Research Planning
Assignment 3

Measurement of microcirculation and development of a multi parameter measuring system.

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# 1 Central Terminology

<table>
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<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>PPG</td>
<td>Photoplethysmography, an optical technique used to detect microvascular blood volume changes.</td>
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<tr>
<td>Perfusion</td>
<td>The perfusion is the process of nutrient delivery to the tissue by the blood due to blood flow in the different vessels.</td>
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<tr>
<td>LDPM</td>
<td>Laser Doppler Perfusion Monitoring is an optical technique to measure the perfusion in one point.</td>
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<tr>
<td>LDPI</td>
<td>Laser Doppler Perfusion Imaging is a technique to visualize the perfusion of a larger area.</td>
</tr>
<tr>
<td>Decubitus</td>
<td>Bedsore</td>
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</table>
2 Research area

The area of my research is the prevention of pressure sores. A common way to prevent pressure sores is using antidecubitus mattresses designed to minimise the interface pressure. The development of pressure sores whoever depends on a number of factors and no consensus exists regarding methods and what parameters to regard in order to evaluate mattresses before purchase.

The supporting areas of the body on a surface are characterized by peak pressure and pressure gradient that combined with the internal nature of the body results in stresses and strains. These factors can lead to locally impaired blood flow. Prolonged impairing of the flow can lead to ischemia involving impaired transport of nutrients and waste products to and from the cells. [1] The problems associated with the experience of pressure sores include pain, anxiety and fear and an association has been found between pressure sore development and increased morbidity and mortality. [14]

One of the major parameters of interests is the blood flow at different depths of tissue. The microcirculation, the most peripheral part of the blood vessels including small arteries and veins, is a parameter that can be measured by a number of methods including Photoplethysmography (PPG) and Laser Doppler flowmetry, both based on the propagation of light in tissue. Other parameters to be taken into consideration are the humidity of the contact area and tissue, the local temperature of the area, local pressure and tear.

2.1 Laser Doppler flowmetry

The parameter in question when performing Laser Doppler flowmetry is the perfusion of the tissue. The perfusion is the process of nutrient delivery to the tissue by the blood due to blood flow in the different vessels.

**LDPM**

Laser Doppler Perfusion Monitoring is based on a single fibre optic probe which measures the perfusion in about 1mm$^3$. This method is suitable for real-time monitoring of the perfusion at a single point. The perfusion is measured in arbitrary units which are calibrated by measuring reference solutions rendering a high and low point in

**LDPI**

Laser Doppler Perfusion Imaging uses a laser beam to successively scan a larger area by using a mirror to move the point to be measured and thereby generating a two-dimensional map of the perfusion of the area. [10]

Neither LDPM nor LDPI can be used for quantitative measuring of microvascular blood flow. The result can vary between individuals
because of differences in the micro vascular anatomy and pigmentation. The best use of Doppler techniques is to use it to monitor changes rather than absolute values. [12]

**PPG**

It has been demonstrated that the use of PPG with different distance between light source and detector can be used to detect vessels at different depths. [6] The use of different wavelengths as a tool to reach different depths is supported by physiological evidence. [7]
3 Method

The method of this project is to further develop a non-invasive device, equipped with an array of a combination of several types of sensors, capable of measuring the different parameters on a body lying on a mattress without affecting the influence of the mattress on the body.

Blood flow measuring will be the primary focus and research will continue by doing comparisons of the measuring depth of different types of Laser Doppler flow meters and PPGs of different wavelengths. The selection of sensors then will be optimised to cover as many depths as possible. To minimise the interference and distance between different types of optical sensors aimed at the same position a system to switch between different sensors is to be developed. This will lead to an array of sensors capable of giving a view of the different factors affecting the body at any moment in order to evaluate the mattresses.

In order to lessen the influence of the sensor system on the measured situation research will be conducted regarding measuring through textiles, this is a concept that has been tested with bandages using ultrasound gel to transmit light.[13]

To evaluate the depth of measurement using the different configurations of transmitter and receiver with regard to the wavelength of the light and distance between the two parts a system will be constructed based on measuring blood flow in flexing muscles at known depths.

The previously developed sensor system has undergone extensive testing with regard to medical application but the technical properties of the system are yet to be properly tested and documented. As a starting point in my own research regarding microcirculation I plan to evaluate that system in combination with the recently acquired LDPM unit.

To estimate the perfusion in a larger area than the few cubic millimetres two different approaches can be made, the local perfusion at several points using a number of sensors scattered around a few inputs of light. The other approach is to place a few sensor modules central and a number of inputs of different wavelengths and distance from the sensors.

3.1 Hypotheses

The superficial blood flow can be monitored for an area at a depth of 0 to 20 mm using cost effective methods without inferring with the interaction between the human and surface upon which it is resting.

Monitoring the total backscattering from an array of light sources can be used as an estimate for the present perfusion in that area.
3.2 Research questions
Can the expensive solution using LDPM be replaced with a PPG without reducing the monitored depth?

Is it possible to utilize a two channel LDPM to measure at multiple points without movement of the probes using optic switching methods? Can this be achieved using green and NIR PPGs in combination with LDPMs at 638.8 and 780nm?

Can the same method used to monitor blood flow be used for monitoring other parameters, such as water content?
4 Research overview

Since the first ideas of measuring microcirculation using light scattering [2] and the development of the first LDPM [3] a lot of different research projects using the principle has been conducted. The applications of laser doppler flowmetry includes pharmacological trials, allergy patch testing, wound healing, physiological assessments and skin disease research.[10] One of the most studied organs is the skin but internal organs such as muscles, kidneys, liver and heart among others has been investigated in different studies.[11]

Lately research has been conducted by Sandberg et. al. to develop a PPG using green and near-IR light to monitor perfusion of skin and muscle. The result of that study showed that the method has potential as a non invasive way of measuring local perfusion but the influence of other factors must be taken into concern. The study also shows that prolonged exposure to the light source of a PPG will lead to a rise in the local tissue temperature and thereby affect the blood flow. [8]

Studies regarding the influence on blood flow at different depths due to alternation of the tissue temperature have been conducted using laser Doppler perfusion monitoring and the result of that study is that the differences are of a rather minor character. [9]

A major factor in the development of a system capable of measuring blood flow in tissue in contact with for example a mattress is to minimise the influence of the sensor system. Recent studies show the possibility of performing measurements through fabric using laser Doppler flowmetry [13].

4.2 Seminal papers

There are a few papers that can be considered as seminal work on the use of laser dopplers and photoplethysmography for measuring blood flow.

"In vivo evaluation of microcirculation by coherent light scattering” [2] stated the basic principles for the use of laser Doppler as a method to measure microcirculation.


Photoplethysmography begun with two research groups in 1936 describing similar instruments to monitor the blood volume changes. A pioneer helping to establish the PPG technique was Alrick Herzmann who together with colleagues published their first paper on PPG in 1937 demonstrating the potential clinical utility of the technique.[5]
5 Related work

Even though both PPG and Laser doppler based systems are widely used in research related to the human blood flow there seems to no other groups currently focus on the applications related to pressure sores except for the group in Linköping.

5.1 Research groups

Some of the groups doing research in areas relevant to mine are:

Linköping University is involved in several research projects regarding pressure sores, both in the area of measuring blood flow as evaluation of pressure reducing materials and risk evaluation.

University of Lund has conducted some research regarding the influence of different wavelengths and probe configurations when using laser doppler perfusion devices to detect vasoconstrictions.

The British Microcirculation Society was founded in July 1963 "to advance the study of circulation of the blood and other tissue fluids especially, though not exclusively, in the small vessels and of matters relating thereto".

5.2 Conferences

There are conferences dedicated to the field of microcirculation and health related electronics, these are a few of those:

The European Society for Microcirculation holds the conference:
Conference of the European Society on Microcirculation:
Microcirculation and Vascular Biology Basic and Clinical Science
http://www.medizin.fu-berlin.de/esm/

Tromsø Telemedicine and eHealth Conference 2008 - Innovation in eHealth
http://www.telemed.no/index.php?id=542870

eHealth: Combining Health Telematics, Telemedicine, Biomedical Engineering and Bioinformatics to the Edge (CeHR)
A conference offering invited speeches from internationally leading experts representing all domains involved in eHealth.
http://www.cehr.de/

European Congress of the International Federation for Medical and Biological Engineering

The biennial conference
Kuala Lumpur International Conference on Biomedical Engineering
http://biomed2008.um.edu.my/
5.3 Journals

**Microvascular Research**
This journal is dedicated to the dissemination of fundamental information related to the microvascular field. Full-length articles presenting the results of original research and brief communications are featured.  

**The Journal of Fluid Mechanics**
The purpose of this journal is the publication of theoretical, computational and experimental investigations of all aspects of the mechanics of fluids.  
[http://www.jfm.damtp.cam.ac.uk/](http://www.jfm.damtp.cam.ac.uk/)

**Microcirculation**
This journal features original contributions that are the result of investigations contributing significant new information relating to the microcirculation addressed at the intact animal, organ, cellular, or molecular level. Papers describe applications of the methods of physiology, biophysics, bioengineering, genetics, cell biology, biochemistry, and molecular biology to problems in microcirculation.  
[http://www.tandf.co.uk/journals/titles/10739688.asp](http://www.tandf.co.uk/journals/titles/10739688.asp)

**Archives of Physical Medicine and Rehabilitation**
This international journal has distinguished itself through its coverage of the specialty of physical medicine and rehabilitation and of the more interdisciplinary field of rehabilitation.  
6. Planned publications

*Paper 1: Technical evaluation of a new sensor design made to discriminate between tissue blood flow at different tissue depths at the sacral area.*

The article will discuss the technical characteristics of a sensor design previously developed by the research group. The sensor has been used in clinical tests and the medical aspects of the performance are currently being analyzed. In order to further develop and optimize the properties of a future sensor a technical review of the current one will be made and presented.

*Paper 2: Development of a sensor system to estimate the tissue blood flow in the lower back.*

This paper will present the development of a system for producing a mean value of the tissue blood flow in a larger area, about 30 x 50 cm by using two PPG sensors surrounded by several common light sources. The system will be based on the knowledge acquired in the production of paper 1 complemented by the introduction of a second type of LDPM. The purpose of this paper is to get a further the insight in the methods suitable for a multi parameter sensor system.
7. Time plan & Milestones

Presented are a few preliminary milestones for the upcoming year and courses related to this project, except for this a I am involved in another project regarding wireless ECG not discussed in this document.

7.1 Milestones

Spring semester ‘08: Technical evaluation of existing sensor resulting in paper I.
Fall semester ‘08: Design and evaluation of new ideas for simultaneously measuring perfusion at multiple points.
Spring semester ‘09: Production of paper 2.

7.2 Planned Courses

The courses planned to be included in my licentiate thesis are listed below.

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<tr>
<th>Course</th>
<th>University</th>
<th>Credits</th>
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<td>Medical measurement systems</td>
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<tr>
<td>Micro Sensors</td>
<td>MdH</td>
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<tr>
<td>Anatomy and Physiology</td>
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<tr>
<td>Research Planning</td>
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<td>In progress</td>
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<tr>
<td>Biomedical Optics</td>
<td>LiU/LTH</td>
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8 References


