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.

Impossible to tell at the moment, to be filled out later.

Summary of Requirements

- Product must be mountable from the outside of the body of the crane
- Product must be economically efficient
- Product must withstand elemental nature and stormy conditions

Applicable Courses from Iowa State University Curriculum

EE 185, 201, 230, 330, 332, 465, 491, CPRE 281, 288

New Skills/Knowledge acquired that was not taught in courses

Working with a client and how to best communicate with them to meet their provided requirements. The use of CAD to develop testing modules.

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 sensor to be used by Stellar Industries. If time allows, secondary goals are to provide options for angular and radial sensors.

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 easily 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 one mandatory and two optional deliverables for this project:

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 in-house components needed for our new design, creating a prototype, and testing.

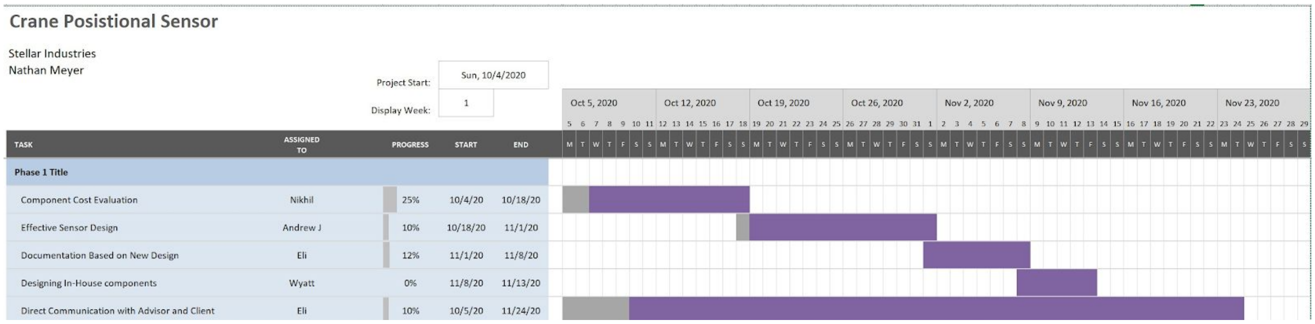
2.2 Risks And Risk Management/Mitigation

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 ~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 in-house 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 possibility is to 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 server 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

Our research has consisted on understanding what type of sensor would best suit our needs. We have settled on two different types of sensors. The gyroscopic sensor and the photo sensor. Stellar wanted us to develop a different type of sensor that was not a gear driven sensor or that could be found on their competitors cranes. The gyroscope sensor has been used in many things including, but not limited to, phones, aircrafts and ships. The photo sensor is used in many things as well, including bus doors and carriage lines in factories. The gyroscope sensor measures angular velocity and can be converted into measuring degrees. The photo sensor detects objects and how much light is reflected or not reflected. Our sensor will be similar to those as stated above but for the crane industry there has not been much, if any, progress with the use of either sensor.

3.2 Design Thinking

For the “define” phase we came up with a couple different aspects that we would have to definitely abide by. We had to be able to use this sensor to compute the angle at which the crane was positioned when the operator was rotating the crane. We also had to be able to place this sensor on the crane without altering any parts of the crane in a substantial way. The sensor has to be a type of “plug and go” solution so the company doesn’t have to spend more money on rebuilding/redesigning their cranes. During our “ideate” phase we came up with many ideas that consisted of a gear driven sensor but after talking to Stellar during our site visit, we found out that they would like to come up with a different type of sensor than what is already being used and can be unique to Stellar Industries. This caused us to rethink what we did in the “define” phase but not too much.

3.3 Proposed Design

The gyroscope sensor design satisfies our needs because it allows us to convert angular velocity into degrees moved. This option also might be able to help us achieve another goal. A gyroscope does not work on only one axis and that will allow us to possibly use it for the angular sensor as well as the rotational. We are planning on trying to implement this onto the joint of the crane where the boom arm meets the base. This should allow us to get the rotational and angular degrees of the crane. This design will hopefully satisfy the functional requirements needed along with the non functional requirements. The non functional requirements consist of how to cover the sensor once we build it so that weather and other environmental hazards do not wear it down.

IEEE, NIST, and many other standards apply to this because when we implement the design we have to make sure that the safety of the user and surrounding area are the first priority. We have to be able to improve upon the understanding of our design so that other engineers can understand what we are trying to achieve. During the design and testing process we also have to be able to accept help from colleagues and other professionals that can help us in designing a well planned design.

Our design is not complete so we can not complete the detailed description of the design.

3.4 Technology Considerations

When considering technology's role in our design process, we went back to the design requirements which were stressed to us in the prompt from Stellar Industries. Their most important need was that of a rotational sensor and for it not to interfere with the physical workings of the crane. In other words, they wanted us to use components that are independent to the working of the crane. Taking this into consideration we went ahead and decided on potentially using a gyroscope component that would attach to the outside of the crane.

3.5 Design Analysis

As discussed in part 3.3 we have not yet completed the design so we aren't able to give a detailed response over the technical limitation of our design yet. As to ideas to modify the design, we have thought of adding dampers which would help make gyroscope drift less of a problem.

3.6 Development Process

We have not really stuck to any development process rationale since many of them really on in person interaction. However, we have chosen to use agile as a framework for understanding how to design and the follow the key beliefs that accompany that philosophy.

3.7 Design Plan

A design plan is an extremely important part of laying the framework of what becomes a prototype.

- Order all necessary elements from Digikey or from the ETG.
- After individual testing of each component we will begin assembly of a hardware design that matches the physical requirements set to us by Stellar.
- Using raspberry pi, along with our compiler to develop code that receives data from gyroscope, makes apt modifications to the raw data and outputs the final data to Stellars transmitter which is present on the crane.

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

We have not started testing our design.

4.2 Interface Testing

To test our design, we plan on creating a turntable to mount our rotational sensor on. This will allow us to test our design on a stable surface and control the angle that the rotational sensor is at. We would be able to collect data from our sensor and compare it to the actual orientation of the sensor

4.3 Acceptance Testing

We will attempt to simulate, as best as possible, outside conditions for this project. We will also travel to Stellar Industries again in the future to mount our prototype and make sure that the company approves of our designs.

4.4 Results

No results have been obtained so far as we have not begun testing.

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.