Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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“WiFi Fingerprinting Based Indoor Localization with Autonomous Survey and Machine Learning”

Department of Electrical and Computer Engineering

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Remote Defence

Supervisory Committee:
Dr. Xiaodai Dong, Department of Electrical and Computer Engineering, University of Victoria (Supervisor)
Dr. Hong-Chuan Yang, Department of Electrical and Computer Engineering, UVic (Member)
Dr. Daniela Constantinescu, Department of Mechanical Engineering, UVic (Outside Member)

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Dr. Steven Capaldo, School of Music, UVic

Dr. Stephen Evans, Acting Dean, Faculty of Graduate Studies
Abstract
The demand for accurate localization under indoor environments has increased dramatically in recent years. To be cost-effective, most of the localization solutions are based on the WiFi signals, utilizing the pervasive deployment of WiFi infrastructure and availability of the WiFi enabled mobile devices. However, one of the major challenges of indoor localization is that many obstacles such as walls, furniture and moving human beings, form fluctuations of WiFi signals known as multipath interferences. Such fluctuations cause significant degradation in the accuracy of indoor positioning, which has yet to be fully overcome. In this thesis, we develop completed indoor localization solutions based on WiFi fingerprinting and machine learning approaches with two types of WiFi fingerprints including received signal strength indicator (RSSI) and channel state information (CSI).

Starting from the low complexity algorithm, we propose a soft range limited K nearest neighbours (SRL-KNN) to address spatial ambiguity and the fluctuation of WiFi signals. SRL-KNN exploits RSSI and scales the fingerprint distance by a range factor related to the physical distance between the users previous position and the reference location in the database. Although utilizing the prior locations, SRL-KNN does not require knowledge of the exact moving speed and direction of the user. Moreover, to take into account of the temporal fluctuations of RSSI, RSSI histogram is incorporated into the distance calculation. Besides, the idea of the soft range limiting factor can be applied to all of the existed probabilistic methods, i.e., parametric and nonparametric methods, to improve their performances. A semi-sequential short term memory step is proposed to add to the existed probabilistic methods to reduce their spatial ambiguity of fingerprints and boost significantly their localization accuracy.

In the following research phase, instead of locating user's position one at a time as in the cases of conventional algorithms, our recurrent neuron networks (RNNs) solution aims at trajectory positioning and takes into account of the relation among RSSI measurements in a trajectory. Furthermore, a weighted average filter is proposed for both input RSSI data and sequential output locations to enhance the accuracy among the temporal fluctuations of RSSI. The results using different types of RNN including vanilla RNN, long short-term memory (LSTM), gated recurrent unit (GRU) and bidirectional LSTM (BiLSTM) are presented.
Next, the problem of localization using only one single router is analysed. CSI information will be adopted along with RSSI to enhance the localization accuracy. Each of the reference point (RP) is presented by a group of CSI measurements from several WiFi subcarriers which we call CSI images. The combination of convolutional neural network (CNN) and LSTM model is proposed. CNN extracts the useful information from several CSI values (CSI images), and then LSTM will exploit this information in sequential timesteps to determine the user's location. All of our proposed algorithms are demonstrated by extensive on-site experiments and are compared with several existing deterministic and probabilistic methods in literature under the same test environment.

Finally, a fully practical passive indoor localization is proposed. Most of the conventional methods rely on the collected WiFi signal on the mobile devices (active information), which requires a dedicated software to be installed. Different from them, we leverage the received data of the routers (passive information) to locate the position of the user. The problem of data insufficiency in passive indoor localization is mitigated by request to send (RTS) and clear to send (CTS) process. Furthermore, the completed localization solutions for two most popular mobile device usage scenarios, i.e., idle and transmission modes, are analyzed in details. The localization accuracy is investigated through experiments with several phones, e.g., Nexus 5, Samsung, Iphone and HTC, in hundreds of testing locations. The experimental results demonstrate that our proposed localization scheme achieves an average localization error of around 1.5 m when the phone is in idle mode, and approximately 1 m when it actively transmits data.