Aided-inertial for Long-term, Self-contained GPS-denied Navigation and Mapping

Erik Lithopoulos, Louis Lalumiere, Ron Beyeler
Applanix Corporation

Greg Spurlock, LTC Bruce Williams
Defense Threat Reduction Agency
Overview

• Navigation and Mapping are positioning functions
• Navigation
  – Determine own position now
    • Real-time
• Map
  – Determine own position, LOS positions
    • Mostly post-mission
  – Photomap
    • Digital Imagery w/ all pixels georeferenced
Aided-Inertial Navigation – Man-portable

- IMU: primary sensor
  - Measures motion dynamics
- ZUP: primary aiding “sensor”
  - Corrects IMU errors
- GPS: “signal of opportunity” aiding

- Real-time navigation
- Post-processing suite

- IMU: Inertial Measurement Unit
- POS: Position Orientation System
- ZUP: (Zero-velocity UPdate)
- PCS: POS Computer System
Portable Aided-inertial Navigation

POS LS – land seismic survey

GPS-DNM – Defense Threat Reduction Agency (DTRA) development rear and side views
Operation

1. Align
   – Static
     • GPS or manual position entry
     – 10 to 20 min at mid-latitudes to find true North and Down
     – Accurate heading is the key in aided-inertial dead reckoning
   – Dynamic
     • Onboard vehicle using GPS

2. Navigate
   – Walk, run, crawl, elevator or vehicle ride
   – Integration of motion parameters – dead reckoning
   – Perform ZUP
     • Stop every 1-4 min
     • Stay motionless for 5-10 sec

3. Post-process (Optional)
   – Enhanced accuracy for survey applications
Position error growth with distance traveled

-1.5 -1.3 -1.1 -0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9 1.1 1.3 1.5

326000 326500 327000 327500 328000 328500 329000 329500 330000 330500

TIME METERS

1.47 km travelled

Straight line trajectory, north to south

Backpack Navigation

Comparison with GPS during ZUPTS

Horizontal: m = 0.5, V = 0.15

Vertical: m = 1.1, H = 0.5

APPLANIX
A TRIMBLE COMPANY
Ft. Hood Silo Run

- 1.5 mile – 1hr underground traverse
- 30cm horizontal accuracy on return
Aided-inertial - Pros

• Entirely self-contained
  – Measurements based solely on motion dynamics
  – No external aiding
    • No GPS, RF, magnetic, barometric
• Accurate 6D measurements over extended periods
  – Horizontal, vertical position plus orientation
  – 8 hours +
• Operates accurately in any environment
  – Accessible by humans or robots
  – Any type of motion or platform
    • No significant accuracy degradation
  – Silos, caves, nuclear facilities, ships
Aided-inertial - Cons

- **Cost-benefit**
  - Cost is driven by navigation-grade inertial
  - Inertial costs will improve slowly
- **ZUPs**: can be an operational impediment
- **Size/weight**
  - Continues to improve
    - Started at 45lbs
    - Down to 12lbs and 6lbs in next releases
Mapping with Aided-inertial

- Operating environment is in and around buildings
- Map buildings of interest
  - Educational, government facilities
  - Public Infrastructure in general
- Line maps, blueprints provide limited information
- Photomaps
  - Require additional sensor
    - Camera or lidar
  - Georeferenced digital imagery
    - Every pixel is assigned long, lat, alt
Aided-inertial with Imaging Sensor

- Operation: Align, walk w/ ZUP, post-process
- High throughput
  - Position all LOS data at fast walking pace
    - Continuously for hours with only ZUPs
    - Sub-Foot accuracy
- Any building, anywhere
  - No prior information, no infrastructure
- 40,000sqft building in 2hrs
- Strong cost benefit
- Complete and accurate map of entire facility
  - “Natural View” as you walk
    - Rooms, corridors, workstations, doors, stairs
  - Seamlessly mosaic with outside photomaps
    - Walls, windows doors, roof (aerial)
- Emergency Crew applications
  - Virtual training, Mission planning, Field support
  - Combine with real-time location for total situational awareness
Aided-inertial Mapping
Conclusions

Aided-inertial for

• Navigation
  – Well suited to special operations
    • Long-missions, no infrastructure support
    • Silos, caves, nuclear sites, ships

• Mapping
  – Complete facility photomaps
  – Well suited for indoor public safety operations
  – Total situational awareness
    • Combine with real-time location