Heliostat Control Tracking

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FUNCTIONAL SYSTEM REQUIREMENTS

REVISION – Draft B
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Functional System Requirements
for
Heliostat Control Tracking

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Change Record

Rev.	Date	Originator	Approvals	Description
A	9/30/2022	Erica Quist, Samuel Dixon, Jordan George		Draft Release
B	10/13/2022	Samuel Dixon		Removed highlighting and made revisions based on draft feedback.
C	11/16/2022	Samuel Dixon		Updated system requirements after changes done to subsystem organization from midterm presentation feedback.

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1. Introduction

1.1. Purpose and Scope

Most heliostat products are made for large solar power systems. For this R&D project, a much smaller-scale heliostat system is desired. This is because larger scale heliostats are costly, burdensome, and have timelines that are unpredictable. The purpose of this research project is to create a stand-alone heliostat unit that can be set up easily, output data, and can be stored in the lab whenever desired. This solar tracking mount will consist of a mirror array that will be tilted and rotated based on where the sun is. A sun tracking algorithm will be coded onto an Arduino board that will move the mirror array accordingly with the help of motors. There will be an Android app that will visualize the data such as the input and output optical rays as well as the rotation and tilt angle of the array.

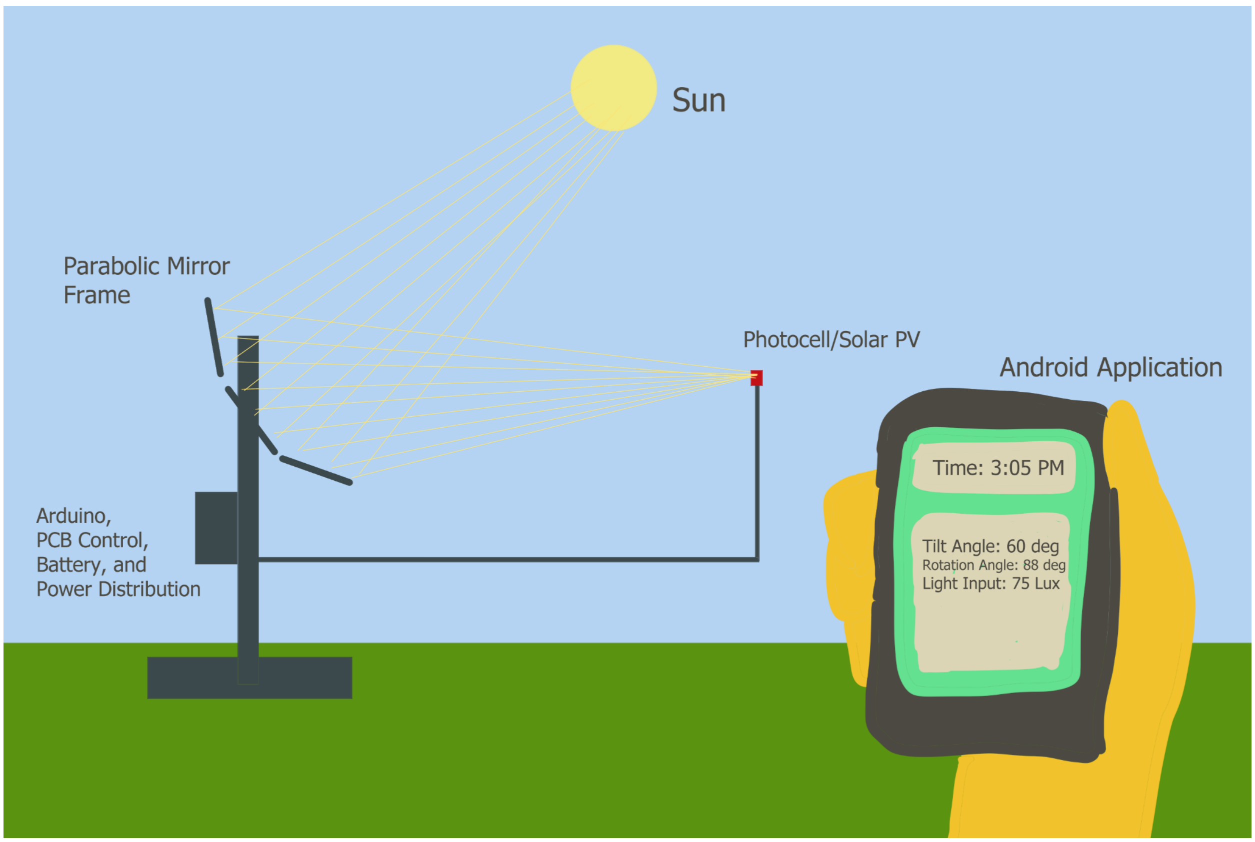

Figure 1. Heliostat Concept Image

1.2. Responsibility and Change Authority

Subsystem	Responsibility
PCB design & Power Delivery	Jordan George
Data Visualization	Samuel Dixon
Tracking Algorithm	Erica Quist
Physical Mirror Array	Jordan George, Samuel Dixon, Erica Quist

Table 1: Subsystem partitioning

2. Applicable and Reference Documents

2.1. Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

Document Number	Revision/Release Date	Document Title
978-1-491-92176-0	First Edition - 5/5/2016	Arduino A Technical Reference
IEEE 802.11-2016	12/14/2016	Standard for WIFI Networks
IEEE 802.15.1-2015	06/14/2005	Standard for Bluetooth Communication

Table 2: Applicable Documents

2.2. Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

Document Number	Revision/Release Date	Document Title
1	01/03/2017	Run-time detection and correction of heliostat tracking errors
2	10/2003	Concentrator Optics
3	9/15/2001	Computing the solar vector
4	09/13/2022	Android Studio API Online Reference

Table 3: Reference Documents

2.3. Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

3. Requirements

3.1. System Definition

This project entails refining the tracking controls, structural arrangement, hardware organization, and data visualization of a small-scale heliostat control system. These refinements include tracing the trajectory of the sun at a given longitude and latitude, while receiving feedback from sensors, incorporating planar mirrors with increased stability, routing signals on a PCB shield, and utilizing internet and bluetooth protocols to visualize system metrics in real-time and on a historical basis.

This proposed solution contains the following subsytems: PCB Design and Power Delivery, Data Visualization, Tracking Algorithm, and Physical Mirror Array. PCB Design and Power involves the physical hardware and the routing of electrical signals, while interfacing the capabilities of the Arduino. Data Visualization involves receiving bluetooth data from sensors and displaying the data in real time, while also storing the historical data into a remote server for other data driven insights. The Tracking Algorithm is the C programming to orchestrate the signals to actuate the motor control and adjustment of the mirrors as a function of the sun's position.

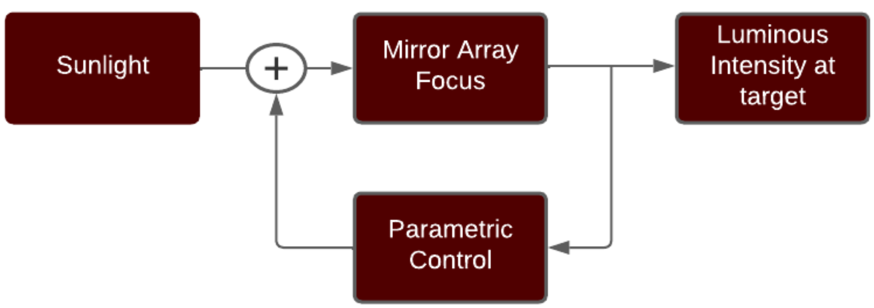

Figure 2. Block Diagram of System

The block diagram in Figure 2 visualizes the control aspects of this project. The input to the system is the position of the sun at a given time. In the forward path, the mirror array is focused based on the time and longitude data. The system then adjusts the position of the mirror array though other aspects of parametric control, such as data received from feedback in the program. This reduces the error signal between the optimal maximum luminous intensity and the observed maximum intensity at a given time.

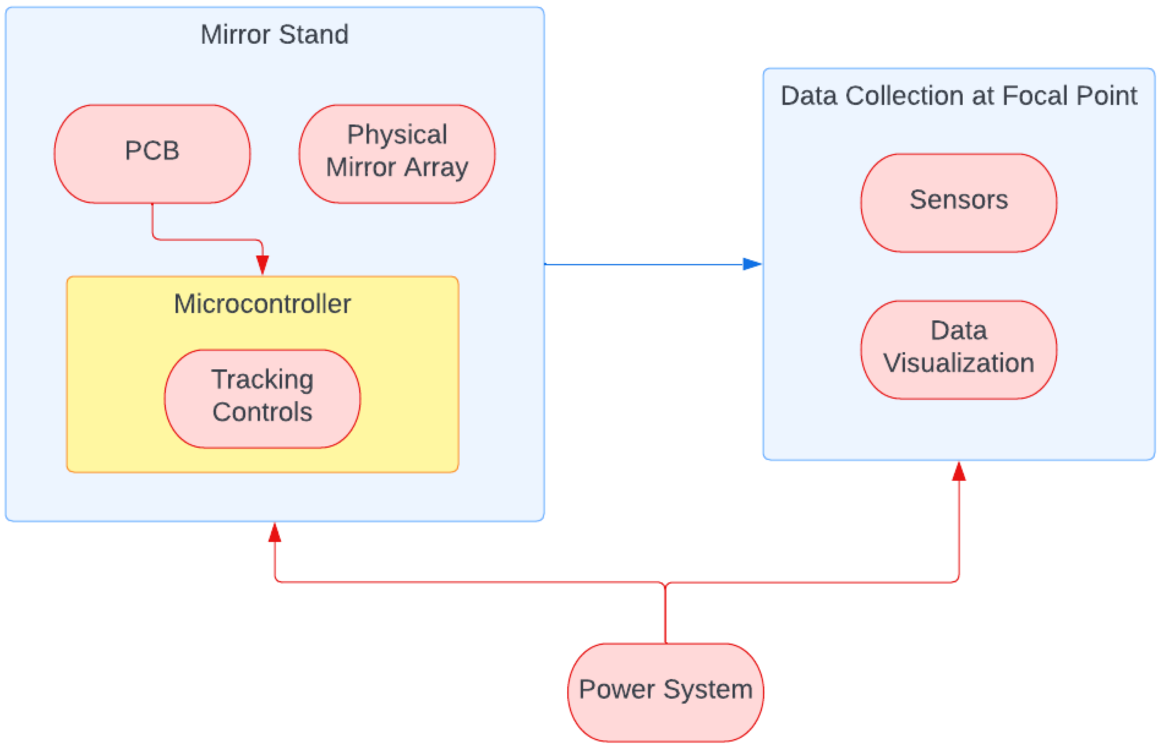

Figure 3. System Relation Diagram

The relational diagram in Figure 3 provides the relationship between the subsystems of the project. Items contained in the respective blue boxes are groups that correspond to each other symbolically and physically. On the left hand side, the PCB shield interfaces the capabilities of the Arduino microcontroller, which serves as the brain for the tracking control of the mirrors. The mirror array and hardware are physically connected together routing light to the right hand of the diagram, the target. At the target, there will be a photodiode with an optic filter for providing feedback to the microcontroller. The target also provides the source of the data for the visualization portion of the code.

3.2. Characteristics

3.2.1. Functional / Performance Requirements

3.2.1.1. Tracking the Sun

The Heliostat tracking system will adjust motors every ten minutes and record ten data points from the photodiode for an average measurement.

Rationale: This is the core system performance requirement. Operating conditions occur in Texas A&M Research Park (30.6280, -96.3344).

3.2.1.2. Data Collection and Processing

The Heliostat tracking system will process the averaged sampled data points from the photodiode. The photodiodes voltage will be communicated serially with the Arduino. Upon receiving the measurements and doing the averaging, the Arduino will use the HC-05 bluetooth module package to send information in packets through bluetooth (if master-slave pair available) to an android phone application. From the phone application, the most recent reading will be displayed in an immediate view. Additionally, the reading will be uploaded through the internet to a web server, utilizing the firebase framework. When applicable, this should be done every 10 minutes when a new reading and average is taken in the program.

3.2.2. Physical Characteristics

3.2.2.1. Volume Envelope

The volume envelope of the Heliostat Tracking Control System shall be less than or equal to 60 inches in height, 48 inches in width, and 48 inches in length.

3.2.2.2. Mounting

There will be nine 12 inch by 12 inch planar mirrors that will be mounted to a frame. This frame rotation and tilt capabilities. They will be mounted with epoxy and 3-d printed fasteners.

3.2.3. Electrical Characteristics

3.2.3.1. Inputs

The inputs of the Heliostat Tracking system include the light given from the sun as well as data from a csv file that includes the elevation and azimuth of the sun throughout the day depending on the latitude of College Station and the date of the year. This data will determine the tilt and rotation of the mirror array.

Rationale: This system is meant to output the optimal amount of solar waves so it is required that the frame is angled to best serve this purpose.

3.2.3.1.1 Power Consumption

The maximum peak power of the system shall not exceed 84 watts.

Rationale: This is a requirement specified by our customer due to the value of the pre-existing battery (12 V, 6A rated) within the system.

3.2.3.1.2 Input Voltage Level

The main battery of the Heliostat Tracking System can supply up to 12 Volts.

3.2.3.2. Outputs

The output of the Heliostat Tracking System is the positioning of the mirrors, which is realized through motor control and voltage inputs. Also, the direct normal irradiance will be measured with a rotating shadowband on a pyranometer.

3.2.3.2.1 Data Output

The Heliostat Tracking Control System will contain an android application that will have a view where the customer can obtain information about the readings of the sensors. This will be crucial in ensuring the system is operating as intended and to validate that the product offered is within the operating guidelines and functional requirements specified above.

3.2.3.2.2 Diagnostic Output

The Heliostat Tracking Control System will contain an android application that will have a GUI view where the customer can externally debug and test certain functionalities, rather than adjustments being made by the program. This external interface will allow the customer to rotate the two motors to move the mirror array translationally and rotationally. Additionally, the application will provide verification of connectivity and option to halt system execution.

Rationale: Provides the ability to debug the system and manually control the mirrors for rotating the mirror around two different axis points.

3.2.4. Environmental Requirements

The Heliostat Tracking System shall be designed to withstand and operate in the environments and laboratory tests except for days with heavy rain, days that are very cloudy, and throughout the night.

Rationale: This is because the system is meant to track the sun so when the sun is not in the sky or is blocked heavily, then the heliostat would not be optimal in these conditions.

3.2.5. Failure Propagation

The Heliostat Tracking System will not allow propagation of error to occur in the system beyond the visual interface. For software, when the sensor consistently is off with respect to the ideal value (determined by experimental testing), the system interface will alert that there are either non-ideal environmental conditions occurring or a physical bug in the system. In hardware, there will be an overcurrent detection device to ensure that the pins of the esp-32 are not being strained past their operating conditions. Additionally, relative location of the esp-32 will be discussed to prevent strain on the mechanical system. Additionally, a safety switch will provide extra security for stopping the process. This is critical for devices involving mechanical motion, where objects can become twisted and broken.

4. Support Requirements

Provided support for this project include an activity page within the android application, involving purpose statement, navigation, and change date. Additionally, there will be a feedback form within the application, where users can query for support to the service team. The service team will be able to consult subsystem owners for expertise regarding specific questions and provide valuable feedback in a timely manner to the customers as needed. The requirement to access this technical support would be a device that utilizes google's android operating system, can download applications from the play store, and has the capability of connecting to the internet.

Appendix A: Acronyms and Abbreviations

BIT	Built-In Test
CCA	Circuit Card Assembly
DNI	Direct Normal Irradiance
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EO/IR	Electro-optical Infrared
FOR	Field of Regard
FOV	Field of View
GPS	Global Positioning System
GUI	Graphical User Interface
Hz	Hertz
ICD	Interface Control Document
kHz	Kilohertz (1,000 Hz)
LCD	Liquid Crystal Display
LED	Light-emitting Diode
mA	Milliamp
MHz	Megahertz (1,000,000 Hz)
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
mW	Milliwatt
PCB	Printed Circuit Board
RMS	Root Mean Square
TBD	To Be Determined
USB	Universal Serial Bus

Appendix B: Definition of Terms

HC-05	Bluetooth Module

Appendix C: Interface Control Documents

The Interface Control Document is attached below