A Multifrequency Multistage Radiolocation System Based on Fingerprinting

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Abstract*—This paper presents a multifrequency and multistage indoor robot localization system based on fingerprinting. The proposed system relies on a 900 MHz Long Range Radio (LoRa) along with 2.4 GHz Wireless Fidelity (WiFi) and Bluetooth (BT) networks. By exploiting different propagation characteristics of different Radio Frequency (RF) signal wave within a Gated Recurrent Unit (GRU) framework, Received Signal Strength (RSS) measurements are used for indoor localization purposes. Similar to conventional fingerprinting systems, the system is consisted of two stages: data acquisition and learning (offline), and localization (online). In offline stage, the signal maps for various AP's are constructed via RSS information and path loss exponent is learned by a network consisted of GRU, whereas the online stage contains an information fusion based localization method. *Add some result once get it

I. Introduction

Inverse pyramid:

- P1: Background
  1) Inverse pyramid
  2) Last sentence: introduce the area of the title of your paper as a significant topic
  3) 5 refs (books, review papers, journals, no conf)
- P2-3: Background
  1) Original classification: Support the objectives with each sentence
  2) Appreciate their work, their focus however different
  3) no technical words
  4) 10 refs (journal, conference papers)
- P4: Objectives
  1) 1-3 objectives
  2) the first sentence: this paper presents
- P5: Outline

II. Fundamentals of Radio Wave Propagation and Radiolocationing

This section will cover the fundamentals of radio wave propagation and radiolocationing systems based on fingerprinting. First the radio wave propagation will be formulated and then the existing methods for radiolocation systems will be covered.

The fundamental relationship between transmitted P_t and received power P_r occurred between ideal antennas in an empty space with a distance d separation is characterized by Friis' Free Space Equation given below [1].

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2} \tag{1}$$

In Equation (1), $P_r(d)$ and P_t denote received, and transmitted power with d meters separation between two antennas in Watts, respectively. G_t, G_r, and λ represent unitless gains of transmitter and receiver antennas, and the wavelength, respectively. Since the received power is minuscule level, Equation (2) represents Friis' equation in dBm.

$$\begin{aligned} P_r^+(d) = P_t^+ + 10\log G_t + 10\log G_r + \\ 20\log\lambda - 20\log d - 20\log 4\pi \end{aligned} \tag{2}$$

$P_r^+(d)$ and P_t^+ represent received and transmitted powers decibel scale. However, neither Equation (1), nor Equation (2) holds true for the distance $d = 0$ and $d < \lambda$. Thus, received power generally is denoted relative to a reference point d_0 with a prior corresponding received power.

$$P_r^+(d) = P_r^+(d_0) + 20\log\frac{d_0}{d} \tag{3}$$

Along with representing modeling the received power with a reference point, path loss is another common terminology used in field. The path loss is the difference between received and transmitted power in decibel scale as positive gain. Equation (4) represents path loss relative to a reference point. One of the major advantages of log-distance path loss model over Friis' free space model is that log-distance path loss model can account for different spaces by varying values of n.

$$\overline{PL}(d) = \overline{PL}(d_0) + 10n\log\frac{d}{d_0} \tag{4}$$

where n is the path loss exponent and varies depending on the environment. Please note $n = 2$ for empty spaces where there is no reflectors, diffractors or scatterers available in the propagation path. As it can be seen in the Equation (4), the received power and separation distance has a log-linear relationship. While the most visited solution in fingerprinting-based indoor radiolocationing system is to estimate n by fitting a curve to collected fingerprints. After acquiring n is enough for solving for the radial distance d from the anchor node, at least 4 anchor nodes are required to localize an agent in an environment.

Given the mean measurement $\overline{PL}(d)$, for a point in the environment and path loss exponent n and mean measurement $\overline{PL}(d_0)$ at the reference point d_0, the approximated propagation function can be written as:

$$f_{\hat{d}} = d_0 10^{\left(\dfrac{\overline{PL}(d) - \overline{PL}(d_0)}{10n}\right)} \tag{5}$$

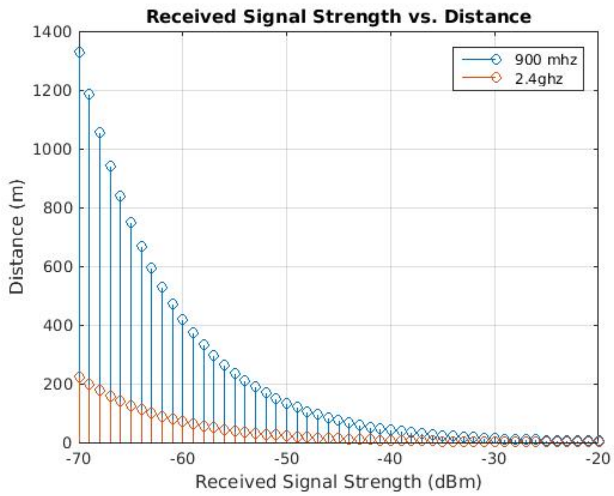

Fig. 1: RSSI readings of NLoS and LoS APs acquired with a stationary agent

However, in order to obtain $\hat{d}$, the path loss exponent n should be estimated from the collected data. Let $\mathbf{m} = \{m_i | i = 1 \ldots n_{location}\}$ and $\mathbf{X} = \{\mathbf{x}_i | i = 1 \ldots n_{location}\}$ be the fingerprints collected during surveying and corresponding locations, respectively. The approximated propagation function for each anchor nodes can be written as $f_{\hat{d}}(\mathbf{x}, m_i, n) : \mathbf{M} \mapsto \mathbf{X}$.

$$n^* = \arg\min_n \{\|\mathbf{X}\|_2 - f_{\hat{d}}(\mathbf{X}, \mathbf{m}, n)\} \tag{6}$$

III. MFMS

A. *Offline Stage*

1) Data Acquisition:

2) Training:

B. *Online Stage*

1) Inference:

2) Information Fusion:

IV. Experimentation

A. *Experimental Setup*

1) Hardware:

2) Software:

B. *Results*

V. Conclusion and Future Work

ACKNOWLEDGMENT

References

[1] H. T. Friis, "A note on a simple transmission formula," *Proceedings of the IRE*, vol. 34, no. 5, pp. 254–256, 1946.