The Geodetics Personal Navigator (GPN)

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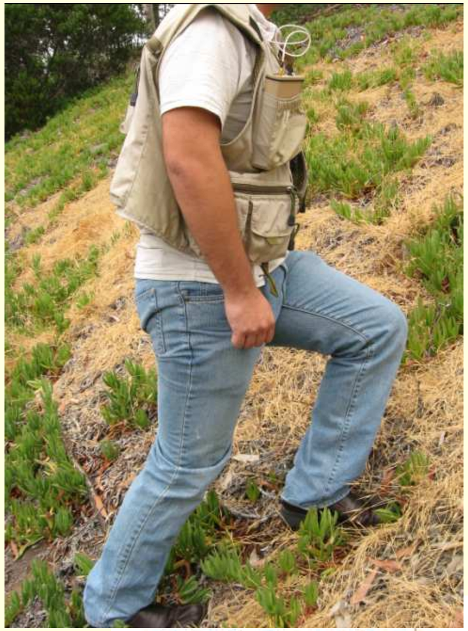
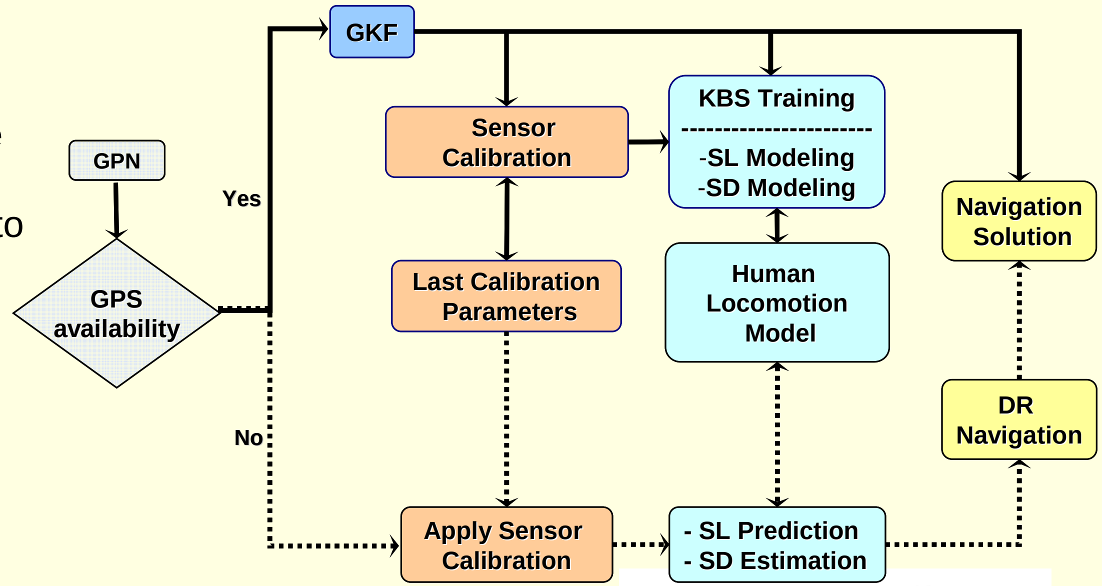
Overview of the System

- GPN
  - GPS receiver
    - Single frequency Novatel
    - Tracking L1, CA Code
  - IMU and embedded magnetometer compass
    - MicroStrain 3DM-GX2
  - Communications
    - Internal wireless TDMA radio
  - Interfaces
    - GPS antenna connector
    - Ethernet data port
    - Programmable bi-directional discrete I/O's
    - Internal wireless TDMA data link
    - Radio antenna connector
  - Power
    - Internal Lithium-Polymer rechargeable cells
- Human as "navigation sensor"
  - Determine the locomotion pattern
  - Supports navigation in 2D
    - Step length (SL), and Step direction (SD) determination
- Dead-Reckoning (DR) navigation unit
- Target goal of 1-3 m CEP (50%)



System Architecture Design

- To accomplish the DR supported by human locomotion and the self-contained sensors, an open-ended architecture was designed
- The architecture has three main modes with sufficient flexibility adaptable in accordance with the change of environments:
  1. Calibration mode
     - An Extended Kalman Filter developed by Geodetics (GKF) was used in order to integrate and calibrate the self-contained sensors
  2. Training mode
     - Training the Artificial Intelligence (AI) in the form of knowledge-based system (KBS) to predict human dynamics
  3. DR mode
     - Maintain navigation parameters during GPS-denied periods



DR Navigation Mode

The primary steps of the DR navigation mode:

1. Detect operator's step and step parameters
2. Determine the dynamic locomotion pattern (gait cycle and type)
   - Step event, step interval
   - Standing, walking, jogging, climbing stairs, backward walking, sideward walking, and athletic motions, etc.
3. Utilize Knowledge Based System (KBS) for accurate determination of SL
   - Fuzzy logic
4. Utilize an adaptive calibration of gyro to provide heading, SD
5. Reconstruct the navigation trajectory using an intelligent Kalman filter structure, called DR-KF.

Human Locomotion Model

- Human locomotion model is a complex process affected by a large number of factors, including:
  - Body characteristics
  - Person's physical condition
  - Locomotion type
  - Terrain topography
  - Environmental conditions
- Exploiting human locomotion as a sensor offers additional information to a personal navigation system
- In this context, the human locomotion model is focused on analyzing measurable parameters of steps:
  - Step interval or step frequency
  - Locomotion pattern
- Considering the human body as a navigation platform, an AI-based human locomotion model was developed and implemented
- Here, 'intelligence' implies a mechanism by which the human dynamics can be parameterized by human body locomotion

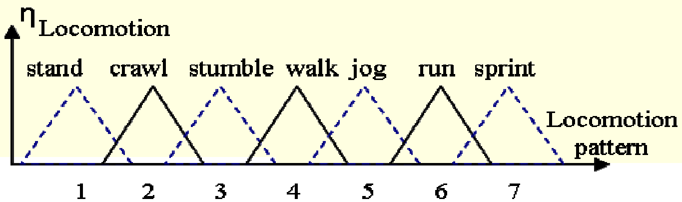
Numerical Results

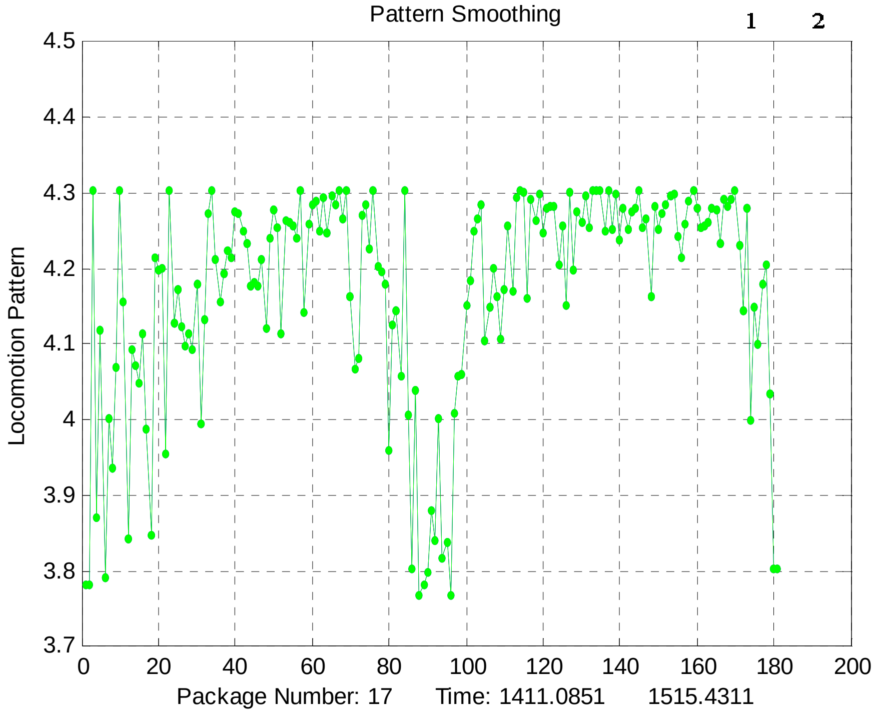
- Outdoor environment
  - April, 13, 2010
  - Kate O.Sessions Park, San Diego, CA
  - 3 loops walking uphill/downhill
    - Slope ±15 %
    - Duration ~ 9 minutes
    - Length: 540 m
  - 4 loops slow jogging (clockwise)
    - Duration ~ 8 minutes
    - Length: 566 m
  - 6 loops walking (anticlockwise)
    - Duration ~ 15 minutes
    - Length: 909 m
  - 2 loops backward walking
    - Duration ~ 5 minutes
    - Length: 296 m

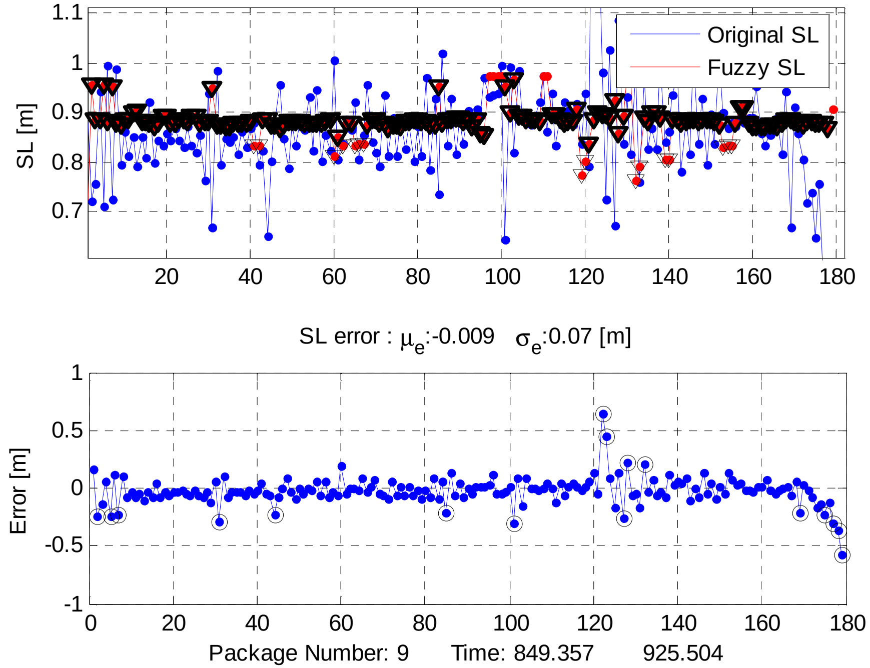
- Reference trajectory: GPS/IMU carrier phase solution provided by GKF
- SL: Fuzzy logic SL modeling
- SD: Calibrated gyro

SL Prediction

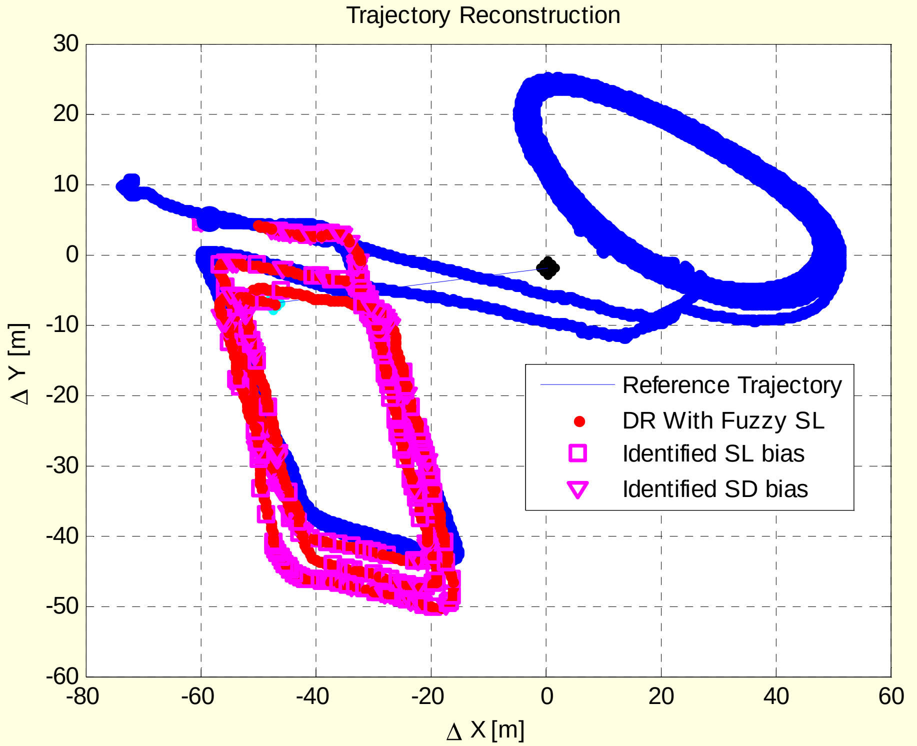
- Fuzzy SL-based modeling: 0 ± 7 cm (mean ± standard deviation)







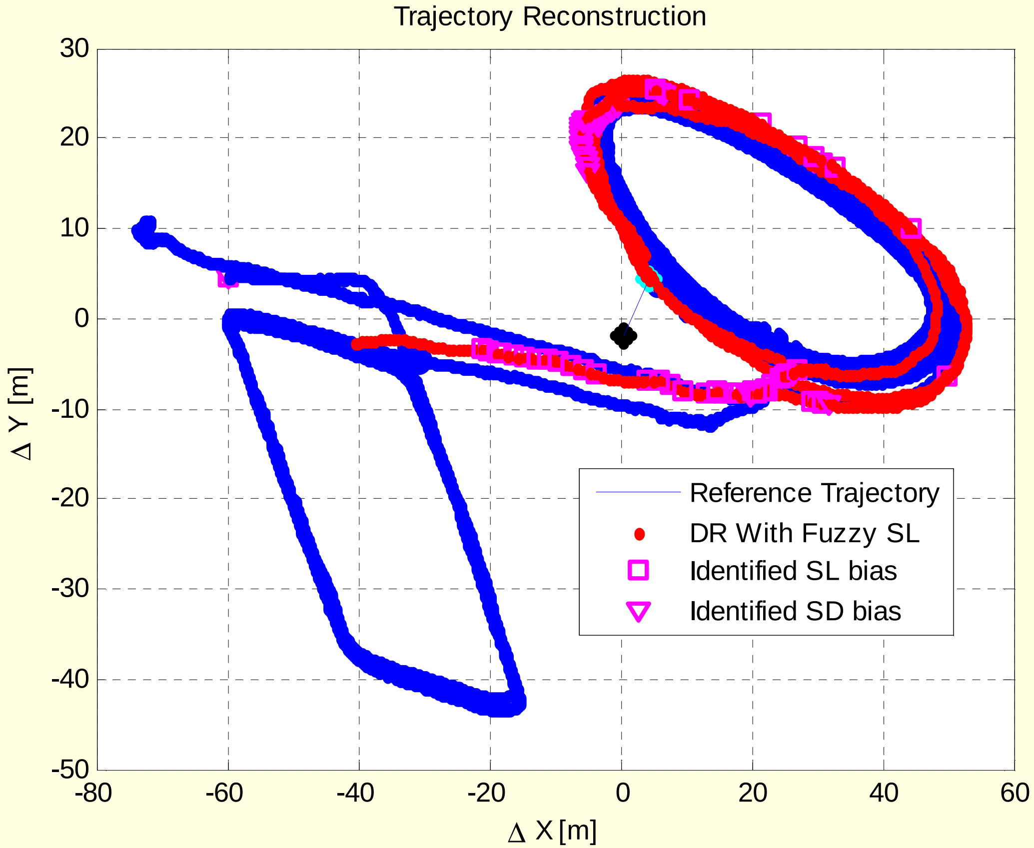
Uphill/Downhill Experiments



Length	Mean [m]	Std [m]	Max Difference [m]	End Misclosure [m]	CEP 50% [m]
540 m	3.6	1.65	3.7	3.8	3.1

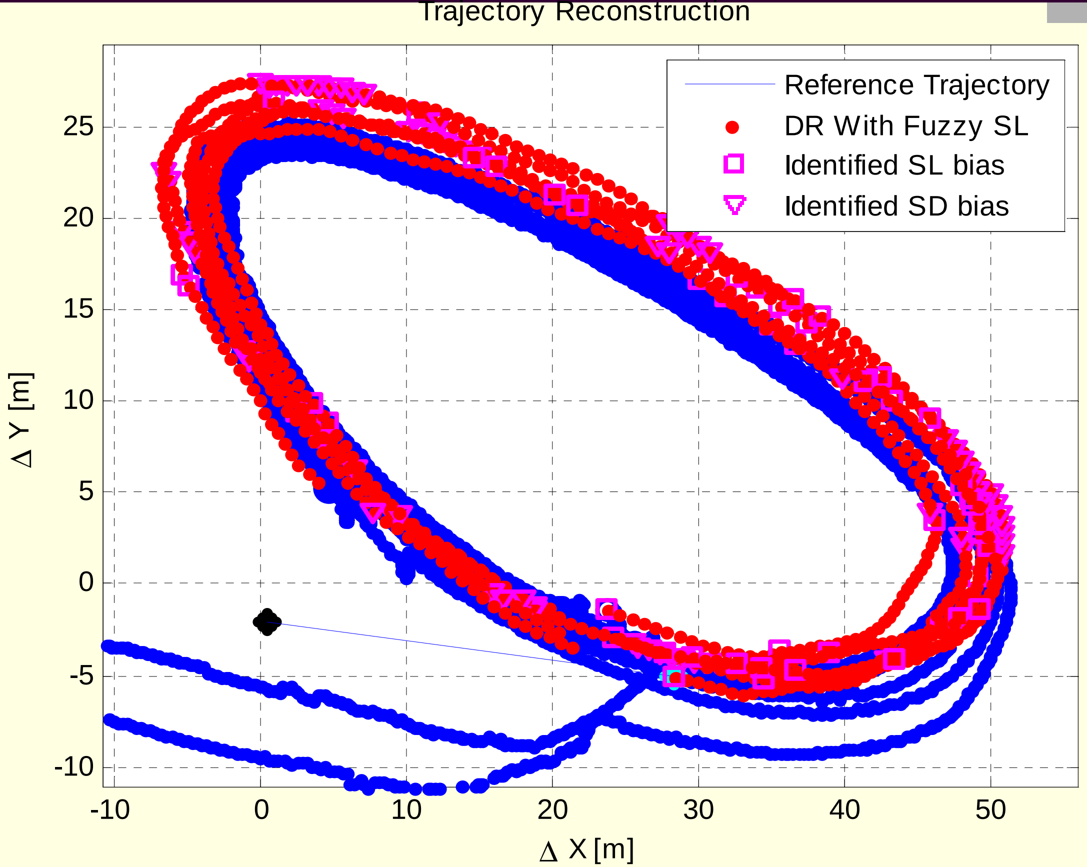
The table illustrates the difference between the reference trajectory and the DR navigation controlled by DR-KF

Jogging Experiments



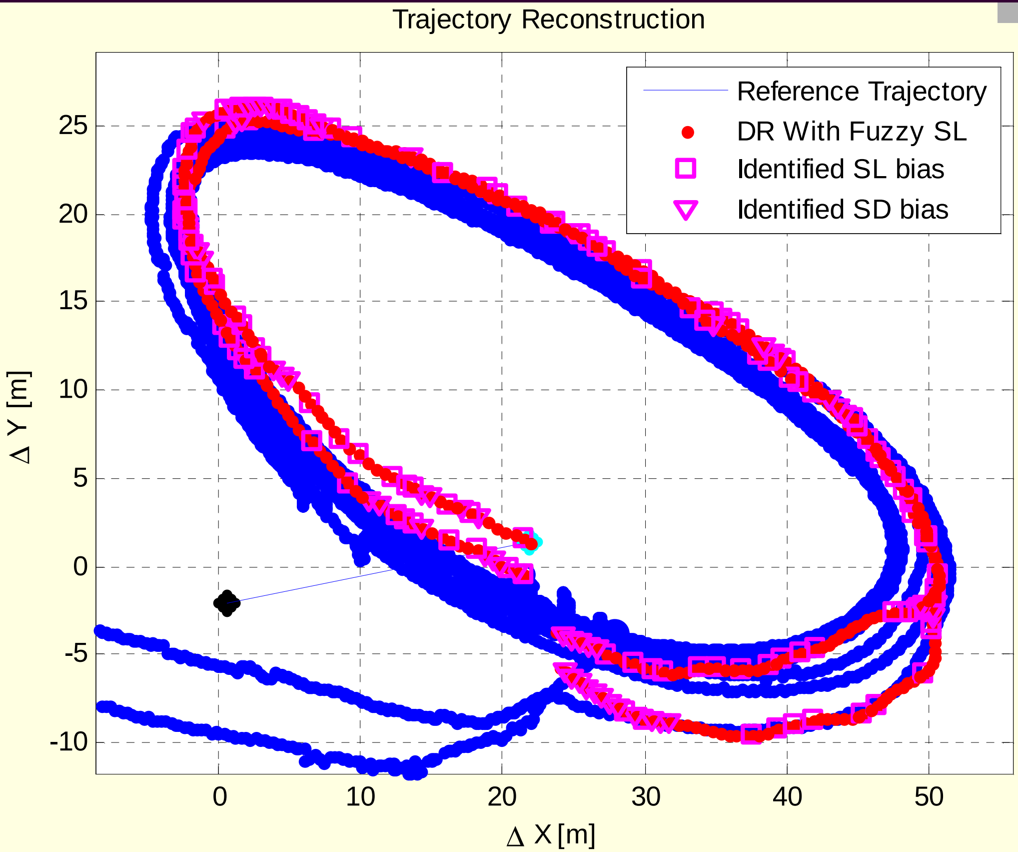
Length	Mean [m]	Std [m]	Max Difference [m]	End Misclosure [m]	CEP 50% [m]
566 m	2.97	1.53	2.27	3.2	3.4

Normal Walking



Length	Mean [m]	Std [m]	Max Difference [m]	End Misclosure [m]	CEP 50% [m]
909 m	3.34	1.28	3.78	3.31	2.6

Backward Walking



Length	Mean [m]	Std [m]	Max Difference [m]	End Misclosure [m]	CEP 50% [m]
296 m	2.63	1.08	2.9	2.16	2.06

Conclusion and Future Work

- The performance assessment of the GPN was tested for different locomotion patterns, including climbing hills, jogging, normal walking, and backward-walking.
- It was determined that for more than six loops normal walking, where the user walked 909m in about 15 minutes, the DR performance still met the required specifications, with the CEP50 within the required 1-3m range.
- For backward-walking, where the user walked 296m in about 5 minutes, the SL, SD, and locomotion pattern were properly predicted by the KBS, with an CEP50 error better than 2.06m.
- However, this performance assessment is not fully completed yet, especially for challenging environments, and more tests are required to address this issue.
- The limitations of the system have also been tested:
  - An update tuning of the KBS with respect to the new environments is likely to improve the performance.
  - More comprehensive performance analysis of heading determination from MicroStrain 3DM-GX2 magnetometer compass is required.