doppler. Either way we will know at 3 weeks which path we are taking.

If the EVM approach appears infeasible, we will have to rely on a laser doppler attachment, and focus on researching methods to best leverage the hardware, and acquiring the data for testing in the following three weeks. If however we move on with the EVM approach, we will spend the following 3 weeks building a classifier using the parameters that we identified. We will evaluate our progress toward the end of the third week by testing the classifier on previously unexamined data sets and assessing its accuracy. This serves as a milestone where, depending on the performance of the classifier thus far, we will move on to further refinement and testing, or single point laser doppler integration.

If the performance is accurate enough to not warrant the laser doppler attachment, refinement of the classifier will continue in the next three week period, at the tail end of which, if we assess our progress to be acceptable we will start advancing toward the maximum deliverable - converting the code base to a fully mobile platform. If the laser doppler is in fact needed, we will spend the beginning of the three weeks acquiring data using the compact laser system, and then the rest of the period will be spent using the additional data points to refine the classification.

The last three weeks will consist mostly of final touch-ups, including code and documentation cleanup, working on maximum deliverable items if time allows, and starting the paper by the 10th week, and the poster by the 11th. The end of the 12th week marks the poster presentations.

Deliverables

The minimum deliverables are validation of EVM-analyzed-video data (and if needed, single point laser doppler data) correlation with LDI data. Included with the proof of concept will be the identification of the image parameters that we find to be the most significant in assessing perfusion. The expected deliverable is a classifier for perfusion bucketing (low, medium, high) using EVM-analyzed-video data and/or single point laser doppler data as features for assessment. The maximum deliverable is complete integration of the expected classifier (which will be initially written in MATLAB) with the existing Tissue Analytics mobile application, and if the compact laser doppler is used,

Management Plan

Biweekly meetings on Wednesdays have been planned with our mentors. The team will meet separately each week on Fridays to review progress, discuss and manage tasking, and briefly walk through (if any) new additions to the code base. The code itself will be managed through a private GitHub repository, and will be documented with comments as it is developed. We will also keep an updated general README for the code which will be thoroughly reviewed during the paper writing phase, as well as one final code walkthrough to clean things up. General team management and tasking will be done through Podio, a project management website.

For breakup of responsibilities, Rohit and Azwad have the most background knowledge of classifiers and machine learning, so they will take the lead on algorithm design. Yvonne has the most experience in developing complete, well structured and documented, tools in MATLAB so she will play the major part in implementation, though Rohit and Azwad will also contribute. Azwad has the most background in image analysis and instrumentation, so he is in charge of the processing of camera video and laser doppler images. Administrative and managerial tasks such as communications and dependency resolution will mostly fall to Yvonne, but project tasking will be a team decision.

References

[1] Wu, H., et al. "Eulerian Video Magnification for Revealing Subtle Changes in the World". ACM Transactions on Graphics (TOG)- Proceedings of ACM SigGraph 2012. 31.4 (2012). July 2012.

[2] Liu, C., Torralba, A., Freeman, W. T., Durand, F., & Adelson, E. H. (2005). Motion magnification. ACM Transactions on Graphics, 24(3), 519–526.

[3] G. Balakrishnan, F. Durand, and J. Guttag, “Detecting Pulse from Head Motions in Video,” in 2013 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2013, pp. 3430–3437.

[4] M. Z. Poh , D. J. McDuff and R. W. Picard “Non-contact, automated cardiac pulse measurements using video imaging and blind source separation”, Opt. Expr., vol. 18, pp.10762 -10774 2010.

[5] B.K.P. Horn and B. Schunk, “Determining Optical Flow,” Artificial Intelligence, vol. 17, pp. 185-203, 1981.

[6] Russell, S. and Norvig, “Chapter 18: Learning from Example”. Artificial Intelligence : A Modern Approach, Englewood Cliffs, NJ: Prentice-Hall, 2009.