Pedestrian Navigation System Using Shoe-mounted INS

By
Yan Li

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Certificate of Original Authorship

I, Yan LI, certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Contents

List of Abbreviations

GPS	Global Positioning System
INS	Inertial Navigation System
IMU	Inertial Measurement Unit
ZUPT	Zero Velocity Update
EKF	Extended Kalman Filter
CUPT	Constant Velocity Update
RFID	Radio Frequency Identification
WLAN	Wireless Local Area Network
UWB	Ultra Wide Band
RSS	Received Signal Strength
SLAM	Simultaneous Localization And Mapping
SINS	Strapdown Inertial Navigation System
MEMS	Micro Electro Mechanical System
ARW	Angular Random Walk
RW	Random Walk
ECEF	Earth-Centred Earth-Fixed
PDR	Pedestrian Dead Reckoning
MV	Moving Variance
MAG	Acceleration Magnitude
ARE	Angular Rate Energy
SHOE	Stance Hypothesis Optimal Estimation
ZVD	Zero Velocity Detectors
RTS	Rauch-Tung-Streibel
VO	Visual Odometry
UKF	Unscented Kalman Filter
PF	Particle Filter

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ABSTRACT

Pedestrian navigation using Global Positioning System (GPS) is still a considerable challenge in indoor environments where GPS signals are blocked. Inertial Navigation System (INS) is a self-contained system which can offer a navigation solution in most environments without the need for any additional infrastructures.

A type of pedestrian navigation system with shoe-mounted Inertial Measurement Units (IMUs) has shown promising results. During walking, the foot is briefly stationary at zero velocity on the ground, named as the stance phase. The technique zero velocity update (ZUPT) is implemented to constrain the sensors' error which uses the stance phase in each step to provide corrections periodically.

In this research, a model with 24 error states is applied to correct IMU errors with an Extended Kalman Filter (EKF). The EKF estimated velocity errors are reset to zero in each stance phases, and successively to correct the IMU measurements. These repeated corrections could effectively control the error growth in navigation solution and minimize the drift.

This thesis introduces three main contributions I have achieved for pedestrian navigation system with shoe-mounted IMU. Firstly, I have developed a new approach to detect the stance phase of different gait styles, including walking, running and stair climbing. Secondly, I have proposed a new concept called constant velocity update (CUPT) which is an extension of ZUPT to correct IMU errors on a moving platform with constant velocity, such as elevators or escalators. This new concept has broadened the practical application of pedestrian navigation based on shoe-mounted IMUs in a modern building environment. Lastly, as ZUPT applied at each step will lead to sharp corrections and discontinuities in the estimated trajectory, I developed a closed-loop step-wise smoothing algorithm to eliminate sharp corrections and smooth the trajectory. A software package in MATLAB has been developed and tested on different subjects. Good pedestrian navigation solutions have been achieved with the proposed method, which are published in journal and conference papers.

KEYWORDS: Pedestrian navigation, IMU, Step Detection, Kalman Filter, ZUPT, CUPT, RTS smoothing.