Microsystems based sensor fusion enabling standalone navigation

Mohammed Jalal Ahamed*

*Mechanical, Automotive and Materials Engineering, University of Windsor
Windsir, ON, Canada, jahamed@uwindsor.ca

ABSTRACT

There is a need for effective and standalone navigation device which not only can track users in unknown environments but also assist their navigation by obstacle avoidance and path guidance. This research developed a state-of-the-art standalone and portable navigation system by implementing improved and effective micro inertial navigation unit that is integrated with environmental mapping sensors. It offers efficient alternative navigation compare to the existing GPS (Global Positioning System) or WiFi assisted systems by providing greater functionality to navigate in dark, visually restricted environments, operate without satellite or other signal, where this type of navigation system could prove most powerful. It is efficient and cost effective alternative compare to existing LiDAR (Light Detection and Range) or vision based SLAM (Simultaneous localization and mapping) systems. The micro inertial sensor research leveraged on the wafer-scale fabrication process to developed higher sensitivity micro-systems based gyroscopes. Rapid development of micro-fabrication technology is allowing both the academia and the industry to pursue mass fabrication of high-precision motion sensors. This research developed micro gyroscope design, fabrication and packaging prospect for MEMS based ultra-precision gyroscopes with robust mechanical materials that have never been explored before in MEMS. The gyroscope motion data is integrated with obstacle sensors for guided navigation. By the sensor fusion it created a fully integrated and automated system that can localize a user in any unknown environment, while simultaneously building a map of the environment from external sensor data. The integrated system development methodology presented in this research has many potential applications including mobile robotics, underground navigation and assisted navigation.

Keywords: Inertial Navigtion, Sensor Fusion, GPS, MEMS, Gyrsocpe

1 METHOD AND RESULTS

The introduction of GNSS (global navigation satellite systems), and specifically the GPS system, have allowed travel in formerly unknown environments with relative ease. While these devices offer a great deal of functionality, they only represent the tip of the iceberg in terms of the potential of future personal navigation devices (PNDs). The research develop functional inertial navigation devices that can operate independent of any radio or satellite signals, in turn solving many of the limitations of GNSS based PNDs. By combining a microprocessor, MEMS (Microelectromechanical Systems) based inertial measurement units (IMUs) and a variety of other sensors, it is possible to create algorithms that accurately track users and can offer personalized aided navigation in all environments. MEMS based inertial sensor systems are showing greater performance characteristics and finding various applications including personalized navigation [1-5].

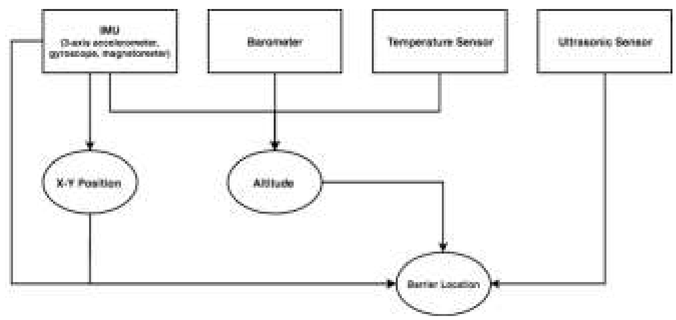

Figure 1. Flow chart showing the complete stand-alone navigation system with sensor fusion.

Figure 1 illustrating the concept of our innovative navigation system. Position, pressure, temperature and ultrasonic sensor are integrated on one platform for navigation. Data from the IMU (accelerometer data, gyroscope data, and magnetometer data) are first passed through a complementary filter. After yaw, pitch, and roll are calculated using several sensor fusion algorithms, they are used to convert the local frame accelerometer data to a global frame. From there, the acceleration is numerically integrated to produce a raw velocity dataset that still suffers from significant drift. Step phases are detected and used to perform zero-velocity updates, which in turn produces a corrected velocity dataset with significantly reduced drift. This corrected velocity is numerically integrated once more to obtain position data. Data from an ultrasonic sensor is used to map the barrier distance by using the position the user was in at the point the measurement was taken and the heading (yaw angle) of the user at that time. The most basic laws of kinematics underline the principles of many inertial based navigation systems. First, algorithms combine data from the IMU in order to accurately extract the PND orientation of the device. Once this is done, acceleration data is rotated into a global frame and integrated in order to obtain velocity and position. For this position data to be useful, the noise of the signal must be drastically reduced my implementing algorithms that constantly correct either the position or velocity data. This attempt to reduce drift via external sensors is one of the largest areas of research in inertial based navigation today. This project uses algorithms that make use of both external sensors (barometers, magnatometer and temperature sensors) as well as unique properties of the human step to reduce noise on shoe-mounted inertial PNDs. In combination with the navigation data, ultrasonic sensors are used to perform barrier detection in order to create devices that can offer real time assisted navigation in indoor environments.

The most basic laws of kinematics underline the principles of many inertial based navigation systems. First, algorithms combine data from the IMU in order to accurately extract the PND orientation of the device. Once this is done, acceleration data is rotated into a global frame and integrated in order to obtain velocity and position. For this position data to be useful, the noise of the signal must be drastically reduced my implementing algorithms that constantly correct either the position or velocity data. This attempt to reduce drift via external sensors is one of the largest areas of research in inertial based navigation today. This innovative system uses sensor information fusion that make use of both external sensors (barometers, magnatometer and temperature sensors) as well as unique properties of the human step to reduce noise on shoe-mounted inertial PNDs. In combination with the navigation data, ultrasonic sensors are used to perform barrier detection in order to create devices that can offer real time assisted navigation in indoor environments.

2 CONCLUSION

A stand-alone collision avoidance navigation system was developing comprising of on-board IMU (Inertial Measurement Unit) providing pedestrian inertial motion data by sensor fusion of between pressure sensor, magnatometer, inertial measurement unit and ultrasonic sensor. Pedestrian localization using step-detection, zero-velocity updates, and inertial dead reckoning performed on board. Obstacle mapping in combination with ultrasonic data, position data, and heading data. This system can operate without the need for external location signals. It can operate in unknown environments without the need for a map of the surrounding. And it can work without reliance on any devices built in nearby infrastructure, such as beacons or signal emitters. This system has the potential to make major technological shift in high accuracy and high precision stand-alone navigation without external signal.

REFERENCES

[1]. J. Jaekel and M. J. Ahamed, "An inertial navigation system wth acoustic obstacle detection for pedestrian applications," IEEE International Symposium on Inertial Sensors and Systems (INERTIAL), pp. 109-112, 2017.

[2]. M. J. Ahamed, D. Senkal and A. M. Shkel, "Effect of annealing on mechanical quality factor of fused quartz hemispherical resonator," 2014 International Symposium on Inertial Sensors and Systems (INERTIAL), Laguna Beach, CA, 25-26 Feb 2014.

[3]. M. J. Ahamed, D. Senkal, A. A. Trusov and A. M. Shkel, "Study of High Aspect Ratio NLD Plasma Etching and Postprocessing of Fused Silica and Borosilicate Glass," IEEE/ASME Journal of Microelectromechanical Systems, vol. 24, no. 4, pp. 790-800, Aug. 2015.

[4]. Liu J, Jaekel J, Ramdani D, Khan N, Ting DK, Ahamed M. Effect of Geometric and Material Properties on Thermoelastic Damping (TED) of 3D Hemispherical Inertial Resonator. ASME. ASME International Mechanical Engineering Congress and Exposition, Volume 10: Micro- and Nano-Systems Engineering and Packaging, pp. V010T13A019, 2016.

[5]. P. Rajai, M. Straeten, J. Liu, G. Xereas, M. J. Ahamed, Modeling of temperature frequency-compensation of doped silicon MEMS resonator, 2018 IEEE International Symposium on Inertial Sensors and Systems (INERTIAL), Comot, Italy, March 26-29, 2018