Intensity-based Alignment of Laser Devices

Track Tech

Dawson Burgess, Spencer Butler, Marissa Samayoa

Email: burg1648@vandals.uidaho.edu

Table of Contents

Executive Summary

We are in charge of automating the alignment process of an optical receiver and laser device. Using the measured light intensity at different positions, we were able to operate the robot to reach optimal alignment by achieving maximum intensity. During this process, we required the purchase of a stronger sensor in order to achieve our 6 feet distance minimum between devices. This allows for the process to work in the presence of artificial and natural light as well as work at greater or smaller distances.

After running into issues with precision and accuracy, our methods of completing this task moved from using GPS positional data to optical (light) intensity. Once this process was developed, we began testing our product. After these trials, our product successfully met the requirements given to us by our client. In the future, our project could be optimized and used for laser data transfer; this is a more cost effective method than for example wifi and fiber cables.

Background

Hansen Photonics Inc is a small, family company located in Burien, Washington. HPI works with universities, environmental science centers, and small businesses to help provide new, cutting-edge hardware solutions for everyone. Our client Hansen Photonics Inc contributes to the computer networking industry with patents that cover modular networking hardware devices and systems. Some of these devices are used for over-the-air optical communications (also referred to as fiber launching).

Fiber and network cables are fast and secure, but often expensive, and require physical connections. Wifi has no cables and can be fast, but struggles with security vulnerabilities and has a hard cap on transfer speeds.

These mainstream methods of handling large amounts of data all have their own unique benefits, but still have associated costs. Our technology will look to take the best of both implementations without their drawbacks.

Specifically, our work will make contributions towards the Hansen Photonics Axon device. The Axon device will enable the copying, multiplexing, and demultiplexing of optical signals at light speed and low cost.

Problem Definition

Our team was tasked with the initial rough alignment process for the alignment of a laser and robot receiver. The robot has movement on the x-axis, y-axis, and r-axis. The robot is to be used to align the laser with a sensor in the robot's head. Once the connection is established, the laser could be used for data transfer in the future. Last year's capstone project completed the fine tuned adjustments for laser optimization. This meant that once the device was already looking in the correct direction, the laser could be more precisely aligned with the sensor to get direct contact. Therefore, we were tasked with the process to get the device looking in the rough direction of the laser, so that their process could kick in. We were assigned to use GPS attachments to complete this rough optimization process. The GPS parts could be used to read in the positional data of each device's location. Then we could translate the latitude and longitude coordinates into directions and manipulate the robot to face the laser. We were given ideal parts to choose for purchasing that were compatible with the boards we were using as well as diagrams for how to properly connect them to our arduino. In the end, our goal is to complete a rough alignment process that could utilize last year's project's fine tuned optimization, so that secure laser connection can occur.

Item	Restriction
Distance	Devices must be at a minimum distance of 6 feet.
Weight	Devices must each be less than 10lbs each.
Ease of use	Process doesn't require user input after initial start.
Coding style	Code must be written in a modular style.

Project Plan

The project team for Track Tech Consists of:

Dawson Burgess (Team Leader)

Dawson assumed the role of Team Leader, responsible for orchestrating and overseeing aspects of the project. His duties included:

Project Coordination:

Dawson facilitated communication among team members (primarily via Discord), ensured adherence to project timelines, and managed project resources effectively. He also scheduled and coordinated project meetings, prepared meeting agendas, and facilitated discussions to ensure productive and efficient meetings.

Client Liaison:

As the primary point of contact for the project, Dawson interfaced with the client and primary sponsor, JP Hansen, to gather requirements, provide updates, and address any existing concerns.

He was also the main point of contact for the lead instructor, Professor Bolden, to ensure essential project documents were submitted.

Risk Management:

Dawson worked to identify potential risks and develop mitigation strategies to minimize project disruptions and ensure a successful outcome.

Marissa Samayoa (Documentation Lead and Meeting Minutes Manager)

Marissa played a crucial role in managing the project documentation and facilitating effective communication through meeting management. Her responsibilities encompass:

Documentation Management:

Marissa oversaw the creation, organization, and maintenance of project documentation, including requirements, documents, design specifications, progress updates, meeting minutes, and all other associated documents. She ensured that documentation is comprehensive, accurate, and easily accessible to all team members.

Meeting Coordination:

She kept detailed meeting minutes of our team, meetings with our client, documenting key decisions and points, action items, follow up tasks, and all other associated items. She also occasionally stepped in to fill roles associated with Team Leader when Dawson was otherwise occupied with scholastic endeavors.

Communication Liaison:

Marissa serves as a communication liaison within the team, disseminating important information, clarifying project requirements, and fostering open communication channels to facilitate collaboration and problem solving.

Spencer Butler (Lead Code Designer and Budget Manager)

Spencer assumed the dual roles within the team, serving as both the Budget Manager and Lead Code Designer. His responsibilities included:

<u>Budget Management:</u>

Spencer oversaw the project budget, tracking expenditures, identifying cost-saving opportunities, and ensuring financial accountability throughout the project lifecycle.

<u>Code Development</u>:

As the Lead Code Designer (most comfortable with arduino/embedded systems), Spencer spearheaded the development of embedded software for driving the robotic arm and implementing the optical alignment algorithm. He collaborated closely with team members to translate project requirements into functional code solutions.

<u>Quality Assurance</u>:

Spencer conducted rigorous testing and debugging of code to ensure reliability, functionality, and adherence to project specifications.

<u>Documentation</u>:

Spencer contributed to project documentation, documenting core modules, development processes, and test results to facilitate future maintenance and knowledge transfer.

While each team member had distinct roles and responsibilities, collaboration and cross-functional teamwork was essential for the successful execution of the project. Dawson, Spencer, and Marissa worked synergistically, leveraging their individual strengths and expertise to achieve common project goals and deliverables. Through effective communication, coordination, and mutual support, the team overcame challenges, maximized productivity, and drove the project towards a successful completion.

Changes in Project Goals and Schedule

The initial schedule for our project (which is outlined in the Gantt chart provided in the appendix) reflected a sequential progression of tasks aligned with the project timeline. This timeline consisted of 5 main sections:

Project conception

This section characterized the conception phase of the project, encompassing the acquisition of project bids, team and instructor meetings, client consultations, and the initiation of planning and documentation.

Project definition and planning

This section delineates the conceptualization phase, detailing the generation of ideas and the development of a comprehensive plan. It encompasses the creation of product requirements documents and our value proposition, the establishment of scope and goal setting, the formulation of a budget and Gantt chart, the evaluation of existing prototypes and code, and the breakdown of tasks required for project execution.

Project launch and execution

This section elucidates the essence of our project, encapsulating its focal points. It comprises several key components, including the testing of existing code and prototype, the prototyping and design of our own code, the procurement, installation, and testing of GPS devices, the development of necessary code, and the subsequent refinement of all code elements.

Project performance and control

This section highlights the final stages of our project, encompassing the deployment and testing of code on the prototype, soliciting client feedback, conducting additional code testing, addressing bugs, making necessary additions, and preparing for packaging.

Project close

This section exemplifies the culmination of our project, encompassing the resolution of project punch list items, conducting a postmortem analysis, preparing for and presenting at expos, and compiling the final report for submission.

The old schedule was focused primarily on the project launch and execution phase, with clear cut sections between each phase. However, as with many complex endeavors, the actual schedule deviated from the intended plan. Primarily, the transition from the old GPS-based approach to the new optical intensity-based approach necessitated adjustments to the project timeline. An additional factor impacting our planned schedule was the considerable time invested in attempting to make the previous project designs operational. Unfortunately, these efforts proved futile, forcing a complete restart of the project. Collaborative discussions with our client led to a strategic reassessment of project priorities and timelines to accommodate the shift in approach. Consequently, certain tasks were rescheduled and new milestones were introduced to reflect the revised project trajectory.

Despite these deviations, proactive communication and project management enabled us to adapt to changing circumstances and mitigate delays. As a result, while the actual schedule may have diverged from the initial plan (also referenced in the updated Gantt chart in the appendix), the project stayed on course for successful completion within the adjusted timeframe. During project execution, several tasks underwent changes, while others had their durations adjusted. Following the prolonged process of ordering, installing, and testing the GPS, our team encountered the need to repeat a similar sequence for a new Adafruit TSL2591 light sensor. This extension impacted both the project's performance and control phases, while also slightly compressing the launch and execution phases.

Concepts Considered

The overall goal of the project was to create software that would align optical data transfer devices. This is a broad goal. However, in order to guide the project and facilitate producing an actual prototype, a specific primary use case was identified: optical transfer between server racks in a datacenter. This primary use case provides several constraints, most important among them being working indoors, and working at 6 feet of separation. Two main approaches for aligning the devices were identified and considered, corresponding with two ways of integrating these into an overall alignment process.

The first approach to alignment was GPS-based. This approach would use two GPS receivers: one at the laser source, and one at the laser receiver. Each of these GPS receivers would measure their position. These positions would be communicated between devices as necessary. Control software at the laser receiver would then compare the positions to calculate their offset. From this relative position, the necessary orientation of the laser receiver could be determined. Its initial orientation would be determined, and then the robot would realign itself to achieve the necessary orientation to face the laser source.

There were several methods considered to coordinate the measurements and comparison of the two GPS locations. The GPS receivers could both integrate directly into a single microcontroller, which would require multiple UART serial ports either via hardware or software. For greater versatility, the two GPS receivers could each connect to their own microcontroller, with the two controllers communicating via any standard protocol to transfer the location of the laser source to the controller at the laser receiver.

This GPS-based alignment approach would come with several vulnerabilities, particularly with the primary use case. In order to function, the GPS receivers need to communicate with satellites and get a positional fix. This fix may not be easily achieved, and it may lack precision. The lack of precision means that this GPS-based approach would not be suitable for very fine alignment of the devices. There were several considerations for ways to compensate for this. Since the two GPS receivers would be physically close to each other, it was hoped that their errors would be similar, and the error in their relative position would be smaller than the error in either absolute position. Additionally, it was hoped that taking measurements over a longer period of time would lead to a more accurate position being calculated, facilitating the alignment process.

The second approach to alignment was signal based alignment. For this, values from the receiver's light sensor would be taken. The control software would then look directly at these values to determine what the optimal position should be. This would necessitate a sensor which could effectively measure a broad range of light values: it must be able to measure both the dim ambience and the extremely bright laser. This also would necessitate a sensor which can measure at a fine resolution: the direct, best alignment has to be distinguishable from catching just the edge of the laser, and the edge of the laser must be distinguishable from ambient light. With these requirements, this approach would be well-suited for fine alignment, as the laser is significantly brighter than any unrelated light sources. However, the laser is finely focused, meaning it can be detected in only a small region in the target search volume, so this approach would have weaknesses in performing initial, broad alignment.

The overall alignment processes considered were a hybrid process and an only intensity-based process. The hybrid process would use the GPS-based approach for initial, broad alignment of the devices, and then use the signal-based approach to finalize the alignment and achieve the necessary precision therein. This would compensate for the weakness of the intensity-based approach for broad alignment, by using GPS to constrain the search region before beginning the intensity-based search. However, this would make the process susceptible to some of the vulnerabilities associated with the GPS-approach, such as difficulty getting a fix or in achieving precise enough locational data. As mentioned, the primary use case, at only 6 feet of separation, was identified as being particularly prone to these vulnerabilities. However, this approach would provide a large degree of adaptability for aligning devices at higher distances than the primary use case called for.

In contrast, the pure intensity-based process was considered particularly well-suited for the primary use case, with less adaptability for others. This process would use the intensity-based approach with two different coaxial light sources: in addition to the highly-intense, focused laser which is the final target for alignment, a broad light source would also be used. This broad light source would create a much larger target for initial alignment. This would compensate for the primary weakness of intensity-based alignment, by creating a larger target for the initial search, and thus allowing both the broad and fine alignment to be performed via the same approach. This works well at 6 feet of separation, since it does not require much volume of light to be visible at 6 feet, so a very broad range of devices would work as the secondary light source. However, this approach would not be viable at significantly longer distances, since the amount of light required for broad alignment would grow prohibitively large.

Both processes were considered viable designs for an alignment system. Despite the increased suitability of the pure intensity-based process to the primary use case, we decided to proceed with testing of the hybrid approach, owing to its greater adaptability to more use cases, along with the initial request of the client for a GPS-based approach.

Concept Selection

In our project's evolution, we transitioned from the original GPS-based approach to a new optical intensity-based approach for alignment.

The initial stages of our project, the concept selection process primarily relied on brainstorming sessions, qualitative analysis, and meeting with our client JP to better understand what he desired out of this project. In this previous phase of the project, our selected concept revolved around utilizing GPS and accelerometers to acquire positional data for the alignment process. We identified multiple approaches based on the project requirements and objectives, followed by discussions to evaluate the feasibility and potential effectiveness of each approach.

However, as implementation progressed, it became apparent that the GPS based approach faced challenges with accuracy and impedance issues. Our original plan also lacked systematic evaluation and quantification, leading to subjective decision making and limited insight into the comparative merits of different concepts. Recognizing a need for a more structured and data-driven approach, our team revamped the concept selection process for the current phase of the project.

We introduced a decision matrix as a key tool to facilitate systematic evaluation and comparison of design alternatives. Our new method, based on optical intensity, emerged as a more promising alternative, with the decision made in collaboration with our client. In conjunction with this, we packaged up all of our previous work for Hansen Photonics to make use of in potential future projects.

Criteria	**GPS-Based Approach**	**GPS-Based Approach with Accelerometers**	**Optical Intensity-Based Approach**
Alignment Accuracy	2	3	4
Impedance Issues	1	2	5
Reliability	1	2	4
Client Satisfaction	2	4	5
Implementation Complexity	2	1	4
Cost Effectiveness	3	2	4

Key: 1-Poor 2-Fair 3-Good 4-Very Good 5-Excellent

GPS-Based Approach: 11

GPS-Based Approach with Accelerometers: 14

Optical Intensity-Based Approach: 26

Final Concept

Optical Intensity-Based Alignment

The optical intensity-based alignment method represents a fundamental shift in our project's approach to alignment. Unlike the traditional GPS-based methods, which rely solely on satellite data, this innovative approach introduces a somewhat novel technique. Here, the robot is equipped to detect a larger light source before aligning with the laser signal. This strategic pivot ensures a more precise and accurate alignment process, promising enhanced efficiency and effectiveness in achieving project goals.

System Architecture

The physical device uses a robot design with three xArm servo motors providing three degrees of motion. Two of these axes are translational, providing movement along a plane containing the vertical axis, while the final axis is rotational about the vertical axis. These servos are interacted with through a Hiwonder board.

It also uses a TSL2591 ambient light sensor integrated in an Adafruit board. This sensor provides a very broad range of measurable values, with configurable gain and integration time settings. It can provide 16-bit output in two wavelength bands: infrared and visible light. All communication with the sensor is done according to the I^2C protocol. The Adafruit board provides easy connection to the sensor, along with voltage regulation to support a range from 3.3-5V.

The target light source is a laser pointer. This is highly focused and very bright. The selected alignment process uses light intensity for both broad and fine alignment. In order to facilitate the broad alignment, a flashlight is attached to the laser pointer, providing a broader cone of light coaxial to the fine beam, and originating from the same location, meaning that aligning to it is aligning roughly to the fine beam.

The software is written in C++ using the Arduino framework. The servos and light sensor are accessed using prewritten libraries. The alignment algorithm integrating these constitutes the original software work of the project.

This alignment algorithm is structured around a generic function to optimize the position of an individual axis of the robot. This function is given an axis, step size, and search radius. It then varies that axis to search the area around whatever the initial position along that axis is. As it progresses, it stores the brightest measurement of the sensor found so far, and the position where that measurement was obtained. This searching can be made more fine-toothed by providing a smaller step size, down to the resolution limit of the servos. When it has searched the entire designated radius, it returns to the brightest position, enabling further alignment to proceed from there.

In order to find the brightest position overall, this axis optimization function is repeatedly called with different axes. First, to find the approximate position of the light source, it searches along the rotational axis with the sensor on medium gain. This supports finding the broad light source amidst the ambient light of the room. Then, to support finding the laser which is focused and very bright, the sensor is swapped to low gain, preventing any possible measurement overflow. The function is then called repeatedly, rotating between the three different axes. After each optimization, the sensor's value is checked. This proceeds until the laser has been found, as determined by the sensor's value crossing a configurable threshold.

One shortcoming in this design is the potential of the device to track to a different light source than the intended signal. This is highly unlikely in the second stage with low gain, as the laser is much brighter than any lights which may normally be in use. It may happen in the initial stage, when searching for the broad light source with medium gain. This will result in the search for the laser beginning from a position facing something else, such as a sunny window, rather than the flash light, slowing down the overall alignment process. However, this was not deemed a significant lack of operational capacity for the device. It is intended to function in controlled indoor environments. Bright lights may be manually occluded to prevent this shortcoming. Additionally, the specific form of the broad light source is not integral to the design, and using a brighter flashlight would generally prevent this.

Design Evaluation

Our project specifications include: a 6ft distance minimum between devices, each device needs to weigh less than 10 lbs, the code needs to be written in a modular style, and the program needs to run without user input after the initial start. According to our DFMEA, the issues that can occur are as follows.

There could be wiring issues which can cause incorrect or loss of light intensity values. We could implement within our code a type of flag that potentially stops the process and alerts the user that there are issues in our values. When the hardware seems to be having issues, there are recognizable numbers that we get repeatedly. This helps us to understand that there is a problem that we need to fix. We can have the flag keep an eye out for these problematic numbers.

There is a possibility of robot range issues where the robot hits the battery below it and sometimes gets stuck. Not only does this cause the robot's values to become skewed, but it can also cause the x-axis cog to come off the track. When this happens, the robot can not move properly and limits our success in finding the laser. Since the range that we were given with the robot seems to be inaccurate, we can find the correct range and while scanning, prevent the robot from even getting near this area. This would eliminate the concern.

Since the robot has a strong sensor, it picks up values from all sorts of light whether it be artificial or sunlight. This can cause issues with the robot accidently getting distracted and not correctly identifying the laser as the correct end point. Since the laser is a stronger source of light, we have implemented a change of gain within the code when doing smaller scale radius searches. This makes sure that the receiving values are above a certain intensity since the lower intensity light sources will not be able to be as easily detected. This makes sure that the light that we are coming in contact with is in fact the laser.

There is an unfortunate issue with the laser that we were given for our project. Due to the same laser being used in previous year's project, the laser has been used continually and nonstop for periods. Now the laser cannot hold a charge. Since the laser is one of the main components that determines the program's success, it poses a big problem when the light we are searching for suddenly goes out and cannot be found. Due to this issue, we purchased a female to male USB cord that must be plugged into the lasers charging port at all times. Another issue with the laser is that the button to turn it on has to be continuously pressed for the light to be on; it is not a switch that stays on. This means we have to tape the button down anytime we need to use it.

When these problems were not present, we tested our project to confirm whether or not our project requirements are satisfied. For the distance, we used a tape measure and confirmed that the 6 feet minimum is being upheld. We used a scale to weigh both the laser and receiver and confirmed they are much lighter than 10lbs. The robot is able to find the laser correctly when we adjust the angle of the laser at multiple increments. The code is also written in a way that the process could work at a smaller or larger distance than 6ft. Below are the results of our tests.

Senior Capstone Design

Project: Intensity Based Alignment of Laser Devices | **Primary Author:** Marissa Samayoa

Team: Track Tech | **Date:** 4/4/24

Design Validation Plan & Results (DVP&R)

Requirement	Test	Test Subject	Target Date	Result	Recommendation
The aligment process shall work at a minimum distance of 6 feet.	Measure distance between devices.	Fully functional prototype	4/4/24	Tested 4/4/24 - Measured distance is 6 feet apart.	Meets requirements - no further action required.
The devices shall weigh fewer than 10 lbs each.	Weigh the full system on a scale.	Fully functional prototype	4/4/24	Tested 4/4/24 - Measured weights are 1.25 and 1.06 lbs.	Meets requirements - no further action required.
After beginning the program, the alignment process shall be fully automatic.	Start the program and make sure it runs on its own, not expecting input.	Fully functional prototype	4/4/24	Tested 4/4/24 - The entire process works on its own after the initial flash of code.	Meets requirements - no further action required.
The program shall be written in a modular style.	Check code to make sure that the program is written in a modular style.	Fully functional prototype	4/4/24	Tested 4/4/24 - The code is scalable and could be used for a smaller or larger distance.	Meets requirements - no further action required.
The code should compile and run.	Compile the code and flash it to the board.	Fully functional prototype	4/4/24	Tested 4/4/24 - The code does compile without errors and runs the program.	Meets requirements - no further action required.
Devices should be able to make a connection from 45 degrees.	Rotate receiver 45 degrees off-axis and run program.	Fully functional prototype	4/4/24	Tested 4/4/24 - The robot successfully aligns with the light.	Meets requirements - no further action required.
Devices should be able to make a connection from 90 degrees.	Rotate receiver 90 degrees off-axis and run program.	Fully functional prototype	4/4/24	Tested 4/4/24 - The robot successfully aligns with the light.	Meets requirements - no further action required.
Devices should be able to make a connection from 180 degrees.	Rotate receiver 180 degrees off-axis and run program.	Fully functional prototype	4/4/24	Tested 4/4/24 - The robot is unable to find the light when it is facing 180 degrees opposite.	Recommendation: The robot's z axis does have a limitation of turning 135 degrees to either the left and right (270 total). This means that the robot itself is causing the limitation due to a blind spot. The only way to solve this problem would to change the robot head itself.

When it comes to sustainability our project supports three of the global goals. The first is industry, innovation, and infrastructure. This pertains to our project since our projects encourages the use of laser data transfer. This is a wireless technology, and our client Hansen Photonics hopes to make this type of technology available to all. The next goal is sustainable cities and communities. This type of data transfer is less intrusive to cities since it does not require digging through the ground like fiber optic cables. In a similar way, the goal of life on land is also supported. Since laser data transfer does not require as many physical connections, it is less harmful to the environment.

Future Work

The prototype is suitable for implementation in the server rack use case as-is. However, it could be further refined by improving the physical structure of the device, with particular focus on the durability and appearance of the attachment of the new sensor. The housing could be redesigned to fit the larger form factor of this sensor, or a smaller board designed around the same sensor could be used.

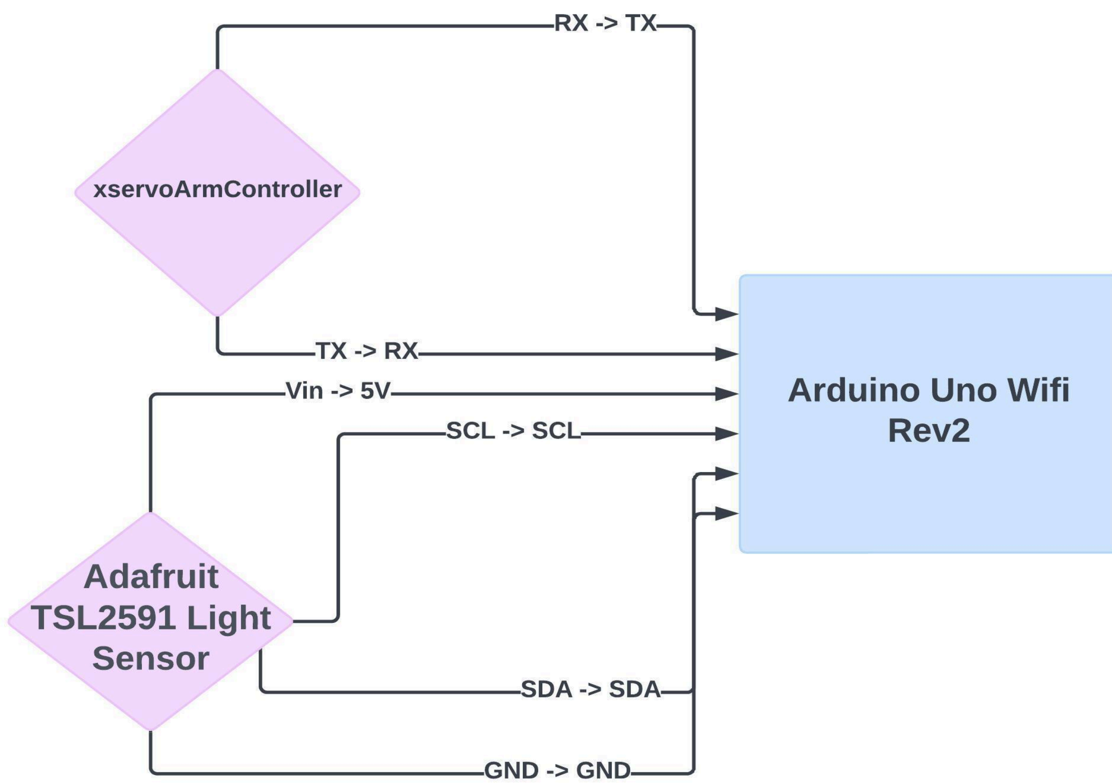
Additionally, there is room for refinement to the alignment software. The search algorithm could be redesigned to support finding the optimal position more quickly via a more structured and comprehensive search of the 3d space, rather than only searching along individual axes. This could take from one to three weeks: there are standard and simple comprehensive search algorithms which could be implemented simply, but guaranteeing higher speed from them would require more testing.

Another step could be added to the end of the search process to ensure that the laser is centered on the sensor, rather than only guaranteeing contact. This has an estimated timeframe of two to four weeks. The sensor is small, and the servos provide very limited resolution of movement at that scale, so this would likely entail establishing the bounds of where the laser can be detected at all, and then going to the center of that space, rather than attempting to directly find the brightest position.

Finally, further development could focus on the GPS-based alignment process for use cases at larger distances. This may take from two to eight weeks. Basic software exists to support GPS alignment, but would need to be significantly altered to function at the distances where GPS alignment is viable, which would add additional constraints and demands, such as needing to coordinate initial communication between separate devices at each GPS receiver.

Appendices

Wiring Diagrams



Coding Libraries

Adafruit_TSL2591.h -- also several others included for this

https://github.com/adafruit/Adafruit_TSL2591_Library/tree/master

xArmServoController.h

https://github.com/ccourson/xArmServoController

Main Program Code

https://github.com/dawson-b23/Cs480CapstoneTrackTech/tree/main/source

DFMEA Worksheet

Potential
Failure Mode and Effects Analysis
(Design FMEA)

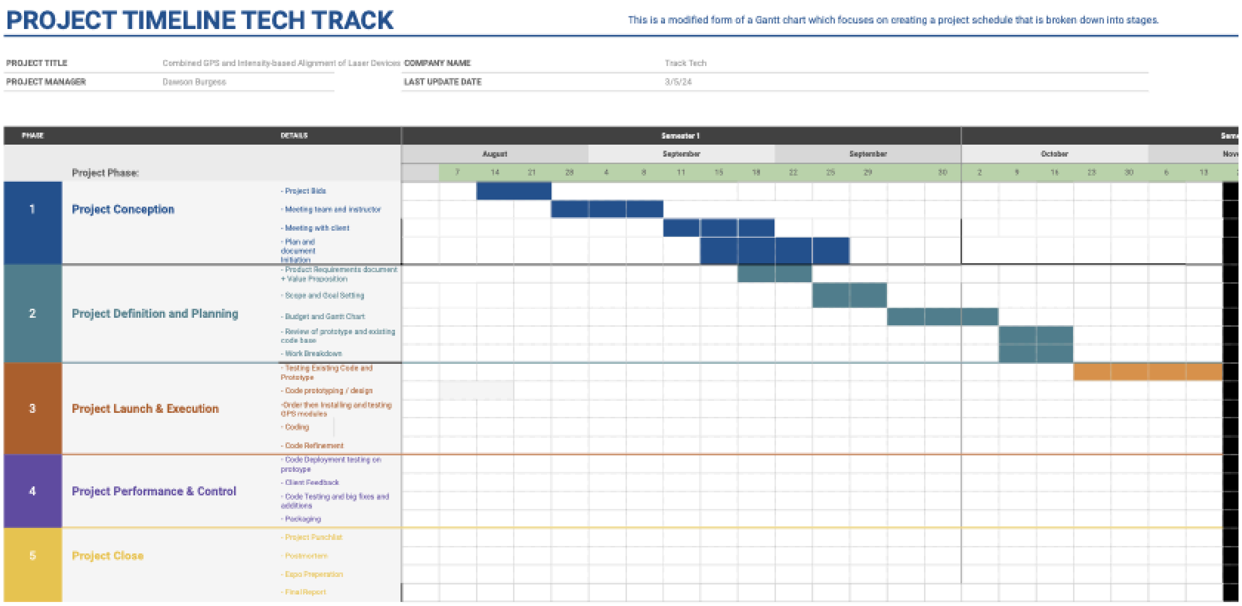
System __________
Subsystem __________
Component __________
Design Lead __________
Core Team __________

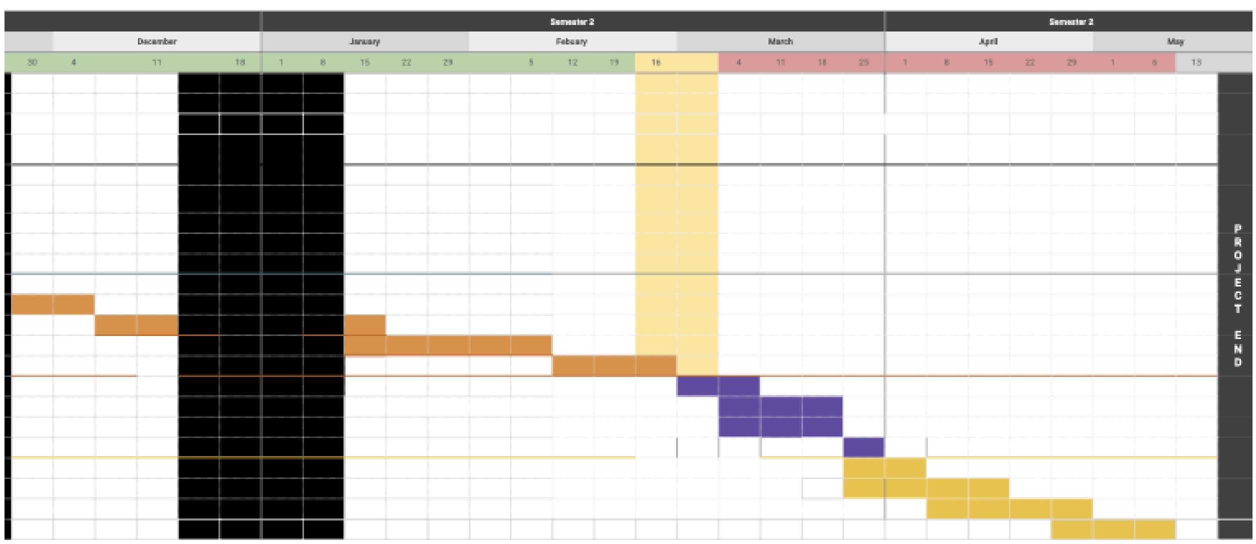
Key Date __________

FMEA Number __________
Prepared By __________
FMEA Date __________
Revision Date __________
Page 0 1 of 1

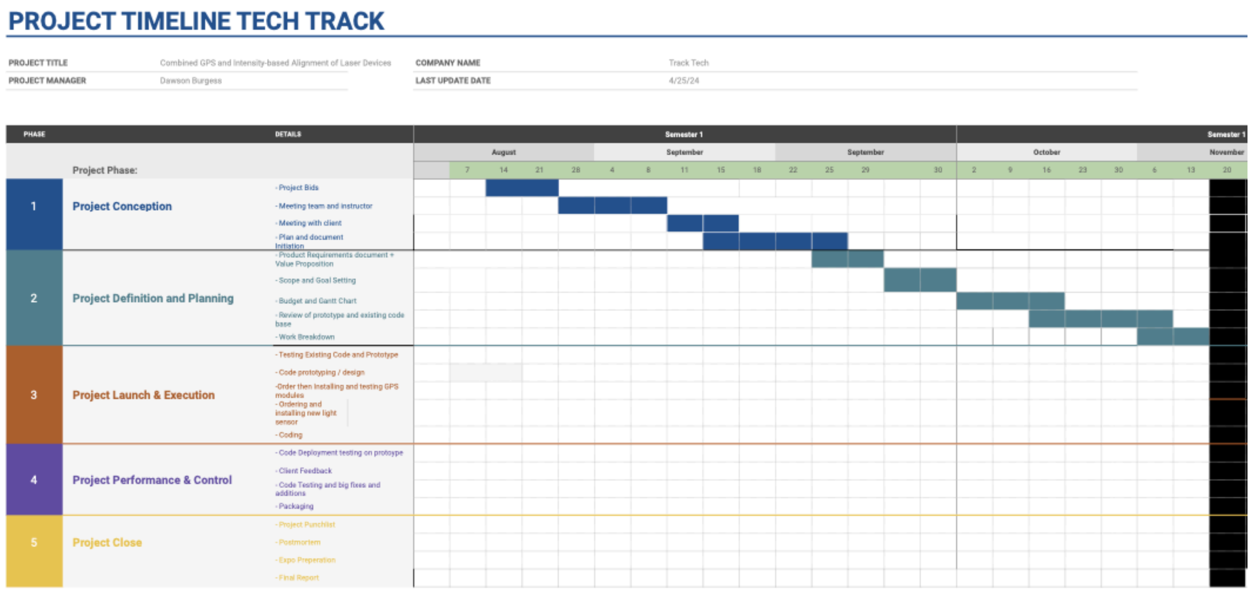
Component	Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Prob	Current Design Controls	Det	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
												Actions Taken	New Sev	New Occ	New Det	New RPN
Connecting wires	Power and communication	Inconsistent light sensor connection	Reported values being incoherent	5	Sensor failing to measure; sensor failing to transmit its measured values	5	N/A	6	**150**	stop and indictate when likely error occurred						0
Laser	Key functionality componenet	Can't hold charge, loses power	Unable to be detected by sensor	5	Has a button that turns it on, faulty battery	7	Button taped down; USB charging cable for wired power	2	**70**							0
Light sensor	Measures light	Measuring other source of light	Initial alignment tracks to other light source	3	Other light source being brighter	4	Manual occlusion of bright external light sources (i.e. large windows)	1	**12**							0
Robot	Movement Range	Robot bottoming out	Incorrect adjustments, cogs going off the track	5	Robot not able to scan	6	Using default robot range for each axis	7	**210**	Limit movement of y axis, so it can't go that far						
									0							0

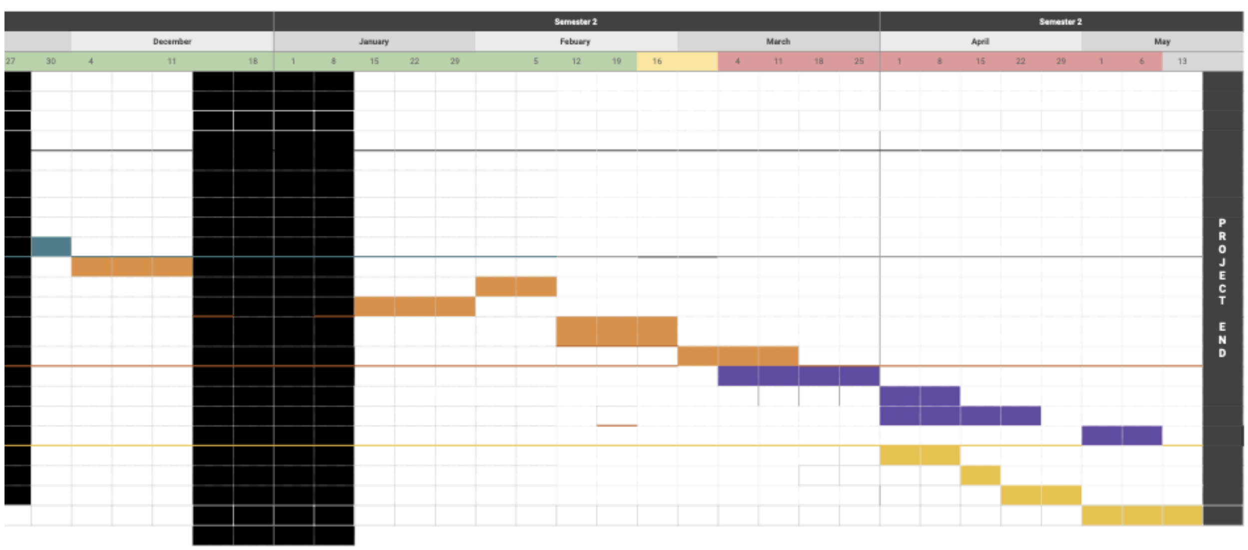
Original Schedule





Executed Schedule





File Organization

Inside source folder of project GitHub:

- basicAlignment -- rough framework for GPS-based alignment
- basicGPSHub -- code for master device in i2c-based reception of two gps locations
- basicGPSReceiver -- code for slave device in i2c-based reception of two gps locations
- **finalFiles -- final design, intensity-based alignment**
- gpsParsing -- basic code to receive and parse a gps location
- lightSensing -- basic code to retrieve light values from the TSL2591 sensor
- oldCode -- program received from the previous team
- projectInitial -- early, flawed attempt at controlling the servos
- servoControlling -- basic code to control the servos
- softwareSerialAlternation -- code for virtual-port-based reception of two gps locations