Symposium Gyro Technology

Karlsruhe, 18/19 September 2007

ABSTRACTS

Single-Chip, Three-Axis Gyroscope Using SOI-Technology

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Abstract:

The market growth of multi-axis inertial measurement units (IMU) using MEMS gyroscopes and accelerometers is estimated to about 10 - 15 % per year. Especially new application fields such as robotics or medical applications require highly accurate, small and lightweight sensor units of low cost with no performance loss due to minimization. State-of-the-art IMU apply single-axis micro-machined gyroscopes arranged rectangular to each other. Problems concerning the assembly of such sensor clusters are the complexity of the packaging with its mismatch in sensor alignment, the immense costs based on the packaging and the big dimensions of such IMU.

In order to overcome these drawbacks a 3-axis gyroscope was realized in one plane on one silicon substrate using a standard silicon-on-insulator (SOI) – technology which is frequently applied to realize state-of-the-art out-of-plane sensitive gyroscopes (z-axis). Only some small adaptations of this technology were necessary requiring no additional buried or cap electrodes to achieve also the second and third sensitive axes (x and y-axis) on chip.

HSG-IMIT presented concepts for realising MEMS multi-axis inertial sensor units and the new approach at the Symposium Gyro Technology 2006. Based on this work the paper illustrates the concept of the sensing structure, the modified SOI-technology and the latest measurement results of the first prototypes of the novel single-chip 3-axis gyroscope.

Quadrature Error Reducing Methods in RR-type Micromechanical Gyroscope

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Abstract:

The Central Research Institute “Elektropribor” started development of angular-rate-sensing Micromechanical Gyroscope (MMG) of 0.01 deg/s accuracy class in 2001. The detailed description of developed gyroscope design has been presented at the Symposium Gyro Technology 2005.

Quadrature error occurs in MMG under development as well as in the majority of gyroscopes of this class. The tests of different micromechanical silicon modules manufactured by Tronic’s Microsystems SA show that the quadrature error varies from sample to sample. The median value of disk deviation caused by quadrature error is equal to 0.3 μm if MMG is working with resonant frequencies of elastic suspension separated by more than 100 Hz. The disk deviation proportional to the angular velocity of 0.03 deg/s, resulting in Coriolis force, amounts to several angstrom.

Quadrature error can be characterized as MMG output voltage at the fixed gyro base or as the torque which causes disk deviation proportional to this error. On the basis of these methods two approaches to reducing and measuring quadrature error are developed. The first approach is based on measuring quadrature amplitude and adaptive compensation of electrical signal proportional to the quadrature error in the channel of output signal processing. The second approach is based on generation of compensating torque using electrodes of secondary oscillation.

The experimental results for MMG with the quadrature error reduced using different methods are presented. Comparative assessment of these methods, their advantages and disadvantages as well as analysis of quadrature error influence on MMG accuracy are given.

MEMS-Foundry Technology for High-Performance Gyroscopes

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Abstract:

Using silicon-based MEMS technologies, the cost-efficient production of gyroscopes has become possible in recent years. As a result, gyroscopes are entering new markets, such as for highly accurate GPS-instruments where the gyroscope enhances accuracy in situations where satellite reception is lost, for example in tunnels. However, since all gyroscopes are very precise resonating measurement devices, this leads to stringent wafer processing requirements for their production. Due to the growing market for different gyroscope applications, a MEMS Foundry Technology has been developed and established in production. This technology will be described in the following paper.

The technology has been developed for capacitive gyroscopes with electrostatic actuation of the seismic mass and capacitive read-out of the sensor signal. It is based on a SOI wafer, this special substrate providing many technological benefits, despite it being cost-intensive. However, the main advantage is that the moveable structures are made from a single crystalline device layer, and hence have excellent, well-defined mechanical properties and high reliability. For the realisation of the complex mechanical gyroscope structures (seismic mass, comb drives, read-out capacitors) trenches and holes are etched anisotropically in the device layer of the SOI wafer, down to the buried oxide, retaining the shape of the gyroscope mechanics. To release the mechanical structures, the sidewalls of the etched silicon structures are passivated, and the buried oxide is opened at the bottom of the trenches. By using isotropic etching into the handle wafer silicon, the structures are then underetched and their ends released. In this process, the structure width defines whether a structure becomes moveable or remains fixed. Afterwards, any remaining oxide is stripped from the mechanical structures, so that they consist of pure single crystalline silicon only. To improve the electrical behaviour of the gyroscopes, filled insulation trenches are processed prior to the fabrication of the mechanical structures. These trenches separate the gyro structure as well as the bond pads from the surrounding chip, and allow defined electrical contacting of the different gyroscope elements by metal wiring. However, the main benefit of the trenches is the reduction of parasitic capacitances, which greatly increases the gyroscope performance. Furthermore, an insulation layer between the device layer silicon and the metal layer in the area surrounding the mechanical structures provides the possibility of complex electrical wiring. Finally, the mechanical structures are sealed with a capping wafer using glass frit wafer bonding.

Evolution and revolution in MEMS accelerometers

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Abstract:

VTI is one of the leading suppliers for low-g, high performance accelerometers today – especially in automotive and medical system business. Starting with bulk micromachining MEMS technology, standards in performance have been set. Coming from those high-end products a commercialization has been successfully implemented in automotive industry meeting the magical price, performance, quality triangle so that annually more than 30M axis are delivered towards applications like ESP/vehicle stability control, electronic parking brake and active suspension control. The new challenge for mass market is the upcoming consumer area where the number of required axis will explode while totally different price targets and requirements for size and quality have to be met. This has lead to leapfrog development in terms of new technology meeting those requirements. In a next step it is also evident that this new technology will effect the automotive sensor technology.

In this presentation the technical roadmap from history towards future acceleration sensor products will be displayed. Significant details like technology enablers as well as lessons learned are demonstrating that solutions for small challenges have created the successful path.

15 Years $LiNbO_3$-Based Integrated Optics Facility at LITEF

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Abstract:

LITEF GmbH has established a medium volume research and production facility for $LiNbO_3$ based integrated optics. The development of integrated optic chips started in 1990 and the first production samples were delivered for the LCR-92, LITEFs first fiber optic gyro based Attitude and Heading Reference System (AHRS) in 1992. Nearly all integrated optic devices are used for the in house production of fibre optic interferometers mainly the fibre optic gyroscope and the fibre optic current sensor. In this lecture the integrated optic facility at LITEF and their capability is presented.

Furthermore the functionality of the integrated optic devices in fiber optic interferometric sensors is described.

Since the beginning different types of multifunction integrated optic circuits were developed for sensors and for systems based on these sensors. At the moment 3 different types of multifunction integrated circuits are used in our products. The standard chip for the gyroscopes integrates a y-junction, a polarizer and a phase modulator. Beside this circuit a digital multifunction integrated optic circuit with a high resolution Digital-to-Analogue converter and a mixed signal chip with DA-converter and a phase modulator for additional signal processing functionality are now produced. The mixed signal chip is used in medium accuracy single axis gyroscope and in the fibre optic current sensor. In this presentation a description of different characterization methods for the unique digital multifunction integrated optical circuit will be given. To test the integrated optical devices in the production and during the development different optical and electro-optical measurement methods are established. Some examples are low coherence interferometers to measure reflection and polarization extinction ratio with a high spatial resolution and a cut-off wavelength test station. Beside the production of devices for in house use LITEF has the capability to develop and produce circuits for other application including high bandwidth optical communication lines.

All integrated optic devices are designed and produced to meet the most stringent civilian, military and space requirements.

Modular Design Approach for a FOG Family Concept

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Abstract:

Sagem Navigation GmbH is a manufacturer of various types of Fiber Optic Gyroscopes (FOG). The products cover the range from single axis FOG modules, single axis Fiber Optic Rate Gyros, dual axis FOG modules, three axis FOG and FOG type Inertial Measurement Units (FMU) up to the use of the sensing and measurement unit as core of the Attitude-/Heading Reference Systems APIRS produced by Sagem Défense Sécurité, France.

Since the beginning of the industrial FOG production in the company a modular approach has been applied. This is especially true for the main part of the FOG, which is the optics. Identical or almost identical modules as source, detector, power splitter, and modulator are used in all types and classes of the sensors. Performance is largely determined by the usage of a different fiber length in slightly different coil assemblies.

The paper addresses the architecture of the sensors, the characteristics of the modules, the assembling process and the manufacturing flow.

Observation of key performance indicators is addressed together with trade-off considerations between cost, performance, and yield.

The evolution from the very first FOG application in industrial environments up to the most demanding application with respect to environment in the Ariane 5 launch vehicle, or with respect to logistics in the Airbus A380 supply chain will be presented.

A special part will deal with the comparison of the Sagem Navigation GmbH proprietary time-multiplex approach and a typical source sharing approach. Advantages and disadvantages of both solutions are discussed.

REGYS20 a HRG Gyrometer for Space Applications

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Abstract:

SAGEM, Europe's leading manufacturer of inertial navigation and provider of space solutions for 30 years proposes the HRG REGYS 20 rate sensor vibrating gyro, a breakthrough technology for medium to high performances space applications.

The inertial measurement unit is composed of hemispherical-resonator gyros, well known for its low random walk and its high reliability. REGYS 20 benefits from SAGEM DS experience in HRG technology, developed several years ago for military systems.

Main principles of HRG technology are recalled along with some analysis of the main performance drivers. The specific controlled loop system developed in order to be compliant with spatial design requirement is presented. We focus on Analog to Digital and Digital to Analog conversion functions that are designed to get good performance at low cost.

The REGYS 20 gyro family product is described and some characteristics and performances figures obtained with a REGYS20 Breadboard Model are presented.

The development performed in the frame of the @BUS program is updated.

Towards a solid-sate ring laser gyroscope

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Abstract:

We report the achievement of a new kind of ring laser gyroscope, based on solid-state laser technologies and free of any gaseous medium. Such a device is intended to become the next generation of ring laser gyroscope, keeping the same high performance and principle of operation while releasing the industrial constraints due to the use of a gaseous medium.

We will first explain how we achieved rotation sensing in a diode-pumped Nd-YAG ring laser thanks to the use of an additional stabilizing coupling, as already reported in [1,2]. We will then present a new method for achieving inertial navigation grade performance in this kind of device. Latest experimental results based on this new technology will be presented.

References :

[1] S. Schwartz et al., Phys. Rev. Lett. **97**, 093902 (2006)

[2] S. Schwartz et al., Phys. Rev. A **76**, 023807 (2007)

Modeling and Design of a Novel Resonance Integrated Optic Gyro Using Single Polarization Waveguide

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Abstract:

Modeling and design of the integrated optic gyro (IOG) based on the passive ring resonator is presented. The passive ring resonators were fabricated on Si substrates by plasma enhanced chemical-vapor deposition (PECVD), photolithography, ion etching technology. It consists of a Ge-doped silica-based single polarization waveguide (SPW) and an low loss directional coupler for input light into and output light out of the ring resonator. The designs of the ring resonator, directional coupler and the method of realizing SPW are proposed.

The SPW only propagates one polarization mode. It can eliminate the cross talk between two resonance dips in the ring resonator, and can solve the gyro bias error due to polarization fluctuation. SPW propagation characteristics are analyzed and simulated by means of the three-dimensional finite-difference time-domain (FDTD) method. The SPW has a high extinction ratio over 25dB/cm for TM mode, very low propagation loss of 0.05dB/cm for the TE mode at 1550nm wavelength. Passive ring resonator IOG based on SPW can obtain good performance and be used in navigation systems.

Performance Analysis of a Deeply Coupled GPS/INS System with Different IMU Grades

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Abstract:

Modern navigation systems are based on the coupling of a GPS receiver and an inertial measurement unit (IMU). The effort of recent research and development is to integrate these two sensors so that they can optimally profit from each other. In a tightly coupled system the pseudo- and delta-ranges are used to correct the state of the navigation filter. This is a well known process and compared to a loosely coupled system it brings some advantages when there are less than four satellites available. Still there are disadvantages on the receiver side of this system.

The main challenge of the GPS receiver is to track the satellite signals in any adverse signal condition. For each satellite signal this is done by so-called tracking loops for the carrier frequency (PLL) and the code phase (DLL). If either one of both tracking loops loses lock, due to weak signals or high dynamics, the tracking and the pseudorange estimation fails. This can be overcome by letting the GPS receiver profit from the presence of an IMU. Even in poor signal conditions the strapdown algorithm always produces a navigation solution that can be used for stabilizing the tracking loops of the GPS receiver. This is done in a deeply coupled system.

Since a deeply coupled GPS/INS system uses the output of the navigation filter the inertial measurement unit is an important part of such a system. After signal outages the precision of the IMU is the limiting factor, if the signal is still in track or the receiver has to switch to conventional re-acquisition. Also during high accelerations the tracking performance depends on the quality of the IMU.

In this paper a deeply coupled GPS/INS system is tested with different IMU grades. This is done in a real time test with a Spirent Space Signal Generator and a software receiver that uses simulated IMU data. In several tests the performance of a deeply coupled system with different IMUs is presented. It is shown that even with MEMS-IMUs there is a gain in robustness of the overall system.

Sensor Data Fusion for Pedestrian Navigation Using WLAN and INS

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Abstract:

This paper presents a sensor fusion approach for pedestrian navigation based on a WLAN positioning system and a MEMS inertial measurement unit (IMU). Using sensor fusion of WLAN and INS data, the noisy position estimates of the WLAN system can be smoothed, dynamic movements of the pedestrian can be followed more accurately and orientation information can be obtained enhancing significantly the WLAN positioning system.

The low cost MEMS-based inertial navigation system (INS) is inaccurate and can diverge very fast over time due to the typical intrinsic errors like bias, misalignment and scaling. However the INS has the advantage of high availability and data rate, and it is immune to external disturbances. In another way the Position of the WLAN system is very stable but due to variations in the signal strength the position estimates are noisy. Some of the error sources have been minimized by calibration, others by online estimation using the sensor fusion algorithms.

By means of INS the WLAN positioning can be improved in two ways. At first, in a set-up phase, it supports the creation of a fingerprint data base of field strength measurements of arbitrary WLAN access points using a backward smoothing algorithm. Later, in the operational phase, at the location of interest field strength levels of all receivable WLAN access points are measured and the best fitting fingerprints are chosen from the data base. Using an extended Kalman filter the chosen fingerprints are fused together with the actual field strength measurements and the acceleration measurements. Parallel a quaternion based Kalman filter extracts the INS orientation and estimates the biases of the gyroscopes, accelerometers and magnetic field sensors as well.

Special attention has been paid to the sensor fusion architecture and algorithms. Simulations and measurements in different scenarios are carried out to demonstrate the performance after system integration. The results are analysed and the system strengths and weaknesses are discussed.

Combined GPS/TRN/INS Navigation System using directional Distance Measurements within a Kalman Filter

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Abstract:

Most aircraft and missile systems use navigation systems that combine satellite navigation systems (for example GPS) and inertial navigation systems (INS) to determine a long term stable position, velocity and attitude. Especially in military applications the availability of satellite navigation is not ensured over all times due to possible jamming or spoofing situations. Therefore, additional navigation systems like radar or laser based terrain reference navigation (TRN) systems are incorporated.

Usually terrain referenced navigation systems are based on the processing of radar altimeter measurements. The beam width of the radar antenna is chosen in a way that even for small roll or pitch angles the nadir point directly below the missile lies within the radar beam. For small variations in the overflown terrain the point of first reflection will most probably be the nadir point. This measurement can now easily be compared to expected heights generated based on a reference map. The actual position aiding can be performed using the terrain gradient and the difference of reference and measurement. Knowing that the measurement is the distance to the nadir point, the measurement function is simply given by the reference map. Unfortunately, the measurement can be disturbed if the terrain has a significant roughness. In such a situation a simple terrain reference navigation system will only provide position estimates with reduced accuracy.

One possibility to avoid theses systematic errors is to use a radar altimeter with a small beam width or a laser altimeter. This new measurement type has a different measurement model. The sensor does not provide the distance to the nadir point but the distance to the intersection between line of sight and terrain. This changed situation has also to be considered in the terrain reference navigation algorithm. This paper provides the measurement models of both described terrain reference navigation algorithms. Simulation results of the navigation solution of nadir point and the directional distance measurement show the advantage of the second method.

Furthermore, this paper shows the system concept of a combined missile navigation system incorporating the proposed terrain reference navigation as well as a satellite and inertial navigation system. This system concept is based on a Kalman filter to allow the integration of GPS, TRN and INS even for a missile application, with only limited calculation power.

Accuracy Improvement of Low-Cost MEMS/GNSS Inertial Navigation Systems by Means of Smoothing

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Abstract:

This paper focuses on Integrated Navigation by means of low-cost MEMS sensors. MEMS sensors have usually large biases and temperature drifts. Hence they are mostly used for automation and control applications. They can be used for integrated navigation systems only if a constant feed with aiding information is available. As soon as outages occur the accuracy drops very fast and it is not possible to calculate position updates.

A tightly coupled smoother is presented that enables inertial positioning even during outages by means of post-processing. Several techniques are used to reach an optimum performance.

With the tightly couple approach it is possible to aid the system during partial outages and to bound the system errors. Compared to a loosely coupled system this approach processes more measurement information as pseudoranges and Doppler measurements are used directly.

Hence, it is possible to aid the system with less then four satellites available. For high-accuracy applications it is possible to extend the tightly coupled approach to an integrated RTK differential GPS system. The central navigation Kalman Filter estimates the carrier phase ambiguities and resolves them with the LAMBDA-Method. (Least Squares Ambiguity Decorrelation Adjustment) So it is possible to achieve centimetre accuracy while GPS is available.

The post-processing is done with a Rauch-Tung-Striebel smoother. It processes the data a second time, but backward in time. Hence, it benefits from measurement information that is located in the future of a certain epoch and it is possible two reduce position and attitude errors by magnitudes during outages.

Measurement results from a test drive with a MEMS IMU are presented. A tactical grade IMU and orthographic pictures are used to provide an attitude and position reference.

The results show that the approach enables MEMS/GPS Low-Cost Integrated navigation systems. It is possible to provide a continuous, steady, smooth position trajectory regardless if outages occurred or not.

Integrated Navigation System Filter Algorithms Based on Evolutionary Artificial Neural Networks

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Abstract:

Kalman filter is an effective optimal estimation algorithm for integrated navigation system, in order to get better estimating results, accurate system model and reliable observation data are necessary. In practice, any inaccurate system model or trustless observation data will lower precision of estimates, and even lead filter to divergence.

In the paper, a kind of adaptive Kalman filter algorithm is introduced to overcome strong dependency on system model of the traditional Kalman filter. And evolutionary neural networks are also put forward to solve the decreasing accuracy of traditional Kalman filter when observation data is unreliable. The artificial neural networks optimized by evolutionary programming can not only overcome easy falling into local minimum, long training time and other shortcomings of traditional artificial neural network, but also avoid the problems of genetic algorithms caused by binary-coded and cross operation. Finally, the method is applied in an integrated navigation system. In the design scheme, the navigation parameters from SINS are used as the input of the evolutionary neural networks, and the errors between parameters of SINS and observation data are used as the reference output. The simulation experiment in which an integrated navigation system is with inaccurate model parameters, noise statistics and with unreliable observation data is also introduced in this paper. When observation data is available and reliable, evolutionary neural networks works in the learning mode, and when the observation data is unreliable or unavailable, the evolutionary neural networks is in the forecasting mode, and it can forecast the observation errors of adaptive Kalman filter which can ensure that adaptive Kalman filter runs continuously. The experiment results indicate that the algorithms can efficiently overcome the shortcomings of traditional Kalman filter with better accuracy.

Development and Test Results of Compact and Accurate Attitude and Heading Reference Systems

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Abstract:

This paper reports on strapdown Attitude and Heading Reference Systemss (AHRS) that Innalabs Holding Inc develops and produces.

Innalabs Holding Inc. has united leading Ukrainian specialists in navigation systems and inertial sensors technology to develop high performance navigation and orientation systems and new sensors for them.

Now Innalabs develops and produces a wide range of its own sensors: Coriolis vibratory gyros with metal alloy resonators, pendulous compensative accelerometers, fluxgate magnetometers. Their combination with modern electronics and proprietary software has allowed development and production of strapdown AHRS of different accuracy and cost for various applications:

– high-performance AHRS based on Innalabs gyros, Innalabs accelerometers and Innalabs magnetometers;
– middle accuracy compact AHRS based on COTS MEMS gyros, small Innalabs accelerometers and Innalabs magnetometers;
– middle accuracy low-cost small AHRS based on all COTS MEMS sensors.

This report is dedicated to development and test results of a compact strapdown AHRS (119 x 33 x 32 mm) in which Innalabs accelerometers and magnetometers provide high accuracy of angular orientation measurements. Application of special algorithms has allowed using MEMS gyros instead of the accurate Innalabs ones with no essential losses in overall performance. In static mode the RMS error does not exceed 0.02 degrees in pitch/roll determination and 0.2 degrees in magnetic heading measurement (for magnetic latitude up to ±70°). In the dynamic motion AHRS provides accuracy not worse than 0.2 degrees RMS in pitch/roll and 0.5 degrees RMS in heading at up to 100 Hz data output.

Special algorithms protect accurate orientation measurement against object accelerations and distortions of magnetic field. Besides, a specially developed procedure is presented which provides automatic calibration of AHRS's magnetic channel to hard and soft iron of the vehicle materials, which eliminates AHRS magnetic deviations.

Performance Evaluation of IMU for Surveying and Mapping Applications

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Abstract:

The inertial measurement unit (IMU) is a major component of modern position and orientation systems (POS) used for surveying and mapping. The performance of POS is highly dependent on IMU performance. During the IMU selection process, POS developers usually face the following tasks:

1. Evaluate the performance of the IMU.
2. Evaluate the performance of POS that includes this IMU.

The first task could be potentially accomplished using IMU manufacturer's data. Unfortunately documents available from manufacturers often are unclear and do not have all the necessary information. In Applanix, to achieve a good final product quality, the following types of testing are typically executed:

- Static, in the lab and in the temperature chamber – to develop gyro and accelerometer bias stability models over the required temperature range using Allan variance approach.
- Dynamic, on the rate table – to develop bias, scale factor error, misalignment models over temperature and signal range, and to evaluate bandwidth and latency.
- Shock and vibration tests, on the shaker – to evaluate vibration rectification and confirm shock resistance.

If IMU performance looks promising, the system performance is evaluated – first by simulation and then by field trials. A number of tools have been developed in Applanix to support mathematical and combined (mathematical with real data) system simulation activities. The final POS performance characteristics and the refined IMU model used in the POS hybrid filters are obtained based on van or aircraft or boat tests depending on application.

Operational Measurement Angles in Flight (LOLA)

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Abstract:

In December 2006, for the first time in the world, an optical link between a flying aircraft and a geo-stationary satellite has been established.

LOLA project is a French MOD /EADS Astrium program. The purpose of this program is to demonstrate the capability of high data rate communications (up to 50 Mbits/s and up to 1 Gbits/s) through an optical laser link between an aircraft and a geo-stationary satellite.

IXSEA provided a FOG INS unit (AIRINS) that allowed an accurate pointing the sighting system. AIRINS provides 3D position, attitude and heading accurate and fast refresh rate reference to the optical sighting system (ELSA) mounted into a French MOD Falcon 20 aircraft.

Since this date, more than 20 flights with different weather conditions have been successfully performed.

The paper shows the measurement of AIRINS residual attitude and heading determined as the initial pointing error when optical link is locked.

It is not easy to have an accurate absolute angular measurement on operational environment.

Three axis simulator allows accurate angular measurement, but there is no acceleration and linear speed. Electromechanical shakers simulate operational vibrations but it is very difficult (almost impossible) to have simultaneously accurate angular measurement because there is no attitude or heading references.

LOLA project give the opportunity to check in operational conditions (vibrations, thermal) the performances of AIRINS with an indirect, independent and very accurate reference.

On Multiple Distributed IMUs for Improved Navigation

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Abstract:

Though the idea of using several redundant inertial measurement units (IMUs) for navigation of a platform is not new and dates back to the sixties of last century, little literature can be found about the benefits of it. Most of the early applications of IMU redundancy were directed for fault detection and isolation purposes only. Later on, applications such as precise trajectory determination were considered.

In this paper we investigated the improved navigation performance resulting of combining multiple distributed IMUs (MDIMUS) outputs and discussed how to maximize the improvement. During our research work we observed that there is less attention regarding MDIMUS benefits. On the other hand, plenty of publications can be found on what have been coined Skewed Redundant IMU (SRIMU), and its optimal configuration. For a rigid body, we have a unique angular rate value all over the body while the acceleration value on the body varies depending on the location of the measurement point with respect to the origin of main body frame. Multiple distributed accelerometers have been used as gyro free IMUs by inferring angular rates from resulting lever-arm effects of distributed accelerometers but our approach is to benefit from both redundancy and distribution.

There are many other motivations for fusing outputs of IMU units such as the low price of micro electromechanical (MEM) sensors. The reduced size and weight of modern MEM IMUs makes it possible to combine multiple IMUs on the same platform.

Moreover, IMU/IMU might be useful incase of using multiple units, each of which has diverse specifications of both gyros and accelerometers from the other units in platform.

In this paper, an approach to exploit the above mentioned effects of redundancy and distribution while considering IMUs as modules is derived and explained in detail. Synthetic data is used to verify the approach. To reduce complexity, the working point has been chosen to be the origin of a common body frame. Appropriate estimation results are presented.

Low-Power Sigma-Delta Interface for Micromachined Gyroscopes

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Abstract:

Gyroscopes are components in many portable devices for applications like mobile navigation, virtual reality, image acquisition etc.. Due to their small dimensions, low weight and reduced cost, micro-electromechanical Coriolis Vibrating Gyroscopes (CVG) are predestined to be employed in these devices. At present the power consumption of a high performance CVG excitation and readout system is still in the range of about 20 to 40 mW, which limits the operating time of a mobile, battery-driven device incorporating a CVG enormously. Thus the goal of the ongoing development is to reduce the power consumption of a CVG system significantly.

Evaluating a capacitive sensor in a closed loop fashion increases the sensor bandwidth, improves its linearity and reduces the sensitivity to process and temperature variations. In combination with a digital feedback an electromechanical Sigma-Delta modulator can be realized. This readout technique benefits from the feedback mode as well as from an intrinsic, high-resolution Analog-to-Digital (A/D) conversion at a relative modest circuit cost. Thus in general the Sigma-Delta approach is suitable for a low-power implementation of a CVG readout circuit.

A further power saving is feasible by a full Continuous-Time (CT) circuit implementation due to the fact that amplifier speed requirements of a CT modulator are more relaxed compared to its discrete-time counterpart.

A reduction of flicker noise and offset errors introduced by the capacitance-to-voltage converter can be gained by a modified chopper stabilization technique without adopting additional hardware. The included demodulation process is accomplished by an undersampled A/D converter convoluting the modulated signal back to its original frequency. Further the task of an error reducing demodulation filter is adopted by the noise transfer characteristic of the Sigma-Delta modulator.

Measurement of Angle Movement Parameters by Means of Ring Laser Goniometer

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Abstract:

The laser goniometry, based on ring laser gyro continuously rotating with constant angular velocity, provides the most favorable conditions for attaining the ultimate precision in angle measurements. The configurations of laser goniometer developed earlier were intended for operating on a stationary base and were using the ring laser gyro as a high-resolution angle transducer. One of the most effective implementation of the laser goniometer is the non-contact measurement of angular movement of an object. The use of the laser dynamic goniometer in the mode of external angle measurement provides high accuracy and wide range of measurements.

In the paper the error analysis of the measurement of angle movement parameters by means of laser dynamic goniometer is considered. It is shown that main error sources are the errors of a null indicator and a scanning mirror. The compensation of scanning mirror systematic error allows to measure the object angular position with an error less than 0,1 arcs. The use of the regression analysis method allows determining the object angular rate with an error 10^{-3} deg/h. The results of the measurements of the various object types are reported.