Crane Positional Sensor

DESIGN DOCUMENT

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Executive Summary

Development Standards & Practices Used

List all standard circuit, hardware, software practices used in this project. List all the Engineering standards that apply to this project that were considered.

Summary of Requirements

List all requirements as bullet points in brief.

Applicable Courses from Iowa State University Curriculum

List all Iowa State University courses whose contents were applicable to your project.

New Skills/Knowledge acquired that was not taught in courses

List all new skills/knowledge that your team acquired which was not part of your Iowa State curriculum in order to complete this project.

Table of Contents

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

1 Introduction

1.1 Acknowledgement

We would like to acknowledge Stellar Industries for contributing to this project by providing financial assistance, equipment, and technical advice. Nathan Neihart will also be contributing to this project with his technical advice and knowledge of the subject. These groups and individuals will provide our team with the assistance required to get the project completed.

1.2 Problem and Project Statement

Stellar Industries currently relies heavily on sensors to monitor the condition of their crane trucks. Since these sensors are integral to the company's business, Stellar is concerned on whether the sensor setup currently used is the most cost-effective solution available. A team at Iowa State has been tasked with identifying the best combination of sensors that will relay accurate data to the crane engineers, while still being economically sound. This is to be accomplished by evaluating current sensor options that are in the market, as well as designing and producing unique sensors specifically for use on Stellar Industries' vehicles. The main goal of this project is to provide the most economically sound choice of positional, rotational, and angular sensor to be used in the future by Stellar Industries.

1.3 Operational Environment

As the cranes that Stellar Industries produces are for outdoor use, the fabricated sensors need to withstand any and all ennvironmental conditions. This includes extreme heat and cold, rain, fog, sleet, snow, and high winds. These sensors need to be fully operational and will spend almost all, if not all, of their usable life outside. Therefore, they need to be evaluated for such at an early stage.

1.4 Requirements

- The final solution must be able to work in all temperatures and all weather conditions.
- It must be more cost-efficient than the current sensor setup.
- It must be able to be mounted on a truck.
- The sensors are expected to communicate to a handheld interface, which will display the sensors' information and outputs.
- The budget for development and testing must not exceed $2000.

1.5 Intended Users and Uses

The final solution is intended for use by Stellar Industries to mount on future trucks.

1.6 Assumptions and Limitations

Assumptions

1. The end product is for Stellar Industries
2. The sensor covers need to withstand the various weather conditions
    a. Silicon
    b. Metal
    c. Polycarbonate
3. Cost of sensors should be less than what is on the market now

Limitations

1. The maximum degree of rotation of the **rotational sensor** will be dependent on the truck size
    a. Truck 3315
        i. 370° (worm gear)
    b. Truck 4421
        i. 370° (worm gear)
    c. Truck 5521
        i. 400° (worm gear)
    d. Truck 6521
        i. 400° (worm gear)
2. The maximum degree of rotation of the **angular sensor** will be from -10° to +80°
    a. Horizontal axis is 0°
3. The maximum length of the **radial sensor** will be dependant on the truck size
    a. Horizontal
        i. Truck 3315
            1. 15'
        ii. Truck 4421
            1. 21'
        iii. Truck 5521
            1. 21'
        iv. Truck 6521
            1. 21'
    b. Vertical
        i. Truck 3315
            1. 17'8"
        ii. Truck 4421
            1. 22'7"
        iii. Truck 5521
            1. 22'11"
        iv. Truck 6521
            1. 22'11"
4. Radio control standard for all functions
5. Able to work in -20° F to +160°F
6. Budget of $2000

1.7 Expected End Product and Deliverables

There are three deliverables that we are expected to turn in:

1. Rotational Sensor
2. Angular Sensor
3. Radial Sensor

Each of these sensors, in their end product form, should be able to do as stated above in the Limitations. The sensors should be able to provide feedback to the UI so the operator knows how the crane is operating. These sensors are to be delivered to Stellar Industries in May of 2021.

The rotational sensor should be able to rotate the crane from 0° to 370° when starting at the boom cradle. Once the crane is unstowed and rotated clockwise to the centerline of the truck, the crane should be able to turn a minimum of another 150° clockwise. This will allow the maximum usage of the crane. The crane sensor should be able to read the centerline of the truck as the 0° mark so the operator knows how far each way the crane is still able to move while the crane is in operation.

The angular sensor should be able to rotate from -10° to +80°. When the crane angle is at 0°, the crane should be at the horizontal position and parallel to the truck bed. The angle of the crane will tell the operator how much payload the crane can handle and if the angle is off the operator could end up seriously hurt.

The radial sensor is truck dependent, so the sensor should be able to read when the crane stops extending and relay the distance back to the operator.

2 Project Plan

2.1 Task Decomposition

Our project has multiple tasks, our first task will be evaluating the cost of sensors currently in use in Stellar cranes. Our next task will be to design a sensor that will have a lower manufacturer and operating cost then what is currently being used. The task of designing a sensor can be broken up into multiple subtasks such as evaluating the components used in the sensors currently in use, forming ideas on a new design, creating documentation of our design, creating any inhouse components needed for our new design, creating a prototype and testing.

2.2 Risks And Risk Management/Mitigation

For the task of evaluating the cost of sensors currently in use, the probability of risk is 0.1, it seems unlikely that we would have issues understanding what is currently in use. As for forming ideas for a new design, the probability of risk would be around 0.7 because our ideas might not work out as planned. For this we would need to consider any risk that we may have when coming up with ideas. for creating documentation, there is no risk as we will just need to make proper documentation. creating inhouse components has a risk of 0.6 as we would have to do our own fabrication and testing to make sure the component works. One alternative would be to use off the shelf components for our design. Finally, testing has a risk of 0.5 because our test might fail. If our testing fails we would have to look at our design and debug it. Another thing we could do is create prototypes of multiple designs as we may have more than one idea.

2.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

For our first task, our milestone is evaluating the cost of the current sensors in use at Stellar. This milestone will be accomplished by doing research on the current sensors in use and coming up with a total cost estimate on the sensor system as a whole. Our next milestone will be forming ideas and creating design documents for our ideas. This will include the documentation for our components, a detailed description of how they work together and instructions on how to create our design. This can be measured in the percentage completion of our design documents. For creating our design/prototype, milestones can be measured by how much of the design is completed. Finally, for testing, milestones can be measured by the accuracy of the sensors used and the speed at which they are able to take measurements.

2.4 Project Timeline/Schedule

2.5 Project Tracking Procedures

We are currently using a discord that will help us develop effective communications and a tracking methodology. Furthermore, we are using a Github page for when we eventually start developing code.

2.6 Personnel Effort Requirements

Task	**Man Hours**
Research on current sensors being used at Stellar	10
Forming ideas for creating a cost effective design	10
Creating documentation and instructions of our design	15
Designing any inhouse components needed	20
Creating our prototype	15
Testing and redesigning	30

2.7 Other Resource Requirements

When we look at resource requirements, we are looking at the requirements such as working stations, and equipment at Iowa State that could benefit us. We can use the workstations at the TLA where we will be able to use soldering stations and yet also be able to code.

2.8 Financial Requirements

We have a few main components which we deem essential in order to complete the project:

1. IPS2200 INDUCTIVE POSITION SENSOR: $10
2. G158 Incremental Encoder: $126.94
3. AN820001 Sensor Angle: $33
4. Raspberry Pi 4B/4GB: $64.32

These component costs have reached around $230, and with site visits and potential other component cost we think the financial requirements may go up to $700.

3 Design

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 Design Thinking

Detail any design thinking driven design "define" aspects that shape your design. Enumerate some of the other design choices that came up in your design thinking "ideate" phase.

3.3 Proposed Design

Include any/all possible methods of approach to solving the problem:

- Discuss what you have done so far – what have you tried/implemented/tested?
- Some discussion of how this design satisfies the **functional and non-functional requirements** of the project.
- If any **standards** are relevant to your project (e.g. IEEE standards, NIST standards) discuss the applicability of those standards here
- This design description should be in **sufficient detail** that another team of engineers can look through it and implement it.

3.4 Technology Considerations

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

Discuss possible solutions and design alternatives

3.5 Design Analysis

– Did your proposed design from 3.3 work? Why or why not?

– What are your observations, thoughts, and ideas to modify or iterate over the design?

3.6 Development Process

Discuss what development process you are following with a rationale for it – Waterfall, TDD, Agile. Note that this is not necessarily only for software projects. Development processes are applicable for all design projects.

3.7 Design Plan

Describe a design plan with respect to use-cases within the context of requirements, modules in your design (dependency/concurrency of modules through a module diagram, interfaces, architectural overview), module constraints tied to requirements.

4 Testing

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

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study or acceptance testing for functional and non-functional requirements).
2. Define/identify the individual items/units and interfaces 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 have determined.

4.1 Unit Testing

– Discuss any hardware/software units being tested in isolation

4.2 Interface Testing

– Discuss how the composition of two or more units (interfaces) are to be tested. Enumerate all the relevant interfaces in your design.

4.3 Acceptance Testing

How will you demonstrate that the design requirements, both functional and non-functional are being met? How would you involve your client in the acceptance testing?

4.4 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 the design iteratively as you progress with your project
- If you are including figures, please include captions and cite it in the text

5 Implementation

Describe any (preliminary) implementation plan for the next semester for your proposed design in 3.3.

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

List technical references and 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 data that does not directly pertain to the problem but helps support it, include it 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.