IZMIR UNIVERSITY OF ECONOMICS
FACULTY OF ENGINEERING

FENG 498 PROJECT
FINAL DOCUMENT

Arduino-based automated irrigation system

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FINAL DOCUMENT OUTLINE

1. Introduction

Nowadays, irrigation systems are used in many agricultural areas and also gardens, greenhouses. However, most irrigation systems are very user-controlled. In this case the dependence on the user is high. In most simple systems, water needs of plants are determined by the user. Therefore, it can cause over-watering or inadequate watering of plants in wrong using. Many problems arise such as decay in plants, late flowering, fewer yields when irrigation was wrong. There are a lot of research in the field of agriculture, most of these focuses on irrigation with measurement [1]. ABAIS that is Arduino-based automated irrigation system is also irrigation system with measurement. In addition, the ABAIS take own energy directly from the sun with solar panel and movement system. It is clear that solar energy is not used in most irrigation systems. The ABAIS is running the system with the energy obtained from the natural source of the sun and it keeps own energy in internal battery, this gives a noticeable advantage.

As in all irrigation systems, the main target of the ABAIS is the irrigation efficiency. The water status in the soil should be measured what happens [2]. As in other projects, the soil moisture sensor takes on one of the most important roles in the project. Thus, when the soil needs water, the information is taken through the soil moisture sensor. Water should be checked frequently because water may be finished. Thanks to the water level sensor that we use in the ABAIS, this job is easily controlled without human need. Water saving is also an important feature. Therefore the water loss should be minimized and the efficiency of the water used should be increased. The water level sensor eliminates unnecessary following of the water supply and thanks to the soil moisture sensor, unnecessary use of water is eliminated [3]. Also, when the occupancy rate of the water tank is followed up and found insufficient, it informs the user via SMS by other important sensors and modules that on the ABAIS. The target of the ABAIS is garden and potted plants. At this point, the ABAIS provides maximum productivity as well as simplicity and ease of use. So, the ABAIS is operated effectively and systematically.

2. Problem Statement

2.1. The main problems

Nowadays, plant cultivation has many challenges. There are many important details such as watering and solar need. When plants need to be watered, how long they need to watering is not known and difficult to follow-up. They are either subject to excessive watering or not getting enough water. The other problem that is encountered is the obligation to follow. They need continuous maintenance. The water needs affect the soil's moisture condition depending on the changing weather conditions. Thus, it is obligatory to follow the plants. In order to grow the plants efficiently, it should control the soil moisture of the plants and carry out the most appropriate amount of watering in the most appropriate time zone.

2.2. Why this project is worth working on?

The most important reason why we consider it worthwhile to do the ABAIS is to grow the plants in an environment-friendly and systematic way. If should explain a little more clearly, the ABAIS will grow the plant in the most effective ways by taking advantages of the solar tracking system and sensors in the most effective way at the right time without needing to follow up.

3. Objectives of the Work

The main objective of the ABAIS is like that using various sensors for the reach informations about the soil, the sun and the irrigation water, provide an efficient growing environment. The ABAIS uses soil moisture sensor for the learning about the wet level of the soil, this also give information about that plant needs water or has lots of water. On the other hand, there is a real-time clock module, in this way the system can decide right irrigation time.

Another objective is creating ease of follow up to all these. The ABAIS have a sim card module and character liquid crystal display for communication plus informative tracking. Thanks to the sim card module, system will use short message services (SMS) for communication. Users can easily track datas which comes from sensors. For instance, the user can learn the water level in the system that measured with water level sensor via SMS. In addition, various warnings will be sent to the user automatically.

Last objective is gaining power that system needs with using sun. With the help of the solar panel, the ABAIS does not need to power adapter. In the ABAIS, will be used 2 motors, these motors are connected to the solar panel and they will help to change the direction of the solar panel all day according to sun, this change of direction will be realized via light dependent resistor (LDR), at the end of the day, system will gain electricity needs.

4. Scope of The Work

The project consists of two parts which are software and hardware. Both parts are based on Arduino. Because, it has open source and extensible software and hardware. As mentioned in its official website [4], the software is published with optional open source tools. Also, the software language can be enlarged using C++ libraries. The parameters and functions to be used in the hardware part shall be as follows:

The cornerstone of the project is Arduino Leonardo. This is a microcontroller board based on the ATmega32u4. It has 20 digital input/output pins (of which 7 can be used as PWM outputs and 12 as analog inputs) [5].

The elements of the data tracking and communication options are 16x2 character LCD and GSM module. The LCD will display coming informations from sensors and modules. Also in this system, will be used the I2C Interface Serial Adapter that reduces the transmission line to 2 cables instead of pulling a lot of parallel cables from LCD. The GSM module is also used for data monitoring. It has a sim800 chip and a sim card slot. IMEI number is registered in Turkey. This is important in terms of communication problems. A sim card is required for processing.

There are auxiliary elements to solve the difficulty of plants care and follow-up obligation. These are real-time clock module and soil moisture sensor. Real-time clock (RTC) modules are used to timekeeping. Time is important for efficiency in the project. Therefore an RTC module with DS1312 will be used. Soil moisture in the system is monitored by soil moisture sensor. Also, there is a water level sensor and water pump. In design, the sensor will follow the amount of water in the tank and the pump transfers water to the required place.

The energy requirement of the project will be provided by the solar panel system. The system will help us to collect energy from the sun in the most efficient way. For this efficiency, light dependent resistors (LDR) will be used. LDRs are light sensitive resistors whose resistance decreases as the intensity of light they are exposed to increases [6]. This allows them to be used in light sensing circuits. The solar panel follows the sun via incoming data from the LDR. Position of the solar panel is adjusted by servo motors. Servo motor is a rotary actuator that allows for precise control of angular position. The MG995 model will be used. It has metal gear structure and high torque feature. Finally, system will accumulate this efficient energy in a 4000mA lithium battery. The components used in the ABAIS are shown in Figure 1.

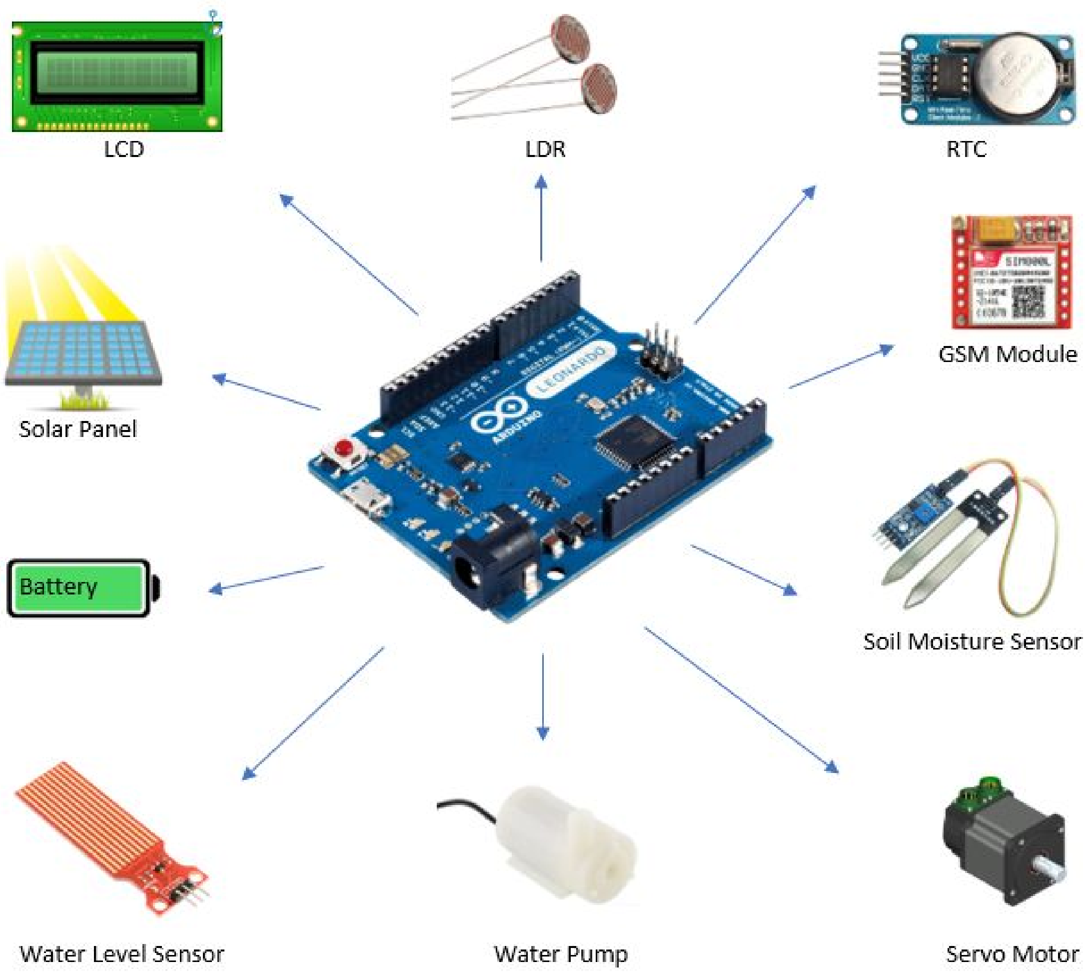

Figure 1 - Components of the ABAIS.

5. Literature Survey

A lot of research has been done in the field of agriculture, most of the focus on sensors and signals of sensors. This part mainly presents a literature survey in sensors, modules and solar panels [1]. Today, the sun is the largest source of heat, light, and energy. The ABAIS take own energy directly from the sun with our solar panel and movement system. It is clear that solar energy is not used in research. The ABAIS is running with the energy obtained from the natural source of the sun. This gives a noticeable advantage. In addition, water saving is an important feature. Therefore the water loss should be minimized and the efficiency of the water used should be increased. The water level sensor eliminates unnecessary following of the water supply and thanks to the soil moisture sensor, unnecessary use of water is eliminated [3].

5.1 Various comparisons

In this section, the data collected as a result of the research is explained in tables. As can be seen them in table 1, table 2, table 3, table 4, table 5, table 6 and table 7.

5.1.1. Project 1 [2]

Projects / Features	Technology	Follow-up	Remote Cont.	Power	Moisture Control	Others
ABAIS	Arduino (Leonardo)	LCD + SMS	GSM (sms)	Solar Panel + Battery	Soil Moisture Sensor	Water Level Sensor
Project 1	Arduino (Mega)	LCD	GSM (gprs)	Power Adapter	Dielectric Soil Moisture	Data Logging Shield

Table 1 - Project 1 comparison.

The technology used by the ABAIS and project 1 carries out the same tasks in the project. In the two technologies that do the same work, the cost of the project is cheaper than it is always preferred. Thanks to the technology that is used by the ABAIS, it does the same job and uses less expensive technology. Another subject is the LCDs, which function by reflecting the read data to the screen. The ABAIS uses an 16x2 character LCD. Project 1 uses a 64x128 graphic LCD. There are two materials that do the same work. That's why the ABAIS's technology is still cheap. As long as the read data is safely written to the screen, it does not add a burden to the project in terms of cost calculation. Thanks to the GSM module that on the ABAIS, when the occupancy rate of the water tank is followed up and found insufficient, it informs the grower via SMS. The ABAIS has a built-in battery which possesses self-charging with solar panel. The solar panels in the ABAIS are used most efficiently during the day thanks to the ability to follow the sun. The solar tracking system and solar panels used add to the environment-friendly feature. It is a feature that can not be ignored today. The ABAIS's use of electricity produced from the sun instead of the electricity grid is one of the biggest advantages. Project 1 used an electronic adapter connected to the electric grid. For open field application, the power supply can be provided through a common lead-acid battery and the environmental sensors are powered directly by a high-efficiency digital switch, by passing the onboard linear converter [2]. Dielectric soil moisture sensors detect the soil moisture by measuring the dielectric constant of the soil, an electrical property that is highly dependent on the moisture content. The used sensor in the ABAIS, soil moisture sensor has low cost, very accurate, continuous measurement at the same location and direct water reading for irrigation but there are disadvantages that are destructive, time-consuming, slow response to changes in soil water content.

5.1.2. Project 2 [3]

Projects / Features	Technology	Follow-up	Remote Cont.	Power	Water Control	Others
ABAIS	Arduino (Leonardo)	LCD + SMS	GSM (sms)	Solar Panel + Battery	Water Level S. + Pump	-
Project 2	Logic Circuit (NE555)	Level Display	-	Power Adapter	Geotextile + Valve	Data Logging

Table 2 - Project 2 comparison.

The main purpose of automation systems is to improve plant growth, to increase efficiency and to monitor it [3]. The ABAIS targets to be suitable for a home user. At the same time, project 2 has set out for this purpose. Project 2 has logic circuit for soil measurement and follow input values. The ABAIS uses Arduino that has a more advanced design. The absorption rate of the plants depends on many factors [3]. The important value in irrigation projects is to control these factors. In the ABAIS, these factors are controlled by various sensors. Project 2 uses geotextile [3] that is reduce the water consumption by limiting the evaporation of excess water and dripline for absorption control. One of the main differences between the two projects is the water control. Project 2 has valve driver, the driver is the circuit that activates the valve on the Flow Control signal from the Logic Circuit. In contrast, the ABAIS controls the water flow with the water pump. The data logging is presented to future developments in Project 2 [3].

5.1.3. Project 3 [7]

Projects/Features	Technology	Follow-up	Remote Cont.	Power
ABAIS	Arduino (Leonardo)	LCD + SMS	GSM (sms)	Solar Panel + Battery
Project 3	Arduino (Mega)	Mobile App	Wi-Fi	Battery

Table 3 - Project 3 comparison.

Project 3 is a Clearwater Industries project and the aim of the project is to ensure efficient growth by monitoring irrigation. Project 3 has a smartphone application based human machine interface. This permits users to optimize watering. These provide to users by microcontroller for processing data, moisture sensors to detect saturation levels, and solenoids connected to drip lines for water distribution [7]. All this works in the same way as the ABAIS, but Project 3 provides the energy needs with batteries that need to be changed. GSM module is used in the ABAIS, which is more convenient than Wi-Fi. And there is no drawback to Wi-Fi as performance. It is even easier to use than Wi-Fi, for instance no mobile application is required.

5.1.4. Project 4 [8]

Projects/Features	Technology	Follow-up	Remote Cont.	Power	Others
ABAIS	Arduino (Leonardo)	LCD + SMS	GSM (sms)	Solar Panel + Battery	Water Control
Project 4	Raspberry Pi + Arduino (Nano)	Mobile App	Bluetooth	Battery	Data Logging

Table 4 - Project 4 comparison.

The biggest difference of Project 4 is that this is a monitoring application instead of automated irrigation system. Soil moisture monitoring is a common fact for both projects. The main aim of Project 4 is to provide low-cost and wireless soil moisture monitoring and help users determine their exact irrigation needs [8]. This tracking is made possible by the base station and the sensor nodes communicating with each other. Users can monitor data with their mobile devices via Bluetooth. The Bluetooth technology is unnecessary for the

ABAIS that has GSM module, because SMS is a more effective solution for data tracking and control than bluetooth + mobile app. For communicate via Bluetooth, the base station, sensor nodes and the mobile phone which application installed must be within a certain range [9]. However, there is no such limitation in GSM. If the user is near the ABAIS, datas can be monitored via the built-in LCD. Also, there is a solar panel in the ABAIS, so it can produce its own energy but Project 4 has only batteries that need charging. As a result, both projects considers users to save on irrigation costs, provide better efficiency and reduce overall water use. While the Project 4 is only monitoring system, the ABAIS provides automatic watering.

5.1.5. Project 5 [10]

Projects/Features	Technology	Follow-up	Remote Cont.	Power	Others
ABAIS	Arduino (Leonardo)	LCD + SMS	GSM (sms)	Solar Panel + Battery	Water Control
Project 5	ZigBee	over the internet	GSM (gprs)	Solar Panel + Battery	Database Connection

Table 5 - Project 5 comparison.

In general, the two projects seems very close to each other. But there are many technological differences. Two projects have multiple advantages and disadvantages. The biggest advantage of Project 5 is that it uses a more advanced database. Also there is an information, Project 5 has been saved up to 90% water in natural environments [10]. This statistic shows that the system has proven itself. Both projects have battery and solar panels. Both projects have almost the same technology about these branch. The biggest advantage of ABAIS is that it has a more modular and improved structure. The Arduino Leonardo used in ABAIS allows further entry and this means that the number of sensors can be increased easily. In terms of communicating with the customers, Project 5 provides internet connectivity with GSM module and allows users to access information over the internet. It also allows users to influence the system over the internet. The ABAIS has also a GSM module, it uses this module communicates information to users via sms method and enables users to access the system via sms method in the same way. The internet used in Project 5 increases the cost and this reduces the efficiency in general. The cost of SMS in ABAIS is much lower.

5.1.6. Project 6 [11]

Projects/Features	Technology	Follow-up	Remote Cont.	Power
ABAIS	Arduino (Leonardo)	LCD + SMS	GSM (sms)	Solar Panel + Battery
Project 6	AT89S52 (8051 Microcontroller)	LCD	-	Solar Panel + Battery

Table 6 - Project 6 comparison.

In general, looking at the two systems, the Project 6 is in the sector, but does not seem a bit professional. However, there are many good comments about this project. In the Project 6, the system operates the irrigation pump with the energy it receives from solar energy [11]. The ABAIS has almost the same technology. So, there are solar panel and the battery in both projects, this system for only provide energy needs. Both projects have a humidity sensor, and when there is not enough moisture in the soil, they are both working. There is also a water level sensor in only the ABAIS and user will informed by the message coming from the system when the water level is low.

5.2. Overall Comparison

Project / Features	Technology	Follow-up	Remote Control	Water Control	Power
ABAIS	Arduino (Leonardo)	LCD - SMS	GSM (sms)	Water level s. + pump	Solar Panel + Battery
Project 1	Arduino (Mega)	LCD	GSM (gprs)	Pump	Power Adapter
Project 2	Logic Circuit (NE555)	Level Disp.	-	Geotextile + Valve	Power Adapter
Project 3	Arduino (Mega)	Mobile App.	Wi-Fi	Valve	Battery
Project 4	Raspberry Pi + Arduino (Nano)	Mobile App.	Bluetooth	-	Battery
Project 5	ZigBee	Over the Internet	GSM (gprs)	Valve + pump	Solar Panel + Battery
Project 6	AT89S52	LCD	-	Pump	Solar Panel + Battery

Table 7 - Comparison of the projects mentioned in Section 5.

The content of all the projects compared is shown in Table 7 that is overall comparison.

6. Ideas of Specialists

Specialists who are from Ege University were interviewed, for the corrections of the project. As a result of the interviews, ideas were developed to develop the project. According to the information about the watering hours, if the watering is done in the summertime, the most efficient watering time is before the sun rises. Evening watering time is after sunset. If watering is done in the winter time, the sun does not irrigate because the soil holds moisture. In addition to the watering hours, the reaction of the soil to water is also important. Since the targeted irrigation pots and horticultural crops are used, irrigation is done using average soil calculations. The important point here is the quality of the sensors used. This situation greatly affects the irrigation efficiency. As stated below, the soil depth must be taken into account when watering. In pots this account is ignored. In the gardens, extra irrigation should be done according to the increasing depth and the layers should be irrigated equally. For irrigation efficiency, the amount of water in the soil must remain between "wilt point" and "field capacity", this is shown in Figure 2. On the advice of specialists, the system to be created should not have a complex structure and the system should have advanced data logging. In addition, if more than one point is to be irrigated, the system must contain a valve. The interview stated in Appendix A made a major contribution to the development of the project.

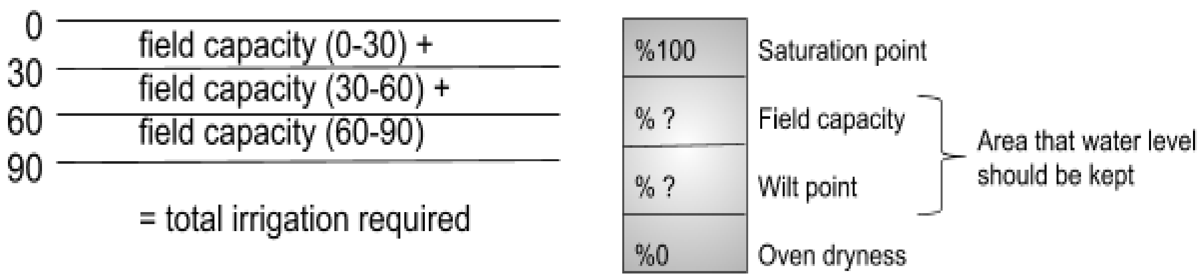

Figure 2 - Details are given in Appendix A.

Interviewees		
Özgür Tatar Associate Professor Faculty of Agriculture Department of Field Crops Ege University	Emrah Özçakal Research Assistant Faculty of Agriculture Department of Agricultural Structures and Irrigation Ege University	Uğur Çakaloğulları PhD Student Faculty of Agriculture Department of Field Crops Ege University

7. Requirements Specification

7.1. Functional Requirements

- **Taking and sending information:** Users can send a message and receive information from the system.
- **Sending information by system:** System can send information to the user regularly.
- **Filling the tank:** Users can fill the tank with the help of given information from the system.
- **Changing irrigation plan:** Users can irrigate the plant or cancel the next irrigation via sms message.
- **The measurements that water level and soil moisture level:** System measures that the water level, soil moisture level.
- **Irrigation time:** With the help of the real time clock, system reach information about the irrigation times.
- **Irrigation process:** System reaches the water pump and with the help of this, irrigates the plant.
- **Locations for energy production:** System can change the position of the solar panel via servo motors and trace the sun, this process produces energy for the battery.
- **LCD display information:** System shows the information that needed via the LCD screen.

7.2. Non-Functional Requirements

- **Security:** User should write your own unique password before the command.
- **Portability:** System will be inside the box and users easily change the position of the system.
- **Accessibility:** User reach the system from anywhere via sms messages.
- **Testability:** Every function in the project written too simple and can test easily.
- **Maintenance:** Correcting the system and sensors in the event of a fault in the sensors or system.
- **Modularity:** System should allow addition of more modules or more users in any module when it is required.
- **Updateable:** System improvements and updates are made and presented to the user.

8. System Design

In this section, design-related models are presented with UML shapes.

8.1. Use Case Diagram

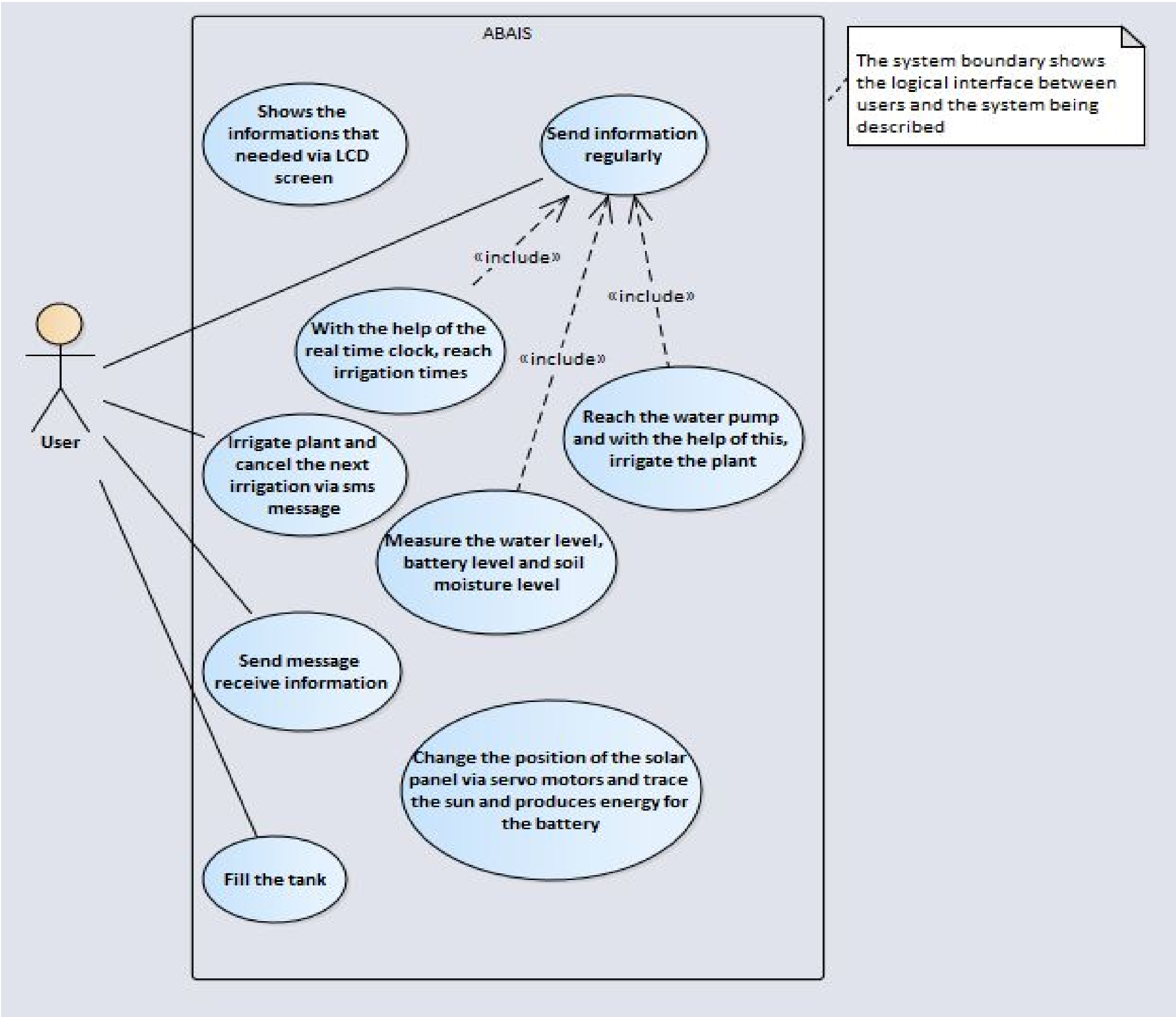

Figure 3 - Use case diagram of ABAIS.

As shown in Figure 3, the ABAIS is described in general as use case diagram. First, the user can send a message to the ABAIS and receive the necessary information as seen. These are watering time, irrigation, water level, battery, soil moisture level information with the help of real time clock. As mentioned, the user can irrigate plant and cancel the next irrigation via SMS message and user can fill the tank. When the time comes, the ABAIS takes water from the tank with water motors and watering the plant. The system shows the information that needed via the LCD screen. The solar panel in the system adjusts its position to the sun with the help of servo motors and collects energy from the sun for the battery. Finally, the user can retrieve all information from the system via message.

8.2. Activity Diagrams

8.2.1. Taking and sending information

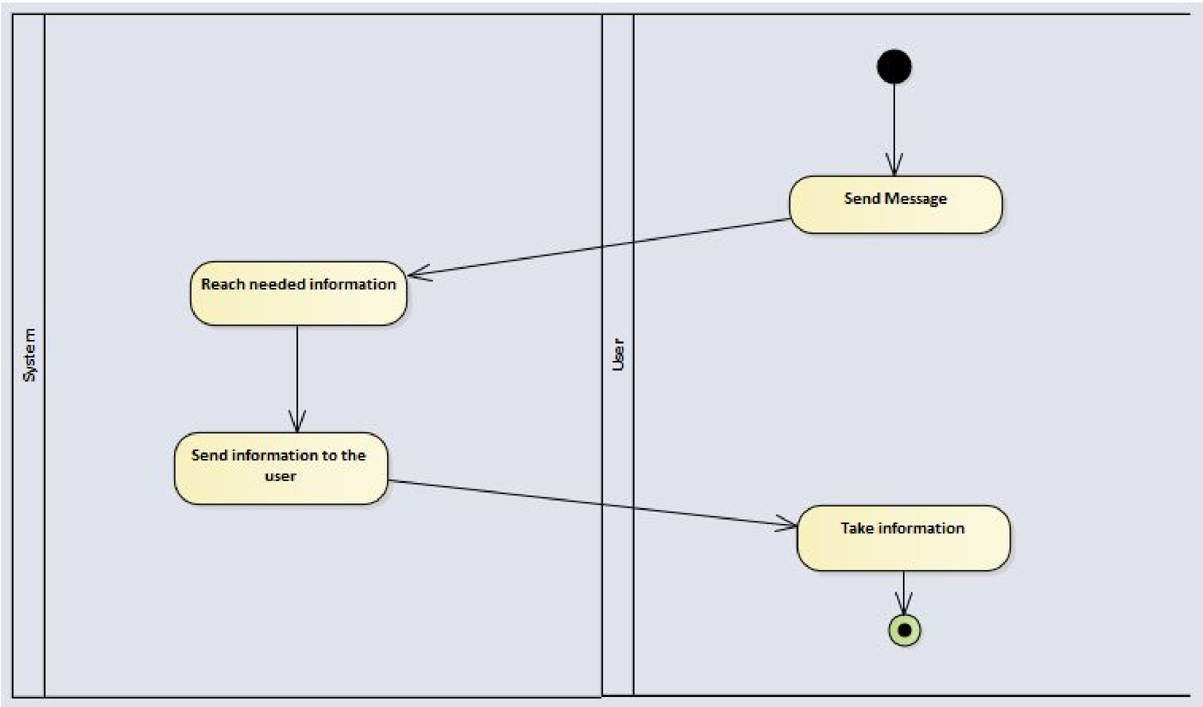

Figure 4 - Activity diagram of taking and sending information.

In the activity diagram shown in Figure 4, the user sends a message to the system and the system sends the information to the user after reaching the needed information. Information retrieval is like this between the user and the system.

8.2.2. Sending information by system

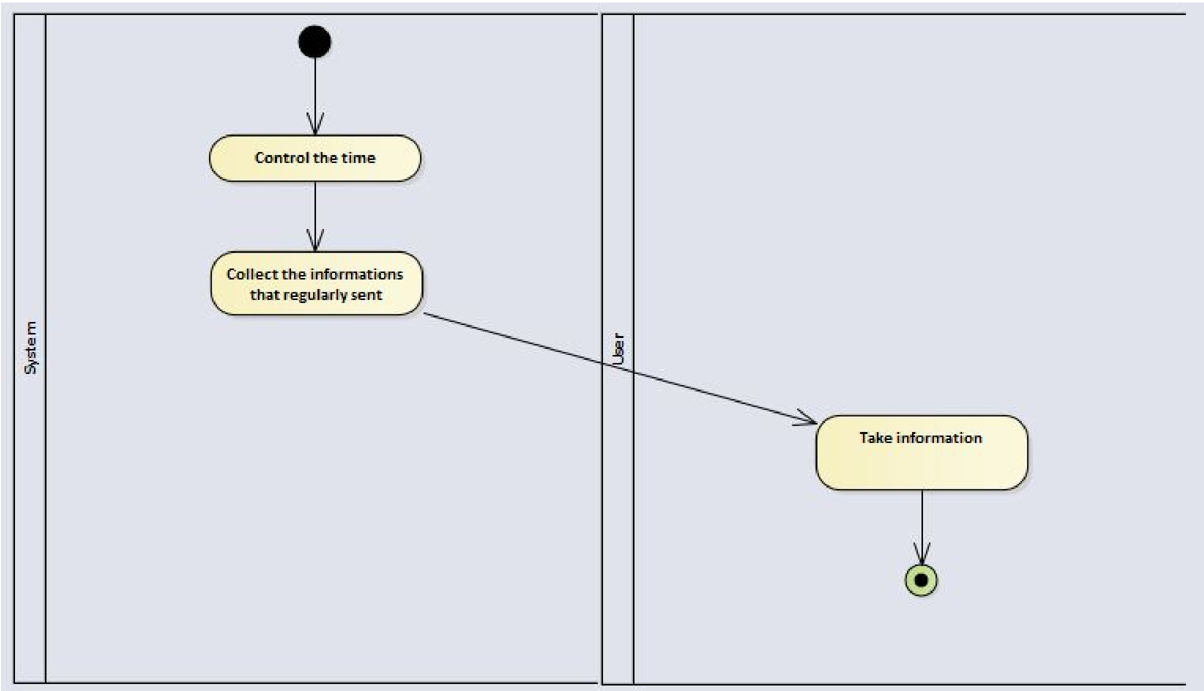

Figure 5 - Activity diagram of sending information by system.

In the above-mentioned activity diagram, the system first checks the time. Then the system collects the information and sends them regularly to the user. The user receives this information regularly. As shown in Figure 5, this information is regularly performed by the system.

8.2.3. Filling the tank

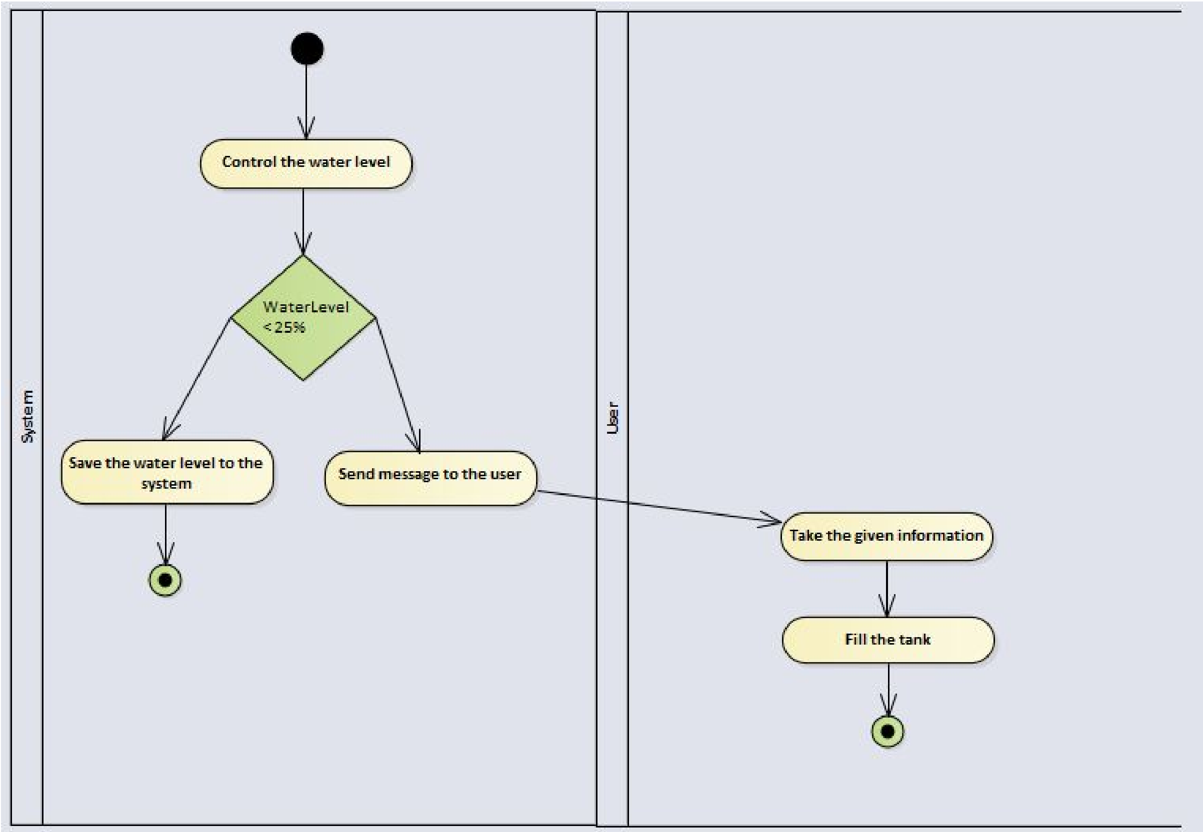

Figure 6 - Activity diagram of filling the tank.

When filling the tank, the system first checks the water level of the tank. According to come information from the water level sensor, if the water level is above 25%, the system saves the information. If the water level is less than 25%, the system sends information to the user. The user receives the information and performs the filling of the tank.

8.2.4. Changing irrigation plan

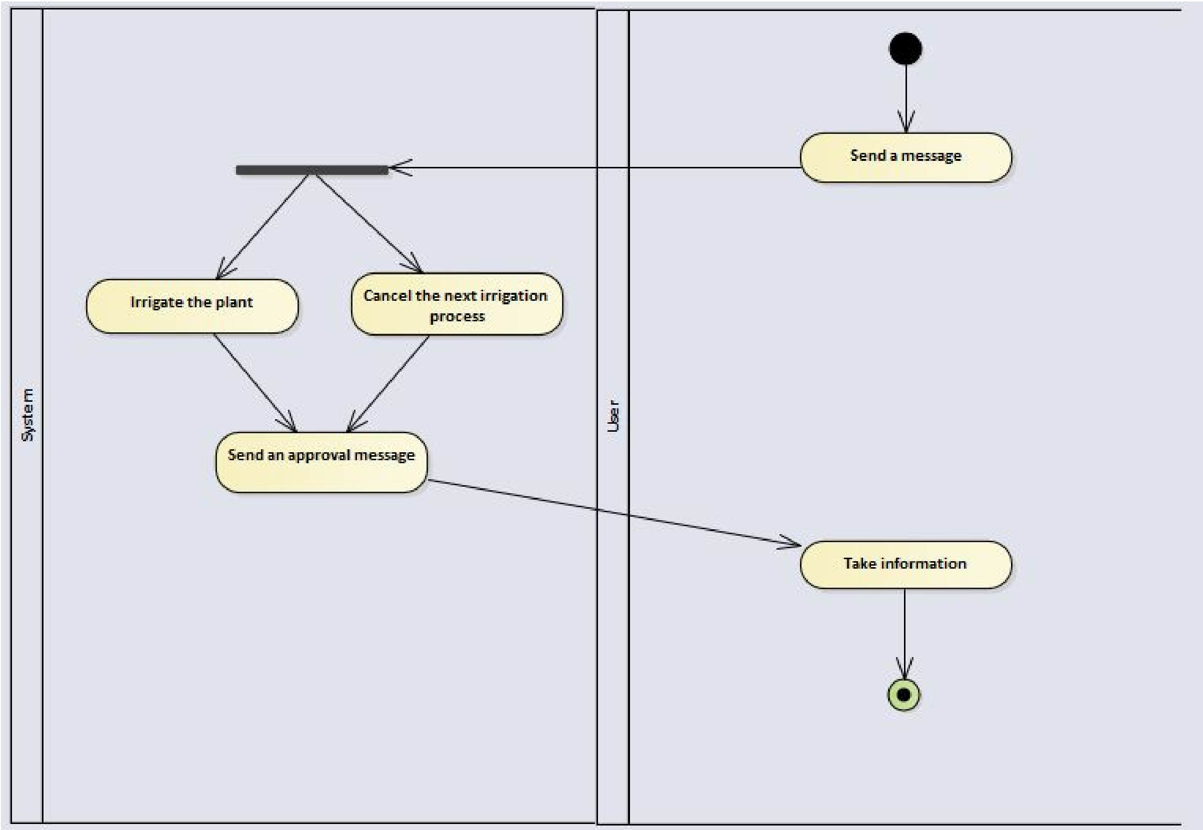

Figure 7 - Activity diagram of changing irrigation plan.

The diagram drawn in Figure 7 is related to the irrigation plan. The user can message to the system to water the plant or cancel the next irrigation process. When one of these processes occurs, the system sends an approval message to the user. In this way, the user receives the approval of the process.

8.2.5.The measurements that water level and soil moisture level

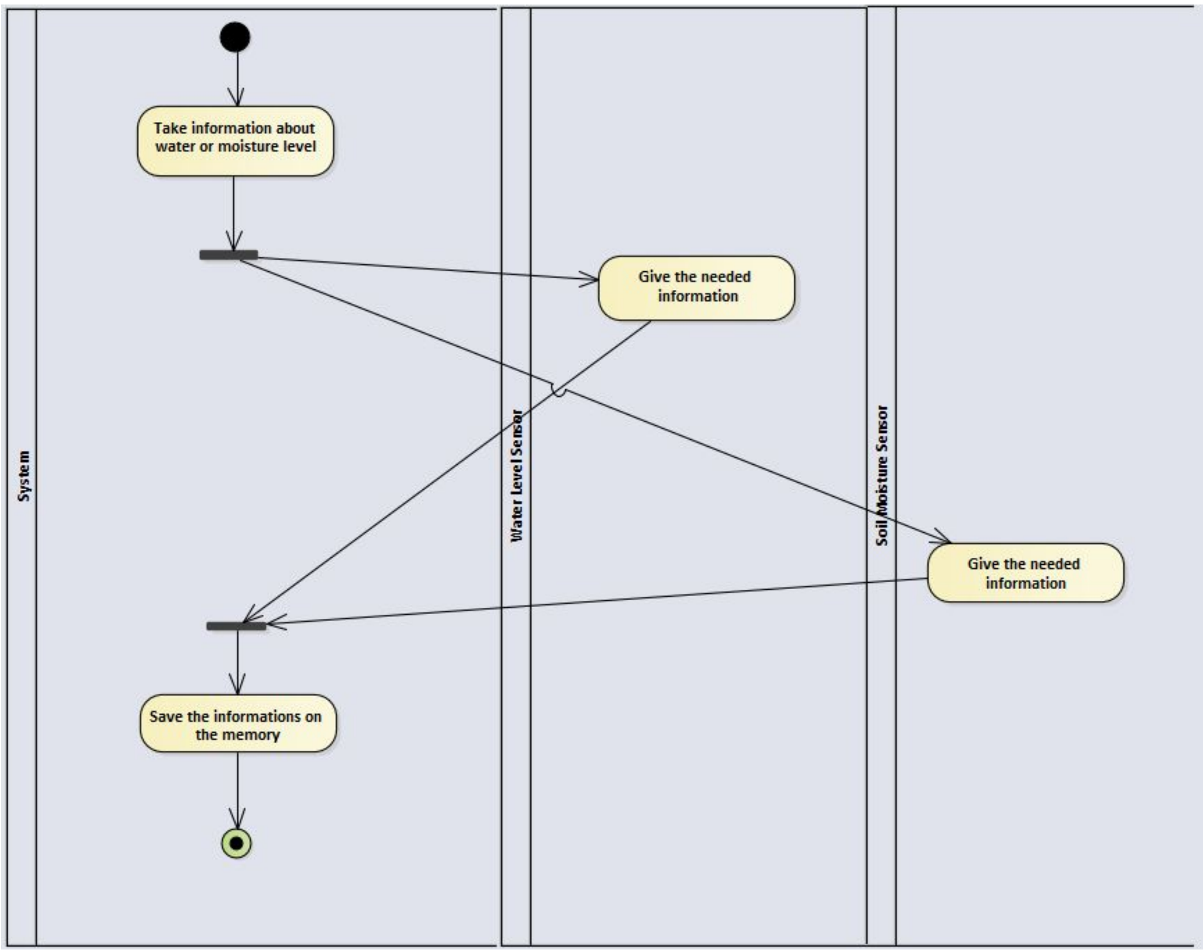

Figure 8 - Activity diagram of measuring the water level and soil moisture level.

Figure 8 shows the measurement of water level and soil moisture level. The system receives and stores information from the water level sensor and the soil moisture sensor.

8.2.6. Irrigation time

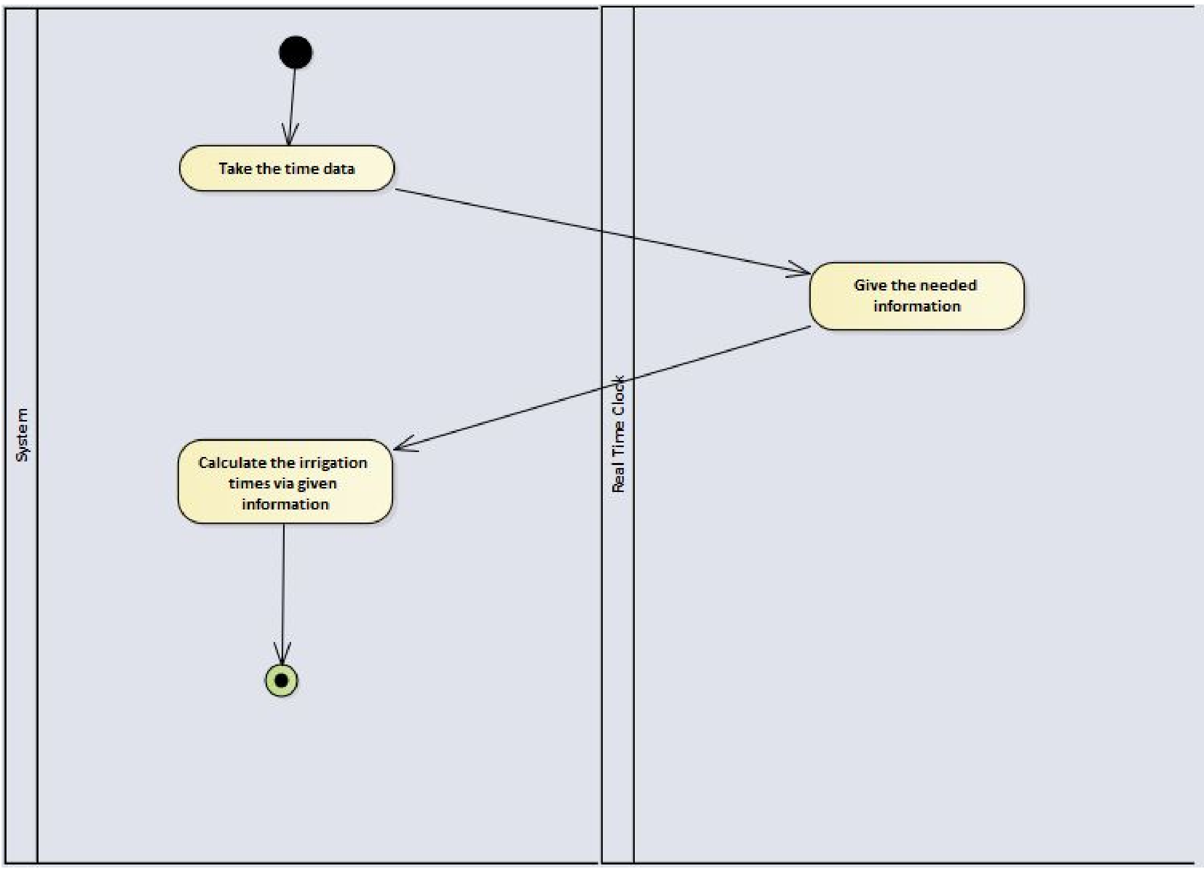

Figure 9 - Activity diagram of computing the irrigation times.

The irrigation time of the system is indicated in Figure 9. The system first takes time from the real time clock at this stage. The real-time clock gives the system the required time and the system calculates the irrigation time based on the information from the real-time clock.

8.2.7. Irrigation process

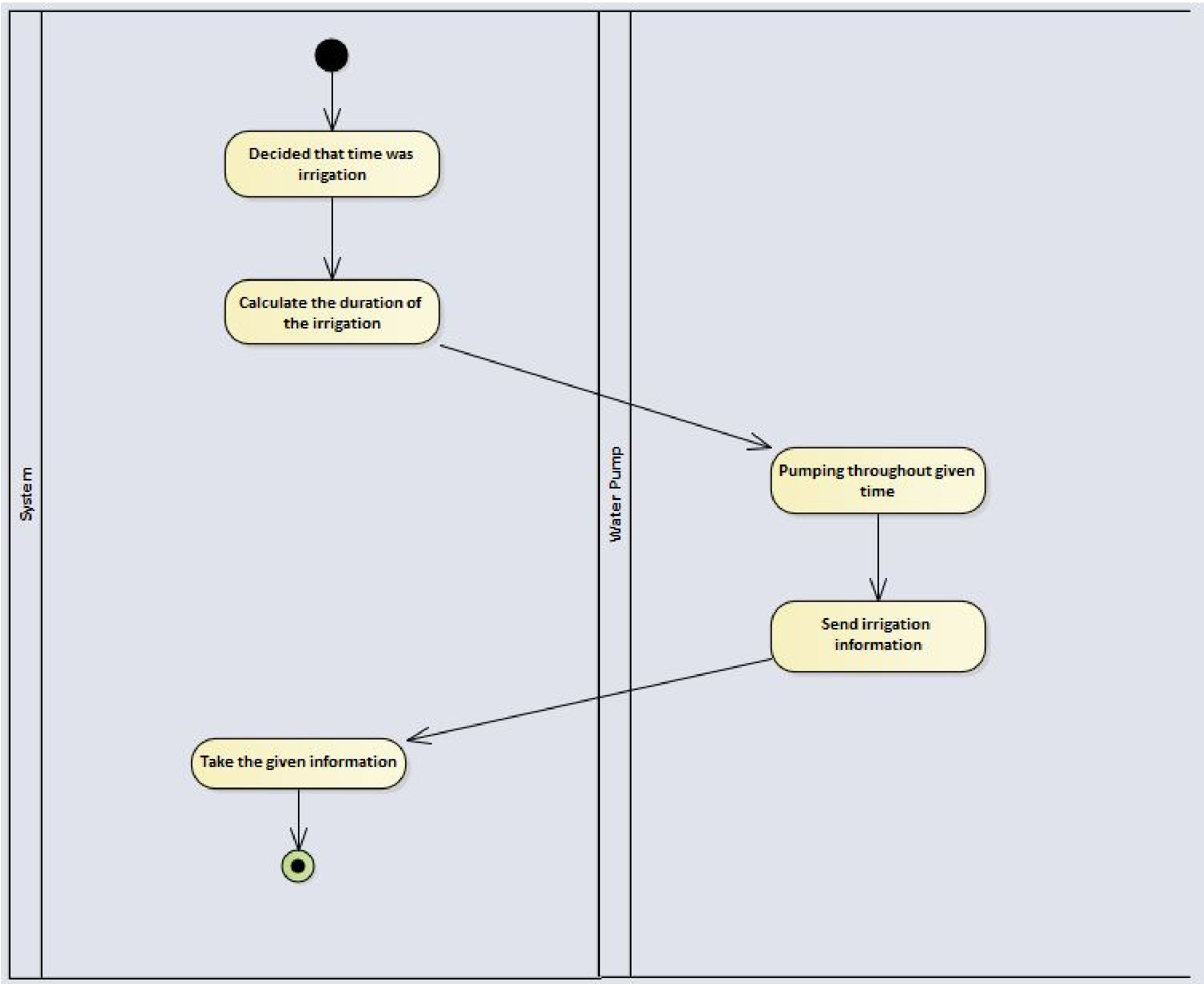

Figure 10 - Activity diagram of irrigation process.

The irrigation process works as shown in Figure 10 above. The system decides the irrigation time after finishing the process in Figure 9. After that irrigation time is calculated by the system. After the calculation is over, the system sends the time to the water pump and the water pump pumping throughout the given time. After the watering process, the water pump sends the irrigation information to the system. The system receives this information.

8.2.8. Locations for energy production

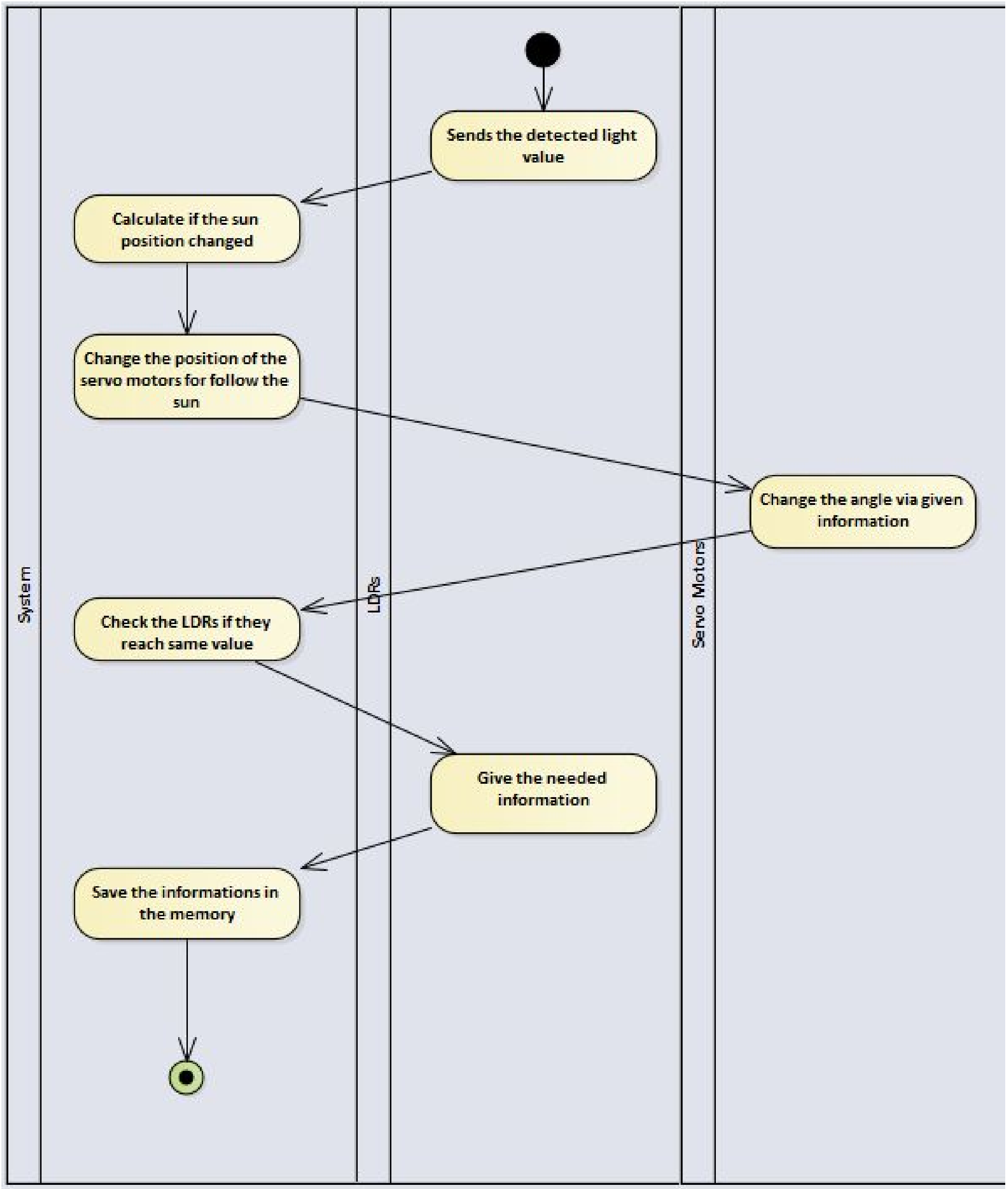

Figure 11 - Activity diagram of locations for energy production

The LDRs send the detected light values to the system. And then the system calculates if the sun position change. And then the system calculates if the sun position change. After that, the process takes place in servo motors. Servo motors change the angle according to the incoming information. The system checks the LDR for the same value and LDRs give needed information. Finally, in Figure 11, the system saves the information and the process ends.

8.2.9. LCD display information

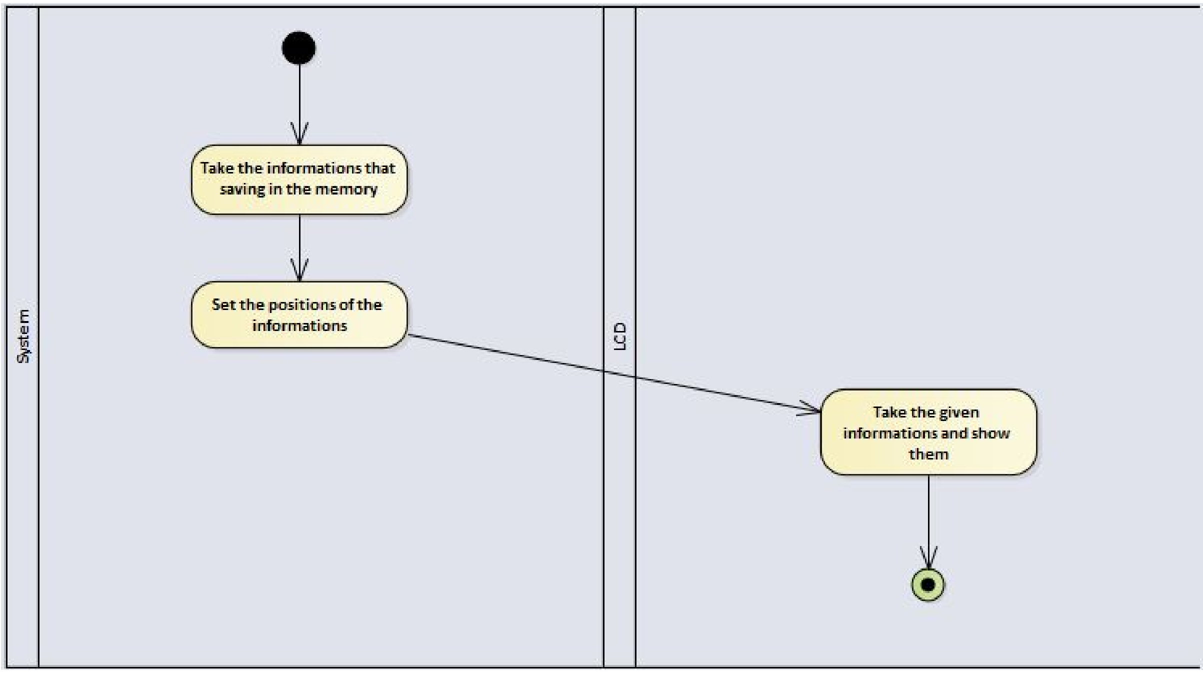

Figure 12 - Activity diagram of LCD display information.

LCD display information shows in Figure 12. The system receives the recorded information from the memory and sends the position of the information to the LCD after editing. LCD takes the given information and shows them.

8.3. Communication Diagrams

8.3.1. Information retrieval

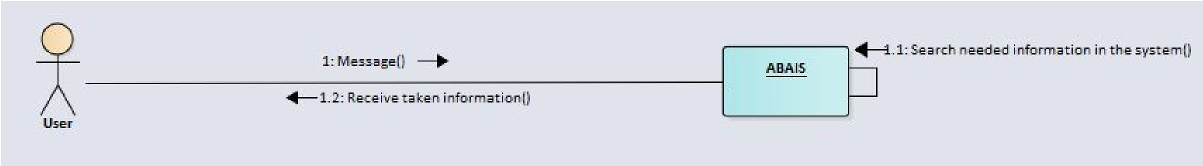

Figure 13 - Communication diagram of information retrieval.

In the communication diagram drawn in Figure 13, the user sends a message to the ABAIS and it searches for the requested information. The ABAIS transmits the required information to the user after the search.

8.3.2. Needed information to be given after time control

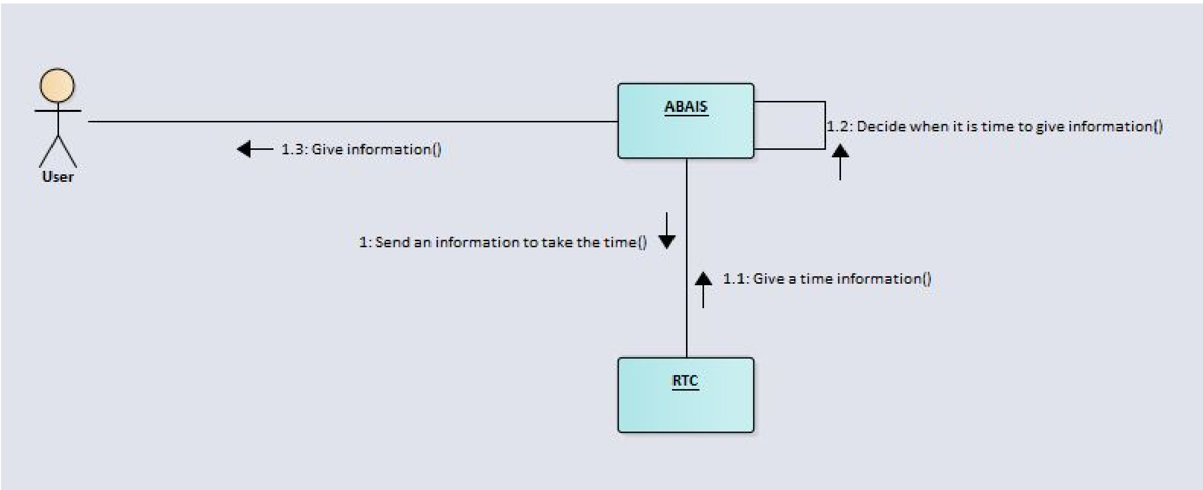

Figure 14 - Communication diagram of needed information to be given after time control.

In Figure 14, the system transmits information to the user. The system receives information from the real-time clock to learn the time. Real-time clock notifies the time to the system. The ABAIS transmits the information to the user when it is time to give information.

8.3.3. Information for tank and control of tank level

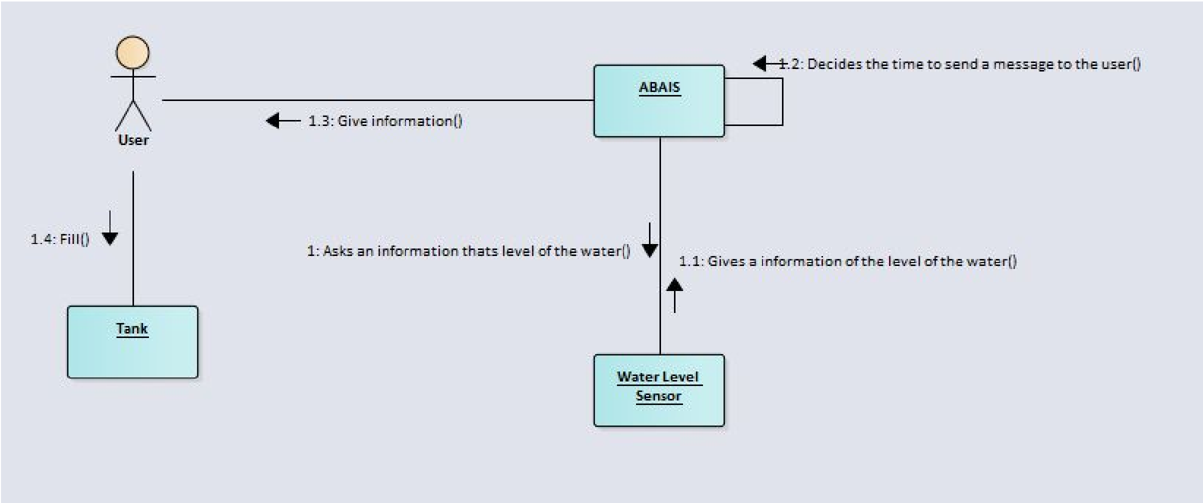

Figure 15 - Communication diagram of information for tank and control of tank level.

Figure 15 gives information about the tank information and level. The ABAIS asks information about the level of the water from the water level sensor and water level sensor gives information about the level of the water. The system decides the time to send a message to the user. The message is sent to the user. User fills the tank.

8.3.4.User changes the irrigation plan

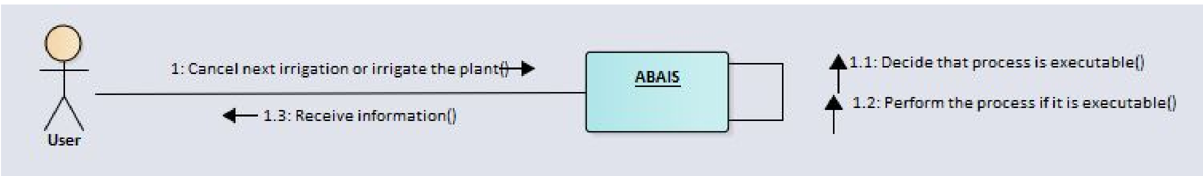

Figure 16 - Communication diagram of user changes the irrigation plan.

Figure 16 shows the user can perform the irrigation process or cancel the next irrigation process. The system operates according to the taken message and sends information to the user.

8.4. Sequence Diagrams

8.4.1. Information retrieval

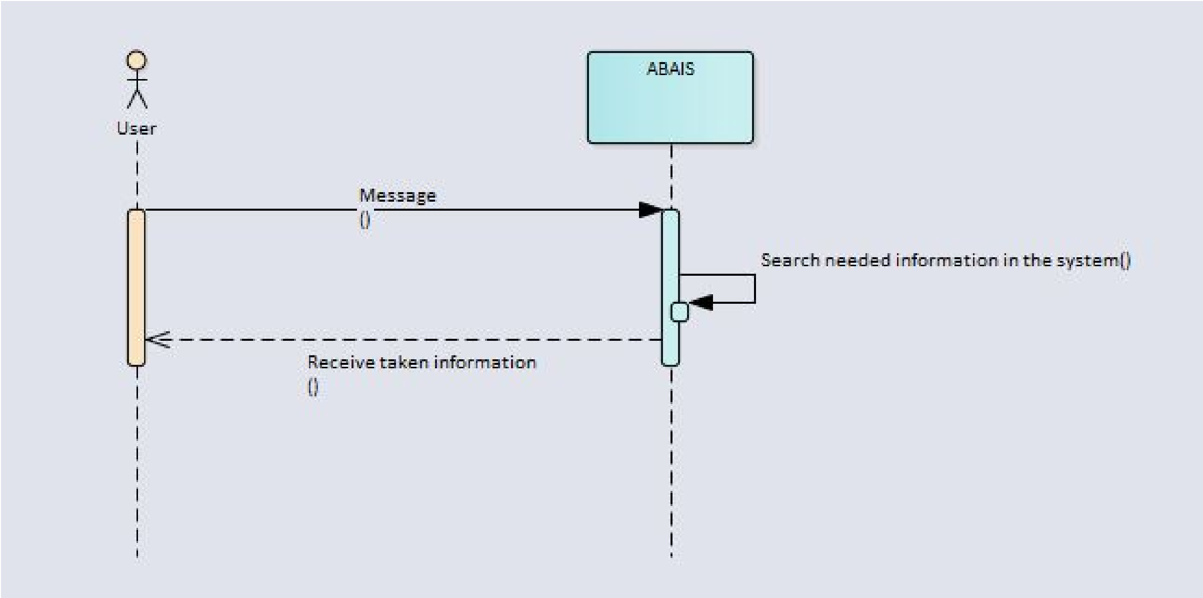

Figure 17 - Sequence diagram of information retrieval .

User requests information from the ABAIS via message. The system reaches the requested information and transmits it to the user. The sequence diagram drawn in Figure 17 gives this information.

8.4.2. Needed information to be given after time control

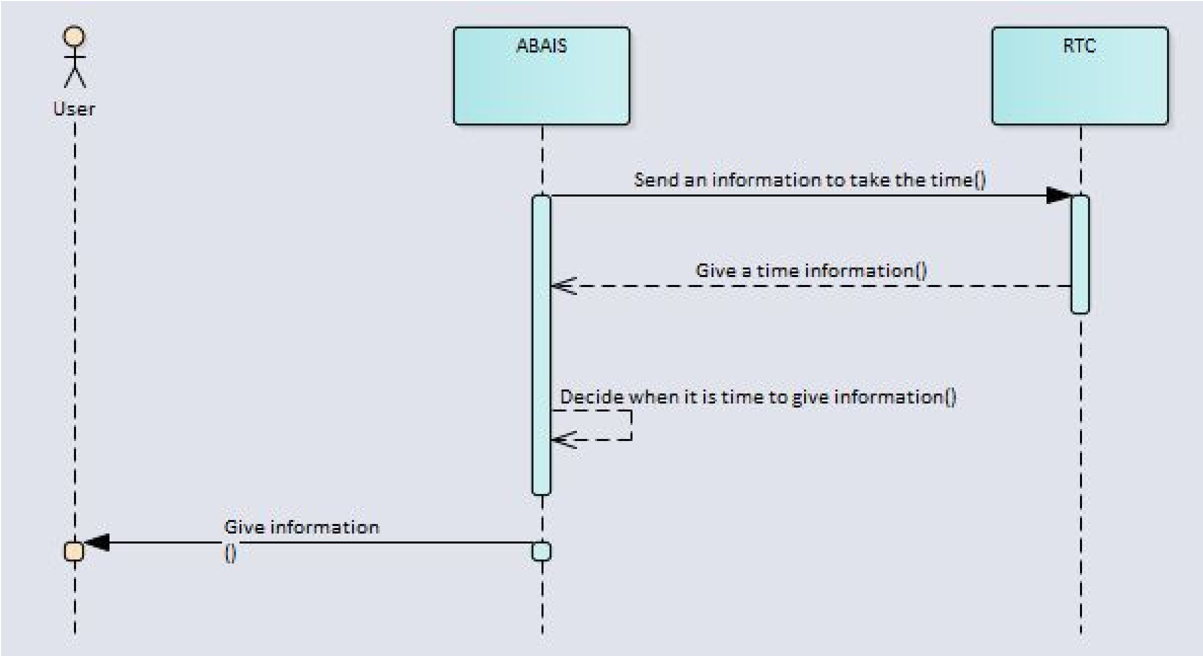

Figure 18 - Sequence diagram of needed information to be given after time control.

As shown in Figure 18, after time control, the system transmits the necessary information to the user. The ABAIS takes the time information from the real-time clock. And then decides when it is time to give information. Finally, after all these processes, the information is transferred.

8.4.3. Information for tank and control of tank level

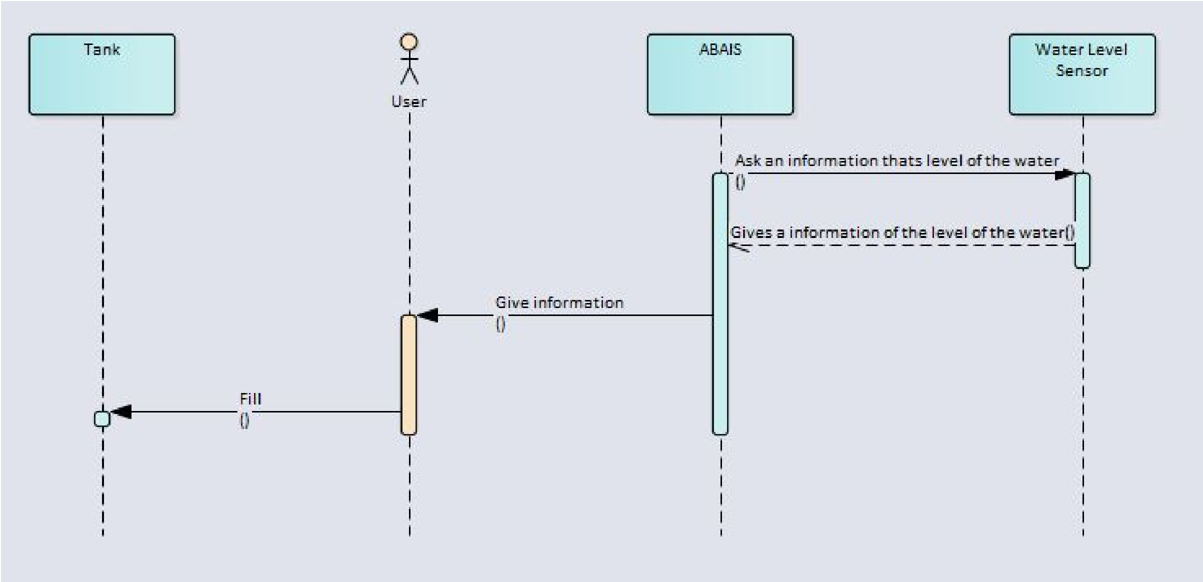

Figure 19 - Sequence diagram of information for tank and control of tank level.

In Figure 19, the system learns the condition of the tank with the water level sensor. The system sends information to the user according to the state of the tank and the user fills the store.

8.4.4. User changes the irrigation plan

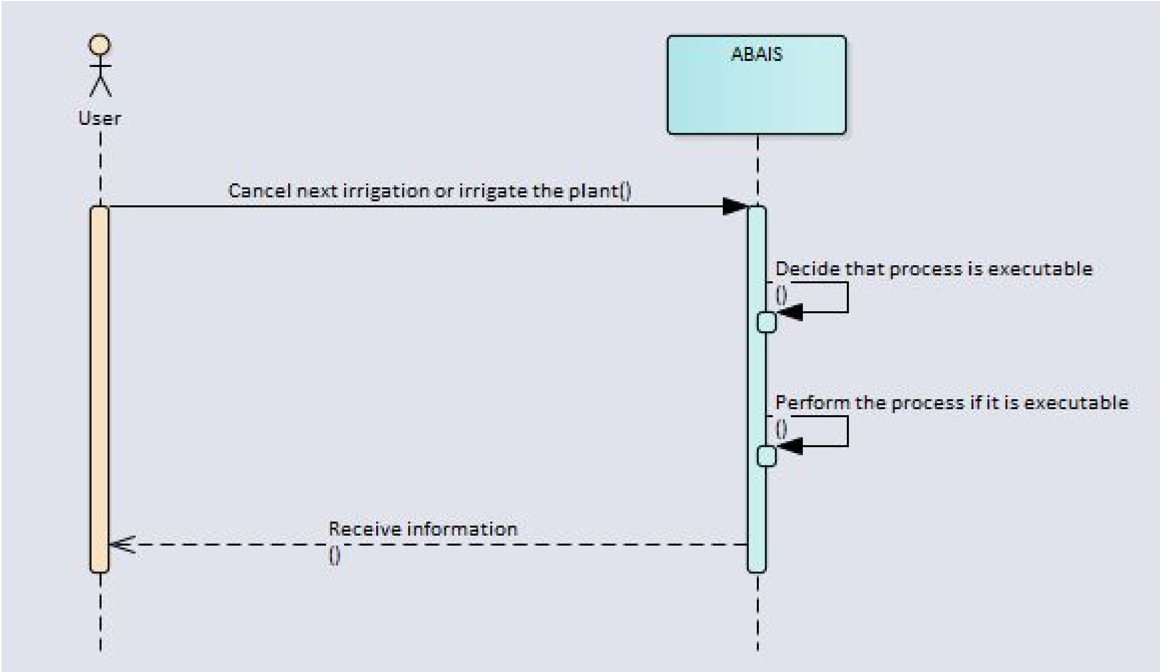

Figure 20 - Sequence diagram of user changes the irrigation plan.

Figure 20 shows that the user can make changes to the irrigation plan. The ABAIS makes decisions based on the information received from the user and applies the processing. And the system transmits to the user.

9. Implementation

9.1. Implementation Issues

In this section, regarding the implementation issues, possible questions in mind are discussed.

The most difficult issues and challenges in the implementation:

The main challenges we have encountered during the project implementation are as follows:

- ***Understanding Arduino and adapting to its unique features.***
  When we decided to make the project based on Arduino, some of us had never used Arduino before. This project also had the opportunity to learn the Arduino. The Arduino language is merely a set of C/C++ functions that can be called from your code. However, it took some time to successfully use the Arduino's own functions. For example, we worked on delay() and millis() functions to work effectively in Arduino.

- ***Hardware installation***
  We have successfully connected the sensors and modules Throughout the test stage, we have observed that some of the sensors were defective. Therefore we have bought the new ones and have built the system successfully after a number of attempts to reconnect the whole modules into each other. This process made us waste extra time in the implementation phase.
- ***Water leak***
  We encountered unexpected water leaks. We sealed the leaky place with silicone and fix it. We have wasted extra time to enclose the unexpected leaks.

How we resolved the problem:

We have investigated many examples of Arduino projects and have read various tutorials as well as articles. We called support from experts whenever we were inadequate for hardware installation. Finally, we have resolved the water leakage issue after a few trial-and-error mechanisms.

The main difference of our project from the others:

Our target customers that are users of garden and balcony plants make our project unique. The fact that it contains only the basic sensors required for plant irrigation monitoring also makes our project unique.

9.2. Implementation Document

Before starting the implementation, we performed an LDR simulation. We prepared this simulation with Autodesk Tinkercad[12]. A few sample images of the simulation designed are shown below in Figure 21.

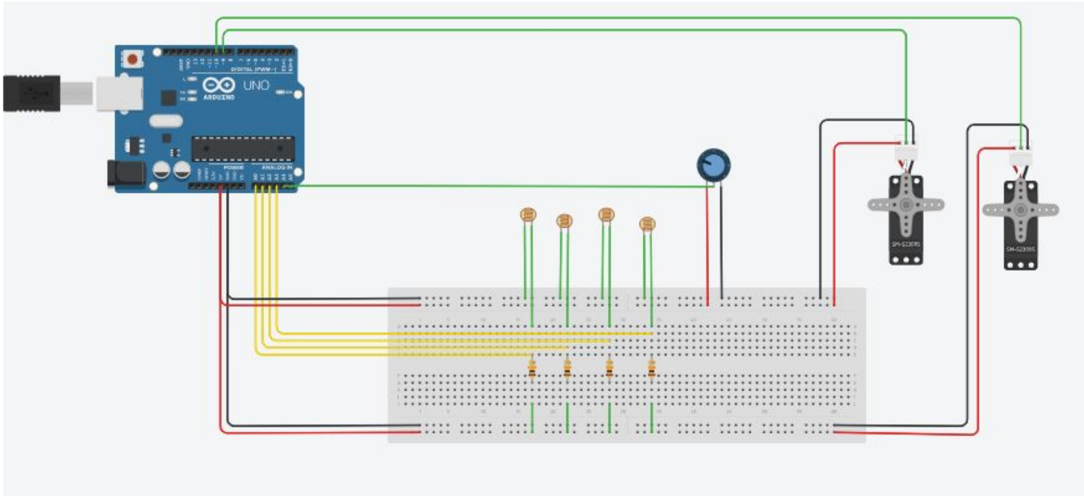

Figure 21 a - Sample screenshot of the simulation.

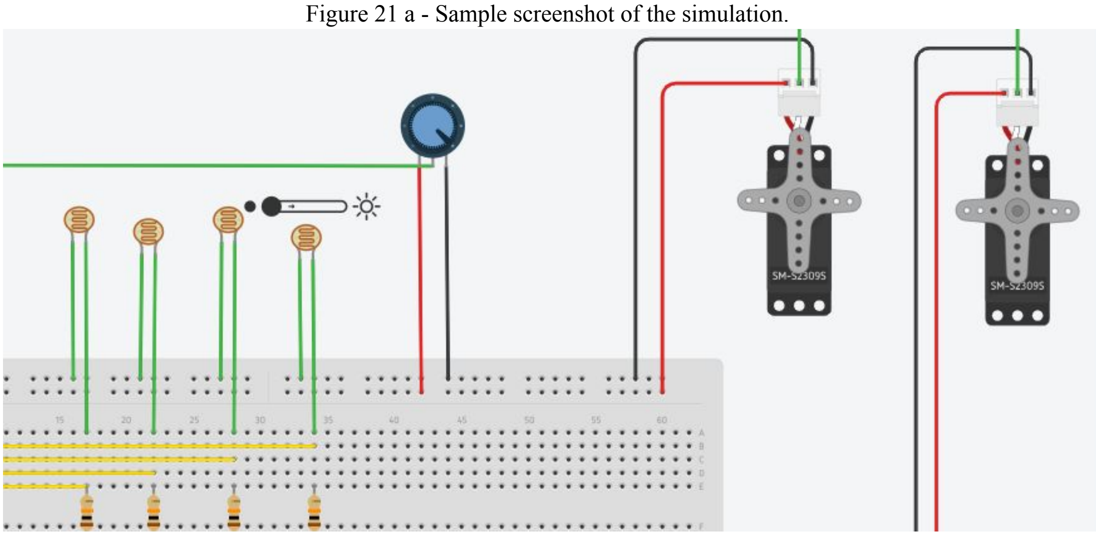

Figure 21 b - Sample screenshot of the simulation.

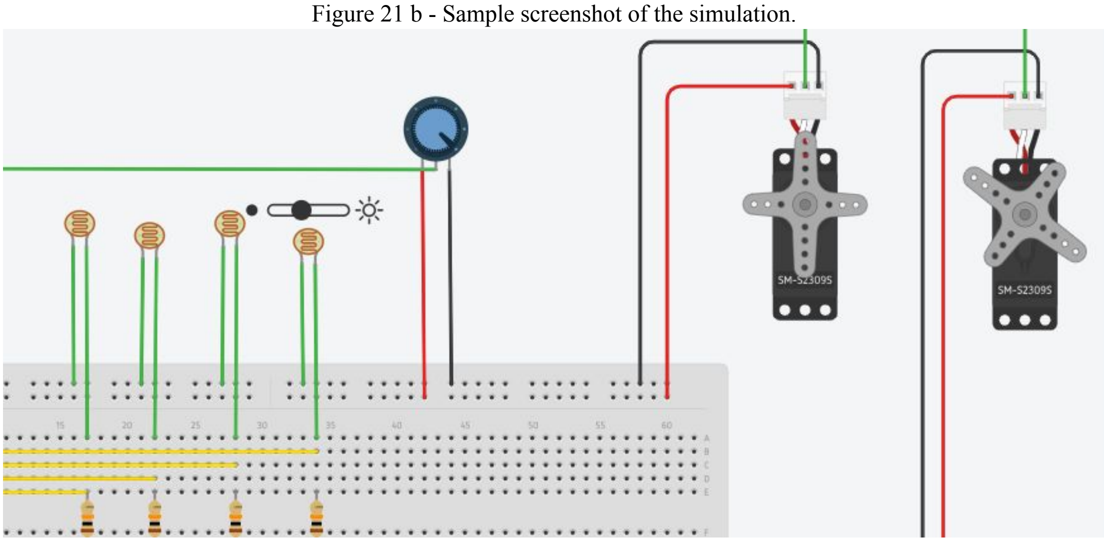

Figure 21 c - Sample screenshot of the simulation.

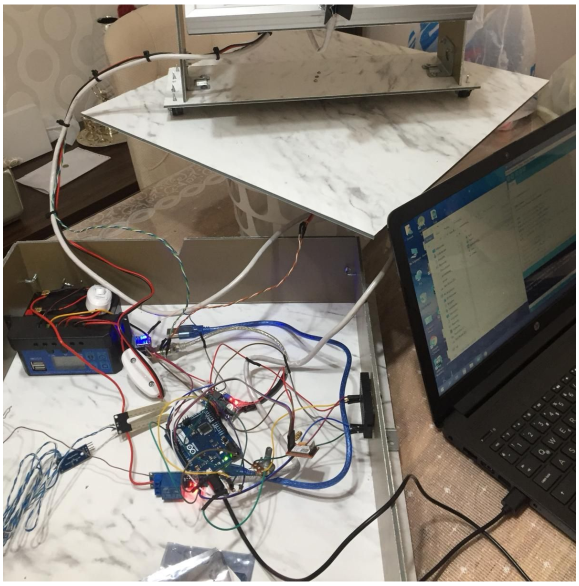

Figure 22 a - Sample picture of the prototype system built.

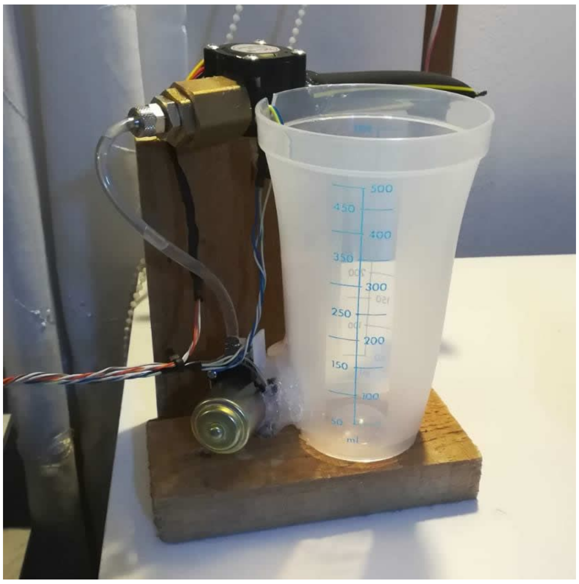

Figure 22 b - Sample picture of the prototype system built.

Figure 22 c - Sample picture of the prototype system built.

Figure 22 d - Sample picture of the prototype system built.

During the implementation, we used Arduino's own language and integrated development environment. We implement the system that is structure-based implementation. We connected the Arduino to the computer with USB and transmit the code that written. Arduino cannot support multi-process at the same time, in the implementation stage, we thought the process queues. As can be seen in Figure 22 a, Arduino, modules and battery are located in the empty space under the solar panel. This provides a protection for the electronic devices. Figure 22 b shows the prototype water pump and water tank. There is also a water level sensor and water flow sensor. The LCD screen and a sample warning can be seen in Figure 22 c. Figure 22 d shows the general view of the prototype system built successfully.

10. Timeline

An timeline of project deliverables and important dates shown below.

Tasks/Times	**10 / 2018**	**11 / 2018**	**12 / 2018**	**01 / 2019**	**02 / 2019**	**03 / 2019**	**04 / 2019**	**05 / 2019**
Project Proposal								
Background Research and Project Planning [S1]								
Requirements Specification [S2]								
System Design [S3]								
Report Writing and Prepare to Oral Presentation								
Verification and Validation								
Implementation								
Maintanence								
Prepare to Delivery and Oral Presentaion								
Subtask 1	Expected to talk with customers. What they need and their expectations will be evaluated.							
Subtask 2	Focus on home flowers. Functional and non-functional requirements will be determined.							
Subtask 3	Designing for the low cost and more efficient for houseplants							

Table 8 - Timeline.

11. Testing

The physical test of our project was carried out by various volunteer users. After the tests, we applied a questionnaire with 13 questions. The questions and inferences are shown below. Survey responses are multiple choice in the form of "disagree", "neutral" and "agree".

QUESTIONS:

1- The most important part of this project is the remote control.

2- The most important part of this project is the produce own energy.

3- The most important part of this project is communication with SMS.

4- Do you think the solar panel can provide the necessary energy?

5- Do you think communicating with the Internet will make an extra contribution to the project?

6- Is the SMS module used by our project sufficient for communication?

7- If you have used an irrigation system in the past, is there any weakness from ABAIS? (If you don't, please select neutral.)

8- Do you think the soil moisture sensor in the project is sufficient as an irrigation criterion?

9- Do you think the project is portable?

10- Do you think the project is innovative?

11- Do you think that this project has enough sensors?

12- Is it easy to use the project?

13- Would you like to buy the project?

# of Attendees	Age	Job	# of Questions												
			1	2	3	4	5	6	7	8	9	10	11	12	13
1	23	Student	-	+	-	+	N	+	N	+	-	+	+	+	-
2	22	Officer	-	N	+	N	N	N	+	-	+	+	N	+	+
3	53	Gardener	+	+	N	+	-	+	-	N	+	+	+	N	+
4	72	Farmer	-	+	N	N	N	+	-	N	+	+	+	N	+
5	34	Teacher	+	+	N	+	+	N	N	+	-	+	+	+	-
6	33	Housewife	N	+	N	+	-	N	-	+	+	-	N	+	+
7	53	Farmer	+	+	-	-	+	N	+	-	+	+	+	+	-
										+: Agree		-:Disagree		N: Neutral	

Table 9 - Questionnaire results.

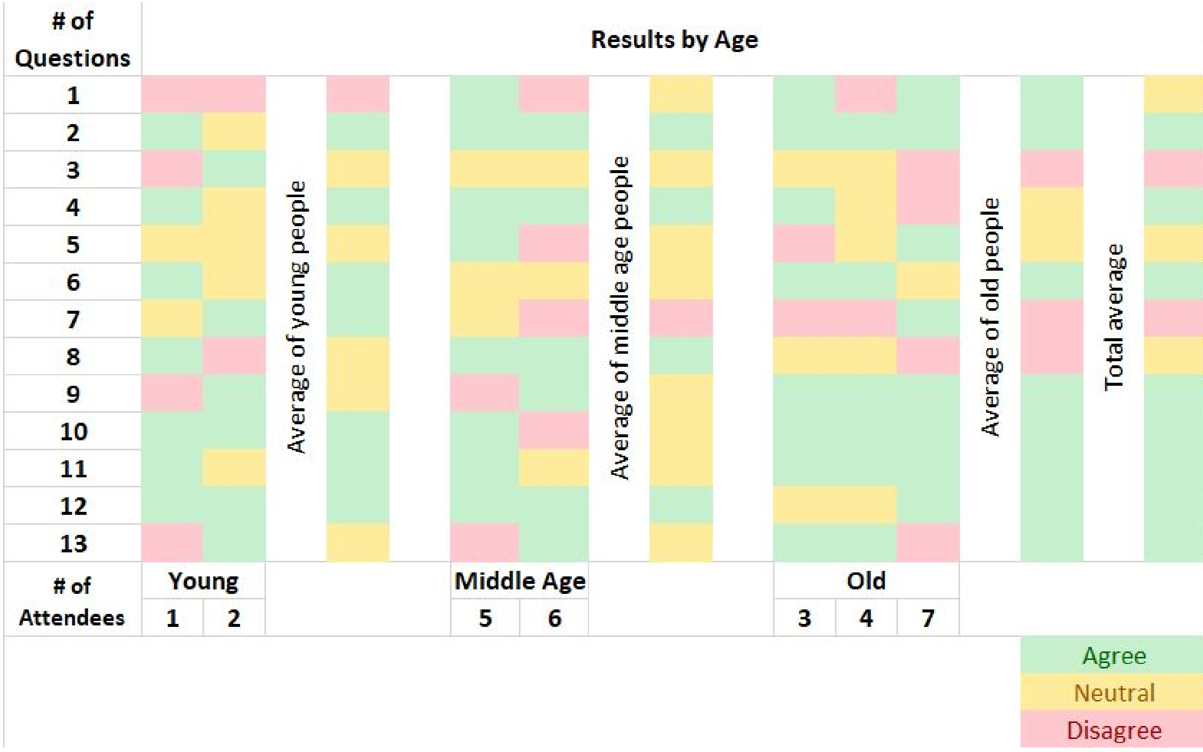

Table 10 - Evaluation of the questionnaire results by age groups.

We have created a graph of results by age groups to catch best comments. The green boxes shows the participant has positive thought in the given statement, the yellow boxes shows the participant has unclear thought in the given statement and the red boxes shows the participant has negative thought in the given statement.

When we examine the result graph, it was revealed that participants responded with a certain tendency according to their age. While remote control is not important for young people, it is important for older people. Remote control no longer attracts young people. However, older people find important every solution that make life easier for example remote control. At this point, it is clear that the most important feature for all age groups is "To provide their own energy". The majority of young people and middle-aged people were undecided about the fact that SMS was the most important part of the project. Old people think that the most important part of the project is not SMS. In another survey question, young people and middle-aged people thought that the project could produce their own energy, while older people were hesitant. People from all age groups were undecided about the extra contribution of the internet to the project. While young and old people thought that SMS could provide all communication between the project and human, middle-aged people were hesitant. While the middle-aged people accepted that the soil moisture sensor in the project was sufficient as the irrigation crest, young and old people refused. Most people surveyed think that the project is portable and innovative. Young, middle-aged and old people think the sensors in the project are adequate and the project is easy to use. Some young and middle-aged people "Would you buy the project?" the answer to the question as an old, but the old people said they would buy the project.

12. Discussion

In this section, regarding the design choices, possible questions in mind are discussed.

Are the sensors used completely sufficient? Why don't we use advanced sensors such as used in the weather station?

- All of the sensors used in the ABAIS are sufficient to grow a plant in an appropriate way. Soil moisture and water level sensors are the two essential sensors that the system includes in default. The soil moisture sensor regularly measures the moisture of the soil. ABAIS starts irrigation according to soil moisture and easily reaches the sufficient level of efficiency. Weather conditions do not play an important role for irrigation systems that are aims house/garden like ABAIS, as soil moisture is regularly measured. Therefore, advanced sensors like the weather station is not considered necessary for this project [8]. Also, one of the main objectives of ABAIS is to minimize cost.

What kind of plants can be used in this system?

- Plants draw their water needs from the soil through their roots. There is no specific watering time. Irrigation is done dynamically according to the water used by the plants. As a result, this system can be used with every garden/house plant.

Why is there no valve in ABAIS?

- The purpose of using valves in irrigation systems is to prevent the pressurized water from reaching the irrigation pipes through the pump. So, in order to need the valve, there must be pressurized water in the system. For example, the need for water for a field irrigation is provided by large tanks [10]. Water tanks can be used with the help of valves, but ABAIS is a system for working in small areas. For example, it addresses house pots and small garden areas. Therefore, the valve is not used. In future, the valve means can be used when the irrigation areas grow. The valves can be easily integrated into ABAIS.

Why does ABAIS use SMS for communication?

- One of the most important reasons for using SMS is to reach more users. Today, many people can use the internet, but there are old people who can not use any smart phone application. But almost everyone can read or send an SMS in some way. Therefore, ABAIS is using SMS for communication.

13. Conclusion

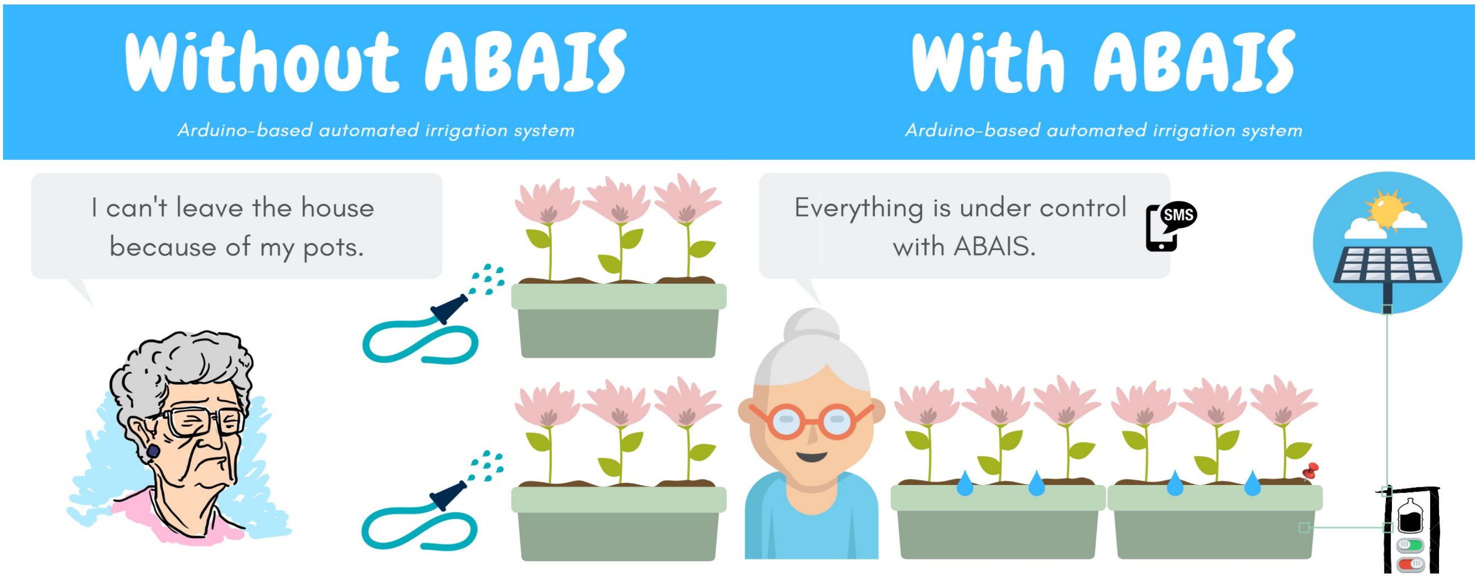

Figure 23. A and B. Comparison of before and after the ABAIS.

The contribution of the ABAIS to daily life is shown in Figure 23 a and b in simplest form. As can be seen, plants expect daily attention in an environment where there is no ABAIS. At that situation, arises addiction to the home. However, this problem disappears with the ABAIS.

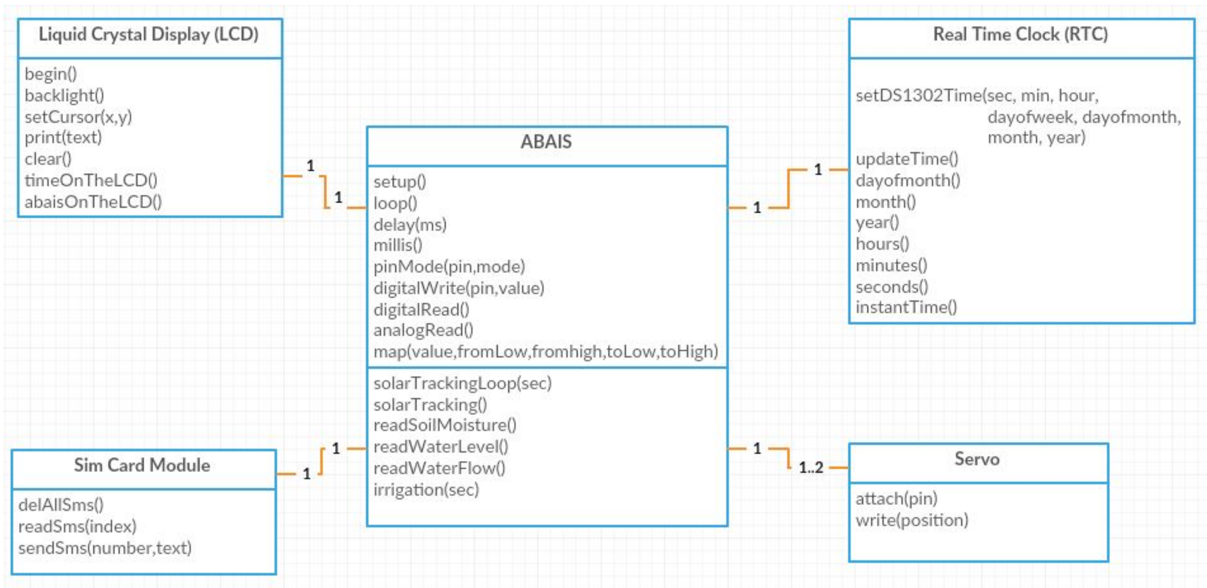

Figure 24 - Functions that are used in the ABAIS.

The functions used in the ABAIS are shown above in Figure 24. These functions indicate the main characteristics of the ABAIS. In general, one of the functions initiates the module and others provide options for the system to work correctly. Details of functions are given in the system design file. Sensors defined as "input" can work in the system without the own functions. These sensors (e.g., moisture sensor) just send 10 bits data (a value between 0-1023) through the input channel and are used directly in the system. The usage of all these sensors and modules provides an effective irrigation system. Irrigation depends on various conditions and these conditions are controlled by the system. The evaluation criteria of the variables were formulated according to the advices which are received from the interviewees.

The formula for irrigation are as follows:

- **The humidity in the soil must be below 20 percent:** Known that the soil moisture sensor returns 10 bits value. So, higher values means the soil is dry and lower values means the soil is wet. When the deviation is taken into account, only if the value is above 700, irrigation begins.
- **Watering is only between 18 and 6 o'clock:** The time in the system is followed with RTC module. This condition is controlled by followed time.
- **850 ml water is used during irrigation:** Irrigation takes ~13 minutes with drippers that has 4 L/h flow rate and 20 cm intermittent. The calculation of taken time formula is:
  taken time = 60 * liter of water / flow rate

14. References

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https://www.academia.edu/9587271/GSM_based_Automatic_Irrigation_System, (accessed on Oct 20, 2018)

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[3] Marie France Leroux, Prof. G. S. Vijaya Raghavan, “ Design of an Automated Irrigation System”, https://www.mcgill.ca/bioeng/files/bioeng/MarieFranceLerou2005.pdf, May 16 2005.

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[11] Electronics | Software & Mechanical Kits web site, http://nevonprojects.com/irrigation-system-based-on-solar/, (accessed on Nov 10, 2018).

[12]Autocat Tinkercard web site, https://www.tinkercad.com/things/5XfKpxzCLkL(accessed on Nov 12, 2018).

15. Appendices

15.1. Appendix A - Research Interview for Requirements

1. The target in our project is potted and garden plants. What should be the watering hours?
    - *Since agricultural irrigation is evaporation, the most effective yield is taken in the morning sunrise and in the evening hours. Weather conditions are of great importance in this case. Evaporation is less in winter and watering is too low because the soil keeps moisture in winter. In the summer period, evaporation is high and therefore watering should be done at appropriate times.*

2. What commands should the user provide to the system via SMS? What informations are expected to request?
    - *First of all, soil moisture is one of the most important issues for the plant and it should be shown on the screen.*
    - *Total amount of water used can be shown(daily, weekly, monthly and all-time sum)*
    - *Automatic watering can sometimes cause undesirable problem, so it can allow manual control.*
    - *The soil moisture sensor should be preferred with the needle foot. This type of sensor loses its sensitivity over time and is always important to use a good sensor. It can be used for longer life, less deviation, and more conductivity (DEKAGON GS1 Model with needle foot).*
    - *GSM can be used instead of bluetooth / wifi. Maybe it can be an app.*

3. The only sensor that we use for the earth values is the humidity sensor. Do you think this is enough for efficient irrigation?
    - *Since the target is potted and garden only the soil moisture sensor is sufficient. But deviations need to be calculated well. The quality of the sensors used is very important, and although they can have the little deviation will affect the plants.*
    - *Another important issue for irrigation is the equal watering of the layers. As mentioned above, the moisture level of all layers must be checked, not just the 0-30m range. If not controlled, yielding irrigation will not occur and the plant will dry out from the roots. Because the target is the flower pot and garden, you will not prefer the deep root plants. That's why it will not be an obstacle about layers.*

4. In our project, there is a light-dependent sensor for the solar panel to follow the sun. Can this light sensor be used for irrigation efficiency other than solar monitoring?
    - *It's nice that you use your system with electricity from solar energy. It has added an environmental aspect to this project. There are more than one irrigation method. For example measuring soil, measuring plant and watering via seasonal measurements. Your irrigation model has that depends on the soil. Therefore you can only produce energy from the sun.*

5. There are 16x2 LCD screens in our project. Which information is important for the user?
    - *LCD can show a faulty sensor if an error occurs.*
    - *Humidity.*
    - *Graph of the amount of water used.*
    - *Battery.*

6. In addition, what are the suggestions you think will contribute to project development?
    - *The system to be created should not have a complicated structure. It should be simple, clear and effective. And solenoid valve should be used. If you want, multiple locations can be irrigated at the same time with the use of the valve. If there is no valve, the valve must be used as the water will flow directly. Finally, fertilization should be carried out.*

15.2. Appendix B - Project Final Codes

```
// Top servo pin          0
// Bottom servo pin       1
// LCD SDA                2
// LCD SCL                3
// Soil moisture          4 (A6)
// Relay pin              5
// Water level pin        6 (A7)
// Real Time Clock        7 8 9
// Sim Card (GSM)         10 11 12
// LDRs + pot             A0-A4
// Water flow             A5

#include <Servo.h>
#include <LiquidCrystal_I2C_AvrI2C.h>
#include <Wire.h>
#include <Sim800l.h>
#include <SoftwareSerial.h>
#include <virtuabotixRTC.h>

//Definitions for sim card usage
Sim800l Sim800l;
char* textMessage;
char* number = "+9055xxxxxxxx"; //User's phone number
String incomingText, numberSms;
uint8_t index;
bool errorSend;
bool errorDel;
bool postpone = false;

//Definitions for servo motors
Servo bottomServo;
Servo topServo;
int bottomServoLocation = 92;
int topServoLocation = 30;
const int bottomServoPin = 1;
const int topServoPin = 0;
```

```
//Definitions for LDRs
const int ldrL = A0;
const int ldrR = A1;
const int ldrB = A2;
const int ldrT = A3;
const int potPin = A4;
int ldrLValue = 0;
int ldrRValue = 0;
int ldrBValue = 0;
int ldrTValue = 0;
int potValue = 0;

//Definitions for water pump and sensors
const int relayPin = 5;
const int soilPin = A6;
const int waterFlowPin = A5;
const int waterLevelPin = A7;
int waterLevelValue;
int soilMoistureValue;
int waterFlowValue;

//Definitions for Real Time Clock
const int rtcCLK = 7;
const int rtcDAT = 8;
const int rtcRST = 9;
int day, month, year, minute, second, hour;
int lastHour = 0;
virtuabotixRTC myRTC(rtcCLK, rtcDAT, rtcRST);
unsigned long lastTime = 0;
unsigned long newTime = 0;

//Definition for LCD
LiquidCrystal_I2C_AvrI2C lcd(0x27, 16, 2);


void setup() //This function is called when a sketch starts.
{
  Serial.begin(9600); //Starts serial communication for debug.

  //Starts the LCD screen on ABAIS.
  lcd.begin();
  lcd.backlight();
  abaisOnTheLCD();
  lcd.print("Please wait...");
  //Attach the Servo variable to a pin.
  bottomServo.attach(bottomServoPin);
  topServo.attach(topServoPin);
  bottomServo.write(bottomServoLocation);
  topServo.write(topServoLocation);
  delay(50); //Pauses the program (in milliseconds) for stable operation.

  Sim800l.begin();
  Sim800l.reset();
  delay(5000);
  textMessage = "Welcome to ABAIS. To learn the available SMS commands, type 'help' and reply to this message.";
  SendSMS();
  errorDel=Sim800l.delAllSms(); //clean memory of sms
  delay(2000);
}

void loop() //This function loops consecutively, allowing your program to change and respond.
{
  solarTrackingLoop(15); //Follow the sun for 15 seconds to determine the position of the sun.
  timeOnTheLCD();
```

```
  //Read sensors values.
  readWaterLevel();
  readSoilMoisture();
  readWaterFlow();

  if (waterLevelValue < 20) {
    Serial.println("Water level is low.");
    abaisOnTheLCD();
    lcd.print("Check water tank");
    textMessage = "The amount of water in the tank is low, please add water.";
    SendSMS();
    delay(2000);
  }

  if (!postpone) {
    if ((myRTC.hours >= 18) || (myRTC.hours < 6)) {
      if (myRTC.hours != lastHour) {
        if (soilMoistureValue < 40) {
          irrigation(15);
          lastHour = myRTC.hours;
        }
      }
    }
  }

  readSMS();
  Serial.println("----END LOOP----");
  delay(5000);
}

void readSMS()
{
  incomingText = Sim800l.readSms(1); //read the first sms
  if (incomingText.indexOf("OK") != -1) {
    if (incomingText.length() > 7) {
      numberSms = Sim800l.getNumberSms(1);
      Serial.println(numberSms);
      incomingText.toUpperCase();
      if (incomingText.indexOf("STOP") != -1) {
        postpone = true;
        Serial.println("postpone = true");
      }
      else if (incomingText.indexOf("START") != -1) {
        postpone = false;
        Serial.println("postpone = false");
      }
      else if (incomingText.indexOf("SYSTEMTIME") != -1) {
        textMessage = myRTC.dayofmonth;
        textMessage += '/';
        textMessage += myRTC.month;
        textMessage += '/';
        textMessage += myRTC.year;
        textMessage += ' ';
        textMessage += myRTC.hours;
        textMessage += ':';
        textMessage += myRTC.minutes;
        SendSMS();
      }
      else if (incomingText.indexOf("HELP") != -1) {
        textMessage = "1/4 To postpone irrigation jobs indefinitely, write 'stop'.";
        SendSMS();
        delay(3000);
        textMessage = "2/4 To start indefinitely postponed irrigation jobs, write 'start'.";
        SendSMS();
```

```
      delay(3000);
      textMessage = "3/4 To learn the system time, write 'systemtime'.";
      SendSMS();
      delay(3000);
      textMessage = "4/4 To learn the available SMS commands,  write 'help'.";
      SendSMS();
      delay(3000);
     }
     else {
      Serial.println("incomingText not compatible!");
     }
     Sim800l.delAllSms(); //when receive a new sms always will be in first position
    }
  }
}

void timeOnTheLCD()
{
  delay(1000);
  instantTime();
  abaisOnTheLCD();
  lcd.print(myRTC.dayofmonth);
  lcd.print("/");
  lcd.print(myRTC.month);
  lcd.print("/");
  lcd.print(myRTC.year);
  lcd.print(" ");
  lcd.print(myRTC.hours);
  lcd.print(":");
  lcd.print(myRTC.minutes);
}

void solarTrackingLoop(int loopSecond)
{
  abaisOnTheLCD();
  lcd.print("Solar tracking..");
  second = myRTC.seconds;
  minute = myRTC.minutes;
  while (1) {
    solarTracking();
    newTime = millis();
    if (newTime - lastTime > 3000) {
      instantTime();
      Serial.println("UPDATED");
      lastTime = newTime;
    }
    if ((myRTC.seconds - second > loopSecond) || (second - myRTC.seconds > loopSecond)) {
      Serial.println("BREAK");
      break;
    }
  }
}

void solarTracking()
{
  ldrLValue = analogRead(ldrL);
  ldrRValue = analogRead(ldrR);
  ldrTValue = analogRead(ldrT);
  ldrBValue = analogRead(ldrB);
  potValue = analogRead(potPin);
  potValue = map(potValue, 0, 1023, 0, 50);
```

```
  if (ldrLValue > ( ldrRValue + potValue ))
  {
   if (bottomServoLocation > 0)
     bottomServoLocation -= 1;
   bottomServo.write(bottomServoLocation);
  }
  if (ldrRValue > ( ldrLValue + potValue ))
  {
   if ( bottomServoLocation < 180 )
     bottomServoLocation++;
   bottomServo.write(bottomServoLocation);
  }

  if (ldrTValue > ( ldrBValue + potValue ))
  {
   if ( topServoLocation > 0 )
     topServoLocation -= 1;
   topServo.write(topServoLocation);
  }

  if (ldrBValue > ( ldrTValue + potValue ))
  {
   if (topServoLocation < 180)
     topServoLocation++;
   topServo.write(topServoLocation);
  }
  delay(50);
}

void instantTime()
{
  myRTC.updateTime();
  Serial.print("Date / Time : ");
  Serial.print(myRTC.dayofmonth);
  Serial.print("/");
  Serial.print(myRTC.month);
  Serial.print("/");
  Serial.print(myRTC.year);
  Serial.print(" ");
  Serial.print(myRTC.hours);
  Serial.print(":");
  Serial.print(myRTC.minutes);
  Serial.print(":");
  Serial.println(myRTC.seconds);
}

void readSoilMoisture()
{
  int x;
  x = analogRead(soilPin);
  x = map(x, 0, 1023, 0, 100);
  x = 100 - x;
  soilMoistureValue = x;
  Serial.print("soilMoistureValue: ");
  Serial.println(soilMoistureValue);
}

void readWaterLevel()
{
  int x;
  x = analogRead(waterLevelPin);
  x = map(x, 0, 1023, 0, 100);
  waterLevelValue = x;
  Serial.print("waterLevelValue: ");
```

```
 Serial.println(waterLevelValue);
}
void readWaterFlow()
{
 int x;
 x = analogRead(waterFlowPin);
 x = map(x, 0, 1023, 0, 100);
 waterFlowValue = x;
 Serial.print("waterFlowValue: ");
 Serial.println(waterFlowValue);
}

void irrigation(int iSecond)
{
 if (waterLevelValue > 20) {
  pinMode(relayPin, OUTPUT);
  digitalWrite(relayPin, LOW);
  Serial.println("Irrigation is started.");
  iSecond = 1000 * iSecond;
  readWaterFlow();
  delay(iSecond);
  if (waterFlowValue < 50) {
   Serial.println("Irrigation is NOT completed. Water flow error.");
   abaisOnTheLCD();
   lcd.print("Irrigation error");
   textMessage = "Irrigation failure. Please check the water pipe connections.";
   SendSMS();
  }
  else {
   Serial.println("Irrigation is completed.");
   textMessage = "Irrigation is completed successfully.";
   SendSMS();
  }
  digitalWrite(relayPin, HIGH);
  delay(50);
  pinMode(relayPin, INPUT);
 }
 else {
  Serial.println("Irrigation is NOT completed. Water level is too low.");
 }
}

void SendSMS()
{
 errorSend = Sim800l.sendSms(number, textMessage);
 if (errorSend != 0) {
  abaisOnTheLCD();
  lcd.print("SMS error!!");
  Serial.println("SMS error!!");
 }
}

void abaisOnTheLCD()
{
 lcd.clear();
 lcd.print("    ~ABAIS");
 lcd.setCursor(0, 1);
}
```