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Development of Inertial Navigation System based on Accelerometer and Gyroscope

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Abstract:
The navigation system provides the position and velocity of the object which plays key role in many applications. It becomes necessary to design and implement inertial navigation systems. In this paper, we proposed inertial navigation system based on arduino microcontroller in which measurements are provided by IR sensor and MPU 6050 sensor which is a combination of accelerometers and gyroscopes. The sensor gives position of the object from its starting point, distance travelled by the object, orientation and velocity of an object.IR sensor measures the distance based on the rotation of the vehicle. Based on the distance and direction of vehicle buzzer gets on indicating that vehicle is going outside the restricted area. These data is send to PC and its motion results are plotted in MATLAB.

Keywords: Inertial Navigation; Accelerometer;Inertial Sensors; Gyroscope; MATLAB.

I. INTRODUCTION

An inertial navigation system has wide range of applications such as submarines, guided missiles, spacecraft and aircraft. An inertial navigation system consists of a computer, inertial sensors such as accelerometers and which is a motion sensor and gyroscopes which is a rotation sensors which continuously monitors calculates the relative position, distance travelled and direction of the moving object. Generally, Inertial measurement units (IMUs) consists of three orthogonal rate-gyroscopes and three orthogonal accelerometers, which measures angular velocity and linear acceleration of the moving object. We get signals from these devices the signals are send to the processing unit so as to track the displacement of the object [3]. Advances in the manufacturing process of MEMS devices we can manufacture a small and light weight inertial navigation system which can be easily mounted on the vehicle in various fields of applications. These advances increased the scope of navigation systems in applications such as motion capture of humans and animals. All inertial navigation systems leads to some error in the measurement of the angular velocity and acceleration which then leads larger errors in velocity and other measurements of the system due to which performance of the system degrades. This error gets carried because every time new position is calculated with respect to the previous position .Therefore, it is necessary to correct the measurement error in every stage. Sensor Error Models are also considered in modern navigation systems in order to increase the performance and robustness of the system. The cost of the system depends on environment where we are going to use the navigation system.

- **Inertial System Configurations**

Basically inertial navigation systems are available in two configurations which are stable platforms systems or gimbaled systems and strap down inertial systems.

***A.* Stable Platform Systems or Gimbled Systems:** In stable platform systems the inertial sensors are mounted on stable platform. These sensors are mechanically isolated from external rotational motion of the vehicle. These systems are used where accurate estimation of the navigation data is required such as ships and submarines. Platform rotations are detected by gyroscope. For tracking orientation of the navigation system adjacent gimbals are read using angle pick-offs.

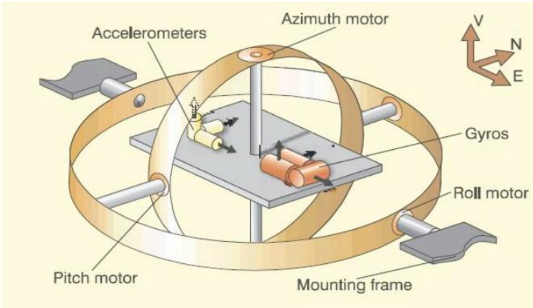

Figure.1. Stable Platform System

B. Strapdown Systems

In strapdown systems, most of the mechanical circuitry is eliminated by attaching sensors directly onto the host vehicle. Rate gyroscopes are integrated for tracking the orientation of the signals. For tracking positions, the three accelerometer signals are adjusted into global coordinates based on the known orientation of the integrated gyro signals. These systems are physically smaller than the stable platform systems. In this types of INS, computational cost is decreased as most of the mechanical parts get eliminated

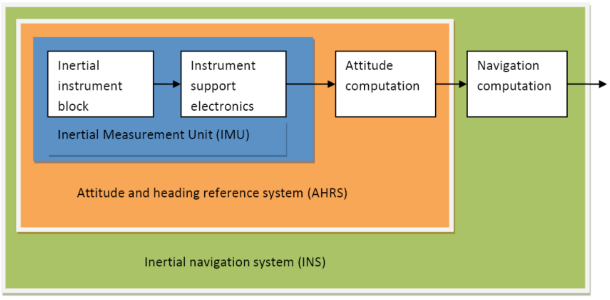

Figure.2. Building Blocks of the strapdown INS System

This paper discusses about the inertial navigation system and its configurations in section I. Proposed System working is given in section II. Implementation components details are given in section III. Results of the system are given in section IV. Applications of the system are given in section V. Conclusion of the work is given in section VI

II. PROPOSED WORK

A. Block Diagram of Proposed Scheme

Proposed system block diagram is shown in figure 3. It consists of arduino microcontroller, IR sensor, MPU-6050 sensor, Buzzer and DC motor. DC motor drives the vehicle and its direction is detected through MPU-6050 sensor. IR sensors shows the distance of the vehicle based on its wheel. Distance travelled by the vehicle equals to the rotations of the vehicle. Motion data captured through IR sensor and MPU-6050 is send to microcontroller arduino through I2C bus interfacing then it is send to PC through serial communication. In PC, we plot motion results of the vehicle based on data send from arduino. If the vehicle is moving outside the restricted area then buzzer will get on indicating that our vehicle is going outside the restricted area.

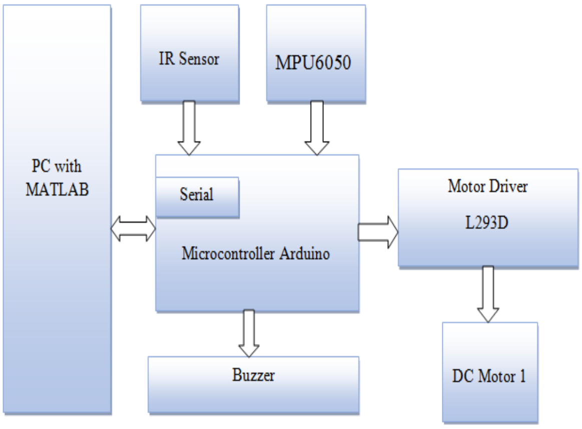

Figure.3. Block Diagram of the proposed system

Figure.4. Arduino Uno Board

III. IMPLEMENTATION

A. Software Design

1. Arduino Compiler

The Arduino Software (IDE) is a open source compiler in which we can write code and upload it to the board. It runs on Mac OS X, Linux and Windows. It is based on processing and other open-source software and environment is written in Java. Arduino compiler accepts C and C++ many of the libraries are written in C++. The Arduino environment performs some small transformations on the code to make sure that the code is correct then it gets passed to a compiler avr-gcc, which turns the code into machine language.

2. MATLAB

MATLAB is a high-performance language its basic data element is an array that does not require dimensioning. Matrix and vector formulations allow us to solve many technical computing problems. It integrates computation with the programming visualization which gives easy-to-use environment where problems and solutions can be expressed in the mathematical notation. Areas in which MATLAB toolboxes are available include control systems, simulation, signal processing, neural wavelets, fuzzy logic, and many others.

B. Hardware Implementation

1. Arduino Uno

The Arduino Uno microcontroller board is based on ATmega328P which has 14 digital input/output pins in which 6 are analog input pins, 6 can be used as PWM outputs), a USB connection, a power jack ,a 16 MHz quartz crystal, ,a reset button and an ICSP header. We can transfer data through serial communication to a computer with a USB cable. We can power it with a AC-to-DC adaptor battery to get started. The microcontrollers are programmed using programming languages such as C and C++.Arduino compiler is used for the Arduino uno based project (IDE) and for processing language of the project.

2. MPU-6050

The MPU-6050 devices consist of combination of two inertial sensors a 3-axis gyroscope and a 3-axis accelerometer on the same silicon die. It has onboard Digital Motion Processor™ (DMP™), which processes comple 6-axis Motion Fusion algorithms. It is provided with I^2C master bus to access external magnetometers or other sensors, which allows the system to gather whole sensor data without intervention from the system processor. The dimensions of MPU6050 are 4 mm x 4 mm x 0.9 mm QFN package. The MPU-6050 sensor has run-time calibration facility. It is provided with the calibration firmware so it avoids the costly and complex system level integration of the devices which are required for calibration procedures. Due to this, inertial navigation system gives good performance.

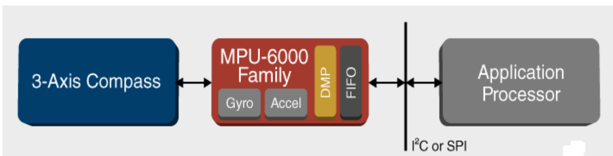

Figure.5. MPU 6000 Family Block Diagram

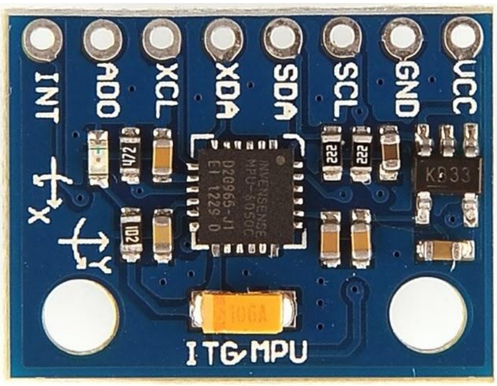

Figure.6. MPU 6050

IV. APPLICATIONS

Inertial navigation has various applications in all the fields which are given below:

➢ **Automotive Applications:**

- Drive dynamics Analysis
- Analysis of test route topology
- Driver assistance systems

➢ **Aeronautics and Space Industry:**

- Autopilot systems
- Helicopters
- Airplane
- Space Shuttle

➢ **Military Applications:**

- ICBM, CM
- Drones (UAV)
- Torpedoes
- Jets

➢ **Maritime Systems:**

- Helicopter Platforms
- Naval Navigation
- Submarines

V. RESULTS AND DISCUSSIONS

Figure 7 shows the results of vehicle motion plotted in MATLAB. In which black color box is the defined restricted area for the vehicle and blue dotted line shows direction and distance travelled by the vehicle. When the vehicle moves beyond the black limiting square then buzzer gets on.

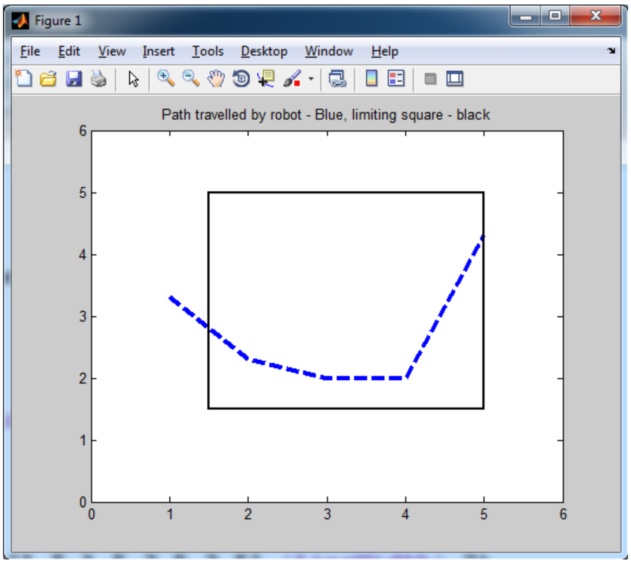

Figure.7. Results of vehicle motion

VI. CONCLUSION

The designed inertial navigation system is implemented on arduino microcontroller and this system is mounted on vehicle which keeps the track of the motion of the vehicle in order to avoid entry of vehicle into the restricted area. Vehicle direction is observed through MPU 6050 sensor and distance travelled is measured through IR sensor. The proposed systems continuously monitor the vehicle motion and gives good results and it is suitable for various types of applications. The system cost is low as compare to the other navigation systems.

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