Managing Uncertainty in RFID Based Tracking Applications

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I would like to dedicate this thesis to my loving family ...

Declaration

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Rengamathi Sankarkumar

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Abstract

Object or people based tracking systems that use RFID have seen increasing usage over the past decade. These systems provide an effective tracking solution by leveraging the non-line-of-sight precise identification capability of RFID technology, however they still have to overcome a number of challenges posed by the nature of the technology to improve their reliability and accuracy, such as uncertain data that leads to location uncertainty. In this thesis, two applications are been concentrated: i) asset tracking; and ii) tracking people. The goal was to develop a generalizable approach for tracking objects or people effectively by managing the location uncertainty problem caused by uncertain RFID data.

In the context of an asset tracking application, we describe an optimized tracking algorithm to predict the locations of objects in the presence of missed reads using particle filters. To achieve high location accuracy we develop a model that characterizes the motion of objects in a supply chain. The model is also adaptable to the changing nature of a business, such as flow of goods, path taken by goods through the supply chain, and sales volumes. A scalable tracking algorithm is achieved by an object compression technique, which also leads to a significant improvement in accuracy.

In the context of a people tracking application for addressing wandering off, one of the common behaviours among cognitively impaired patients, we have developed an approach for identifying the traversing direction and the traversing path used by the patients wearing an RFID tag integrated into clothing for the first time. Our approach uses a particle filtering (PF) based technique with Received Signal Strength Indicator (RSSI) maps obtained from scene analysis to continuously track a person wearing an RFID tag over their attire. Using real-time spatial and temporal data obtained from the PF based tracking approach, we develop two algorithms: i) tag traversing direction (TD) algorithm to identify the tag bearer's moving direction (e.g. moving out of a room); and ii) tag traversing path detection algorithm (TPD) to estimate the traversal path used by the tag bearer.

Furthermore, we propose a generic model for RFID sensing infrastructure using Kernel

Density Estimation (KDE) to eliminate the need of generating an RSSI map for every new environment. The newly developed algorithm can be implemented in practice without the need for further training data. We then integrate Kullback-Leibler (KL) divergence into our sensor model to overcome problems posed by information loss when the RSSI distribution in the training data set is used to generate a generic sensor model based on approximating RSSI distribution over the monitoring region. Moreover, we also utilize a Dynamic Time Warping (DTW) technique to improve the performance of our TPD algorithm by measuring the similarities between the real-time temporal data and the trail walking temporal data. At last, we investigate the accuracy of our algorithms in a multiple-participants environment. A detailed discussion of all the proposed method's performance and accuracy for both applications show that our algorithms are robust.

Statements of Authorships

This thesis contains one journal paper (under review), and three conference papers (all peer reviewed and published). I have provided a statement of authorship for each of these articles to certify that I was actively involved in the process of preparing each article.

The following is the list of all publications included in this thesis.

- R. Sankarkumar, D. C. Ranasinghe, and T. Sathyan. A highly accurate method for managing missing reads in RFID enabled asset tracking. *In 10th International Conference on Mobile and Ubiquitous Systems (MOBIQUITOUS)*, Tokyo, Japan, 2013. Ranked as A according to Core conference ranking 2014.

- R. Sankarkumar, D. C. Ranasinghe, and T. Sathyan. A highly accurate and scalable approach for addressing location uncertainty in asset tracking applications. *In IEEE International Conference on Radio Frequency Identification (IEEE RFID)*, Orlando, USA, 2014. Ranked as B according to Core conference ranking 2014.

- R. Sankarkumar and D. C. Ranasinghe. Watchdog: A novel, accurate and reliable method for addressing wandering-off using passive RFID tags. *In Proceedings of the 11th International Conference on Mobile and Ubiquitous Systems (MOBIQUITOUS)*, London, UK, 2014. Ranked as A according to Core conference ranking 2014.

- R. Sankarkumar and D. C. Ranasinghe. Watchdog: Practicable and unobtrusive monitoring technology for addressing wandering-off with low cost passive RFID. *In the International Journal of Pervasive and Mobile Computing (PMC), Special Issue on Pervasive Computing for Gerontechnology* (Under Review). Ranked as B according to Core journal ranking 2014.

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Author Contributions

By signing the Statement of Authorship, each author certifies that their stated contribution to the publication is accurate and that permission is granted for the publication to be included in the candidate's thesis.

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Contribution to the Paper	Performed simulation, gathered and interpreted data, wrote manuscript and acted as corresponding author.		
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Name of Co-Author	Damith C Ranasinghe		
Contribution to the Paper	Formulate the problem, supervised development of work, help in data interpretation and manuscript evaluation.		
Signature		Date	10/07/2015

Name of Co-Author	Thuraiappah Sathyan		
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Contribution to the Paper	Actively involved in the conceptualization of the work, formulation of the problem to a tracking problem, developed algorithm, conduct the experiments, interpreted data, wrote manuscript and acted as corresponding author.		
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Name of Co-Author	Damith C Ranasinghe		
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