Frugal Biomedical Innovations Research Internships
Summer Projects 2023

Low Cost Remote Pulse Oxymetry Systems

Supervisors:
Dr. Michael Rieder, Robarts Research Institute
Dr. Ehsan Kamarn
Dr. Abdelbaset Elzagallai

Location of Study Robarts Research Institute

Project Description

This project is to continue our pilot work in developing robust small wireless pulse oximetry systems to provide continuous real-time readouts of blood oxygen content in mammalian systems including humans with a focus on children and infants. Determination of blood oxygen content is an important part of clinical care and also research studies. Current systems are primarily conducted using technology wired to dedicated and expensive monitors. Our work will establish a low cost point-of-care device for use in remote, rural and resource-constrained settings. This project is an extension of previous work establishing the hardware and software for system development to enable data to be collected on conventional laptop/desktop computers or mobile devices.

Skills Necessary

Familiarity with 3D printing, software development and prototype design

Non-Invasive Characterization of White Blood Cells

Supervisors:

Dr. Michael Rieder, Robarts Research Institute
Dr. Ehsan Kamarn
Dr. Abdelbaset Elzagallaai
Dr. Alejandro Lazo-Langer

Location of Study: Robarts Research Institute

Project Description

This project is to continue our pilot work in developing robust non-invasive wireless systems to characterize and count white blood cells with a focus on children and infants. Determination of white blood cell count is an important part of clinical care. Currently this is done by collecting blood using a needle, collecting the blood in a specialized tube, sending this tube to a laboratory when the white blood cells are separated and counted and then the result is sent back to the clinic or Emergency Department. This process is painful for the patient, time consuming for the clinician and significantly limits the availability of testing notably in remote or resource limited settings. We propose to address this issue by developing non-invasive systems for characterization of white blood cells. We propose to develop a system to direct light across the fingernail capillary bed which will generate images captured by a sensor on the other side of the fingernail. The images will be compared to an image library using software designed to characterize the number and type of white blood cells, which can then be read immediately in real time on a mobile device via wireless signal transmission. Our work will establish a low cost point-of-care device for use in remote, rural and resource-constrained settings. This will greatly increase diagnostic capacity in rural and remote settings and in urgent and emergency care settings.

This project is an extension of previous work establishing the hardware and software for system development to enable data to be collected on conventional laptop/desktop computers or mobile devices.

Skills Necessary

Familiarity with 3D printing, software development and prototype design

Open source 3D printed adaptive aids

Supervisors

Dr. Joshua Pearce, Electrical & Computer Engineering, Thompson Centre for Engineering Leadership and Innovation, and Ivey School of Business Project

Dr. Jacob Reeves, Thompson Centre for Engineering Leadership and Innovation

Project Description

Previous work has shown that distributed manufacturing with 3D printing radically reduces adaptive aid product costs, which makes them much more accessible to elderly. This project will build on this past work and create extensions of previous designs like walkers (i.e. converting to a rollator that would focus on wheel design and integration). Students will select from a list of requests for those that need products to assist with aging at home. They will then search the literature for standards, then design, 3D print, build, and test the limitations of their design and iterate until the standards are exceeded.

Skills/Experience Necessary

1-2 qualified engineering students will have past mechanical design and CAD experience. Ideally in parametric CAD packages like OpenSCAD, FreeCAD, or OnShape. 3D printing experiences is also beneficial.

Open-source bioreactor applications

Supervisor

Dr. Joshua Pearce, Electrical & Computer Engineering, Thompson Centre for Engineering Leadership and Innovation, and Ivey School of Business Project

Project Description

A bioreactor provides a controlled environment to ensure ideal growing conditions for organisms like bacteria and yeast. Enzymes, plant or animal cells, and microorganisms need specific environmental conditions within bioreactors to produce the desired output of organic material. The pharmaceutical industry uses bioreactors to create medicines, vaccines, produce antibodies and even food. Proprietary bioreactors are extremely expensive and rigid in what they allow users to do with them. This makes the innovation cycle slow and inequitable as those without financial resources simply do not have access to them. To overcome these challenges, our group has designed an open source bioreactor library. This project will involve selecting design specifications, build and test a new open source bioreactor using the library as a base and then apply it to applications that benefit human health.

Skills/Experience Necessary

1-2 qualified students will have either a Biomedical Engineering, Chemical Engineering, or Electrical or Computer Engineering and control systems background, be a persistent problem solver and an enthusiastic team player (joining the Free Appropriate Sustainability Technology (FAST) Research Group). Generally FAST members are in the top 10% of their class in GPA. The ideal candidate(s) would have previous experience with bioreactors.

Computational Optics Design of an Optical Microscope for Malaria Diagnoses

Supervisor

Dr. Ian Cunningham, Medical Biophysics and Robarts Research Institute

Project Description

Malaria is one of the four most life-threatening infectious diseases worldwide. While treatments are often available, they must be delivered as quickly as possible after onset of symptoms. Malaria is a parasite carried by mosquitos and can be diagnosed with a microscope and blood smear. However, most infections occur in rural areas where these facilities are not available due to limited resources. We are developing a low-cost microscope that is based on recent discoveries in the field of computational optics that have the potential to change the world of microscopy imaging. Using a simple 3-D printed microscope design and Raspberry Pi camera, we use optics to capture the image as a Fourier transform and take the inverse Fourier transform to create the image. With this approach, ultra-high resolution (1 µm) images with large field of view (10 mm) can be acquired at the same time, which is ideal for microscopy. Our goal is to be the first team in the world to use this approach for malaria diagnoses.

Skills/Experience Necessary

We are looking for a student with good computer programming skills, in particular Python and Matlab, an interest in physics, and a willingness to learn about optics and Fourier transforms.

A cost-effective method for fabricating conductive thread and e-textiles

Supervisor

Dr. Ana Luisa Trejos

Project description

Conductive thread is a common material used in electronic-textiles (e-textiles). It allows electricity to and from transducers, data acquisition boards, and other electronic components to be conducted. At the WearME lab, our current focus is on using conductive thread to develop and integrate soft electronic components into smart mechatronic garments (e.g., shirts, sleeves, gloves). However, work is limited by the conductive thread that can be purchased, which is formed by a standard thread coated in conductive material (therefore the conduction of electricity happens through the outside of the thread). While great success has been achieved from the use of these threads, their availability is limited due to their high production cost. Many of the best-performing solutions are produced by very complicated and expensive methods, and the materials used become damaged over time. Preliminary tests with sample materials, as well as related work found in the literature, have shown that some of the limitations of the current sensors and actuators could be addressed by using thread that has a conductive core and braided nylon or cotton on the outside, essentially the reverse of what can be purchased. Therefore, the purpose of this project is to develop a method for manually creating conductive thread that is formed by a metal wire as the core of the thread, and has nylon or cotton braided on the outside of the conductive core. Furthermore, the project will then aim to evaluate methods for creating sensors and/or actuators by weaving this manually made conductive core thread, in order to significantly reduce the cost of producing e-textiles. Since both braiding and weaving are manufacturing methods that could be done manually, this can result in significant positive implications for the accessibility of the technologies in low-income countries or remote communities.

Skills/Experience Necessary

The successful student will be an undergraduate student in Electrical, Mechanical or Mechatronics Systems Engineering. Preference will be given to students completing a dual degree with Biomedical Engineering, or who have experience with sewing, embroidery and/or weaving.

Development of a low-cost near-infrared spectrometer for biomedical applications

Project Supervisor

Dr. Keith St. Lawrence

Project Description

Near-infrared spectroscopy provides a vital tool for measuring tissue oxygenation and metabolism with a myriad of applications from assessing muscle physiology to monitoring brain health in critically ill patients. Historically, spectrometers adapted for these applications were originally developed to resolve fine spectral features. These spectrometers are typically costly and over-engineered for biomedical applications. This project will focus on developing an inexpensive alternative, taking advantage of the availability of inexpensive light sources (i.e., laser diodes and LEDs) and silicon photomultipliers (SiPMTs) for light detection. The project will focus of selecting the appropriate number and colours of sources to generate light across the near-infrared spectrum and constructing a linear array of SiPMTs with the spectral resolution to detect the broad features encountered in tissue applications. Our vision is to build a compact, low-cost spectrometer with the flexibility to support a range of applications. The project will provide the student with the opportunity to learn how the practises of frugal engineering can benefit biomedical optics.

Low-cost digital x-ray imaging

Supervisor

Dr. David Holdsworth, Medical Biophysics and Robarts Research Institute

Project Description

Diagnostic radiography is still not available to hundreds of millions of people in low- and middle-income countries; this is part of a global phenomenon related to inequitable access to essential healthcare technology. This project takes advantage of a number of recent developments in consumer-off-the-shelf (COTS) technology to create a new type of robust, low-cost, high-quality digital radiographic system for use in low-resource settings (LRS). Recent technological advances have greatly increased the performance of digital cameras, computers and portable displays, making it timely to develop a portable digital X-ray system for peripheral musculoskeletal radiography. Our idea is to use a professional-grade digital camera to acquire an image directly from a phosphor screen, using a battery-powered X-ray source.

A prototype device has been constructed and tested, but the current challenge is to develop a dedicated micro-controller based system to control the x-ray source in synchrony with the image acquisition. There is also a need to develop advanced image-processing utilities to produce high-quality radiographs from the raw image data.

Skills/Experience Necessary

Completion of second year courses in Mechanical Engineering, Mechatronic Systems Engineering, Computer Engineering, or Electrical Engineering would be preferred. Students in Medical Biophysics or Physics with a background in working with microcontrollers would also be eligible. Experience with Python, C, and the Arduino IDE would be preferred.

Low-cost soft-tissue testing device

Supervisor

Dr. David Holdsworth and Dr. Maria Drangova, Medical Biophysics and Robarts Research Institute

Project Description

One of the challenges in biomedical training programs in low- and middle-income countries is the high cost of laboratory equipment that is required during training. For example, biomedical engineering programs typically require access to material testing systems, such as indentation testers to characterize low-modulus materials and soft-tissues. While these devices are commercially available, even a small unit is typically over $50,000 CAD, making it difficult or impossible to incorporate into training programs. Our group has developed a low-cost soft-tissue testing device, which is based on common-off-the-shelf mechanical components and open-source software control using a common microcontroller (Arduino Uno). The device has been developed to operate with a simple serial command-line menu, and also incorporates a Python-based control program that can be used to acquire and save data according to specific protocols. The challenge now is to develop additional modules that will allow the device to perform additional material testing protocols (such as compressive, tensile, and flexural), as well as cyclic testing for fatigue analysis. The ultimate goal of this project is an open-source product that can be widely distributed in low-resource settings.

Skills/Experience Necessary

Completion of second year courses in Mechanical Engineering, Mechatronic Systems Engineering, Computer Engineering, or Electrical Engineering would be preferred. Students in Medical Biophysics or Physics with a background in working with microcontrollers would also be eligible. Experience with Python, C, and the Arduino IDE would be preferred.

Low-cost emergency ventilator

Supervisor

Dr. David Holdsworth, Medical Biophysics and Robarts Research Institute

Project Description

One of the lessons from the ongoing pandemic has been the importance of access to critical biomedical infrastructure, such as mechanical ventilation devices for assisted breathing. While the most urgent need for ventilators (which we experienced at the beginning of the pandemic) has passed, the experiences of the pandemic have placed a spotlight on the need for mechanical ventilation devices in low-resource settings, including emergency medicine and low- and middle-income countries. Our team has developed a mechanical ventilator that actuates a conventional bag-valve mask, using common-off-the-shelf components and open-source hardware and software. Before this device can be developed into a practical product, we must complete a thorough risk assessment, using established principles (i.e. ISO14971). The student will employ strategies from ISO14971 to identify potential risks to the patient, as well as develop appropriate risk-mitigation strategies.

Skills/Experience Necessary

Completion of second year courses in Mechanical Engineering, Mechatronic Systems Engineering, or Electrical Engineering would be preferred, although students in Medical Biophysics with a background in physics and device design would also be eligible. The student will learn valuable skills related to regulatory requirements for medical devices

Miniature spectrometer for tissue blood oxygen monitoring in low-resource settings

Supervisor

Dr. Mamadou Diop, Medical Biophysics and Lawson Health Research Institute

Project Description

Near-infrared tissue spectroscopy (NIRS) is now widely used in pre-clinical and clinical research, and patient management. This is because the technology is safe, portable, and can be used to noninvasively measure tissue blood content and oxygenation, which are sensitive biomarkers of tissue health and well-being. To accurately quantify these biomarkers a hyperspectral NIRS technique (i.e., NIRS with a large number of wavelengths) is required. In hyperspectral NIRS, light absorption is measured at dozens of wavelengths with a spectrometer to estimate tissue blood content and oxygenation. Since the absorption spectra of oxyhemoglobin and deoxyhemoglobin − the two main constituents of blood − are broad in the near infrared, the objective of this project is to determine the optimal (i.e., minimum) spectral resolution needed to accurately estimate tissue blood content and oxygenation, while maximizing light throughput. It is noteworthy that increasing the width of the entrance-slit will decrease spectral resolution but increase light throughput. Therefore, if high spectral resolution is not needed, very low-cost miniature spectrometers could be used to accurately measure tissue blood content and oxygenation, which would be valuable in low resource settings.

The student will use a custom-made spectrometer with a variable entrance-slit to change the device’s spectral resolution and light throughput. Measurements will be acquired for slit width from 10 μm to 1 mm in a tissue-mimicking phantom containing bovine blood. Blood oxygenation will be altered by bubbling oxygen or nitrous oxide into the phantom. Measurements will be analyzed to determine the widest optimal entrance slit (i.e., the optimal light throughput) that provide accurate measures of blood content and oxygenation.

Skills/Experience Necessary

The student should able to develop Matlab scripts for data analysis and visualization and should be interested in learning about light-tissue interaction, the use of NIR light to measure physiological parameters, and tissue-mimicking phantoms. The student will be trained in scientific communication, including oral presentation and scientific writing.

Optimization of spectral resolution and light throughput for in vivo tissue spectroscopy in low-resource settings

Supervisor

Dr. Mamadou Diop, Medical Biophysics and Lawson Health Research Institute

Project Description

Near-infrared tissue spectroscopy (NIRS) is now widely used in pre-clinical and clinical research, and patient management. This is because the technology is safe, portable, and can be used to noninvasively measure tissue blood content and oxygenation, which are sensitive biomarkers of tissue health and well-being. The accuracy of NIRS is greatly increased by acquiring measurements at dozens of wavelengths (i.e., hyperspectral NIRS) as this improves the robustness of the algorithms used to estimate tissue blood content and oxygenation. Nevertheless, hyperspectral NIRS devices are typically based on expensive custom-made spectrometers. We have recently demonstrated that low-cost, off-the-shelf spectrometers can be easily modified to become suitable for tissue spectroscopy. However, while these spectrometers cost about $10,000, which is much less than custom-made units, they are still too expensive for many low-resource settings.

The objective of this project is to develop a low-cost miniature spectrometer by leveraging recent advances in compressive sensing to reduce both size and cost. The student will work identify low-cost (~$100) digital micromirror devices (DMD) and sensitive photodetectors to build a low-cost, yet high quality optical spectrometer. To assess the quality the low-cost spectrometer, its spectral and temporal resolution will be characterized and compared to those of a custom-made unit for tissue spectroscopy.

Skills/Experience Necessary

The student should able to develop Matlab scripts for data analysis and visualization and should be interested in learning about light-tissue interaction, the use of NIR light to measure physiological parameters, and tissue-mimicking phantoms. The student will be trained in scientific communication, including oral presentation and scientific writing.

Cold-chain refrigeration and monitoring for vaccines and biologics

Supervisor

Dr. David Holdsworth, Medical Biophysics and Robarts Research Institute

Project Description

A significant fraction of vaccines and other drugs are wasted each year in low- and middle-income countries because of difficulty in maintaining a required temperature range during shipment and storage. This process of maintaining refrigeration is referred to as the "cold chain", and it is made more difficult in low-resource settings due to unreliable electrical supplies and high ambient temperatures. Many groups have investigated this issue over the past several years, but significant deficiencies remain, with respect to cost-effective refrigeration processes, as well as robust monitoring systems.

The goal of this project is to review the current state of the art in low-cost, robust portable refrigeration for vaccines and drugs, and design an optimal system using state-of-the-art capabilities (3D printing and micro-controllers). A secondary goal will be to develop a low-cost Internet-of-Things (IoT) solution to provide accurate temperature monitoring and appropriate alarms.

Skills/Experience Necessary

Completion of second year courses in Mechanical Engineering, Mechatronic Systems Engineering, Computer Engineering, or Electrical Engineering would be preferred. Students in Medical Biophysics or Physics with a background in working with microcontrollers would also be eligible. Experience with Python, C, and the Arduino IDE would be preferred.