Human Localization Using Body-Worn Inertial/Magnetic Sensors

Kerem Altun and Billur Barshan
{kaltun@ee.bilkent.edu.tr, billur@ee.bilkent.edu.tr}
Department of Electrical and Electronics Engineering
Bilkent University, Ankara, Turkey

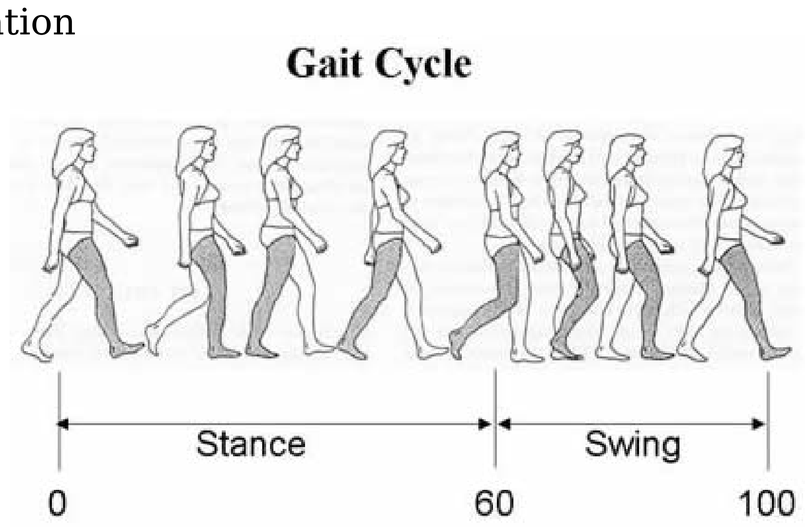
Introduction

- in many intelligent systems, the current location and activity context of the user can be helpful
- location is usually determined by externally-referenced sensors such as
  - satellites (GPS)
  - cellular networks (GSM)
  - local wireless networks (RFID, WiFi)
- here we determine location using body-worn inertial and magnetic sensors

- provide GPS-free localization in indoor environments and outdoor environments with GPS outages
  - emergency responders
  - underground miners
  - military applications

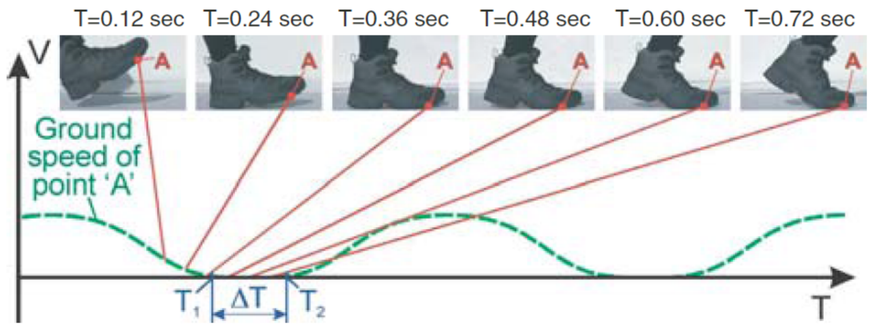
Methodology

- inertial sensors suffer from integration drift
- gyroscope signals are integrated once to find orientation, accelerometer signals are integrated twice to find position
- the slightest error in sensor signals causes unbounded error growth in orientation and position
- magnetometers are used to provide external reference for orientation



(figure taken from http://me.queensu.ca/people/deluzio/images/GaitCycle.jpg)

- human gait is periodic, and each period is divided into two phases, depending on whether the foot is in contact with the ground or not: the ***stance phase*** and the ***swing phase***



(figure taken from [1])

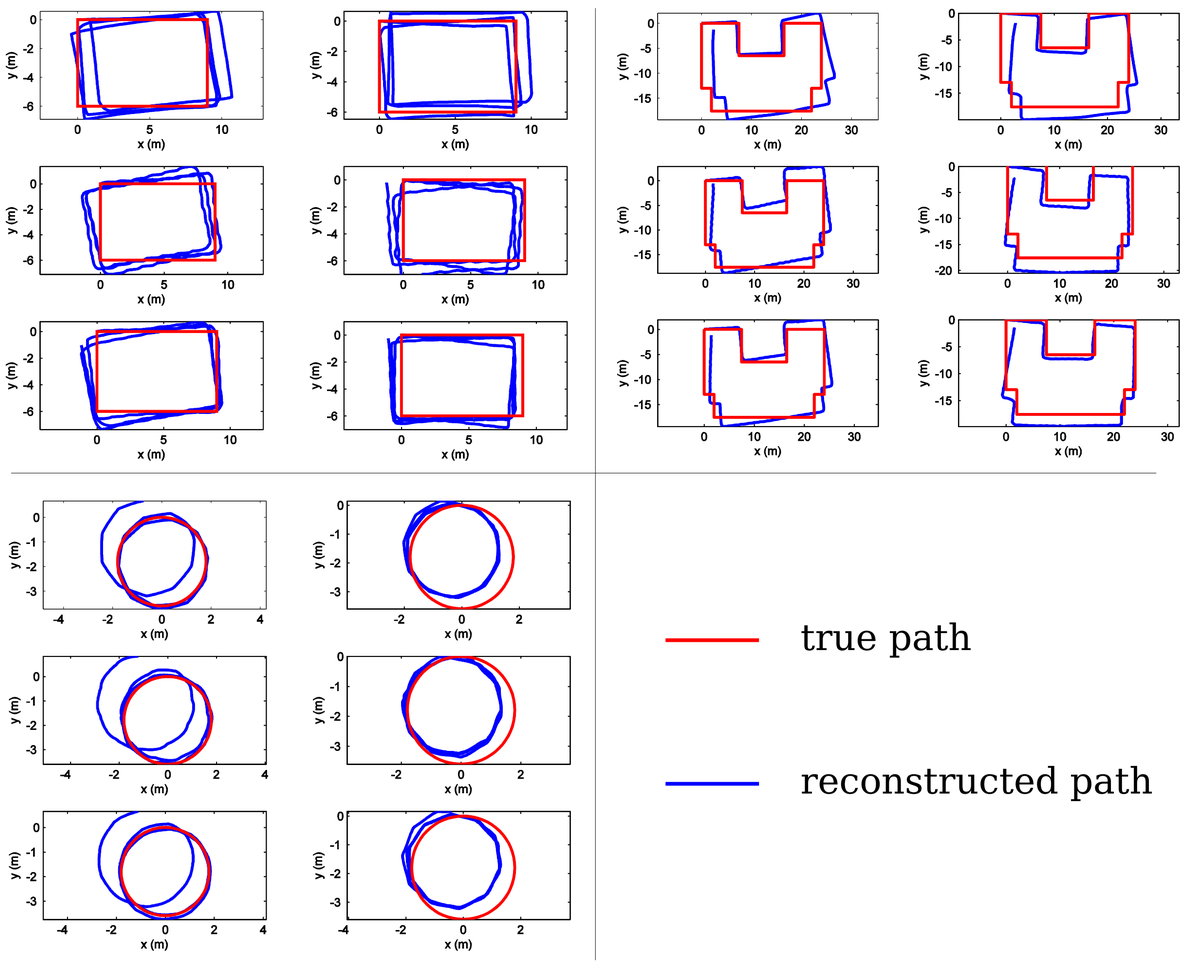
- in some time interval ΔT during the stance phase, the foot velocity and acceleration are ***exactly zero***
  - so, the true values of velocity and acceleration are known
  - the velocity and acceleration can be reset to the true value (zero) at one point in ΔT
  - the error in one step is not accumulated to the next step
  - this is called a ***zero-velocity update (ZUPT)*** [1]

Zero-Velocity Update

- it is required to determine ΔT accurately
  - then we can perform ZUPT at one point inside ΔT
- in the literature, there are methods to determine ΔT [2]
- we threshold the angular velocity magnitude

Experimental Results

- we mount Xsens MTx sensors [3] on both feet and the chest
- we perform the following experiments
  - walking on a rectangle with dimensions 9m x 6 m (for three laps)
  - walking on a rectilinear polygon
  - walking on a circle with radius 3.6m (for three laps)
- we use ZUPT to find the traveled distance
- for the heading, we use three different methods, using the Kalman filter output of the MTx sensors



Discussion and Future Work

- the heading error contributes more to the overall error
- ZUPT is not applied to the heading data
- in our previous work on activity recognition [4], we use the same sensors and determine the activity with 99% accuracy
  - using activity recognition cues and a map, we can perform updates for the true position
  - provide localization without any external reference if a map of the environment is available

Acknowledgments

This work is supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK) under grant number EEEAG-109E059 that participates in MOVE (COST Action IC0903).

References

[1] L. Ojeda et al., ''Non-GPS navigation for security personnel and first responders,'' *J. Navigation*, 60(3): 391—407, 2007.
[2] I. Skog et al., "Zero-velocity detection – an algorithm evaluation," *IEEE T. Bio-med. Eng.*, 57(11): 2657—2666, 2010.
[3] MTi and MTx User Manual and Technical Documentation, Xsens Technologies Inc., http://www.xsens.com
[4] K. Altun et al., "Comparative study on classifying human activities with miniature inertial/magnetic sensors," *Pattern Recogn.*, 43(10): 3605—3620, 2010.