Project 1: Circuit and system for biomedical applications, robotics and human-machine interface

Supervisor: Dr Yu Wu, Email: yu.wu.09@ucl.ac.uk

This project aims to create a motion capture system tailored for sports, utilising IMU (Inertial Measurement Unit) sensors combined with machine learning to accurately monitor athletes' movements during training or competitions, offering immediate performance feedback. The hardware setup includes multiple IMU sensors strategically placed on the athlete's body, such as arms, legs, torso, and head, to measure three-dimensional movements, including acceleration, velocity, and orientation.

On the software front, the data from these sensors will be processed by a microcontroller and then sent wirelessly to a computing device. Machine learning algorithms will analyse this data to deduce valuable insights into the athlete's movements. For the machine learning component to accurately identify and analyse various movements, it will be trained using a comprehensive dataset of motion capture data from professional athletes, helping it to pinpoint crucial performance-enhancing factors.

Once the algorithm is adept at recognising different movements, the system will offer instantaneous feedback on the athlete's performance, highlighting areas for improvement. For instance, if an athlete's form is lacking during a specific exercise, the system will promptly signal this, suggesting necessary adjustments. This advanced feedback mechanism aims to pinpoint and rectify performance deficiencies, thus optimising the training outcomes.

Necessary skills expected:

Experienced with developing IMU on flexible PCBs using Altium Designer, Wi-Fi with ESP32, embedded C programming, Python, and some CAD design is a plus.

Potential benefits:

· Enhance critical thinking and problem-solving skills.
· Provide hands-on experience and the opportunity to contribute to groundbreaking work.
· Opportunities to work with athletes at Stone X Stadium.

Project 2: Flexible cylindrical pressure sensor for AI fencing referee

Supervisor: Dr Thomas Gilbert, Email: thomas.j.gilbert@ucl.ac.uk

An AI referee needs to determine two factors to assign a valid point in fencing: the validity of an attack and the establishment of priority—a rule that identifies which fencer gets the point during simultaneous hits. Electrical scoring machines can detect valid attacks, but ascertaining priority remains a challenge. The latest advancement in this field is the "Allez Go," an AI system that uses visual skeleton motion capture to indicate priority in fencing broadcasts [1]. Its effectiveness is limited by the inability to track blade positions, essential for distinguishing between the upper and lower blade contacts and identifying the attacking fencer.

To enhance accuracy, incorporating sensors to track blade movements is proposed. IMUs attached to the blade's guard could analyze motion, providing data to determine the initiator of an attack by comparing acceleration patterns. This approach draws inspiration from similar technologies, such as IMUs on golf clubs predicting ball trajectories [2], and their application on fencers' forearms for dynamic analysis during competitions [3]. Besides IMUs, this planned research aims to develop a network of flexible non-planar pressure sensors designed to be easily implemented on foils and capable of detecting pressure changes in blade contacts through shear force and bending during swishing motions [4].

[1] AllezGo: allzgo.com [2] IMU golf tracking:
https://ieeexplore.ieee.org/document/6337519 [3] IMUs on fencer arms:
https://ieeexplore.ieee.org/document/9250439 [4] Non-planar pressure sensor
https://www.mdpi.com/1424-8220/24/1/222 ;Yuki’s blade tip tracking project :
https://research.rhizomatiks.com/s/works/fencing_tracking/en.html

Requirements:
- A good working knowledge of Arduino or embedded C coding
- Experience designing PCBs using software like KiCAD/Eagle/Diptrace
- Precise soldering experience, both by hand and using an oven
- Happy to be in the lab daily

Benefits:
- Gain an insight into the research lifestyle, very useful for students considering an MSc or PhD position. This experience will be very valuable on your CV when applying for these positions.
- Gaining an in-depth understanding of the PCB manufacturing process, including flexible etching techniques and the use of precision LASER cutting.
- Learn how micromechanical structures can be used in sensors
- Potentially create a new type of pressure sensor and write a conference paper in a conference such as UBICOMP/ISWC.

Project 3: Photonic integrated circuit packaging: design and testing

Supervisor: Dr Alfonso Ruocco, Email: a.ruocco@ucl.ac.uk

Integrated photonics, implemented on scalable technology, has the potential to revolutionize several aspects of optics such as communications, computing, sensing, spectroscopy, imaging, beam steering, and quantum information. Photonic Integrated Circuits (PICs) can be manufactured with standard CMOS-compatible technologies, delivering high-yield and low-cost components. While the packaging for microelectronics has been largely addressed, the PIC counterpart, however, poses a challenge to their manufacturability, giving rise to the so-called “package bottleneck”.

The target of the internship is to design, implement, and test PIC packaging for research purposes. The outcome of the internship will bridge the gap between PIC lab testing and PIC commercialization by delivering a custom packaging solution, yet compatible with several PIC technologies and architectures. This technological solution will allow for an in-house implementation of a carrier PCB capable of accommodating the PIC and its electrical and optical connections via wire bonding and fibre attachment, respectively. Thermal management of the PIC is also a critical aspect to account for.

The internship is envisioned to evolve as follows:

1) Understanding of PIC fundamentals: Coupling light and electrical signals in and out.
2) PCB design for integrated photonics applications.
3) PCB fabrication (carried out by EEE lab staff).
4) PCB electro-optical assembly.
5) Packaged PIC testing and characterization.

Skills Expected and potential benefits:

Knowledge of PCB design software and analog/digital electronics are required. Basic knowledge of optical and photonics components and RF signals is desirable. At the end of the internship, the intern will have developed a deeper understanding of integrated photonics circuits and PCB design at the verge of two worlds: electronics and photonics. Last but not least, hands-on experience of PCB (DC and RF) design and PIC testing will be gained.