Investigation of Attitude Sensors for Hydrographic Applications
– GNSS, Motion Sensor and Low Cost Sensors
-First results-

Volker Böder

Motivation

- Especially multibeam however also singlebeam applications need high reliable attitude determination
  - Direct referencing with RTK: heading, roll, pitch
  - Indirect referencing with tides: heave, roll, pitch
- Challenge: dm-accuracy in shallow waters
  - Wreck search, feature detection
  - Archaeology
  - Exploration
- Different sensor technology is available
  - GNSS, IMU (AHRS, INS)
- Missing: control of attitude determination
  - System calibration in MBES before measurement
  - SBES?
Equipment

- **Positioning and Attitude Determination**
  - Leica: System 500 (RTK)
  - Javad: JAVAD 4 Gyro (GNSS Positioning and Attitude)
  - Geo++ GNSS-Software GNATTI
  - IXSEA: OCTANS III (fiberoptic IMU)

- **Echosounder Reson SeaBat 8101**

Photo from P. Andreec

Archaeology under water

- „Mäuseturm“ in Güttingen, CH
- Cooperation with Archaeologists from Kanton Thurgau
- Manmade structure (completely?), probably Middle Ages
Research/Exploration

- Cooperation with „Institut für Seenforschung“, Lake Constance
  - With Dr. Martin Wessels
  - Methane gas?
### Advantages/Disadvantages GNSS/IMU

<table>
<thead>
<tr>
<th>GNSS</th>
<th>Inertial Measurement Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ no drift</td>
<td>+ high data rate</td>
</tr>
<tr>
<td>+ long baseline: high accuracy</td>
<td>+ usually small unit</td>
</tr>
<tr>
<td>+ price ?</td>
<td></td>
</tr>
<tr>
<td>- Short baseline: low accuracy</td>
<td>- Drift</td>
</tr>
<tr>
<td>- Low data rate (usually 10 Hz, but increasing)</td>
<td>- Influences by high dynamics</td>
</tr>
<tr>
<td>- signal shading (installation on board, buildings, cranes, quay walls …)</td>
<td>- Location on board should be near gravitational center</td>
</tr>
</tbody>
</table>
Investigations

- Project Norwegian Gem
  - GNSS
  - Motion sensor without GNSS support
  - Motion sensor with GNSS support
- Comparison GNSS – Motion Sensor
- Investigation of “just another sensor”
- Investigation Low Cost Sensor

Project Norwegian Gem

- Goal of the Project
  - Shipping of luxury ship backwards along the river Ems
    - Length 300 m, width 32 m
  - High accuracy needed for precise navigation

- Project carried out by
  - HydroSupport: Bernd Koop
  - LGN: Cadastre and Land Surveying Authority of Lower Saxony
  - Investigation of attitude sensors within diploma thesis at HCU
    - Mario Röttger
Accuracy of Attitude Sensors

- **GNSS (geodetic equipment)**
  - Depending on length of baseline between antenna
  - Approximation for accuracy
    - $0.3\ [\text{deg} \cdot \text{m}] / \text{Length} [\text{m}]$ for Heading ($300 \text{ m} : 0.001^\circ$)
    - $0.5\ [\text{deg} \cdot \text{m}] / \text{Length} [\text{m}]$ for Roll and Pitch
  - Higher accuracy with more sensors

- **IXSEA OCTANS III**
  - Heading
    - $0.1^\circ$ secant latitude (HH: $0.17^\circ$)
    - Drift 0.05°/h
  - Roll/Pitch
    - 0.01°

- **IXSEA HYDRINS**
  - Heading
    - $0.02^\circ$ secant latitude (HH: $0.034^\circ$)
    - Drift 0.01°/h
  - Roll / Pitch: see OCTANS III
Project Norwegian Gem

Difference between GPS-ATTI, HYDRINS and OCTANS

- Motion Heading
  - 1.3° in 14 min

- Differences
  - GPS – OCTANS
    - Noise <0.1°
    - Drift 0.1° / 14 min!
  - GPS – HYDRINS
    - +/- 0.02°
    - Drift 0.01°/14min => 0.04°/h
Project Norwegian Gem

- Motion in Heading
  - 2 circles in 36 min
- Rate of Turn
  - Varies between -0.25°/s to -0.45°/s

- Differences between
  - GPS-ATTI and OCTANS
    (unsupported IMU)
    - -0.6° to 0°
    - Drift 0.5°/5 min!
  - GPS-ATTI and HYDRINS
    (IMU supported by GNSS)
    - +/- 0.1°
Conclusions Project Norwegian Gem

- HYDRINS operates within specifications
- OCTANS III didn’t work within the specifications, as expected before
  - Replaced by another OCTANS III from IXSEA
- GPS supported IMU work properly and reliable
- GPS best method in this case, because of the long baseline (250 m)

- Shipping successful !!

Investigation GNSS – OCTANS III (new)

“Cloverleaf” manoeuvre

- Heading 0° to 360°
- Roll -6° to +2°
- Pitch -1° to +3°
“Cloverleaf” manoeuvre

Heading

RoT < 5°/s
⇒ within specifications

RoT > 5°/s
⇒ increasing errors?

Drift after manoeuvre?

Additional investigation will follow

“Investigation GNSS – OCTANS III (new)

“Cloverleaf” manoeuvre

Roll

⇒ within specifications

(of GNSS-Attitude)
Conclusion GNSS – OCTANS III (new)

“Cloverleaf” manoeuvre

Roll and Pitch
within specifications of GNSS-Attitude

Heading
shows increasing errors starting from
rate of turn of ca. 5°/s

Just another sensor

- Project Lake Constance
- Investigation
  - Geo++ - GNATTI
  - IXSEA OCTANS
  - SENSOR ?? (anonymous)
    - Sensor sold with new echosounder (not HCU!)
    - Installed as good as possible, but not in gravitation center
    - Installation was not optimal !
    - Announced accuracy 0.3° in roll and pitch
  - First result: be aware of + and – declaration!
    - Offsets and
    - Angle definition
Results OCTANS - ??

- Roll
  - -1° to +4°
  - Rate of Roll: ca. +/- 2°/s
  - Std.dev. dROLL: 0,35°

- Pitch
  - -0,5° to +1°
  - Rate of Pitch: ca. +/- 0,8°/s
  - Std.dev. dROLL: 1,5°
Low-Cost Sensor XSENS MTi

- Diploma Thesis Michael Barth
- Xsens MTi consists of
  - 3 fiber optical gyro, 3 accelerometer and 3 magnetometer
  - MEMS-components (micro electronic measuring system)
  - output in quaternions and/or Euler

<table>
<thead>
<tr>
<th></th>
<th>Heading</th>
<th>Roll / Pitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Accuracy</td>
<td>&lt;1 deg</td>
<td>&lt;0.05 deg</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.05 deg</td>
<td>(for ±50 deg amplitude)</td>
</tr>
<tr>
<td>Range No Limitation</td>
<td>180 deg to 180 deg</td>
<td>0.05 deg</td>
</tr>
<tr>
<td>Dynamic Accuracy</td>
<td>2 deg RMS</td>
<td></td>
</tr>
</tbody>
</table>

Tests on Survey Launch Level-A

Xsens MTi

Performance

IxSea Octans III

JAVAD 4 Gyro
Geo++ GNATTI
Tests on Survey Launch Level-A

Comparison between Octans III and MTi

Mean difference: 1.8° +/- 0.8°

Conclusions XSENS MTi

<table>
<thead>
<tr>
<th>Messung</th>
<th>Heading</th>
<th>Pitch</th>
<th>Roll</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std.</td>
<td>Range</td>
</tr>
<tr>
<td>C2</td>
<td>2.4°</td>
<td>±0.9°</td>
<td>13.5°</td>
</tr>
<tr>
<td>C3</td>
<td>1.5°</td>
<td>±0.7°</td>
<td>6.8°</td>
</tr>
<tr>
<td>C4</td>
<td>1.8°</td>
<td>±0.8°</td>
<td>6.8°</td>
</tr>
</tbody>
</table>

- within specifications regarding std. dev., but several outliers
  - (see the range)

→ heading: homogeneous magnetic surrounding necessary
→ sometimes deviations >40° in heading, not shown here
Conclusions

• Each motion sensor has own error characteristics, depending on
  – dynamics
    • of the ship
    • of the location on board the ship.
  – Vibrations on board
  – geographical latitude
  – Magnetic influences (In case of use of magnetometer inside the motion sensor)

• Reducing the error
  – GNSS support / use
  – System calibration before measurement (!),
  – calibration of motion sensors (?)

• Take care of all sensors!

• First results inside other projects
  – Goal: systematic investigation / calibration procedure

IHSC2007
Add ons

2nd IHSC 2008

- Addressed to interested students
- 18.08.-30.08.2008 at the Schlei
- Near ancient Viking Metropolis Hedeby (Haithabu)
- No participation fees
  - accommodation must be paid
    - bed for 6 Euros in a Danish Rowing Club with kitchen
- Contact to Producers, Companies and Archaeologists
- Searching for
  - Wrecks (ships and planes), underwater archaeological sites, morphological structures
Participants of IHSC 2007

Prof. Dr.-Ing. V. Böder
HafenCity University Hamburg
Department of Geomatics
volker.boeder@hcu-hamburg.de

Welcome to the
- IHSC at the Schlei (18.08.-30.08.2008)
- in the course M.Sc. Hydrography (application until July, 15th, 2008)?
Project Norwegian Gem

• Investigation of Attitude Sensors
  – GPS-Attitude
    • 4 GPS-antennae
  – IMU with GPS-Support
    • IXSEA HYDRINS
  – IMU without GPS-Support
    • IXSEA OCTANS III
    • Known before the project:
      – Showing abnormal drifting in hydrographic measurement
        => Investigation necessary