Demo: Meta2Locate: Meta Surface Enabled Indoor Localization in Dynamic Environments

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ABSTRACT

Received signal strength (RSS) fingerprint map is one of the most widely-used indoor localization approaches, but it often relies on multiple access points (AP) for data collection and suffers from frequent data updates due to dynamic wireless environments. In this work, we implement a reconfigurable-intelligent-surface (RIS) assisted indoor localization system named *Meta2Locate* to tackle the above issues using only one AP. In the proposed system, we deploy our self-designed RIS at 5.5GHz in an indoor environment. Serving as an intelligent reflector that flexibly reconfigures the phase shifts of incident signals, the RIS can customize the propagation channels between the AP and the target. For the changing propagation environment, we design a mean maximum discrepancy weighted meta-learning approach to train a model that maps the RSS fingerprint to the location of the user, and it only needs a few data for the model update. Experiment results show that our proposed method can achieve better location accuracy using a small amount of RSS data given unpredicted propagation environment changes compared to state-of-the-art methods.

CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile computing design and evaluation methods**.

KEYWORDS

Indoor localization, Meta learning, RSS Fingerprint, Reconfigurable intelligent surface

1 INTRODUCTION

With the proliferation of smartphones and other wireless devices, indoor localization has been widely investigated in recent years concerning industrial settings like robot/UAV navigation and healthcare applications. Various methods have emerged for indoor localization, in which the received signal strength (RSS) fingerprint approach is one of the most cost-efficient and widely-used approaches. It first selects multiple sample points in the room and collects RSS from several APs, i.e., the reference points to form a fingerprint map. Thus, by comparing the RSS values from the user with the map, we can locate the position of the user [3].

However, systems based on traditional RSS fingerprint mapping often require multiple APs to form the fingerprint, which brings a burden of extra devices. Recently, the introduction of reconfigurable intelligent surface (RIS), a planar sheet consisting of numerous electrically tuneable elements, is considered as a promising solution for indoor localization systems. By configuring RIS elements, it can change the phase shifts of the reflected signal to obtain multiple RSS values to form the fingerprint map using only a single AP.

Although RIS improves the simplicity of indoor localization, in real indoor wireless environments, the RSS fingerprints are very noisy and time-varying due to shadowing and multi-path effect. Thus, once the environment has changed, it is necessary to recollect the RSS fingerprints, which costs a lot of effort and time [2]. However, to the best of our knowledge, current works barely build a practical RIS-assisted indoor localization system meanwhile considering the problem of onerous data recollecting for a changing environment.

To tackle the aforementioned issue, we first build a practical indoor localization system assisted by self-designed RIS named *Meta2Locate* using only one AP, then design the mapping module between RSS fingerprints and the user's location. In detail, we propose a meta-learning [1] method implemented in the mapping module based on a novel weighting scheme for RSS fingerprints collected from different environments. We first conduct the meta-learning phase with all the data collected at different times to build a meta model, i.e., generalized convolutional neural network (CNN), followed by the online learning phase where we re-train the meta-model with only 20% of data in a new environment. Evaluated by the data collected with the above system under the time-varying environment, our proposed approach achieves better localization accuracy compared to other benchmark methods trained by fewer data, lowering mean localization error by 21.5%.

2 SYSTEM ARCHITECTURE

The layout and architecture of our proposed *Meta2Locate* are shown in Fig. 1(a) and 2 respectively. The system design is illustrated in detail as follows:

- **Transmitter&RIS**: The transmitter is placed on the right side of the room along our self-designed RIS depicted by Fig. 1(c), which consists of 28*28 elements

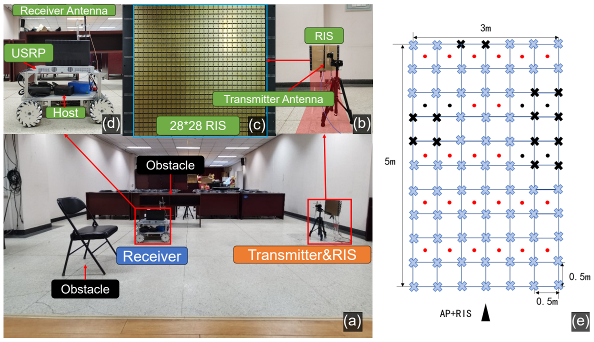

Figure 1: (a) Layout of *Meta2Locate*, (b) Transmitter&RIS, (c) RIS, (d) Receiver, (e) Data collection map

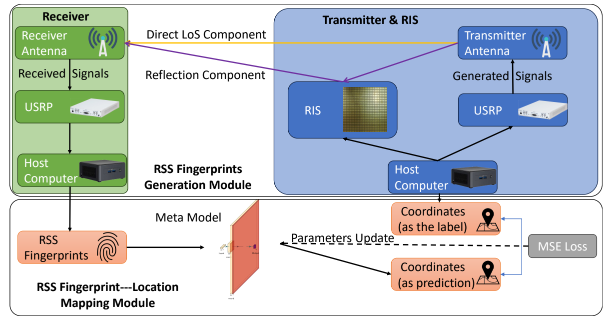

Figure 2: Architecture of *Meta2Locate*

and works at the sub-6G band centered by the frequency of 5.5 GHz. As shown in Fig. 1(b), it combines the RIS, control circuits and transmit antenna together to reconfigure the wireless environment. It also includes a Universal Software Radio Peripheral (USRP) to generate transmit signal and is controlled by a host computer, which also controls the configuration of RIS.

- **Receiver**: The receiver of the system is deployed on a robot as in Fig. 1(d). It is equipped with a USRP connected to a host computer, which records RSS from USRP and generates the RSS fingerprint.
- **Data Collection**: As shown in Fig. 1(e), we divided the plane of the room into grids and choose multiple points to collect data. The blue × data points are collected as the training set, while the red · points form the test set. All the black × and · points are not sampled due to the obstacles and restrictions of the environment. In the process of data collection, we move the car to each point and change the configuration of RIS 10 times and record the corresponding RSS as the fingerprint. The protocol of *Meta2Loate* is shown in Fig. 3.

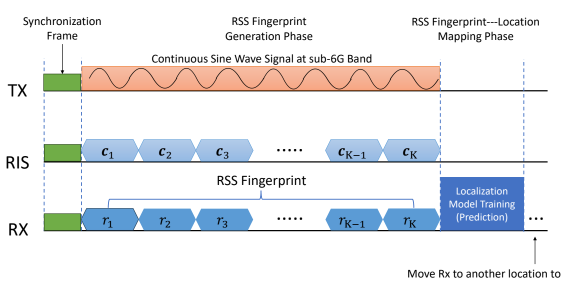

Figure 3: A cycle of the protocol for *Meta2Locate*

3 DEMONSTRATION

As illustrated in Section 2, we use two Intel NUC11PAHi5 with Intel® Corel™ i5-1135G7 as the host computers to control transmitter and receiver respectively. For the transmitter, we deploy a USRP 321 and a single antenna, which keep generating a complex sinusoidal signal with constant amplitude. Our self-designed RIS is 330*281mm in size and 2.935mm thick with each element in the size of 10*10mm. The phase shift of each element is controlled by FPGA ALINX AX301 of 1-bit state, i.e., each element has two states of phase shift.

The receiver is deployed on a robot as in Fig. 1 (d). A robot operating system is installed in the host computer to control the robot. We use USRP 310 to receive the signal and transmit it to the host computer to generate the RSS fingerprint.

The whole demo is deployed in a classroom, thus it needs a space of 3m*5m to achieve localization. The required setup time is 10 minutes to build up and synchronize the transmitter, receiver, and RIS. The two host computers and the robot are connected to the campus network through WiFi to control the whole system. The transmitter and RIS are powered by commercial power with 220V, while the receiver is powered by portable power with a voltage of 30~32V.

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