Inside-Out Tracking Sensor Suite

ODTÜ
METU

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PROJECT DESCRIPTION

- Virtual reality technologies are rapidly spreading in entertainment, education and industrial sectors. Therefore, the demand for portable, flexible and immersive VR systems is increasing.
- Current VR systems usually use external sensors, which restricts the user's freedom. The Inside-Out Tracking Sensor Kit for Virtual Reality Applications project aims to overcome this problem by switching to an inside-out tracking system.
- In this way, it can achieve the goals of providing users with more immersive and free virtual environments, encouraging innovation and increasing the accessibility of VR for wider applications.
- This project aims to provide a portable, flexible, and immersive VR experience by implementing an inside-out tracking system that uses sensor fusion techniques to accurately track head movements using a camera and IMU.

COST BREAKDOWN

- MicroController $ 174.809
- BNO055 $ 47.666
- Camera Module $ 47.553
- Connection $ 4.9
- Power $ 40.274
- Headset Design $ 7.73

Total Cost: $322.93

REQUIREMENTS

Customer Requirements:

- The system should obtain 6-DoF head pose information
- The system should be able to render a 3D model of the user head
- The system should be lightweight not to disturb the user
- The headset should be compact

Engineering Requirements:

- The system shall estimate headset orientation with an error margin not exceeding ±10 degrees.
- The system shall provide positional tracking with an error less than ±10 cm
- The maximum delay at the end of rendering will be 200 ms.
- The system shall operate continuously for at least 4 hours on portable battery power.
- 3D Head Model should be rendered at 20 FPS with smaller delay than 2 seconds

DELIVERABLES

- Complete Hardware Suite
- Real Time Pose Estimation Software
- Wireless Data Transmission System
- Synthetic Head Model Visualization
- User Manual

ENERGY BUDGET

- Raspberry Pi 5 15 W
- BNO055 60 mW
- Camera Module 990 mW

METHOD OF SOLUTION

- The method of solution comprises four subsystems, each explicitly meeting its design requirement: the BNO055 IMU provides fused quaternion and Euler-angle outputs with an angular error under ±10°, satisfying the orientation accuracy target.
- The Raspberry Pi Camera Module 3 running ORB-SLAM3 on the Pi 5 delivers x/y/z position estimates with error below ±10 cm, meeting the positional accuracy goal.
- The communication subsystem which is UDP-based wireless transmission from the Pi 5 achieves one-way latency under 6 ms (TCP-tested), comfortably under the 20 ms limit.
- PC Python/VTK rendering runs at approximately 20 FPS with end-to-end latency below 200 ms which meets the design requirements.
- Apart from that 20 000 mAh, a 5 V/3 A power bank supplies the system which draws up 2.5A on average (3A max) long enough for 4.18–4.93 hours of continuous operation. Therefore, it satisfies the operation time design requirement which is at least 4 hours of operation.
- The camera module weighs 50 g, SBC module weighs 260 g, Power module wighs around 400 g.

CONSTRAINTS

- The starting position should be 1m away from features.
- The user should not move his/her head faster than 30°/s for system to work properly.
- The user should not walk faster than 20 cm/s in order system to work in a proper way.
- Users should operate the product in well-lit conditions for optimal performance.
- Before running the algorithm, users must securely fasten the equipment and ensure it's properly seated.

TEST RESULTS

Parameter	Mean Absolute Error (°)
Roll Angle	3.40
Pitch Angle	2.02
Yaw Angle	2.93

Parameter	Mean Absolute Error (cm)
X position	10.0
Y position	1.33
Z position	15.14

SYSTEM DIAGRAM