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SMART AGRICULTURE WITH IoT

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ABSTRACT

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Food security is one of the crucial challenges people must face in the coming days. A majority number of farmers still cultivate in conventional farming methods, for which, the progress of crop production is not notable. The aim of this thesis is to examine the digitalization of farming. The thesis finds a way to cultivate in the challenging areas like Nordic countries.

The research begins with the challenges people face with current farming system in the natural disasters, cultivable land, etc. Then it presents the IoT and its integration with agriculture. The research explores the expansion of sensor networks, data analytics, and communication technologies these create a network environment that simplifies the real-time monitoring and control agricultural process.

The research creates a real-time demo with Arduino hardware and software. It shows how smart agriculture works and how programming language is used in the system. The demo shows the easy live monitoring. The thesis analyses the difficulties people can face in the implementation of smart agriculture. Then it finds the solutions to solve the difficulties.

In the end, the thesis displays the revolutionary way to implement the smart agriculture with IoT. It finds the way to produce food in the challenging areas.

Key words
Arduino, IoT, Irrigation System, Programming Language, Smart Agriculture, Sensors

CONCEPT DEFINITIONS

IoT

Internet of Things

AI

Artificial Intelligence

GDP

Gross Domestic Product

LTE

Long Term Evolution

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1 INTRODUCTION

In 1950, there were 2.5 billion population in the world. Today, the number is close to the total population of the Indian subcontinent alone. According to the UN Population Division, the population of the world will reach to 9.7 billion by 2050 (Haddad, 2023). The data shows how the population of the world is increasing rapidly. It should be a serious concern to the world. But there is one more thing that is bigger concern than the increasing population, even though they are related to each other. Food, providing food for this growing population is the biggest concern to the world. Although food is one of the top biological needs of humans, but it's supply is now the biggest anxiety to the people. Various natural and unnatural disasters, and climate change are the one of the major causes for this food crisis. The amount of agricultural land is decreasing due to urbanization and industrialization which is another big reason of the growing food crisis. Still, most of the farmers practice their conventional farming practices which hinder them from bringing progressive results in crop production. As the food crisis continues to grow with world's population, technology can play influential role in addressing this crisis.

The applications of the Internet of Things have grown in every sector of social during the decades. Internet of Things have a significant impact on agriculture during those times by addressing problems including scarcity of food, environmental issues and resources. IoT helps to monitor and control the agricultural environment to maximize productivity, minimize environmental impact, and optimize resource use in precision or smart agriculture.

The Internet of Things (IoT) is a developing concept that allows electrical gadgets and sensors to communicate with each other via the Internet (Sachin Kumar, 2019). In IoT-based smart farming, there are several sensors like- soil moisture sensor, temperature sensor, humidity sensor, motion detector sensor, etc. and drones used to monitor and control the field or firm from everywhere and automates the irrigation system (Ravindra, 2020). IoT sensors collect and transmit data from agricultural environments and send these data to central receiver that helps farmers to monitor the field and make decisions if need. For example, soil moisture sensors use capacitance or resistive techniques to provide real time information on soil water level, guiding irrigation practices to minimize water use (Bogena, 2007). IoT technology allows live monitoring that helps farmers to monitor livestock's live location, health and behavior. This leads to improvements in progress and production.

The aim of this thesis is to delve into the IoT impact on agriculture. This thesis seeks to explain how IoT devices and sensors are revolutionizing farming methods by deeply exploring the diverse impacts of IoT on agriculture. As the aim of this thesis is to evaluate significant influence of IoT on agriculture, the following crucial research questions would act as the road map:

1) How are the IoT technologies being integrated into various agricultural practices, and what are the significant results of those integration in terms of crop production, resource management, and economic growth?
2) How can IoT help Nordic countries to improve in agriculture by using IoT based greenhouse model?

A several methods will be used to find out the answer to these questions including – case study analysis, literature review, expert interview analysis, etc. The chapters of this thesis are structured to break down the complexity of these questions and show proven results to improve our understanding about the IoT in agriculture. This thesis aims to conclude with clear findings and proposals that will be helpful for everyone and open new possibilities for the agricultural industry.

2 BACKGROUND INFORMATION

Using advanced devices connected to the Internet of Things (IoT) instead of primitive machinery has significantly transformed farming methods due to the integration of technology in agriculture. The foundation for modern innovative IoT systems was built by the advent of computer technology in the 1980s, which marked the beginning of the digital era and carried over the mechanical breakthroughs. Those technologies are crucial for addressing the issues brought on by an increasingly populous world and developing environmental concerns because they enable accurate control over agricultural operations and real time monitoring. Bogue (2016) states that the smart utilization of IoT technology can result in notable improvements in crop production and resource management, which are essential for navigating some of the major obstacles dealing with the world's agriculture industry.

2.1 Current Challenges in Global Agriculture

Several problems affecting the world's agriculture sector that threaten food security and sustainable development. Serious land degradation, water scarcity, and the detrimental effects of climate change on agricultural output are some of these problems. Sub-Saharan Africa, for example, faces unique challenges due to its unpredictable rainfall patterns and acute water scarcity when, which impact both crop and livestock farming. Agriculture contributes up to 60% of some countries GDP (Omotoso, 2023). In northern Europe, on the other hand, Finland faces particular difficulties because of its colder climate, which means that energy-efficient agricultural solutions are crucial. The global increase in food consumption brought on by population expansion and shifting dietary choices makes those challenges even more urgent (Nordic Council, 2019). Innovative technology interventions that could boost farming systems endurance against climate abnormalities and offer sustainable solutions are needed to address these challenging concerns.

2.2 IoT Framework and Components

The implementation of Internet of Things (IoT) technology in agriculture involves the utilization of a system comprised of sensors, actuators, and connectivity solutions. This system enables the collection, transmission, and analysis of data especially for agricultural purposes. Field deployed sensors monitor areas of environmental and soil parameters, with the aim of adjusting water levels or applying fertilizers in response to sensor activity. The system employees advanced data analytics to examine and comprehend data, and it makes use of technology to guarantee that data does not clash between devices and central management. With this knowledge, farmers can decide how best to manage their crops and use their resources to increase agricultural productivity and sustainability (Shahab, 2024).

2.3 IoT in Precision and Smart Farming

IoT plays a revolutionary role in precision and smart farming, providing strategies to increase crop yield while reducing environmental effects. Smart farming utilizes IoT techniques to guarantee the accurate use of water, fertilizers, and pesticides in the optimal quantities is required by individual plants. This approach significantly minimizes waste and environmental harm. This strategy is very efficient in countries like Africa, where the preservation of resources is crucial. In the regions with colder climates such as Finland, the adoption of IoT technologies enables the efficient management of smart greenhouses. These greenhouses employ automated temperature control systems to extend the growing seasons and improve agricultural yields by creating regulated conditions (Bartzanas, 2021). These technological improvements not only facilitate traditional farming methods but also facilitate the implementation of noble farming techniques that can promote sustainable agricultural practices globally.

2.4 Significant Implementations and Trends

The use of IoT in agriculture has significantly increased production and operational efficiency globally. Smart irrigation systems for instance automatically modify water consumption based on real time soil moisture data, guaranteeing optimal plant development. Drones, on the other hand, are used for aerial data collecting to monitor crop health and optimize field conditions. These examples highlight how IoT may improve farming operations and increase the sustainability of agricultural methods. In addition, new developments like artificial intelligence (AI) integration to forecast crop yields and identify plant diseases early on, as well as vertical farming, which makes use of controlled environment agriculture (CEA) technologies, are raising the bar for agricultural innovation (Mike O. Ojo, 2022).

2.5 Regulatory and Socioeconomic Factors

As Internet of Things (IoT) technologies grow more deeply rooted in agriculture, they give rise to important regulatory and social concerns. The prominence of data privacy and security issues is due to extensive data collection by IoT devices. Furthermore, there are ethical concerns surroundings the enhanced surveillance possibilities facilitated by these technologies. In terms of socioeconomic factors, the automation of conventional agricultural activities has the capacity to replace employment, emphasizing the necessity for policies that strike a balance between technological progress and the economic and social welfare of farming communities (Food and Agriculture Organization of the United Nations, 2017). In order to ensure that the advantages of IoT in agriculture are distributed fairly among diverse areas and groups, it is essential for regulatory frameworks to adapt and keep pace with these technological improvements.

IoT in agriculture is expected to make significant advances in the future, potentially improving farming methods sustainability and efficiency. It is anticipated that developments in genetic modification and increasingly complex biotechnologies, along with sophisticated Internet of Things applications, will result in the creation of crop types that are more resistant to environmental challenges.

3 METHODOLOGY

A research methodology explains and displays the methods used in the research (McCombes, 2023). Although this thesis is a practice-based work, additionally this thesis will use some methods to collect ethical information and gain clear knowledge. This thesis uses a mixed-methods approach to understand the impact of IoT on agriculture. It will review the literature, case studies, and interviews to gain a comprehensive understanding of the practical implementation and outcomes of IoT technologies in various agricultural scenarios. The study will also identify the challenges and difficulties of implementing IoT technology in agriculture. Surveys and interviews will be conducted to gather quantitative data on the prevalence of IoT technology, while thematic analysis will be used for qualitative data. Factor analysis, regression analysis, and descriptive statistics will be used to analyze the quantitative data. The ethical considerations of privacy, confidentiality, and informed permission will be respected throughout the research process. Institutional review boards will be consulted for ethical approval, and all research operations will follow accepted ethical norms and procedures.

4 OVERVIEW OF IOT

In recent months, there has been a notable increase in interest surrounding the Internet of Things, as firms have been releasing goods and services based on IoT technology, and acquisitions connected to IoT have been generating news. According to IDC 2014, the Internet of Things has the potential to expand into a market value at $7.1 trillion by 2020 (Spencer, 2014). Nevertheless, there is a lack of consensus over the specific scope of the Internet of Things. The phrase developed from the research conducted by the Auto-ID Labs at the Massachusetts Institute of Technology (MIT) on networked radio-frequency identification (RFID) infrastructures. The International Telecommunication Union (ITU) currently defines the Internet of Things as a worldwide framework for the Information Society. It facilitates enhanced services by linking physical and virtual objects using established and developing interoperable information and communication technologies. Alternative definitions of the IoT emphasis the interconnectedness of objects, the Internet related features of the IoT, and the semantic issues that arise in the IoT (Wortmann, 2015).

The implementation of IoT technology is becoming more widespread in different aspects of daily life, including industries, housing, energy systems, transportation, healthcare, and urban development projects. The primary domains where this technology finds extensive use include industry, intelligent thermostats, security systems, smart energy applications, advanced transportation solutions, intelligent healthcare, and real time monitoring of parking and street lighting.

4.1 IoT Components

The structure of the IoT consists of a number of important components that work together to provide the user-friendly interaction between the physical and digital worlds. By analysing the hardware components of IoT, it becomes apparent that five crucial factors are important in building this revolutionary environment.

4.1.1 Sensors

IoT sensors are electrical chipsets or modules that detect and transmit data about the surrounding or system conditions to the Internet. Sensors can be operated by direct physical touch, electromagnetic radiation, or magnetic fields (Gerlée, 2023). Sensors are the key factor of this environment. Sensors are the responsible to collect real-time data from environment. The IoT technology works based on the data that was collected by the sensors. For example, automated gate opens when it detects any motion within its yard. Here, the gate is operated with motion detection sensor, the sensor detects motion from environment as data, and the gate works based on that data (motion). A several sensors work for the IoT technology, including temperature sensors, humidity sensors, soil moisture sensors, motion sensors, light sensors, fire detection sensors, etc.

Two major types of sensors used in IoT:

Table 1: Passive Sensors vs Active Sensors

Passive Sensors	Active Sensors
Do not need any external connection of power	Require external power sources
Example: temperature	Example: microphone in a cell-phone

4.1.2 Gateway

IoT gateways are designed to communicate between device to device or device to cloud. IoT gateways create a link between sensors, machinery, and controllers. With offering management, data processing, and communication gateway is one of the important components in IoT system (Tisha, 2024). These gateways provide unique solutions for industrial applications and are often used in complex automation systems where they act as a central hub for all IoT devices and sensors. IoT gateways increase the security of IoT networks and data by adding additional security measures. They can perform many IoT applications including data filtering, advanced analytics, and data visualization. IoT gateways add ideal solution for expanding IoT environments and improving enterprise infrastructure. They can be used on devices or machines that are not connected to the Internet, allowing them to access local networks or wireless IoT networks in the cloud (RS Components Ltd., n.d.).

4.1.3 Cloud

Cloud computing is crucial in Internet of Things systems, enabling data transmission, storage, processing, and analysis from afar. Cloud platforms offer storage and application hosting services, allowing devices to interact, analyze data, and execute instructions without relying on local computer resources (Rajiv, 2024). Cloud systems provide high-performance processors and advanced analytics tools for complex calculations, generating nuanced insights. Effective device management and integration are essential for IoT system protection. Cloud platforms offer adaptability, productivity, and enhanced performance, with security measures protecting data and privacy. Examples include smart cities enhancing traffic efficiency and healthcare monitoring for valuable information.

4.1.4 Analytics

The IoT is a complex network that depends on analytics to derive practical insights from the extensive data produced by networked devices. IoT analytics encompasses several elements including sensors, devices, data transfer, processing and storage, visualization, user engagement, and alerts and notifications. Sensors get instantaneous data from the surroundings, whilst technologies such as smartphones and wearables gather various forms of data. Data transmission entails the seamless transfer of data captured by sensors and devices to a central processing facility in real time, assisted by wireless communication technologies such as Wi-Fi, Bluetooth, LTE, and emerging technologies like NB-IoT (Pons, 2023). Data processing and storage encompass the use of cloud and edge computing, as well as the management of data lakes and warehouses. Data analysis and encompasses the use of real-time predictive, And prescriptive analytics. Customizable interfaces in visualization and user interaction facilitate the interpretation of information and enable users to make well informed decisions. IT analytics applications include several fields, gaining valuable knowledge in manufacturing, health care, agriculture, and smart cities. Nevertheless, obstacles such as data privacy, security, quality, and scalability persist.

4.1.5 User Interface

The user interface (UI) of the Internet of Things (IoT) is crucial for user engagement, efficient control, and data analysis. The design of IoT technologies impacts user experience, system usability, and adoption. Key elements include simplicity, uniformity, immediate reactivity, personalization, and multiple interaction modes. Challenges include managing complexity, accessibility, security, and privacy. Examples include smart home hubs, wearable health gadgets, and vehicle IoT systems. Efficient IoT user interfaces include voice, mobile application, and dashboards. Prioritizing user-friendly, safe, and responsive interfaces is essential for IoT advancements.

4.2 IoT Architecture

The Internet of Things is a concept that imagines a vast network of interconnected devices exchanging data and influencing our daily existence. The architecture of IoT has four essential layers: sensing or participation, network or connection, processing of data, and user interface or application (GeeksforGeeks, 2023). These layers collaborate to effectively manage the transmission of information from the physical layer to the application layer by integrating sensors, apps, and physical devices into a unified system.

The significance of IoT architecture is in its capacity to oversee by IoT enabled systems, facilitating streamlined data analysis and processing. Nevertheless, IoT designs present other hurdles, including the absence of standardized protocols or languages come on complexities in establishing Interconnectivity between systems, difficulties in accessing networks that may not be readily available, and concerns over portability.

In order to achieve successful implementation across different sectors, it is imperative to have a well-designed and efficient architectural framework. The user interface/application layer serves a vital platform for human interaction with the system and enables access to certain services. Incorporating additional components such as edge Computing, business layer, and security layer can enhance the design and effectively address specific issues.

Concrete examples of IoT architecture in the real world illustrate the adaptability and efficiency of this framework in enhancing several aspects of our life. Smart cities utilize an Internet of Things framework to improve the quality of life by connecting networks and sensors, gathering data, and overseeing services like transportation, safety standards, and energy optimization. IoT devices and technologies are utilized in healthcare to facilitate remote patient monitoring, telemedicine services, and medical device management, leading to enhanced patients' outcomes. IoT architecture may be utilized in agriculture to gather data on soil moisture temperature, and nutrient levels, facilitating precision farming and promoting sustainability.

5 IOT APPLICATIONS IN AGRICULTURE

The Internet of Things is significantly contributing to the modernization of agriculture, and it is estimated that the industry will achieve a value of $84.5 billion by 2031 (Samriddhi Chauhan, 2023). The driving force behind this rise is the imperative to grow agricultural production and fulfill the worldwide demand for food. Internet of Things applications in agriculture encompass precision farming, livestock monitoring, hence enhancing the efficiency and productivity of the industry.

Precision agriculture, facilitated by the Internet of Things, enhances resource utilization, such as water, fertilizers, and pesticides, by applying them at specific moments and locations, customize to individual section of a field. This methodology not only improves crop productivity but also preserves essential resources, in contrast to traditional agricultural methods. IoT driven precision agriculture in the United States has demonstrated significant enhancements in resource efficiency and crop production. Soil moisture sensors and automated irrigation systems have effectively decreased water used by up to 30% and equally improved crop yields by around 20% (Schimmelpfennig, 2016).

Picture 1: IoT application in agriculture (Image generated by AI)

Conversely, conventional farming practices in many regions of Africa encounter obstacles and inefficiencies due to the absence of IoT technological advantages. South African farmers who have implemented IoT technology have observed a decrease in water uses and an improvement in crop productivity. IoT applications also go beyond agricultural production and include livestock management, which enhances animal health and improves firm efficiency. In Europe, the use of livestock collars for health monitoring has been shown to decrease death rates and enhance milk production (Tzounis, 2017). These collars enable farmers to promptly and efficiently identify and address infections, surpassing the effectiveness of conventional approaches.

The extensive data gathered by Internet of Things devices facilitates sophisticated data analysis, empowering farmers to make well-informed choices that improve long-term sustainability and production. With the ongoing advancement and increasing availability of IoT technology, it is positioned to bring about a significant transformation in the agriculture industry, enhancing productivity and sustainability (Weersink, 2018).

5.1 Precision Farming

Precision agriculture is an approach that enhances the management and precision of livestock and agricultural cultivation via the use of information technology, sensors, control systems, robots, autonomous vehicles, and automated hardware. The trend is being driven by crucial technologies such as high-speed internet, mobile devices, and cost-effective satellites. CropMetrics is a precision agricultural company that specializes in advanced agronomic solutions and precise irrigation management. Their offerings encompass VRI optimization, soil moisture sensors, optimizer PRO. VRI improves profitability in irrigated agriculture fields by optimizing irrigation practices based on variations in topography on soil conditions. It also enhances crop yields and improves water uses efficiency. Soil moisture sensor technology provides real time assistance and advice for optimizing water uses efficiency during the growing season. The virtual optimizer PRO integrates several water management technologies into a centralized, cloud-based platform for consultants and producers (Ravindra, 2020).

5.2 Agricultural Drones

The utilisation of IoT drones in agriculture is on the rise, as they are employed for a range of functions including evaluating crop health, managing irrigation, monitoring fields, applying pesticides, planting, and analysing soil composition. These drones have advantages such as capturing images of crop health, using GIS mapping, being user-friendly, saving time, and having the potential to enhance crop yields. PrecisionHawk, a company, use unmanned aerial vehicles (UAVs) fitted with sensors to capture high-quality data about agricultural land using imaging, mapping, and surveying techniques. Farmers provide field details and choose and altitude or ground resolution. That room data offers valuable information on various aspects of plant health and growth, including plant counting, yield prediction, plant height measurement, canopy cover mapping, field water ponding mapping, scouting reports, stockpile measurement, chlorophyll measurement, nitrogen content in wheat, drainage mapping, and weed pressure mapping. The drone acquires multispectral, thermal, and visual imagery while in flight and returns to its original takeoff position upon landing (Ravindra, 2020).

5.3 Livestock Monitoring

The use of IoT technology into livestock management has fundamentally transformed the health and productivity of cattle enterprises. Wireless IoT apps are being utilized by large farm owners to monitor the whereabouts, welfare, and general condition of their animals, therefore minimizing the spread of diseases and minimizing labor expenses. Landowners may effectively track the whereabouts of their livestock by utilizing sensors based on the IoT, therefore reducing the necessity for human inceptions, and enhancing operational efficiency.

JMB North America provides advanced cow monitoring technologies, including a sensor that notifies herd managers or farmers when a heifer’s amniotic sac splits, indicating the beginning of labor. This forecast involvement guarantees that well-being of both the newborn calf and the mother, revolutionizing conventional methods in cattle management.

Picture 2: IoT based livestock monitoring (picture generated by AI)

The utilization of IoT technology is also being employed to improve reproductive control, optimize feeding techniques, and carefully monitor animal behavior. Sensors have the ability to identify alterations in eating pattern or movement, which serve as early signs of health problems. This enables timely veterinarian attention and enhances the well-being of animals. IoT devices have the capability to monitor and evaluate the efficiency of different feed kinds and feeding patterns. This enables the development of customized nutrition programs that are optimized for each individual animal or specific breed.

These IoT technologies optimize management practices and enhance sustainability in cattle farming by facilitating accurate and timely interventions, minimizing waste, decreasing emissions, and promoting responsible utilization of resources. The data obtained through IoT devices offer significant information on health trends and productivity patterns in the herd. These data-driven approaches allow for informed decision making which may ultimately result in improved productivity and profitability (Ravindra, 2020).

5.4 Smart Greenhouse

Smart greenhouse is a IoT-based automated agricultural system that helps to increase the growth season even in bad environment. In smart greenhouse agricultural system, IoT technology, like sensors continuously monitor the agricultural project. Smart greenhouse monitors environmental conditions like temperature, water level of soil, humidity, etc. At the same time, the system also monitors plant's needs, like fertilizer, water, etc. Sensors collect real-time data from the system and provide important information about environmental factors that are analyzed by the central control system.

Smart greenhouses can use artificial lighting systems to augment or replace natural lights, while LED lights are used to increase photosynthesis and accelerate plant growth. These lights have the ability to automatically adjust their brightness levels based on varying natural light levels.

Smart greenhouses provide a shield against the external weather and its volatility, to create a controlled environment for continuous production throughout the year, even in extreme climates. This optimizes efficiency and ensures uninterrupted access to fresh cut produce.

IoT based smart greenhouse increases resources efficiency, alongside reduces water waste. Smart greenhouse also decreases the environmental effects from the agricultural sector. Smart greenhouses can continuously refine and improve growing methods by collecting data that provides valuable insight into optimal growing conditions and strategies. Smart greenhouses integrate cutting-edge technology with existing agricultural practices to provide a sustainable solution to modern agricultural constraints (Ravindra, 2020).

6 IOT IMPLEMENTATION IN A GREENHOUSE

IoT based smart greenhouse has transformed the traditional agriculture. The smart agricultural system offers to monitor the environment and plant's needs by using sensors that help to increase growth season and increase crop production. Smart greenhouse is a crucial agricultural system in the areas like Nordic countries where the growth season is lower than others due to winter effects. Smart greenhouses offer to enable accurate regulation and surveillance of internal temperature conditions, irrespective of fluctuations in external weather by using IoT technology. Smart greenhouse monitors the agricultural project live, including temperature, humidity, soil moisture level, etc. Sensors collect data in real time and transmit it to a central system, which then automatically changes the environment to create the best possible growing conditions for different types of crops. Improved adaption supports year-round agriculture but also improves the use of resources such as energy and water. According to research conducted by the Nordic Council of Ministers, the utilization of IoT technology in greenhouses may result in a 20% boost in productivity and a reduction in energy uses of up to 25% (Nordic Council, 2019). It shows positive results in terms of sustainability and economic stability.

This part of the research focuses on the implementation of a digitally simulated smart greenhouse project to demonstrate how IoT technology can be applied in a greenhouse environment. Its aim is to make environmental monitoring more automatic and effective, especially in harsh environments such as those found in the Nordic countries, thus making that use of IoT to improve greenhouse farming. The smart greenhouse is controlled by an automated system, enabled by a complex network of Internet of Things integrated devices using the Arduino Uno platform. These elements are needed to collect real time data and make autonomous changes to the environment to increase crop growth. Sensors continuously monitor essential things like soil moisture level, temperature, humidity, etc. The data is immediately sent to a centralized system which autonomously controls conditions in the greenhouse. The degree of automation guarantees ideal uninterrupted growing conditions and greatly reduces the labor normally required to operate the greenhouse. The project exemplifies the practical application of IoT in smart agriculture, offering valuable knowledge on the utilization of IoT systems and the integration of IoT in greenhouse environments. Continuous data monitoring enables valuable insights to be generated, enabling continuous improvement of methods aimed at improving yield and crop quality.

6.1 Software Components

There are some components needed to implement the project. Since, the project is done digitally, the first requirement is a software through which the project can be executed. In this case, the project used Tinkercad software to work on the project. Tinkercad is open-source online platform that allows 3D modeling program. Tinkercad does not require downloading or installation separately, there is a web version available to use the application (Macdonald, 2016). Tinkercad offers a simple drag and drop system for the users, and it has two types of method to input data or write code/command, either blocks, or code/text.

6.2 Hardware Software

Beside software, additionally the project needed to use some other components these are given in the Tinkercad. The components are listed below:

Table 2: Components List

Name	Quantity	Component
U1	1	Arduino Uno R3
SEN1	1	Soil Moisture Sensor
D1	1	Red LED
D2	1	Green LED
R3 R4	2	300 Ω Resistor
SERVO1	1	Positional Micro Servo
U2	1	Temperature Sensor [TMP36]
M1	1	DC Motor
P1	1	5.5 Power Supply
K1	1	Relay SPDT
L2 L3 L4	3	Light bulb
R1 R2	3	1 kΩ Resistor

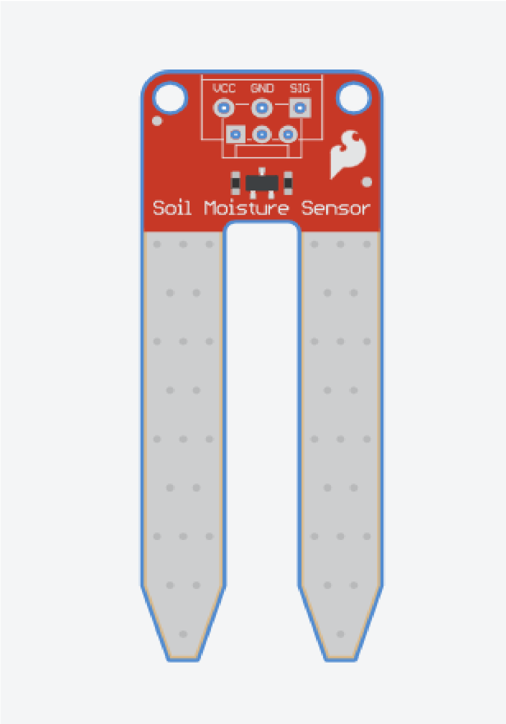
R5		

6.2.1 Arduino Uno R3

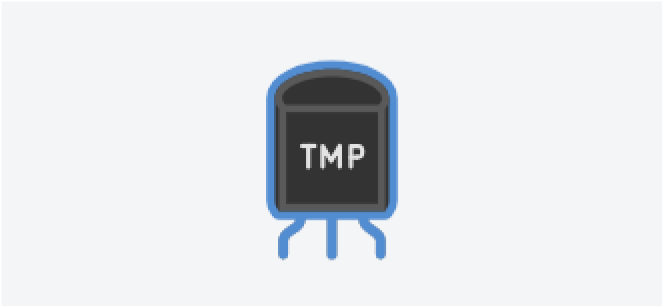
The Arduino Uno R3 is a easy to use and flexible microcontroller board, based on the ATmega328P Microprocessor. The device provides USB connectivity, and ICSP header, 14 digital input/output pins, 16 MHz quartz crystal, 6 analog inputs, and a reset button. Its inherent simplicity makes it appropriate for a wide range of undertakings, spanning from do-it-yourself crafts to scientific equipment. The fact that it is open source and has support from a community makes it a perfect option for students and educators. The Arduino Uno R3 serves a central processing unit in IoT applications, such as smart greenhouse systems, by analyzing data collected from environmental sensors and managing the operational of actuators. The capacity of this device to interact with sensors and actuators, operate autonomously or link to a computer, is crucial for the development of intelligent, automated systems in contemporary agricultural advancements.

6.2.2 Soil Moisture and Temperature Sensor

Soil moisture sensor is an important equipment for smart agriculture. Especially it is essential for smart irrigation system. In smart agriculture, soil moisture sensor provides essential information for making decisions on irrigation strategies and water conservation. The sensor continuously measures the water level of soil and sends the data the central controller to make decision, and this way it helps to reduce the uses of water. Department of the soil moisture sensor usually depends on one or more technologies; capacitance and resistive sensing techniques are often used. The change in capacitance between the two plates, which is dependent on soil moisture, is measured by a capacitance sensor. This technique gives accurate moisture measurements and is quite sensitive (Bollinger, 2024). Conversely, resistive sensors detect the electrical resistance existing between 2 probes grounded; this resistance decreases as humidity increases.



Picture 3: Soil Moisture Sensor



Picture 4: Temperature Sensor

A temperature sensor uses an electrical signal to deliver a temperature measurement in a readable format. These devices are often thermal or resistant temperature detectors. One of the most basic types of temperature monitoring equipment for determining heat and cold is a thermometer. In the geotechnical sector, thermometers are used to track changes in foundation integrity caused by seasonal fluctuations in concrete, constructions, water, soil, bridges, and other materials. Two different metals are used to concrete a thermocouple (T/C), who is produces an electrical voltage directly proportional to temperature change. A variable resistor known as an RDT (Resistance Temperature Detector) adjusts it's electrical resistance precisely, consistently, and almost linearly in response to temperature variations (Encardio Rite, 2023).

6.2.3 LED and Light bulb

LED, also known as light-emitting diode, is a semiconductor that releases light when electrical current flows through it (Kashyap, 2024). LED is perfect for a multitude of uses, including farming endeavors for its superior efficiency, longevity, and reduced power consumption over conventional incandescent bulbs. In a smart greenhouse, LED can be used for supplementing plant illumination. LED has the ability to emit light at certain wavelengths, which improves growth rates and yield while providing exact control over the light spectrum. In IoT-based agricultural systems, where they may be controlled based on sensor data, LEDs are also essential components.

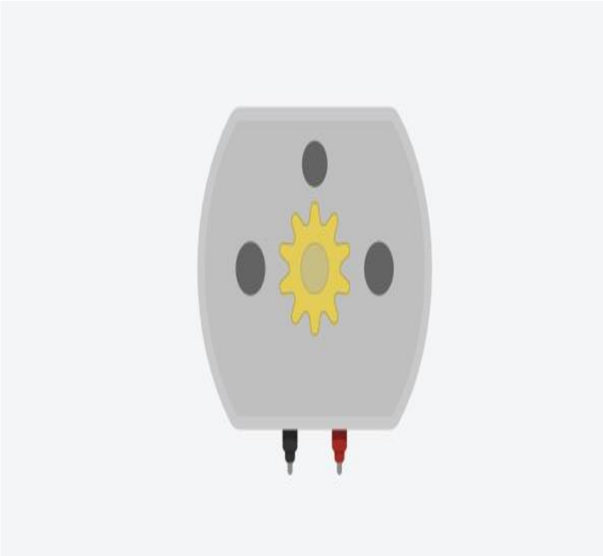
On the other hand, smart greenhouse relies heavily on conventional light bulbs like halogen and incandescent because of their strong light production and wider spectrum range. While halogen bulbs are more effective and brighter and are utilized for supplemental lighting in denser plant growth canopies, incandescent bulbs give more heat in colder weather (Apex-books, n.d.). Although they have disadvantages like inefficiency, increased operating cost, and frequent bulb replacement, but it's still crucial for smart greenhouse to generate heat.

6.2.4 Resistors

In agricultural technology projects, resistors are crucial electronic parts that regulate current flow in circuits to guarantee safety and stability. They aid in limiting current and shielding delicate electronics from damage or inefficient operation. Variable or fixed resistors are available based on the application. Variable resistors enable resistance adjustment, whereas fixed resistors provide proper working currents for gadgets like LED indicators and sensors. In order to ensure safe conditions and prolong life span, resistors are utilized in sensor integration and LED lighting control. Resistance value, power rating, and the ability to tolerate external elements including moisture, temperature swings, and chemical exposure are all included into it during design. Despite their simplicity, resistors correct selection and implementation are crucial for the efficiency and longevity of agricultural technologies, optimizing operations and productivity and hence comment (A Complete Guide to Resistors, 2024).

6.2.5 Servo Motor and DC Motor

A servo motor is a type of actuator that is capable of accurately controlling the position, velocity, and acceleration of a system, whether it is rotational or linear in nature (Gastreich, 2018). It is often employed in the fields of robotics, radio-controlled airplanes, and precision agriculture to regulate devices such as vents, gates, and automated plant feeding systems. Servos are composed of a motor, control board, potentiometer, and the gear system. They have a vital function in agricultural technology, particularly in greenhouses and mechanized planting systems. They have the capability to automatically control window or roof vents, regulate watering systems, and maintain a consistent flow of light and nutrients. Additionally, they play a crucial role in IoT systems by enabling real time modifications and improving accuracy in plant maintenance. Nevertheless, the obstacles encompass intricacy and expenditure, and may want regular maintenance and adjustment.



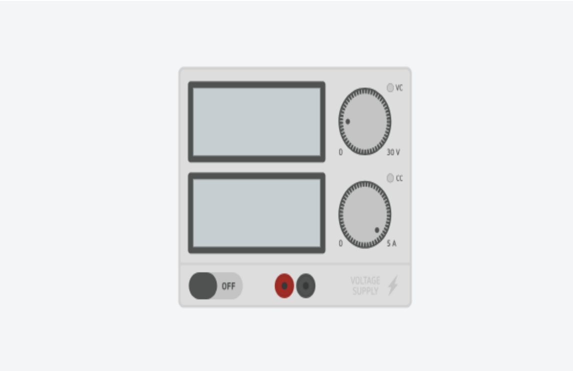
Picture 5: DC Motor

Picture 6: Servo Motor

On the other hand, electricity serves as automated machinery in many industries, including agriculture, and transforms the electrical energy of a DC motor into mechanical energy. They exhibit the dependability, effectiveness, and accuracy of machine functioning. DC motors have application in diverse domains, including power systems, conveyors, irrigation systems, and automated ventilation systems. These devices can be incorporated into information technology systems to enable remote monitoring, real time operational modifications, proactive maintenance, and energy management. DC motors possess the benefits of being controllable, adaptable, energy efficient, durable, and dependable. Nevertheless, they encounter challenges such as exorbitant installation costs, demanding maintenance needs, and complex integration processes. Although facing those these difficulties, the incorporation of these systems with IoT technology is a crucial element of intelligent agriculture solutions, contributing to the enhancement of productivity and ecological sustainability.

6.2.6 Power Supply and Relay

The power supply is an essential element of electrical and electromechanical systems, particularly those employed in agriculture. It transforms alternating current (AC) into direct current (DC) to ensure the effective functioning of electrical devices. Reliable and adaptable power supply is crucial in agriculture for operating systems like automated feeders, irrigation pumps, and monitoring sensors. Advanced power systems sometimes incorporate functionalities such as voltage control, power conditioning, and uninterruptible power supply (UPS) to provide backup power in the event of outages.



Picture 7: Power Supply

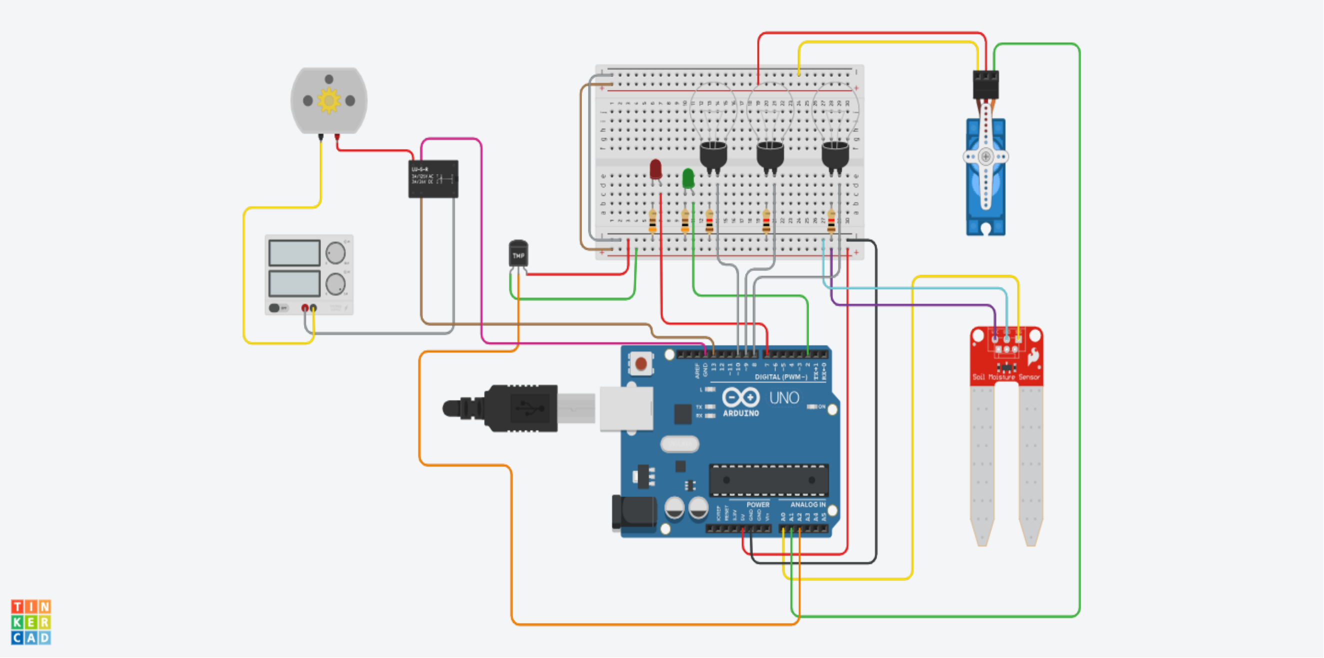
Picture 8: Relay

Relays are electromechanical devices employed in industrial and agricultural environments to control the flow of electric current. They manipulate high-voltage circuits using low-voltage signals without any physical actions, which is very beneficial in automated systems. Supplies and relays are crucial components for the incorporation of automated systems in contemporary agriculture. Properly specifying and installing them enhances the dependability of the system, improves safety, and increases efficiency. Implementing automated control systems using relays and ensuring consistent power supply can result in substantial enhancements in agricultural production and efficiency in resource utilization (Upadhyay, 2022).

6.3 Project Plan

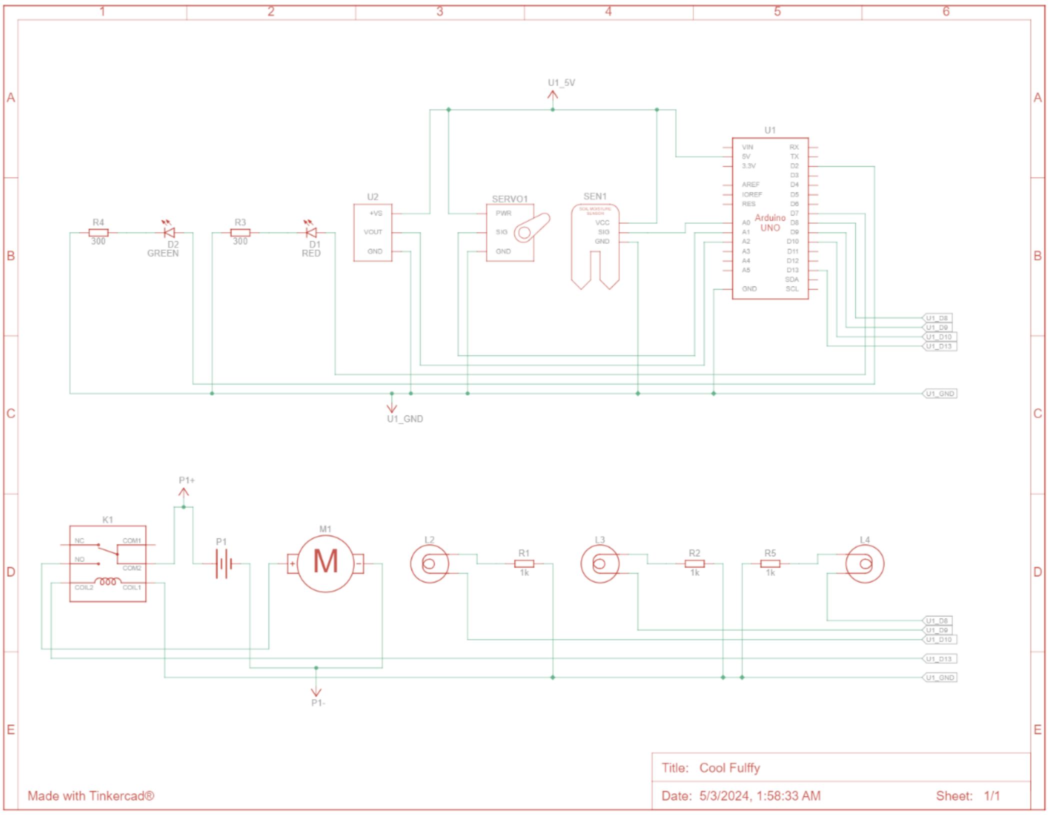
The aim of the thesis project is to implement a smart greenhouse designed with an automated control system by managing irrigation, temperature, heating, and lighting to regulate plant growth. Arduino Uno is the main component or the controller of this project. A several sensors and actuators will be used in the project to continuously monitor and regulate ambient conditions.

The system employs soil moisture sensors to quantify Soil moisture levels, ensuring that plants receive an optimal amount of water. The Arduino reads the humidity data and operates a water pump to irrigate the plants as necessary. The system will start a pump to distribute water if the soil moisture falls below a threshold of 100 (only a scale of 0 to 1023). Conversely, it will cease the pump operation to prevent water surplus if the soil moisture remains above the threshold. There will be LED light used in the project that would work based on the water pump. If the water level of the soil is lower than the required amount, red LED will turn on and it will remain on until the water level is enough. The red LED will turn off when the water level is higher than the required amount, and green LED will turn on then that will remain on until the water level is low again. This is how visitors will understand that the water pump is on.



Picture 9: The implementation of the project in Tinkercad

Temperature regulation is another crucial element in maintaining optimal conditions within this greenhouse. Temperature sensors serve the purpose of monitoring ambient temperature and providing data. Additionally, they are utilized in the regulation of servo-controlled windows and some heat generating light bulbs. The servo unit regulates the window's position based on the temperature. If the temperature exceeds 25°C, the servo unit opens the window to allow cold air to enter, so decreasing the greenhouse temperature. On the other hand, as the temperature decreases the window closes. The light bulbs will work based on the temperature too. If the temperature is between 1 to 10, one light bulb will turn on and generate the heat; if the temperature is between-10 to 0 another light will turn on to increase the heat level. If the temperature is below -10 another light will turn on and increase the heat level of the greenhouse. These bulbs will maintain the heat level of the greenhouse in winter season, and it will increase the growth season. This method is very beneficial for the countries like Nordic Nations where the growth season is lower than other countries. There are several types of light bulbs these can be used in this method, the bulbs are directly operated by the Arduino, so there is no physical operation need.



Picture 10: Schematic view of the implemented project

This advanced control system is specially intended to autonomously regulate the greenhouse environment, ensuring the ideal conditions for plant growth with no need for human involvement. The project employs temperature sensor, servo motor, DC motor as water pump, electronic bulbs, and LED to address contemporary agricultural difficulties in a sophisticated manner. Combines technology with conventional farming methods to enhance the effectiveness of agricultural activities, enhance sustainability, and boost productivity. By utilizing the Arduino and its programmable adaptability, the system can be effortlessly altered or enhanced by incorporating supplementary sensors or actuators as required to enhance environmental control system in forthcoming greenhouses.

6.4 Flowchart of the Project

A flowchart is diagram that displays the work process step by step. A flowchart is important in a project as it makes the work process fluent. Flowchart informs the moderator about the next step of his work. The flowchart of this project is given below -

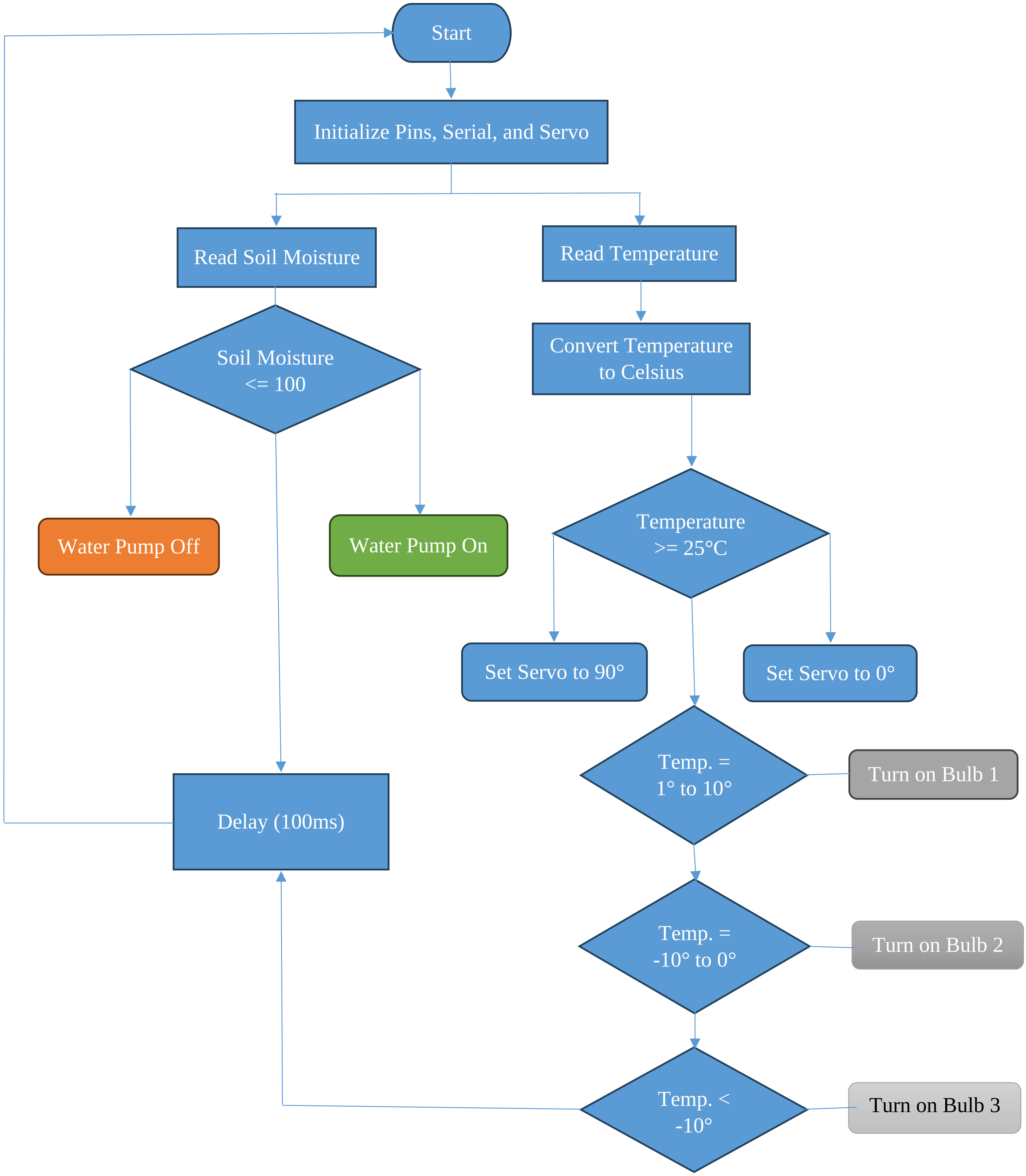


Figure 1: Diagram of the project

6.5 Programming Part of the Project

Programming part is one of the crucial parts of the project. Because the project/program will work based on the command that is included in the code. Tinkercad, where the project has implemented, supports C++ programming language that the project has used.

First of all, needed declare variables for the soil moisture sensor, temperature sensor, and servo. Then, needed to define the bulb pins as 8, 9, and 10, respectively. The setup function comes next, where needed declare the pin configurations:

```
void setup() {
    pinMode(A0, INPUT);
    pinMode(A2, INPUT);
    Serial.begin(9600);
    pinMode(13, OUTPUT);
    pinMode(7, OUTPUT);
    pinMode(2, OUTPUT);
    servo_A1.attach(A1, 500, 2500);

    // Setup bulb pins as outputs
    pinMode(bulb1, OUTPUT);
    pinMode(bulb2, OUTPUT);
    pinMode(bulb3, OUTPUT);
}
```

In the next step, author used the loop function where author declared commands for the project. It starts by reading the soil moisture sensor (A0) and temperature sensor (A2). Author also included `Serial.print` statements to display the values of both sensors. After declaring the commands, project needed add a 100ms delay to improve the simulation performance.

The code, that is written for the project (given in Appendix) works perfectly in Tinkercad without any errors. It is very simple and easy to follow.

7 RESULT OVERVIEW AND FUTURE PERSPECTIVES

Throughout the thesis paper, we have seen that IoT implementation in agriculture has a significant advantage over the conventional agricultural method. Higher crop production, less human involvement, economical growth, etc. are benefits of IoT implementation in agriculture. The thesis has illustrated that how IoT-based smart greenhouse can help countries these do not have suitable weather for agriculture, like Africa, Nordic, and Arabs nations. This section of the thesis will display the results of IoT implementation in agriculture. At the same time, it will also focus on the future perspectives of the research topic.

7.1 Result Overview

According to the explanation that we have observed during the thesis report, we can understand that this thesis explores the use of IoT technology in agriculture, with specific emphasis on smart greenhouses, in order to enhance productivity, optimize resource utilization, and promote sustainability. Smart greenhouses equipped with IoT technology have demonstrated notable enhancements in agricultural productivity. Automated irrigation systems have effectively decreased water consumption by up to 30%, while temperature control systems have successfully prolonged growing periods. Furthermore, these technologies contribute to favorable environment outcomes by diminishing the ecological impact of farming operations and fostering sustainable behaviors.

From an economic standpoint, the deployment of IoT in agriculture yields significant advantages, including enhanced profitability for farmers and decreased operational expenses. Nevertheless, there are notable obstacles to overcome, including the substantial upfront expenses, the intricate nature of IoT systems, the limited technical knowledge among farmers, and the apprehensions around data confidentiality and protection. In order to tackle those problems, it is necessary to implement extensive training programs and establish support systems.

To summarize, the findings of this thesis emphasis the significant the impact of IoT in improving agricultural methods, tackling crucial issues in contemporary farming, and providing effective remedies for strengthening food security. The significance of using IoT in farming is highlighted by the economic, environmental, and social advantages it brings, as well as the useful insights it provides in the burgeoning subject of smart agriculture. This study offers a strong basis for comprehending the present influence of IoT in agriculture and defines essential measures for improving its implementation.

7.2 Future Perspectives

Technological improvements and the global demand for sustainable agricultural practices are projected to drive substantial growth in the future of io T in agriculture. Advanced data analytics an artificial intelligence are key methods that can offer precise and predictive insights into agricultural operations. These methods allow for real time decision making and more efficient use of resources. The integration of genomics with the Internet of Things has the potential to enhance crop and livestock breeding programs by increasing precision, improving desirable features in plants and animals, and mitigating resistance to diseases, pests, and climatic changes.

Autonomous robots, including drones and self-driving vehicles, will have a growing significance in agriculture in the future. This is due to the Internet of Things, which enhances their effectiveness and ability to link with farm management systems. The Internet of Things will bring about a significant transformation in agricultural supply chains through enhanced transparency and traceability, waste reduction, and improved product quality. Effective resource management is essential for IoT technologies, as it enables accurate water management, optimal utilization of pesticides, and efficient monitoring of soil health. This, in turn, reduces the environmental impact of agriculture activities.

With the increasing prevalence of the Internet of Things in agriculture, there will be a growing need to address regulatory and ethical concerns. Stakeholders must establish frameworks to guarantee the conscientious utilization of new technologies and promote advantages for all partners involved in the agricultural value chain. To summarize, the future of IoT in agriculture has prospects for tackling both conventional and emergent obstacles, but necessitates cooperation among technologists, farmers, researchers, policymakers, and other industries.

8 CHALLENGES AND DIFFICULTIES

The IoT application in agriculture or smart greenhouse has some difficulties these could be problematic for the farmers or users. This section of the thesis delves into the hurdles faced during the application of IoT in agriculture.

The adoption of smart agriculture has various challenges, such as the high cost, technical obstacles, lack of expertise, environmental problems, and power supply limitations. Several costly components are utilized in a smart agricultural system. Many farmers lack the financial means to invest in the system. Conversely, numerous farmers lack sufficient expertise in technology, making it challenging for them to effectively utilize it. In most rural areas, there is a lack of sufficient expertise, which might make it challenging to address any technical issues that may arise. The power supply is a crucial component in smart agriculture. Solar power plays a crucial role in smart agriculture by enabling the monitoring of remote farms and fields. However, supplying the power source in a vast expanse of land in rural areas poses a challenge. However, it is crucial to supply the necessary power source for the program to function. Environmental problems are significant concerns. Extreme weather conditions such as floods, storms, high temperatures, and powerful winds might pose challenges for the sensors. This could potentially interrupt the sensors to gather data.

Agriculture is an essential for economic growth in all countries, making a significant 4% contribution to the world gross domestic product (GDP). In many underdeveloped countries, it may account for almost 25% of their GDP (Agriculture and Food, 2023). Government can play a crucial role by offering loan to the farmers for agricultural sector. In this way, farmers could get the budget to spend on smart agriculture. Many non-governmental banks or organizations also can come forward to solve the budget problem my offering short-time or long-time loan. Many governmental and also non-governmental organizations can teach and train farmers about technologies and its implementation on the field. Additionally, they can offer to solve the technical issues by providing experts. Agricultural practitioners have the option to use renewable resources such as solar power, wind power, and biogas as alternatives to electricity. These alternatives are more affordable and dependable in comparison to electricity. Cybersecurity is crucial since a cyberattack has the potential to devastate the system. Therefore, it is essential to guarantee the protection of cybersecurity. This collective approach will help to overcome the challenges and increase the productivity and sustainability.

9 CONCLUSION

The extensive resource executed in this thesis convincingly illustrates the significance of IoT technology in transforming the agricultural sector. The implementation of innovative I T technologies has achieved substantial advancements in enhancing agricultural productivity, optimizing resource allocation, and enhancing sustainability, hence revolutionizing conventional farming into more effective and innovative methods. The implementation of IoT in agriculture allows for accurate resource management, as demonstrated by a 30% decrease in water consumption through the implementation of smart education systems and the ability to increase growing seasons in unfavorable climate areas with the help of smart greenhouses. These enhancements are crucial not just for optimizing crop productivity but also for mitigating the ecological repercussions linked to traditional agricultural practices.

The incorporation of IoT has significant economic ramifications, since it has the potential to decrease operational expenses and enhance profitability by improving efficiency in crop management and resource utilization. Nevertheless, this thesis identifies and rigorously analysis significant obstacles that impede the extensive implementation of IoT technology in agriculture. These factors encompass substantial upfront expenses, the intricacy of IoT systems, and the evident disparities in technical expertise needed across farmers. Furthermore, the text highlights the crucial issues related to data privacy and security, underscoring the immediately requirement for a robust legislative structure to implement IoT technology in agriculture.

In conclusion, it can be said that this thesis argues that although there are substantial obstacles to the widespread implementation of IoT in agriculture, its extensive advantages make a strong argument for its ability to effectively tackle global food security issues. Stakeholders in the agriculture sector, such as technology developers, legislators, and academic institutions, must recognize and address the socio-economic, ethical, and legal obstacles that arise when forming partnership to advance technology. Continued research and development, together with targeted policy interventions and educational programs, are essential for fully harnessing the transformative power of IoT in agriculture. This thesis makes significant contributions to academic discussions regarding the incorporation of IoT technology in agriculture. Additionally, it provides guidance for future research and practical applications, with the goal of developing environmentally sustainable and economically feasible approaches to agricultural practices and enhancing global food systems.

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APPENDIX 1/2

Code:

```
#include <Servo.h>

int soil_moisture_sensor = 0;
int temperature_sensor = 0;
Servo servo_A1;

// Calibration values
float temperatureOffset = 0; // Adjust based on calibration
float temperatureScale = 1.0;   // Adjust based on calibration

// Define bulb pins
int bulb1 = 8;
int bulb2 = 9;
int bulb3 = 10;

void setup() {
  pinMode(A0, INPUT);
  pinMode(A2, INPUT);
  Serial.begin(9600);
  pinMode(13, OUTPUT);
  pinMode(7, OUTPUT);
  pinMode(2, OUTPUT);
  servo_A1.attach(A1, 500, 2500);

  // Setup bulb pins as outputs
  pinMode(bulb1, OUTPUT);
  pinMode(bulb2, OUTPUT);
  pinMode(bulb3, OUTPUT);
}

void loop() {
  soil_moisture_sensor = analogRead(A0);
  temperature_sensor = analogRead(A2);

  Serial.print("Soil Moisture: ");
  Serial.println(soil_moisture_sensor);

  // Apply temperature calibration
  float voltage = temperature_sensor * 5.0 / 1023.0;
  float temperatureC = (voltage - 0.5) * 100.0;
  temperatureC = (temperatureC + temperatureOffset) * temperature-
Scale;

  Serial.print("Temperature: ");
  Serial.println(temperatureC);
```

```
// Control water pump and servo
  if (soil_moisture_sensor <= 100) {
    digitalWrite(13, HIGH);
    digitalWrite(7, HIGH);
    digitalWrite(2, LOW);
  } else {
    digitalWrite(13, LOW);
    digitalWrite(7, LOW);
    digitalWrite(2, HIGH);
  }

  // Control servo based on temperature
  if (temperatureC >= 25) {
    servo_A1.write(90);
  } else {
    servo_A1.write(0);
  }

  // Bulb control based on temperature
  if (temperatureC > 0 && temperatureC <= 10) {
    digitalWrite(bulb1, HIGH); // Turn on one bulb
    digitalWrite(bulb2, LOW);
    digitalWrite(bulb3, LOW);
  } else if (temperatureC > -10 && temperatureC <= 0) {
    digitalWrite(bulb1, HIGH);
    digitalWrite(bulb2, HIGH); // Turn on two bulbs
    digitalWrite(bulb3, LOW);
  } else if (temperatureC <= -10) {
    digitalWrite(bulb1, HIGH);
    digitalWrite(bulb2, HIGH);
    digitalWrite(bulb3, HIGH); // Turn on all three bulbs
  } else {
    digitalWrite(bulb1, LOW);
    digitalWrite(bulb2, LOW);
    digitalWrite(bulb3, LOW); // Turn off all bulbs
  }

  delay(100); // Delay a little bit to improve simulation perfor-
mance
}
```