HIGH ACCURACY GPS-FREE VEHICLE LOCALIZATION FRAMEWORK VIA A SINGLE RSU

By

Ahmed Abdel Wahab Mohamed El Marady

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
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Title of Thesis:

High Accuracy GPS-Free Vehicle Localization Framework via a Single RSU

Key Words:

Roadside unit; Dead reckoning; Inertial navigation system; Dedicated short-range communication (DSRC); Vehicular ad-hoc network (VANET); Kalman filter.

Summary:
This thesis presents a high accuracy GPS-free vehicle localization framework to be used in collision avoidance applications. In contrast to the error-prone existing localization techniques, the approach proposed in this thesis determines the vehicle location, up to lane-level accuracy via a single Road Side Unit (RSU). By using one RSU, the cost of the localization system installation is reduced. The suggested framework integrates the information from the local Inertial Navigation System (INS) and a single RSU via Kalman and extended Kalman filters.

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Dedication

To my mother, my father and my wife.

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List of Abbreviations and Symbols

List of Abbreviations

ACC	Adaptive Cruise Control
ACK	Acknowledge
A-GPS	Assisted–Global Positioning System
AIFS	Arbitration Inter-frame Space
AoA	Angle of Arrival
AP	Access Point
ARIB	Association of Radio Industries and Businesses
ASTM	American Society for Testing and Materials
CWS	Collision Warning Systems
CCW	Cooperative collision warning
CCH	Control Channel
CEN	European Committee for Standardization
CW	Contention Window
CSMA/CA	Carrier Sense Multiple Access/ Collision Avoidance
CTS	Clear–to–Send
DCF	Distributed Coordination Function
D-GPS	Differential–Global Positioning System
DIFS	DCF Inter Frame Space
DR	Dead Reckoning
DSRC	Dedicated Short–Range Communication
EDCA	Enhanced Distributed Channel Access Function
EKF	Extended Kalman Filter
EIFS	Extended IFS
ETC	Electronic Toll Collection
FCC	Federal Communications Commission
GBAS	Ground–Based Augmentation System
GOT	Grid-based On-road localization
GEO	Geostationary
GPS	Global Positioning System
HCCA	Hybrid Controlled Channel Access
IFS	Interframe Space
INS	Inertial Navigation System
IVCAL	Inter–Vehicle–Communication–Assisted Localization
ITS	Intelligent Transportation Systems
KF	Kalman Filter
LOS	Line of Sight
MAC	Media Access Control
MANET	Mobile Ad-Hoc Networks

MCC	Mission Control Centers
MSC	Mobile Switching Center
NAV	Network Allocation Vector
NHTSA	National Highway Traffic Safety Administration
NLOS	Non Line of Sight
NLES	Navigation Land Earth Stations
OBU	Onboard Unit
PCF	Point Coordination Function
PHY	Physical
QoS	Quality of Service
RIMS	Ranging and Integrity Monitoring Stations
RFID	Radio Frequency Identification
RF-GPS	Radio-Frequency-GPS
RMSE	Root-Mean-Square Error
RSU	Roadside Unit
RTS	Request–to–Send
RSS	Received Signal Strength
RTT	Round–Trip Time
SBAS	Satellite–Based Augmentation System
SCH	Service Channel
SIFS	Short Inter-Frame Space
TDOA	Time Difference of Arrival
TOA	Time of Arrival
TTFF	Time-To-First Fix
VANET	Vehicular Ad-hoc Networks
V2V	Vehicle-to-Vehicle
V2R	Vehicle-to-Roadside
WAVE	Wireless Access in Vehicular Environments
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network

List of Symbols

A, B	Control matrices
C	Speed of light =3x10^8
CLT	Change-lane-threshold
CW_{min}	Minimum contention window
CW_{max}	Maximum contention window
EMA_K	Exponential weighted moving average
ε_k	Curvature noise which reflects the lane-level ambiguity
g_k	Kalman gain used in one-dimensional Kalman filter
$\underline{g}_k$	2x1 Kalman gain used in two-dimensional extended Kalman filter
$h(\cdot)$	Non-linear function used to compute the predicted single-value measurement, $R_{V,RSU}$
$\underline{h}_k$	1x2 Jacobian vector of the partial derivatives of $h(\underline{\varphi})$
I	2x2 unit matrix
L	Length of the road
L_{RSU}	y-coordinate of the RSU
L_i and L_{i-1}	The boundaries of lane i
MA_K	Moving average
M	Number of prior observations of $\tilde{x_k}$
N	North road driving direction
n_r	Noise comes from range estimation, $R_{V,RSU}$
θ	Drift angle
p_k	Posteriori estimate error variance
p_k^-	Priori estimate error variance
P_k	2x2 posteriori estimate error covariance matrix
P_k^-	2x2 priori estimate error covariance matrix
Q	2x2 covariance matrix of the process noise
$R_{V,RSU}$	Estimated range between vehicle and RSU at time t_2
$R'_{V,RSU}$	Estimated range between vehicle and RSU at time t_1
$RMSE_x$	Root-mean-square error of vehicle location in x dimension
$RMSE_y$	Root-mean-square error of vehicle location in y dimension
S	South road driving direction
T	Time interval
τ	Time delay experienced at the RSU
$\underline{u}_k$	2x1 vector that represent vehicle velocity components in the x and y directions
v	Vehicle speed
v_{min}	Minimum vehicle speed

v_{max}	Maximum vehicle speed
W	Width of the road
$\underline{w}_k$	Process noise comes from using INS
$\bar{y}_k$	Estimated vehicle location using our One-RSU-based approach at time t_k
$\hat{y}_k$	Posteriori state estimate of the vehicle location in y-dimension
$\hat{y}_k^-$	Priori state estimate of the vehicle location y-dimension
σ_r^2	Variance
z_k	Measurement
$(x_{actual.i}, y_{actual.i})$	Real vehicle location at time instant i
ζ_k	Measurement noise
α	Weighting factor
$\underline{\hat{\varphi}}_k^-$	2x1 priori state estimate of the vehicle location
$\underline{\hat{\varphi}}_k$	2x1 posteriori state estimate of the vehicle location