Personal Navigation for First Responders
Honeywell, Advanced Technology

Precision Indoor Personnel Location and Tracking for Emergency Responders
Worcester Polytechnic Institute, August 3rd & 4th, 2009
Agenda

• Honeywell First Responder Products Background
• Background Navigation Technology
  – Can We Use Magnetics
  – Strapdown Inertial Personal Navigation Solutions
• First Responder Solution
  – Key System Elements
  – System Architecture
• Conclusions
Honeywell First Responder Products

- Morning Pride
  by Honeywell

- Pro
  by Honeywell

- Ranger
  by Honeywell

- Servus
  by Honeywell

- American Firewear
  by Honeywell

- Morning Pride Fire-Warrior
  by Honeywell

- Kore Kooler
  by Honeywell
Honeywell First Responder Products

- We have been in the Fire Fighter PPE business for over 75 years

- The primary focus has been to improve and enhance safety for first responders

- Project HEROES is one of our latest answers to improved protection for Fire Fighters
Challenges Facing First Responders

- Time to respond is **KEY** for any incident, every minute is critical for effective and efficient knockdown
  - Point of Detection
  - Alert
  - Turnout time
  - Response time

- The first ten minutes of an incident have the highest amount of radio traffic and chaos
Location & Tracking - Basic Needs

• Fire teams won’t take time to deploy location tracking equipment if it requires precious time to setup and configure.

• Systems should be as “automatic” as possible with regards to set-up and use.

• In addition, the location tracking equipment needs to be adaptable to handle expanding incident needs
  - Additional equipment
  - Additional responders
Fire Fighter Location Challenge From VOC

- Fire fighters are not willing to add location items which add bulk or weight and are not built into existing PPE, Hand Radio, SCBA or PASS device.

- Municipal fire departments cannot afford complex, high cost equipment with limited budgets.
Fire Fighter Location Challenge From VOC

- Location information is primarily used in emergency situations supporting RIT and RAT

- Display of location information must be highly intuitive and understandable with little or no prior training.

- Systems must be reliable and “Fire Fighter Proof”
Personal Navigation for First Responders

Honeywell

Navigation Background
Can we Use Magnetic Dead Reckoning?

- Magnetic measurements are frequently integrated with motion classification and provide acceptable performance outdoors.

- However, magnetic measurements in buildings are sensitive to metal which causes variations which are trajectory dependant and cause significant variations in heading and position.
Individual Precision Inertial Navigation (iPINS)

- DARPA Seedling executed in 2005 to demonstrate the capability of a mid grade inertial to provide Personal Navigation (PN) in GPS denied environments.
- Results were very promising for environments when periodic geo referenced position resets are obtained periodically.
iPINS Hardware Architecture

Diagram showing the hardware architecture of iPINS, including components such as GPS Antenna, HMR3300 Magnetometer, BG1920 Processor/GPS, System Interface Assembly, Handheld Control, Wireless Modem, Handheld PC, HG1930 IMU, HPA Pressure Sensor, DC Power, Port 5 (RS-232), Port 4 (RS-422), Port 1 (RS-422), Ethernet, and Discrete I/O.
iPINS Demo – Wright-Patterson AFB

- Demo conducted over one week
- Demo included three scenarios:
  - Urban canyon (outside near large buildings)
  - Forested area
  - In-building
- Scenario paths previously mapped and surveyed by AFRL personnel
  - Survey points provided after the demo was completed
Area 1: Urban Canyon

- Total path length approximately 2400 m
- Time without GPS about 2200 seconds
- Note: GPS enabled throughout path for Randy
  - Very large errors during a portion of the path, most likely due to multi-path in urban canyon

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<tr>
<th>Test Subject</th>
<th>Final error</th>
<th>% distance traveled (2400 meter)</th>
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<tbody>
<tr>
<td>Jeff</td>
<td>42.72 m</td>
<td>1.78 %</td>
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<tr>
<td>Jessica</td>
<td>25.15 m</td>
<td>1.05 %</td>
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Test Subject Final error % distance traveled (2400 meter)
Area 2: In Woods

- Route in woods approximately 1100 meters
- Time without GPS aiding: 13-14 minutes

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<tr>
<td>Jeff</td>
<td>14.8 m</td>
<td>1.3 %</td>
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<tr>
<td>Jessica</td>
<td>4.2 m</td>
<td>0.38 %</td>
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<tr>
<td>Brendon</td>
<td>7.4 m</td>
<td>0.67 %</td>
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Area 3 In-building

- In building about 500-600 seconds
- Path about 700 m long
- Path included three floors and multiple stairs
- Note: Algorithm has not been optimized for stairs

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<th>% distance traveled (700 meter)</th>
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<tbody>
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<td>Jeff 6-22</td>
<td>35.95m</td>
<td>5.13 %</td>
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<tr>
<td>Jessica 6-22</td>
<td>18.92m</td>
<td>2.7 %</td>
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<tr>
<td>Wayne 6-22</td>
<td>5.88 m</td>
<td>0.84 %</td>
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<tr>
<td>Brendon 6-24</td>
<td>10.45 m</td>
<td>1.49 %</td>
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<tr>
<td>Jessica 6-24</td>
<td>3.69 m</td>
<td>0.52 %</td>
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<tr>
<td>Mikel 6-24</td>
<td>27.47 m</td>
<td>3.92 %</td>
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Elements of a Fire Fighter Tracking System

1. Relative location sensing technology
   - Uniform performance throughout building
   - Performance degradation over time
   - Independent of infrastructure
   - Low product cost

2. Absolute location sensing
   - Required for inertial sensor updates
   - Critical to obtain higher system accuracy
   - Solution to multipath/interference

3. Communication infrastructure
   - Communicate location data to command center and support navigation
   - High reliability and availability
   - Operation in challenging environments
   - Ease of installation and commissioning

4. User interface
   - High resolution display with accurate up-to-date maps
   - Dynamically synthesize maps from location information from all first responders
   - Support for portable hand held displays
   - Support for non-visual interfaces (audio)

Solution Combines Multiple Technologies
Navigation Solution Architecture

- Inertial Sensors
- Magnetic Sensors
- Altimeter
- GPS/DGPS
- Initial Input
- Human Input
- UWB Radio

Step Model

Input Preprocessing

Measurement Prefilter

Kalman Filter

Navigation Solution

- Distance Traveled
- Navigation State

- KF Resets
- Pseudorange
- Magnetic Sense
- Absolute Position
- Altitude Sense
- Landmarking
- TDOA

- KF Resets
- Human Model
- User State
Navigation Algorithm Approach

- Geolocation output is based on strapdown inertial navigation (not dead reckoning)
- Use Motion Classification to significantly improve distance traveled estimate while allowing individual to move in a more natural manner
  - Motion classification allows system to identify the motion type of the user (walking, crawling, side-stepping, etc.) and apply the best model to sensor data to estimate distance traveled
- Kalman filter resets strapdown navigation solution
  - UWB ranging radio provides absolute range measurements used in Kalman filter to reset strapdown navigation solution
  - Residual test is used to reject poor measurements from Motion Classification
Conclusions

- A robust navigation solution for indoor operations requires both absolute and relative navigation components optimally integrated with an understanding of the environment
  - The absolute navigation sensors provide fixed reference used to reset the drift of the relative inertial components
    - Must operate in high multipath environments
    - Must deal with high loss signal environments
  - The relative navigation solution provides a continuous medium bandwidth solution between resets
    - Provides a solution during periods where absolute updates are inhibited by multipath or signal losses
    - Increases integrity of multipath detection
- Given demonstrated UWB and Relative navigation performance results we expect to locate first responders to within 1 meter