Automatic Tracking of Actors with Intelligent Theatrical Lighting Systems

Design Document

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Executive Summary

Engineering Standards and Design Practices

- J-STD-016-1995 - Standard for Information Technology--Software Life Cycle Processes--Software Development--Acquirer-Supplier Agreement
    - This standard outlines good development practices and activities for software development. It includes planning practices and examples of good software products.

- American National Standard For Evaluation of Wireless Coexistence
    - This standard explains the use of GPS (radio frequency), to coexist with other equipment (PCBs) to function (communicate data) in its intended operational environment (stage theater).

Summary of Requirements

List all requirements as bullet points in brief.

- The spotlight must autonomously track an actor/actress
- The spotlight must work in an indoor environment like a theater
- The spotlight tracking system must have a reasonable cost

Applicable Courses from Iowa State University Curriculum

CS227, CS228, CS311, CS309, EE224, EE 201, EE 414

New Skills/Knowledge acquired that was not taught in courses

Computer vision/video processing

Group Management

Antenna Transmission

Infrared sensors

Infrared cameras

Table of Contents

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

1 Introduction

1.1 Acknowledgement

This project is being made for Story Theater company, located in Ames, under the vision of our advisor Mat Wymore. Story Theater company also contributed financial support and provided a programmable spotlight.

1.2 Problem and Project Statement

In small theater organizations, autonomous tracking spotlights could provide an easy way to program a show's spotlights, but commercial tracking systems for spotlights are too expensive. An automatic tracking spotlight would allow the Story Theater company to save time and money as they wouldn't have to hire a dedicated spotlight person.

This project hopes to design and implement an affordable spotlight tracking system that can be used by Story Theater company in their box theater. The spotlight system should be able to track an actor/actress after started and with no human intervention. The spotlight system could be programmed to start and stop tracking a person at different positions so it can change its focus at set times.

1.3 Operational Environment

The operational environment for this product would be a theater environment. The space would be a low light environment, and the theater is a box style theater. The product would be kept in an environment that would be at normal room temperatures and moderate dust levels.

1.4 Requirements

- Limiting the budget to $300 for equipment
- Having a functioning autonomous spotlight to track the actor
- Tracking the actor on the stage while moving on x, y, and z axis

1.5 Intended Users and Uses

This project is to be used in Story Theater Company to track a specific actor across the stage autonomously during an act regardless of other lights.

1.6 Assumptions and Limitations

Assumptions:

- The actor will not get out of the stage given parameters.
- The tracking will start from a given point on stage

Limitations:

- The budget is $300.
- There must be no human control to the spotlight besides the movement of the actor.

1.7 Expected End Product and Deliverables

- A Software application, modem, that will receive the location of an actor/actress and move the spotlight accordingly .
- A tracking indoor GPS device that determines the position of the actor on stage and sends data to a wall beacon
- The wall beacon connects back to the modem informing the position (x,y,z) of the actor and move the spotlight accordingly

2. Specifications and Analysis

2.1 Proposed Design

tracking the actor's location on stage:

- 4 wall beacons and a 1 indoor tracking sensor
- infrared camera

Moving the spotlight

- feeding the software the location through a modem

- We have been testing different open source codes to receive the data and control the spotlight.

- We have been playing around with Freestyler software to move the spotlight around.

- Contacted Follow-Me company, but we are not considering them because of their price.
- contacted Marvelmind robotics for their indoor GPS tracking devices, and we are considering their product.

2.2 Design Analysis

The team's progress:

- We have figured out how to move the spotlight using Freestyler software.
- We also detected faces using a regular camera.
- We figured out how to use the wall receiving beacons and the indoor tracking device to track the location of the actor.
- The modem receives the location information, and sends it to the spotlight to move accordingly.

What worked well:

- Freestylers website has worked fine, and the spotlight moved according to the commands from the software.
- The tested camera detected faces with some challenges.
- We still need to buy the products, indoor tracking sensor, to try them out, but the Youtube video shows that it works well, https://www.youtube.com/watch?v=lImQtorAezU. I also have been contacting the customer service of the company, Marvelmind Robotics, asking them about their indoor tracking device.

Observations and ideas:

- The camera needs to be accurately detecting faces in order to link it to Freestyler software.
- The team will most probably be buying the indoor tracking GPS kit from Marvelmind Robotics, to place around the theater and test with the spotlight.

Strengths and weaknesses:

- The indoor tracking GPS kit is accurate (+/- 2 cm) tracking locations.
- The infrared camera is still not solid for face detection.

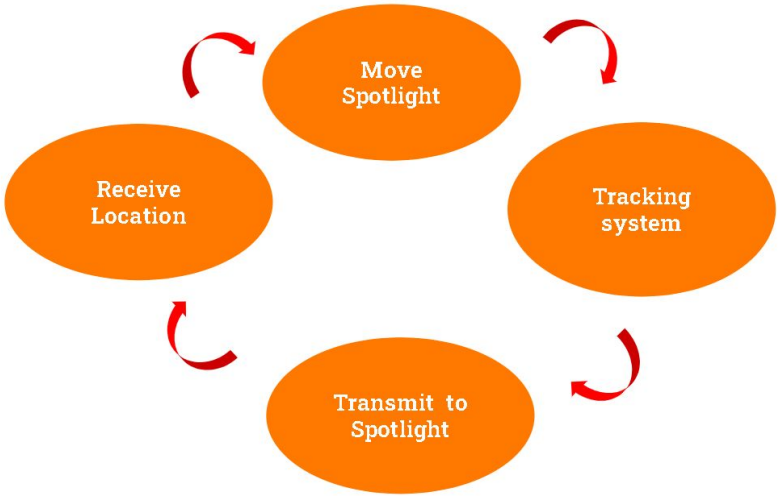
2.3 Development Process

The team is following the Agile process in terms of planning and testing. The team has two meetups per month. During these meetups, we plan what to design (antennas, infrared camera, sensor kit) throughout the month. After that, the team research, and prepares the needed parts. Next, we test the spotlight with the prepared devices to see if they work. Finally, we evaluate the performance of the spotlight based on the tested spotlight.

Reaching out for tracking companies has been helpful for considering the exact devices needed for this project. As of now these are the devices we are planning to buy: **Starter Set IA-01-2D**, **Beacon Mini-RX,** and **Inverse Architecture in the Paired Beacons configuration.**

2.4 Design Plan

Conceptual Design Diagram



3. Statement of Work

3.1 Previous Work And Literature

People tracking has been done in many ways before but usually the solutions that are there, are not exactly tailored towards theater and if they are they are way too expensive for our budget. This research has been done by our client to reach to the conclusion of building an affordable easy to use tracking system. We have looked at other research work that was similar to what we want to do. for example this is one research we looked at:

Jayanth, S Narasimha & Teja, N & Bhagyasri, Y & Shahapur, Kiran. (2016). RF based Remote Stage Lighting Controller. 10.13140/RG.2.1.4553.8165. https://www.researchgate.net/publication/302590662_RF_based_Remote_Stage_Lighting_Controller

The previous work talks about using RF transmitter to control DMX lighting , we gain interesting things from the documents as to how a control system was built to interface into the DMX lighting as well as using an RF transmitter to wirelessly control the DMX lighting which might give us an idea about how to track an actor from far away.

One of the products we looked at for tracking is this kit from Pozyx that uses wireless communication but it is ridiculously expensive, priced at 1050 euros per kit. https://www.pozyx.io/shop/product/creator-kit-65 this could potentially automate much of our

project and we would be just left to make a control hub for the lighting. However this is not a feasible solution taking in consideration our budget.

3.2 Technology Considerations

The tracking system we considered is Localino, which uses four printed circuit boards (PCB). Three of which are anchors (receivers), and one PCB is a tag (transmitter).

Method	Accuracy (%)	Cost	Advantage	Disadvantage
Antennas &transmitter	%99	High	Have the choice of tracking manually or automatically	Too expensive
Infrared Camera	------	Low	Potential to easily switching targets without multiple tracking devices	Hard to work with, inconsistent tracking.
Localino	+/-10 cm	$159	It has a scalability, user-friendly, and high-quality design and open source software	----------
Indoor GPS	Precise (+/-2cm)	Low-moderate	Precision is exact and performs well indoors	Beacons must be mounted on the walls around the corners of the stage.

3.3 Task Decomposition

1. The tag PCB transmits the location of the actor to the anchor PCBs.
2. The anchor PCBs receive the coordinates, then transmit them to the DMX spotlight.
3. The spotlight receives these data coordinates, then moves accordingly.
4. The DMX spotlight is now following the actor.

3.4 Possible Risks And Risk Management

Possible Risks:

- The Localino Kit is not accurate or working at all.
- Localino kit is not documented well
- Localino is not a verifiable Tested DIY kit

Risk Management:

- Contact Localino Company.
- Use people's projects as a guide.

3.5 Project Proposed Milestones and Evaluation Criteria

- The spotlight is controllable by a python code.
- The tracking system can track the position of the actor/actress.
- The computer vision software can track the position of the actor/actress.
- The tracking system can connect to the programmable controller and send the position data to the controller

3.6 Project Tracking Procedures

We will use group messaging to keep in constant contact with each other and to inform others about progress. We can also use Gitlab issues and milestones to track the progress of the application.

3.7 Expected Results and Validation

The expected results will be a computer application along with a tracking system that works together to control a DMX spotlight. The spotlight will track an actor/actress autonomously and will be able to be programmed to start and stop tracking through the application.

The Localino tracking system was not fully documented, and could not have received the coordinates of the actor or move the spotlight accordingly. Although, we were able to establish a communication between the tag and anchor PCBs. As a result, an arbitrary plot showed up in the software. The plot shows the anchors and the tag moving around as the actor is moving. On the other hand, these plots are not exact coordinates of the position of the actor as of now.

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

Project development will be divided into three different phases, by the end of each phase a set of deliverables expected crospond to that phase. Phase one consists of researching different types of software that could be used to control the spotlight. A suitable tracking system will also be decided. Phase two implementing the hardware for the tracking system and spot light control. Phase three testing and final documentation.

1st Semester:

Phase Number	Description of work	Comments
Phase 1	Theatrical Spot Light Control System and Automatic Tracking System research. ● Research different options for how we control the spot light. ● Research different options for a tracking system that support the spotlight. ● Research on the ability of integrating the spot light control software and automatic tracking system.	This will be the start of the first semester
Phase 2	Implementing the hardware for the tracking system and spot light control. ● integrating the software and hardware for the tracking system ● integrating spotlight software with DMX ● integrating the spotlight with the tracking system.	This will be the start of the second semester
Phase 3	Testing and Final Documentation	

2nd Semester:

Phase Number	Description of work	Comments
Phase 1	Receive the Localino PCBs and get them setup with software.	
Phase 2	Solder the PCBs	
Phase 3	Flash the microcontroller and initiate communication between the tag and anchors.	Heavily coding is involved
Phase 4	continue to work on using OLA to make the spotlight controller	
Phase 5	Continue development of a Python software controller for the spotlight controls.	
Phase 6	Update the Documentation of the project and Test everything	

4.2 Feasibility Assessment

one of the challenges could be developing software to interact with the client equipment.

buying some hardware for this project will be another challenge.

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

4.3 Personnel Effort Requirements

Our team consists of two computer engineers who are responsible for developing software.

three electrical engineers working on RF signal and antenna design.

4.4 Other Resource Requirements

some material might be required to conduct the project, and we agreed with the client to provide these materials. Other resources, we can share some money to complete the project.

4.5 Financial Requirements

Our team purchased the localino tracking system from an online store. The system cost around $200.

5. Testing and Implementation

5.1 Interface Specifications

The spotlight will be controlled by DMX signals sent with the help of the Open Lighting Architecture framework.

5.2 Hardware and software

For the control module we created simple test data with a python function that saves it to a file. The control code is run and reads the file line by line to simulate a flow of data from the tracking system.

For the tracking system we tested the localino boards and verified that we received communication from the tag to the base station, but we were unable to get positional coordinates out of the program.

5.3 Functional Testing

- System supports automatic tracking with at least one light.
- System supports automatic tracking with at least one actor.
- System supports tracking an actor assuming a fixed starting location for the actor.
- Delay between actor movement and light movement is less than one second.
- System supports a rectangular, two-dimensional playing space.

We mounted the spotlight with a laser pointer attached to it in the theater classroom in Carver 308. We set up the stage space choosing a zero point and input the calibration information into the controls program. We were planning on measuring the accuracy of the spotlight by inputting coordinates and measuring the difference of the actual positions from the laser pointer's position but were unable to due to COVID-19.

5.4 Non-Functional Testing

Testing for performance, security, usability, compatibility

- System must be designed as an add-on to existing hardware.
- System should be low cost(less than $500 fixed cost).
- System should be designed such that it could be integrated with typical theatrical lighting software in the future.

5.5 Results

Tracking System:

- We purchased the localino tracking system and WiFi chips and soldered them together.
- We have been able to flash the localino boards and solder them to distinguish each as either anchor or tag (3 anchors and 1 tag), as well as we have established intercommunication between the boards but not with the PC server .
- We were able to compile and run the python code that is supposed to a base server for the localino

Control System:

- We have a working python controller that uses OLA's APIs to send signals to the DMX spotlight.

- The controller takes a three-dimensional coordinate and calculates the correct DMX tilt and turn values and sends it to the spotlight.

6. Closing Material

6.1 Conclusion

We have a functioning control module written in python that takes 3D coordinates and controls the spotlight. The tracking system is partially working but does not give us 3D coordinates and so we are unable to put the system together.

6.2 References

https://github.com/thotro/arduino-dw1000/wiki