

ECE 445
Senior Design Laboratory
Project Proposal

CfA Flying Area Accuracy Determination

Team No. 78

Bella Altenbach
(ialten2@illinois.edu)

Juliana Temple
(jtemple4@illinois.edu)

Alex Hu
(alexhx2@illinois.edu)

TA: Sarath Saroj
Professor: Arne Fliflet

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Abstract

This document describes the overall design plan for the remainder of the semester, including the parts needed, description of the test environment, and outline of testing processes. Ethics, cost, and tolerances will also be discussed and an estimation of the total workload will be given at the end.

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1. Introduction

1.1 Problem

The challenge faced right now is that the Intelligent Robotics Lab Facility would like to design a software that will analyze how consistently the position of a drone is able to be tracked throughout the Flying Arena based on the configuration of the motion tracking setup. The current motion tracker system used in the Flying Arena is the Vicon Tracker 3 which gathers up to mm position accuracy. However, in areas where the motion tracking camera's configuration does not allow for optimal observation, the accuracy has proven to decrease. The goal is to see how the accuracy changes when the drone would move higher, lower, and further away into the arena and away from the cameras throughout the entire volume of the arena. Ideally after testing, the camera locations can be recalibrated to get the best observation angle.

1.2 Solution

The goal is to see how the accuracy changes when the drone would move higher, lower, and further away into the arena and away from the cameras throughout the entire volume of the arena. Ideally after testing, the camera's locations and angles can be recalibrated to get the best observation angle.

Several subcomponents will need to be put in place. The first is the motion capture setup itself. This consists of the Vicon Tracker 3 software and the multiple Vicon Cameras which will record the position and is currently what the robotics lab utilized for their own experiments. Users are able to record real-time data on a created object's three dimensional position and stream it over WiFi to a supported third party software, such as MATLAB. Several objects can be analyzed in the software at once, each of which is organized and pre-determined by the user. In order to be measurable, the objects must either reflect or emit infrared light.

In order to adjust the configuration of the cameras, a calibration device must be designed. This will consist of a PCB, a microcontroller, switches, a power source, various resistors and capacitors, infrared LEDs (with wavelengths of either 780 nm or 850 nm), and reflective balls. The microcontroller we are choosing to use is the ATmega328P as it has enough programmable I/O ports to connect to eight infrared LEDs individually and three buttons that will control three main configurations of the LEDs. The PCB board will be shaped similar to the top-view of a drone, in which there are four different "wings". Four of the eight LEDs will be on the outer edge of the wings, and the remaining four will be closer to the center. On each wing in between the two LEDs, there will be a hole that allows for mounting a reflective ball. Two switches will control three different LED configurations, being that the outer four emit light (one switch), the inner four emit light (second switch), and all eight LEDs emit light (both switches at once).

Since reflective balls are normally used in the Flying Arena to reflect the infrared flashes from the cameras, these will act as the "true" location. Due to the balls reflecting instead of emitting, they are considered passive markers and will act as one passive object all together. Our design with the LEDs will act as the second object and will represent the measured location. From a performance perspective, since LEDs emit infrared light they are active markers and can

be measured at a further distance than passive markers. By comparing the motion-captured location of the reflective balls and infrared LEDs at the same time, we will be able to analyze how accurate the two markers are in comparison in real time. Based on the result, we will reconfigure the camera setup until both the reflective balls and LEDs have similar position measurements on the x,y, and z axes all within six degrees of freedom.

The last subcomponent of the project is the software that we will write that will calculate the percent error between the two measured locations. Data recorded by the motion tracking sensors will be streamed over illinoisnet WiFi in the form of a csv file that we can read and analyze on a personal computer using an approved third party system such as MATLAB.

1.3 Visual Aid

An example of a deck that includes a PCB and programmable LEDs is shown in Figure 1. An example of a deck that includes reflective balls is shown in Figure 2. We plan to reference both of these decks when designing our PCB, and combining the qualities to utilize the LEDs and reflective balls at the same time.



Figure 1. Drone carrying a deck that has an LED-configured PCB [1].



Figure 2. Drone carrying a deck that has holes to attach the reflective balls [1].

An example of the camera setup that we will be using is shown in Figure 3 below. As detailed by the Vicon user manuals, each camera will be connected to an ethernet cable [2]. The calibration object will either be flown on a drone or carried by one of us within the field of view of all the cameras.

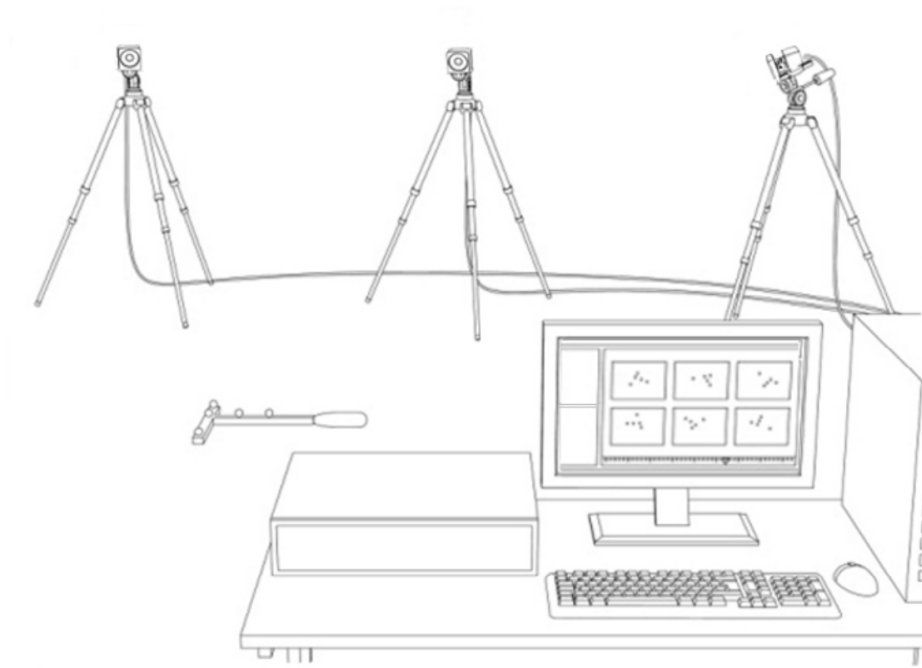


Figure 3. Similar camera setup to what is in the Flying Arena [2].

1.4 High Level Requirements

1. Design and create a PCB board with IP addresses correctly assigned to individual Infrared LEDs that emit into different configurations light once the switch is flipped. There should be the possibility of adding more configurations in the future, time permitting. This must be controlled by the switches and the ATmega328P, and all components must be visible to the Vicon Software.
2. Design an algorithm in the software to compare the locations of the reflective balls and the Infrared LEDs simultaneously.
3. Be able to continuously stream data from the Vicon camera Tracker 3 System to the designed Software as a csv file. Simultaneously track two objects, the reflective balls and the LEDs.

2. Design

2.1 Block Diagram

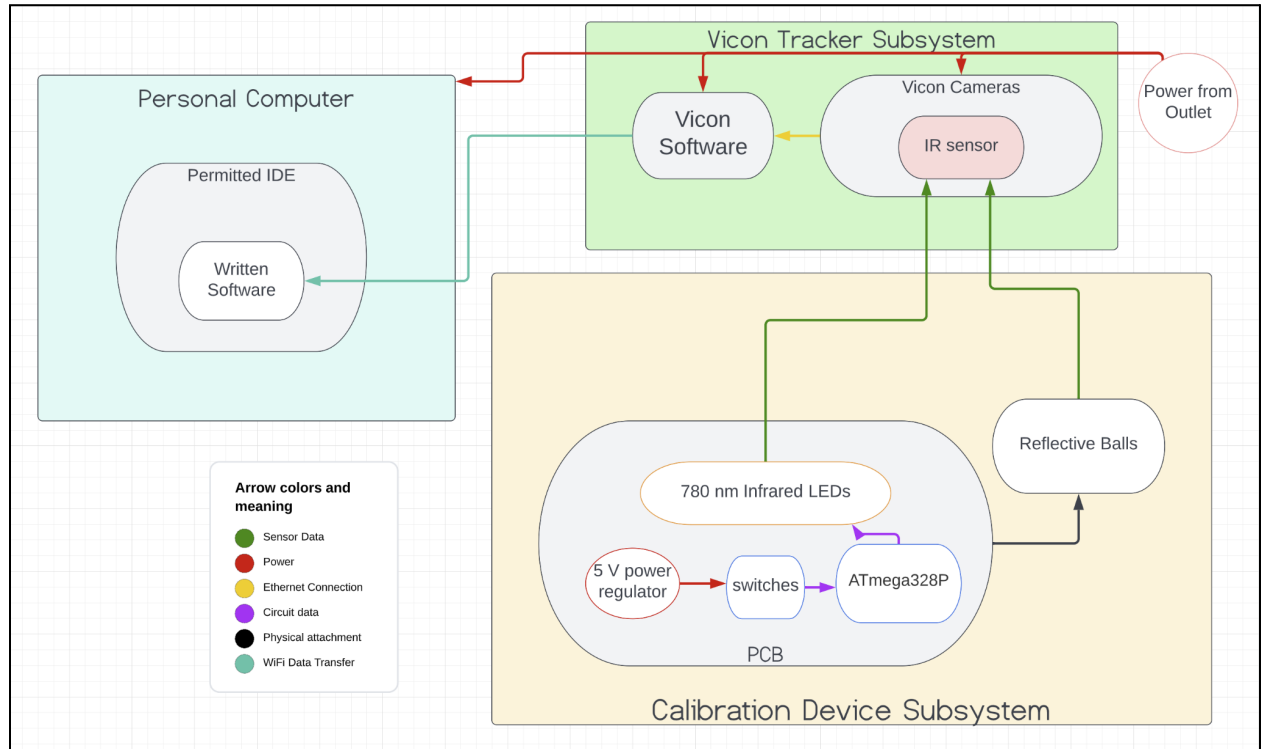


Figure 4. Block Diagram of Configuration

2.2 Subsystem Overview

- **Software:** The software will be designed to read data from a csv file that is sent from the Vicor Tracker 3 Motion Capture System to the personal computer we are working on via the local illinoisnet Wifi. Using a compatible system such as MATLAB, the two main groups of data that we will have to analyze is the 3-dimensional measured location of the reflective balls and infrared LEDs. At each parallel recorded set of (x,y,z) points, the percent error will be calculated and used to determine the accuracy of the current Motion Tracking Camera configuration.
- **Motion Tracking Configuration:** The Motion Tracking Configuration consists of multiple cameras and the Vicor Tracker software. Both will be powered by the wall outlets, but the data collected by the multiple camera system will be sent to the software over an ethernet connection. The cameras record 240 frames per second, meaning that there will be 240 data points per second. The camera flashes a near infrared light of about 780 nm, which will be reflected by the reflective balls [3]. Using the Vicor Tracker 3 software, the user will be able to group multiple items into one “object”. Since there can be multiple objects focused on at one time, two will be tracked for this project [2].

- **Drone/Test Object and Flying Arena:** The Flying Arena will be the test space, and the test object or drone will have the PCB board mounted onto it as well as the reflective balls. The PCB itself will need to have a 5 V power source that leads into both the switches and the Atmega328P, which is the microcontroller of our choice. Two I/O pins will be designated for the switches, while another eight I/O pins will lead to individual LEDs. There will be two switches, each one controlling four LEDs. There will also be several resistors so as to not overload the Infrared LEDs. During testing, the drone will either be carried around by one of us, or mounted onto a drone given that we have been through flight training.

2.3 Subsystem Requirements

- Software:

- **Continuous Recording of Motion-Captured and True Locations.** In order to properly analyze the data collected, it must be streamed to the designed software at the end of the given trial in the form of a csv file which can be immediately read and analyzed.
- **Constantly Compare the Two Data Sets.** As the two groups of data will be sent and read in parallel, they must also be stored in a way that each respective set of points can be directly compared for the percent error on the x, y, and z axes. Percent error will be determined by taking the infrared LEDs' location as the expected value, and the location of the reflective balls as the observed value.

$$\left| \frac{\text{observed} - \text{expected}}{\text{expected}} \right| * 100 = \text{percent error \%}$$

- **Tests Separated by Camera Configuration.** Each set of trials will correspond with one camera configuration, and ideally our design will have a way to collect and store data from individual celebration tests. There will also be separated trials for the different LED configurations to test how the distance between the illuminated LEDs changes the accuracy. In each trial, however, both defined objects will be on the same trajectory.
- **Motion Tracking Configuration:**
 - **Vicon Tracker 3 System.** The system will process the data collected from the cameras to determine a 3D image of the calibration object and determine its location. Both the reflective balls and the infrared LEDs will be tracked as separate objects, each of which will be manually grouped together by the user before each trial. Both sets of data processed by the system will be saved in a csv file and sent over WiFi to the designed software to further analyze for accuracy

[2]. The (x,y,z) location will be the center of the object, and therefore the center of the calibration device.

- **Vicon Tracker 3 Cameras.** The Vicon cameras are a slightly older model that strobe an “near infrared” wavelength of about 780 nm - 850 nm. The strobes act as flashes that will be reflected by the reflective balls. Providing that the LEDs are within the proper bandwidth range, they will be registered by the cameras when illuminated [3]. The LEDs will stay illuminated throughout the entirety of the trial, instead of responding to the strobes like the reflective balls will. About 240 points of data will be collected per second, all of which will be transferred to the Tracker 3 software over an ethernet connection. The cameras can be moved around throughout the Flying Arena to gain optimal viewing angles of the markers.
- **Routing Over WiFi.** The local Illinoisnet WiFi will be the routing method when sending the csv file from the computer running the Tracker 3 software to the personal computer we will be using for testing.
- **Drone/Test Object and Flying Arena - two prototypes will be designed, one smaller and one larger to ensure that there is enough space to combine all the LEDs into one object, and all the reflective balls into another while still accurately recording data.**
 - **PCB.** The PCB will resemble the shape of the drone, as shown in Figures 1 and 2. The required materials will be soldered onto it. It will also have holes in it so that the reflective balls can be mounted onto it. The final PCB design will be mounted onto a deck that has a similar size and shape.
 - **LEDs.** The LEDs will be Infrared because that is what the Vicon Cameras register. Specifically, though, they need to have a wavelength of around 780 nm - 850 nm to mimic the strobe of the cameras. Since these emit light instead of reflect, it needs to produce a similar wavelength compared to what the camera will strobe. There will be eight in total, four close to the center of the deck and four close to the outer wings of the deck. This will allow testing of various configurations, when the light emission is concentrated in the middle or spread out across the deck. This will test active marking [3].
 - **Switches.** There will be two switches connected between power and the microcontroller. One will control the innermost LEDs and the other will control the outermost LEDs. When both switches are closed all eight of the LEDs will be illuminated.
 - **Atmega328P.** The Atmega328P is the microcontroller of our choice, as it has 23 I/O pins that can easily address the eight different LEDs. It will be programmed to turn on LEDs based on which switch is currently flipped. This will allow for different configurations to be tested on top of just the base ones stated previously, provided that there is more time after initial testing is complete.

- **Reflective Balls.** The reflective balls will reflect the flashes of the camera and can be mounted into the holes on the deck. There will be one main configuration of four different balls, as this is what is normally done in the Flying Arena. Having the reflective balls will test passive marking.

2.4 Subsystem Requirement and Verification Table

Requirement	Verification
Continuous Recording of Motion-Captured and True Locations using Vicon Tracker 3 Cameras	Vicon Tracker 3 cameras would be used to record 240 frames per second and thus capture data from the LEDs and reflective balls with high accuracy and precision over the period of the drone flight.
Constantly Compare the Two Data Sets using Vicon Tracker 3 System	Data from the cameras are exported in csv files from the Vicon Tracker 3 System to a personal computer that tracks frame and location data for the true position and position gained from infrared LEDs. A software program will then construct a graph of the percent error between the two trackers.
Tests Separated by Camera Configuration	The starting and motion of the drone will be conducted exactly the same for each test by aligning the drone at the exact same position and verifying with the Vicon Tracker 3 software.
Deck That Can Be Mounted Onto the Drone/Test Object	The deck will consist of the pcb and must successfully match the dimensions shown in figure 4 and 5 below.
PCB	We will make 2 prototypes testing a different variable, different board sizes. These will consist of designing and implementing a board as well as successfully soldering multiple components ensuring clean connections between everything.
Atmega328P	This microcontroller is easily programmable for the purposes of keeping different configurations of IR LEDs illuminated [4].

LEDs	LEDs must successfully turn on when the remote switch is hit. Working along with the camera the frequencies must be picked up and read into computer data.
Reflective Balls	Reflective balls must successfully be picked up by the Vicon cameras simultaneously as the leds are on.

2.4 Tolerance Analysis

Some of the risk involved in pursuing this project involves the Infrared LEDs and determining the wavelength that will function best with the cameras. As we cannot see Infrared light without proper equipment, it may take some trial and error and multiple types of IR LEDs to be purchased. This may take time, so it could impact the progression of the project.

Another risk that could be met throughout the experiments involves designing the software and taking the time to properly debug it. If the software does not work, the entire system may not function properly as a whole.

Bad data from inaccurate location measurements would lead to a larger percent error.

The largest percent error that we will allow recording location is $\pm 0.01\%$.

$$\left| \frac{\text{observed} - \text{expected}}{\text{expected}} \right| * 100 = 0.01$$

Providing that the expected value is at location 1 m in the x-direction:

$$\left| \frac{\text{observed} - 1}{1} \right| * 100 = 0.01$$

$$\text{Observed} - 1 = 0.0001$$

As a result the observed center can be at maximum 0.0001 m away from the center of the expected location.

3. Ethics and Safety

The main ethical concern of this project is if we irresponsibly were to fly the drone. According to rule number II.9 in the IEEE code of ethics, we must “avoid injuring others, their property, reputation, or employment by false or malicious actions, rumors or any other verbal or physical abuses” [4]. If we irresponsibly fly the drone, it may cause damage to others or the lab environment/equipment. Regarding safety we must take the proper precautions and training when entering the robotics lab. Mechanically we run the risk of damaging lab equipment (drone), if it were to be operated improperly. Electrically we must design a PCB board that will have fully functioning connections, short circuits can damage the PCB board as well as the frame depending on the level of issue.

References

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