GPS-Denied Navigation and Mapping Technology for DTRA

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GPSDNM Program Overview

- Sponsored by Defense Threat Reduction Agency (DTRA)
- 3 year, $3.8M program
- CHI Systems (Now Harris) Prime, Honeywell Sub
- Key Performance Parameters
  - Accuracy:
    - Threshold - 30 feet after 4 hours
    - Objective - 10 feet after 12 hours
  - Physical Requirements:
    - Threshold - <10 lb, multiple components, no component larger than 5”x4”x3”
    - Objective – One component, <3 lb, < 12 cubic inches
  - Start Up Time:
    - Threshold – cold start in < 5 minutes
    - Objective – Instantaneous start
  - Mapping Information:
    - Threshold and Objective – Display user location on moving map (preferably FalconView, make mapping software easy to use, similar to Garmin

Technical Approach

- Hardware and firmware improvements by Honeywell
  - Improve existing DRM-4000 with better gyros
  - Improved calibration algorithms
  - Still essentially pedometry-based
  - MIL-STD-810F hardening

- Software Innovations from Harris/CHI
  - Algorithms for real-time track correction based on user movements and structure geometry
  - Algorithms for track correction based on movements and tracks of multiple users
  - Map display software
  - Real-time transmission of tracks
  - Software embedded on PDA

Technical Progression

- Spiral 0
  - Location: Honeywell DRM-5 with internal GPS
  - Microcomputer: Sony U280 or OQO UMPC/Windows XP
  - Software: Harris/CHI situational awareness and mapping software
  - Comms: WiFi or commercial UHF data radio
- Spiral 1
  - Location: Honeywell DRM-5000
    - Smaller internal space requirement
    - External USB power
    - 16-channel commercial GPS daughter board internal
    - Improved heuristics for GPS “jump” and transition to DRM
  - Microcomputer:
    - Nomad hardened PDA/Windows Mobile 6.
    - Yuma hardened Tablet for base station display
  - Software: Improved Harris/CHI situational awareness software, with interface to FalconView and Garmin devices
  - Comms: military tactical data radio supplied by DTRA or commercial UHF
  - Single power supply
- Spiral 2
  - Location: Honeywell DRM-5000 plus high accuracy HG-1930 IMU, hardened cases
  - Microcomputer: Nomad hardened PDA and Toughbook hardened notebook.
  - Software: Harris/CHI situational awareness software, user constraint algorithms, track correction algorithms, DRM control algorithms.
  - Comms: multiple military tactical voice/data radios from SELEX, Harris, others

Technical Progression

Spiral 0: DRM-5, OQO Computer, external GPS, Harris/CHI SA software, UHF data radio

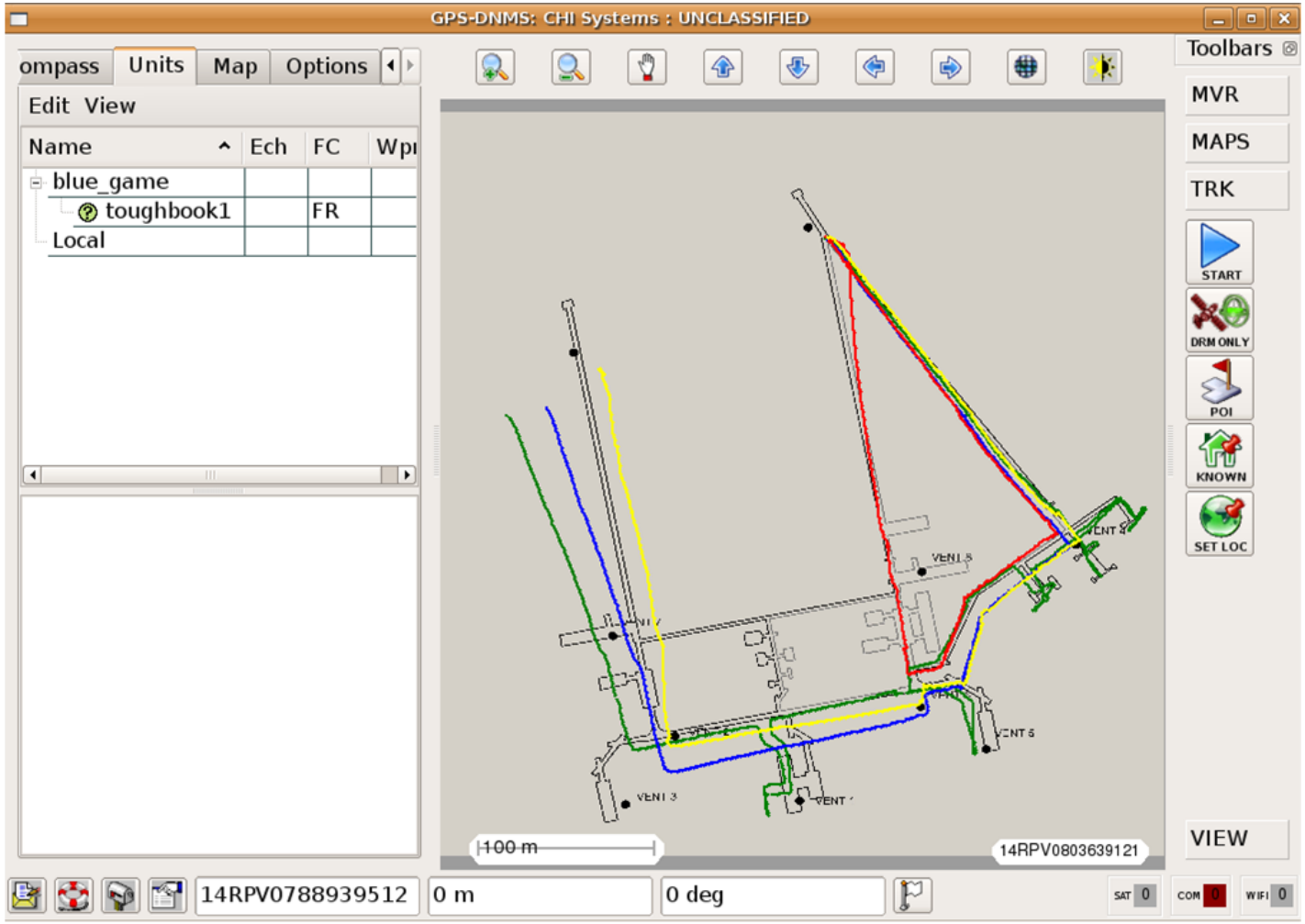
Spiral 1: DRM-4000/5000, Nomad hardened PDA, DTRA or commercial UHF data radio, improved Harris/CHI SA and navigation software, power supply

Spiral 2: DRM-5000 plus HG-1930 IMU, Nomad hardened PDA, military voice/data radios, improved Harris/CHI SA software and track correction algorithms

Results – Spiral 1

- Spiral 1 prototype tested in underground tunnel complex at Fort Hood, June 2008. 1st major test of the system.
- Environment has heavy magnetic influence due to steel reinforced concrete, motors, rails, vault doors, etc.
- DRM-5000 inconsistent in this environment; some good results, some not so good.
  - Some issues with device calibration due to intermittent GPS and stride length calibration
  - Issues with metal safety equipment such as oxygen generators and safety harness clips affecting magnetometer output
  - Issues with initial direction of travel
  - DRM-5000 inconsistent in this environment; some good results, some not so good.
  - Gyros in DRM-5000 not likely to allow us to meet accuracy KPP of the program
- Inconsistent radio communications did not allow multi-track correction algorithms to work to their best ability.
- Testing was not a loss
  - Many good tracks, plus a good body of track data to work with.
  - Estimated 2-4% accuracy over the distance traveled, average distance 900 meters

Results – Spiral 1

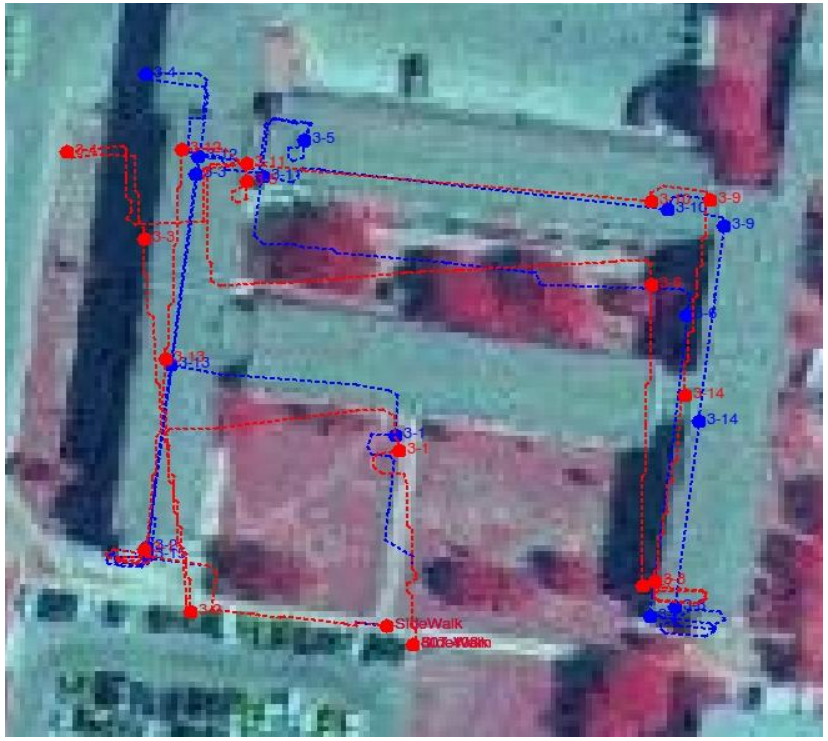


Representative Tracks in Fort Hood Tunnel Complex

Results – Spiral 2

- Spiral 2 prototype tested multiple times in underground tunnel complex and building complex at Fort Hood from April to December 2009.
- Environment still has heavy magnetic influence.
- Harris/CHI Track correction algorithms significantly improved location results for both the DRM-5000 alone, and for the DRM-5000/HG-1930 IMU combination.
  - Straightening
  - Orthogonality
  - Initial orientation
  - Transition from GPS to GPS-denied
  - Special calibration to compensate for local magnetic influence of safety gear
- HG-1930, with far better gyro performance allowed much better directional stability than the DRM-5000
- Good radio communications allowed multi-track correction algorithms to work to their best ability.
- Overall error less than 1% of distance travelled in final set of tests.

Results – Spiral 2



Representative Spiral 2 Tracks in Fort Hood Building Complex
Red = Raw Hg-1930 Track
Blue = Corrected Track
Less than 1% x, y, z error

Results – Spiral 2

Tracks in Fort Hood Tunnel Complex with HG-1930 and Track Correction Algorithms
Less Than 1% x, y, z, error over 1 km distance

Conclusions

- 3 of 4 KPPs Met
- Accuracy KPP not met under all circumstances
- DRM-5000/HG-1930 in combination with Harris/CHI Track Correction algorithms produced better than 1% accuracy in most cases
- Better accuracy needed for this customer
- DRM-5000/HG-1930 combination not practical for non-military users:
  - Too expensive ~ $12-14K; needs to be less than $3K
  - Too power hungry; 3-5 watts; needs to be less than 500 mW
  - Too big, although it met KPP for size; needs to fit into a shirt pocket
- Specialized communications required to get data out of tunnels or heavily constructed buildings for real time tracking
  - MANET
  - Repeaters
  - Mesh

Future Direction

- Smaller, lighter, higher performance, and less power hungry IMU devices are now becoming available.
  - Use same algorithms with these devices
  - Would need to harden the devices
  - Really need to have IMU, onboard processing, power, and possibly a MANET radio within a single small box
- Users don't want to use a bunch of software on a PDA to perform location tracking; A black box with no user interface would make many users extremely happy
- Inertial navigation by itself is only part of the solution
  - Radio ranging
  - UWB
  - SLAM