Development of a 3-D Personal Navigation System for First Responders Using Human Gait Characteristics

Timofey Spiridonov
Graduate Research Assistant
University of Maryland

Dr. Suneel Sheikh
Research Associate
ASTER Labs, Inc

Dr. Darryll Pines
Professor and Dean
University of Maryland

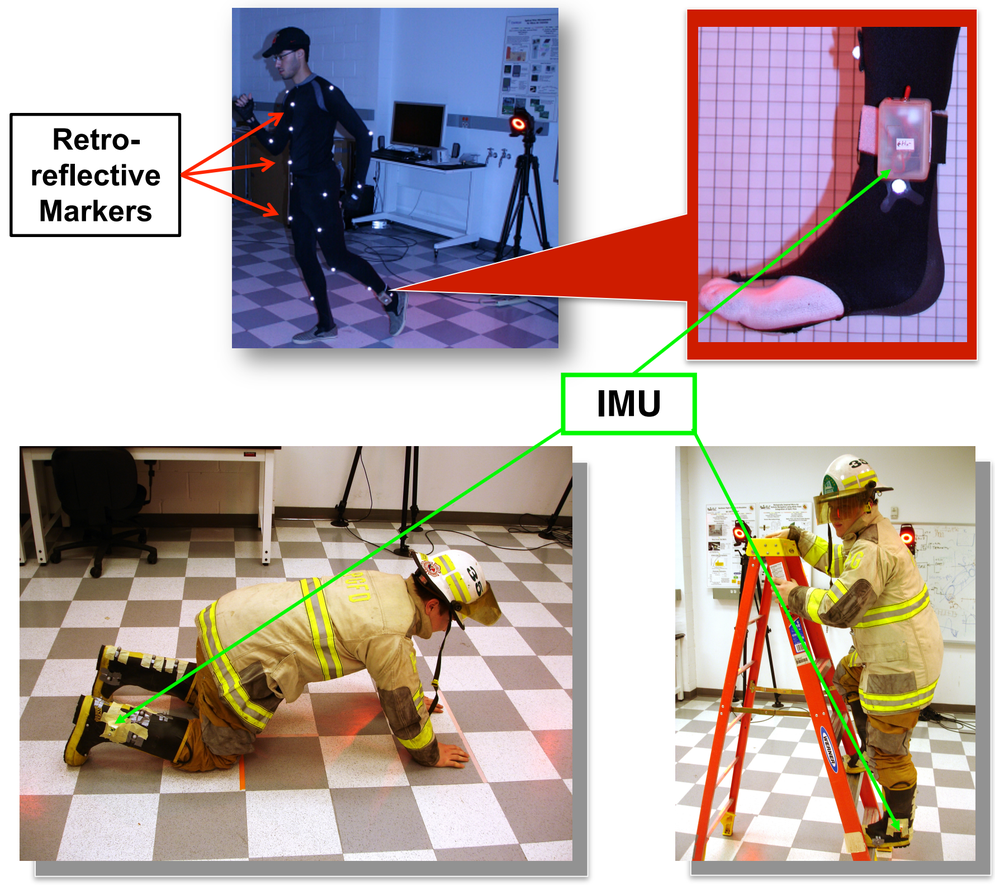
Motivation: Provide a proof of concept for a system capable of tracking first responders without the use of a Global Positioning System in a variety of operational conditions.

Objective: The study of human kinematics can facilitate the design of a system in a variety of operational environments. The design must be capable of tracking First Responders to within 1 meter accuracy.

Approach:

- The design philosophy is that the body must travel wherever the feet go.
- Human gait characteristics coupled with inertial navigation and an array of distance-measuring sensors are used to obtain distance and heading information.
- A pair of inertial measurement units (IMU) composed of MEMS sensors packages are positioned on each ankle (complete with a set of accelerometers, gyroscopes, and magnetometer).
- The IMU sensors track the type of motion that the subject undergoes, but difficulties in eliminating the accelerometer and gyroscope drift over time make the system inefficient.
- To enhance and improve IMU measurements a measure of direct foot separation and incremental heading is being developed using a RF modulation technique.

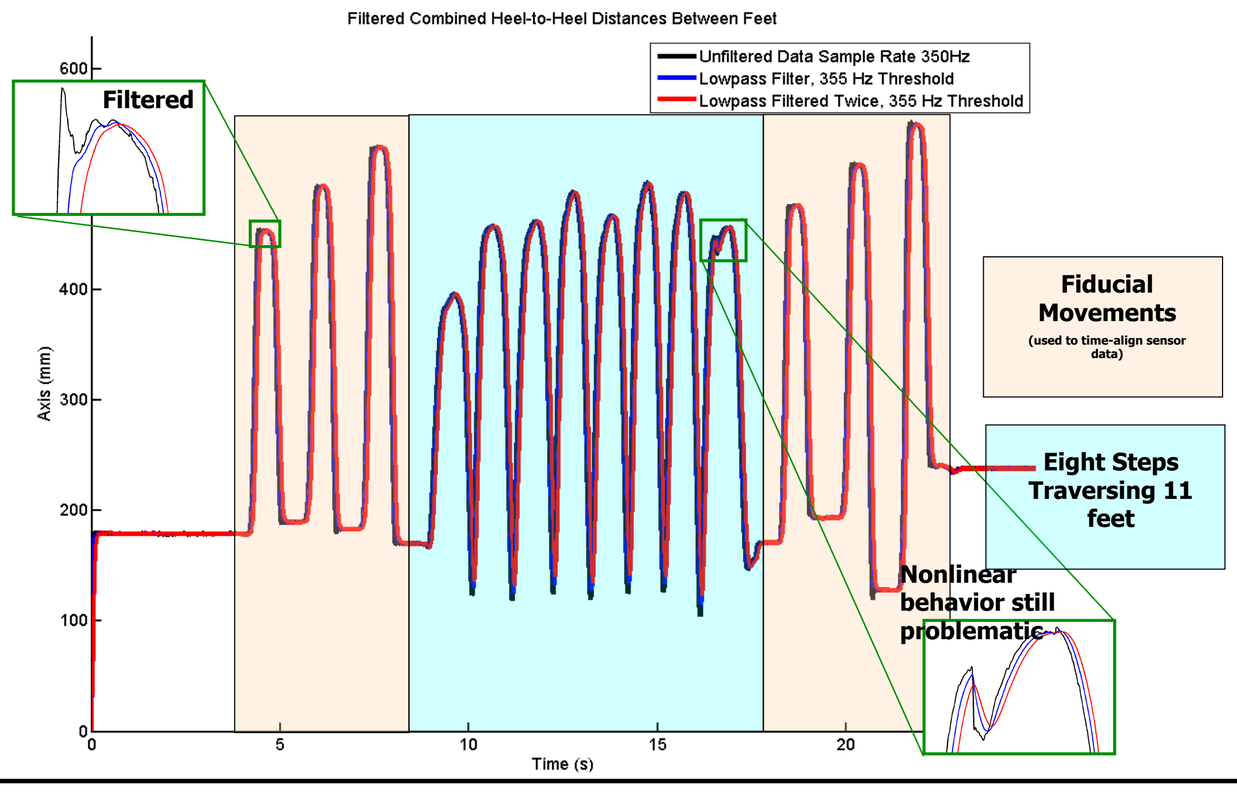
VICON Motion Capture for Gait Modeling:



Five different gait modes were investigated for a variety of subjects:

- Forward Walk
- Backward Walk
- Forward Shuffle
- Forward Crawl
- Forward Army Crawl

VICON Analysis of Forward Walk



Mode Analysis Results Using 2 Nodes:

Run Scenario	Distance Subject Instructed to Move	Peak Computed Distance	Single Trial Error	Error 'Range'
Straight Line Walk	11 ft	3.30 m = 10.83 ft	1.55%	1-5%
Forward Shuffle	6 ft	1.88 m = 6.16 ft	2.66%	1-5%
Backward Shuffle	6 ft	1.80 m = 5.92 ft	1.35%	1-5%
Side-to-side Shuffle	7.5 ft	2.27 m = 7.46 ft	0.53%	1-5%
Forward Crawl	13 ft	3.83 m = 12.55 ft	3.58%	1-10%
"Duck" or Crouch Walk	13 ft	4.12m = 13.51 ft	3.92%	1-10%

Relative Foot Sensor Concept:

- Create a network of RF sensors within the First Responder boots. Utilize differential-GPS techniques for optimal relative range measurements.
- At least 4 nodes would be implanted in the sole and ankle of the boot, for full 3-D functionality.
- VICON markers in motion capture simulate the approximate order of accuracy as expected from relative foot sensor.
- 2D analysis conducted successfully. Large data sets to be processed with 3D algorithms.

Using all measurements in batch processing to solve for stride length, L_1, and heading, ψ