Needs Analysis for Mechatronic Systems

Group Name:

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*** This section will be completed only by the course assistant and supervisor.**

1. Project Overview

1.1 Project Title

AGV Roboshuttle Goods to Person System

1.2 Project Description

AGV Roboshuttle Goods-to-Person System uses automated vehicles to bring items from storage to workers, speeding up order picking in warehouses. It helps reduce manual work, boosts efficiency, and can easily scale as needed.

2. Problem Identification

2.1 Current Challenges

Identify and describe the specific problems or inefficiencies in the current system that you aim to address with the mechatronic solution.

- Manual Labor Dependency
  Description: The system relies too much on human workers for picking and transporting items.
  Impact on the system: This leads to slower operations and more mistakes, which can frustrate customers and increase costs.

- ### Inefficient Space Utilization
  Description: Items are often stored in ways that waste space and make them hard to access.
  Impact on the system: This limits how much can be stored and makes finding items take longer, driving up costs and slowing down processes.

- ### Slow Order Fulfillment
  Description: Locating and picking items manually takes too much time, especially during busy periods.
  Impact on the system: This results in delays in shipping, which can disappoint customers and hurt the company's reputation.

3. Stakeholder Analysis

3.1 Key Stakeholders

List the stakeholders involved in the project. These could be end-users, engineers, clients, etc.

Stakeholder Name	**Role/Interest**	**Requirements/Concerns**
Warehouse Workers	End-users who operate and interact with the system.	Efficient operation, eas of use, minimal need for technical knowledge.
Logistics Department	Manage inventory and ensure order fulfillment.	Faster order processing scalability, optimized space utilization.

3.2 Stakeholder Needs

Warehouse Workers:

They need a user-friendly interface for operating the system, with minimal technical issues or complex procedures. Their primary concern is the ease of interaction with the AGV system.

Logistics Department:
They expect the system to speed up the order picking process, reduce the need for manual labor, and efficiently utilize storage space. The system should handle both regular and peak demand without issues.

Customers:
Their main concern is receiving their orders on time and accurately. Any delays or mistakes in order fulfillment could impact their satisfaction and future purchases.

4. Functional Requirements

4.1 Core Functions

Define the essential functions your mechatronic system must perform to address the problems identified.

Function ID	Description	Importance (Low, Medium, High)
F1	Automated item retrieval and transport: The AGV must autonomously retrieve items from storage and deliver them to designated pick stations.	High
F2	Dynamic route planning: The AGV must calculate and follow the optimal path to minimize travel time and avoid obstacles in the warehouse.	Medium
F3	Integration with warehouse management system (WMS): The system should communicate seamlessly with existing WMS for order processing and inventory updates.	Medium

4.2 User Requirements

Describe the specific functionalities that end-users require from the system.

User Requirement ID	Description	Priority Level (Low, Medium, High)
UR1	Quick response times for item retrieval and order fulfillment, especially during peak hours.	High
UR2	Flexible integration with the warehouse's existing software and equipment.	Medium

5. Technical Specifications

5.1 Hardware Requirements

List and describe the hardware components and their specifications required for the system

Component	Specification	Justification/Reasoning
AGV Chassis and Drive	2-wheel drive and 2-ball caster with 360° rotation capability.	Support mobility and stability in tight warehouse spaces.
LIDAR Sensor	2D range Lidar, high resolution	LIDAR ensures real-time obstacle detection and helps drivers drive.
Cameras (for Vision)	1080p resolution, 60fps	Provides visual input for QR and verification of items during packing and transportation.
Control Unit (Microcontroller, Microprocessor)	ESP32, Raspberry Pi	Ensures efficient control of AGV operations, including sensor inputs, motor control.
Motor Drive System	Brushless DC motors, with PID motor control system.	Ensures smooth, precise movement and speed control of the AGV.
Battery Management System (BMS)	12V Li-ion battery pack with charging dock.	Provides uninterrupted power for AGV operations and facilitates fast, safe charging for continuous operations.

5.2 Software Requirements

Describe any software or programming needs, including algorithms, platforms, and control systems.

Software Component	Description/Requirements	Justification/Reasoning
Warehouse Integration System	Recognition items from location information.	Order processing
Robot Operating System (ROS)	ROS for robotic control and communication. Provides frameworks for sensor integration, motor control, and inter-node communication.	ROS is essential for managing the AGV's functionalities, sensor fusion, and system communication.
Machine Learning Algorithms	Uses necessary models or genetic algorithms to dynamically optimize paths based on warehouse layout and traffic. Ensures efficient pickup and delivery of products.	Improves AGV efficiency by optimal paths, reducing travel time and energy consumption for better performance.
QR Detection by using Image Processing	Utilizes OpenCV or TensorFlow for real-time QR code detection and decoding using camera inputs.	Enables the AGV to identify storage locations or specific items using QR codes, simplifying path and product pickup/dropoff tasks.
Human-machine interface (HMI)	A simple and specialized customer friendly interface HMI software. Accessible via tablet or PC.	Provides warehouse workers with an easy-to-use interface for monitoring AGV operations, issuing commands.

6. System Constraints

6.1 Budget Constraints

Outline any financial constraints for the project, including hardware, software, and other expenses.

- **Budget Total :** 12.000 TL
- **Cost Breakdown**
  - Hardware: 10.000 TL
  - Software: 0 TL
  - Other: 2.000 TL

6.2 Time Constraints

Indicate the timeline for each phase of the project, including milestones for development and testing.

Phase	**Duration**	**Milestones/Deadlines**
Phase 1: Research	5 Week	01.10.2024 - 05.11.2024
Phase 2: Development	5 Week	05.11.2024 - 10.12.2024
Phase 3: Testing	4 Week	10.12.2024 - 07.01.2024

6.3 Technical Constraints

Note any limitations in technology, components, or integration that may impact system design or performance.

- **Hardware Drawing and Designing**
- **Hardware Manufacturing**
- **Control System Complexity**
- **Creating Simulation Environment**
- **Integrated Operation of the Software**
- **System Algorithm Design**

7. Feasibility Study

7.1 Technical Feasibility

Assess whether the proposed solution is technically viable given the current state of technology and available resources.

- **Challenges**
  - Integration of hardware components (cameras, LIDAR, microcontrollers).
  - Algorithm optimization for path planning and QR detection.
  - Real-time performance of image processing with limited processing power.
  - Simulation environment development.
- **Potential Risks**
  - Risk of incompatibility between hardware components or delays in data processing due to sensor/communication latency, which can impact real-time navigation and item handling.
  - The algorithms (machine learning for path optimization, image processing for QR code detection) might require significant fine-tuning, increasing development time and computational demand.
  - Onboard processing units may struggle with real-time tasks, leading to potential lags or errors in AGV operation, especially during peak workloads.
  - Creating a comprehensive simulation environment could be resource-intensive, especially to model the full-scale warehouse operations.

7.2 Economic Feasibility

Evaluate the cost-effectiveness of the system. Include a cost-benefit analysis to determine if the investment is justified.

- **Cost Estimate**
  - Initial investment: Hardware (AGVs Chassis , sensors, cameras), software development, and integration costs.
  - Ongoing maintenance costs for hardware and software updates.
- **Expected Benefits**
  - Reduction in labor costs: The system could significantly cut manual labor costs by automating picking processes, resulting in long-term savings.
  - Increased operational efficiency.

7.3 Operational Feasibility

Consider whether the system can be effectively implemented and used within the operational environment.

- **Operational Requirements**

    - Trained personnel: Warehouse workers will need training on how to interface with the AGV system (HMI), including basic troubleshooting.
    - Ongoing system monitoring: Regular monitoring of AGV operations is required to ensure optimal performance and address any issues that arise.
- **Integration with Existing Systems**
    - The system must integrate seamlessly with existing Warehouse Systems for order fulfillment.

8. Conclusion & Recommendations

Summarize the findings of the needs analysis. Provide recommendations for the next steps in system development based on the information gathered.

- **Key Findings**

  The AGV Roboshuttle Goods-to-Person System presents a technically and economically feasible solution for improving warehouse efficiency by automating picking processes, reducing manual labor, and increasing operational throughput. Key constraints include hardware integration, real-time performance issues, and potential development complexity in software algorithms and simulation environments.
- **Recommendations for Development**
    - Hardware integration: Begin by ensuring compatibility between sensors, cameras, and control units, focusing on resolving latency and performance challenges.
    - Simulation environment: Develop a robust simulation model for testing AGV behaviors, navigation algorithms, and real-time decision-making before large-scale deployment.
    - Path optimization: Continue refining machine learning algorithms for path planning to ensure real-time optimization and minimize travel distances within the warehouse.

Appendix

Add any additional materials, references, or supplementary documentation here. These could include diagrams, stakeholder interviews, or additional technical details.