



IOT-BASED SMART ELDERLY MONITORING SYSTEM WITH FALL DETECTION

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INTRODUCTION

Taiwan has entered an aging society, and traditional caregiving models often face manpower shortages and rely on passive monitoring, making it difficult to provide timely rescue during emergencies or offer diverse, well-rounded care for the elderly. We therefore aim to develop an IoT-based smart home care robot integration system that combines hardware and software to enhance emergency response, reduce home safety risks, and provide daily assistance and companionship. The system uses MediaPipe for human pose recognition to enable real-time fall detection, paired with a smart wristband for physiological monitoring. On the IoT side, Firebase and AWS Lambda serve as the backbone for data access and long-term analysis, working alongside a Flutter-based caregiver app and the Zenbo robot to build a system with proactive companionship, mobile alerts, and shared medical data.

EXPERIMENT PROCEDURES

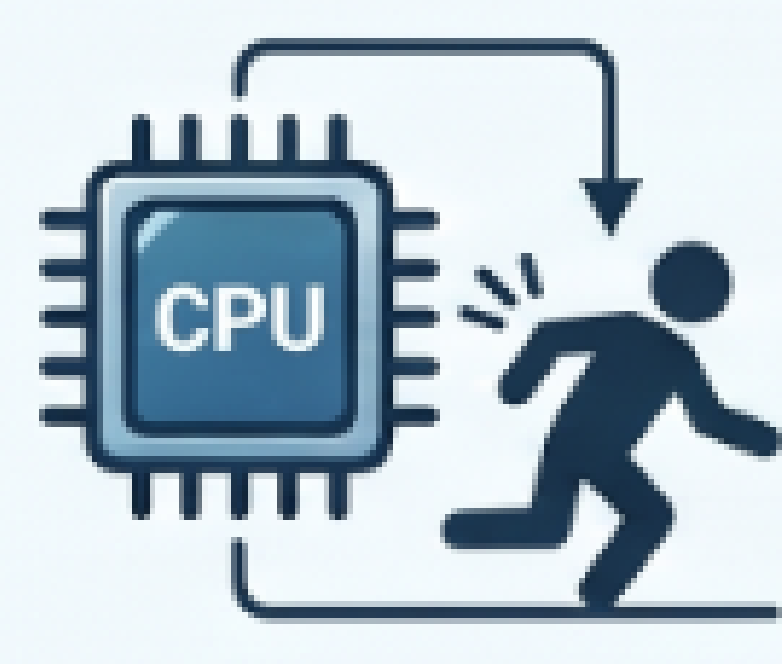
- Technical Performance Testing • Simulated daily movements (sitting, bending, crouching) vs. simulated falls • Measured detection accuracy & false alarm rate • End-to-end latency test across ESP32 → AWS Lambda → Firebase → ThingSpeak / Zenbo
- User Evaluation (Elderly Participants) Pre-test → System Operation → Post-test • Pre: Digital Literacy Questionnaire • Post: Short STAM (technology acceptance) SUS (system usability)

Stage 1: Multi-Modal Perception & Sensing



MediaPipe
33-point skeleton
tracking

Stage 2: Edge-to-Cloud Dual Decision Making



Local Vy posture
variation analysis

Stage 3: Closed-Loop Active Response



Stage 4: Evaluation & Empirical Evidence

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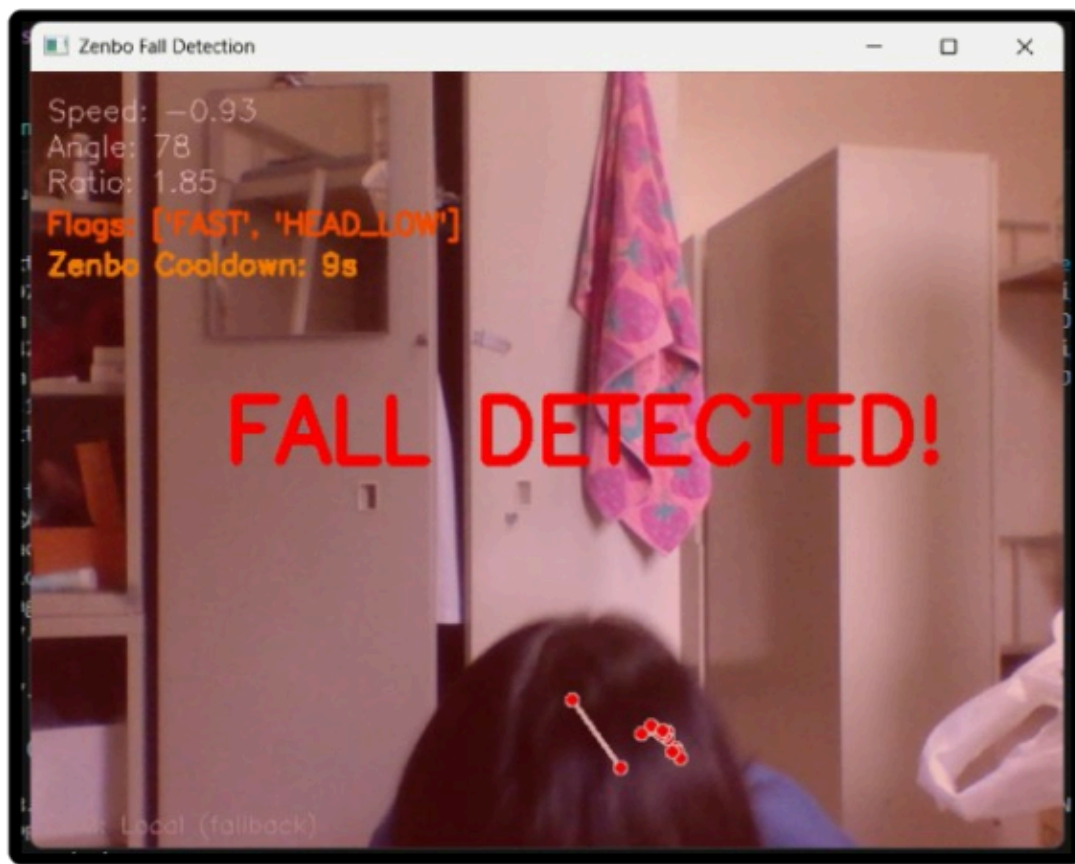
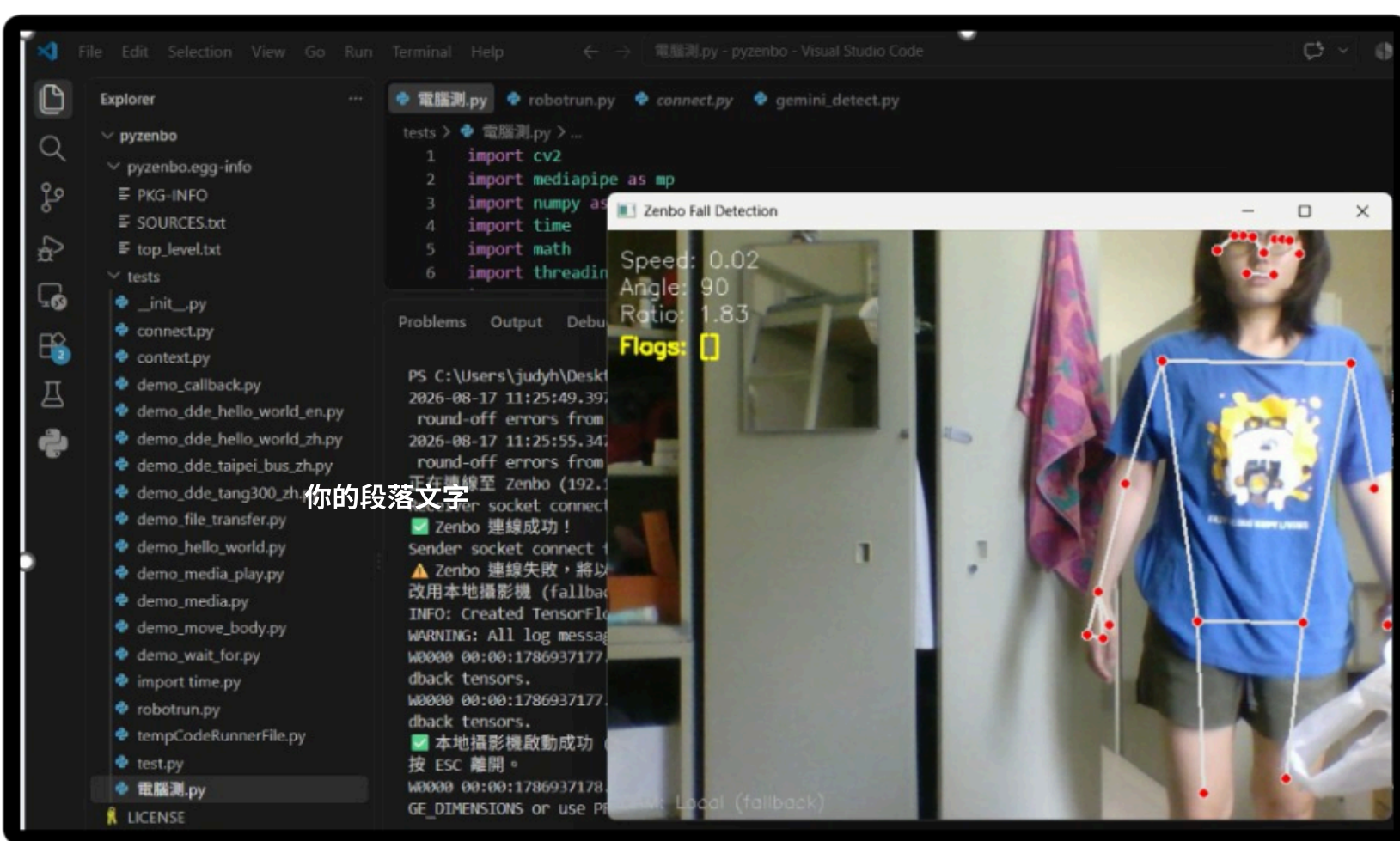
RESULTS & DISCUSSION

Cloud Architecture & IoT Integration

The system builds a dual-track cloud data pipeline. Physiological data is collected via a wearable sensor and transmitted through ESP32 to AWS IoT Core, where AWS Lambda performs real-time decision logic—checking physiological thresholds and validating suspected fall coordinates through spatial vector calculations. ThingSpeak provides real-time dashboard visualization of vital signs and system status for caregivers, while Firebase (Cloud Firestore) stores long-term health records, enabling low-latency access even under concurrent requests from multiple devices such as Zenbo and family apps.

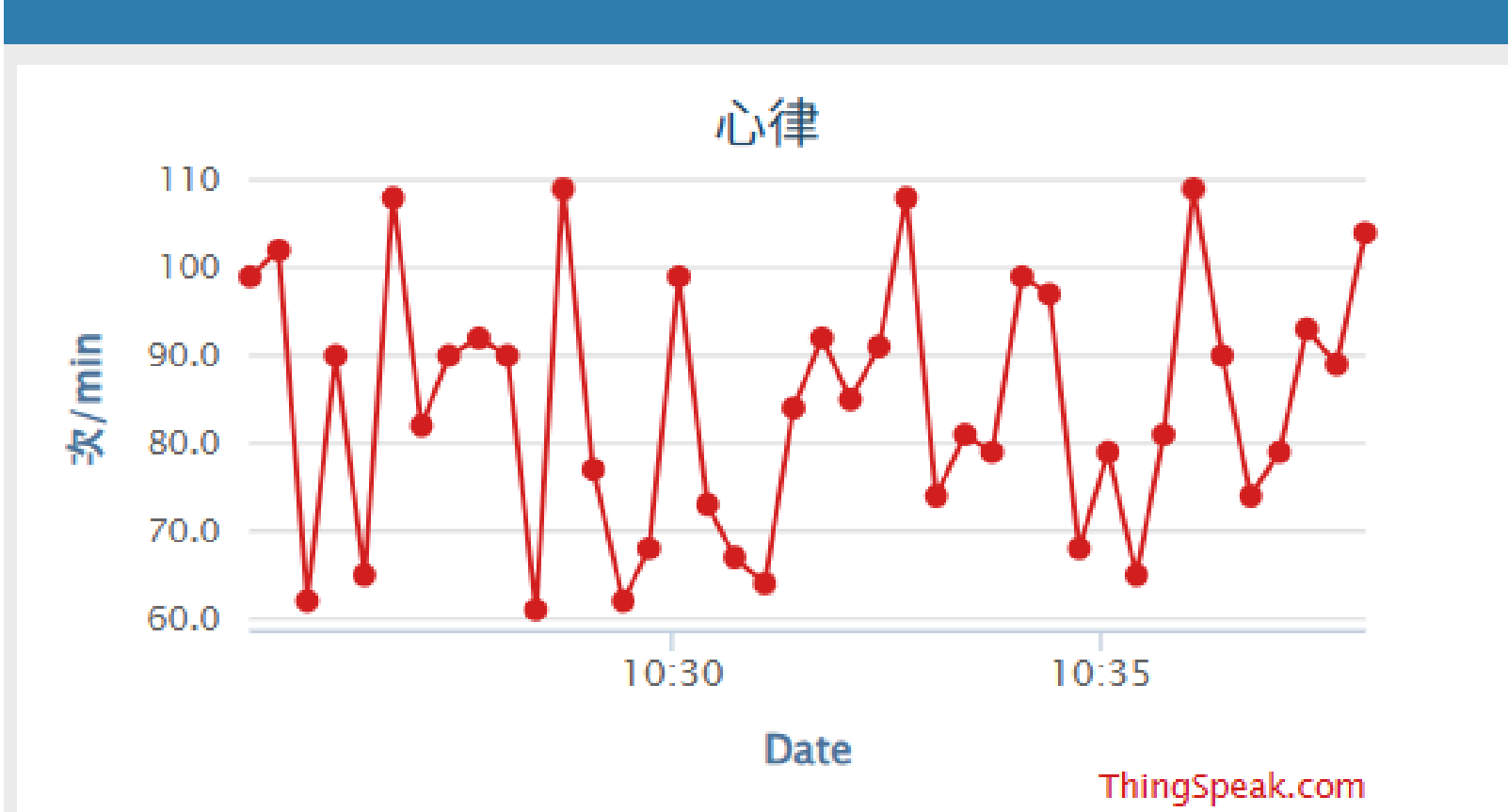
System Validation & User Evaluation

System performance is validated through fall-detection accuracy testing (comparing daily activities like sitting and bending against actual falls) and end-to-end latency testing across the full IoT pipeline. User evaluation includes the Older Adults' IT Ability scale, the Short Smart Technology Acceptance Model (Short STAM), and the System Usability Scale (SUS) to assess perceived usefulness, ease of use, and interface intuitiveness for both the Zenbo interaction and the Flutter caregiver app.

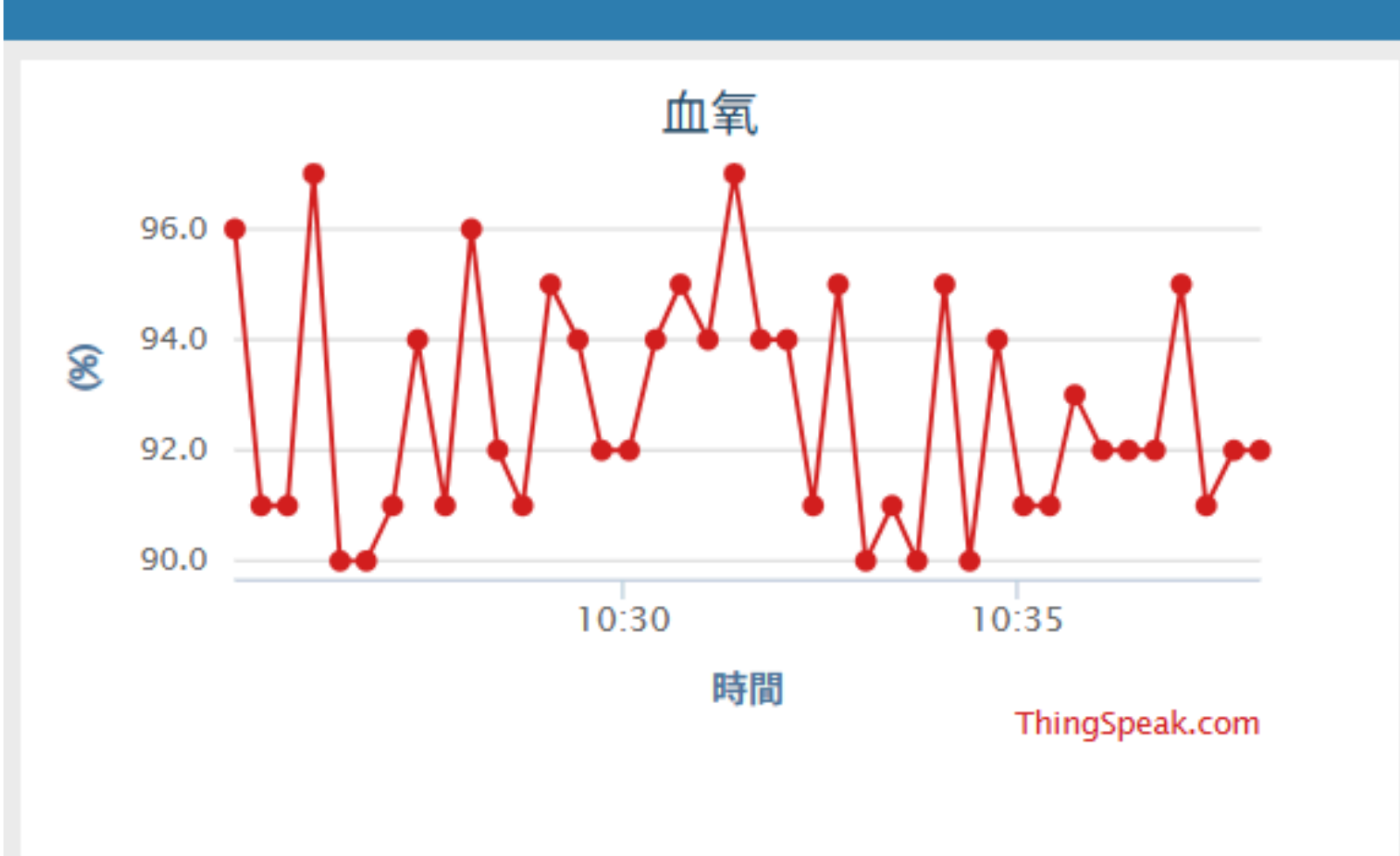


(c)Human Pose Estimation & Fall Detection

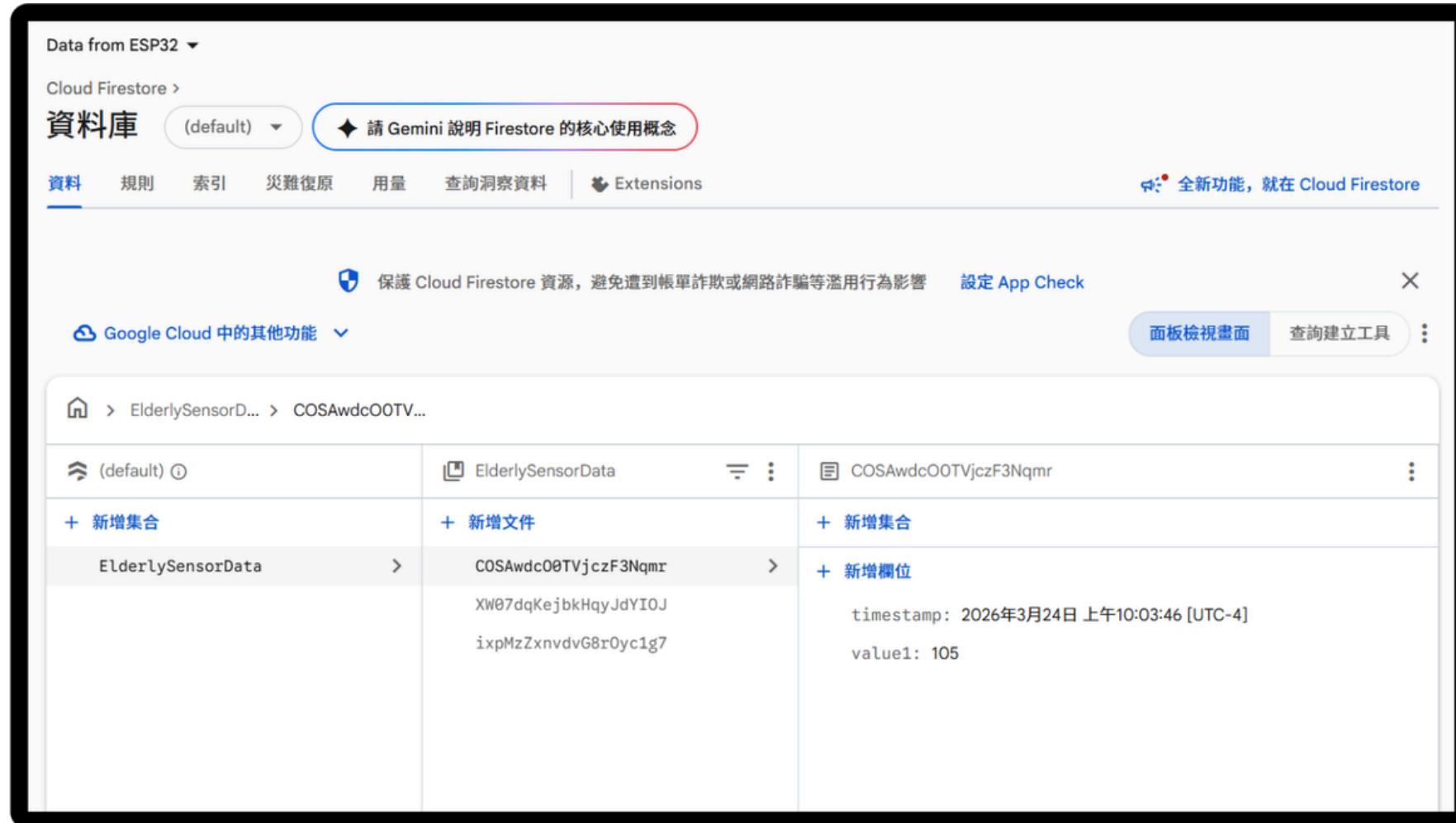
字段 1 图表



字段 2 图表



(a)Real-Time Vital Signs Monitoring



(b)Cloud Firestore

Fall Detection via MediaPipe Pose

The core visual monitoring technology uses the MediaPipe Pose framework to extract 33 human skeletal keypoints in real time through non-invasive image processing. The algorithm tracks the elderly user's center-of-gravity and shoulder displacement, computing vertical velocity (Vy) and the body's angle relative to the ground to build a precise fall-detection logic. To avoid false alarms, the system incorporates a stillness-monitoring mechanism: if abnormal posture change is followed by 5–10 seconds of no movement and no voice response, a fall event is confirmed and the alert protocol is triggered. All image processing occurs on the edge device—only skeletal coordinates are uploaded to the cloud, never raw video—ensuring both detection accuracy and user privacy.

CONCLUSION

This study integrates image-based fall detection (MediaPipe Pose), physiological sensing, and a dual-track cloud architecture (AWS Lambda + Firebase + ThingSpeak) with a companion robot (Zenbo) into a closed-loop smart elderly care system — addressing the fragmentation of existing single-function monitoring solutions. By processing pose estimation on-device and transmitting only joint coordinates, the system balances detection accuracy with home privacy. Results from technical testing and elderly user evaluation (STAM, SUS) are expected to inform the feasibility of deploying integrated, closed-loop smart long-term care systems in real home settings.