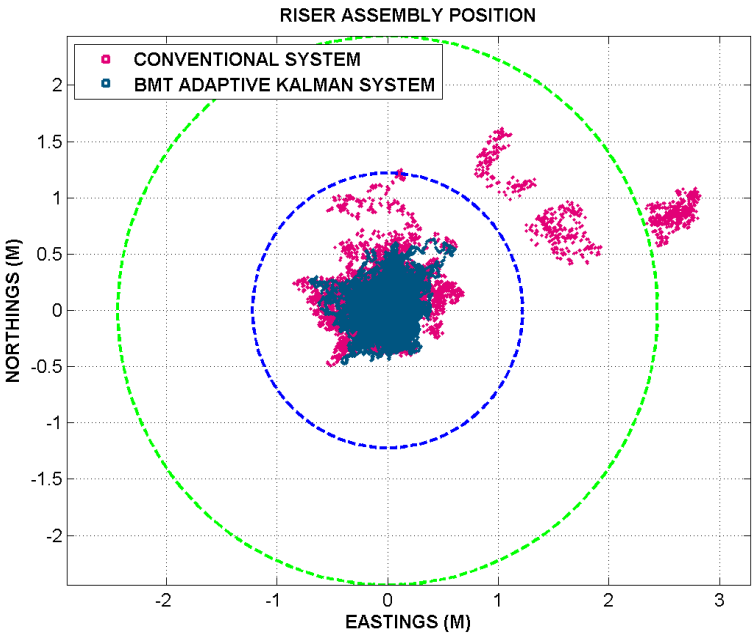
BMT Scientific Marine Services

"Where will our knowledge take you?"

Adaptive Kalman Filtering



BMT Adaptive Kalman system prevents false alarms due to sensor errors

BMT Scientific Marine Services has developed and fielded an innovative GPS/INS fusion system which applies adaptive Kalman filtering to the problem of combining GPS and Inertial Navigation System (INS) data. It merges the output of multiple GPS receivers, gyros and an INS into an optimal estimate of platform position and attitude.

To ensure safe production, floating ocean platforms normally contain systems that monitor platform's position (latitude, longitude and elevation) and attitude (roll, pitch and yaw). Typically, these monitoring systems include one or more Global Positioning System (GPS) receivers along with rotation rate sensors and linear accelerometers.

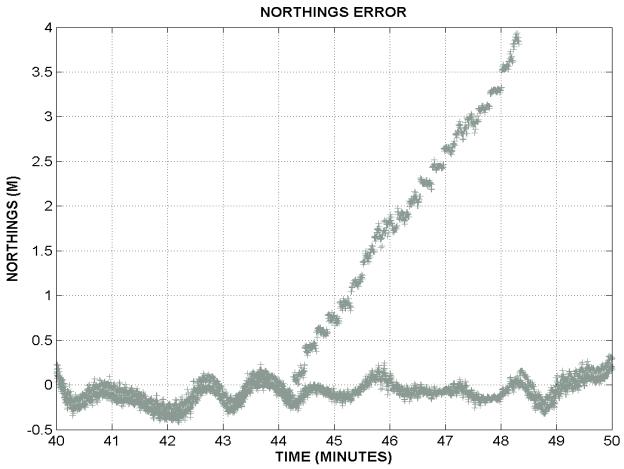
The measurements from these sensors must be carefully combined to estimate platform attitude and position, for two reasons. First, none of the desired variables can be computed from a single measurement. For example, GPS receivers are affected by not only platform position, but also platform attitude, since the receiving antennas are generally mounted high above the platform and will move significantly when the platform rolls, pitches or yaws. Similarly, the measured linear accelerations can be caused by shifts in platform position or by gravity if the platform is not perfectly leveled. Solving the platform motion equations—which link the desired variables with the available measurements—one at a time results in suboptimal state estimates.

Secondly, measurements must be carefully merged because all sensors are subject to errors. Merely averaging sensor measurements in the face of such non-Gaussian errors is inadequate, while outlier rejection algorithms often fail to recognize errors which grow steadily.

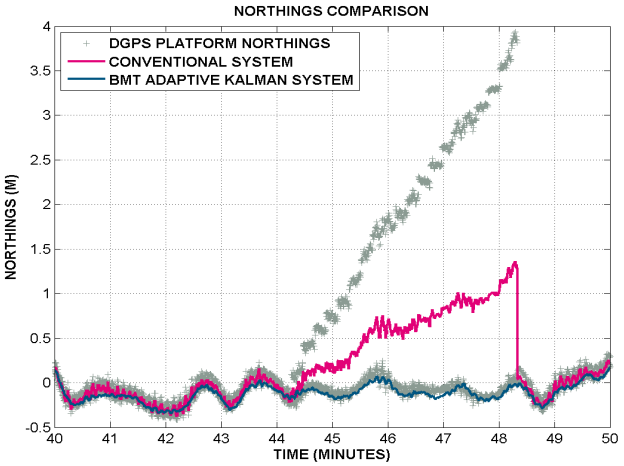
The Kalman filter provides a solution to both problems. First, since the filter solves all the platform motion equations simultaneously, it computes the optimal state estimate. Second, by inversely weighting each sensor's measurement by its noise level, the Kalman filter allows us to seamlessly handle sensor errors.

Advantages

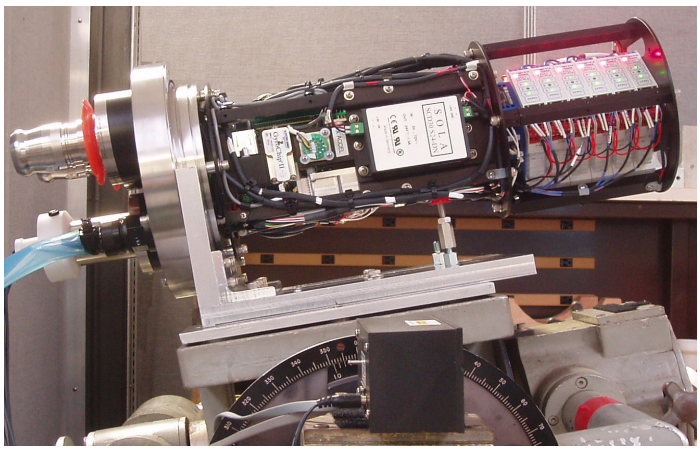
- **Accuracy**: Kalman filters minimize the mean-squared estimation error; tests confirm that the BMT adaptive Kalman system consistently delivers lower RMS error than conventional GPS/INS fusion systems.
- **Adaptive Rejection:** Each sensor's signal variance is estimated in real-time from the data, allowing immediate recognition and rejection of faulty data.
- **Fail-Safe Operation:** Should sufficient sensors fail to make position estimation impossible, the BMT adaptive Kalman system alerts the operator that the estimate is not being updated. Once sensors return to service, the system automatically continues normal operation.
- **Speed:** BMT's adaptive Kalman system runs in real-time.
- **Fault Rejection:** The adaptive Kalman system rejects position and attitude state updates that exceed preset criteria, so that simultaneous sensor failures cannot result in erroneous position estimates.
- **Gimbal-Lock Free:** All platform attitude (roll, pitch & heading) computations are handled in quaternion space, guaranteeing seamless computation of rotations.
- **Variable Dimension:** The system automatically adjusts as sensors fail or are returned to service - on a sample-by-sample basis.



GPS glitch in real world data



BMT Adaptive Kalman system rejects GPS receiver error



BMT inertial navigation unit in laboratory calibration

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