Demo Abstract: A Modular and Reconfigurable Sensing and Actuation Platform for Smarter Environments and Drones

Minghui Zhao
Columbia University
New York, New York, USA
mz2866@columbia.edu

Yanchen Liu
Columbia University
New York, New York, USA
yl4189@columbia.edu

Avik Dhupar
Columbia University
New York, New York, USA
ad3910@columbia.edu

Kaiyuan Hou
Columbia University
New York, New York, USA
kh3119@columbia.edu

Stephen Xia
Columbia University
New York, New York, USA
sx2194@columbia.edu

Xiaofan Jiang
Columbia University
New York, New York, USA
jiang@ee.columbia.edu

ABSTRACT

There has been an immense growth in sensors, actuators, and smart devices in recent years, which enable us to better sense, actuate, and understand the physical world. Despite this growth, we have yet to achieve fully intelligent environments. This is, in part, due to the large number of different organizations creating smart devices with proprietary technologies and communication protocols that are not compatible with each other and require significant engineering to incorporate and adapt to specific applications. In this work, we present an easy-to-install and low-cost embedded platform that allows users to rapidly configure a mixture of sensors and actuators. The system is based on the commonly-used Raspberry Pi ecosystem, easily configurable, and does not require users to have prior knowledge of programming, which allows anyone, regardless of background, to use. We also introduce a battery-powered wireless extension module that is suitable for mobile drone applications, where a chord-powered Raspberry Pi is not suitable. We demonstrate the impact our system has on enabling drones with flexible sensing modalities and creating smarter environments by integrating our platform into a variety of intelligent home applications.

CCS CONCEPTS

• **Computer systems organization** → **Sensor networks**; **Sensors and actuators**.

KEYWORDS

embedded systems, sensor networks, drones

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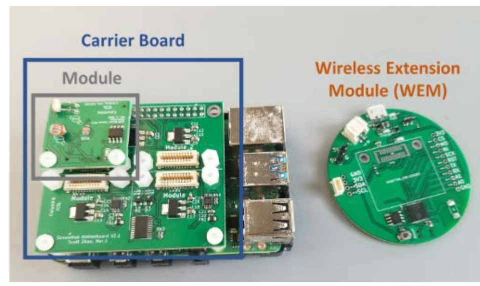

Figure 1: System Design. Left: *Carrier board* attached to a Raspberry Pi. One of its available slots is occupied by an interchangeable *module* equipped with a sensor. Right: *wireless extension module (WEM)* that communicates wirelessly with the *carrier board* for mobile applications.

1 INTRODUCTION

There is an increasing amount of artificial intelligence embedded around us to increase our productivity and quality of life. Our environments are seeing a rapid increase in smart devices, sensors, and actuators, with more than 10 billion smart devices in 2022, and is expected to grow to more than 25 billion by 2030 [1]. Despite this growth, we have yet to achieve fully intelligent and autonomous environments that can not only provide useful services, but also adapt to different buildings, neighborhoods, cities, and the people who inhabit them. One of the biggest hurdles to achieving truly intelligent environments is a lack of an extension architecture that supports a wide configuration of sensors and actuators. The billions of smart devices on the market today are developed and manufactured by numerous companies, each with their own proprietary systems and communication protocols, making it difficult to create systems and platforms than enable generalized intelligence.

Existing platforms for integrating different configurations of sensors and actuators generally fall into two categories. The first category are custom-made industrial sensing systems that are bundled with proprietary software that allows users to gain access to the data [2]. These systems are easy to configure, but generally cost thousands of dollars. The second category are the numerous sensor breakout boards for a variety of popular open-source platforms, like Arduino and Raspberry Pi. These platforms are low-cost, but generally require users to have some knowledge of how to select correct

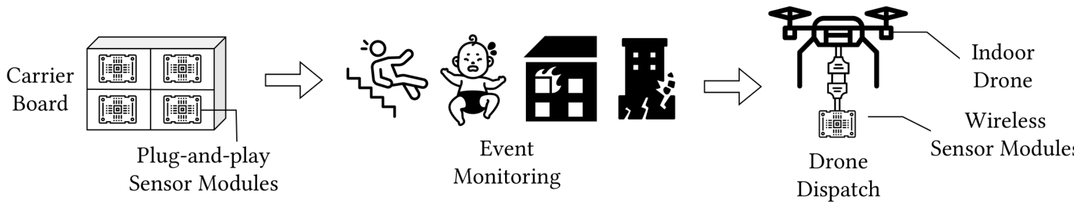

Figure 2: Demonstration procedure.

components and program these platforms. Most importantly, existing extension board architectures, such as Arduino shields and Raspberry Pi HATs, do not easily allow co-existence of multiple sensor boards, which is vital for modularity and reusability.

We present a modular and reconfigurable system for embedding intelligence into environments, requiring users to have no programming knowledge. Our system consists of two main components. First, we present a low-cost embedded platform that allows users to easily install a variety of sensors and actuators. This platform consists of a *carrier board* that communicates with a series of *modules*, each containing different sensors that users may deploy into homes, offices, parks, etc. Our platform, built on top of the Raspberry Pi ecosystem, is easy to use and configurable, allowing users with no engineering background to "plug and play" and "mix and match" a wide variety of sensors.

Second, we introduce a battery-powered *wireless extension module (WEM)* for drones and other mobile robotic vehicles. This extension module can operate at a distance from the carrier board, can be attached to drones, and enables drones to dynamically pick up and swap sensing and actuation modalities depending on the application. For example, in an emergency situation involving a fire, a drone can pick up a WEM equipped with a temperature sensor to map out areas with low temperatures for survivors to move through to get out of the danger zone. Afterwards, the drone can pick up a WEM equipped with a powerful light that it can use to guide survivors out using the paths it mapped.

This low-cost, flexible, secure, and easy-to-install system is an important step towards creating smarter environments, such as offices, cities, and homes [3].

2 SYSTEM DESIGN

Figure 1 shows the major components of our platform for embedding intelligent sensing and actuation into environments. The *carrier board* rests on top and communicates with a Raspberry Pi. Users can easily plug and play a wide range of *modules*, each equipped with different sensors, depending on application needs. There is a separate *wireless extension module (WEM)* that is battery-powered and can be used in mobile applications, where a chord-powered Raspberry Pi is not suitable. Each WEM has one open slot that users can "plug and play" one module equipped with a sensor that is relevant to the application domain.

Users do not need any programming experience to configure the carrier board, module, or WEM. The drivers are automatically loaded in the system and users can configure the necessary drivers through our web interface.

3 DEMONSTRATION DESCRIPTION

Figure 2 shows our demonstration procedure. We will show the flexibility and configurability of our platform in context of creating more intelligent home environments with drones. We will deploy a variety of sensors throughout the environment by equipping our *carrier board* with a variety of *modules*, each equipped with different sensors, to sense a variety of physical phenomena. If a specific event is detected, which requires a mobile platform, our home-based system will command a drone to pick up a WEM equipped with a relevant sensor to assess the situation with greater detail. We list a few of the scenarios we will demonstrate next.

- **Privacy-aware fall detection.** Rather than using a camera, which is privacy sensitive, a privacy-aware system may deploy vibration sensors throughout the home using our system. Once a potential fall is detected, the drone equips itself with a microphone-equipped WEM and flies to location to see if there are any cries for help.
- **Emergency alert system.** Using our system, we will deploy gas and temperature sensors throughout the environment to detect the presence of fires. If a potential fire is detected, our system will command a drone to pick up a gas or temperature sensor and map out areas where people can move through to escape the hazardous situation.

By demonstrating our platform in the context of a variety of intelligent home-based applications, we show that our platform is flexible, capable of impacting a wide range of domains, and an important step towards realizing fully intelligent environments.

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