Adwait Lele

Mick West, Whit Smith

Underwater Navigation and Communications

INS Sensors and Sensor Fusion for Autonomous Underwater Vehicle Navigation

1. Introduction

There are a few different ways of doing localization and navigation for Underwater Autonomous Vehicles (AUVs). This paper reviews the use of inertial navigation systems (INS) and their integration with other sensory inputs like GPS, by way of sensor fusion methods. The *overall state* of an AUV can include various states like the position, velocity, roll, pitch, yaw, etc. of the vehicle and these need to be frequently updated to so that the navigation is accurate [1]. Inertial navigation systems employ the use of accelerometers and gyroscopes to further propagate the current state of an AUV [2]. This paper also discusses the possible methods of updating these state values with input from other sensors.

2. Hardware Requirements

Separate Components

There are a couple different ways to integrate the hardware required for inertial navigation sensors with other sensors like GPS. One such way is having a separate gyroscope/accelerometer and GPS receiver connected to microcontroller that acts as central processing unit. The price of medium-tier commercial GPS receiver modules runs anywhere from around $40 - $75 [3]. These medium-tier modules can narrow down location to +/- 3m, while higher end modules that can resolve less than 1m or 1cm cost substantially more [3]. Gyroscopes and accelerometers are usually sold together as one IMU (Inertial Measurement Unit) and moderately priced modules are sold from around $10 to upwards of $150 [4]. The prices vary based on the precision of the IMU and the number of axes the gyro/accelerometer has.

Integrated Hardware

Another method is to have one piece of hardware that can take inertial measurements and GPS measurements, as well as process the measurements using sensor fusion algorithms itself. An example of such an option is an industrial level surface-mount device sold by VectorNav Technologies (VN-200), which costs $2100 [5]. With this device, an AUV doesn't need the microcontroller to perform state-estimation and so it can stand to be less powerful.

3. Commercial Applications

There are many commercial applications that use inertial navigation systems, specifically MEMS sensor technology. MEMS (Microelectromechanical Systems) inertial sensors are used in air-bag deployment systems in cars. MEMS inertial sensors are also used in devices like phones and Nintendo Wii remote controllers to determine changes in orientation, speed, and acceleration [6].

There are also IMUs developed for industrial applications. Seiko Epson Corporation has developed a very small IMU that includes a QMEMS (combination of quartz and MEMS) device, gyroscopes, and accelerometers [7]. It has applications in medicine for body motion sensing and can be used in industrial machinery controls. It also has applications in determining altitude or depth of unmanned systems, which is useful for AUVs [8].

4. Sensor Fusion

To use input from inertial navigation systems sensors, there must be software to combine it with GPS and other sensory input that an AUV may receive. Sensor fusion is the process by which information from multiple sensors is combined and in the case of AUVs, is used to accurately determine position of the AUV and a mapping the surroundings. Sensor fusion of GPS and INS can be achieved using many techniques, but using Kalman Filters is by far the most prevalent. The Kalman Filtering algorithm is a state estimator that that uses the dynamic characteristics of a system and Bayesian probability theory to approximate states of an object, like position and velocity [9].

For instance, to combine GPS and INS data for distance state estimation, first both INS and GPS must make a distance measurement (or compute distance using accelerometer and gyroscopic angle readings) [9]. Then the results can be put together in a Kalman Filter to estimate the actual distance state of the AUV. For this method, the distribution of the measurements is assumed to be Gaussian and the variances need to be input. Subsequent measurements can be taken and be used to find the next state of the AUV or the surroundings (which are also dynamic).

5. Conclusion

Ultimately, it can be seen that INS sensors can be integrated with other sensors, like GPS, to accurately determine the physical states of system such as an AUV. INS can make measurements that can be combined using Kalman Filtering techniques with other sensory information of a similar type to estimate the location of an AUV and map its surroundings. Inertial sensor IMUs are already used for many commercial applications and can be reliably used for AUV navigation as well.

References

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