PROBABILISTIC ESTIMATION OF LANES USING VEHICLE GPS TRAJECTORIES

E.R.I.A.C. Manel

(108006 M)

Degree of Master of Philosophy

Department of Electronic and Telecommunication Engineering

University of Moratuwa

Sri Lanka

November 2013

PROBABILISTIC ESTIMATION OF LANES USING VEHICLE GPS TRAJECTORIES

Epa Ranasinghe Imia Appuhamilage Champika Manel

(108006 M)

Dissertation submitted in partial fulfillment of the requirements for the degree of Master of Philosophy

Department of Electronic and Telecommunication Engineering

University of Moratuwa

Sri Lanka

November 2013

Declaration

I, declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future work (such as articles or books)

Signature: ..... Date: .....

E.R.I.A.C. Manel

The above candidate has carried out research for the MPhil dissertation under our supervision.

Signature of supervisor 1: ..... Date: .....

Professor S.A.D. Dias

Signature of supervisor 2 ..... Date: .....

Dr. A. S. Perera

Abstract

This dissertation presents a novel process for generating lane-level information for road maps using a collection of trajectories from vehicles travelling on the road. The information thus generated will aid a range of Intelligent Transportation System (ITS) applications.

Recently, there has been a surge of interest in research in the arena of Intelligent Transportation Systems (ITS). These systems are expected to ensure driver/passenger safety, assist the driver, support green concepts and to improve the overall efficiency and the performance of transportation systems. However, ITS require more information than what current road maps provide. Generating and refining road maps having such level of detail using the existing methods such as surveying and digitization are time consuming, costly and incompatible with the real-time and the dynamic nature of the road network. Therefore, finding new ways of generating this additional information is of high importance in making ITS a reality.

The new method we propose generates lane-level information such as lane centerlines, boundaries and lane-width using vehicle trajectory data. This is achieved by modeling the Probability Density Function (PDF) of trajectories across the road using the non-parametric Kernel Density Estimation (KDE). Unlike the existing methods that use Differential GPS (DGPS) data or improved GPS data, the proposed method uses ordinary GPS data obtained from vehicles moving along the road. It does not require any information regarding the road parameters and is completely automatic. Furthermore, it is completely independent of the lane/road width and does not use stringent assumptions on lane parallelism and constant lane width. In particular, it estimates the locations of lane centers, locations of lane boundaries and lane width. The proposed method for calculating the lane centers was proven to be successful in different road geometries such as straight sections, curved sections and sections with lane splits and merges. The method proposed for calculating lane boundaries produced good results when there are no gaps in between lanes. The lane width calculated using the proposed method is compatible with the recorded standard lane with of the chosen road.

Keywords: GPS, Lane level maps, Kernel density estimation, Kernel bandwidth

To My Parents

Acknowledgement

I extend my sincere appreciation, first to the University of California, Berkley for providing the Mobile Century Dataset that served as a key component from the inception of the project. I equally thank the Staff Development Centre, University of Moratuwa for funding for the two years of my MPhil. Professor S.A.S Kulathilake, director, Staff Development Centre deserves a big thank you for his kind support extended to me with the funding application. I am also grateful to Dr. J.C Balasooria, former Head, Department of Information Technology, University of Moratuwa and Dr. Lochandaka Ranatunga, current Head, Department of Information Technology, University of Moratuwa for granting me two years of leave for my studies.

I would like to thank, in a special way, Professor Dileeka Dias and Dr. Shehan Perera, my supervisors, for their advice, guidance and enthusiasm and for supporting and standing by me throughout my first steps in research. I equally thank Professor J.M.S.J Bandara and Dr. Ajith Pasqual, the progress review committee members for directing and providing valuable input throughout this research. I am grateful to Dr. K.C.B. Wewagedara, postgraduate coordinator of the Department of Electronic and Telecommunication Engineering, for supporting and guiding through the administrative work related to this research. I do thank Nimalika Fernando for all her advices and support extended during the initial phase of the project. Nimalika, the discussions with you accelerated this research and were a relief during difficult times. Thank you very much Indika Karunaratne, for all the valuable comments for the draft version of the thesis. Finally, a big thank you for you, Anjana Uduwaragoda, my husband for all the support and encouragement extended throughout these two years.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
ADAS	Advanced Driver Assistance Systems
BCV	Biased Cross Validation
BOT	Kernel bandwidth calculation method by Botev et al. [97]
CALM	Communications Access for Land Mobiles
DGPS	Differential Global Positioning System
D^2ITS	Data Driven Intelligent Transportation Systems
DVB-SH	Digital Video Broadcasting - Satellite services to Handhelds
GMM	Gaussian Mixture Model
GPS	Global Positioning System
ISO-GDF	ISO- Geographic Data Format
ITS	Intelligent Transportation Systems
KDE	Kernel Density Estimation
LDM	Local Dynamic Maps
LSA	Least Squares Approximation
LSCV	Least Squares Cross Validation
NDS	Navigation Data Standard
NECTOD	Network Constrained Trajectory Outlier Detection
OSM	Open Street Maps
PDA	Personal Digital Assistant
PDF	Probability Density Function
PSF	Physical Storage Format
PPP-GPS	Precise Point Positioning – Global Positioning System
RT	Rule of Thumb for Gaussian
SJ	Sheather & Jones Plug-in Method
SPCS	State Plane Coordinate System
TRAOD	Trajectory Outlier Detection
UCV	Unbiased Cross Validation
WAVE	Wireless Access in Vehicular Environments

LIST OF APPENDICES