Reducing Tracking Error in RFID Real-Time Localization Systems Using Kalman Filters

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ABSTRACT

The use of Radio Frequency Identification (RFID) has become widespread in industry as a means to quickly and wirelessly identify and track packages and equipment. Now there is a commercial interest in using RFID to provide real-time localization. Efforts to use RFID technology in this way experience localization errors due to noise and multipath effects inherent to these environments. This paper presents the use of both linear Kalman filters and non-linear Unscented Kalman filters to reduce the error rate inherent to real-time RFID localization systems and provide more accurate localization results in indoor environments. A commercial RFID localization system designed for use by the construction industry is used in this work, and a filtering model based on 3rd order motion is developed. The filtering model is tested with real-world data and shown to provide an increase in localization accuracy when applied to both raw time of arrival measurements as well as final localization results.

Keywords: Kalman Filters, Localization, Real-Time, RFID, Tracking, Unscented Kalman Filter

INTRODUCTION

Indoor object localization and tracking is a growing field with direct applications in both the private and public sectors. The ability to track people and objects indoors, in real-time, is a valuable tool both for business and government. In the public sector localization can provide lifesaving information to military, law enforcement, and emergency services (Harris, 2013), as well as inform traffic and city management. In the construction industry object tracking is a growing field with important applications to asset and building site management (Akanmu et al., 2013).

GPS provides highly-accurate and functional localization outdoors but performs poorly indoors where direct line-of-sight to GPS satellites is not possible. As there is no direct means

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to allow GPS to function indoors, novel indoor localization systems must utilize a completely different methodology. Alternatives to GPS primarily utilize existing wireless systems and expand their functionality to include localization. Prominent methods include IEEE 802.11 wireless LAN, ultrasonic and infrared methods, laser range finding, and Radio Frequency Identification (RFID) (Sanpechuda and Kovavisaruch, 2008).

All of these methods however, suffer from noise and multipath issues. To combat this many turn to the Kalman filter (KF). The KF is a predictive filtering model that can be applied to noisy systems to predict the actual system state based on recursive sampling. Used widely in GPS tracking, navigational guidance systems, and image detection, it is a powerful tool for noise reduction and system control. When applied to localization problems KF can greatly reduce the effects of multipath and time of arrival (TOA) errors and increase the feasibility of these systems for real-world applications (Bekkali et al., 2007; Lee and Park, 2006).

Non-linear Kalman filters have been applied to ultrasonic localization networks, similar to the MIT Cricket (Ko et al., 2006), laser rangefinding robots (Martinelli, 2008), and wireless LAN patient tracking (Paul and Wan, 2008).

RFID localization involves the use of multiple RFID readers set up in a grid pattern. Using the readers a system can track the location of a tag within the grid using TOA. Non-linear KF have been applied to such systems and found to reduce noise and increase localization accuracy (Nick et al., 2011a,b).

Existing work has used only simulated data and statistical models and has lacked real-world experimentation. This paper presents the application of linear and non-linear KF to a commercial RFID localization system operating in indoor environments. The RFID system is set up in an indoor environment containing noise and NLOS situations. Real-time data is collected, and KF techniques are designed based on the output and statistics of the system. The performance of the KF is analyzed and linear and non-linear implementations of the KF are also compared.

**RFID Localization**

RFID localization involves the use of multiple, long-range, RFID readers (antennas) set up in a known grid pattern to create an enclosed tracking area. Using the readers a system can track the location of a tag within the tracking area using either TOA and trilateration, time-difference of arrival (TDOA) and trilateration, or angle of arrival (AOA) and triangulation. Depending on the size and capabilities of the system just one, or multiple tags may be tracked simultaneously. Data is collected from the system via a data uplink from the readers to a control or monitoring PC. The PC generally provides software which performs analysis and graphical display of the tracking information. A typical system layout is shown in Figure 1.

As RFID localization utilizes TOA/TDOA/AOA methods of localization, it is very susceptible to noise, detuning, and multipath effects. These effects are especially intensified in indoor environments where there may be large metal obstacles and non-line of sight in the tracking area. The exact position of the readers must also be known and any error in reader location will propagate errors throughout the system.

There are three main types of RFID tags, some more useful to localization than others (Fennani et al., 2011). The first and simplest type are passive RFID tags. These tags tend to be small, have no on-board power source of any kind, and operate in low frequency (LF), high frequency (HF), and ultra-high frequency (UHF) ranges. As the tags have no on-board power, they must utilize power harvesting techniques to capture or modify the power from the transmissions of the RFID readers. Because of their power constraints, passive tags also have a relatively short usable range of up to 3-10 feet and only maintain a static set of data (Chawla and Ha, 2007).
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