Chapter 4
Study of Zero Velocity Update for Both Low- and High-Speed Human Activities

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ABSTRACT

Previous studies show that inertial sensor-based personal positioning benefited from Zero Velocity Update (ZUPT) method by resetting the foot speed at every foot step. However, only the solution for normal pedestrian movement with small velocity like walking was given. This paper presents a novel ZUPT system which can be used in a wide range of human activities, including walking, running, and stair climbing by using two inertial measurement unit (IMU) modules. One is attached on the centre of the human body for human activities' classification and recognition. The other one is mounted on the foot for ZUPT algorithm implementation based on the result of activities' recognition. Test cases include stair climbing by walking and running, walking, fast walking, and running. In all cases, most of the steps are able to be detected and the new ZUPT system can be successfully implemented.

1. INTRODUCTION

Although localization is becoming available to the general public and businesses via widespread use of Global Positioning System (GPS) receivers, GPS still needs support in urban and indoor environments, since GPS signal can be blocked by high buildings, canyons or forests among others. As indoors localization can not rely on GPS, it can be a serious problem in certain situations for emergency responders such as fire fighters. There are some non-GPS approaches to track and navigate personal position (Fischer & Gellersen, 2010) and these systems normally require external

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references. (Zhang, 2009) used mobile base-station based wireless infrastructure to track the moving object with the help of Kalman filter and Interacting Multiple Mode (IMM). Sippel (2010) used Optical Laser Tracking System (OLTS) consisting of the Laser Base Station (LBS) and the Intelligent Sensor Node (ISN) to obtain the information of position. Widyawan et al. (2008) showed that a novel Backtracking Particle Filter (BPF) could be combined with different levels of building plan detail to improve Pedestrian Dead Reckoning (PDR) performance. Butz et al. (2000) presented a building information and navigation system based on Palm Pilot Personal Digital Assistants (PDAs) and a set of strong infrared transmitters, located throughout a building. Newman et al. (2001) provided personnel with Augmented Reality (AR) services using data from an ultrasonic tracking system. Generally, these reference-based systems have advantages of being able to deliver an absolute position and orientation in real-time and the error will not grow with time. However, these systems can only be utilized if the application permits the installation of those external references ahead of time. Cinaz and Kenn (2008) used simultaneous localization and mapping techniques to automatically generate both localization information and 2D environment maps by using head-mounted inertial and laser range sensors. Although no references are needed, the approach fails when the tracked object locates on ruins where no architectural constructions exist to generate map.

Inertial sensor-based localization systems provide a solution for personal navigation and positioning by using inertial sensors such as accelerometer and gyroscope which neither depend on the environments in which pedestrians are located nor the references. However, these systems suffer from the sensor drift when using low cost inertial sensors. As there are no references available, the position and orientation errors will grow with time. In order to provide a long term stable orientation solution, generally, some other sensors, such as magnetometer and pressure sensor, are integrated with inertial sensors by Kalman filter, which is used by modern Attitude and Heading Reference Systems (AHRS) (Foxlin, 1996; Luinge et al, 2004; Roetenberg et al., 2005). However, large velocity and position errors are still not able to be efficiently reduced after two times integrations due to the sensor drift.

In order to overcome the drift error, Zero Velocity Update (ZUPT) algorithm resetting the foot speed at every foot step was introduced (Ojeda & Borenstein, 2007a, 2007b) by using a foot-mounted sensor module. Although the drift problem of normal pedestrian movement with small velocity like walking is able to be solved if accurate orientation data can be obtained from AHRS, the same algorithm-setting fails when operating high-speed movement, since the durations of the still phase, whose definition will be given later on, is not capable of being detected by using the same threshold value. Foxlin (2005) suggested enlarging the step detection threshold when experiencing high-speed movement, but no further details were given. Even if the correct threshold value for detecting high-speed movement can be determined, how to switch the threshold values between activities with different velocities is still a problem. ZUPT algorithm must be informed to change the threshold values when the operated movement starts to change.

Multiple sensor modules were commonly used to cope with kinematic analysis of complicate movement. Renaudin et al. (2007) presented a distributed architecture of sensors for agent, in which chest-attached sensor module was used for orientation analysis, both thigh- and chest-attached sensor modules were used for posture analysis and leg-attached sensor module was used for gait analysis. Zhu and Zhou (2004) described a real-time motion tracking system, which required more than ten sensor modules for whole body kinematics analysis. Schepers et al. (2010) developed an Inertial and Magnetic Measurement System (IMMS) which used three

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