A PROTOTYPE IMPLEMENTATION OF IMU BASED POSITIONING SYSTEM FOR HAND-HELD DETECTORS

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Abstract

Location-dependent data collection is crucial for some subsurface imaging detectors. The positioning information in question can be obtained based on image processing, Radio Frequency (RF), and Inertial Measurement Unit (IMU). In this study, IMU-based positioning system for Ground Penetrating Radar (GPR) sensor has been studied. Ultimate aim is to use this system for GPR based mine detectors. In order to obtain ground truth for acceleration values, IMU module was placed on a four-wheel mechanism and the acceleration data was obtained and registered by using the data coming from embedded encoders. In the next stage location calculation was carried out by using Kalman filter and then we made a comparison between ground truth data and Kalman filter estimation.

Project Description

The IMU plays a single role in many countries. For example, autonomous vehicles, drones, and robots use IMUs to determine their location. IMUs are also available for people where it is difficult or impossible to receive a GPS signal, for example in confined spaces or in cities. IMU programs are one of a number of factors, including:

- Easy to install and use: IMUs are smaller, lighter and easier to install and use than GPS devices.
- Low cost: IMUs cost more than GPS devices.
- Versatility: IMUs, unlike GPS, can be used indoors or for those living in cities.

METHODS

1. Test Setup:
   - Robotic system with four wheels, L298N motor driver, MPU6050 IMU sensor, and two Arduinos (Nano and Uno).
2. Data Collection:
   - IMU sensor recorded acceleration data.
   - Embedded encoders provided ground truth.
3. Kalman Filter:
   - Estimated position from IMU data, considering noise covariance.
   - Compared estimates with ground truth.
4. Evaluation:
   - Achieved acceleration estimate of 40$m/s^2 \pm$0.25 over 1 meter.

DESIGN PROCESS

1. Define Objectives:
   - Real-time position tracking
   - Low power consumption
   - Compact and lightweight
2. Research:
   - Types of IMUs (accelerometers, gyroscopes, magnetometers)
   - Positioning algorithms (dead reckoning, Kalman filtering)
   - Error sources and mitigation
3. System Specifications:
   - Hardware: MPU6050 6 Axis Acceleration and Gyro Sensor, microcontroller (Arduino), power supply
   - Software: Sensor fusion, position estimation, error correction
4. Component Selection:
   - IMU: MPU6050
   - Microcontroller: Arduino Nano
   - Power Supply: Rechargeable battery
5. Hardware Design:
   - Create schematics and pin layouts
6. Software Development:
   - Firmware for IMU data acquisition
   - Sensor fusion with Kalman filter
   - Position estimation algorithms
7. Integration and Testing:
   - Integrate hardware components
   - Ensure the system meets real-time performance requirements for navigation or control tasks

System Design

This diagram illustrates the hardware setup for the IMU-based positioning system. The key components include:

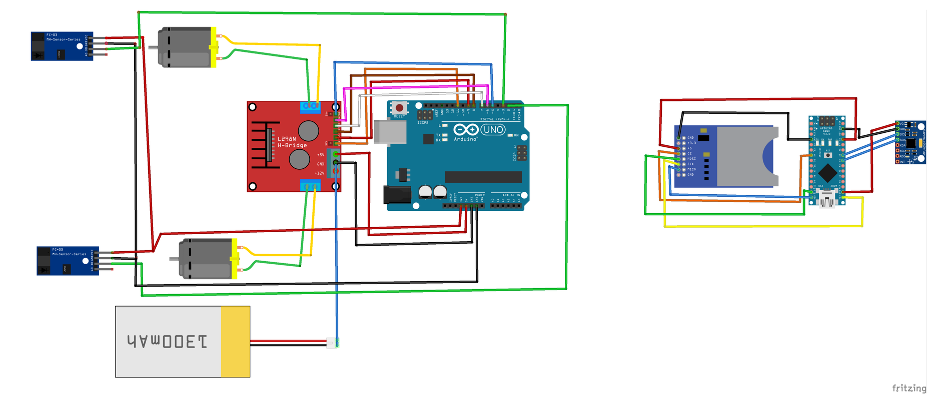

Figure 1. System Design of the Car

The system integrates these components to achieve real-time position tracking, with the Kalman filter processing IMU data for accurate positioning.

Kalman Filter

The Kalman filter presents numerous advantages in estimation and control contexts. By effectively merging noisy sensor data with a predictive model, it offers precise assessments of a system's state.

```
Step 1
Estimated position: 0.0872261904761905
Estimated velocity: 0.7023809523809524
Measured acceleration: 0.67
Filtered acceleration: 0.7023809523809524

Step 2
Estimated position: 0.14659960159362553
Estimated velocity: 0.6727091633466136
Measured acceleration: 0.67
Filtered acceleration: 0.6727091633466136

Step 3
Estimated position: 0.2037598629220997
Estimated velocity: 0.6702273487128051
Measured acceleration: 0.67
Filtered acceleration: 0.6702273487128051

Step 4
Estimated position: 0.2608706545832048
Estimated velocity: 0.6883406750652338
Measured acceleration: 0.69
Filtered acceleration: 0.6883406750652338

Step 5
Estimated position: 0.3194628014768037
Estimated velocity: 0.6990215469236003
Measured acceleration: 0.7
Filtered acceleration: 0.6990215469236003

Step 6
Estimated position: 0.37867261154476267
Estimated velocity: 0.6724354945125951
Measured acceleration: 0.67
Filtered acceleration: 0.6724354945125951

Step 7
Estimated position: 0.4358122556330782
Estimated velocity: 0.6702043872277567
Measured acceleration: 0.67
Filtered acceleration: 0.6702043872277567
```

Figure 2. The output of the Kalman Filter

Prototype Car

During the realization phase of this project, acceleration data was obtained from the car and ground truth was provided in the test results conducted in one dimension.

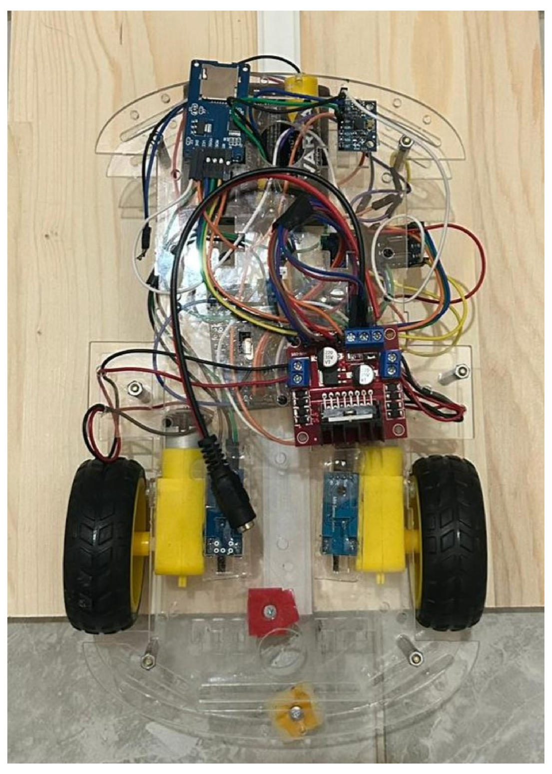

Figure 3. The car which makes the ground truth and obtained the acceleration

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