22AIE214 Introduction to AI Robotics

22MAT230 Mathematics for Computing 4

AUTOMATIC FORKLIFT PROTOTYPE

Group - **C06**

Varshitha Thilak Kumar-CB.SC.U4AIE23258

Siri Sanjana S-CB.SC.U4AIE23249

Shreya Arun-CB.SC.U4AIE23253

Anagha Menon-CB.SC.U4AIE23212

INTRODUCTION

- Definition: A forklift is an industrial vehicle designed to lift and move heavy materials over short distances.
- Components: Equipped with a set of forks or prongs for lifting and transporting goods.
- Navigation: Operated by a driver, using forks to lift and move materials.

INTRODUCTION

- Warehouses: Load/unload goods and organize stock.
- Construction Sites: Transport heavy building materials.
- Manufacturing: Move raw materials, components, and finished goods.

- Increased Demand: Growing need for unmanned forklifts that can be operated remotely.
- Benefits of Unmanned Forklifts:
- Eliminate the need for training highly qualified operators.
- Reduce accident rates due to driver fatigue.

PROBLEM STATEMENT

- Traditional forklifts lack real-time load balancing and automation.
- Instability increases the risk of tipping and inefficiency.
- Limited obstacle detection leads to safety hazards.
- This project integrates load balancing, LIDAR collision avoidance, and omnidirectional movement.
- Enhances safety, stability, and efficiency in industrial environments.

OBJECTIVE

- Solution: Design of a semi-automated, eco-friendly forklift suitable for small warehouses.
- Enhance industrial safety and efficiency in material handling.Provide automated load balancing to prevent tipping.
- Improve navigation and collision avoidance using LIDAR
- Implement real-time data processing to ensure stability
- Operated using a smartphone application.
- Designed to lift a maximum load of 300 grams.

YEAR	AUTHORS	TITLE	REMARKS
2021	FB Setiawan,PM Siva, LH Pratomo	**Design and implementation of smart forklift for automatic guided vehicle using raspberry pi 4**	Automatic Guided Vehicle (AGV) pallet trucks, combining AGV technology with forklift mechanisms, are widely used in Industry 4.0 for automated lifting and transporting tasks.
2024	Abuzied, H., Nazih, N., and Sahbel, A.	**Design and simulation of eco-friendly smartphone controlled forklift**	The eco-friendly forklift is a cost-effective, energy-efficient solution for small warehouses, featuring remote operation and sustainable design.
2024	Faris, F., Sulistiyowati, I., Falah, A.H., and Ahfas, A.	**System Control of Prototype Forklift Using Android and ESP32 Based on MQTT Communication**	This research develops an IoT-based forklift robot using ESP32 and MQTT, enabling remote control, efficient warehouse operations, and stable performance across various devices and network conditions, with a load capacity of up to 300 grams

YEAR	AUTHORS	TITLE	REMARKS
2015	Liang Xue, Chengyu Jiang	**Noise Reduction of MEMS Gyroscope Based on Direct Modeling for an Angular Rate Signal**	In this paper, a novel approach for processing the outputs signal of the microelectromechanical systems (MEMS) gyroscopes was presented to reduce the bias drift and noise
2018	Chihiro Ito, Xin Cao, Masaki Shuzo,	**Application of CNN for Human Activity Recognition with FFT Spectrogram of Acceleration and Gyro Sensors**	FFT spectrograms of acceleration and gyro sensor data as input to a CNN for human activity recognition, and improving recognition rates by synthesizing and combining spectrogram images from multiple sensor axes
2017	Ling Wang, Wei Zhang, Zeng-ping Zhang & Yuan-an Liu	**Spinning frequency estimation algorithm of MEMS gyro's output signal based on FFT coefficient**	This paper proposed a frequency estimation algorithm based on FFT coefficients (real and imaginary parts) for demodulating the spinning frequency of MEMS gyro signals, which significantly improves precision and reduces computational complexity compared to traditional spectrum detection methods.

YEAR	AUTHORS	TITLE	REMARKS
2022	Qingmeng Li1, Haixia Wang1, Huibin Liang	**Research on Dynamic Trajectory Planning Algorithm for Safe Obstacle Avoidance of Automatic Forklift**	The kinematic and dynamic models of the vehicle are derived. Then a trajectory planner based on model predictive control (MPC) is designed to make the forklift plan the driving trajectory reasonably and legally in the face of obstacles.
2022	Bin Wu, Xiaonan Chi, Congcong Zhao	**Dynamic Path Planning for Forklift AGV Based on Smoothing A* and Improved DWA Hybrid Algorithm**	The improved A* and DWA algorithm ensure the global optimal path more suitable for FAGV and the local path closer to the global path.
2021	Gang Liu,Rongxu Zhang, Yanyan Wang	**Road Scene Recognition of Forklift AGV Equipment Based on Deep Learning**	The results show that the performance of the H-Swish activation function is better than that of the ReLU function in recognition accuracy and computational complexity, and it can save costs as a calculation form of the mobile terminal.

Existing Systems:

1.Traditional Forklifts rely on manual control

2.No Real-time load balancing mechanisms.

3.Limited automation for obstacle detection

Innovation in our Project

1.Dynamic load balancing using signal-based gyroscopic analysis.

2.Omnidirectional movement with Meccanum wheels mechanisms.

3. Pulley Lifting Mechanism about more weight of 300 grams

CHALLENGES in traditional AGV

1. **Manual Load Balancing:** Most of the Traditional forklifts require skilled operators to maintain stability.
2. **Lack of Real Time Safety Adjustments:** No automated mechanism to prevent tipping.
3. **Limited Collision Avoidance:** Most forklifts rely on operator judgment for obstacle detection.
4. **Restricted Mobility:** Traditional forklifts lack omnidirectional movement.
5. **High Energy Consumption:** Inefficient power usage results in shorter operational hours.

CHALLENGES ADDRESSING

1. **Automated Load Balancing:** Real-time signal-based weight distribution ensures stability
2. **Advanced Collision Detection:** LIDAR prevent accidents.
3. **Enhanced Mobility:** Meccanum wheels allow movement in all directions.

ADVANTAGES

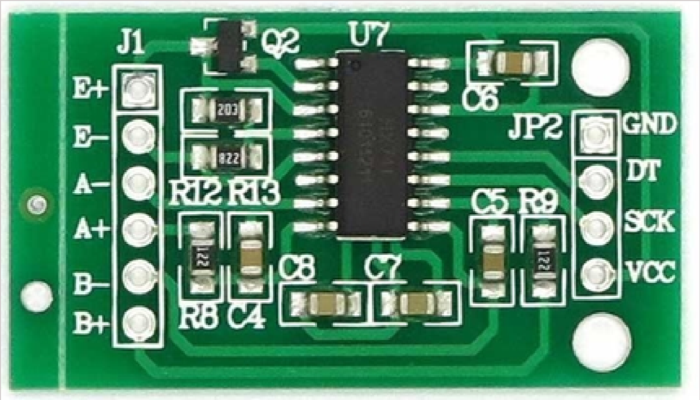
- **Increased Safety**: Automatic load balancing prevents tipping.
- **Enhanced Productivity**: Automated features reduce operator effort.
- **Better Navigation:** Mecanum wheels allow movement in any direction.

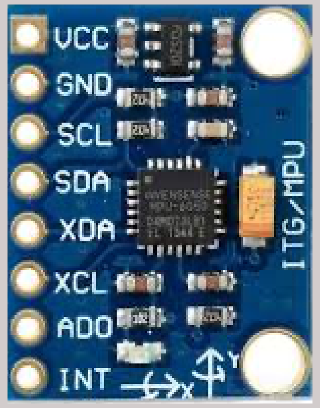
DISADVANTAGES

- **High Initial Cost**: Advanced sensors and processing units increase expense.
- **Complex Implementation:** Requires specialized knowledge to maintain.
- **Battery Dependence:** Limited operation time before requiring recharge.

COMPONENTS

- ***Microcontroller***: Raspberry Pi for control processing
- ***Motors:*** DC motors with encoders for precision movement
- ***LIDAR Sensor :*** Positioned at the front for obstacle detection
- ***Load Sensor(HX711):*** Monitors weight distribution for load balancing
- ***Servo Motors(SG90):*** Used for lifting mechanism.
- ***Gyroscope(MPU6050)*****:** Used for tilt measurement
- ***Bluetooth module(HC05)****:* Mobile navigation

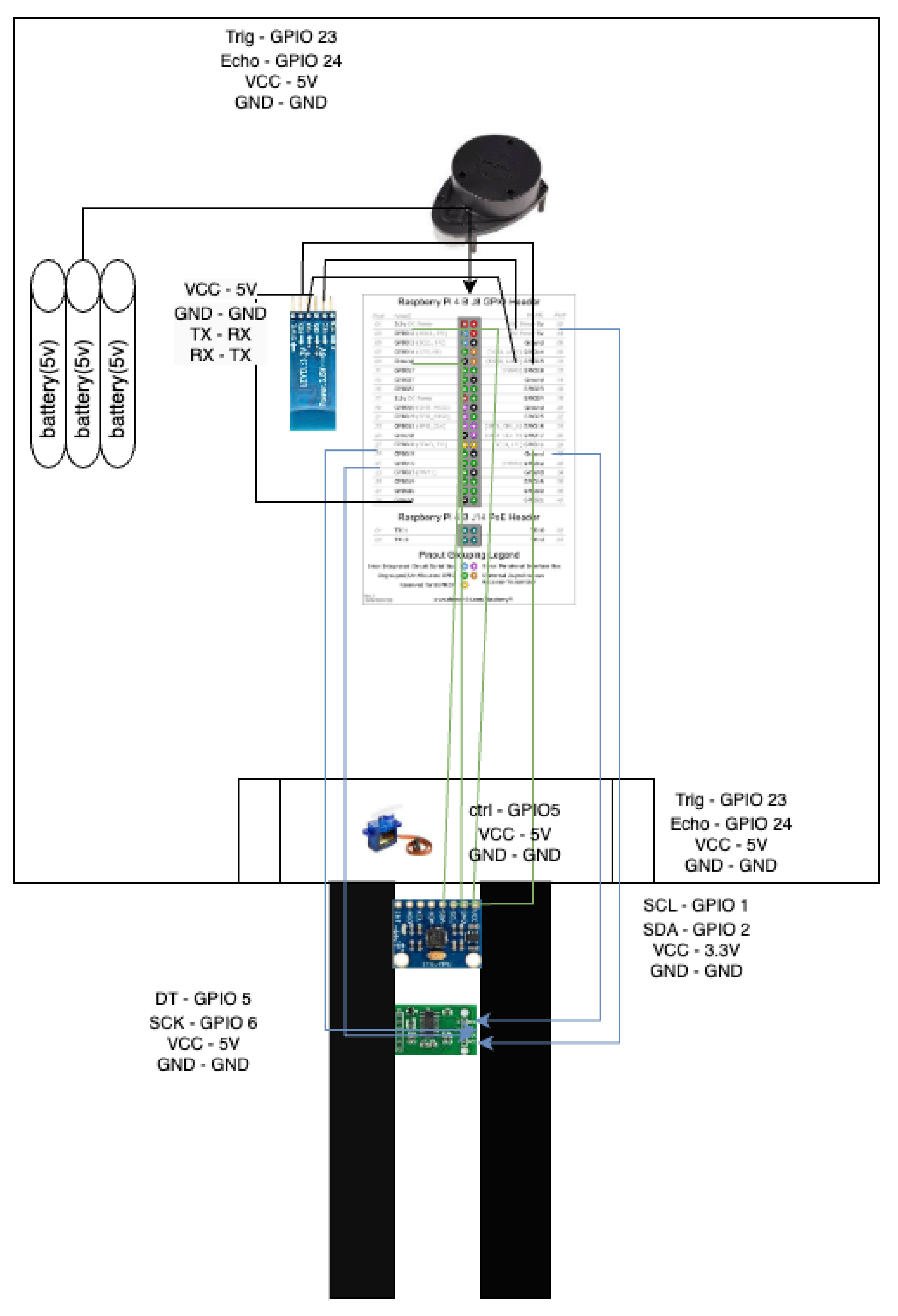




HARDWARE

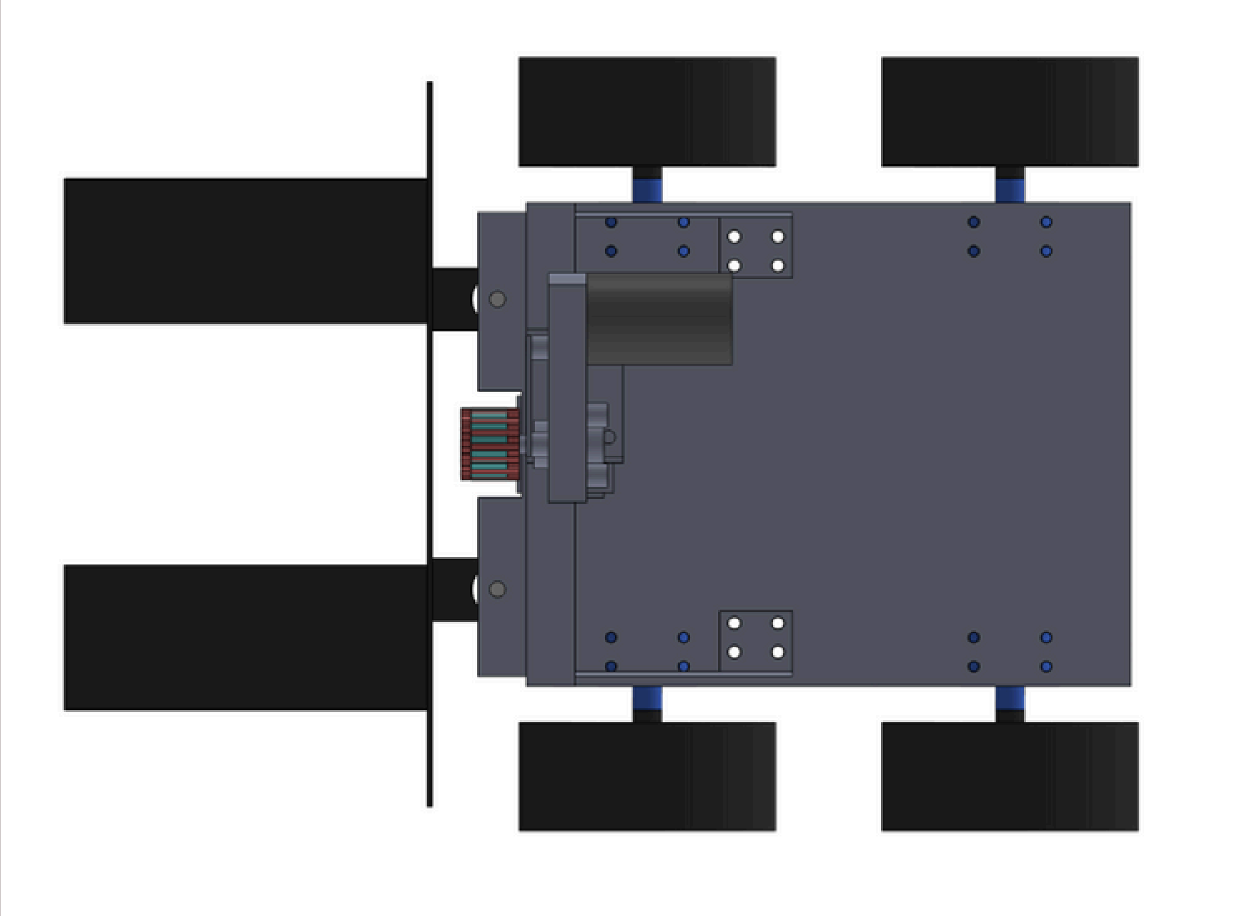
- ***Pulley Mechanism:*** The lifting system is driven by pulley, ensuring precise vertical movement and high load stability.
- ***Servo-Motor Driven Lift:*** Provides fine control over height adjustments.
- ***Weight Distribution Sensors***: Ensures stability while lifting heavy loads.
- ***Automatic Height Adjustment:*** Prevents instability by adjusting lift based on real-time load data.
- ***Fork Structure:*** Custom-fabricated fork assembly attached to the pulley mechanism to lift and hold objects securely.
- ***Mecanum Wheels:*** Allow omnidirectional movement
- ***Gyroscope & Accelerometer(MPU6050):*** Used for stability measurement

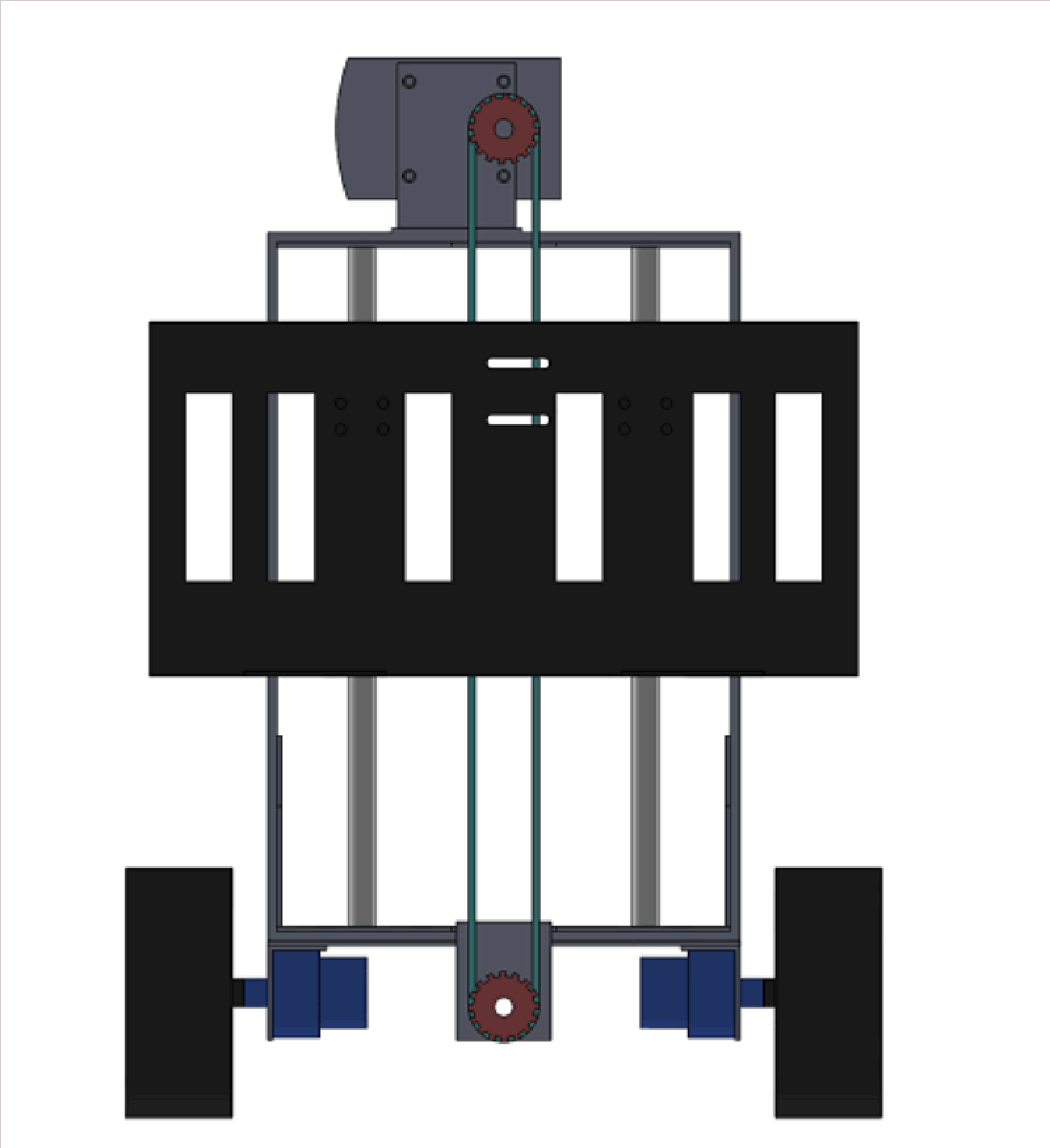
HARDWARE


Trig - GPIO 23
Echo - GPIO 24
VCC - 5V
GND - GND
battery(5v)
battery(5v)
battery(5v)
VCC - 5V
GND - GND
TX - RX
RX - TX
ctrl - GPIO5
VCC - 5V
GND - GND
Trig - GPIO 23
Echo - GPIO 24
VCC - 5V
GND - GND
SCL - GPIO 1
SDA - GPIO 2
VCC - 3.3V
GND - GND
DT - GPIO 5
SCK - GPIO 6
VCC - 5V
GND - GND

Lifting Mechanism

- Servo motor and pulley system for precise and efficient lifting.
- Load sensors and gyroscope ensure stability during operation.
- The automated load balancing system prevents instability by adjusting in real time.
- Safety, precision, and energy efficiency are key benefits of the system.

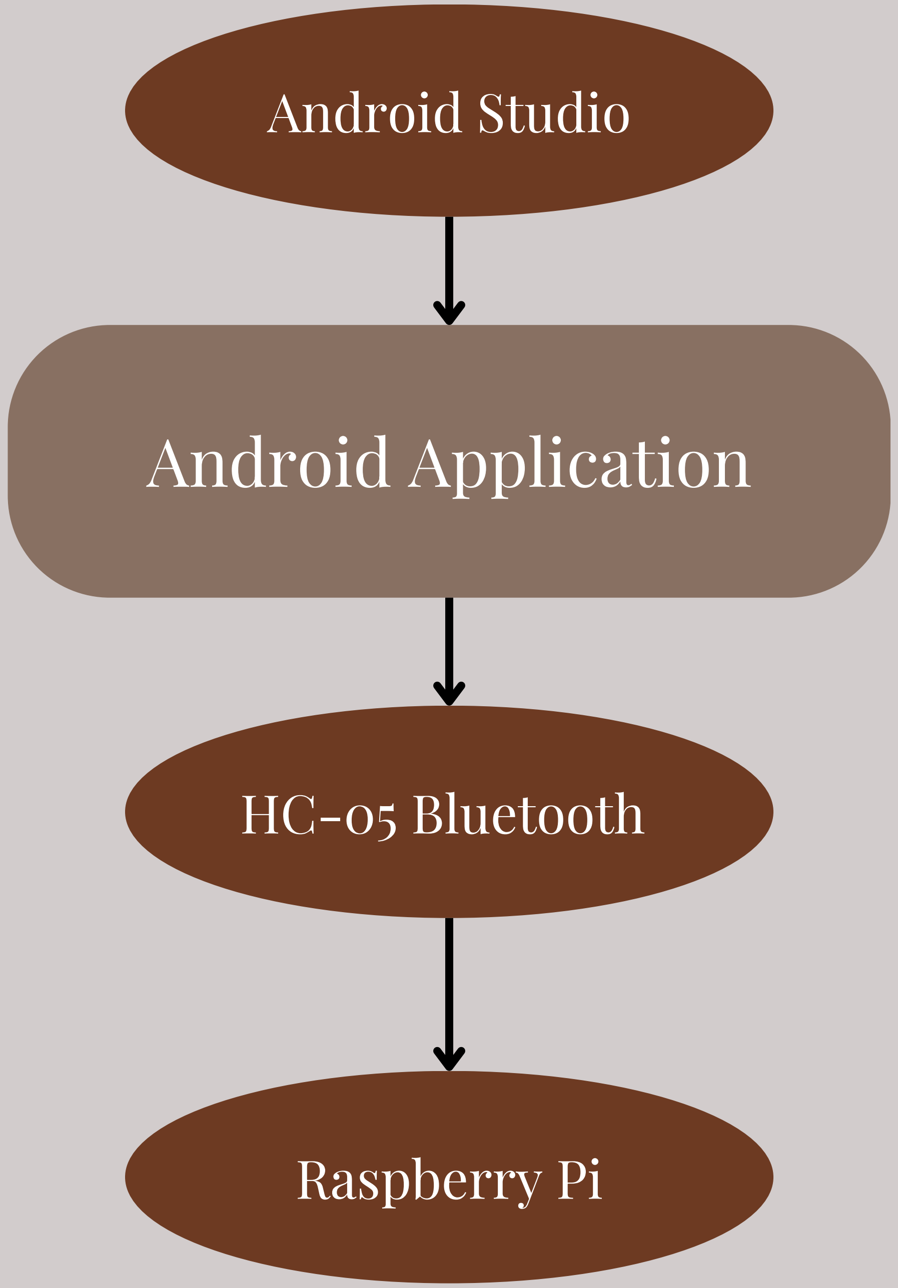


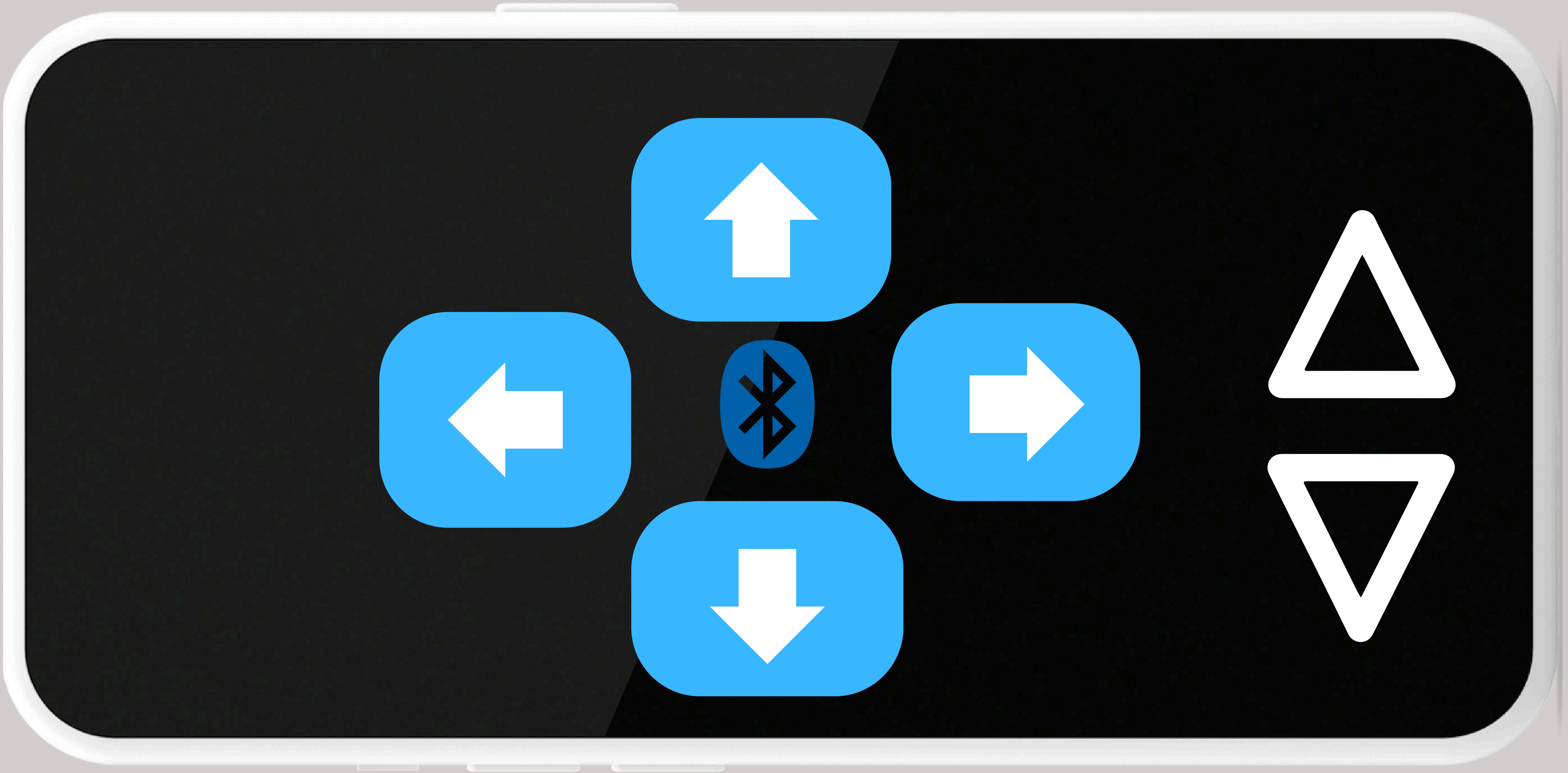


SOFTWARE

- ***Micro Controller:*** Python for microcontroller firmware (raspberry pi)
- ***Real-Time Processing:*** Signal processing methods for stability detection
- ***Sensor Fusion Algorithm:*** Merging data from load cell, gyroscope
- Remote Control Interface:
- ***Mobile App:*** Developed for controlling and monitoring
- ***Wireless Communication:*** Wi-Fi/Bluetooth integration
- ***Load Balancing***: Algorithms for weight distribution optimization

SOFTWARE


Android Studio
Android Application
HC-05 Bluetooth
Raspberry Pi



Our forklift prototype aims to achieve the following objectives:

- **Enhance Industrial Safety:** Reduce the risk of accidents by implementing an automated load balancing system that prevents tipping.
- **Improve Operational Efficiency:** Automate material handling with collision detection and real-time obstacle avoidance.
- **Optimize Load Stability:** Utilize gyroscopic analysis to ensure even weight distribution and quick stabilization.
- **Enable Smart Navigation:** Implement omnidirectional movement with Mecanum wheels to maneuver in complex spaces.
- **Develop a User-Friendly Interface:** Provide a smartphone-controlled system with real-time monitoring and automated adjustments.

MFC-4

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Problem Statement:

- Load imbalance in forklifts can lead to instability, inefficiency, and potential hazards..

Why Load Balancing?

- Ensures smooth movement, avoids tipping, and prevents motor stress.

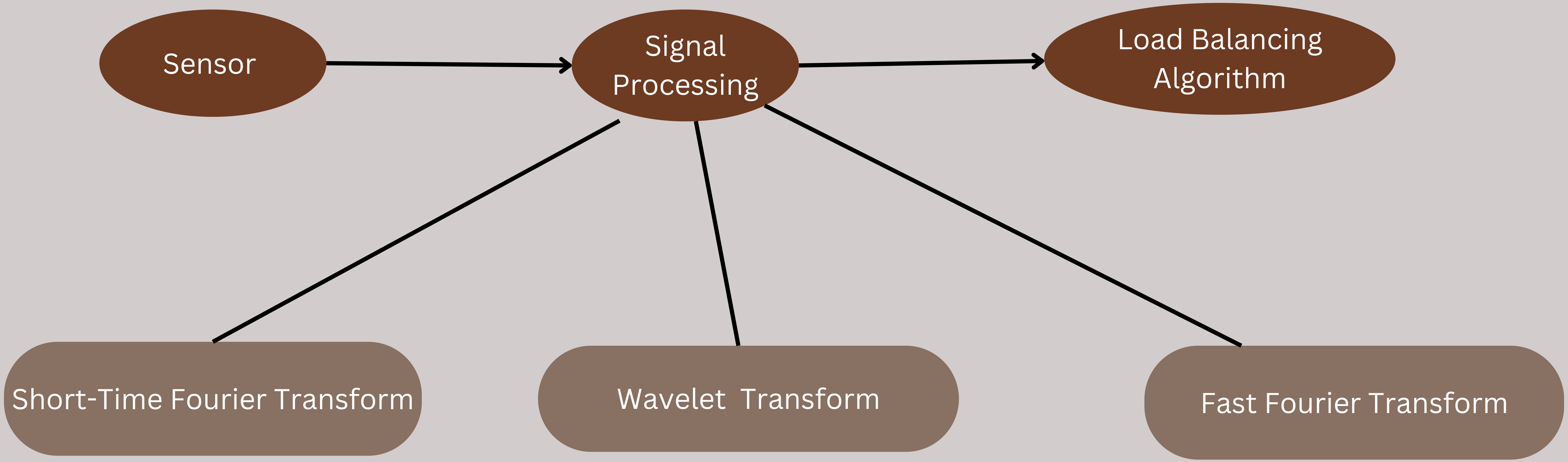
How are we solving this?

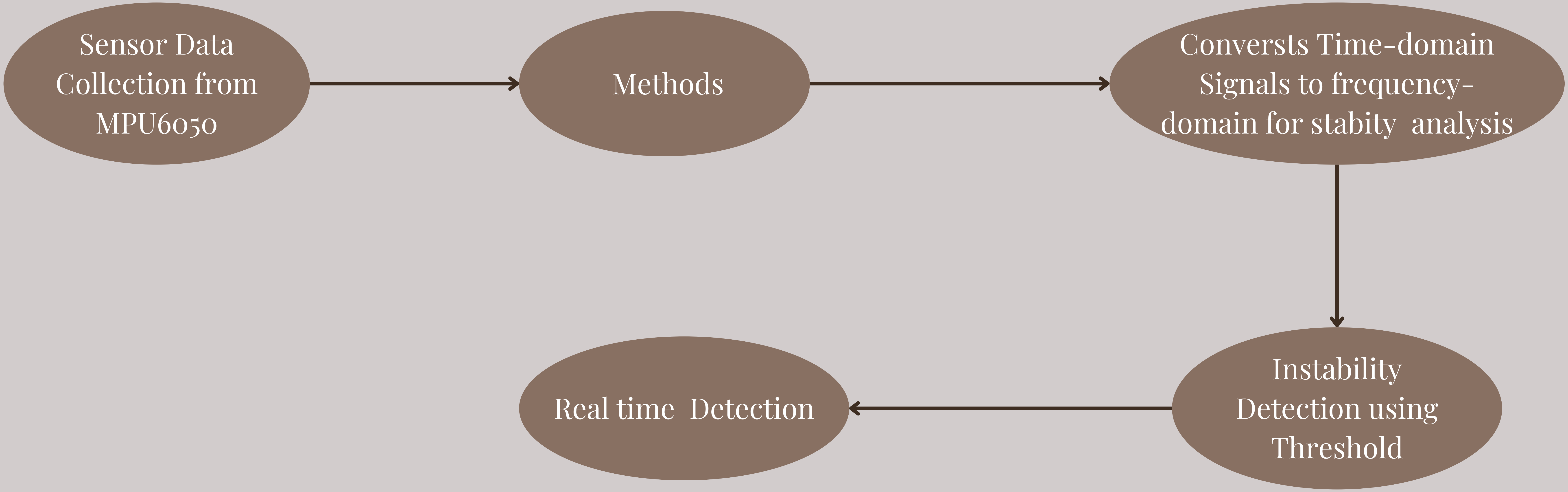
- Using sensor data (gyroscope, accelerometer), signal processing techniques (FFT, WT, STFT), and real-time corrections.

Objective:

- Use sensor data to detect instability.
- Apply FFT, WT, and STFT for signal analysis.
- Implement a correction mechanism for load distribution

Role of FFT, WT, STFT,FT in Load Balancing




Sensor Data Collection from MPU6050
Methods
Converststs Time-domain Signals to frequency-domain for stabity analysis
Instability Detection using Threshold
Real time Detection

Role of FFT,WT,STFT in Load Balancing

FFT (Fast Fourier Transform)

- Converts sensor data from time to frequency domain.
- Helps detect vibrations and oscillations.

STFT (Short-Time Fourier Transform)

- Tracks real-time movement variations.
- Detects sudden jerks and tilts.

WT (Wavelet Transform)

- Provides multi-resolution analysis (detects both slow drifts and sudden shocks).

This helps classify small vs. large load shifts.

By comparing the results from FFT, STFT, and WT, the system determines the type and severity of load imbalance.

- Based on the analysis, the forklift adjusts its fork angle or lifting mechanism to compensate for the imbalance.
- If imbalance is detected, an alert can be triggered to warn the operator.

CHALLENGES

1. Spectral Leakage
2. Resolution Limitations
3. Aliasing
4. Computational Complexity for Large Data

Topic	February	March	April
Research and finalize hardware components.			
Design and fabricate the chassis and lifting mechanism.			
Develop basic motor control and remote operation.			
Integrate LIDAR for collision detection.			
Implement real-time load balancing			
Develop and test the power management system.			
Optimize the remote control interface.			
Conduct final testing and debugging.			
Document results and prepare for project presentation.			

Topic	February	March	April
Gather sensor data, Normalize and filter noise and Define testcases imbalance			
Implement FFT,ST,WT			
Compare performance of the methods			
Finetuning the balancing algorithm			
Test with different loads and real-world conditions			