Project: Affordable Near-Infrared Spectroscopy (NIRS)

Supervisors:
Keith St Lawrence, Department of Medical Biophysics, Western University
Daniel Milej, Department of Medical Biophysics, Western University

Location of Study:
Lawson Research Institute, St Joseph Hospital, F0-102

Project Description:

This project aims to create a miniaturized, affordable Near-Infrared Spectroscopy (NIRS) device that uses a white light source for non-invasive tissue analysis. Traditional NIRS systems are often expensive and complex, making them inaccessible in low-resource settings such as remote areas in sub-Saharan Africa or Northern Canada. Our goal is to build a simple, cost-effective device that can bring advanced diagnostic capabilities to places with limited healthcare infrastructure.

The device will use a white LED light source, which covers a broad spectrum of wavelengths, allowing the measurement of various tissue components, including oxyhemoglobin, deoxyhemoglobin, and water content. A compact diffraction grating and basic lens system will separate the light into individual wavelengths. At the same time, a photodiode array will detect the signals, providing the necessary data without relying on expensive sensors.

To keep the design simple, we will integrate the optical components into a small, custom-built PCB, which will be powered by a microcontroller (such as the ESP32). This will handle data collection, processing, and wireless communication to a mobile app for real-time analysis. The app will allow healthcare workers to view results instantly and make decisions quickly, even in settings with limited access to medical equipment.

This frugal spectrometer can be used for applications like anemia screening, hydration monitoring, and checking vascular health. This project aims to improve healthcare access and diagnostic accuracy in underserved areas by keeping costs low and the design user-friendly.

Skills and Experience Necessary:

- Potential student should have experience designing simple analog and digital circuits, particularly for signal amplification and processing. In addition, some proficiency in programming microcontrollers (e.g., ESP32, Arduino) for data acquisition and control of optical components and the ability to design and fabricate a custom PCB (Printed Circuit Board) for integrating the components is required.

Project: Prototype Optimization for Non-Invasive Blood Cell Determination by Image Capture

Supervisors:
Dr. Michael Rieder, Robarts Research Institute, UWO
Dr. Ehsan Kamrani, Department of Engineering, University of Waterloo

Location of Study:
BioNext Hub, Robarts Research Institute

Project Description:
This internship is to work on prototype optimization for non-invasive blood cell determination by image capture of directed light across the capillary nailbed. The hypothesis is that using single cell imaging and image analysis a blood count can be determined that obviates the need for bloodwork and laboratory analysis, facilitating care in rural, remote and resource-constrained environments. The research and development team includes clinicians, clinician investigators, biomedical engineers and software developers. The project is based in the BioNext Medical Innovations Hub at Robarts, a technology incubator with a strong biomedical engineering core and numerous graduate and summer students and with key core facilities including robust 3-D printing capacity. The student will be involved in the fabrication of prototype devices and in working with the research and development team to create and then validate prototype devices as well as in optimizing hardware-software integration for image analysis and blood count determination. The student will also work with the clinical team to facilitate real world validation of the prototypes developed in a series of health care settings and to explore the possibility of remote and continuous data capture.

Skills and Experience Necessary:

- Skills in biomedical engineering including prototype fabrication and software/hardware integration
- Skills/experience in image capture and photoimaging

Project: Low-Cost Smart Toothbrush for Children Living with Neuro-developmental Challenges in Low-Resource Settings

Supervisor:
James Lacefield
Faculty of Engineering and Schulich School of Medicine & Dentistry

Location of Study:
Building, Office or Lab room number: Robarts Research Institute

This project was suggested by our partners in the Department of Dental Sciences at the University of Nairobi, Kenya. Studies in high-income nations demonstrate that using a smart toothbrush to guide brushing technique and promote brushing habits can improve the oral health of people facing neurodevelopmental challenges, but sophisticated commercial toothbrushes are unaffordable even for upper-middle-class families in sub-Saharan African nations. The goals of this project are to design a device that provides capabilities comparable to a commercial smart toothbrush at < 25% of the cost, and is effective when used by children under the supervision of their caregivers with minimal coaching from dental care professionals.

The current prototype employs inertial measurement units (IMUs) to track the position and orientation of the brush-head and a Hall effect pressure sensor to measure the contact pressure at the tooth surface. An Arduino Nano BLE Sense microcomputer in the brush handle analyzes the user's brushing performance. Brushing performance metrics are transmitted via Bluetooth to a second Arduino within the brush's charging stand and presented to the user by a child-friendly color LED display. A student joining this project will complete the design and fabrication of a mechanical assembly to rotate the brush-head and will develop an AI algorithm to identify the mouth section currently being brushed using the IMU data. A research ethics protocol for a pilot patient study of usability will also be devised with guidance from faculty members in the Schulich School of Dentistry.

Skills and Experience Necessary:

- Experience with computer-aided design and 3D printing of small mechanical components. Experience with, or strong interest in learning, tiny machine learning (also known as edge AI) methods to implement AI algorithms efficiently on a microcomputer processor.
- Whereas this project is an ongoing activity of the Western Engineering Biomedical Club (WEBMC), preference will be given to applicants who are active members of the WEBMC Design Team.

Project: Ultra-Miniature Optical Instrumentation: qPCR Systems

Supervisors:
David Holdsworth, Schulich School of Medicine & Dentistry
Tamie Poepping, Physics & Astronomy, Faculty of Science

Location of Study:
Robarts Research Institute, Centre for Medical Imaging Technology & Physics & Astronomy Building, PAB 136

Project Description:
Analytic instrumentation for biomedical research is typically too expensive for low-resource settings, limiting research capacity. However, recent developments in ultra-miniature optical instrumentation provide the opportunity to re-think some types of lab equipment, such as quantitative PCR (qPCR) systems. Like many lab instruments, qPCR depends on accurate measurement of weak fluorescent signals, and a new generation of low-cost, low-power miniature spectrometers may provide a solution for epi-fluorescent acquisition during qPCR thermal cycling.

The selected student will be expected to participate in:

- investigating the performance of a 14-channel spectrometer (AS7343, Osram) as a candidate for a data acquisition module in a low-cost qPCR system using a programmable microcontroller (Raspberry Pi Pico);
- developing and testing a multi-well configuration;
- testing spectrometer performance and compatibility with a thermal cycler.

Skills and Experience Necessary:

- Basic knowledge of electric circuitry is required.
- Programming experience (C/C++, python) would be an asset but not required.