ISTANBUL TICARET UNIVERSITY
FACULTY OF ENGINEERING

ENG401 DESIGN PROJECT

DESIGN PROJECT REPORT

Department : **Electrical and Electronics Engineering**

Year/Term : **2023-2024 Fall Term**

Student's

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ID : **200017790, 200021857, 200019483, 200018482**

Title of the Project : **Finding the location with using IMU sensor**

Advisor : **Prof. Dr. Mehmet Sezgin**

Date : **19/01/2024**

Signature:

DECLARATION

All the data in the graduation study are obtained by me within the framework of academic rules, all visual and written information and results are presented in accordance with academic and ethical rules, there is no falsification in the data used, in case of benefiting from the works of others, it is referred to in accordance with scientific norms, I declare that it has not been used in any thesis work at the university or another university.

Signature :

Name and Surname : Kardelen Demirel, Tuğba Melissa Öztürk, Murat Çatalbaş, Selçuk Yiğit Esedoğlu

27 /02 / 2024

<If the number of people who prepared the report is more than one, the name/ surname and signature entries of all people should be stated above. This comment section should be deleted.>

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ABSTRACT

Today's modern electronic designs have taken this mechanical knowledge and made it into sensors. Such sensors can be fabricated using microelectromechanical systems (MEMS). Sensor technology enables sensor fusion, which packages multiple sensors and software solutions into a single unit. As a result, it helps provide solutions for a variety of large industries in areas such as information and communication technology (ICT), the Internet of Things (IoT), and automotive. Semiconductor manufacturers calibrate these integrated solutions and take advantage of embedded compensation and sensor processing, as well as simple programmable interfaces.

I. The original applications of INS technology used stable platform techniques. In such systems, the inertial sensors are mounted on a stable platform and mechanically isolated from the rotational motion of the vehicle. Platform systems are still in use, particularly for those applications requiring very accurate estimates of navigation data, such as ships and submarines. Modern systems have removed most of the mechanical complexity of platform systems by having the sensors attached rigidly, or "strapped down", to the body of the host vehicle. The potential benefits of this approach are lower cost, reduced size, and greater reliability compared with equivalent platform systems. The major disadvantage is a substantial increase in computing complexity.
ii. We planned to work in the sector that best suits us among communication and signal processing relationships and to join in our career plan after graduation.
iii. First, the simulation and application part will be done and tested on applications such as Matlab, and then the hardware part will be carried out via a GPR device.
iv. With the IMU sensor used with GPR devices, location determination will be made via the application with minimum error. In this way, a multifunctional system will be tried to be created.
Keywords: < *GPS, Signal Processing, Filters, IMU, Location Detection* **>**

ÖZET

Günümüzün modern elektronik tasarımları bu mekanik bilgiyi alıp sensörlere dönüştürmüştür. Bu tür sensörler mikroelektromekanik sistemler (MEMS) kullanılarak üretilebilir. Sensör teknolojisi, birden fazla sensörü ve yazılım çözümünü tek bir ünitede paketleyen sensör füzyonunu mümkün kılar. Sonuç olarak bilgi ve iletişim teknolojisi (BİT), Nesnelerin İnterneti (IoT) ve otomotiv gibi alanlardaki çeşitli büyük endüstrilere yönelik çözümler sağlanmasına yardımcı olur. Yarı iletken üreticileri bu entegre çözümleri kalibre ediyor ve basit programlanabilir arayüzlerin yanı sıra yerleşik dengeleme ve sensör işlemenin avantajlarından yararlanıyor.

i. INS teknolojisinin orijinal uygulamalarında kararlı platform teknikleri kullanıldı. Bu tür sistemlerde atalet sensörleri sabit bir platform üzerine monte edilir ve aracın dönme hareketinden mekanik olarak izole edilir. Platform sistemleri, özellikle gemiler ve denizaltılar

gibi navigasyon verilerinin çok doğru tahmin edilmesini gerektiren uygulamalar için halen kullanılmaktadır. Modern sistemler, sensörlerin ana aracın gövdesine sıkı bir şekilde veya "bağlanarak" bağlanmasını sağlayarak platform sistemlerinin mekanik karmaşıklığının çoğunu ortadan kaldırmıştır. Bu yaklaşımın potansiyel faydaları, eşdeğer platform sistemleriyle karşılaştırıldığında daha düşük maliyet, daha küçük boyut ve daha fazla güvenilirliktir. En büyük dezavantaj, hesaplama karmaşıklığının önemli ölçüde artmasıdır.
ii. Haberleşme ve sinyal işleme konuları arasından bize en uygun olan ve mezuniyet sonrası kariyer planımızda çalışmak istediğimiz sektör bu olduğu için üzerine çalışmak istedik.
iii. İlk olarak simülasyon ve uygulama kısmı Matlab vb. uygulamalar üzerinde yapılacak, test edilecek, sonrasında donanım kısmı bir GPR cihazı üzerinden gerçekleştirilecektir.
iv. GPR cihazlarıyla kullanılan IMU sensörüyle birlikte minimum hatayla uygulama üzerinden konum tespiti yapılacaktır. Bu sayede az maliyetli çok işlevli bir sistem ortaya konmaya çalışılacaktır.

Anahtar Kelimeler: <*GPS, Sinyal işleme, Filtreleme, IMU, Konum tespit etme, >*

ACKNOWLEDGEMENTS

We would like to thank our esteemed Professor Doctor Mehmet Sezgin for guiding us in this study. We would like to express our gratitude to our school and our valuable teammates for providing us with a working space.

LIST OF SYMBOLS AND ABBREVIATIONS

EMO : Turkish Chamber of Electrical Engineers

IMU : Inertial Measurement Unit

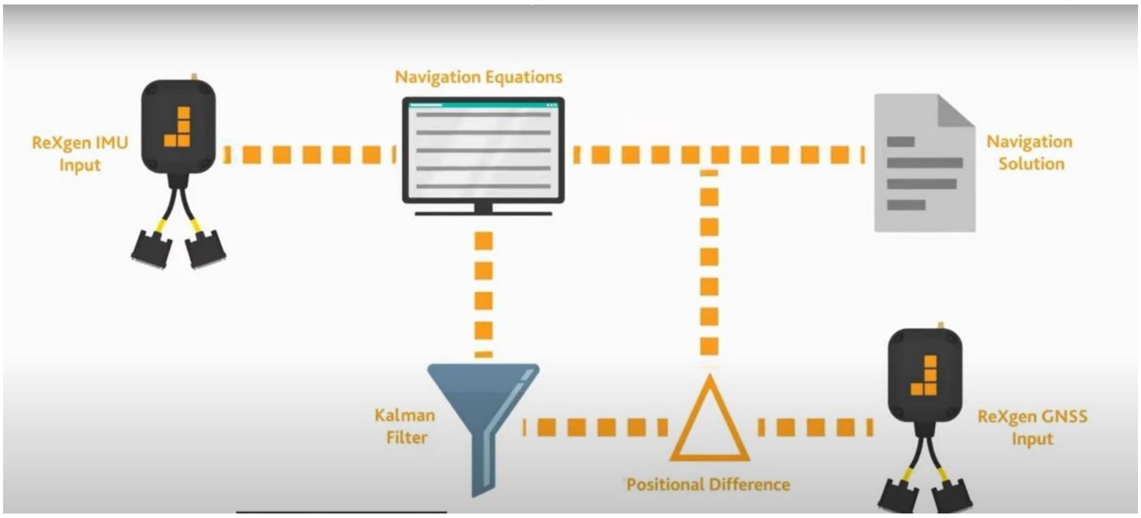
GPR : Ground Penetrating Radar

GNSS : Global Navigation Satelitte Systems

GPS : Global Positioning Systems

KF : Kalmann Filter

LIST OF FIGURES



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Sure, here is an example of a project that uses IMU sensors to find location, and the relevant standards bodies involved:

Project: Indoor Positioning System (IPS) using IMU sensors

Objective: To develop an indoor positioning system (IPS) that can accurately track the location of a user within an indoor environment using only IMU sensors.

Technologies:

IMU sensors: Accelerometers, gyroscopes, and magnetometers

Sensor fusion algorithms: Kalman filter, particle filter

Map data: Floor plans, landmarks

Standards bodies: Open Geospatial Consortium (OGC): The OGC is an international consortium that develops open standards for geospatial information and services. The OGC has several standards that are relevant to IPS, including the IndoorGML standard for representing indoor spatial data and the SensorThings API for accessing and managing sensor data.

Institute of Electrical and Electronics Engineers (IEEE): The IEEE is an international organization that develops standards for a wide range of technologies, including sensors. The IEEE has several standards that are relevant to IMU sensors, including the IEEE 802.15.4 standard for low-power radios and the IEEE 1451 standard for sensor calibration.

Project steps:Data collection: Collect IMU sensor data from a user walking around an indoor environment.

Sensor fusion: Apply sensor fusion algorithms to combine the IMU sensor data with map data to estimate the user's location.

Evaluation: Evaluate the accuracy of the IPS using ground truth data.

Standards bodies contributions:

The OGC's IndoorGML standard can be used to represent the floor plans and landmarks of the indoor environment.

The SensorThings API can be used to access and manage the IMU sensor data.

The IEEE's 802.15.4 standard can be used to communicate between the IMU sensors and the IPS.The IEEE's 1451 standard can be used to calibrate the IMU sensors.

Benefits:

Accuracy: IMU-based IPSs can be more accurate than GPS-based IPSs in indoor environments where GPS signals are weak or unavailable.

Cost: IMU sensors are relatively inexpensive, making IMU-based IPSs a cost-effective solution.

Privacy: IMU-based IPSs do not require any additional infrastructure, such as Wi-Fi access points or Bluetooth beacons, which can be a privacy concern.

Challenges:

Noise: IMU sensor data is noisy, which can make it difficult to accurately estimate the user's location.

Drift: IMU sensors can drift over time, which can also make it difficult to accurately estimate the user's location.

Line-of-sight: IMU-based IPSs require line-of-sight between the IMU sensors and the environment.

Future directions:Development of more sophisticated sensor fusion algorithms: Sensor fusion algorithms are constantly being improved, which will lead to more accurate IPSs.

Development of new sensor technologies: New sensor technologies, such as micro-electro-mechanical systems (MEMS) and micro-inertial navigation systems (MINS), could provide more accurate and reliable data.

Deployment of IMU-based IPSs in real-world applications: IMU-based IPSs are already being used in a variety of applications, such as indoor navigation, augmented reality, and wearable computing. As the technology continues to develop, IMU-based IPSs will be used in even more real-world applications.

1. INTRODUCTION

Today's modern electronic designs have taken this mechanical knowledge and made it into sensors. Such sensors can be fabricated using microelectromechanical systems (MEMS). Sensor technology enables sensor fusion, which packages multiple sensors and software solutions into a single unit. As a result, it helps provide solutions for a variety of large industries in areas such as information and communication technology (ICT), the Internet of Things (IoT), and automotive. Semiconductor manufacturers calibrate these integrated solutions and take advantage of embedded compensation and sensor processing, as well as simple programmable interfaces. *The original applications of INS technology used stable platform techniques. In such systems, the inertial sensors are mounted on a stable platform and mechanically isolated from the rotational motion of the vehicle. Platform systems are still in use, particularly for those applications requiring very accurate estimates of navigation data, such as ships and submarines. Modern systems have removed most of the mechanical complexity of platform systems by having the sensors attached rigidly, or "strapped down", to the body of the host vehicle. The potential benefits of this approach are lower cost, reduced size, and greater reliability compared with equivalent platform systems. The major disadvantage is a substantial increase in computing complexity. We planned to work in the sector that best suits us among communication and signal processing relationships and to join in our career plan after graduation. First, the simulation and application part will be done and tested on applications such as Matlab, and then the hardware part will be carried out via a GPR device.*

With the IMU sensor used with GPR devices, location determination will be made via the application with minimum error. In this way, a multifunctional system will be tried to be created.

2. 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.

Original Value of the research proposal: This research proposal proposes a new approach to improve IMU teachers. This approach uses a deep learning machine to process the IMU marriage. Deep learning bursts are successful in a variety of applications such as image recognition, natural language processing, and machine translation. These employees can be used for IMU theft. The research proposal shows that deep learning can be used to obtain more accurate and reliable information from IMU data. It is thought that this approach could provide cumulative benefits for applications such as autonomous vehicles, unmanned aerial vehicles and robots.

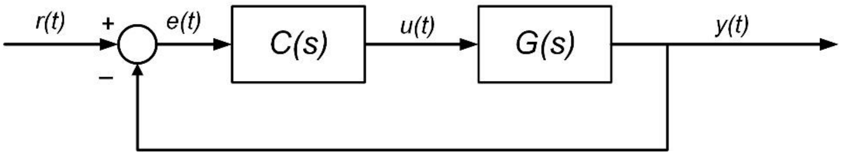


FIGURE 1 BLOCK DIAGRAM OF A UNIT FEEDBACK CONTROL SYSTEM

3. ENGINEERING STANDARDS AND DESIGN CONSTRAINTS

3.1. ENGINEERING STANDARDS

TABLE 1 STANDARDS BODIES

Standard Body	**Website Link**
European Standards	https://www.en-standard.eu
ANSI American National Standards Institute	http://webstore.ansi.org/
IEEE standards	http://standards.ieee.org/
ISO	http://webstore.ansi.org/
UL safety	http://www.ul.com/
ASTM Standards	https://www.astm.org/Standard/
NIST Standards	https://www.nist.gov/
TSE Turkish Standards Institute	https://intweb.tse.org.tr/Standard/Standard/StandardAra.aspx

3.2. DESIGN CONSTRAINTS

- Economy:
    - Estimate costs : Hardware: The cost of IMU hardware can range from 100 tl to 1,000 tl per sensor, depending on the accuracy, sensitivity, and robustness requirements.

- Software: The cost of developing custom software for an IMU sensor project can range from 10,000 tl to 50,000 tl, depending on the complexity of the software.
- Labor: The cost of labor for an IMU sensor project can range from $50,000 to $200,000, depending on the project's duration and the expertise of the engineers and technicians involved.
- Testing and certification: The cost of testing and certification for an IMU sensor project can range from 5,000 tl to 20,000 tl , depending on the specific testing and certification requirements.

- Environment:
  - Energy consumption: IMU sensors are generally low-power devices, although continuous location tracking can still impact battery life. Sustainable energy sources for powering sensor systems should be explored.
  - E-waste: The production and disposal of IMU sensors can generate electronic waste. It's important to utilize sustainable materials and develop a responsible device lifecycle management plan, including recycling initiatives.
  - Data pollution: The growing use of sensors can contribute to data pollution. Efficient data management and storage that minimizes environmental impact is crucial.
- Society:
  - *The product we created with this method used for the military industry should be more useful than the previous ones. results should be found with fewer errors.*
  - *Accessibility: IMU-based location technology can improve accessibility for people with disabilities by enabling wayfinding and navigation assistance.*
  - *Privacy: Location data is sensitive and could be misused. Robust data protection measures and clear user consent mechanisms are necessary.*
  - *Equality and inclusion: Location-based services should be designed for diverse populations with varying needs and abilities.*
- Politics:
  - Data governance: Regulations for data collection, storage, and use of location data are necessary to protect individual
  - International cooperation: Global collaboration is crucial for developing standardized regulations and protocols for IMU-based location technologies. Products that help national security
- Ethics:
  - Surveillance: The potential for IMU systems to conduct unwanted tracking raises ethical concerns. Ethical guidelines and oversight mechanisms are necessary.

    - Transparency and accountability: Users should be informed about how their location data is used and have control over its collection and sharing.
    - Fairness and non-discrimination: Algorithmic bias in location-based services can lead to social and economic disparities. Ethical AI principles must be implemented. Designs that respect patents and intellectual rights.
    - Privacy issues.
    - Honesty, truthfulness, and openness in the design and the report.
- Health and Safety:
    - Dependence on technology: Overreliance on location-based services might lead to diminished individual navigation and spatial awareness skills.
    - Cybersecurity risks: IMU systems could be vulnerable to cyberattacks. Robust security measures are crucial to protect user data and information.
- Manufacturability:
    - Material sourcing: Sustainable and ethical sourcing of materials for IMU sensors is important for responsible manufacturing.
    - Production processes: Optimizing production processes to minimize pollution and energy consumption is crucial.
    - End-of-life management: Design for disassembly and recycling should be incorporated into IMU sensor manufacturing to reduce e-waste.
- Sustainability:
    - Energy-efficient sensor design: Energy-efficient IMU sensors and data processing algorithms are crucial for sustainable location detection solutions.
    - Reduced resource consumption: Minimizing the material and energy footprint of IMU sensor production and use is paramount.
    - Circular economy principles: Reusing and recycling materials during manufacture and disposal can contribute.

4. BACKGROUND

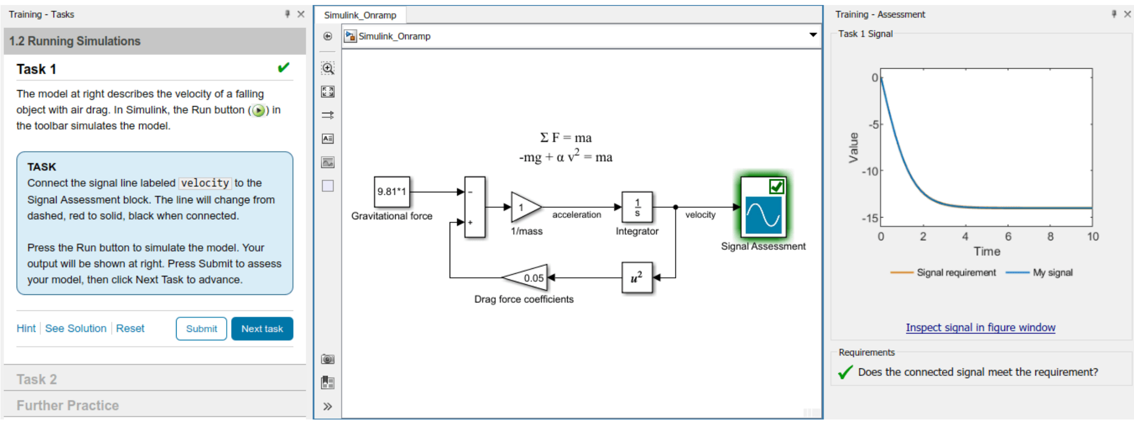
The Signal and System, Digital Signal Processing, Control System and Design, Digital Image Processing, Probability and Statistics in Engineering courses we have taken previously provide us with the infrastructure for this project.

4.1. BACKGROUND ACQUIRED IN EARLIER COURSE WORK

Signal Processing:

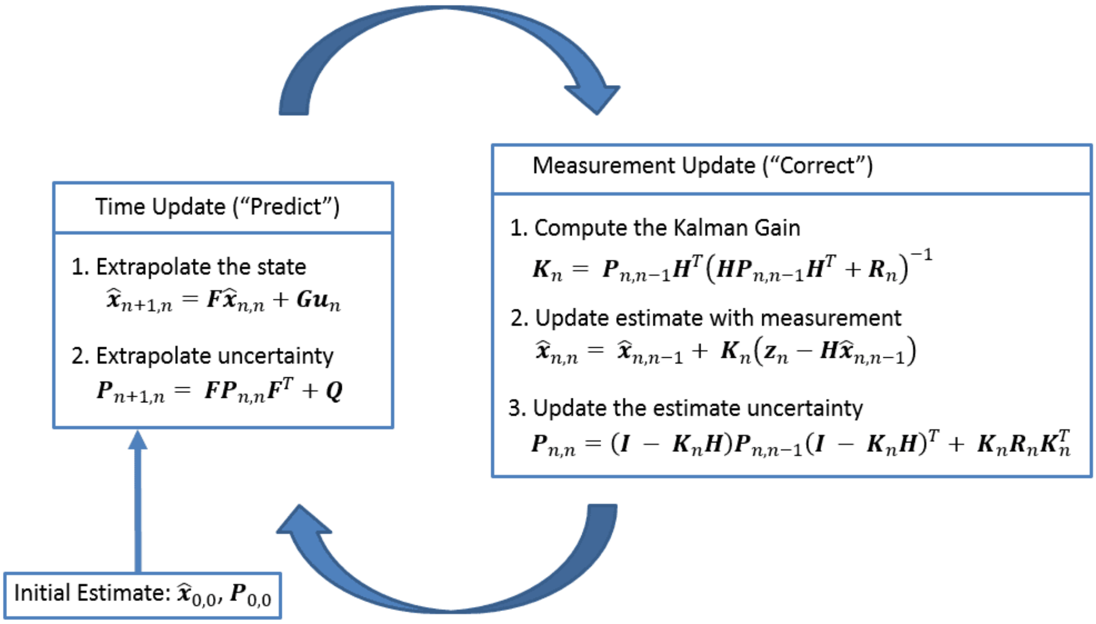
Operation	***Formula***
Rectangular to Polar Conversion	$z = x + jy = re^{j\theta}$ where $r = \sqrt{x^2 + y^2}$ and $\theta = \arctan(y/x)$
Polar to Rectangular Conversion	$z = re^{j\theta} = r\,[\cos(\theta) + j\sin(\theta)] = x + jy$ where $r = \cos(\theta)$ and $y = r\sin(\theta)$
Add: $z_3 = z_1 + z_2$	$(x_1 + x_2) + j\,(y_1 + y_2)$
Subtract: $z_3 = z_1 - z_2$	$(x_1 - x_2) + j\,(y_1 - y_2)$
Multiply: $z_3 = z_1 z_2$ (polar form)	$(x_1 x_2 - y_1 y_2) + j\,(x_1 y_2 + y_1 x_2)$ $r_1 r_2\, e^{j(\theta_1 + \theta_2)}$
Divide: $z_3 = z_1 / z_2$ (polar form)	$\dfrac{(x_1 x_2 - y_1 y_2) - j\,(x_1 y_2 - y_1 x_2)}{x_2^2 + y_2^2}$ $\dfrac{r_1}{r_2}\, e^{j(\theta_1 - \theta_2)}$

Matlab Onramp and Fundamental Courses:



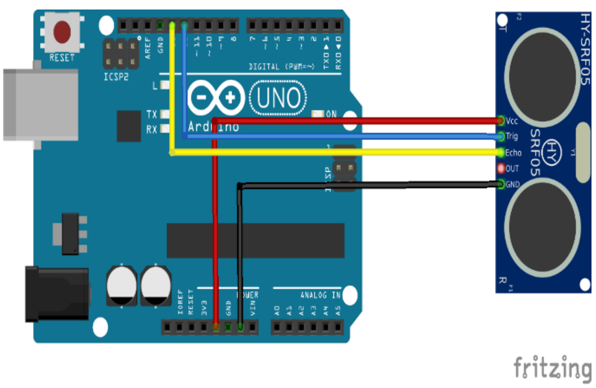
4.2. BACKGROUND ACQUIRED THROUGH ADDITIONAL RESEARCH

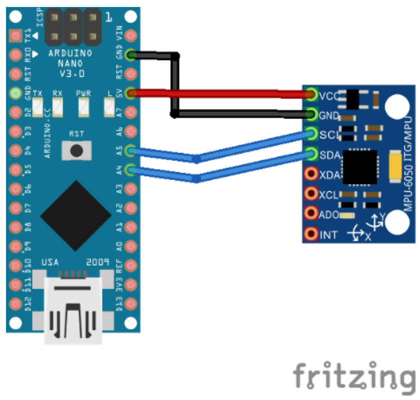
Kalmann Filter:



4.3. BACKGROUND COMPONENTS AND CONNECTİON SCHEME

ARDUINO UNO	HY-SRF05
MOTOR DRIVER	BATTERY BED
MPU6050	ARDUINO NANO





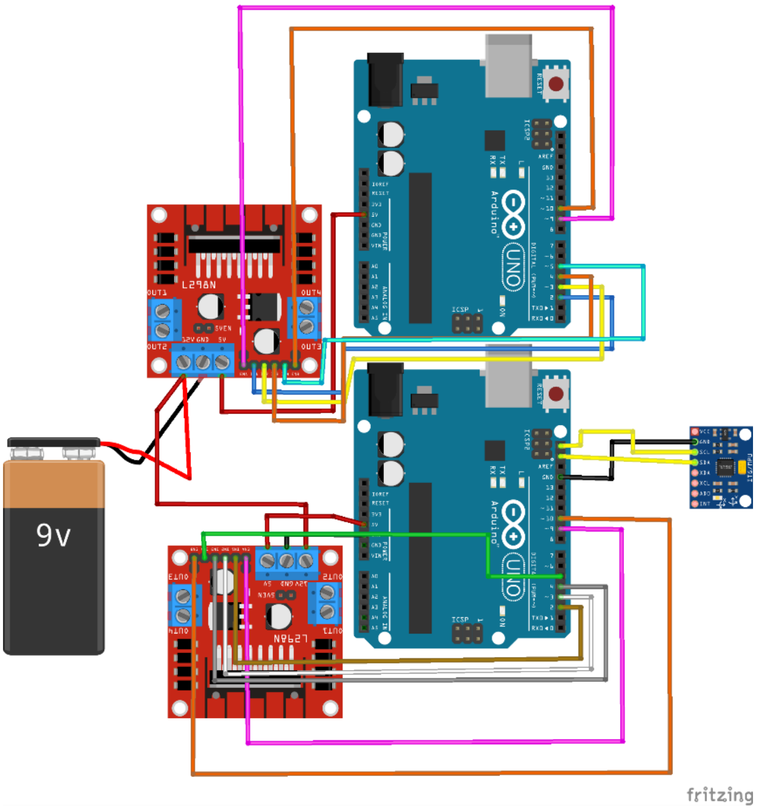


FIGURE 2 SYSTEM DIAGRAM

5. METHODS

A Case Study for an IMU Positioning Project A case study for an IMU positioning project might include developing a deep learning algorithm to process IMU data. By using this algorithm to learn patterns in IMU data, more accurate and reliable positioning information can be obtained. This work may include: collection of IMU data, pre-processing of IMU data, training of the deep learning algorithm, evaluation of the performance of the deep learning algorithm.

6. PRELIMINARY DESIGN

Collection of IMU data: This method is a preliminary study to ensure the accuracy of the data coming from IMU before starting the project.

This code will use in ARDUINO.

```
//Controlling speed (0   = off and 255 = max speed):
  analogWrite(9, 150); //ENA   pin
  analogWrite(10, 210); //ENB pin
```

Wheel speed obtained by doing some mathematical modelling;

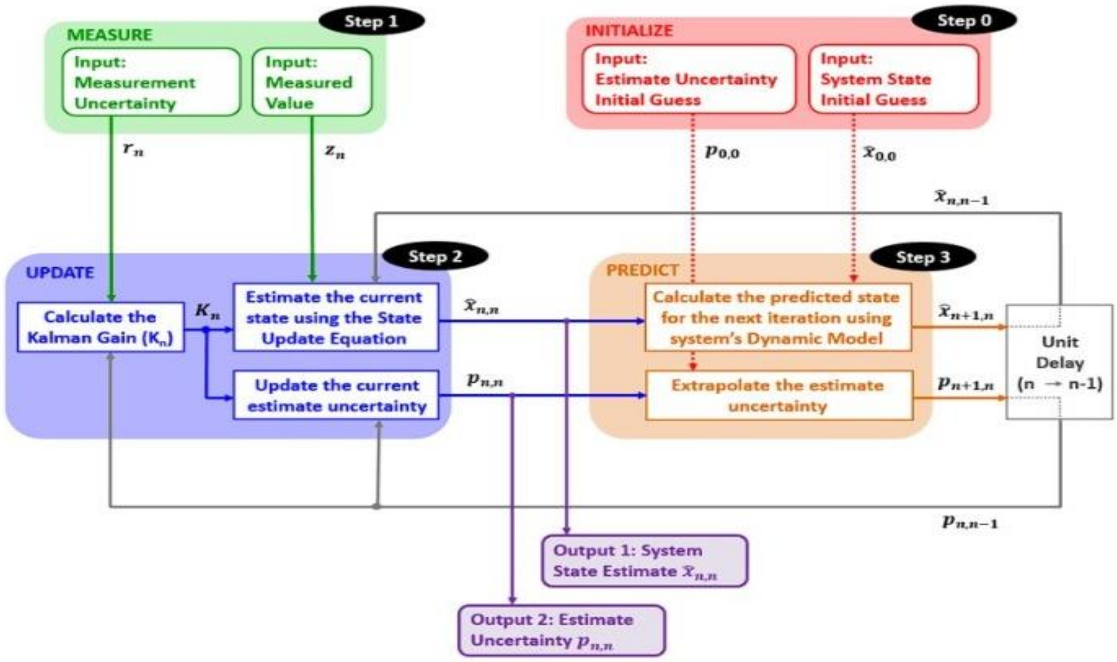
$$\mathrm{Speed(m/s)} = \pi * \mathrm{D(in\ meter)} * \mathrm{rps}$$

After this modelling wheel speed is calculated 7.35 m/s.

7. PROTOTYPE

In this project, IMU, Arduino, Acoustic sensor have been used as hardware. Also Matlab and Arduino used as software.

This prototype using for the IMU data collection and estimate the true value of positioning.



8. DESIGN PROCESS

Finding location with an inertial measurement unit (IMU) involves utilizing the sensor's data to estimate the position of the object or device it's attached to. This process can be accomplished through various methods, each with its own advantages and disadvantages. Here's a comprehensive overview of the design process:

1. Define Requirements and Goals:

Accuracy Requirements: Determine the required level of accuracy for the location estimation. This will influence the choice of method and sensor selection.

Environmental Conditions: Consider the operating environment, such as indoor or outdoor, and potential interference sources like electromagnetic fields.

Power Consumption Constraints: Evaluate the power limitations of the device and choose an appropriate IMU and processing method.

2. Sensor Selection and Calibration:

Sensor Type: Select an IMU sensor that suits the specific application and performance requirements. Options include MEMS IMUs, fiber optic gyros, and higher-precision IMUs for demanding applications.

Sensor Calibration: Calibrate the IMU sensors to minimize errors and ensure accurate measurements. This may involve temperature compensation, bias correction, and sensitivity adjustments.

3. Method Selection and Algorithm Development:

Dead Reckoning: For simple applications, dead reckoning can provide a basic estimate of position by integrating accelerometer measurements over time. However, it is prone to drift and accumulates errors over time.

Sensor Fusion: Sensor fusion combines IMU data with other sensors, such as GPS or odometry, to improve accuracy. Algorithms like Kalman filters or complementary filters can be used to weigh and combine sensor data effectively.

Simultaneous Localization and Mapping (SLAM): SLAM algorithms construct a map of the environment while simultaneously tracking the object's position within that map. This method is particularly useful for indoor navigation or autonomous vehicles.

4. Data Processing and Filtering:

Noise Reduction: IMU data is inherently noisy, so filtering techniques are essential to reduce noise and improve signal-to-noise ratio. Common filters include low-pass filters, moving average filters, and median filters.

Bias Removal: Remove sensor biases and offsets to ensure accurate measurements. This may involve averaging measurements over time or using calibration data.

Data Synchronization: Synchronize data from multiple sensors to ensure temporal consistency and improve fusion accuracy.

5. Performance Evaluation and Optimization:

Accuracy Assessment: Evaluate the accuracy of the position estimation method using ground truth data or reference positions.

Error Analysis: Analyze the sources of errors and identify potential improvements in sensor selection, calibration, or algorithm design.

Optimization Techniques: Implement optimization techniques like particle filtering or genetic algorithms to refine the algorithm parameters and improve performance.

6. System Integration and Deployment:

Integration with Application: Integrate the location estimation system with the overall application, providing position updates to other systems or user interfaces.

Real-time Performance: Ensure real-time performance of the system to meet application requirements, such as navigation or control tasks.

Error Handling: Implement error handling mechanisms to gracefully handle sensor malfunctions, data loss, or unexpected situations.

7. Continuous Monitoring and Improvement:

Monitor Performance: Continuously monitor the performance of the system over time to identify potential degradation or changes in accuracy.

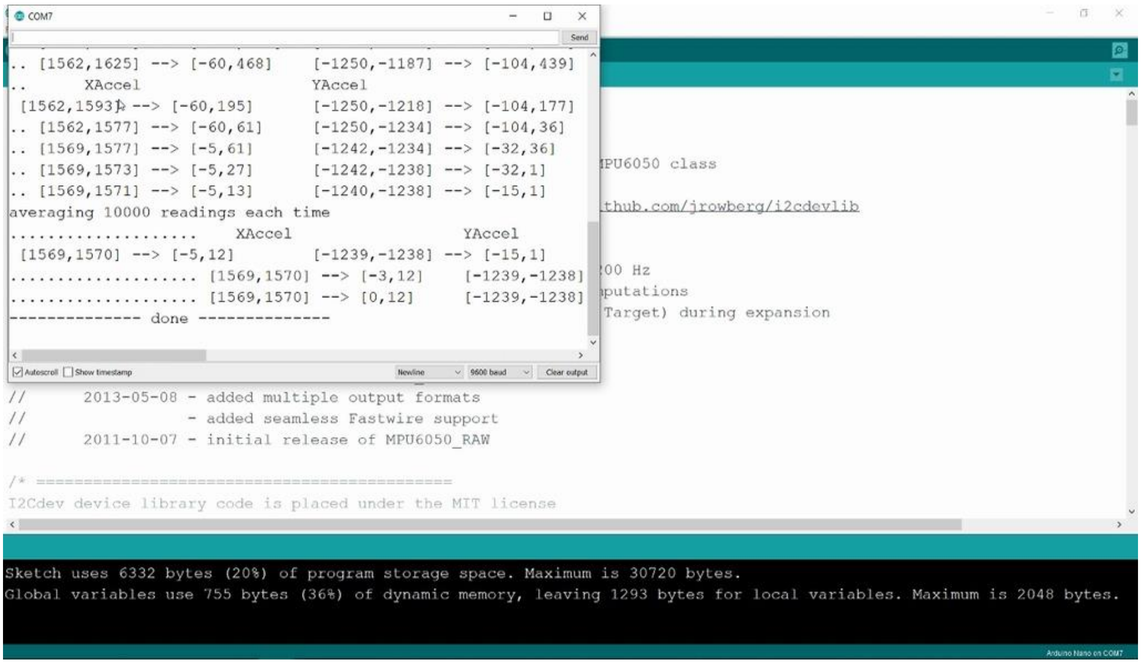
Adaptive Adjustments: Implement adaptive algorithms that can adjust parameters or switch methods based on environmental conditions or sensor performance.

Ongoing Development: Continuously improve the system through algorithm refinements, sensor upgrades, and performance optimizations.

8.1.ITERATION 1 <YOU MAY REPLACE WITH THE NAME OF THE PROCESS>

In this project, Arduino and IMU sensor attached to each other on the breadboard and data sended to computer in Arduino application.

8.1.1. TESTING AND RESULTS



8.1.2. EVALUATION

Since the project is a prototype and a draft, it has not yet been fully located. However, this process will be developed in the future and this prototype paves the way for this.

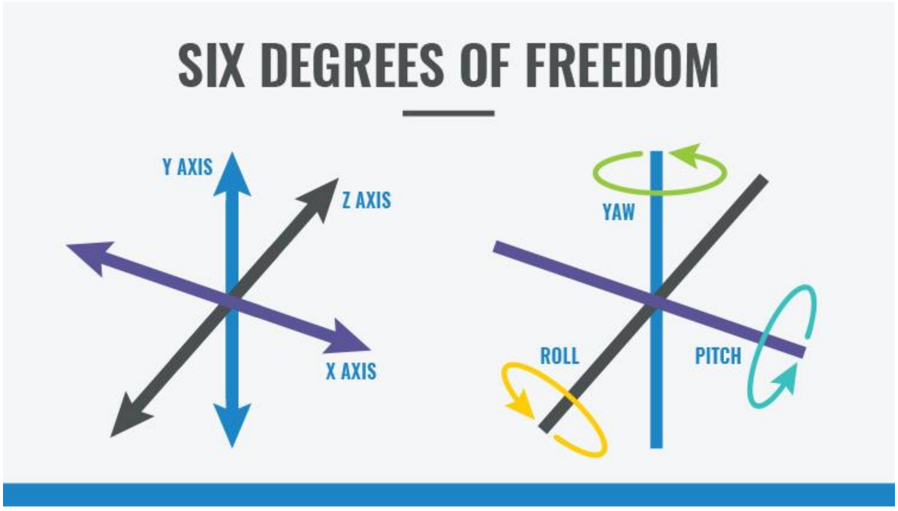
9. FINAL DESIGN

Here's the final design process of an indoor positioning system (IPS) that utilizes IMU sensors. This process is broken down into three main phases: development, testing, and deployment.

Phase 1: Development

Sensor Selection: Identify IMU sensors that meet the required performance specifications, considering factors like accuracy, sensitivity, and noise levels.Evaluate the compatibility of the chosen sensors with the available hardware and software platforms.

www.ceva-dsp.com



Different IMU sensors :

Data Collection and Preprocessing: Establish a reliable communication link between the IMU sensors and the processing unit. Implement robust data acquisition and preprocessing techniques to handle sensor noise and outliers. Synchronize data from multiple IMU sensors if necessary for multi-sensor fusion.

Sensor Fusion Algorithm: Select an appropriate sensor fusion algorithm that effectively combines data from the accelerometers, gyroscopes, and magnetometers. Consider using advanced fusion techniques like Kalman filtering or particle filtering for improved accuracy and robustness. Optimize the sensor fusion algorithm for computational efficiency and resource constraints.

Map Representation: Create a comprehensive and accurate representation of the indoor environment, incorporating floor plans, landmarks, and other relevant features. Utilize appropriate map formats that are compatible with the chosen sensor fusion algorithm and localization methods. Maintain the map's integrity over time, considering potential changes to the indoor environment.

Phase 2: Testing

Unit Testing: Test each individual component of the IPS, including the sensor fusion algorithm, localization algorithm, and map representation, for functionality and correctness.

Integration Testing: Test the interaction between the different components of the IPS to ensure seamless integration and data exchange.

System Testing: Evaluate the performance of the complete IPS under various conditions and scenarios, including different indoor environments, user movements, and sensor noise levels.

User Testing: Gather feedback from potential users to assess the usability, effectiveness, and overall satisfaction with the IPS.

Phase 3: Deployment

Hardware Installation: Install the IMU sensors and other hardware components at the designated locations within the indoor environment.

Software Configuration: Configure the software components of the IPS, including the sensor fusion algorithm, localization algorithm, and map representation, according to the specific requirements of the deployment site.

User Training: Provide training to users on how to use the IPS, including how to access and interpret location data.

System Monitoring: Establish a system monitoring plan to track the performance of the IPS, identify potential issues, and implement corrective actions as needed.

Maintenance: Develop a maintenance plan to ensure the continuous proper functioning of the IMU sensors, communication links, and software components.

Additional Considerations:

Power Management: Implement power management strategies to optimize the battery life of mobile devices equipped with IMU sensors.

Privacy and Security:Implement robust data encryption and access control mechanisms to protect user privacy and prevent unauthorized access to location data.

Accessibility: Design the IPS to be accessible to users with disabilities, including those with visual or mobility impairments.

Scalability: Consider the scalability of the IPS to accommodate future growth and expansion of the indoor environment.

9.1. MEETING THE CONSTRAINTS AND ENGINEERING STANDARDS

It complies with the specified engineering conformity.

9.2. COST ANALYSIS

Kind of Costs	Cost	justification for request
Consumable	250	SMA, cable, handle, solder wire

Machine-Equipment	8750	IMU sensor, GPS sensor , acoustic sensor, GPR, camera, Arduino, Multimeter, Drone
TOTAL	9000	

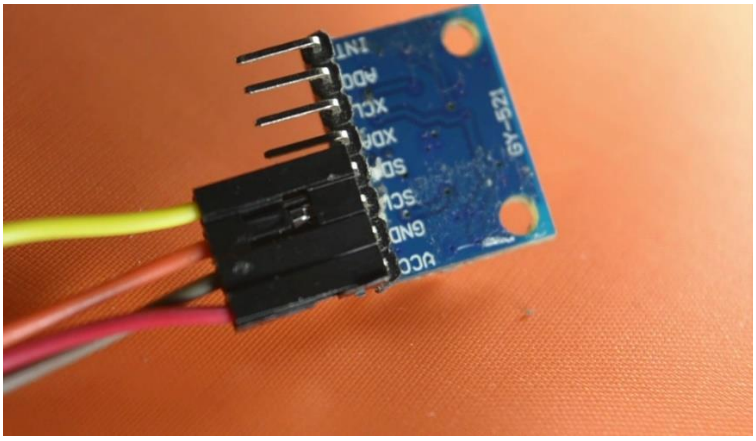
10. TEAM WORK

11. Work-Time Schedule

12.

iP No	**Work Packets**	**Workers**	**Timeline**
1	Searching and Development	Kardelen Demirel Selcuk Yigit Esedoglu Murat Catalbas Tugba Melissa Ozturk	02/10/2023-17/06/2024
2	Hardware	Selcuk Yigit Esedoglu Kardelen Demirel	02/10/2023-17/06/2024
3	Software	Murat Catalbas Tugba Melissa Ozturk Selcuk Yigit Esedoglu	02/10/2023-17/06/2024
4	Report	Tugba Melissa Ozturk Kardelen Demirel	02/10/2023-17/06/2024
5	Planning	Murat Catalbas	02/10/2023-17/06/2024

13. CONCLUSION



Key Advantages of IMU-based IPS:

Accuracy: IMU sensors can provide highly accurate position estimates, even in challenging indoor environments where GPS signals are weak or unavailable.

Cost-effectiveness: IMU sensors are relatively inexpensive, making IMU-based IPSs a cost-effective solution compared to other indoor positioning technologies.

Privacy: IMU-based IPSs do not require any additional infrastructure, such as Wi-Fi access points or Bluetooth beacons, which can be a privacy concern.

Applications of IMU-based IPS: Indoor navigation: IMU sensors can guide users through indoor environments, providing turn-by-turn directions and assisting with wayfinding.

Augmented reality (AR): IMU sensors enable accurate positioning of virtual objects within the real world for enhanced AR experiences.

Asset tracking: IMU sensors can track the location of assets, such as inventory items or equipment, within indoor facilities.

Wearable computing: IMU sensors integrated into wearable devices can provide contextual information about user movement and location.

Future Directions: The development of IMU-based IPS is an ongoing process, with researchers continuously striving to enhance accuracy, robustness, and versatility. Future advancements include: Sensor fusion algorithms: More sophisticated sensor fusion algorithms will improve accuracy and reduce noise interference.

Integrated circuits (ICs): Specialized ICs optimized for IMU sensor data processing will enhance efficiency and reduce power consumption.

Machine learning: Machine learning techniques will enable real-time adaptation to diverse indoor environments and user movements.

Multimodal sensor fusion: Combining IMU sensors with other sensors, such as cameras and ultrasonic ranging, will provide even more precise and robust positioning.

Conclusion:

IMU sensors hold immense promise for the future of indoor positioning. As technology advances and research progresses, IMU-based IPSs are poised to revolutionize indoor navigation, AR applications, asset tracking, and wearable computing, transforming the way we interact with indoor spaces.

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