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**Course name** | **Reviewer**  
HL205X Degree Project in Medical Engineering | Rodrigo Moreno  
**Preliminary title**  
Development of a real time autofocus algorithm for Perimed’s Perfusion Speckle Imager (PSI)  

**Background to the problem and description of the aim of the degree project**

Microcirculatory tissue blood perfusion consists in the local fluid flow through the capillary network and extracellular spaces, and it is behind the transport of oxygen, nutrients, and waste products. Perimed’s Perfusion Speckle Imager (PSI) is an instrument that measures microcirculatory blood perfusion in living tissues [1]. It is based on the Laser Speckle Contrast Analysis (LASCA) technique, an imaging method where the object is evenly illuminated by a laser radiation and the backscattered light interferes to form a pattern called the “speckle” [2]. The speckle pattern is imaged on an industrial camera sensor by an objective lens. By using special image processing, the speckle contrast can be monitored to provide information about blood perfusion in the tissues.

When performing a measurement with PSI, it is essential for the acquired image to be sharp, to probe fine details of the object under study, and to guarantee high image quality. Acquiring sharp images becomes particularly important to distinguish small details both for clinicians and researchers, for example when a small vessel or a mouse brain are imaged. Autofocus (AF) process is used to control the objective lens parameters so that the image is always brought to the focal plane, where image sharpness is the highest [3].

PSI instrument consists of measurement Laser (CW laser diode emitting at 785 nm), indicator laser (red laser at 635 nm), measurement camera (CMOS sensor), power zoom objective lens, and optical filters. The power zoom lens has 3 motors (Zoom motor, Focus motor, Iris motor). The 3 motors are integrated internally inside the body of the lens, and it is possible to control them via the measurement camera hardware. By adjusting the focus motor of the objective lens, it is possible to get sharp images at given zoom and distance values. The role of the AF procedure in PSI is to find the best focus position corresponding to the highest sharpness level of the acquired images. The implemented AF method is based on precalibration of the focus in the production phase to generate curves of the best focus position as a function of the distance for a given zoom. The fitting coefficients of the curves are saved in the EEPROM of the main electronic board of the PSI. The main software PIMSoft that controls the PSI will calculate the best focus position by using the fitting coefficients and send a command to the lens focus motor to get sharp image. The weakness of the implemented AF is the difficulty to get always sharp images at any zoom and distance due to the fitting error, distance measurement error (done by PIMSoft), and the calibration curves doesn’t cover all zoom values and all distances.
Main goal of the project: The goal of this project is to develop a real time AF algorithm for PSI, with efficient evaluation of a robust passive AF procedure based on image processing techniques. The algorithm should be as fast as possible (execution time is less than 10 seconds), considering the hardware limitations. The performance and the ability of the AF algorithm to set the lens in the proper focus position will be compared against Perimed’s focus pre-calibration. The final AF function will drive the hardware in an optimal way, incorporating image acquisition, image processing and image quality assessment.

Specified objectives and tasks

1. Identify the best autofocus algorithms and techniques employed in different applications
   a. What are best practices?
   b. What are the biggest challenges?
   c. What criteria are used to determine the right algorithm or technique?
2. Apply algorithms and techniques in MATLAB environment and perform experiments
   a. What are experiment settings?
   b. What are key performance data that I need to observe?
3. Improve the algorithms
   a. What are acceptable focus ranges?
   b. What is a balance between doing it faster or doing it with better quality?
   c. How to deal with noises?
4. Investigate the effect of the laser speckle
   a. Does laser speckle affect images?
   b. How to find the best focus position considering the degradation of the details in an image?
5. Finalize AF algorithm development for PSI
   a. How previous tasks can be combined and adapted into a single real-time AF function?
   b. What results give AF function when it is tested against external mechanical noise?
   c. What results give AF function when it is tested in a real-life scenario?

Expected result
A real-time AF algorithm for PSI

Methodology

1. Literature Review: literature research study concerning autofocus algorithms and techniques employed in different applications (e.g., mobile phone cameras and microscopy systems), the state of the art image quality assessment and blind image sharpness methods (BISA) [4], laser speckle phenomenon and how to deal with it. More advanced methods are also considered.

2. Programming and experimental work: The development of the considered techniques will be performed in this phase in a MATLAB environment. Sensitivity,
computational simplicity, execution time, and coherency (monotonicity) of the method are the main parameters to be evaluated. Testing is carried out through experiments on both static diffuse objects and on human skin tissue by using a PSI imager head. Images without laser speckles are acquired by using a uniform illumination source (LED) at 785 nm. The goodness of the algorithms is also assessed in two ways: (a) by comparing the obtained BFP with the one calculated from the focus pre-calibration method and (b) by monitoring the sharpness of the acquired image at the obtained BFP.

3. Optimization of the selected algorithms: Given the time constraint posed by a real time AF procedure, one cannot afford to acquire many images to process and compare. The optimization is done in terms of selecting the focus ranges and performing fast scan to get a good result in shorter time. Noise resistance has to be guaranteed and the scorer (image sharpness assessment criterium) from phase 2 is employed.

4. Laser speckle treatment: The effect of the laser speckle on the images is investigated. Laser speckle plays the role of the signal for PSI, but it is considered as a noise [5] for AF purposes. The speckle degrades the details in an image and makes it difficult to find the best focus position. It is unavoidable to filter out the speckle, therefore several digital filters are tested. Results are shown with and without filtration.

5. Real time AF procedure: After performing the previous steps, the acquired knowledge and algorithm’s pieces are combined and adapted into a single real time AF function to perform the real time AF procedure for PSI. The function has to be optimised and tested against external mechanical noise. The function is also tested in a real-life scenario.

6. Ecological and social impact of laser speckle: Once the development of the algorithm is complete, the assessment will be conducted to determine how this design affect environment around. Additionally, the impact of society, especially from different social levels, will be addressed.

**Project and schedule**

<table>
<thead>
<tr>
<th>Week</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Literature review</td>
</tr>
<tr>
<td>3-6</td>
<td>Programming and experimental work. Writing Thesis report.</td>
</tr>
<tr>
<td>6</td>
<td>Week 6 milestone: working model</td>
</tr>
<tr>
<td>14</td>
<td>Week 14 milestone: working laser treatment</td>
</tr>
<tr>
<td>20</td>
<td>Week 20: End of the Thesis work.</td>
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</tbody>
</table>

**Attachments**

Supervision agreement

**External participation**

Olof Olofsson Optical AB
References


