NAVIGATION DEAD RECKONING SYSTEM BASED ON A MOBILE PHONE

Lazarevskiy O.A.
National Aviation University, Kyiv
Scientific supervisor - Mukhina M.P.,
Doctor of Engineering Science. Associate Professor

The problem of pedestrian dead reckoning (PDR) is referred to the class of individual navigation problems. The common solution in mobile phones is the use of satellite navigation (GPS, GLONASS, Galileo, etc.).

But satellite signal sometimes can be jammed intentionally or lost due to obstacles in urban area. Also, the problem of PDR is interesting in the user localization in indoor environment such as large garages, city molls, etc. Instrumentation of smartphones is now based on Micro-Electro-Mechanical Sensors (MEMS) technology and includes standard set of Inertial Measurement Unit (IMU): accelerometers, gyroscopes, magnetometers and pressure sensor (optionally).

Accelerometers can be used to detect step events and further to calculate lengths. But it is sensitive to walking speed, slope of the road, etc., which leads to inaccurate results of calculating the stride length. Also, as any dead reckoning technique PDR suffers from the cumulative error. Since the location estimate is always calculated based on the previous result, the error accumulates rapidly over time. This means that correction updates are necessary on regular basis.

For example, the error in determining the direction has a greater effect on the estimation of the location than the error in calculating the step length.

The readings of magnetometers and gyroscopes can be used to calculate the course. However, the magnetometer is exposed to electric current and metals in the environment; the gyroscope has a drift problem, which means that the reading error increases with time. Besides, tilting the smartphone can lead to a deviation of its course from the direction of user walking. Smartphone poses also contributes to course accuracy, which must be considered in practice.

The crucial question is how to detect the step by IMU readings. There are a variety of different methods and techniques: zero crossing, peak detection, normalized auto-correlation based step counting, etc.

The threshold method is based on counting the steps by detection of reaching the threshold of sensor readings (usually accelerometers). But the value of threshold depends on sensor type and also on the walking pattern of pedestrian. However, though the threshold method is the simplest, it is mostly related to empirical techniques, since the optimal threshold for all the cases does not exist, especially when smartphones are used in an unconstrained manner.

The autocorrelation method is combined with additional techniques like thresholding. The one more problem of autocorrelation method is connected with the necessity to work with long sequences (means either offline processing of data or delay in step counting if working in real time modes). Also, the computing sufficiency of method is lower than methods of peak detection or zero crossing.

The peak detection method calculates steps based on the number of peaks in accelerometer vector magnitude. It is more flexible but suffers from interference peaks due to environmental noises and occasional disturbance. There is variety of method modification: low-pass filtering to remove interferences, limiting the time interval between two peaks, use of vertical acceleration data for smartphone position constraints.

Zero crossing method of step counting is based on the detection of zero points in accelerometer vector magnitude. Again, the sensor readings must be pre-filtered to smooth the instrument noises.

For both methods, zero crossing and peaks detection there is the problem of unconstrained manner of smartphone holding.

The most interesting method is the normalized auto-correlation based step counting since it works directly with periodical nature of walking.

Accelerations. MEMS-accelerometers provide three components of acceleration vector $a_m = (a_x, a_y, a_z)$. Optionally the readings of accelerometers can be already calibrated and filtered from thermal noises. The magnitude of acceleration vector is found as $a_m = \sqrt{a_x^2 + a_y^2 + a_z^2}$.

Inertial Measurement Unit readings needs to be interpreted depending on the walking type. Generally, the transmission between walking phases is accompanied by the respective change of acceleration. That is why most of the method of step detection and counting are based on processing the acceleration vector magnitude.

The magnitude of acceleration vector must be preprocessed to eliminate gravity components, $a_{ng} = a_m - g$ and filtered to delete random noises by low-pass filter with cut-off frequency corresponding to the update sensor rate.

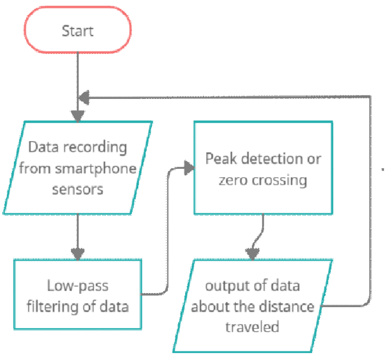

Fig.1. Algorithm of the system pedestrian dead reckoning

Therefore, the algorithm of the system pedestrian dead reckoning (Fig.1) has the following sequence:

1) Reading and writing data from MEMS components;

2) Filtration of the received data using low-pass filters;

3) Isolation from the data array of fluctuations according to the specified parameters of the peaks or passing through zero;

4) Detection of characteristic points;

5) Data output about the change in position in space on the smartphone screen.

The investigated methods of step counting provide accurate results for the constrained holding of smartphone (strictly in hands) and differ in the computing efficiency. Both of peaks detection and zero crossing are of good speed of response and can operate in real time mode to calculate step for the task of active pedestrian dead reckoning. When the smartphone is in the hands/bags, the accuracy radically drops up to 40–50%.

References:

1.S. Beauregard and H. Haas, "Pedestrian dead reckoning: A basis for personal positioning," in Proceedings of the 3rd Workshop on Positioning, Navigation and Communication, March 2006, pp. 27–35.

2.A. R. Jimenez, F. Seco, C. Prieto, and J. Guevara, "A comparison of pedestrian dead-reckoning algorithms using a low-cost MEMS IMU," in 2009 IEEE International Symposium on Intelligent Signal Processing, August 2009, pp. 37–42.

3.P. Kasebzadeh, C. Fritsche, G. Hendeby, F. Gunnarsson, and F. Gustafsson, "Improved pedestrian dead reckoning positioning with gait parameter learning" in 2016 19th International Conference on Information Fusion (FUSION), July 2016, pp. 379–385.

4.A. Brajdic, R. Harle, "Walk detection and step counting on unconstrained smartphones," in Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing, September, 2013, pp. 225–234. https://doi.org/10.1145/2493432.2493449