Zero Velocity Detection in Foot-Mounted Inertial Sensors: Novel Method for Generating Zero Velocity Labels and a Comparative Analysis of Data Driven Methods

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Key words: Geoinformation/GI; Positioning; Inertial navigation; IMU; machine learning; zero-velocity detection; UWB; pedestrian dead reckoning; dataset

SUMMARY

Foot mounted inertial navigation is a hotspot problem in the field of indoor localization nowadays. It has various applications like navigation, indoor mapping, first responder positioning, gait analysis etc. In foot mounted inertial navigation, sensors such as Inertial measurement units (IMU) are installed on the feet of a user to utilize it for localization of the user. For user localization initial position, attitude of the user and current IMU sensor observations are used to find the current position of the user. However, IMU sensors used in indoor localization are low-cost sensors hence they suffer from various errors and biases which leads to drift in the final position estimation of the user. To bound the error growth, zero velocity update (ZUPT) is used which requires a crucial step of zero velocity detection. In zero velocity detection, time interval at which the foot of the user is firmly placed on the ground is evaluated and is referred to as zero velocity interval (ZVI). During ZVI it is assumed that the velocity of the foot is zero and this information is used as an update in the Kalman filter, referred to as ZUPT which in turn helps to reduce the error in position. Zero velocity detectors (ZVD) such as: ARED, SHOE etc. uses fixed threshold to perform zero velocity detection but fails in case of dynamic motion. To counter this problem, data driven ZVD which depends on learning-based models such as: CNN, LSTM, SVM, LSTM-CNN etc. are developed. But these detectors require large amount of data for training the models. Currently, the amount of publicly available datasets for training and testing of these models are quite few in number. Another problem is that the datasets which are available do not contain proper labelling of ZVI and the approach used to perform ZVI labelling in those datasets is quite computationally expensive. The performance of the learning-based detectors relies solely on the quality of the dataset. This paper proposes a novel approach to capture and automatically label the IMU observations needed for ZVD algorithms. In this approach, foot mounted IMU is proposed to be integrated with a dual foot mounted UWB (Ultra-Wide Band) sensor and periodicity of the UWB distance observations (between the feet) is used to detect and automatically label the ZVI. The quality of the labelled dataset thus, collected is

discussed and analyzed.

The second part of the paper assesses and compares the performance of various ZVD algorithms including ARED, AMVD, SHOE, LSTM, CNN, LSTM-CNN on the pyshoe dataset and new dataset collected using the proposed methodology. The preliminary results demonstrate the machine learning based algorithms (such as ARED, AMVD and SHOE) can yield accuracy of the order of 85-90%, while other algorithms such as LSTM, CNN and LSTM-CNN may perform better albeit at the cost of increased efforts in training the networks. The main contributions of this paper are: (1) a new methodology for labelling the dataset by using an additional UWB sensor, (2) dataset produced will be made publicly available for better training and testing of new algorithms of zero velocity detection, (3) comparison of existing zero velocity detection approaches on both the publicly available dataset and our dataset.