Faculty of Engineering

Smartphone-based GPS-integrated Location Prediction Model for OBD-II-Equipped Land Vehicle Localization

Chai Nee Ping

Doctor of Philosophy
2018

Smartphone-based GPS-integrated Location Prediction Model for OBD-II-Equipped Land Vehicle Localization

Chai Nee Ping

A thesis submitted

In fulfillment of the requirements for the degree of Doctor of Philosophy

(Electrical and Electronics Engineering)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2018

DECLARATION

I, Chai Nee Ping (11011557) from Faculty of Engineering UNIMAS hereby declare that the work entitled, Smartphone-based GPS-integrated Location Prediction Model for OBD-II-Equipped Land Vehicle Localization is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person. The thesis has not been previously accepted for any degree and is not concurrently submitted in candidature for any other degree.

____

Chai Nee Ping (11011557)

Date:

ACKNOWLEDGEMENT

First of all, I would like to dedicate thousands of thank to my supervisor, Assoc. Prof. Dr. Wan Azlan Bin Wan Zainal Abidin for his supervision, guidance, advices and encouragement throughout the progress of this research work. Dr. Wan has always been patient in giving motivation during the hard time of research and he is patient in discussing about the problems and the solutions for the research work. His efforts and contributions are highly appreciated.

Furthermore, I would like to thank all the lecturers of the Faculty of Engineering, UNIMAS and all my colleagues in postgraduate room for their patient knowledge sharing, advices and guidance throughout the time of research work being carried on. They are always helpful and their help contributed towards the actualization of this thesis.

Last but not least, a grateful appreciation is dedicated to my beloved family and dearest friends for their help and support. Their endless love, patience, understanding and encouragement never fail to motivate me to work harder in completing this research. Their mental support and financial support are significant along the completion of this thesis.

ABSTRACT

Vehicle localization is important to track the movement of a particular land vehicle especially company vehicle. Global Positioning System (GPS) is commonly utilized in current vehicle localization applications. However, GPS has the issues of Non-Line-of-Sight (NLOS). Tremendous of research works had been carried out to remedy the shortcoming. Most of the research works deployed off-the-shelf Inertial Measurement Unit (IMU) to support GPS positioning when GPS signal lost. However, the IMU that can provide high accuracy positioning is usually expensive and the size is bulky. These make it not user-friendly and not applicable for civilian users. Thus, the objective of the study is to develop affordable smartphone-based GPS-integrated location prediction model for OBD-II-equipped vehicle localization to track the real-time location of vehicle. The focus of this study is the development of location prediction model which can perform integration of GPS data, OBD-II data and the vehicle's heading direction to present the location of vehicle with high continuity and reasonable accuracy. To validate the findings, experimental works were carried out for 5 different scenarios, involving straight road, right-angle-turning, non-right-angle-turning, roundabout and U-turn. The results are presented in the graphical form to show its continuity and in the form of Root Mean Square Error (RMSE) to show its accuracy. The accuracy shows that the GPS-integrated location prediction model is within an accuracy range of 5.2 to 15.8 meters while the cost is affordable and the size is small.

Keywords: Smartphone-based, GPS; OBD-II, Vehicle's Heading Direction, Location Prediction Model

Penentuan Lokasi Kenderaan Darat yang Mempunyai OBD-II dan Berasaskan Telefon Pintar dengan Integrasi GPS dan Ramalan Algoritma

ABSTRAK

Penentuan lokasi kenderaan adalah penting untuk mengesan pergerakan kenderaan darat terutamanya kenderaan syarikat. Sistem Kedudukan Global (GPS) biasanya digunakan dalam aplikasi penentuan lokasi kenderaan semasa. Walau bagaimanapun, GPS mempunyai isu Bukan Dalam Garis Penglihatan (NLOS). Banyak kerja-kerja penyelidikan telah dilakukan untuk membetulkan kelemahan tersebut. Kebanyakan kerja-kerja penyelidikan menggunakan Unit Pengukuran Inersia (IMU) untuk menyokong penentuan kedudukan GPS apabila isyarat GPS hilang. Walau bagaimanapun, IMU yang boleh memberikan kedudukan dengan ketepatan yang tinggi biasanya mahal dan bersaiz besar. Ini menjadikannya tidak sesuai diguna oleh pengguna awam. Oleh itu, objektif kajian adalah untuk membangunkan model ramalan lokasi bersepadu dengan GPS berasaskan telefon pintar yang mampu dimiliki oleh pengguna awam untuk memantau lokasi kenderaan yang mempunyai OBD-II. Tumpuan kajian ini adalah pembentukan model ramalan lokasi yang boleh melakukan integrasi data GPS, data OBD-II dan arah pergerakan kenderaan untuk membentangkan lokasi kenderaan dengan kesinambungan yang tinggi dan ketepatan yang munasabah. Demi mengesahkan penemuan kerja ini, eksperimen dijalankan bagi 5 senario yang berbeza, melibatkan jalan lurus, putaran bersudut tegak, putaran bukan bersudut tegak, bulatan dan pusingan U. Hasilnya dibentangkan dalam bentuk graf untuk menunjukkan kesinambungannya dan dalam bentuk Kesilapan Punca Kuasa Min (RMSE) untuk menunjukkan ketepatannya. Ketepatan *menunjukkan bahawa model ramalan lokasi bersepadu dengan GPS adalah berada dalam lingkungan 5.2 hingga 15.8 meter manakala kosnya berpatutan dan saiz adalah kecil.*

Kata kunci: *Berasaskan telefon pintar, GPS, OBD-II, Arah Pergerakan Kenderaan, Model Ramalan Lokasi*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

4G	Fourth Generation of GSM
5G	Fifth Generation of GSM
ABAS	Aircraft-based Augmentation System
AI	Artificial Intelligence
ANFIS	Adaptive Neuro-Fuzzy Inference System
AOA	Angle of Arrival
AP	Access Point
AR	Auto Regression
AR	Axial Ratio
ASFP	AI-based Segmented Forward Predictor
ASFP	AI-based Segmented Forward Predictor
BDS	BeiDou Navigation Satellite System
BKF	Backward Kalman Filtering
BS	Base Station
CDKF	Central Difference Kalman Filter
CEP	Circular Error Probability
CGI	Cell Global Identity
CI	Cell Identity
CKF	Cubature Kalman Filter
CN	Cellular Network
CR	Circular Polarization
dB	Decibel

dBic	Decibel (measurement unit for circular polarization)
DF-CSA	Dipole-Fed Cross Spiral Antenna
DoD	Department of Defense
DOP	Dilution of Precision
DR	Dead Reckoning
DTC	Diagnostic Trouble Code
ECU	Engine Control Unit
EKF	Extended Kalman Filter
EOBD	European On-Board Diagnostic systems
ETCS	Electronic Toll Collection System
EU	European Union
FKF	Forward Kalman Filtering
FOG	Fiber Optical Gyro
FOS	Fast Orthogonal Search
GBAS	Ground-based Augmentation System
GEO	Geostationary Orbit
GHz	Giga Hertz
GIS	Geographic Information System
GLONASS	Global Navigation Satellite System
GM	Gauss Markov
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication

GSO	Geosynchronous Orbit
HDCKF	High Degree Cubature Kalman Filter
HPE	Horizontal Positioning Error
IDNN	Input-Delayed Neural Network
IMM-EKF	Interactive Multi Model Extended Kalman Filter
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IRNSS	Indian Regional Navigation Satellite System
ISO	International Standardization Organization
ITS	Intelligent Transportation System
IVC	Inter-Vehicle Communication
kbps	Kilobyte per second
KF	Kalman Filter
km	Kilometre
km/h	Kilometre per hour
LAC	Local Area Code
LMA	Levenberg-Marquardt Algorithm
LMU	Location Measurement Unit
LOS	Line-of-Sight
LP	Linear Polarization
m	Meter
Mbps	Megabyte per second
MCC	Mobile Country Code
MEMS	Micro-Mechanical System

MHz	Mega Hertz
MNC	Mobile Network Code
MS	Mobile Station
NLOS	Non-Line-of-Sight
NN	Neural Network
OBD-II	On-board Diagnostics-II
PDF	Probability Density Function
PDR	Pedestrian Dead Reckoning
PF	Particle Filter
PID	Parameter Identification Number
PIFA	Planar Inverted-F Antenna
PPS	Precise Positioning Service
QZSS	Quasi Zenith Satellite System
RBFNN	Radial Basis Function Neural Network
RFID	Radio Frequency Identification
RHCP	Right-hand Circular Polarization
RMSE	Root Mean Square Error
RNS	Regional Navigation System
RSS	Received Signal Strength
RTSS	Rauch–Tung–Striebel Smoother
RTW	Real Time Workshop
s	Second
SA	Selective Availability
SAE	Society of Automotive Engineers

SAR	Specific Absorption Rate
SBAS	Satellite-based Augmentation System
SINS	Strapdown Inertial Navigation System
SM-EKF	Single Model Extended Kalman Filter
SPS	Standard Positioning Service
STCKF	Strong Tracking Cubature Kalman Filter
TA	Timing Advance
TDOA	Time Difference of Arrival
TFS	Two-Filter Smoother
TOA	Time of Arrival
UKF	Unscented Kalman Filter
US	United States
UTM	Universal Transverse Mercator
V	Speed/Velocity
V2V	Vehicle-to-Vehicle
VaNet	Vehicular Ad Hoc
VUT	Vehicle Under Test
WAVE	Wireless Access Vehicular Environment
WBNN	Wavelet-based Neural Network
WLAN	Wireless Local Area Network
ZUPT	Zero Velocity Update