TriSense: A Wearable Sensor System for Triathlon Technique Feedback

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Abstract* — *TriSense is a low-cost wearable sensor pod for triathlon technique feedback. Existing sports wearables provide useful metrics like pace, distance, and heart rate, but give limited feedback on body position and technique. The initial prototype focuses on swimming, where beginners often struggle to judge body roll and breathing rhythm without a coach. A waterproof lower-back inertial measurement unit (IMU) records acceleration and gyroscope data locally to a microSD during a training session, before post-session analysis estimates body-roll symmetry, stroke rhythm, rest/turn events and fatigue-related movement changes. The same hardware can be tuned and adapted for cycling posture and running cadence. By starting with a low-cost waterproof sensor pod, rather than integrated smart textile sensors, TriSense focuses on making movement-quality feedback more accessible to amateur athletes while being realistic to prototype, test and manufacture.

I. Introduction / Background

Triathlon combines swimming, cycling and running, so athletes are expected to manage techniques across three different movement patterns while also building fitness. For new triathletes, the biggest limitation is often not motivation but feedback. A coach can see a hip drop, over-rotation, breathing asymmetry or a collapse in running posture, whereas the athlete tends to focus on pace, heart rate and distance after the session.

This feedback is of great importance as triathlon training is associated with high overuse problems, particularly in running. A systematic review of short-course triathletes reported injury incidence rates of 15.7-24.3 injuries per 1000 athlete exposures [1]. Swim-related injuries report injuries with a lower frequency, but swimming is the least visible discipline to self-correct and is hard to judge when moving underwater without external aid. Research on first-time triathlon participation suggests that novice athletes commonly report uncertainty around training progression and low confidence in swimming ability, reinforcing the importance of accessible feedback mechanisms during early skill development [2].

Hence, TriSense will be deployed first for the swim leg. The device is a small waterproof pod worn on the lower back, aligned with the torso. Most Tri suits have a compressed back pocket where the pod can sit snugly during training. If the user does not have a Tri suit, an elastic/swim strap can be provided for the pod to be placed. The pod records IMU data that is processed after the swim session to explain how their movement data and how it had changed from previous swim sessions.

II. Related Work

Commercial endurance wearables are strong at tracking performance. Watches and smart goggles can show pace, distance, stroke rate, heart rate and calories. The FORM Smart Swim 2 provides real-time in-goggle metrics and app-based analysis. [3]. While these products are valuable, they prioritise output metrics instead of the simple, body-mounted view of the torso position and consistent technique across training sessions.

Research shows inertial sensors to be suitable and useful tools for analysing swimming phases, stroke mechanics and body kinematics [4]. A later review on real-time swimming wearables highlights the potential of feedback systems for swimming analysis, while emphasising practical design constraints, including waterproofing, sensor placement, comfort, battery life and underwater communication reliability, which directly influence wearable usability in real training environments.[5]

TriSense addresses the gap between specialist lab analysis and consumer performance tracking. Version 1 avoids complex physiological sensors such as ECG, EMG or sweat chemistry because these increase waterproofing, cost, customer privacy and interpretation challenges. Instead, it will focus on of interpretable movement features from one robust location. During swimming, data is logged locally to a microSD, after the session once the pod is removed from the body, Bluetooth or app synchronisation can be used. The optional vibration motor is included for start/stop confirmation or future basic haptic alerts, not full live coaching.

III. Imagined or Existing Prototype Sketches/Drawings/Photos

A. *Prototype General Requirements*

The prototype consists of a Seeed Studio XIAO nRF52840 Sense, LiPo battery, microSD storage, wireless power receiver coil, reed switch, status LED, vibration motor and sealed enclosure.

The XIAO nRF52840 Sense is great for prototyping because it is a combination of a Nordic nRF52840 microcontroller, Bluetooth Low Energy and a built-in 6-axis IMU in a 21 x 17.5 mm board, with onboard battery charging support [6]

A charging port is avoided in the sealed design by using a Qi or inductive receiver coil to provide 5 V through the case wall; commercial receiver modules already provide 5V outputs suitable for low-power prototypes [7]

The pod deliberately avoids a screen to reduce distraction and complexity. Detailed feedback is intended to be reviewed after training through a phone app or offline analysis. A high-level overview of the system can be found in Figure 1.

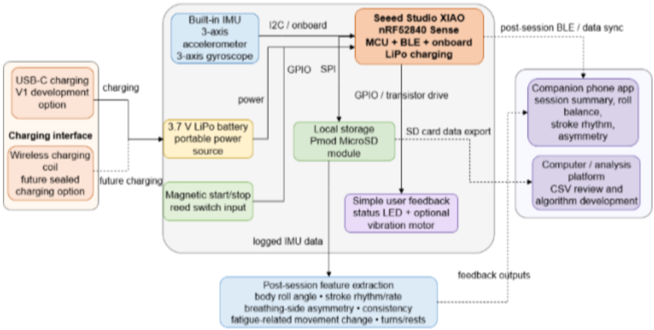

Figure 1: High Level System Overview

Figure 2 shows lower-back position of the pod in 2 scenarios.

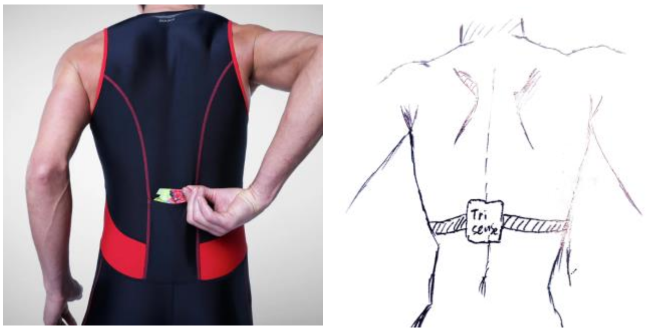

Figure 2 Triathlon Compression suit with a back pocket where pod sits and sketch of the pod with an elastic band

B. The circuit design

Figure 3 gives an overview of the circuit diagram. The XIAO nRF52840 Sense is placed centrally and fixed within the enclosure so that the onboard IMU follows torso movement rather than moving independently inside the case. The microSD module enables local data logging, while the reed switch allows magnetic start/stop control without an exposed button.

C. The metrics and algorithm

At the start of each session, the user performs a short calibration while standing or sitting upright so the pod can record the baseline orientation in the vertical position. The device then samples acceleration and angular velocity at a fixed rate, storing raw data for offline analysis. The first software goal for Version 1 is not to “coach” the athlete live, but to produce reliable, explainable post-session summaries.

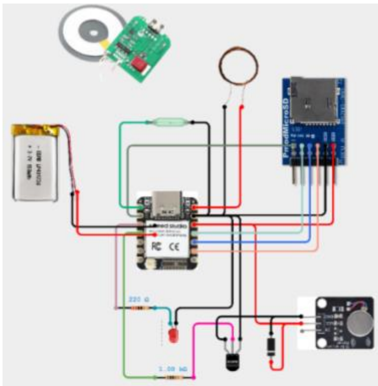

Figure 3 Circuit Diagram

Raw values are centre-aligned (sample – baseline). Including timestamps, acceleration x,y,z and gyroscope x,y,z.

Within each data collection window, the six measurements are accumulated in Table 1. The Version 1 metrics are deliberately small in number so that each can be validated and explained.

Feature	How it is estimated	Why
Body roll angle	Torso rotation from accelerometer/gyroscope data	Shows left/right body rotation during swim
Overall body angle	Gyroscope data	Shows whether the body remains fully horizontal during swimming
Stroke rhythm	Repeating angular-velocity peaks	Shows timing and cycle consistency of stroke
Breathing side asymmetry	Compare left and right roll patterns	Detects imbalance linked to breathing side
Fatigue related technique change	Change in roll/rhythm/asymmetry over time	Possible technique breakdown
Rest/turn detection	Low-motion periods and acceleration spikes and gyroscope readings	Data separated from active swimming

Table 1: Metrics recorded by TriSense

The fatigue-related measurement is not a medical fatigue diagnosis, but a practical indication that movement quality has changed during the session.

The software will begin with simple signal-processing rather than a black-box machine-learning model. Body roll angle will be estimated from accelerometer and gyroscope data, with filters used to reduce noise and drift. Repeating patterns in angular velocity will segment strokes. The app can then show trends such as whether roll symmetry or stroke rhythm becomes less consistent over a session.

Initial validation will compare pod outputs against labelled video of pool lengths from swimmers of different ability levels and genders. Early success criteria are reliable waterproof operation for more than two hours, clean timestamped data, correct rest/turn segmentation and repeatable left/right roll trends. Future work will replace modules with a compact PCB.

D. *Initial case design*

To protect the electronics underwater and keep the IMU fixed relative to the body, the enclosure was designed around real component dimensions. The concept uses a rounded 6 cm by 7 cm case, clipped lid and gasket seal to reduce exposed openings while still allowing access for repair. The pod should sit in a back pocket or elastic strap without discomfort under a wetsuit or swimsuit. Figure 4 shows the CAD casing and internal component layout.

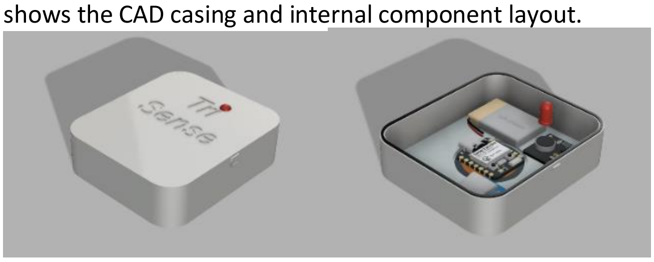

Figure 4: Casing with a closing clip mechanism and electronic Components stored inside TriSense

IV. Responsible innovation

TriSense has been designed with accessibility, privacy and safety in mind. Triathlon can be an expensive and intimidating experience for beginners, especially without access to coaching or specialist analysis tools. TriSense aims to lower this barrier by providing a low-cost sensor pod that helps users understand movement patterns between sessions without replacing a coach.

Because the device collects personal movement data, the first prototype prioritises local logging rather than constant cloud connection. The system must also avoid overclaiming: TriSense would not diagnose injury, fatigue or medical conditions, but instead present movement-based features such as roll consistency, stroke rhythm and asymmetry to aid in their mitigation. These outputs would need validation against video analysis, coach feedback or labelled swim sessions before strong claims about technique correction are made.

Inclusivity and sustainability are also central to the design. Swimming technique varies with body proportions, flexibility, confidence and experience level, so future testing should include different genders, body types and ability levels. The removable pod approach also supports repairability, as the sensing unit can be removed, repaired or upgraded separately instead of permanently embedding electronics into a garment.

V. Author bio(s) / experiences

<u>Abhay Bhabhu:</u> I am an MEng Engineering Mathematics student at the University of Bristol and an IET Future Talent Award recipient. During my year in industry at IAAPS, I worked on embedded systems and EV test-rig projects, including an Arduino-controlled robotic arm integrated with AVL PUMA. This gave me experience with sensor wiring, system documentation, validation and practical prototyping. Outside of university, I am training for my second triathlon, which is what first made me interested in using wearable sensors to make technique feedback more accessible to beginners.

<u>Lady Payan Cepeda:</u> I am a Beng Electrical and Electronic Engineering graduate at the University of Bristol, starting an MSc in Microelectronics Systems Design. My thesis focused on hardware-software co-design for coherent optical communication, and I was awarded a UK Electronics Skills Foundation scholarship with an offer to do my Year in Industry with Cadence Design Systems as an Application Engineer for EDA (Electronic Design Automation) tools. As a runner and prospective triathlete, I am particularly interested in ensuring TriSense is designed and tested for women as well as men, rather than treating one body type as the default, closing the gender data gap.

Figure 5 Picture of Abhay and Lady at the Bristol AJ Bell Great Run

VI. References

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