Continuous Wellbore Path Estimation Using Multiple Integrated MEMS Sensors

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Speaker Information

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    University of Calgary, Canada, 2015-present
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  - University of Waterloo, Canada, 2013-2014
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Specializes in:
Sensor fusion, data processing, control, mechanical system dynamics...
Outline

• Problems and Challenges
• Objectives
• Methods and Experiments
  – A. Methods (Angle & Position)
  – B. Tests (Lab Scale & Field Scale)
• Summary
Problems and Challenges

1) Low robustness to unknown interference [Goodall, 2009]

2) Field calibration hard [Li, 2015]

3) Low accuracy on position estimation [Stockhausen, 2016]
Objectives

1. Hardware Design of Proposed Subsurface Measurement System

2. Robust Orientation Fusion-minimizing Magnetic Distortions for Azimuth Control
   - Local Fusion – Quaternion Kalman Filter (QKF)
   - Global Fusion – Adaptive Neuro-Fuzzy (ANFIS)

3. Identification of Position
Experimental Setup

2 MEMS IMU sensors
3 axis accelerometers
3 axis magnetometers
3 axis gyroscopes
MEMS based Monitoring System

Sensor

100 feet long cable

Long distance data transportation

Data convert box

Wellbore Positioning Technical Section
Calibration (3D)
Calibration (2D)

Horizontal movement
Calibration (Positions)

Sensor A

Sensor B

47th General Meeting
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Wellbore Positioning Technical Section

The Industry Steering Committee on Wellbore Survey Accuracy (ISCWSA)
How to reduce the magnetic disturbances?

With a known distance

Sensor A

Sensor B

Magnetic interference
Angular Sensor Fusion

Sensor 1

Sensor 2

QKF1

QKF2

ANFIS

Global fusion

Local fusion

Output
Sensor Fusion Method (Position,2D)

**System Model**

\[
\begin{align*}
\alpha_T & \rightarrow S \rightarrow R_{ad} \\
\dot{x} & \rightarrow \int \rightarrow x \\
\dot{y} & \rightarrow \int \rightarrow y
\end{align*}
\]

**Measurement Model**

Azimuth
Inclination

\[\hat{R}_{ad}, \theta, \Delta M D\]

MCM

\[\begin{align*}
\hat{x} & \rightarrow \frac{dx}{dt} \\
\hat{y} & \rightarrow \frac{dy}{dt}
\end{align*}\]

Not pipe length!
Sensor Fusion Method (Position, 3D)

Teaching signal (Survey data)

- MCM-splines
- $|\text{MCM-Ref}| - |\text{Splines-Ref}|$
- MCM value
- Splines value
- MCM-Ref
- Splines-Ref

Output ($x, y, z$)
Lab Test (Angles)

- **Reference**
- **Proposed Method**
- **ANFIS**
- **Magnitude of disturbances is in the training range**
- **Traditional Method (QKF)**

The graph shows the azimuth error with samples ranging from 0 to 180. The y-axis represents the error in degrees, ranging from -40 to 20. The x-axis represents the samples. The graph compares the reference, QKF, and ANFIS methods. The ANFIS method shows a lower error compared to the QKF method, especially in the training range, indicating improved accuracy in wellbore positioning.
Field Test (Angles)

Campus of University of Calgary

Data collection Equipment

Sensor

Magnetic interference strength 1200 mGauss

Three points of the locations of magnetic disturbance

PC
Continuous survey results

Magnetic disturbance

Azimuth Comparison

SensorA
SensorB
Proposed
Field Test (Positions)

GPS signal was used as reference (survey)
Route with rigid body and two IMU sensors

GPS receiver
Results
Accuracy

MCM & Spline [SPE 178796, 2016] same, proposed method is better
Potential Industry Applications

Pad Drilling: Many Wells Are Drilled by a Single Drilling Rig

- Multiple paths with same formation
- Same inclination and azimuth angles, the moving distances are similar too
- One path can be used as teaching signal then high accuracy can be duplicated to the other paths

Magnetic Disturbances

Source: eaglefordshale.com

Assumptions

- Two sensors were not influenced by magnetic disturbances at the same time with the same magnitude.

Limitations

- Need high accurate survey data as teaching signal.
- High accuracy only can be duplicated in the similar conditions.
Summary

A subsurface measurement system with two redundant IMUs sit on a rigid body with a special distance $d$ was designed.

Two level structure of filter which combined local and global to remove unknown magnetic disturbances was proposed and investigated.

High accuracy orientation and position estimation can be realized by this proposed method which proved by lab and field tests.

This technique can be applied to pad drilling to reduce the drilling cost and manual work.
Thank you for your attention!

Questions?

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