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Project

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Introduction

Accurate measurement of human movement is essential for both **elite sports** and **medical applications** such as rehabilitation and the study of chronic or neurodegenerative diseases. Traditionally, body kinematics assessment has relied on laboratory systems or wearable devices based on inertial sensors (IMUs), whose accuracy in real outdoor conditions is limited. At the same time, Global Navigation Satellite Systems (GNSS) have been widely used in sports for over a decade, mainly for tracking trajectories and positioning. The **EU GESTUS project, involving 8 partners across 4 countries, aims to revolutionize movement tracking by fully integrating GNSS and IMU approaches** to achieve centimeter-level accuracy in human kinematics, even outdoors.

Methodology

The project is developing a wearable device that integrates miniaturized GNSS and IMU sensors, connected to a cloud-based platform for data processing, visualization, and clinical reasoning support (Fig. 1).



Fig. 1. Gestus overview

Devices are rigidly attached to the subject's body parts of interest. In our preliminary tests we used 3 devices put on sternum and the two feet (Fig. 2). The devices record the IMU data and the GNSS satellite observations.

Results

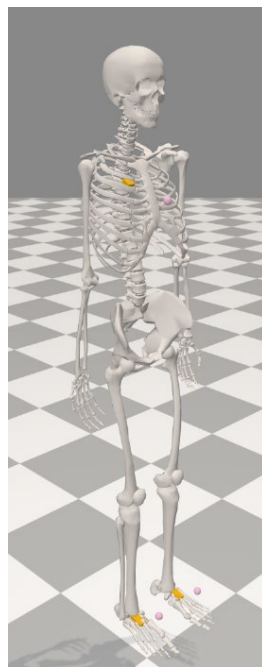


Fig. 2. Body model with virtual IMUs (yellow) and GNSS markers (pink) associated

Design phase completed : all main hardware and software components selected and evaluated.

System architecture: processing software and cloud platform defined.

Development: devices and software components currently under implementation. (Fig. 3)



Fig. 3. Device render image

GNSS data processing (Fig. 4):

- Differential positioning with respect to local base station.
- Achieved precision: **~1 cm** (good satellite visibility, smooth motion).
- **GREP algorithm** mitigates multipath effects, improving accuracy.

IMU data processing:

- Orientation estimated for each device.
- Data fused with GNSS through interpolation to synchronize frequencies.
- Combined in a **scalable musculoskeletal model** with virtual IMUs and markers.

Kinematic reconstruction:

- Inverse kinematics computed using GNSS (as markers) + IMU orientations.
- Joint constraints applied to approximate real motion.
- Output: **3D reconstruction of joint and whole-body movement**.

Devices 3D Trajectories

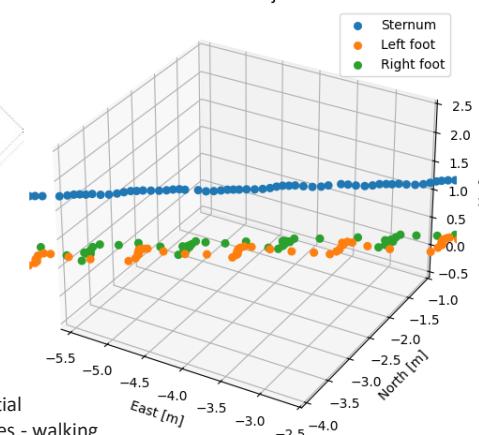


Fig. 4. Spatial coordinates - walking

Conclusions

GESTUS aims to overcome the trade-off between precision and usability in wearables, redefining movement measurement in sports and medicine. The impact is twofold: athletes and coaches gain new tools for **performance optimization**, while the medical community benefits from reliable data for rehabilitation and movement disorder studies. GNSS-IMU integration opens new possibilities in human movement science that were previously unattainable.