Integrating GNSS and INS to Provide Reliable Positioning

Hydrographic Society in Scotland Meeting – 27 March 2013

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Presentation Overview

Surface Positioning
GNSS Technology
Inertial Technology
Sensor Integration
Operational Implementation
System Validation
Surface Positioning

- Ideal surface positioning system should provide a position that is...
  - Constant
  - Stable
  - Accurate
  - Repeatable

- Essential to safe and productive operations
GNSS Technology

• GNSS satellites
  – Located approx 20,000km above surface of the Earth
  – Transmit power 50W

• Signal weak by time it reaches user antenna

• Signal susceptible to degradation through interference
  – Propagation through the atmosphere
  – Jamming (intentional or un-intentional)

• Require line-of-sight to receive signal
  – Obstructions (like platforms) will mask the signal

• Result = unreliable position
Ionosphere Effect on GNSS Signals

- Ionosphere more active
  - Solar Cycle 24 nearing peak
  - Increased electron content
  - Delays GNSS signal = range error
  - Compute error with dual frequency GNSS

- Scintillation more serious problem
  - Localized, small scale irregularities
  - Increased measurement noise/error on GNSS
  - Worst case is loss of lock on satellite
  - Typically occurs after sunset for several hours
Scintillation Monitor

S4 index at INPE - São Jose dos Campos, BR 2012/09/26 15:10 UTC

GPS Position Error at INPE - São Jose dos Campos, B 2012/09/26 15:10 UTC
Average Position (LLA): -23.207691, -45.859805, 619.072236 m
Scintillation Effect on Positioning

- Monitor site located in Macae, Brazil
- Data captured 22/23 Nov 2011
- Apex² GPS+GLO PPP
- Fluctuation in SV’s tracking
- Error in position
Scintillation Effect on Positioning

- Monitor site located in Macae, Brazil
- Data captured 22/23 Nov 2011
- Apex GPS PPP
- Fluctuation in SV’s tracking
  - Low number of SV’s
- Error in position with some position spikes
Inertial Technology

• Inertial Navigation involves determining a position through dead reckoning
  – INS calculates position, velocity and attitude changes using gyros and accelerometers
  – Completely self contained and therefore inherently robust
  – Continuous output with very good short term accuracy

• But drifts with time...
  – Magnitude will depend on quality of sensor
  – High quality sensors = more cost
  – Also potential export restrictions (ITAR)
  – Integration with external sensors can constrain the drift
Inertial Navigation Systems

INS

Gyros

Accelerometers

IMU

Navigation Equations

External Aiding

Velocity

Attitude

Position
Integration Strategies

- INS and GNSS are complementary sensors
  - GNSS can help constrain the drift of the INS sensors
- Integrated solution exploits
  - Long term accuracy and precision of GNSS positioning
  - Continuous availability and fast update rate of inertial sensors

<table>
<thead>
<tr>
<th>Loose</th>
<th>Integration of Navigation/Position Solutions</th>
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<tr>
<td>Tight</td>
<td>Integration of measurements</td>
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<tr>
<td>Deep</td>
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INS-GNSS Integration

- No Integration
- Loose Integration
- Tight Integration
- Deep Integration

Increasing Performance & Robustness
Increasing Complexity
Overview of Axiom System

• Development of a loose coupled INS-GNSS solution

• Using a Sonardyne solid state IMO-approved Lodestar INS with North-seeking capability

• GNSS and INS solutions are combined mathematically to compute position
  – Appropriate QC parameters provided allow appropriate weighting of GNSS solution

• System designed to bridge any GNSS disruptions and also to detect position outliers
  – Common mode failures which can otherwise affect vessel GNSS systems simultaneously
Operational Implementation
Visualization

• Visibility on performance & independence of sensors plus integrated solution

• Correct interpretation of information
  – Needs to be basic and easy to understand
  – Ability to know when something is about to go or is going wrong
  – GNSS or INS affected

• Interfaces and protocols needed to maximize the benefits of integrated solution
  – Opportunity to re-evaluate the information provided to users
  – Opportunity to visualize additional information
Data Interfacing

• NMEA telegrams used
  – Output messages
  – Include quality information on the calculated position

• No specific provisions for integrated position solution
  – Independence
  – Quality
  – Consistency

• Interface telegram has to...
  – Ensure compatibility between systems
  – Provide the appropriate information to the operator
System Validation

- Important aspect to ensure that integrated solution can provide reliable surface positioning
- Initial testing conducted controlled environment where a truth data set could be derived
- Scenario based testing to simulate typical GNSS events
  - Loss of augmentation data
  - Loss of GNSS observations
  - Masking of satellites
- Also ensuring testing that the visualization reacts correctly
Static Test

- High accuracy PPP solution input to INS
- GNSS observations removed at 14:40
- Quick recover of position solution
Static Data

GNSS Solution

INS/GNSS Solution
Dynamic Trial Setup

- Controlled environment
  - Scenario testing
  - Future testing
- Benchmark system performance
- Derive ‘truth’ data set
Dynamic Testing

- High accuracy PPP solution
- Loss of augmentation data
- Jump in PPP solution
- No issues with INS solution
Dynamic Testing

- Vessel anchored
- DGPS solution
- GPS SV’s reduced to 4
- Some instability in DGPS solution
Low SV count - scatter plot
Failure of GNSS

Total Error (2D)
- 5min - 11.4m
- 10min - 52.3m
- 20min - 125.6m
Conclusions

• Integrated INS and GNSS solution can provide...
  – Constant / Stable / Accurate / Repeatable position

• Additional analysis of dynamic trial data

• Further system validation trials in operational environments

• Investigate use of additional QC information from the GNSS position solution
  – Better weighting in integrated solution

• Further work to develop tightly coupled solution