A Model of a Smart Garden Using the Integration of a Set of Components

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***Abstract* – The purpose of this paper is to describe an experiment in the design and construction of an intelligent irrigation system based on the integration of ready-made programmed components and programmable ones, which, if necessary, will provide watering of plantations. This paper presents a model of an integrated multi-component architecture for a smart garden, which is based on the combination of various components and techniques in small-scale urban garden irrigation by using Internet of Things (IoT) technologies. Automation is related to planning based on sensor data processing, determining when to activate water supply. Unlike manufacturers who offer "smart irrigation" solutions with all the automated components needed to build a complete intelligent system, our approach is different. We combine components from various manufacturers to create an independent irrigation system. The challenge lies in ensuring these components can seamlessly work together, processing automation instructions through external software, and storing data on a remote server. The described model represents an innovative solution that enhances the functionality and sustainability of urban gardens by combining an understanding of the gardens' needs and effective resource management, contributing to an improved quality of life for citizens and the sustainable use of natural resources.**

***Keywords* – IoT, sensors, model, smart irrigation, integrate.**

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1. Introduction

Throughout human history, there has been a continous interaction between humanity and nature. However, the impact of human activity on the natural world has grown significantly over time. Technological advancements have enabled the exploitation of natural resources on a greater scale, resulting in a wide range of environmental issues. These issues include air and water pollution, deforestation, global climate change, and the extinction of numerous plant and animal species. With his activity, man causes enormous damage to nature and thus threatens his own existence. Interest in the protection of the environment and natural resources is growing. Interest in innovative solutions for managing green spaces has also increased. Interest in the protection of the environment and natural resources is growing as well as the interest in innovative solutions for managing green spaces has also increased.

Gardening is a branch of horticulture and represents the activity of growing plants. At first, it was labour intensive due to the use of only human and animal labour, but nowadays agriculture and horticulture use a number of machines that automate and ease the process and at the same time give better results in terms of the produce produced.

In this context, the concept of "smart garden" arises as a promising solution that seeks to integrate different components and technologies to ensure optimal management and maintenance of green areas in the urban environment. To make themselves more resilient to future climate conditions, to live greener, to save money, and to improve the quality of their food [1], [2] many people are turning to home gardening. The term "home gardening" has been considered by Birgit Penzenstadler [3] as the non-professional cultivation of plants for recreation, personal health, cost savings, and for other environmental and social benefits. Often, the main problem in home gardening is the high consumption of water. Research shows that people consume more water during outdoor activities, such as gardening, than during indoor activities [4].

For example, watering gardens can account for up to a third of household water use annually and nearly 50% of total summer use [5]. Research shows that insufficient water supply will stunt plant growth and reduce quality, while too much water will wash away fertilizers and reduce soil aeration [6]. In other words, adequate watering dictates the quality of the crop, which is why we need to try to facilitate it through automation. This will lead to lower levels of water consumption and ensure no drying of the soil, relevantly will provide growth in terms of harvest. To reduce outdoor water use by the individual, researchers and practitioners have developed a number of automated watering systems. [7], [8], [9]

There are many horticultural automation solutions on the market today. Building a smart solution is still in development stage and is novelty for farmers. Most of them are oriented to larger agricultural areas. The main challenge in the field of home gardening is to find an affordable, scalable solution that can reduce the cognitive effort and cost of home gardening.

The purpose of this article is to present a model of a smart garden, representing an intelligent irrigation system based on the integration of ready-made programmed components and programmable ones, providing watering of the plantations. Various components are considered within the framework of the presented model, including sensors for monitoring the environment, sensors for reading soil moisture, for temperature and air humidity, automatic watering systems and other innovative technologies. Each of these components plays an important role in the operation of the smart garden, providing data collection and analysis, decision making and process automation.

The current research focuses on the automation of small-scale urban garden irrigation by using IoT technologies. Automation is related to planning based on sensor data processing, determining when to activate water supply. The expected result of the integration of a smart solution for irrigation is associated with satisfying the need to maintain constant soil moisture, the value of which is determined by the specifics of the particular agricultural plantations.

The paper reviews existing automation solutions in the field of garden irrigation and designs a model of an IoT solution for irrigation of agricultural production in small and medium-sized households by integrating ready-made programmed components and programmable components. It is organized into three relatively self-contained sections.

In the first section, the essence and significance of smart irrigation is considered and existing garden irrigation automation solutions are discussed.

In the third section a model IoT solution is proposed for irrigation of agricultural production applicable in small household farms.

The designed model combines components from different manufacturers that work together in a self-contained irrigation system. The solution could be used in small and medium farms in the process of growing the seasonal crops.

2. Methodology

The methodology used in the research is based on the fundamental idea underlying IoT - things controlling other things, without human intervention. For this purpose, ready-made programmed products from different manufacturers, working with different platforms and sensor programmable boards, have been selected. A remote Home Assistant environment is organized to integrate this set of manifold sensors and organize their "smart" management. Home Assistant is used both to organize scenarios and to record and accumulate the sensor data in the built system.

The developed architecture is tested and evaluated to confirm its reliability.

Applied research was used in the course of the study. An irrigation system was created and tested by planting vegetables. The proposed automation includes tracking the soil moisture level. The system is connected via Home Assistant. The data generated by the sensors is accumulated on its own server.

The developed architecture is tested and evaluated to confirm its reliability.

3. Smart Irrigation to Help Agriculture

Today, humans not only inhabit the natural world but also possess the capability to construct, innovate, and automate their surroundings through the power of their intellect. The use of machinery and automation eases human labor and often results in better productivity. The development of "smart automation" is driven by the goal of conserving resources in automated processes. In this context, the concept of "smart garden" arises as a promising solution that seeks to integrate different components and technologies to ensure optimal management and maintenance of green areas in the urban environment.

The term "Smart garden" combines two concepts - "Smart" and "garden". "Garden" suggests that it is related to gardening, and "Smart" indicates that not just automation is used, but intelligent process automation. That is to say, the combination "Smart garden" usually means an automated intelligent solution to ease the labour of growing agricultural crops or a "smart irrigation system".

According to Geng [10], the application of smart solutions in agriculture is related to the improvement of comprehensive agricultural production capacity and international competitiveness.

Smart solutions in agriculture have emerged as a crucial factor influencing the advancement of agriculture and agricultural production, significantly enhancing productivity [10].In recent years, the interest and desire of people to grow agricultural crops for their own account has increased, but they often face the impossibility of doing so due to the lack of time and conditions. This necessitates the construction of an IoT- based irrigation control and monitoring system.

3.1. Smart Irrigation

In practice, automatic irrigation consists of automated systems that take care of the specific level of humidity for each type of plant. In this way, the maintenance of the garden is carried out quite easily, without problems and regardless of the activity of its owner at a particular moment. Automatic irrigation is important not because of its popularity, but rather because of its level of utility. In his article, Khaled Obaideen [11] shows the benefits of using an IoT smart irrigation system.

The advantages of automatic irrigation systems are most often associated with (1) the absence of the need for human intervention due to the high degree of automation involved in the design of the system; (2) providing water savings, which in turn results in savings of money and time for the owner; (3) the processes are controllable and provide opportunities to analyze the results.

From the point of view of irrigation efficiency, it can be argued that maintaining a constant humidity and a good level of irrigation is achieved.

In practice, the use of automated irrigation systems saves money in long-term use, not only because they optimize the amount of water used, but also because it saves monitoring time [12].

The control that is required can be exercised at any time, namely the optional human presence makes such watering systems "smart", since they themselves cope with the important task of maintaining a set humidity, instead of the person.

All these factors make smart watering a good enough investment for any home garden.

3.2. Existing Smart Irrigation Solutions on the Market and Analysis of Their Capabilities and Limitations

Today, various solutions for automation in the process of growing agricultural crops are available on the market [13], [14].

These solutions are mainly focused in the field of automating the irrigation process [15], [16]. Building a smart irrigation system requires a set of electronic devices that can be controlled by humans as well as communication with each other. This in turn requires a power supply and technology to enable communication – human/device and device/device [17]. Depending on the location of the garden in a given urbanized area, different technologies are used to build a "smart garden". Gutierrez, J and S. Ghosh [18], [19], describe different IoT devices connectivity technologies depending on the location of the garden. Usually, if the garden is located near or in an urbanized area, the smart irrigation system can use a local LAN network signal. In other cases, it is necessary to use the Global System for Mobile communication (GSM) [20], and mobile devices to enable Fuzzy logic to allow android apps and master irrigation management. M. Monica [11] also describes other communication protocols between IoT devices for smart irrigation.

In the event that the garden is located outside an urbanized area, it should be provided for powering the devices, a data transmission channel, and also a water source for the watering process itself [21].

There are several possible options for implementing automated irrigation:

- Using sensors and devices to signal the need for watering, and the watering process itself is done mechanically. The humidity data is saved locally or to a server of the software manufacturer.
- Using a ready-made smart irrigation system - one manufacturer offers a complete range of irrigation products on the market - from the humidity sensor to the device that controls and activates the irrigation faucet or irrigation pump. The irrigation data and instructions are stored on the software of manufacturer's server.
- Use of automated irrigation devices - faucets with timers for the duration of irrigation or with setting the start and end time for irrigation. In this case, there is also an option to compile a weekly program. No data is collected. A rain sensor can be turned on or the unit can read the weather forecast and skip watering.

4. A Smart Irrigation Model With Component Integration

In this section, a general architectural model for IoT-based irrigation is presented, suitable for a small urban garden located in an urbanized area, with a nearby water source, availability of electricity, and the possibility of the Internet signal coverage.

To build the model, ready-made programmed components from different manufacturers using different management applications and with different integration options were selected.

A programmable component is also included in the designed model. The data for the selected components are shown in Table 1.

Table 1. Description of the components involved in building a smart irrigation system

Component name, model and directionality	programmed	software	work with	pcs
SONOFF TH Elite 16A (Sonoff THR316D) - smart-switch	programmed	eWelink	Alexa, Google Home, Home Assistant	8
SONOFF MS01 - Soil Moisture Sensor	programmed	eWelink	–	4
Sonoff - AM2301 - Temp & Humi Sensor	programmed	eWelink	–	4
Wi-fi Smart Valve Controller Bluetooth - Smart Valve	programmed	Smart Home	Smart Home, Tuya, Google Home	3 pcs
Higrow ESP32 Wireless LAN + Bluetooth Battery + DHT11 - Temp & Humidity Sensor	programmable	MQTT	MQTT Broker	2
Raspberry Pi 4 with Home Assistant				1
Ground Drip Irrigation Construction Components with Multilayer Compensating Drip Hose (Inovato Engineering Ltd)				1 set
A regular garden hose for irrigation				1

The smart irrigation model is built on an area with a pre-built drip irrigation system. The water supply network was used as a water source.

On the recommendation of Inovato Engineering Ltd, a water pressure reducer was used and drip irrigation was constructed using a multi-layer compensating drip hose, which ensured uniform drip irrigation along the entire hose route.

At the beginning of the system, a water meter is installed, which serves to measure the water flow rate used in the watering process. A central water valve is placed after the water meter to power the entire IoT smart watering system.

Drip irrigation is organized in three rounds, with an IoT water valve placed at the beginning of each round. For each circle there are sensors for soil moisture and air humidity and temperature.

The smart irrigation model is built in the usual three layers:

(1) perception layer - sensors that monitor soil and air indicators; sensors and IoT devices from different manufacturers were used. Some of the devices are factory programmed, but the model also includes devices that are programmable.

(2) transmission/communication layer - via various network protocols for the Internet, the connected sensors feed data to the cloud and to other "things".

(3) application layer - includes applications accessed via the Internet and control algorithms. The application layer is implemented using a Raspberry Pi 4 with memory and the Home Assistant application installed. Data is accumulated when the device is located remotely on another network.

The challenge of the architecture is associated with the fact that programmed sensors from different manufacturers are implemented in it, i.e.:

- Soil moisture sensors and air temperature and humidity sensors, which are manufactured by SONOFF and work with eWelink software.
- Higrow ESP32 Wireless LAN sensor + Bluetooth Battery + DHT11 Soil Temperature and Humidity Sensor Module, which needs to be programmed and paired with Home Assistant to be able to provide data.
- Automatic Stopcock Valve, working with Smart Home and Tuya.
- A home automation center or Home Assistant automation software, organized on a Raspberry Pi 4 and located outside the local network, which serves both to collect and store the data from the smart devices and to organize the automation between the devices in the smart garden.
- Remote data recording and automation instructions.

The overall architecture of smart irrigation can be traced in the following figure:

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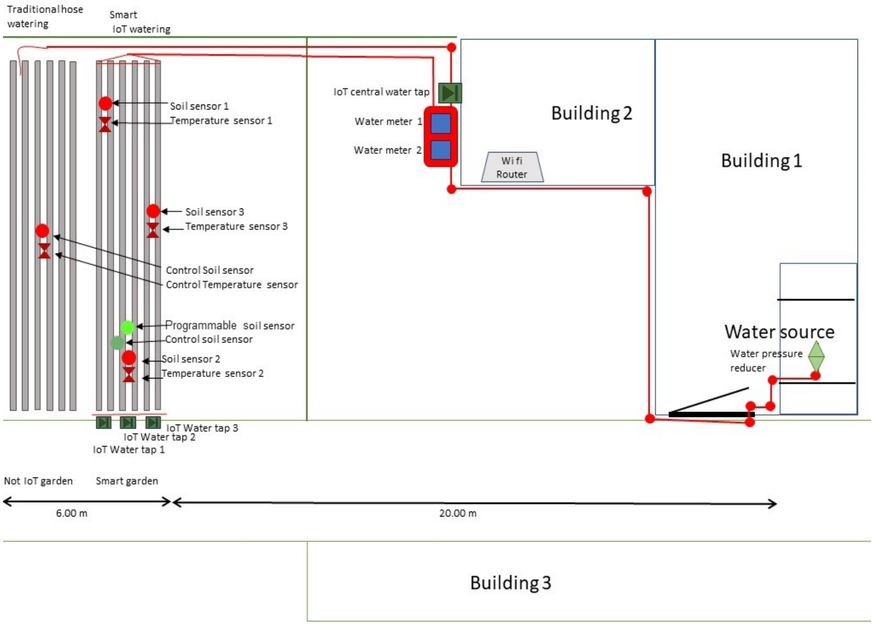

Figure 1. A smart irrigation model with component integration

5. Model Approval

The designed intelligent irrigation model with component integration is tested and applied on a garden area of 6 meters long and 2.6 meters wide outdoors. The garden area is conventionally divided into two parts. There are 6 beds in each of the parts. In one part, drip irrigation was built and the above-described smart garden model was applied. The other part serves as a control and in it the irrigation usual for every household is applied - usually in the evening or in the morning with an amount of water at the owner's discretion.

The study is planned to be conducted in two phases:

Phase 1: planting of early vegetable crops - lettuce. 66 lettuces are planted in each of the two parts of the garden. Lettuce is a cold-resistant low-stemmed vegetable that can be grown outdoors from March to October throughout the year. Due to its cold resistance, this vegetable is produced most intensively in early spring in countries with a temperate climate.

Phase 2: planting other agricultural crops to compact the garden - tomatoes and peppers. In each of the two parts of the garden, 21 tomato roots and 51 pepper roots were planted.

Irrigation mode:

Control field: manual irrigation, evening, amount of water at the discretion of the farmer.

Terrain with intelligent drip irrigation: setting threshold levels when considering the level of humidity for the different plantations presented in Table 2.

Table 2. Setting threshold levels for turning on irrigation when reporting moisture level for different plantations

A vegetable	minimum threshold level of irrigation inclusion	maximum irrigation cut-off threshold level
lettuce	20% RH	42% RH
tomatoes	20% RH	42% RH
pepper	15% RH	35% RH

The IoT-based irrigation model described in the text so far combines several benefits:

- Uses Smart Irrigation - The model uses IoT devices and sensors that monitor important indicators such as soil moisture, air humidity and temperature. This allows the system to water plants only when needed, based on real data. Such a precise approach to irrigation can reduce excess water consumption and maintain optimal soil moisture for plant growth.
- Management through a centralized system - Integrated components provide a convenient way to manage the smart irrigation system (remotely and adjust the parameters according to the needs of the plants).
- Watering efficiency - The model uses drip irrigation with multi-layer compensating drip hoses, which ensures an even distribution of water along the entire hose route. This helps avoid uneven watering and save water by watering more efficiently.

- Remote data storage and automation - the user has the ability to track and analyze plant irrigation data. The system supports automation that can be programmed and controlled remotely, which allows for more convenient system management and irrigation optimization based on preset parameters.

The expected results are that the model will provide the necessary soil moisture both in the spring and in the intense summer season. This, in turn, will lead to a greater yield of produce than usual for the same urban garden. All these benefits combined with the use of IoT devices, data, and automation can contribute to more efficient and intelligent irrigation of the garden, thereby improving water resource management, saving time, and improving the growth and production of plantations. The results and analysis of mining production when applying the model will be the subject of an upcoming study.

6. Conclusion

The paper has presented a model of an integrated multi-component architecture for a smart garden, combining various components and technologies in order to achieve optimal management and maintenance of garden spaces. This model represents an innovative solution that improves the functionality of small urban gardens and the management of the irrigation process.

The integration of environmental monitoring sensors, automatic watering systems, soil and air moisture monitoring and other technologies provide the ability to collect, analyze, and use large volumes of data. This leads to a better understanding of the needs of garden spaces, improves resource management and leads to more efficient and sustainable use of urban garden spaces.

In conclusion, the integrated multi-component smart garden architecture model represents an innovative approach for irrigation management of a garden area in an urban environment. It opens up opportunities to improve the quality of life of citizens and sustainable use of natural resources. The future of urban gardens lies in integrated multi-component architecture and smart technologies that improve their functionality and sustainability.

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