Warehouse Automation

DESIGN DOCUMENT

sddec20-10
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Executive Summary

Development Standards & Practices Used

MVC style coding in backend.

Agile and Test Driven Development practices will be used

Must follow FAA flight regulations.

Summary of Requirements

- Have some method to take inventory in a warehouse
- Create a module design which can be integrated into different warehouses
- Design and develop an aerial vehicle
- The drone should navigate autonomously
- The drone must scan barcodes off of pallets in each aisle
- The gathered data from the scanner must be transmitted to the server via wireless communication
- Data in the server must be viewable in a web application

Applicable Courses from Iowa State University Curriculum

- CprE 288
- CprE 488
- Com Sci 309
- Com Sci 319

New Skills/Knowledge acquired that was not taught in courses

A lot of the skills and knowledge required for this project are a part of CprE 488, which no one on the team has taken. So many of the skills needed for making and controlling a flying drone.

Table of Contents

List of figures/tables/symbols/definitions (This should be the similar to the project plan)

1 Introduction

1.1 Acknowledgment

The team appreciates Dr. Rover for choosing our team for the warehouse automation project. Our team is excited to contribute efforts in this regard and would like to deliver a project that is sustainable, integrative, and cost-effective. Our team has a wide range of skills from embedded systems and circuit design to application development. These skills can be combined to deliver an effective product that meets all the requirements set by the client.

1.2 Problem and Project Statement

Warehousing contributes up to 30% of the cost of logistics in most developed economies. Billions of dollars of capital are locked up at a time, in high-volume-high-value inventory. Since the rise of the internet, eCommerce has exponentially increased in consumer demand and efforts need to be made to keep up with this demand. Traditional warehouse workers are falling short and need technological integration to help keep track of the high volume of inventory moving in and out of the warehouse.

Our team will research, design, build, and demonstrate a warehouse inventory application using ground and/or air AV technology. The team will need to realistically scope the project for the time, resources and expertise available. The team is responsible for creating a small warehouse environment appropriate for the AV technology being used. The team needs to identify and select a cost-effective off-the-shelf robot and/or drone. This application will serve as a demonstration to potentially initiate a larger automated warehouse testbed for the department with industry collaboration.

A modern warehouse is expected to use technologies such as RFID, QR code, sensors, autonomous ground, and aerial vehicles, and computer vision to improve its efficiency. The team has opted for the aerial autonomous vehicles as a means to automate the inventory tracking of a warehouse.

Autonomous aerial drones will be utilized to scan the barcodes for each pallet at different heights in an aisle. Our team will be designing and building drones with a vision tracking system to identify barcodes and a barcode scanner will be installed on the drone to scan that barcode. Data will be transmitted from the drone to the server via wireless communication. A frontend will also be developed to run analytics on the data generated from the drones as they scan each aisle in the warehouse.

1.3 Operational Environment

The operational environment of our project will be a warehouse atmosphere. Since this is indoors, the team isn't worried about any potential environmental hazards that might affect the drones in flight. However, there're indoor hazards that the team is taking into consideration. As the drones will be operating autonomously, the team wants to include sensors like lidar and cameras for obstacle detection while performing tasks. This will ensure that drones don't collide with each other or any item present in the warehouse.

1.4 Requirements

- **Market requirements:**

    - Create a module design which can be integrated into different warehouses
    - Develop a cost-effective system
    - Ensure low running cost
    - Ensure customer requirements are being met through seeking feedback on the project
- **System Requirements:**
    - Design and develop an aerial vehicle
    - Ensure autonomous navigation through the use of sensors
    - Integrate scanners into the system to scan barcodes
    - Use wireless communication to transmit data from the aerial vehicle to the server
    - Develop a web application which shows the warehouse data gathered by the drones
- **Administrative Requirements:**
    - Create a Gantt chart to keep track of the project
    - Assign tasks on Trello to each member of the team
    - Weekly team meeting to discuss progress and concerns
    - Weekly team meeting with the faculty advisor to discuss progress
- **Functional Requirements:**
    - The drone should be able to fly to the height of the warehouse
    - The drone should navigate autonomously
    - The done must scan barcodes off of pallets in each aisle
    - The gathered data from the scanner must be transmitted to the server via wireless communication
    - Data in the server must be viewable in a web application
    -

1.5 Intended Users and Uses

The intended users for our project are the companies operating warehouses for their inventory. Our product will be used to automate inventory tracking in those warehouses. This will enable warehouse owners to keep track of their inventory effectively and will result in long term savings through better analytics and elimination of existing personnel.

1.6 Assumptions and Limitations

- **Assumptions:**
    - There is sufficient space between the aisles for operating multiple aerial vehicles simultaneously
    - The drones aren't intended to be used outdoors
    - Since the location is indoors, no extra water or dust protections will be installed
    - The environment is well lit for the drone to scan barcodes
- **Limitations:**
    - A single drone shall operate for a minimum of 2 hours on a single charge (Project Requirement)
    - The drone shall be no larger than 300 mm in length (Project Requirement)
    - The drone shall not have a swappable battery (Size Constraint)
    - The drone shall use a lithium-ion battery (Feasible and Affordable)

- The drone shall always operate in the range of a wireless access point (Project Requirement)

1.7 Expected End Product and Deliverables

The expected end product will be a drone with a charging base station. The drone will be operating autonomously in the warehouse while keeping track of the inventory. This autonomous navigation will be achieved through lidar and cameras. The lidar will ensure obstacle detection and the camera will be used to detect barcodes on the pallets in every aisle of the warehouse. The drone shall also have a scanner built-in which will be responsible for scanning the barcodes. The data will then be transmitted to the server via wireless communication. The drone shall be powered with a battery with a minimum operating life of 2 hours. Once on a low charge, the drone will move to the base station for charging and will continue once fully charged.

A web application will also be shipped with the drone which will show the data in the server. This data will be updated in real-time as shipments move in. The user will also have the option to run analytics on the existing data to see which aisle has been the busiest or which product has been shipped the most etc.

	Project Deliverables	**Status**
1	Product Design	In progress
2	Preliminary Design Review	To do
3	Critical Design Review	To do
4	Product Prototype	To do
5	Product Testing	To do
6	Test Readiness Review	To do
7	Product Delivery	To do

2. Specifications and Analysis

2.1 Proposed Approach

The team's approach for undertaking this task will consist of both functional and nonfunctional requirements.
When considering the project functional requirements, the aerial drone should be able to navigate autonomously in the warehouse, this means avoiding obstacles while performing its tasks. The drone has to scan barcodes off of pallets in each aisle of the warehouse. The data from the scanner will then be transmitted to the backend server and this data is viewable through a web application that will be developed by our team.

When considering the nonfunctional requirements, the drone must operate autonomously with the help of lidar for obstacle detection and a camera to detect barcodes on each pallet in the warehouse. A scanner will be integrated into the drone to scan the barcodes after being detected by the camera. The drone will be using an onboard computer to perform all the calculations and gathering input from the scanner. The onboard computer will be powered by a battery that will provide a minimum of 2 hours of operating capability. The data gathered from the scanner will be transmitted by the onboard computer to the backend server via HTTP requests. A web application will be developed by the team to view and analyze data collected by the drone.

For NIST standards, general security practices should be implemented and continuously assessed to make sure the drones are operating as expected. For IEEE standards would just be to meet FAA standards, which are not set for drone flight indoors.

2.2 Design Analysis

Most of the team's discussion thus far has been focused on long-term planning, primarily about whether the team wants to pursue ground or air-based robots for our project. The team has decided to opt for aerial vehicles after consulting our faculty advisor. The team believes that aerial drones are an exciting technology with an immense amount of possibilities and can be effective in a warehouse environment.

Thus far, the drone project has been working well. The team is currently deciding on the hardware components needed for the project to function as needed. There's still a lot of planning needed to satisfy hardware and software limitations and requirements.

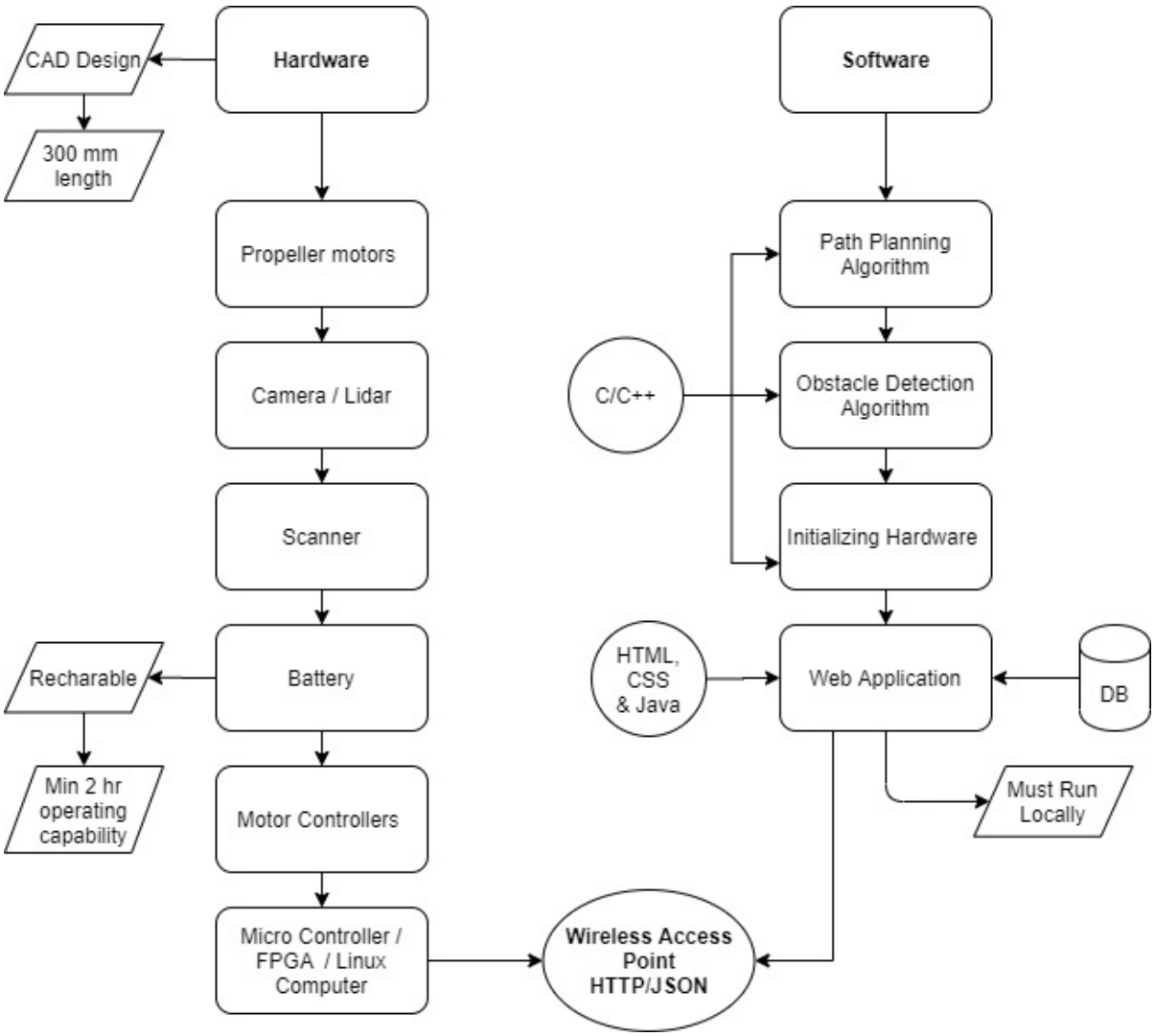
The autonomy aspect of the robot still needs to be decided upon. Autonomous navigation can be implemented in multiple ways and the team is currently deciding on the most efficient and cost-effective way. Due to the complexity of autonomy, hardware and software requirements are still being discussed upon and we hope to have a plan of action by the end of the semester. Since the team is still in the planning stage, no testing has been carried out yet. The team wants to ensure a clear vision before any components are ordered and tested.

The team believes that the proposed solution has the potential to improve current warehouse operations. This solution will not only speed up the inventory management process but also save companies millions in the long run through cutting employee costs. The current situation is a warehouse setting isn't safe for the warehouse workers. Employees reach high stacked inventory through the help of ladders is risky and has resulted in many fatalities. Through our solution, the team believes that the employee will be safer than ever as our drones will be doing most of the high-risk operations in the warehouse.

2.3 Development Process

As Agile and TDD development processes are not mutually exclusive the team will be following both of these development processes. The team chose these processes over the Waterfall development process because they are cyclical which we believe will help create better-written code and better products. They also allow for more flexibility and as a smaller team with no client that is highly desired.

2.4 Conceptual Sketch



3. Statement of Work

3.1 Previous Work And Literature

Include relevant background/literature review for the project

– If similar products exist in the market, describe what has already been done

– If you are following previous work, cite that and discuss the **advantages/shortcomings**

– Note that while you are not expected to "compete" with other existing products / research groups, you should be able to differentiate your project from what is available

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

3.2 Technology Considerations

Highlight the strengths, weakness, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

3.3 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and to understand interdependence among tasks.

3.4 Possible Risks And Risk Management

Include any concerns or details that may slow or hinder your plan as it is now. These may include anything to do with costs, materials, equipment, knowledge of area, accuracy issues, etc.

3.5 Project Proposed Milestones and Evaluation Criteria

What are some key milestones in your proposed project? Consider developing task-wise milestones. What tests will your group perform to confirm it works?

3.6 Project Tracking Procedures

What will your group use to track progress throughout the course of this and next semester?

3.7 Expected Results and Validation

What is the desired outcome?

How will you confirm that your solutions work at a **High level**?

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

- A realistic, well-planned schedule is an essential component of every well-planned project
- Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity
- A detailed schedule is needed as a part of the plan:
    - Start with a Gantt chart showing the tasks (that you developed in 3.3) and associated subtasks versus the proposed project calendar. The Gantt chart shall be referenced and summarized in the text.
    - Annotate the Gantt chart with when each project deliverable will be delivered
- Completely compatible with an Agile development cycle if that's your thing

How would you plan for the project to be completed in two semesters? Represent with appropriate charts and tables or other means.

Make sure to include at least a couple paragraphs discussing the timeline and why it is being proposed. Include details that distinguish between design details for present project version and later stages of project.

4.2 Feasibility Assessment

Realistic projection of what the project will be. State foreseen challenges of the project.

4.3 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be based on the projected effort required to perform the task correctly and not just "X" hours per week for the number of weeks that the task is active

4.4 Other Resource Requirements

Identify the other resources aside from financial, such as parts and materials that are required to conduct the project.

4.5 Financial Requirements

If relevant, include the total financial resources required to conduct the project.

5. Testing and Implementation

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, or a software library

Although the tooling is usually significantly different, the testing process is typically quite similar regardless of CprE, EE, or SE themed project:

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study for functional and non-functional requirements)
2. Define the individual items to be tested
3. Define, design, and develop the actual test cases
4. Determine the anticipated test results for each test case 5. Perform the actual tests
6. Evaluate the actual test results
7. Make the necessary changes to the product being tested 8. Perform any necessary retesting
9. Document the entire testing process and its results

Include Functional and Non-Functional Testing, Modeling and Simulations, challenges you've determined.

5.1 Interface Specifications

– Discuss any hardware/software interfacing that you are working on for testing your project

5.2 Hardware and software

- Indicate any hardware and/or software used in the testing phase
- Provide brief, simple introductions for each to explain the usefulness of each

5.3 Functional Testing

Examples include unit, integration, system, acceptance testing

5.4 Non-Functional Testing

Testing for performance, security, usability, compatibility

5.5 Process

– Explain how each method indicated in Section 2 was tested

– Flow diagram of the process if applicable (should be for most projects)

5.6 Results

– List and explain any and all results obtained so far during the testing phase

- – Include failures and successes
- – Explain what you learned and how you are planning to change it as you progress with your project
- – If you are including figures, please include captions and cite it in the text

  • This part will likely need to be refined in your 492 semester where the majority of the implementation and testing work will take place

-**Modeling and Simulation**: This could be logic analyzation, waveform outputs, block testing. 3D model renders, modeling graphs.

-List the **implementation Issues and Challenges**.

6. Closing Material

6.1 Conclusion

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals and indicate why this surpasses all other possible solutions tested.

6.2 References

This will likely be different than in project plan, since these will be technical references versus related work / market survey references. Do professional citation style(ex. IEEE).

6.3 Appendices

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc. PCB testing issues etc. Software bugs etc.