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# Demo: DotBot, a cm-Scale, Easy-to-Use Micro-Robot for Swarm Research

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**Abstract**—This paper introduces DotBot, a cost-effective, easy-to-use micro-robot designed for swarm robotics research. DotBot is a 10 cm, differential-drive mobile robot that offers fast speeds (up to 1 m/s), accurate localization using the Lighthouse V2 system, and secure internet-based control via MQTT. With a total material cost of approximately 40 EUR per unit, DotBot aims to lower the barrier of entry for researchers and educators in swarm robotics. The system was successfully demonstrated at the “Breaking Swarm Stereotypes” workshop at ICRA 2024, where it received the “Best Demo Award”.

## I. INTRODUCTION

Building and deploying a large swarm of robots (of more than one hundred units) can be prohibitively expensive to many research laboratories. Swarm robotics research is therefore often validated through simulations [1]. Simulation has many merits: reproducibility, scalability, low-cost and low barrier of entry. Yet, simulations are inherently inaccurate, and have limited applicability to the real world.

Several swarm robotics platforms have been proposed in the last decade for use in research [2], [3], but tend to be too expensive to scale to hundreds or thousands of agents [4]. To be usable in a testbed that mimics real-world use cases, some existing platforms move very slowly [5], don’t have an accurate positioning system [3], or are difficult to deploy.

In this paper we demonstrates the DotBot: a cm-scale, easy-to-use, micro-robot for swarm robotics research. The DotBot is designed to be simple, inexpensive (40 EUR), fast (1 m/s) and open-source. It is equipped with a localization sensor compatible with the Lighthouse V2 (LH2) positioning system [6] which offers scalable cm level positioning accuracy at 50 Hz. The DotBot user interface securely controls the DotBots over the Internet, over MQTT [7].

## II. HARDWARE

The DotBot (shown in Fig. 1) is a wireless, two-wheeled, differential-drive mobile robot 10 cm on a side. It is designed for research and education.

The DotBot features the nRF5340 microcontroller. This is a dual-core Cortex-M33 processor, clocked at 128 MHz, with 1 MB of flash and 512 KB of RAM. It has an integrated 2.4 GHz radio compatible with the BLE and IEEE802.15.4 standards. The robot is equipped with the following sensors: a LH2 positioning sensor (TS4231), a 6-degree of freedom IMU (ISM330DHC), a 3-axis magnetometer (LIS3MDL), and magnetic speed sensor on each wheel. The DotBot also has

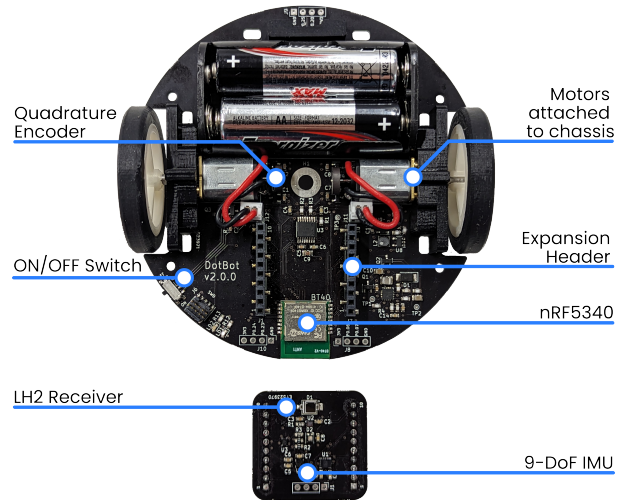


Fig. 1. The Dotbot (top) and the optional lighthouse localization board that can be inserted onto the expansion header (bottom).

two status LEDs (red and orange), an RGB LED, and two expansion headers to connect external sensors.

The DotBot is powered by two AA batteries. A step-up converter circuit (LM5158) converts the 3 V from the batteries into the 6 V needed by the motors. Another step-up converter and low drop-out regulator (LDO) provide the 3.3 V required by the sensors. Fig. 2 is a general circuit diagram. DotBot is a fully open-source platform<sup>1</sup>.

### A. Material Cost

Table I lists the component cost of one DotBot, when buying at a scale of 1000 units. Components costs are taken in 2024 from Digikey, a popular distributor of electronic components.

## III. LIGHTHOUSE LOCALIZATION

We leverage HTC’s Lighthouse Positioning System to localize the DotBots. This system was designed to localize VR gaming headsets. It relies on two spinning laser beacons, called basestations. Using their on-board receivers, The robots capture light pulses emitted by the beacons. They decode data transmitted in the laser, and with it, compute their azimuth

<sup>1</sup> As an online addition to this paper, the DotBot schematics and Printer Circuit Board (PCB) design files are published under an open-source BSD license at <https://github.com/DotBots/DotBot-hardware>.

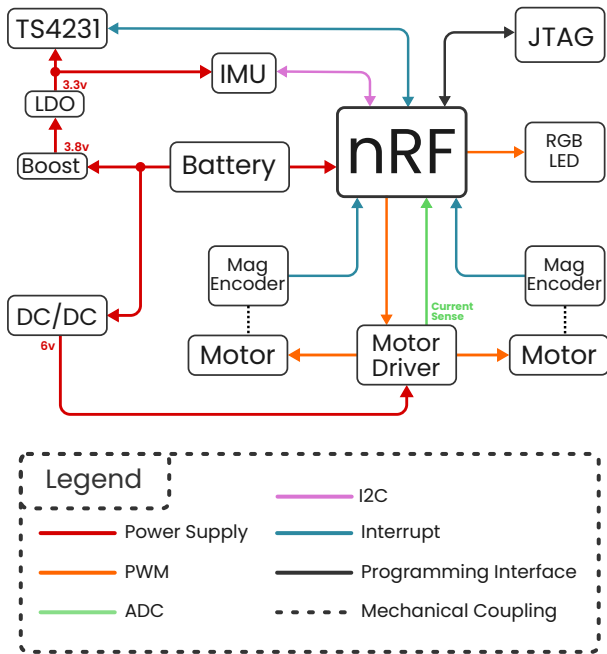


Fig. 2. DotBot platform hardware.

TABLE I  
MATERIAL COST OF ONE DOTBOT AT A VOLUME OF A 1000 UNITS.

Components	Price [USD]
Battery & Protections	1.6
3.3V Regulator	3.1
6V Regulator	3.0
Wheel Encoders	2.1
Motor drivers	1.5
Headers	5.0
Status LED	0.1
Microcontroller	8.7
Lighthouse Receiver	1.2
RGB LED	0.3
IMU	7.1
Motors	3.0
PCB	0.5
Total	37.2

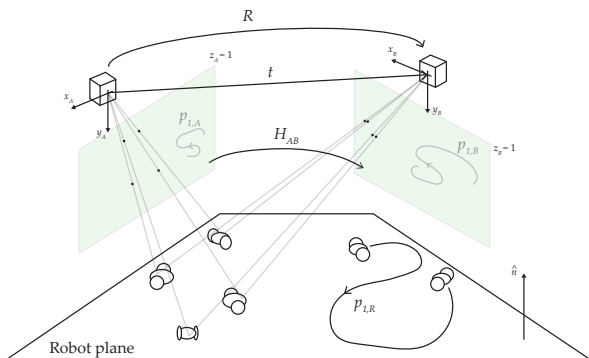


Fig. 3. Lighthouse localization for robots (as previously published [6])

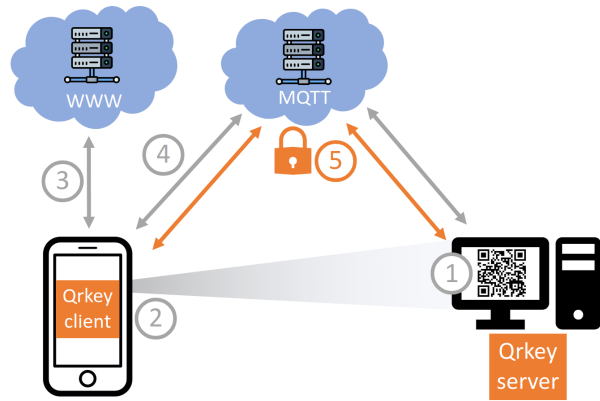


Fig. 4. MQTT control scheme (as previously published [7])

and elevation with respect to the basestation (see Fig. 3). This information allows them to estimate their location in 3D space with 11.2 mm accuracy on average [6]. To run the system, we position the DotBots on the corners of the experimentation area, also allowing the position system to calibrate. Once this calibration is done, the localization algorithm is fully decentralized: each robot computes its position locally. This makes the lighthouse positioning system ideal for a swarm robotic environment.

#### IV. MQTT CONTROL

We use QrKey [7] to simultaneously control several DotBots from a computer or a cell phone. QrKey is an open-source solution, designed to help users easily deploy a swarm of robots and to control them through a public MQTT server. A user scans a QR code with their phones to register into the server. The QR code contains a key that allows the user's cell phone or laptop to establish a secure end-to-end encrypted connection with the server. Encryption is done using AES GCM with a 256-bit symmetric key. Because the payload is encrypted, all communication between the user and the DotBots can happen through a public (and unsecure) MQTT server without compromising end-to-end security. Fig. 4 shows the general diagram of QrKey.

#### V. DEMONSTRATION

We have presented the DotBot at the “Breaking Swarm Stereotypes” workshop at the 2024 IEEE International Conference on Robotics and Automation (ICRA) [8]. The demonstration consisted of six DotBots, a  $2 \times 2$  m fence, a lighthouse basestation, and a laptop to run the QrKey server. HiveMQ was chosen as the public MQTT broker. A computer monitor displayed the QR code that users could flash with their smartphones. This allowed user to choose and control one of the DotBots. The entire set-up was deployed in less than 10 min. This demonstration received the “Best Demo Award”.

#### VI. CONCLUSIONS

This paper demonstrates the DotBot: a low-cost robotic platform designed to lower the barrier of entry to swarm

robotic research. We discuss the hardware specifications, the lighthouse-based localization system, and the MQTT-based scheme for securely deploying a swarm of robots. We have presented this system at work at the IEEE ICRA 2024 conference where it received an award. We are developing the DotBots to help increase the access to swarm robotics, both in education and research.

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