Attitude estimation by using a minimum variance data fusion method in a redundant three-axial gyro MEMS detection unit

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Inertial Navigation Systems (MEMS, NEMS, MOEMS, NOEMS)

- Oversized and expensive classical inertial measurement units (IMU) were replaced with low-cost and low-dimensions ones.

- Advantages and disadvantages brought by the miniaturization.

- Inertial sensors noise overlaps over the output of the sensors, cannot be totally eliminated but it can be modeled by stochastic processes.
INS errors

Inertial sensor errors

High-precision strap-down inertial navigators based on the connection and adaptive integration of the nano and micro inertial sensors in low cost networks, with a high degree of redundancy.

Construction of algorithms based on the idea of building redundant linear networks of sensors in the same navigator, followed by each sensors network data fusion.
A redundant strap-down attitude system which uses three miniaturized gyro sensors linear clusters in the inertial detection unit was proposed.

A redundant cluster of sensors supposes the mounting of several gyro sensors in the same measurement unit.

Data was fused using a statistical method based on the minimum variance method in order to improve the useful angular speed signal measured by the detection unit.

The new proposed structure had a redundant attitude system in the inertial navigator and offered significant improvements of the angular speed detection accuracy.

In the paper are successively exposed the data fusion algorithm and the theoretical background of the attitude system.
Finally, are shown the Matlab/Simulink software implementation and experimental validation of the redundant inertial attitude system.

To perform the experimental validation of the developed redundant attitude system some data were simultaneously acquired from a three-dimensional redundant gyro sensors unit, and from an INS/GPS integrated navigator.

Both systems were boarded on a testing car which played the role of the monitored vehicle.

The INS/GPS system was used as reference system to evaluate the errors of attitude angles determination.

The three-dimensional redundant gyro sensors unit contained twelve gyros disposed in three clusters of four sensors each, along the x, y and z axes of the body frame.
For developing the entire inertial attitude system in the redundant proposed variant, the data fusion algorithm model for each of the three channels was inserted between the gyro sensors and the attitude algorithm model.
Data fusion algorithm inputs are the signals from the gyro sensors in each of the three detection clusters, while its outputs are the fusion signal, the variance of the fusion signal, and the variances and weights of each of the fused sensors data.
Attitude algorithm implementation in Matlab/Simulink

NED (local frame) to SV (body frame)

\[ p, q, r \text{ [deg/s]} \]  
Euler angles [deg]

Attitude

a. NED (local frame) to SV (body frame)

b. Euler angles [deg]

om_x, om_y, om_z
roll, pitch, yaw

Simulink block “Attitude”

Graphical User Interface of the algorithm.
Experimental validation of the redundant attitude system

Matlab/Simulink model for experimental validation
Fusion signals and achieved data

- Significant reduction of the noise levels when using the data fusion algorithm can be easily observed.
A comparative study between the attitude angle solution of our redundant attitude system and of the reference INS/GPS navigator.

Also, are shown the results obtained if the attitude solution is founded by using the data from the first sensor in each of the three gyro sensors clusters included in redundant detection unit.

The initial values of the attitude angles were: 0.027 deg for roll angle, 0.051 deg for pitch angle, and 108.103 deg for yaw angle.
Attitude angles errors: the deviations between the attitude angles solution in our configuration and the reference INS/GPS navigator, and between the attitude angles solution in non-redundant configuration and reference INS/GPS navigator.
The maximum absolute deviations between the redundant attitude system and reference INS/GPS attitude angles founded during 180 s are: 0.1468 deg in roll angle, 0.0487 deg in pitch angle, and 0.6558 deg in yaw angle.

On the other way, the same deviations, but between the attitude solution in non-redundant configuration and reference INS/GPS are: 0.5020 deg in roll angle, 0.0674 deg in pitch angle, and 1.1603 deg in yaw angle.

By comparing the deviations resulted from our system with those resulted from the non-redundant configuration can be easily observed a significant improvement of the attitude angles determination accuracy brought by the proposed configuration!
THANK YOU KINDLY FOR YOUR ATTENTION!

PLEASE CONTACT US FOR ANY QUESTIONS YOU MAY HAVE:
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