A Smart Wearable IIoT Device for Production Support and Human-machine Collaboration*

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***Abstract*—This paper presents a smart wearable Industrial Internet of Things (IIoT) device that operates as an industrial production support system and a human-machine collaboration assistant. The device is composed of two parts, a smart watch and a smart band. Both of them include motion sensors capturing the user's movements and a smart device performing data processing, fault detection, and communication with other industrial devices. The system runs a trained AI model that is able to detect the tasks performed by the user and assist him in his work. The model is trained to detect forgotten or improperly performed tasks and notify the user about them. The system also promotes human-machine collaboration by communicating with industrial systems and assisting the human users in operating them.**

***Index Terms*—IIoT, Wearable devices, Production support system, Industry 4.0, Industry 5.0, Industrial control systems.**

I. Introduction

The evolution of computational systems and artificial intelligence are driving Industrial production systems from traditional control systems into connected smart systems where physical equipment, cloud services, electronic control systems, and artificial intelligence coordinate to create efficient, intelligent, and flexible production systems. While Industry 4.0 laid the foundation of this evolution through automation, digitalization, connectivity, and data-driven decision-making, Industry 5.0 builds on it by promoting human-centric, resilient, and sustainable production systems. Consequently, modern automation technologies are able to optimize industrial processes, increase productivity and efficiency, and strengthen collaboration between human operators and intelligent control systems, fostering more adaptive, responsive, and user-oriented manufacturing environments [1], [2].

The realization of human-centered manufacturing increasingly relies on technologies that integrate computing, communication, and decision support in the production environment. Edge computing enables data processing close to industrial assets, reducing latency and supporting time-critical applications, while cloud computing provides scalable storage, centralized data management, and powerful computational resources for large-scale analytics and remote access. Industrial Internet of Things (IIoT) establishes the connectivity between machines, sensors, controllers, and information systems, allowing continuous acquisition and exchange of operational data. Wearable sensors and smart mobile devices further enhance this ecosystem by delivering information to operators and facilitating real-time interaction with industrial processes while promoting the human's safety and well being in the industrial environment. Moreover, Artificial Intelligence (AI) transforms the collected data into optimized decisions through predictive analytics and anomaly detection allowing operators to effectively react to dynamic production conditions [3]. The integration of these technologies augment human capabilities, improve situational awareness, and promote effective and safe human-machine collaboration.

Motivated by the need for human-centric production support systems, this paper proposes a smart IIoT system with wearable sensors assisting human operators to perform their tasks with minimum errors and to interact safely and surely with the different industrial machines.

II. System Design

The proposed system includes both systems and methods. The systems part includes smart sensors, a central computing unit and a human-machine interface that are specifically adapted to support industrial applications. While the methods part includes an AI model that runs inside the developed smart system and the communication techniques with the different industrial equipment. The smart sensors include wearable motion sensors that are able to track the movements of the human operator and his tasks. They also include sound and vibration capabilities to notify the operator about any missing tasks or required interactions with the industrial equipment. The operator interacts with the developed system through a graphical interface displayed on a touch screen. The smart device should have the computational capabilities to run an AI model that can detect missing tasks and support the human operator in his work. All these devices should also have the communication capabilities to share data between them and with the other industrial equipment. To facilitate the operator's movement and to make the system always in his hands, the previously mentioned devices can be encapsulated in a

This work is a result of Agenda Microeletrónica /Amkor Technology Portugal (ATEP), investment project 19 – ATEP - nr. C644916358-00000028, financed by the Recovery and Resilience Plan (PRR) and by European Union - Next Generation EU

smart-watch and/or smart band. However, the smart watch and smart band have to be optimized in size and weight to make them comfortable to wear and not impede the user's work nor delay it. In addition to supporting the operators in their tasks, the proposed system can also be used to train new users to perform their tasks based on the data collected from previous users. The proposed design of the smart-watch and smart band is given in Figures 1 and 2. The smart component used in both of them is an ESP32 microcontroller that comes equipped with two processing cores running at 240MHz, wireless communication capabilities including WiFi and Bluetooth, 8MB of memory, and 32 GPIO pins. Both of the smart-watch and smart-band are equipped with a 9 axes inertial measurement units and can perform sensor data fusion in real-time to detect the operator's movements. The smart-watch is equipped with a touchscreen interface and has sound and vibration-based notification capabilities. Both of the systems are battery operated and include advanced power management to optimize battery life.

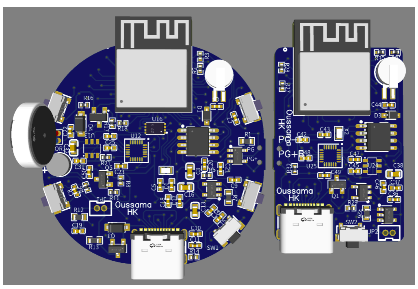

Fig. 1: Smart watch and smart band printed circuit board design.

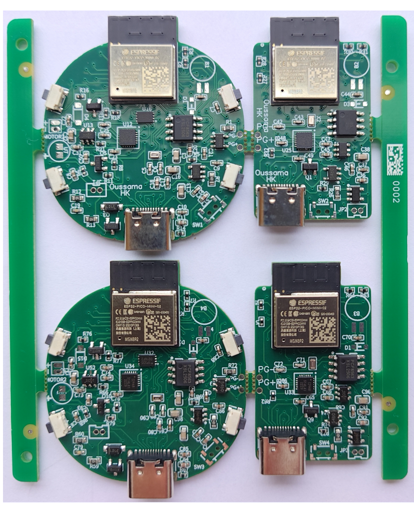

Fig. 2: Smart watch and smart band printed circuit board result.

III. PCB test program

To validate the functionality of the developed printed circuit board, a comprehensive hardware verification procedure was carried out by testing each integrated peripheral individually. Rather than simply confirming device detection, the tests exercised the primary functions of each component under normal operating conditions, including communication, data acquisition, user interaction, and power management. This approach ensured the correct operation of both the hardware design and the associated firmware drivers before system integration. These tests, are given in Table I.

TABLE I: PCB validation tests

Test	Procedure	Validated parts
Display	Draw graphics, text, change backlight	SPI; LCD driver; backlight control
Touch panel	Detect taps and drag	Touch controller; I2C; touch interrupt
Flash memory	Write, read, erase data	SPI memory
IMU	Read quaternion values, Movement detection	I2C; IMU; DMP; IMU interrupt
RTC	Set time, read time, set alarm	RTC; alarm interrupt
Buzzer	Generate songs	PWM output; transistor
Motor	Generate vibration frequencies	PWM output; transistor
LEDs	Generate different colors	GPIOs
Battery	Read voltage and charge status	ADC Circuit; Charger IC
Buttons	Detect clicks	GPIOs
Power outputs	Enable/disable peripherals	Power circuit

IV. Conclusion

This paper proposes an IIoT device that can be used to support human operators in their tasks and reduce production errors, downtime and waste. The design of the device has been shown in addition to the test of each of its components. future work will focus on the software part of the device.

Acknowledgment

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