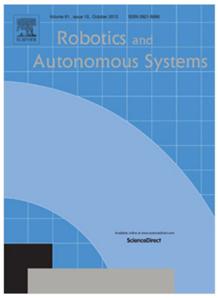
Accepted Manuscript



Precise and accurate wireless signal strength mappings using Gaussian processes and path loss models

Renato Miyagusuku, Atsushi Yamashita, Hajime Asama

PII: S0921-8890(17)30392-5
DOI: https://doi.org/10.1016/j.robot.2018.02.011
Reference: ROBOT 2989

To appear in: *Robotics and Autonomous Systems*

Received date : 8 June 2017
Revised date : 19 January 2018
Accepted date : 19 February 2018

Please cite this article as: R. Miyagusuku, A. Yamashita, H. Asama, Precise and accurate wireless signal strength mappings using Gaussian processes and path loss models, *Robotics and Autonomous Systems* (2018), https://doi.org/10.1016/j.robot.2018.02.011

Precise and accurate wireless signal strength mappings using Gaussian processes and path loss models

Renato Miyagusuku*, Atsushi Yamashita, Hajime Asama

Dept. of Precision Engineering, Graduate School of Engineering, The University of Tokyo, 113-8656 Tokyo, Japan

Abstract

In this work, we present a new modeling approach that generates precise (low variance) and accurate (low mean error) wireless signal strength mappings. In robot localization, these mappings are used to compute the likelihood of locations conditioned to new sensor measurements. Therefore, both mean and variance predictions are required. Gaussian processes have been successfully used for learning highly accurate mappings. However, they generalize poorly at locations far from their training inputs, making those predictions have high variance (low precision). In this work, we address this issue by incorporating path loss models, which are parametric functions that although lacking in accuracy, generalize well. Path loss models are used together with Gaussian processes to compute mean predictions and most importantly, to bound Gaussian processes' predicted variances. Through extensive testing done with our open source framework, we demonstrate the ability of our approach to generating precise and accurate mappings, and the increased localization accuracy of Monte Carlo localization algorithms when using them; with all our datasets and software been made readily available online for the community.

Keywords: Robot localization, Wireless sensor model, Signal strength mapping, Gaussian processes

1. Introduction

The usage of wireless signals for robot localization in indoor, GPS-denied, locations has gained popularity in recent years, partly due to the almost ubiquitous presence of wireless local area networks (WLANs) in most buildings. Although wireless signals-based localization systems do not achieve as high accuracy as those based on sensors such as laser rangefinders or RGB-D cameras, they possess certain characteristics that make their usage appealing, which are listed below:

Signals' uniqueness IEEE802.11 compliant packets transmit its source's own unique identifier (i.e., the access point's macaddress) as part of its header. By extracting this identifier, its source can be identified unequivocally. This makes wireless signal-based systems never suffer from data association problems, which refers to those that arise from incorrectly identifying two or more similar features or landmarks (e.g., failing to distinguish between two similar doors when using a camera, or two similar rooms using laser scans). This makes wireless signals-based systems inherently robust.

Lower computational requirements The amount of data that needs to be processed for wireless signals-based localization is significantly lower than that produced by more accurate sensors like RGB-D cameras or laser rangefinders, which implies lower computational requirements.

Readily available hardware WLANs being almost ubiquitously present in most buildings means no hardware infrastructure is required. Furthermore, most robots already possess wireless capabilities, in which case the required additional hardware would be none. Even if the robot does not possess wireless capabilities, a wireless network interface controller (WNIC) can be added for a really low price. Thus making the additional hardware cost almost nonexistent.

Therefore, wireless-based localization is inherently robust, computationally fast, and does not require any type of hardware deployment or modifications on the environment, making it ideal to use with other sensors, or by low-cost robots. Its main drawback, which limits these potential applications, is its accuracy. To increase this localization accuracy, precise and accurate signal strength mappings are needed. In wireless-based localization, these mappings are used to generate signal strength predictions, necessary for computing the likelihood of locations given acquired measurements. Figure 1 shows an overview of wireless-based localization and illustrates the essential role these mappings play. Therefore, by improving these mappings, better localization accuracies can be obtained. It is important to notice, that in a Bayesian approach, for computing the likelihood of locations, not only predicted signal strength mean values are required, but also their predicted variances.

When propagating through space, signals interact with all objects in the environment, either being reflected, scattered or diffracted. Therefore, the challenges for generating signal strength mappings arise due to the difficulty of modeling these phenomena, as well as the noisy nature of the signals them-

*Corresponding author

Email addresses: miyagusuku@robot.t.u-tokyo.ac.jp (Renato Miyagusuku), yamashita@robot.t.u-tokyo.ac.jp (Atsushi Yamashita), asama@robot.t.u-tokyo.ac.jp (Hajime Asama)