"Solar Tracker: an Arduino-Powered Solar Tracker to Boost Panel Efficiency"

A Proposed Thesis Study

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Solar Tracker: an Arduino-Powered Solar Tracker to Boost Panel Efficiency

This chapter presents the introduction, objective of the study, significance of the study, current state of technology, scope, limitations and delimitation's of the study, and definition of terms.

Introduction

Renewable energy is a topic that has been garnering increased attention in recent years, particularly with the rise of climate change concerns and the push for sustainable living. Among the various forms of renewable energy, solar power has emerged as a particularly promising option due to its efficiency and low environmental impact. However, the efficiency of solar panels can be greatly improved by utilizing a device called a solar tracker.

A solar tracker is a device that adjusts the orientation of a solar panel in order to keep it facing the sun throughout the day. By doing so, it ensures that the panel receives maximum sunlight and produces the most energy possible. While static solar panels can still be effective, they are limited by the fact that they cannot adjust to the changing position of the sun. By contrast, solar trackers offer an efficient way to optimize energy production, particularly for large-scale solar installations.

While commercial solar trackers can be expensive and may require professional installation, it is possible to build a simple solar tracker using an Arduino microcontroller. The Arduino is a user-friendly electronic platform that can be programmed to control the motion of a solar panel based on sensor inputs. By using a light sensor or a GPS module to detect the position of the sun, an Arduino-powered solar tracker can adjust the orientation of a solar panel to optimize energy production.

Building an Arduino-powered solar tracker may seem like a daunting task, but it can be a valuable learning experience for anyone interested in renewable energy or electronics. The project requires some basic knowledge of electronics and programming, but there are many resources available online to help guide beginners. By following a step-by-step tutorial, students can gain hands-on experience in building and programming an electronic device that has practical applications in the field of renewable energy.

In addition to its practical benefits, building an Arduino-powered solar tracker can also provide insight into the challenges and opportunities of sustainable living. By taking a DIY approach to renewable energy, students can develop a deeper understanding of the principles and technologies involved in harnessing solar power. With this knowledge, they can contribute to the growing movement toward sustainable living and help to create a more eco-friendly future.

Objectives of the Study

The project study aims to provide a comprehensive overview of solar tracking and its potential applications in the field of renewable energy.

- To develop a basic understanding of solar trackers and their role in maximizing the efficiency of solar panels.
- To explore the capabilities of the Arduino microcontroller and how it can be used to control the motion of a solar panel.
- To build a functional solar tracker using an Arduino microcontroller, a light sensor, and basic electronic components.
- To evaluate the effectiveness of the Arduino-powered solar tracker in maximizing the energy production of a solar panel.
- To consider the implications of solar tracking for the field of renewable energy and sustainable living.

Significance of the Study

The study lies in its potential to promote the use of renewable energy sources by increasing the efficiency of solar panels through the use of solar trackers. By building and evaluating an Arduino-powered solar tracker, this study aims to demonstrate the practical benefits of this technology and encourage further research and experimentation in this area.

One of the main advantages of solar trackers is that they can significantly increase the energy production of solar panels, particularly in regions with high levels of solar irradiation. This can make solar energy a more viable and cost-effective option for households, businesses, and communities looking to reduce their reliance on non-renewable sources of energy.

In addition to its practical applications, the study of solar trackers has broader implications for the field of sustainable living. By promoting the use of renewable energy sources, we can reduce our carbon footprint and mitigate the effects of climate change. The development of solar trackers and other renewable energy technologies can also help to create new jobs and industries in the green energy sector.

From a technical perspective, the study of solar trackers can also provide valuable insights into the use of microcontrollers like the Arduino in controlling electronic devices. By learning about the programming language and electronic components involved in building a solar tracker, students can develop practical skills in electronics and programming that can be applied to other projects and industries.

Overall, the significance of this study lies in its potential to promote sustainable living and renewable energy use through the development of a simple and accessible technology like the Arduino-powered solar tracker. By demonstrating the practical benefits of this technology and encouraging further research and experimentation, we can help to create a more eco-friendly and sustainable future.

Scope and Delimitation of the Study

This study is limited to the design, construction, and evaluation of an Arduino-powered solar tracker for use with a single solar panel. The study will focus on the use of a light sensor to detect the position of the sun and the use of an Arduino microcontroller to control the motion of the solar panel.

The study will also include an evaluation of the effectiveness of the solar tracker in increasing the energy production of the solar panel.The study will not include an evaluation of the economic feasibility of using solar trackers, as this would require a more comprehensive analysis of factors such as the cost of materials, installation, and maintenance.

The study will also not address issues related to the scalability of solar tracking technology, as this would require a more extensive and complex analysis of factors such as the size of solar arrays, the amount of solar irradiation in different regions, and the availability of resources and expertise.

The study will rely primarily on online resources and tutorials for information and guidance on the design and construction of the solar tracker. While the study aims to provide a comprehensive overview of the principles and practices of solar tracking, it is limited by the knowledge and experience of the researcher and the availability of resources.

Finally, the study will focus on the use of an Arduino microcontroller as a control mechanism for the solar tracker. While there are other microcontrollers and control mechanisms that can be used for this purpose, the study will not evaluate these alternatives in depth.

Current State of Technology

The history of solar panels dates back over a century, with early experiments in harnessing the power of the sun for energy. In 1839, French physicist Alexandre Edmond Becquerel discovered the photovoltaic effect, which is the basic principle behind solar panel technology. He observed that certain materials are capable of converting sunlight into electricity.

In the years that followed, scientists continued to explore the potential of solar energy, but it wasn't until the mid-twentieth century that solar panels began to be developed for practical use. In 1954, researchers at Bell Labs in the United States created the first modern solar cell, which was capable of converting sunlight into electricity at a rate of 6% efficiency.

Over the following decades, advances in materials science and manufacturing techniques helped to improve the efficiency of solar cells and make them more affordable. In the 1970s, the oil crisis led to a surge of interest in solar energy as a viable alternative to fossil fuels. Governments around the world began investing in research and development of solar technology, and the use of solar panels began to increase in homes and businesses.

In the 1980s and 1990s, advances in the efficiency and affordability of solar panels continued to drive growth in the industry. Governments began to introduce incentives and subsidies to encourage the use of solar energy, and the development of large-scale solar farms began to take off.

The current state of solar panels is one of rapid growth and innovation. Over the past decade, there has been a significant increase in the use of solar panels as a source of renewable energy, driven by falling costs and growing concerns over climate change.

One of the key developments in solar panel technology has been the increasing efficiency of photovoltaic (PV) cells. Advances in materials science and manufacturing techniques have allowed for the production of cells with higher conversion efficiencies, which means that they can convert more of the sun's energy into usable electricity. This has helped to drive down the cost of solar panels, making them more accessible to homeowners and businesses.

Definition of Terms

The terms are conceptually and operationally defined for the readers' reference.

Solar irradiation. is the output of light energy from the entire disk of the Sun, measured at the Earth. It is looking at the Sun as we would a star rather than as a image. The solar spectral irradiance is a measure of the brightness of the entire Sun at a wavelength of light.

Renewable energy. is energy derived from natural sources that are replenished at a higher rate than they are consumed. Sunlight and wind, for example, are such sources that are constantly being replenished. Renewable energy sources are plentiful and all around us.

Solar power. is the converting energy from the sun into power. There are two forms of energy generated from the sun for our use – electricity and heat. Both are generated through the use of solar panels, which range in size from residential rooftops to 'solar farms' stretching over acres of rural land.

M**icrocontroller.** is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip.

Green energy sector. Solar, wind, water, biomass, and geothermal are all renewable energy sources. Green energy, while similar to renewable energy, is a subset of sources that have the highest environmental benefits. Clean energy sources emit low carbon, and include renewable energy sources along with nuclear power.

GPS module. is used to locate and acquire farmland information, including yield monitoring, soil sample collection and etc. The computer system determines the management measures of farmland plots by analyzing and processing the data, and loads the yield and soil status information into the GPS equipment.

CHAPTER II: REVIEW OF RELATED LITERATURE

This chapter presents the review of conceptual and research literature, synthesis and conceptual framework.

Conceptual Literature

These studies were reviewed, analyzed, and used as background of the study: Smart solar tracking system based on fuzzy-Pi controller for maximizing the power of PV, Design and Implementation of a Dual Axis Solar Tracker Using Arduino microcontroller, Intelligent Arduino Based Automatic Solar Tracking System using Light Dependent Resistors (LDRs) and Servo Motor, Maximizing The Output Power Harvest Of A PV Panel: A Critical Review, Recent Innovations in Solar Energy Education and Research towards Sustainable Energy Development

Smart solar tracking system based on fuzzy-Pi controller for maximizing the power of PV

Imam Abadi, Chairul Imran, and Nadia Fasa(2019). Solar energy is a potential renewable energy to be developed as an alternative energy due to its abundant availability and environmentally friendly. Indonesia, as a tropical country has a very large intensity of solar irradiance and evenly distributed throughout region. However, the energy has not been optimally utilized because the existing technology today cannot significantly improve the efficiency of solar panels especially in terms of material technology. Nowadays, researchers have developed a technology capable of improving the performance of solar panels through solar tracking mechanisms.

Solar tracker is a combination of electrical and mechanical systems that can move a solar panel to locate the position of the sun. The solar tracker system is expected to enhance the output power of solar panel (PV) because the intensity of solar radiation received is always maximum. Generally, solar tracking system has been operated on fix-based, so its usage has been limited to stationary objects.

Design and Implementation of a Dual Axis Solar Tracker Using Arduino microcontroller

Energy is pivotal to the human and capital development of any nation; hence, the ever growing quest to discover reliable and sustainable energy sources. Researches on renewable energy sources ranging from wind, tidal, hydro power and solar energy is on-going; all geared towards providing better electrical energy source. Solar energy, however, holds a very promising future as far as sustainable energy solution is concerned. It is silent, green, with zero negative impact to the globe and no pollution.

The self-controlled tracking is achieved by using a MEGA2560 microcontroller board, programmed to read analog values from an array of LDRs, convert them to digital values, compare them and drive the stepper motors in the desired direction until equal light is sensed by alternate LDRs. At this point, the panel is aligned perpendicular to the sun rays to capture the maximum possible energy.

Intelligent Arduino Based Automatic Solar Tracking System using Light Dependent Resistors (LDRs) and Servo Motor

Rufai Hassan, Bashir Abubakar(2020). In order to ensure maximum power output from PV cells,the sunlight's angle of incidence needs to be constantlyperpendicular to the solar panel. This requires constanttracking of the sun's apparent daytime motion, and hencedevelops an automated sun tracking system which carries thesolar panel and positions it in such a way that direct sunlightis always focused on the PV cells.

This project presents a moving a solar panel along with the direction of sunlight; it uses a Servo-motor to control the position of the solar panel, which obtains its data from an Arduino uno microcontroller. Two light dependent resistors (LDR) are used for each degree of freedom. LDR's are basically photocells that are sensitive to light.

Maximizing The Output Power Harvest Of A PV Panel: A Critical Review

E. O. Ogundimu, E. T. Akinlabi, and CA Mgbemene(2019). The quick exhausting of traditional energy sources and the present consistently expanding energy request with regards to ecological issues have supported concentrated research on solar energy innovation. Apprehending most extreme energy from the sun by utilizing solar PV technology is impenetrable. A few features that influence the solar energy yield of this technology comprise the material of the photovoltaic, solar irradiance topographical area, the orientation of the panel, the angle of sun and surrounding climate.

This present work reviews the ideologies and contrivances of solar PV tracking systems to decide the greatest solar panel tilt-angle, both isotopic and ant isotopic solar models and uses of numerous procedures for outlining solar panel tilt- angle by means of dissimilar optimization techniques. The work displays that sun-tracking systems are quite expensive than the opposing fixed mounted variety.

Recent Innovations in Solar Energy Education and Research towards Sustainable Energy Development

Ramalingam Senthil(2022). The essential requirements of our everyday lives are fresh air, pure water, nourishing food, and clean energy in a most sustainable manner. The present review article concisely discusses recent innovations in solar energy education, research, and development toward providing clean and affordable energy and clean water to some extent. This article primarily addresses the Sustainable Development Goal 7 of the United Nations (SDG 7: Affordable and Clean Energy). Over the past few decades, many research activities have been carried out on solar energy conversion and utilization. The deployment of solar energy technologies has been witnessed to combat global warming and the betterment of the planet. Drivers and barriers to implementing solar energy systems from school to master's level through real-time deployments are discussed for further development and innovations. Mainly, expedited solar energy education and research are essential to improve solar energy utilization. The advancements in solar energy education and research towards sustainable energy development and circular economy are highlighted along with further directions required.

Research Literature

For the development of the proposed study, the proponents have conducted a review of published and unpublished theses. This is to acquire background information about other theses and research that were completed during recent years. The information acquired through research is vital to complete this project study.

The study conducted by Amaize et. al(2018) entitled, “Arduino Based Solar Tracking System For Energy Improvement of PV Solar Panel” includes that Nigeria is among the tropical countries that fall between 4 degrees and 13 degrees and enjoys sunshine of 6.25 hrs daily. Presently, public electricity covers only 40% of Nigerian homeland this is not still on a consistent basis. Due to lack of constant power supply in Nigeria,people have started embracing the culture of generating their own power supply. The use of fossil fuels as a means of generating electricity has become expensive making cost of living very high, especially in the rural part of the country. Also the use of fossil fuel has brought about pollution to the environment which in turn is not safe for our health. It releases carbon dioxide which causes the greenhouse effect. This brings about the deforestation of land and also the pollution of air and water. Solar energy is gotten solely from the sun and as a result does not emit carbon dioxide which prevents the green-house effect. The development of solar energy in Nigeria has the potential to create jobs. Employment in renewable energy industry would reduce occupational hazards especially when compared to coal mining and the extraction of oil. Nowadays solar energy is becoming one of the most reliable source of energy as a result of its surplus and environmental friendly .

According to reference a system that tracks the sun will be able to know the position of the sun in a manner that is not linear. The operation of this system should be controlled independently. Maximum energy is produced by a solar PV panel when it is positioned at right angle to the sun. Therefore, the aim of this research is to develop an Arduino based solar tracking for energy improvement of solar PV panel.

The study conducted by Karthika et. al(2019) entitled, “Dual Axis Solar Tracking System using Arduino” includes that Solar energy is emerged as a possible source of renewable energy over the past two to three decades. This solar energy is converted into electrical energy by using solar panel according to the principle of photovoltaic effect. Out of various renewable energy sources solar energy is widely used. Because it is simple and it is easy to use in household too. Solar Trackers is a device used for the rotation of solar panel according to the sun’s rays. To utilize this renewable solar energy solar trackers are employed. For static solar panel, there is no movement in the panel. But the position of the sun changes during rising and setting (sun rises in the east and sets in the west). Due to this reason, single axis solar tracker is developed for rotation of solar panel in east and west direction. But due to the rotation and revolution of earth we cannot get equal amount of sun rays throughout the year. So that we adopted dual axis solar tracker to utilize the solar energy effectively and efficiently by rotating the panel in both horizontal and vertical direction. The main objective of dual axis solar tracker is to increase the efficiency of the solar panel by 30-45% when compared to the static and single axis solar tracker. The literature survey clearly shows the different methods of solar tracking for maximum utilization of solar power [1-15].

The single axis tracker is able to rotate only on horizontal(or) vertical. But this dual axis tracker is able to rotate on both horizontal and vertical movement. This dual axis solar tracker was implemented by using Arduino board . Low cost of implementation by Arduino is the reason behind choosing Arduino in this project. This was achieved even by using microcontroller.

Also, the study entitled “Dual axis solar tracker with IoT monitoring system using arduino” by Mohamad Nur et. al(2020) includes that due to the shortage of electricity, the mankind always looked for the most available and environmental friendly type of the electric power in the way of development. Renewable energy is an energy which comes from natural resources such as sunlight, wind, tides, hydro, biomass and geothermal,which are naturally replenished. Nowadays, Malaysia have look at solar energy as one of renewable energy that useful because Malaysia's electricity gain ration totaled at 30,875.23 MW including solar system which contribute 0.55%. This is proving that Malaysia has the higher solar radiation that can be used to generate electricity. Besides that, solar energy is one of the best power sources since it is available in nature and not generates any pollution in this world. It is the conversion of energy from sunlight into electricity and this process is known as the photoelectric effect. This renewable energy had been widely use and keep on improving continuously. Despite of solar energy being a good source of energy, it is needed to improve the methods to harness this energy. This can be achieving by using dual solar tracking system that has two degrees of freedom that act as axes of rotation. The axis that is fixed with respect to the ground can be considered a primary axis and the other axis that is referenced to the primary axis can be considered a secondary axis. Solar tracker is a device with the orientation of following the sun's path to maximize energy capture. It helps to minimize the angle of incidence which will make a greater performance of Photovoltaic panel. A solar tracker can be completed with the presence of the PLC, servo motors, wormgears, photo-sensors, encoders and power relays. In paper discuss a development of dual solar tracker that has high efficiency on trace the maximum sunlight source to power the solar panel. The researcher has been using light dependent resistor (LDR), two servo motor that control by Arduino UNO to move the solar panel directly to the sunlight. These research are comparing a dual solar tracker with static solar panel. This paper, decided to design and construct dual solar tracker that control by Arduino UNO. The construction on dual solar tracker will be considered on types of motor, numbers of light dependent resistors will be use and compression using Lab View software. This paper discussed of a design and build internet of things on solar tracker. The platform that has been use in this project is Raspberry Pi 3 (RPi3). In this paper,the researcher is focusing on build dual-axis solar tracking system using programmable logical controller(PLC) based on automatic tracking system.

The study conducted by Das et. al(2016) entitled "Single Axis Solar Tracking System using microcontroller(ATmega328) and Servo Motor" includes that tracker systems follow the sun throughout the day to maximize energy output. The Solar Tracker is a proven single-axis tracking technology that has been custom designed to integrate with solar modules and reduce system costs. The Solar Tracker generates up to 25% more energy than fixed mounting systems and provides a bankable energy production profile preferred by utilities.

The study conducted by Alijanov & Topvoldiyev(2021) entitled "Solar Tracker System using Arduino" includes that An important part of the mobile solar module system is the supporting structure for the solar panels.It provides the required strength for the entire system and the right angle of inclination for the solar panel.The combination of the solar panel and the supporting structure must be resistant to various wind speeds another environmental influences.

This article uses an Arduino-based solar tracking system. Light-dependent resistors (LDR) are used to sense the intensity of sunlight, and the solar module is adjusted to maximize sunlight observation. A servomotor is used to control the solar module. The results show that a moving solar module produces more energy than a static solar module.

Synthesis of the Study

The concepts that define solar tracker using arduino as seen in the related literature are somehow connected to each other. Researchers discusses the concept that are related or relevant to the current study.

The current study discussed the use of an Arduino-powered solar tracker to improve the efficiency of solar panels. It provided an overview of the concept of solar tracking, the benefits of using a solar tracker, and the process of building an Arduino-powered solar tracker. The study focused on the practical applications of solar tracking technology, particularly for large-scale solar installations, and highlighted the potential of DIY approaches to renewable energy. The study did not involve any empirical research but provided a conceptual framework for the development of an Arduino-based solar tracker.

On the other hand, the other study focused on the development of an Arduino-based solar tracking system for energy improvement of PV solar panels. The study aimed to address the energy challenges, particularly the lack of constant power supply and the high cost of living, by developing a solar tracking system that can maximize the energy production of PV solar panels. The study involved empirical research, including the design and implementation of an Arduino-based solar tracking system, and the measurement of energy output and efficiency of the system.

The current study and the other related studies are similar in that they focus on the use of Arduino-based solar trackers to improve the energy efficiency of solar panels. All the studies highlight the potential of solar energy as a clean and renewable source of power, and they emphasize the importance of optimizing solar panel performance in order to make the most of this resource.

Conceptual Framework

INPUT	PROCESS	OUTPUT

Knowledge Requirements	**System Analysis**	**Solar Tracker: an Arduino-Powered Solar Tracker to Boost Panel**
• Electronics: Basic understanding of electronic components such as resistors, capacitors, diodes, and transistors is essential. This knowledge is necessary to design and assemble the solar tracker circuitry. • Solar energy: To design an effective solar tracker, you need to have an understanding of solar energy principles such as solar irradiance, solar panel efficiency, and photovoltaic technology.	• Requirements Analysis • Requirements Definition **System Design** • Hardware Design • Software Design • Flow Chart Design **Hardware Assembling** • Gathering Ideas • Gathering	

• Sensors: Knowledge of sensor technology is crucial for designing a solar tracker. Understanding how to use light sensors, GPS modules, or any other sensor technology to detect the position of the sun is essential. • Control systems: An understanding of control systems, including feedback loops and PID (proportional-integral-derivative) controllers, is essential for designing a solar tracker. This knowledge is necessary for controlling the motion of	Materials • Building • Testing **System Development** • System Design • System Prototyping • System Programming • System Testing • Implementation	

the solar panel and optimizing energy production. ● Mechanical design: While not a core requirement, a basic understanding of mechanical design is useful for designing the physical structure of the solar tracker. This includes understanding the materials to be used, the design of the frame, and the motor mounting mechanisms. **Software Requirements** ● Arduino IDE		

• C++ Programming Language **Hardware Requirements** • Arduino Board • Light Sensor • Servo Motors • Solar Panel • Pushbuttons • Resistors • Capacitors • Jumper Wires • Rotary Potentiometer		

Figure 1

Conceptual Paradigm of the Study

The table above describes the steps necessary to complete a specific task, which includes determining the knowledge, software, and hardware requirements needed for an Arduino-based solar tracker system. The hardware requirements section lists the necessary hardware components required for building the solar tracker. This includes the Arduino board, light sensors, servo motors, solar panels, push buttons, resistors, capacitors, jumper wires, and rotary potentiometer. The software requirements section lists the required software tools for the project, which includes the Arduino Integrated Development Environment (IDE) and SolidWorks, a computer-aided design (CAD) software tool that can be used to design the mechanical structure of the solar tracker.

On the other hand, The System Analysis process involves identifying the knowledge, software, and hardware requirements for the project. The second step is System Design, which includes Hardware Design, Software Design, and Flow Chart Design. The third step is Hardware Assembling, which involves gathering ideas and materials, building the physical components, and testing the system. The fourth step is System Development, which includes System Design, System Prototyping, System Programming, System Testing, and Implementation. System Design involves refining the design based on feedback from testing, System Prototyping involves building a functional prototype, System Programming involves writing the code that will control the solar tracker, System Testing involves testing the system to ensure it works properly, and Implementation involves deploying the solar tracker in the field.

Chapter III: Methodology and Hardware & Software Design & Development

This chapter presents the target user of the study, methods of data gathering, methods of software development and system design specification. It may also include in this study the software and hardware requirements, data flow diagram and context free diagram to talk about the activities and tools that used to develop the current study.

Research Design

In this study, researchers create a system that can improve the efficiency of solar panel systems. Utilizing the chosen research techniques, the researcher gathers data. This could entail installing a prototype solar tracker and gathering data on its performance, or polling solar panel system operators. After gathering the data, the researcher uses the necessary statistical procedures or qualitative analytic tools to analyze it. The researcher makes judgments regarding the performance of the solar tracker and its potential advantages for increasing solar panel efficiency based on the findings of the data analysis.

Research Methodology

The proponents developed a methodical approach to looking at and researching their issue. The target user's perceptions can be gathered in this way using surveys and questionnaires. The researchers will compile the data and then analyze it.

In order to maintain the usability and dependability of the suggested system, the proponents additionally identified numerous instruments and procedures for data collecting and processing and used the survey and questionnaire as a gathering tool. To ascertain the study's scope and constraints, the researchers gathered data from a variety of linked publications, books, journals, and other sources. Additionally, the advocates gather concepts and plans for the research via the internet that can make use of the hardware and software needed for this study.

Target User of the Study. The target users of the study are those who are looking to maximize the efficiency and output of their solar panel system. This includes individuals and businesses that rely on solar power as their primary source of energy, such as homeowners, commercial building owners, and farmers. Additionally, solar trackers may be used in remote areas where access to electricity is limited, or in disaster relief situations where access to electricity is temporarily disrupted.

Table 1

Distributions of Respondents

Type of Respondents	Number of Respondents	Percentage (%)
Business Owners	100	50%
Home Owners	100	50%
Total	200	100%

As shown in Table 1, there were 200 survey respondents in the study which comprise of one hundred (100) older adults, and one hundred (100) people with conditions.

Data Gathering Instruments. The proponents conduct a survey for business owners and home owners to seek accurate information for the overall completion of the proposed project. Furthermore, the proponents place a high value on achieving the intended goal. They guarantee that the proper and appropriate instruments are applied in order to produce complete data that enables the dependability, accuracy, and viability of the planned study.

In addition to interviewing the intended study participants, the proponents also conducted related research in books and other educational institutions' learning resources.

The questionnaire plays a significant role in both the system's design and operation. A questionnaire used by the supporters asks questions on the functionality and user interface of the system. In a similar vein, the questionnaire's purpose is to ascertain how the target consumers view the project's functionality, reliability, and final product in terms of presentation and appearance. The system's effectiveness is then determined by evaluating and interpreting the outcome. Validation and scoring of replies are done after the evaluation is completed.

Data Gathering Procedure. For the purposes of this research, in-depth interviews are being used. In-depth interviews are personal and unstructured interviews whose aim is to identify participants' emotions, feelings, and opinions on the project.

A semi-structured questionnaire that serves as the researcher's interview guide is utilized as one of the data gathering strategies for this study. While the researcher has some prepared questions to use as a roadmap to help the interview proceed in a way that advances the study's goal, other questions often come up in the course of the interview.

The proponents are also conducting extensive research in libraries and consulting with professionals. Additionally, the internet is used to acquire technical data for the hardware and software assembly.

Statistical Treatment of Data. The majority of evaluations aim to give various audiences helpful feedback. Using an evaluation questionnaire, the respondents carried out an evaluation survey.

The following scale was used to interpret and analyze the result:

Scale	Option	Verbal Interpretation
4.50-5.00	5	Excellent
3.50-4.49	4	Very Good
2.50-3.49	3	Good
1.50-2.49	2	Fair
0.1-1.49	1	Poor

Afterwards, the proponents computed for the weighted mean of each category using the formula: $Wm=\sum fw /N$

Wm= weighted

meanN= number of respondents

W= assigned weight

f= frequency

∑= summation

A weighted mean is an average that has been calculated by assigning various weights to various individual values. It is the study of methods and processes for acquiring, organizing, and evaluating data based on the principles of probability and statistics. It uses a variety of tools. Additionally, it is a set of concepts that are meant to pave the way for scientific inference from the obtained data. Calculating the weighted mean for a set of data with various individual mistakes is important in many applications.

Based on the weighted mean result, the proponents utilized the following scale to rank and compare the responses: 1 is equivalent to poor, 2 to fair, 3 to good, 4 to very good, and 5 to excellent.

Methods of Hardware and Software Development

The proponents used System Analysis and Design in developing their proposed system. Systems analysts do system analysis and design, which aims to systematically examine data intake or dataflow, processing or changing data, data storage, and information output within the context of a specific organization.

The system can become unusable if it is installed without sufficient design, which will generate a tremendous deal of frustration. The design and analysis of information systems are more organized when they are done using system analysis and design. Working with the system's existing and future users is a significant aspect of system analysis and design.

The first process in the study's creation was information collection, which comprised searching for crucial data. It required learning more about the study, what it was about, and how the data collected could assist its proponents in developing the study. The advocates looked for gear and software that could be utilized to conceptualize the desired result.

Preliminary and general design and detailed design are typically the two stages of the design process. The system's features were specified at the first design phase. Because this idea is seen as realistic, the expenses of creating this hardware were estimated. The detailed design phase, which contains the input, output, and processing parameters, is when work became increasingly computer-oriented. The new application's platform and programming language were also chosen during the design phase. Various methods and resources were employed for designing. Data flow diagrams and context-free diagrams were the methods and instruments used.

Furthermore, the design has gone through multiple hardware development phases, including testing and assembly. The manufacture of the body itself is included in the hardware development process. Gloves, flex sensors, and copper foil materials were employed by the proponents to ensure precision in creating the desired and effective output.

The system development stage came last. It entails a succession of system design coding, testing, and debugging operations until the design and anticipated results are realized. Additionally, documentation is crucial throughout this stage.

System Design Specifications

The researchers utilized the Hardware and Software design and Flow chart design to specify the design of the system. It is also presented in this study are the software and hardware components of the system.

Software Requirements. are the functional and non-functional specifications that describe by researchers what a software system should do and how it should perform.

Table 2

Software Requirements of the Proposed Study

Software	Minimum	Suggested
Integrated Development Environment	Arduino IDE	Arduino IDE 2.0
Programming Language	C	C++
Computer-Aided Design Software	SolidWorks	HelioScope

Table 2 illustrates the needed software for the proposed technology to work as intended. The following software categories such as Integrated

Development Environment, Programming Language, and Computer-Aided Design Software is used. Additionally, the bare minimum and recommended software are present to ensure the intended study runs smoothly. The researchers recommended employing more advanced tools for creating systems.

Integrated Development Environment: Arduino IDE. Is an open-source integrated development environment used to write and upload software code to Arduino boards. It is a simple and user-friendly interface designed for beginners and advanced users alike. It includes a code editor with features like syntax highlighting, code completion, and error highlighting, as well as a serial monitor for debugging purposes. The Arduino IDE also comes with a library manager that provides access to a wide range of pre-built software libraries for various hardware components and functionalities. It is available for Windows, Mac OS X, and Linux operating systems.

Programming Language: C. Is a high-level programming language used for system programming and embedded systems. Dennis Ritchie at Bell Labs created it in the early 1970s as a successor to the B programming language. C has grown in popularity due to its efficiency, portability, and powerful features such as low-level memory manipulation and direct hardware access. It has been used to create operating systems, device drivers, compilers, database systems, and many other types of software. C is also the basis for many other programming languages, such as C++, Java, and Python.

Computer-Aided Design Software. Is technology for design and technical documentation, which replaces manual drafting with an automated process. If you're a designer, drafter, architect, or engineer, you've probably used 2D or 3D CAD programs such as AutoCAD or AutoCAD LT software. These widely used software programs can help you draft construction documentation, explore design ideas, visualize concepts through photorealistic renderings, and simulate how a design performs in the real world.

Hardware Requirements. The physical components of the software development tools employed by the researchers are referred to as hardware requirements.

Table 3

Hardware Requirements of the Proposed Study

Hardware	Minimum	Suggested
Arduino Board	Arduino Uno	Arduino Uno

Light Sensors	LDR, 5 Mohm	LDR, 5 Mohm
Servo Motors	SG90 Micro-servo motor	SG90 Micro-servo motor
Solar Panel	Mini Solar Panel	Mini Solar Panel
Pushbuttons	Tactile pushbutton switch	SPST-NO contact, momentary action
Rotary Potentiometer	10k Ohm, Linear	10k Ohm, Linear
Resistor	Resistor 330 ohm	Resistor 330 ohm
Jumper Wires	Male-to-male jumper wires	20 cm length, 30 AWG wire

Table 3 outlines the minimum and suggested hardware requirements for a solar tracker using an Arduino board.

The minimum requirements include an Arduino Uno board, a light sensor (LDR), a micro-servo motor (SG90), a mini solar panel, a tactile pushbutton switch, a 10k ohm linear potentiometer, a 330 ohm resistor, and male-to-male jumper wires.

The suggested hardware includes the same components as the minimum requirements, but with some variations. It recommends the use of an SPST-NO (single-pole single-throw normally open) contact, momentary action pushbutton instead of a tactile pushbutton switch, and 20 cm length, 30 AWG wire instead of male-to-male jumper wires.

Other than that, the suggested hardware list is similar to the minimum requirements, including an Arduino Uno board, an LDR, an SG90 micro-servo motor, a mini solar panel, a 10k ohm linear potentiometer, and a 330 ohm resistor.

Arduino UNO. is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

Light Sensor. are a type of photodetector (also called photosensors) that detect light. Different types of light sensors can be used to measure illuminance, respond to changes in the amount of light received, or convert light to electricity.

Servo Motor. is a rotational or translational motor to which power is supplied by a servo amplifier and serves to apply torque or force to a mechanical system, such as an actuator or brake. Servo motors allow for precise control in terms of angular position, acceleration, and velocity. This type of motor is associated with a closed-loop control system. A closed-loop control system considers the current output and alters it to the desired condition. The control action in these systems is based on the output of the motor. It uses a positive feedback system to control the motion and final position of the shaft.

There are two types of current flow in these motors – AC and DC. AC servo motors can handle higher current surges and are thus more commonly found in heavy industrial machinery. ISL's DC Servo Motors are best suited for smaller applications and have excellent control-ability and feedback. In a servo motor speed is determined by the frequency of the applied voltage and the number of magnetic poles.

Solar Panel. is a device that converts light from the sun, which is composed of particles of energy called "photons", into electricity that can be used to power electrical loads.Solar panels can be used for a wide variety of applications including remote power systems for cabins, telecommunications equipment, remote sensing, and of course for the production of electricity by residential and commercial solar electric systems.

Energy Storage. is the ability to capture energy at one time for use at a later time. Storage devices can save energy in many forms (e.g., chemical, kinetic, or thermal) and convert them back to useful forms of energy like electricity.

Pushbuttons: These can be used to start and stop the exercise routine, or to switch between different exercises.

Rotary Potentiometer. is an adjustable electrical resistor that can be moved by means of a rotary motion. This allows control processes to be implemented in various electrical or electronic systems, for example for volume control in multimedia devices.

Resistors: These are used to limit the current to the LEDs and other components.

Capacitors: These can be used to smooth out voltage fluctuations in the circuit.

Jumper wires: These are used to make connections on the breadboard.

Shown in Table 4 are the hardware performance specifications to present the technical capability of the hardware presented in the study.

Table 4

Hardware Performance Specification

Hardware	Performance Specification
• Arduino Uno	• Microcontroller: ATmega328P • Operating Voltage: 5VInput Voltage (recommended): 7-12V • Input Voltage (limits): 6-20V • Digital I/O Pins: 14, of which 6 provide PWM output • Analog Input Pins: 6 • DC Current per I/O Pin: 20 mA

	• DC Current for 3.3V Pin: 50 mA • Flash Memory: 32 KB (ATmega328P) of which 0.5 KB used by bootloader • SRAM: 2 KB (ATmega328P) • EEPROM: 1 KB (ATmega328P) • Clock Speed: 16 MHz
• LDR, 5 Mohm	• Diameter: 5mm. • No. of Pins: 2. • Type of Mounting: PCB Through Hole. • Maximum Operating Temperature: +800°C (Approx.) • Dark resistance:1-20 Mohm.
• SG90 Micro-servo motor	• Operating Voltage is +5V • typicallyTorque: 2.5kg/cm • Operating speed is 0.1s/60° • Gear Type: PlasticRotation : 0°-180°

	• Weight of motor : 9gm • Package includes gear horns and screws
• Mini Solar Panel	• Material: Polycrystalline Silicon • Nominal Capacity: less than 2W • Number of Cells: 10pcs • Max. Power: 0.44W 0.55W 0.6W 0.88W 1W 1.6W • Type: Solar Cells • Number of Panels: 11
• Jumper Wires	• Wire gauge: 22 AWG • Length: 3 in (75 mm) or 6 in (150 mm) • Material: Copper with PVC insulation
• Pushbutton	• Contact resistance: 100 mOhm max • Operating force: 180-300 gf • Operating voltage: 5 V DC
• Rotary Potentiometer	• 10K ohm potentiometer, linear taper • 100,000 Cycle Life

	• 16mm Body • Rotational travel: 300 ° • Static Stop Strength: 90 oz-in • Rotational Torque: 0.5 to 1.25 oz-in
• Resistor	• Resistance range: 10-1M Ohm • Tolerance: 1-5% • Power rating: 0.25-1 W
• Capacitor	• Capacitance range: 1-1000 uF • Tolerance: 10-20% • Voltage rating: 10-50 V DC

The enlisted performance specifications in Table 4 serve as the basis of the researchers to select the right tools for the development of their project study.

Design Tools

The CFD first displays the interaction between the system under study and various external entities as a single high-level process for the system under investigation. A DFD may also be used to graphically represent the flow of data within an information system. The researchers will take the data flow diagram into account as one of the crucial elements of analysis and design.

Context Free Diagram

Context Free Diagrams are top-level views of systems that display the system's borders and areas of interaction with other entities. The planned study's interfaces and boundaries are made clear through its visual style.

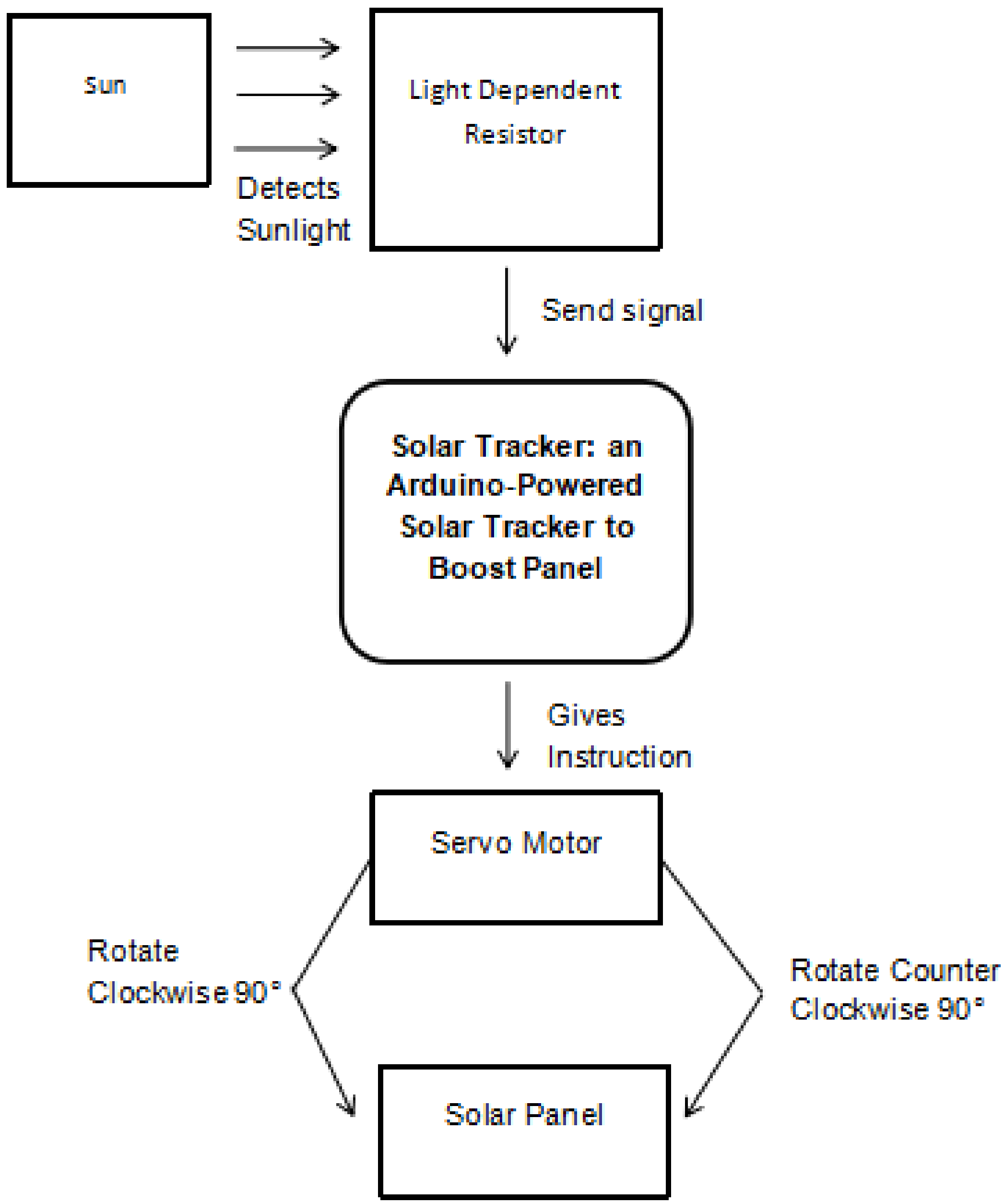
Sun
Detects Sunlight
Light Dependent Resistor
Send signal
Solar Tracker: an Arduino-Powered Solar Tracker to Boost Panel
Gives Instruction
Servo Motor
Rotate Clockwise 90°
Rotate Counter Clockwise 90°
Solar Panel

Figure 2

Context Free Diagram of the Proposed Study

Figure 2 shows the summary of the whole process of the proposed design. It shows the external factor that interact with the system. This would include the sun, which is the source of the solar energy being captured and tracked by the system.

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