Demo: uFiμ: An open-source integrated UWB-WiFi-IMU platform for localization research and beyond

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1 INTRODUCTION

Ultra-wideband (UWB) radios are gaining popularity following their inclusion in consumer devices such as Apple Watch and iPhone 15, as well as their inclusion in several innovative applications such as FIFA soccer balls, in cars to detect children and pets accidentally left behind, for firefighter safety, and so on. Some of these are ranging applications which rely simply on distance measurements, some are localization solutions that require multiple ranges to determine accurate location, while some are sensing applications that require capturing the reflections of radio signals. Due to the vast application space, research opportunities using UWB radios abound, however, researchers have to oftentimes develop their own hardware and software solutions—a time-consuming and agonizing process since one has to learn all of the skills (and art) that underscores such a hardware-software development effort.

To overcome the platform development challenge, and enable swifter application-level UWB research, drawing on our long-term experiences with UWB radios [2]–[1], we have developed an open source platform called uFiμ. We have combined UWB, Wi-Fi, and an inertial measurement unit (IMU) to provide an integrated solution that can range with another similar device, improve ranges using support from the IMU [3], and also stream raw data via Wi-Fi. We have followed Adafruit's Feather platform pinout so that other compatible peripherals can also be added to this platform. On the software side, we have developed an open-source Rust library for the underlying hardware that provides safe-language advantages, and a flexible demo code-base that simplifies development of ranging protocols and formulations. This demo will serve as a launch for our platform, dedicated to advancing UWB research.

2 TECHNICAL INNOVATIONS

Hardware Design: The uFiμ platform has been designed in KiCad and consists of an ESP32-S3 Wi-Fi module, LSM6DSO inertial sensor, and SGM41511 battery charger (BMS) in the Adafruit Feather form-factor. GPIO pins, power rails, and SPI and I2C pins have been brought out so that compatible Feather Wings can be easily added. Separately, the DWM3000 UWB module is mounted in Feather Wing form-factor with several LEDs to indicate packet transmission and reception, or as general purpose indicators. Following best practices in hardware design and manufacturing, we have correctly placed bypass capacitors to absorb ripples created by bursts of current draw, properly designed antenna keepouts, and allow LiPo battery powered operations, USB-C power, and battery charging on device. The hardware has been tested with several days of *continuous operation* in our lab, without discernible variations in performance.

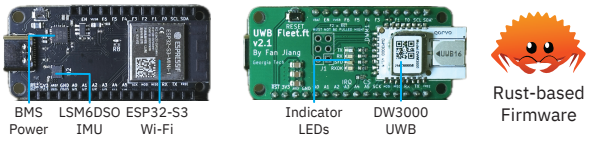

Figure 1: The uFiμ Wireless Research Stack

Guaranteed-Secure Programming Model: uFiμ introduces a software programming model that is guaranteed-secure. This model is underpinned by: (1) the use of Rust, a safe programming language, for the firmware and (2) using the async/await paradigm instead of manually-written state machines. Rust's ownership model and borrow checker guarantees memory safety and prevents race conditions, making uFiμ an inherently more secure and reliable platform. This approach significantly reduces the likelihood of security vulnerabilities and programming errors.

Open-source Software: All firmware and driver components in uFiμ are fully open-source, ensuring complete transparency and auditability of the code. This further enhances the security and reliability of the system as all drivers are written in safe Rust. Researchers can implement their own ranging protocols and formulations (or use the already implemented standard protocols), perform passive listening, and also capture the complex channel impulse response (CIR). Both UWB and IMU data can be streamed using Wi-Fi, providing capability for real-time localization and sensing. You can find the source at https://github.com/ProfFan/magic-loc-rs.

3 OUR DEMO

We will showcase the platform and demonstrate its Wi-Fi data streaming capabilities, robustness to errors and packet losses, and the ease of tweaking the protocol state-machine.

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