Project Title: Low-Cost Smart Toothbrush for Children Living with Neurodevelopmental Challenges in Low-Resource Settings

Supervisors: James Lacefield, School of Biomedical Engineering, Department of Electrical & Computer Engineering, and Department of Medical Biophysics

Location of Study: Robarts Research Institute

Project Description:
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. The 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.
**Project Title:** Low-Cost Intraoral Camera System for Tele-Dentistry in Low-Resource Settings

**Supervisors:** James Lacefield, School of Biomedical Engineering, Department of Electrical & Computer Engineering, and Department of Medical Biophysics

**Location of Study:** Robarts Research Institute

**Project Description:**

This project was suggested by our partner, Dr. Regina Mutave, of the Department of Dental Sciences at the University of Nairobi, Kenya. Although the WHO has declared oral health to be a basic human right, 70% of the world’s people lack access to affordable dental care, and untreated caries and periodontal disease rank first and sixth, respectively, among the most common health problems worldwide. The technology developed through this project will help close urban-rural disparities in oral hygiene and access to dental care that are observed in Kenya (e.g., 58% of rural children and 33% of rural adults in Kenya have never visited a dentist) and is expected to be applicable to similar oral health challenges globally.

The current camera prototype consists of a 3D-printed handheld “wand” that contains a 5 megapixel mini-camera and several LEDs controlled by a Raspberry Pi Zero and is capable of linking wirelessly with a laptop computer to store and transmit images to dentists in distant locations. The device performs white-light imaging of tooth surfaces. The student joining this project will advance the technology by implementing auto-fluorescence imaging to detect caries and/or periodontal disease without requiring a staining solution and developing an algorithm to automatically label individual teeth. A research ethics protocol for a pilot patient study of usability and imaging performance must also be devised. The student will collaborate with faculty members from the Schulich School of Dentistry to plan that study.

**Skills and Experience Necessary:**

Experience with, or strong interest in learning, Python coding for the Raspberry Pi.

Whereas this project is an ongoing activity of the Western Engineering Biomedical Club (WEBMC), preference will be given to active members of the WEBMC.
**Project Title:** Non-Invasive Sensor Systems to Characterize and Count Blood Cells

**Supervisors:** Dr. Michael Rieder, Molecular Medicine Group/Department of Paediatrics, Robarts Research Institute, Dr. Abdelbaset Elzagallaai, Drug Safety Laboratory/Department of Physiology & Pharmacology, Robarts Research Institute, Dr. Ehsan Kamrani, Biomedical Engineering, CellSees

**Location of Study:** Robarts Research Institute

**Project Description:**

The determination of white blood cell count (WBC) and red blood cell counts (RBC) and characterization of WBC populations is an important part of management of common acute and serious diseases. The only method currently available is to obtain a blood sample by venipuncture or finger prick and have the sample sent to a laboratory. This imposes a delay on diagnosis, is costly, is limited to a specific point in time and limits the availability of testing notably in resource-constrained or remote settings. In addition to the issues noted above, the requirement for blood for testing and the use of either venipuncture or a finger prick produce pain and anxiety.

To address this we have created a non-invasive sensor system visualizing blood cells in capillaries captured by capilloscopy followed by image analysis driven by an algorithm accessing a large image library to characterize and blood cells. We a prototype which we have validated in adult healthy volunteers. The next stage will be to conduct a series of cohort studies using our sensor our among people of color and then healthy children, finally in children with respiratory disease.

The student will work with the development team to modify our existing capilloscopy system and software based on the work done to date to reliably collect images from people of European, Asian, Native American and African ancestry. The primary outcome for the validation studies will be agreement between blood counts obtained by the sensor to those obtained by venipuncture and laboratory analysis.

**Skills and Experience Necessary:**

- Knowledge and experience in device development/fabrication
- Experience in software development and validation
- Being comfortable and effective in working as part of a multi-disciplinary team
**Project Title:** Development of a low-cost near-infrared spectrometer for biomedical applications

**Supervisors:** Keith St Lawrence, Medical Biophysics

**Location of Study:** Lawson Research Institute, Lab: F0-102

**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 on 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 practices of frugal engineering can benefit biomedical optics.

**Skills and Experience Necessary:**

Some familiarity with Matlab and a background in electronic engineering.
**Title:** Development of capacitive e-textile sensors

**Supervisor:** Ana Luisa Trejos

**Location:** This work will take place in the Wearable Biomechatronics Laboratory (WearME Lab) in ACEB 3410.

**Project Description:**

At the WearME lab, our current focus is on the development and integration of soft electronic components into smart mechatronic garments (e.g., shirts, sleeves, gloves). Some of our work has focused on designing embroidered sensors and weaved sensors using conductive thread with promising results. Based on our progress to date, this project focuses on evaluating a new method for creating conductive thread combined with weaving and embroidery. This work will aim to design a capacitive sensor using different embroidered and weaved patterns (plain weave, twill weave, satin weave, etc.), as well as using different stretchable fibres (spandex) combined with the new conductive thread. The work will involve evaluating the performance when the sensors are created using the different patterns. Once the best design is identified, we will use the sensor developed to measure biological signals.

**Skills or experience required:**

The student should be an undergraduate student with an interest in electrical engineering or mechatronics systems engineering.
**Project Title:** Development of a low-cost synthetic knee for surgical training and innovation

**Supervisors:** Ryan Willing, Faculty of Engineering

**Location of Study:** Thompson Engineering Building, TEB 306

**Project Description:**

The mechanics of the human knee are determined by the interplay of joint contact surfaces surrounding soft tissues. While knee phantoms exist for imaging studies, and fake knee models (such as those made by Sawbones) are available for education purposes, these can be expensive, and none match the actual mechanical behavior of the real knee. The objective of this project is to develop a technique for creating both population-average and patient-specific synthetic knees that can be manufactured inexpensively using consumer-grade 3D printing and provide a mechanical response to applied loads which is similar to that of the real knee. If successful, these could be used for training surgeons surgical techniques related to soft-tissue injuries (ACL and multi-ligament injury repair) and knee joint replacement (arthroplasty). They can also be used as low-cost but repeatable testing platforms for innovative surgical techniques or biomedical devices.

**Skills and Experience Necessary:**

Some experience with computer aided design (CAD) and additive manufacturing will be beneficial for this project.