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"ANALYSIS AND DESIGN OF A REMOTE BEEHIVE SURVEILLANCE AND MONITORING INFORMATION SYSTEM"

Ioanna Siakampeti – 1075725

Supervisor:

Nikos Karacapilidis, *Professor*

Members of the Supervising committee:

Nathanael Dimitrios, *Assistant Professor*

Christos Bouras, *Professor*

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Abstract

Human and Computer Interaction is now a new field in the academic world but provides humans with new technologies and solutions to their everyday problems. The aim of this dissertation is the creation of an application in a prototype form that will help beekeepers in their everyday activities. Someone can be a beekeeper as a professional or as an amateur but in both situations the activities that one has to do are many and complex. They must constantly have their attention to their beehives and the behavior of the bees. In order to do this they must be informed about the weather, the climatic conditions, the areas that are appropriate to put in their apiaries etc. This study starts with a literature review that concerns relevant bibliography and underlying technologies like Internet of Things, sensors and remote monitoring systems. Then, it continues with the methodological analysis that is based on the principles of the HCI field. It describes the methodological approach of the interview and observation, the reason for choosing mock-ups and the basic heuristics in the user centered design. The chapter 4 is the description of the final prototype while the evaluation process is presented in chapter 5. The thesis ends with the conclusion and proposal for future work in Chapter 6.

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Chapter 1: Introduction

Human computer interaction (HCI) has been characterized as multidisciplinary field that studies design of computer technology and systems, more particular interactive technologies and how those systems interact with humans. In other words, it is the study that focuses on the relationship between the human-user and computer. The field of HCI is wide and includes computer, cognitive science and human factors engineering. The investigation of researchers and scientists at first has as topic the usability of computer systems but with the rise of internet, smartphones and new technologies HCI now focused on user experience and follows a human to human approach (Bødker, 2006).

One of the fields that has benefited the most from HCI is agriculture. Alternative systems of farming and harvesting, combination of human and robot practices, new applications that help farmers gather data about their job and communicate with each other (Liu, Bardzell, & Bardzell, 2019). A new addition comes from the area of bees and their products. The utilization of precision agriculture permits us to screen the beehives for some potential reasons, for example, research, data about the every-day the board of bees by beekeepers, and figuring out how to diminish the assets and time allocated to assignments without decreasing creation (Von Frisch, 1994).

Beehive monitoring permits us to screen various boundaries, for example, the temperature and dampness levels inside the beehives, just as the weight, sounds, and gases delivered, which can create significant data. For instance, this information can advise us on whether the beehives are amassing depending on the temperature, regardless of whether any activity is needed from the beekeeper, whether the bees are influenced by any infection, or even whether the hives are moving. This last application is exceptionally helpful in zones where beehives can be taken (Kulyukin, Mukherjee, & Amalthie, 2018).

Various advances can be applied to screen the hives. Lessening the expense and size of the sensors permits the chance of sending them in the wide open to extricate data and gather information all the more without any problem. At first, far off electronic monitoring of beehives had a predominantly logical application, permitting the monitoring of elements inside the hives, for example, the temperature and the stickiness, with negligibly obtrusive strategies. These days, these developments have started to be adjusted by beekeepers through pragmatic applications that can give distant data to the dynamic cycles without reviewing the beehives (Kulyukin, Mukherjee, & Amalthie, 2018).

In any case, the monitoring of natural cycles is certainly not a trifling assignment, because of the way that the conduct of the organic system and its response to human collaboration isn't unsurprising. The securing of information in mechanical cycles is a typical issue, and there are numerous business systems for such undertakings. In any case, in the extent of organic cycles, information obtaining turns into an unpredictable errand, particularly on account of honeybee hives, where any unfamiliar article can go into a danger of being killed by the bees (Bromenshenk , et al., 2015).

Lately, monitoring systems have enormously advanced because of the utilization of remote sensor organizations (WSNs). A WSN consists of implanted gadgets that can secure information from various sensors, measure them, and speak with a PC with a cloud data set. These gadgets are known as nodes or bits and are the primary center of the Internet of Things (IoT). People have utilized WSNs in numerous everyday life exercises, for example, farming. They have been likewise utilized in medical services, smart home monitoring, archeological monitoring systems, and military and modern applications (De Freitas, et al., 2010).

WSNs are likewise starting to be utilized to screen honeybee colonies. The nodes of a WSN can be utilized to acquire information from the sensors monitoring the natural states of a beehive (humidity, CO2, temperature, and so forth) and even its weight. The nodes associate and convey through a door that can send the information from the bits to a base for capacity and preparation. This has expanded the highlights of the monitoring systems, prompting what is now known as precision apiculture. WSNs are a notable option for disseminated and distant detecting. These sorts of organizations offer solid potential for beekeepers, because of the way that they meet a few huge necessities: (I) they are an insignificantly obtrusive technique because of the little size of the nodes and sensors; (II) they can be operational in distant regions for an extensive stretch of time because of their low energy utilization; and (iii) they permit constant monitoring (Gil-Lebrero, Latorre, Ortiz, & Ruiz, 2017).

This work presents a remote monitoring system for honeybee hives. The system architecture permits simple arrangement in the field and guarantees simple versatility. We utilized business nodes yet adjusted them to acquire estimations from the hives. We additionally built up a connector board.

The motivation that led to the design and implementation, as well as the evaluation of such a monitoring system, was that Greek apiculture lacks such systems. Therefore, one of the main targets was the design and implementation according to the Greek standards, as well as the evaluation through a questionnaire to Greek bee farmers. The contribution of this study will be the application of this system in the Greek reality and the comparison of the assimilated data with the data collected from international studies. This thesis will be structured in the following chapters including the related work and underlying technologies, the methodological Analysis, the system overview and finally the evaluation of the system by Greek bee farmers.

Chapter 2: Related work & Underlying technologies

2.1. Internet of Things

Internet of Things terminology encompasses a variety of solutions and technologies that describe the communication and interaction of smart objects. Among the various proposed solutions there are usually no possibilities of interaction as each of them evolved with the aim of solving a specific problem and following specific requirements.

Also, as the IoT umbrella covers a wide range of applications, the technologies being developed vary and isolated solutions are emerging (Laubhan, et al. 2016).

In order for IoT to mature and perform to its full potential, common technical principles, protocols and architectures must be found that will link the above solutions. An example of this need can be found in the recent history of technology, specifically in the field of communication networks. Isolated technologies and solutions were abandoned and the TCP / IP protocol suite was adopted which describes the general principles of operation of each layer of the network. In the same way, a reference model should be developed for IoT so that through the reference architectures it describes, more and more focused solutions can be developed (Placidi, Gasperini, Grassi, Cecconi, & Scorzoni, 2020)

Most IoT definitions include the concept of physical objects or devices that can "feel" or affect the natural environment. They also include virtual items such as electronic agendas, books and wallets. IoT always involves the involvement of people, for example in the field of home automation, people can control the environment through an application. Through various applications and services, a large amount of data is collected that is processed and converted into valuable information. IoT also uses various platforms, which act as bridges to connect the various components of IoT (objects-devices, people, services). The platforms provide various functions such as accessing the devices, ensuring the correct installation and behavior of the device, analyzing data and connecting the various devices to the local network, the cloud or other devices. Finally, all IoT components are interconnected through a network that uses wireless or wired technologies, protocols and standards (Laubhan, et al. 2016).

Sensors are a system for collecting information from devices. They convert information they collect from the physical environment into electrical signals that can then be processed by computers. Some examples of such sensors are humidity, air temperature, radioactivity and motion sensors. These sensors play an important role in connecting devices that traditionally did not have such capabilities in IoT.

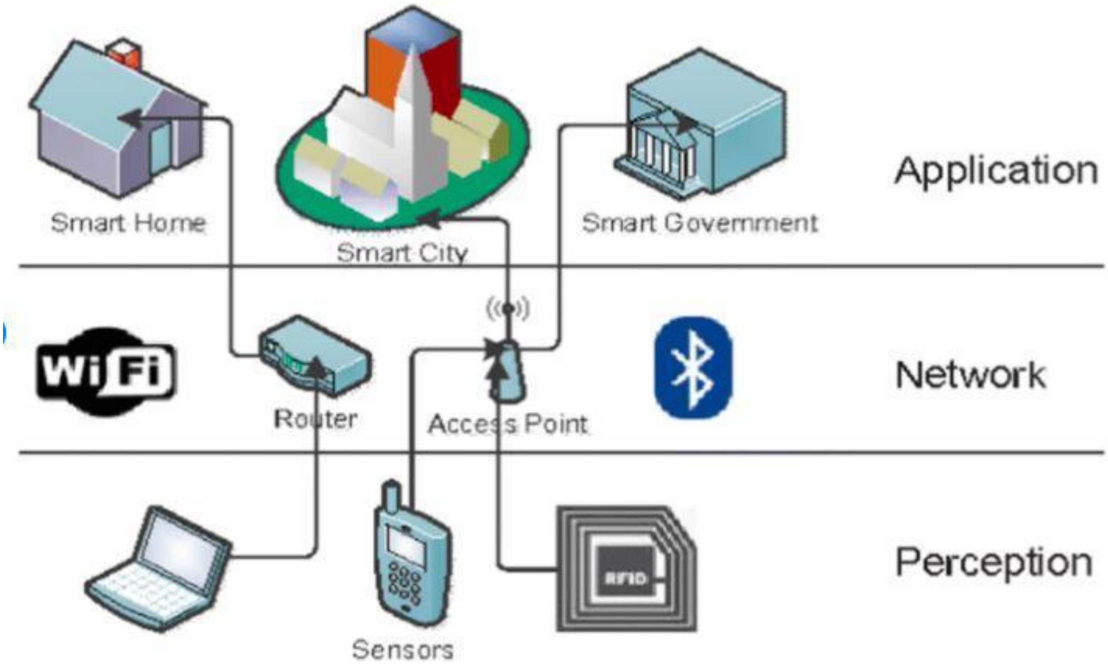

Figure 1: The IoT world (Panchiwal & Shah, 2020)

Many sensors use RFID (radio frequency identification) technology. This technology uses the radio frequencies of electromagnetic fields to exchange information between tags and RFID readers. Usually RFID tags are used to identify and track objects to which they are embedded e.g. books. Thanks to their small size, they can be placed on a large number of items including clothes and cash. Some of them have the ability to operate without batteries (Panchiwal & Shah, 2020). The necessary energy to be able to transmit information is collected through the electromagnetic field emitted by their reader. The label receives the signal from the reader and uses some of its energy to send the information it has gathered (Figure 1). The emission radius of these labels is limited to a few meters, while labels with batteries reach a radius of up to a few hundred meters (Malavade & Akulwar, 2016).

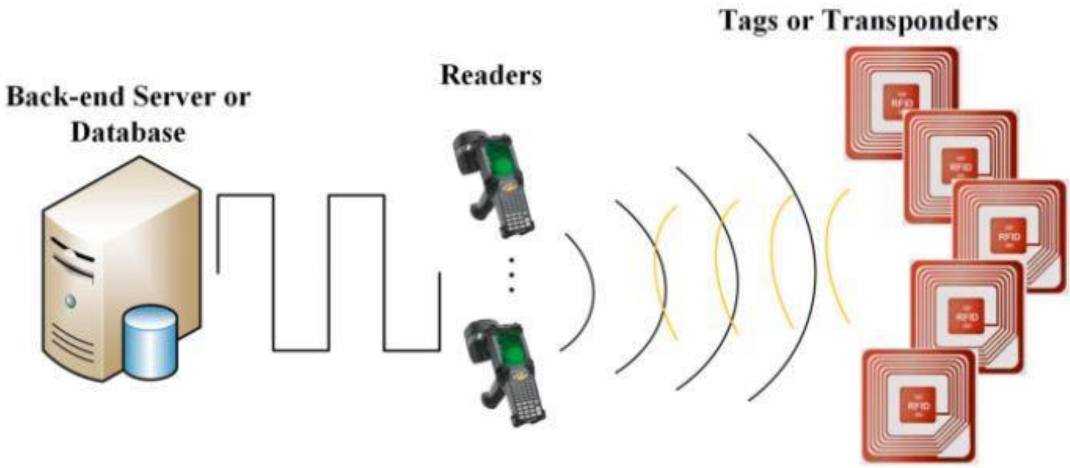

Figure 2: RFID system (Baghery, Abdolmaleki, Akhbari, & Aref, 2015)

Unlike barcodes, RFID technology is based on radio frequencies and does not require visual contact between transmitter and receiver. Due to the flexibility of labels and their low energy requirements, they are an easy and convenient way to connect devices and objects to the IoT (Baghery, Abdolmaleki, Akhbari, & Aref, 2015).

For example, it is common practice for car manufacturers to affix labels to the car body they make. This way, they can detect at which point on the production line each car is located. The first generation of labels allowed data to be written once and transmitted multiple times - "write once read many". This means that they can be programmed at the factory once but cannot be modified at their installation site. The new tags have circuits with a life cycle of 40 to 50 years and can change their write data over 100,000 times. These tags can easily save the entire history of the object in which they are installed, such as the date of construction, the history of the locations where the object was found, when it was modified or repaired, and the current owner (Hui-Ping , Shi-De, & Xiang-Yin, 2015).

The sensors can be programmed to take various measurements, translate the data they collect into signals, and send these signals to a central control group. This unit is responsible for collecting data and providing Internet access. It can also make immediate decisions based on the data it receives or forward them for analysis to other computers. These computers can be installed either on the same LAN or be accessible over the Internet (Muncuk, Alemdar, Sarode, & Chowdhury, 2018)

Another sensor technology used in recent years is NFC (Near-Field Communications). NFC is a way to transfer a limited amount of data, between devices, in a short range and with low power consumption. This technology can be enabled on a large percentage of mobile phones and is commonly used for mobile payment services such as Google Wallet.

Another device used to implement IoT is the actuator. An actuator is an engine used to move or control another mechanism or system based on specific instructions. There are three types of actuators in IoT (Baig, Afifi, GholamHosseini, & Mirza, 2019):

- Hydraulic - Uses fluid pressure to perform mechanical movement.
- Pneumatic - Uses high pressure air to allow mechanical operation
- Electric - Powered by a motor and converts electricity into mechanical operation.

Regardless of the type of actuator to be used, its main function is to receive a signal with instructions and to perform some tasks based on these instructions. They are usually not able to process data. The actions performed by an actuator are based on the signal it receives. The central control group is usually responsible for sending the signal (Pachero & Hariri, 2018)

In IoT it will be possible to communicate directly between systems and devices. The acronyms M2M (machine to machine) refer to this type of communication, such as a smartwatch and a mobile application that reads data from it. When two devices communicate with each other, they collect data via a sensor and then transmit it over the wired or wireless network. Mobile telephony and data transfer protocols such as LTE, 4G, GSM and CDMA can also be used. Systems that exchange large amounts of data communicate with each other through wired technologies such as Ethernet and fiber optics. The easiest way to communicate remains with the wireless connection through wireless cards that are integrated into the devices and use protocols such as Wi-Fi, Bluetooth, ZigBee, Z-Wave, NFC and RFID mentioned above. Mobile and mobile service providers are seeing increased use of these technologies, with Verizon reporting a 45% increase in IoT-enabled technology and a 135% increase in 4GLTE activation (Laubhan, et al., 2016).

Finally, the use of the IPv6 protocol will play an important role in the adoption of IoT. Unlike IPv4, IPv6 has theoretically inexhaustible IP addresses that are enough to connect any device and service to the Internet. Experiments have shown the successful use of IPv6 addresses in large-scale developments such as sensors in smart buildings or smart cities, even with cattle (Laubhan, et al., 2016)

2.2. Sensors

In many cases, electronic devices are used to monitor and control (i.e guide) physical, chemical, mechanical and generally technological processes, from the automatic lighting of a lamp at night to the automatic mixing and processing of chemicals in a factory. This is the essence of the concept of automation, the guidance of systems from electronic systems without the requirement of human intervention.

The course of a process can be known from some physical quantity associated with its result. For example, we can monitor the heating process of a product by measuring its temperature (Placidi, Gasperini, Grassi, Cecconi, & Scorzoni, 2020).

Measurements of physical quantities are made with the help of sensors or sensors. These are devices that have some suitable property, which varies as a function of the measured physical size. Thus, the measurement of the property of the sensor allows the direct quantitative calculation of the value of the physical size. The study and application in practice of sensors is the subject of Instrumentation (Laubhan, et al., 2016)

The following paragraphs describe the main types of sensors that can work with a PC, depending on the physical size they measure. This describes sensors for temperature, light level, pressure and weight, level, volume, displacement and movement. Each type of sensor first describes its principle of operation and then gives detailed examples of commercial products, which can be economical options for general use.

Often the sensors do not give a proper electrical signal at their output. It is then necessary to use an additional electronic circuit, which receives the output of the sensor and converts it into a suitable electrical signal, according to the requirements of the following steps. This circuit is called a signal conditioning circuit, control circuit, or external or external module. For example, there are level sensors that measure the time it takes for an ultrasonic wave to reflect off the measured surface and return to where it was emitted. They must have a suitable circuit for converting time values into corresponding voltage values (Placidi, Gasperini, Grassi, Cecconi, & Scorzoni, 2020).

Sensors that require external power to operate are called active. For example, a LVDT linear shift sensor must be powered by a suitable AC voltage. Sensors that generate a voltage on their own and do not need external power supply are called passive. Such are, for example, the piezoelectric crystals, which when pressed develop an electrical voltage at their ends (Baig, Afifi, GholamHosseini, & Mirza, 2019).

The characteristics of the sensors constitute their specifications and there are many. Although the various sensors that exist today are based on different operating principles, they have in common their basic characteristics. These are the following:

2.2.1 Linearity

Each sensor has a characteristic or property, the value of which changes when the physical quantity measured by the sensor changes. It is desirable that changes in physical quantity cause strictly proportional changes in the property of the sensor. This property is called linearity and is of particular importance. If the sensor is not linear, then the values of the measured quantity are matched with the output values of the sensor based on the "calibration" curve. Non-linearity is often an inherent property of the material from which the sensor is made and is generally impossible to zero (Baig, Afifi, GholamHosseini, & Mirza, 2019).

2.2.2. Sensitivity

Sensitivity expresses how high an output signal the sensor gives for each unit of measured physical size. Thus, if one temperature sensor has a sensitivity of 1 mV / oC, it means that it produces an output equal to 1 mV for each degree of temperature measured and is obviously more sensitive than another sensor with a sensitivity of 0.5

mV / oC, which for each temperature produces as output half voltage (Pachero & Hariri, 2018).

2.2.3 Distinctive ability

Resolution expresses the smallest change in physical size that the sensor can detect and change its output accordingly. For example, a thermometer with a resolution of 0.1 oC means that it can distinguish between two temperatures that are 0.1 oC apart, ie produce outputs of slightly different value (Hui-Ping , Shi-De, & Xiang-Yin, 2015)

2.2.4 Accuracy

Accuracy is equal to the error inherent in the value given by the sensor to the output, ie it indicates the uncertainty that exists in the output value. It can be expressed in absolute values (for example □0.05 oC) or in percent (for example 1%). In the first case the inaccuracy is constant and independent of the value of the measured physical size, while in the other case the inaccuracy is proportional to the above value (Malavade & Akulwar, 2016).

2.2.5 Entry value range

The full-scale input (FSI) range determines in which frames of the measured physical size the sensor can be used. For example, there are many temperature sensors (thermocouples, thermistors, thermoelectric resistors) but not all are suitable for measuring temperatures in the range of 1000 oC. Knowing the range of input values allows us to select the appropriate sensor that suits the needs of the application (Placidi, Gasperini, Grassi, Cecconi, & Scorzoni, 2020).

2.2.6 Exit value range

The full-scale output (FSO) range defines the format (i.e. values) that can be taken by the output voltage or current of a sensor. The sensors are generally available in variations with different output value ranges, so that the user can choose the format that best suits the circuits that will receive the output signal (for example in an A / D converter). The output value range is often determined by a signal adjustment circuit, which is permanently connected to the sensor.

2.2.7 Temperature

Finally, we must mention that temperature is the most common factor that alters the specifications of the sensors. The effect of temperature on the sensors can be known and there is often a way to compensate for it with appropriate electronic signal regulation circuits. Various quantities are defined to describe this effect, such as temperature zero shift, temperature sensitivity, and thermal sensitivity shift (Mois, Folea, & Sanislav, 2017).

2.2.7.1 Temperature sensors

The various thermometers are based on the change due to the temperature of a characteristic property of a selected material. The properties that can be used to measure temperature are generally the following (Mois, Folea, & Sanislav, 2017):

1. The linear expansion of a liquid

2. The linear expansion of a metal

3. The electrical resistance of a metal

4. The phenomenon of thermoelectricity (or thermoelectric effect)

5. The thermal radiation emitted by a hot body

The property of linear expansion is utilized by the well-known mercury thermometers, metal thermometers, etc. However, it is difficult to convert it into an electrical signal, which can be properly digitized. The property of electrical resistance is easier to use, as it is easy to generate an electrical voltage, which varies depending on the electrical resistance. The thermoelectric effect also leads to the appearance of an electrical voltage (Laubhan, et al., 2016).

In the following paragraphs we will describe the basic sensors that utilize the properties (3) and (4), which are the thermistors and the thermocouples. We will also describe a temperature sensor in the form of an integrated circuit, called LM35.

2.2.7.2 Optical Sensors

We know that electric current is transferred into a material by the electrons of the material that can move in it and are called free electrons or conduction electrons. The more conductivity electrons a material has, the higher the conductivity, and therefore the lower the resistance, in the current flow.

When light strikes a photoconductive material, the number of its free electrons increases. This is because the incident photons excite electrons that are bound and make them free. This reduces the resistance of the conductive material. The relationship between the incident luminous power P and the resistance R is not linear but logarithmic and has the form:

$$R = \frac{a}{P^b}$$

From this we come to the empirical relationship

$$logR = a - b\ logP$$

The quantities α and b are characteristic of the conductive material. Based on these materials, the commercial products of photoresistors or light-dependent resistors (LDRs) are manufactured (Malavade & Akulwar, 2016).

2.2.7.3 Pressure and Weight Sensors

Pressure is a measure of the force or mechanical stress exerted on the outer surface of a body by an external cause. Weight is the -stable- downward force exerted by the Earth on a body and is a special case of force. Thus, if a body is placed in contact with a pressure sensor, the sensor can measure the force received by the body from an external cause or from the Earth depending on the relative position of the body and sensor (vertical, horizontal, etc.). In other words, weight measurement is reduced to pressure measurement, which is why pressure gauges are also used to measure weight (Deepu, Hang, & Lian, 2016).

Table 1. Relationships between pressure units

1 atm = 101325 Pa
1 atm = 760 mmHg = 760 Torr
1 atm = 1.01325 bar
1 atm = 14.7 psi
1 bar = 100000 Pa
1 Torr = 133.32 Pa
1 psi = 6895 Pa

Pressure is related to strength in relation to:

$$P = \frac{F}{A}$$

and therefore its units are units of force per unit area. There are many units of pressure: First of all it is the atmosphere (atm), which was created based on the pressure exerted by the atmosphere. An atmosphere (1 Atm) is defined as the atmospheric pressure at sea level and at latitude 45o. This pressure is created by the air above us. The Earth's atmosphere consists mainly of oxygen and nitrogen, reaches a height of several thousand kilometers and pushes all objects on the Earth's surface. Its unit according to the International System of Units is Newton per square meter (N / m2) or Pascal (Pa). Because one square meter is a very large area, we expect that the pressure created at a point by a normal force is equal to thousands of Pa. Indeed, one atmosphere equals 101325 Pa. For convenience it is defined that one hundred thousand Pa is equal to 1 bar. Atmospheric pressure balances the weight of a 760 mm high mercury column, so as a unit of pressure there is a millimeter of mercury column (1 mmHg), called a Torr (from the Italian Evangelista Torricelli who observed the phenomenon). In the Anglo-Saxon system of units the unit of pressure is one pound of power per square inch (pound per square inch, lbf / in2), or psi, where it is 1 lbf = 4.4484 N and 1 in = 2.54 cm (Muncuk, Alemdar, Sarode, & Chowdhury, 2018). The relationship between the above units is summarized in Table 1.

The main types of pressure sensors are the following (Placidi, Gasperini, Grassi, Cecconi, & Scorzoni, 2020):

1. Liquid and gas manometers
2. Capacitive sensors
3. Inductive sensors
4. Piezoelectric sensors and piezoelectric sensors
5. Mechanical voltage meters and load cells

Liquid and gas pressure gauges are the only type of sensor that gives visible indications but not directly convertible into electrical signals. These include hose manometers, sloping manometers, Bourdon hose manometers and bellows manometers. In the following we will describe the other types of pressure gauges, their basic principles of operation and the specifications of standard commercial gauges (Laubhan, et al., 2016)

2.2.7.4 Level and volume sensors

Level and volume sensors are used in the case of liquids, which occupy the lower part of the container or tank in which they are placed and form a horizontal free surface at the top. How large the part of the tank that is occupied depends on the volume of the liquid. The distance of the free surface from the bottom of the tank is the level of the liquid.

In addition to observation vessels, volumetric cylinders and sonar rods, which are graded vessels and refer to small-scale applications (i.e. small quantities of liquids), capacitive pressure sensors and pressure sensors are currently used to measure liquid levels (Malavade & Akulwar, 2016).

2.2.7.5 Displacement and movement sensors

Detecting the physical position and motion of objects is vital, as most structures and devices have movable mechanical parts. It is often necessary to know the location of an object. We may want to determine if or when a moving part is in a predetermined location. Sometimes it is necessary to know if and to what extent a moving part moves or rotates in one direction or the other. Sometimes we are interested in how fast a mobile part moves. In all the above cases, the knowledge of the position, approach, displacement and speed or acceleration of an object concerns the general issue of detecting a parameter of its motion (Laubhan, et al., 2016).

Therefore, depending on the nature of our application, we must use sensors that detect any of the following quantities (Malavade & Akulwar, 2016):

- Location
- Approach

- Shift (straight or rotary)
- Speed or acceleration

Displacement results from the calculation of the distance between the new and the old position of the object under consideration, and therefore the position detection is reduced to the displacement detection and vice versa. Proximity is a special case of position detection, as then we are interested to know if the object in question will be found in a specific, predefined position. Thus, the detection of the approach gives two strong results (YES and NO) and is simpler than the location detection, which must give as results continuous numerical values (in millimeters or degrees). The measurement of speed and acceleration differs from the measurements of lengths and angles (positions, displacements, etc.) and is based on different principles (Baig, Afifi, GholamHosseini, & Mirza, 2019).

The displacement can be measured in the simplest cases with mechanical systems (linear micrometers or angle meters) and in order to do this there must be human intervention, in terms of reading the measurement and often in its execution. A better way is with the help of a potentiometer (linear or rotary), as we know that the output of a potentiometer is proportional to a certain length or angle. The disadvantages of potentiometers are the dependence of the output voltage on the resistor connected to it, the mechanical wear of the potentiometric rod or the potentiometric ring by the constant sliding of a rotor on it and the often step-by-step nature of the output voltage values. rod consists of a winding cable and therefore the runner is generally parked between the windings. The most modern ways of measuring displacement and position are the inductive and capacitive displacement sensors, which will be described below.

The proximity measurement can be done mechanically with the help of a contact switch: We place the switch in the position we are interested in and when the moving object reaches this position it closes or opens the switch, activating through it a control circuit. A more comprehensive way of measuring the approach is through the corresponding position. To do this we use a displacement sensor, which produces a voltage proportional to the position. We compare this voltage with the voltage that develops when the object in question reaches the predetermined position and from the result of the comparison we activate or not the control circuit. Thus, the approximation measurement is reduced to the displacement measurement. However, there are special methods for measuring displacement, which rely on magnetic field measurement (variable magnetic resistance approach sensors, Hall effect approach sensors) and the reflection of a light beam from the displaced object (optical approach sensors) (Muncuk, Alemdar, Sarode, & Chowdhury, 2018).

Ultrasound or radar (radar) techniques are used to measure the speed of an object. According to them, a wave (ultrasound or radio wave) is transmitted to the object, which is reflected by the object and a part of it returns to the transmitting device. The part of the returning wave has a wavelength slightly different from that emitted due to the Doppler effect and this difference is related to the speed of the object. Speed measurements are required in special applications (Lee & Ke, 2018).

The measurement of acceleration is related to the measurement of force, as these quantities are proportional. However, the force sensors described in the previous paragraph are based on measuring the magnitude of the pressure, which presupposes the physical contact of the object under consideration with the object that presses it. However, it is possible to accelerate an object without pressure, if, for example, its support is violently displaced due to a force (gravitational, centrifugal, electric, etc.) acting on it from a distance. Thus there are sensors specially designed to measure only the magnitude of acceleration and are called accelerometers (Mois, Folea, & Sanislav, 2017)

2.3. Remote monitoring systems

The abbreviation RMM represents Remote Monitoring and Management. Hence there are two perspectives included the remote monitoring viewpoint and the remote management angle, the two of which should be talked about independently.

PSA (proficient administrations robotization) apparatuses assume a critical job in the functions of any MSP. PSA devices help track client data, work done, and that's only the tip of the iceberg. They additionally create solicitations from the work. A PSA instrument is the focal archive for all data identified with MSP measures, customers, resources, stock, charging time, and that's only the tip of the iceberg (Zacepins, Brusbardis, Meitalovs, & Stalidzans, 2015)

RMM instruments assist MSPs with accomplishing the work that PSA apparatuses track. So it's the RMM programming that MSPs need to use to remotely interface with customers and complete work. Occupations a RMM can deal with incorporate looking for some kind of employment, computerizing errands, keeping a tab on frameworks and gadgets, and so on.

PSA RMM alludes to incorporating a RMM arrangement and PSA apparatus into a MSP foundation, in this way helping cut expenses and smooth out efficiencies.

Remote Management is dealing with a PC or an organization from a remote area. It includes introducing programming and dealing with all exercises on the frameworks/organization, workstations, workers or endpoints of a customer, from a remote area (Zogović, Mladenović, & Rašić, 2017).

Remote Monitoring (additionally abbreviated to RMON) alludes to the determination that helps MSPs screen network operational exercises of their customers by utilizing remote gadgets, which are known as tests or screens. This assists MSPs with guaranteeing productive organization foundation control and management.

2.4. Precision Beekeeping

Precision agribusiness (PA) is a subject of tremendous interest for specialists. The objectives of PA are to upgrade crop creation and to improve the nature of the end results; driving agribusiness towards modernization, as horticulture is as yet a conventional area. The utilization of PA is likewise conceivable in a vital area for the climate, for example, beekeeping, offering ascend to what in particular is characterized as precision beekeeping (PB) or precision apiculture, an apiary the executives technique dependent on the checking of individual honey bee states to limit asset utilization and augment the profitability of honey bees (Zogović, Mladenović, & Rašić, 2017).

The role of honey bees in the environment is connected to the fertilization of productive yields, yet in addition to the protection of unconstrained and wild harvests, consequently shielding an immense biodiversity. Honey bees likewise assume a significant job as markers of the condition of contamination and they are utilized as bio screens in identifying and observing natural contamination, especially radioactive components, pesticides, and harmful metals (Zacepins, Brusbardis, Meitalovs, & Stalidzans, 2015).

Beekeeping is a significant piece of agribusiness, with disseminated areas, requiring the observing of creatures in an every minute of every day mode. The nectar creation cycle happens inside beehives put in an open field within the sight of plants in sprout. This relies upon numerous elements, some of which are natural elements, for example, temperature, relative moistness, and wind, and can profit by cutting edge smart feeling advancements (Zogović, Mladenović, & Rašić, 2017).

Numerous online information stockpiling and continuous examination frameworks have been as of late created utilizing the PB approach to assess the hive inward boundaries as temperature and relative mugginess and the natural condition, for example, temperature, relative moistness, precipitation, wind, and overcast cover. These boundaries can be utilized to foresee amassing or departing suddenly measures having a solid connection with the wellbeing and efficiency of beehive settlements (Komasilovs, Zacepins, Kviesis, Fiedler, & Kirchner, 2019).

A framework to screen bumble bee province temperature was created in utilizing a remote sensor network where sensor hubs can speak with a fundamental module a ways off of 20 m in an open field. A model was created to screen and control honey bee province action as far as weight of the beehive, outside and inside temperature, and stickiness, which should have been executed to make it independent regarding energy supply(Figure 3). Similar boundaries were estimated by the framework proposed in a study, which recommends the full mix of equipment to the hive structure for future examination to encourage beekeeper tasks. These investigations reaffirm that checking the natural states of hives is the reason for improving their administration and encouragement crafted by beekeepers. They mean to enhance the apicultural chain, protect the species, and deal with the climate (Komasilovs, Zacepins, Kviesis, Fiedler, & Kirchner, 2019).

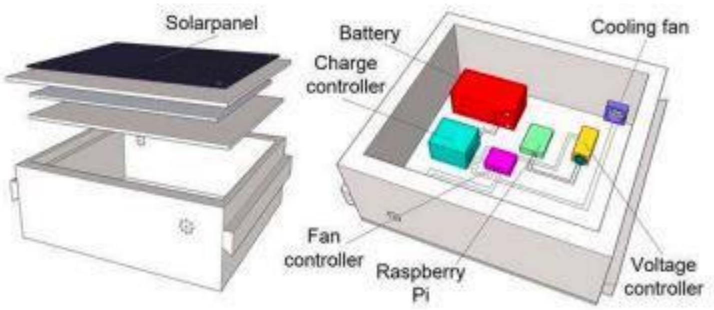

Figure 3: Sensory hardware (Komasilovs, Zacepins, Kviesis, Fiedler, & Kirchner, 2019)

A honey bee swarm checking framework, working with sound signs caught in a beehive, is depicted in another study. The caught beehive sound information contains diverse honey bee exercises, in view of various frequencies and energies of the sign. These were concentrated to do a honey bee swarm action acoustic arrangement helpful to improve beehive the board.

The issue of radio recurrence electromagnetic radiation (RF-EMR) emanation, brought about by the previously mentioned frameworks, was as of late tended to to prove whether RF-EMR from Wi-Fi influences the expressed in-hive estimations, by utilizing a wired variant of the created sensor organization. The creators inferred that there is no proof of beehive climate change because of RM-EMR, temporarily (30 days) (Catania & Vallone, 2019)

Wind is an apiary-found meteorological boundary valuable to clarify a few quirks in state conduct. It is notable that low temperatures and wind are two factors that keep honey bees from leaving the hive for searching. The mating conduct of bumble bee sovereigns can be impacted by the presence of twist, especially with high wind speeds (9–14 km/h) in blend with low temperatures (15–20 °C). Wind is viewed as one of the factors that can be surveyed depending on hive area. In another study wind has been utilized to appraise the wellbeing status of honey bee settlements using some characterization calculations, in light of a managed AI approach; the creators consolidated in-hive sensors information and outside climate information to acquire data on the wellbeing status of a honey bee province. Regardless of various references to the breeze, the investigations distributed so far don't show wind information straightforwardly comparable to the creation of nectar (Zacepins, Brusbardis, Meitalovs, & Stalidzans, 2015)

In the two-year time of 2018–2019, especially unfavorable climate conditions were recorded in Italy, with outrageous occasions that were successive, extreme, and unsafe to beekeeping, causing significant misfortunes underway. In different circumstances, there was a genuine focusing of the nectar creation. Delayed times of dry spell, drawn out precipitation that harmed or dropped blossoms, and low temperatures and wind, two factors that keep honey bees from leaving the hive for rummaging, are considered as outrageous occasions. Every one of these elements make it especially imperative to actualize checking techniques for hives that help their administration by beekeepers (Zogović, Mladenović, & Rašić, 2017).

2.4.1 Remote beehive monitoring systems

The requirement for improved beekeeping has been examined intensely lately. Unmistakably the worldwide supply of bumble bees is developing at a much slower rate than farming interest for fertilization. Albeit the number of inhabitants in oversaw honeybee hives has expanded by roughly 45% over the most recent 50 years, the small amount of horticulture that relies upon fertilization has expanded by more than 300%. From a biological viewpoint, bumble bees give a wellspring of both immediate and circuitous food to an entire host of creatures, including people. After some time various conditions experience bugs, new illnesses and so forth Hereditary variety inside plant populaces (which bumble bee cross fertilization is fundamental for) permits them to adjust to and conquer these changes. Hence, just as numerous others, finding new techniques for ensuring the bumble bee populace has become a vital concentration inside the scholarly world, just as industry (McAfee, 2020).

Visual review of the bee state is a significant device for the beekeeper to decide the state of the hive. The point of the work depicted was to actualize a visual monitoring system into the hive inside, which would negligibly affect the bees. Bumble bees can't see light in the infrared (IR) range, consequently an infrared camera along with a variety of IR LED's were utilized to gather pictures from inside the hive. Visual examination of the hive outside is additionally significant, just as noticing the movement of the bees leaving the hive. Warm imaging of the hive outside can likewise be utilized to evaluate the beehive populace in a non-intrusive way. To encourage the most complete conceivable outline of the hive movement and conditions a system including an inside warm imaging sensor, and two outer cameras (CMOS and FLiR long wave infrared sensor) is proposed. These sensors are remembered for a WSN with critical computational abilities which can gather and handle the picture information (Bromenshenk , et al., 2015).

It is conceivable to acquire a lot of data from monitoring the differing sounds happening inside a beehive. In this undertaking the plentifulness of the sound inside the hive was observed and to the bee guardian was cautioned by SMS when the sound levels inside the hive expanded generously. An abrupt ascent in commotion levels structure the bumble bees could mirror an assortment of occasions which may bring about loss of benefit to the bee guardian, for example, attack by a bug or a hive proliferation occasion known as "amassing". Amassing is an action where a bumble bee states parts in two to shape another hive, the expression "channeling" alludes to the sounds made between sovereign bees during these occasions. An event of such an occasion could likewise trigger snapping a photo of the occasion for an away from the reason. Beehives are made of light materials, for example, wood, and are regularly situated in far off territories with next to no security. They are helpless to being pushed over or upset by high breezes, passing creatures, or even disrupted by people. On the off chance that the beehive was to fall or be opened, it could bring about the deficiency of a few if not all the number of inhabitants in the hive. In this paper an early admonition system inside the hive is depicted, which makes the beekeeper aware of the hive falling over or moving. This was accomplished by coordinating an accelerometer into the hive cover; this sensor is utilized to decide whether the hive has fallen over, or on the off chance that somebody has taken out the hive top (Bromenshenk , et al., 2015).

As by far most of the beehives are kept in provincial areas, where admittance to electrical cables and web associations are amazingly restricted, GSM/GPRS organizing was chosen. This arrangement permitted the keen beehive to send writings to the beekeeper's cell phone when the hive needs consideration at the earliest opportunity, just as having the option to transfer gathered pictures. This permits the beekeeper to lessen the recurrence of hive visits, as the hive data can be gotten to distantly (Bromenshenk , et al., 2015).

Utilizing information assortment to assess the states of bee hives has been a hotly debated issue in the scholarly world during ongoing years. An intrusive, non WSN based technique for long haul hive monitoring is proposed. Phillips et al. propose an open source WSN system for anticipating amassing, yet just in sweltering environments. The system depicted in this paper is successful in any environment and doesn't include intrusive techniques. To date a few endeavors have been made to improve the monetarily accessible innovation for bee hives. Two such organizations are "Arnia – distant hive monitoring" and "BeeWise". BeeWise permits beekeepers to get SMS updates of the heaviness of their hives. This is valuable in choosing when to reap the nectar just as understanding when the hive isn't working appropriately and so on Arnia takes in considerably more data with its system, which incorporates sound, vibration, temperature, mugginess, hive weight, precipitation, and daylight.

Some work and examination has been done in the field of sound investigation inside a hive. An illustration of such work was completed (Eren , 1997). Inside this examination, 3 separate hives were checked for more than 10 days, utilizing the two amplifiers and thermometers. The sounds were recorded with an example pace of 2 KHz and examined utilizing different PC programming. During the time frame, 9 diverse amassing occasions happened. There were two significant markers of the amassing happening, that is an increment in the force ghostly thickness at around 110 Hz and an increment in temperature from 33°C to 35°C. This is until the amassing really happens, when the temperature drops to 32°C because of the ventilation from the bee's wings.

Utilizing both of these highlights it was conceivable to foresee when a multitude is inescapable. The second such work zeroed in on the event of channeling inside the hive. This work was completed by recording the sounds made by a working drone, at that point contrasting this and the sounds made by a sovereign bee. It was presumed that the sovereign bee radiates sounds at moderately higher frequencies. Following this underlying work, an endeavor was made to control the sovereign bee's conduct by sending PC reenacted sounds into the hive. Shaw et al. affirm that long wave infrared (for example warm) imaging of the hive outside is a viable technique for researching the state of bumble bees in a non-intrusive way. Shaw et al. present an answer which is powerless to mistake when the hive is warmed by the sun/cooled by wind, or if close by objects are in casing. The stage depicted in this paper can utilize information from different hubs in the organization to approve and improve the estimations from the FLiR sensor. The work portrayed in this paper is intended to be utilized related to a bigger sensor network planned and created by the Embedded Systems bunch at UCC for monitoring the wellbeing of the beehive. This sensor network was fit for monitoring boundaries, for example, temperature, CO_2, poisons, O_2, NO_2, relative dampness, and residue. Climate conditions all through the monitoring stage were recorded and a connection between outer climate conditions and hive conditions were noticed. The information gathered was examined from an organic point of view, by a bunch of individuals from the School of Biological Earth and Environmental Sciences (BEES). This considered the improvement of a calculation for consequently recognizing the condition of the beehive, without the requirement for human collaboration. Following this a subsequent calculation was created which anticipated transient climate conditions in the region around the hive, for example, future downpour fall.

Visual review of the hive is quite possibly the main exercises a beekeeper participates in, it is utilized to analyze the state of the bumble bees, including the quantity of laborers and robot bees, the advancement of the bees, and inspect for sovereigns. Visual review additionally permits the guardian to identify a scope of infections by eliminating outlines and analyzing them. Be that as it may, an exhaustive investigation is a tedious and intrusive cycle, which irritates the bumble bees, uncovered within the state to the outer climate conditions, and can prompt bees being squashed when the manager moves outlines. Infrared cameras giving great pictures of the hive inside to the beekeeper distantly, for example, the ones portrayed in this work can possibly give data on state condition and sickness, along these lines decreasing the recurrence of actual investigations.

Numerous beehives are kept in very distant or country areas. Examinations of hives in such areas require the guardian to embrace long excursions. They are likewise frequently positioned in farmland where they might be close to domesticated animals or different animals which may push the hive over. Hives can likewise be pushed over in high breezes, it is fundamental to reassemble the hive at the earliest opportunity in the wake of being thumped to limit misfortunes. The fall ready system depicted in this paper dispenses with the need to investigate each hive for such harm consistently (Kleinman, 2016).

2.5. Related Work

IoT Precision Agriculture has been widely created and intriguing examinations have been done throughout the most recent years. Various measures of such IoT frameworks are at present utilized (or proposed for use) in apiculture. A fascinating overview on IoT the executives systems is introduced by Kiani, where the design of each current IoT structure is clarified. Scientific categorization between Software-Defined IoT (SDIoT) and non-Software-Defined Networking (SDN) structures is likewise pinpointed, trailed by a correlation of SDIoT and non-SDN-based current systems. The upsides and downsides of every structure are likewise examined. In the "SmartFarmNet" system, an IoT-based structure is recommended that gathers ecological, soil, treatment, and water system information. It thinks practically all information from the IoT sensors, actuators, cameras, and climate stations in the cloud (Zogović, Mladenović, & Rašić, 2017).

Moreover, an examination investigation between IoT cloud stages, for example, UBIDOTS, Xively, SensorCloud, IBM Bluemix, Amazon IoT, IoTCloud, Apache Storm and the proposed SmartNet is introduced. The benefits of SmartNet is that it underpins for all intents and purposes any IoT gadget, it gives quick examination of information progressively, it is coordinated with Semantic Web and it bolsters a do-it-without anyone else's help perception and information investigation capacity. (Triantafyllou , Sarigiannidis, & Lagkas, 2018) presents the spaces and the connected applications in the territory of IoT, further ordering all the IoT network innovations in shrewd urban areas and horticulture apparatus. The highlights, the qualities, and the accessibility of all the realized IoT network innovations and directing conventions are dissected. Moreover, the systems administration challenges with respect to the security, the interoperability, the distinguishing proof, the adaptability, the huge information, the versatility and the energy efficiencies are investigated. Ojha traces the Wireless Sensor Network (WSN) organizations for different cultivating applications, breaking down the contrasts among earthly and underground WSNs. The handiness and the expected utilizations of WSNs in the territory of precision horticulture is talked about and correlation between existing sensor stages and correspondence advancements is attempted (Catania & Vallone, 2019)

(Jayaraman, Segonzac, Cho, Jung , & Sohn, 2016) played out an examination of models and correspondence conventions in the region of precision horticulture. A client driven model on the plan and coordination of edge figuring, haze correspondence, and cloud administrations is proposed. Models dependent on two degrees of interchanges and preparing hubs are sketched out, and a trial work dependent on the proposed engineering is introduced, by the utilization instance of a nursery. The main issues of present day beekeeping include: 1. Conditions with respect to suitability, dietary patterns of the honey bee swarm, ecological hive conditions or medications by outside variables and 2. Security of the beekeeping establishment (for both moving and relocation apiaries). The two issues are defined with the utilization of occurrence reaction and the board frameworks that utilize sensors and actuators working over IoT foundations. In the accompanying sub-areas, existing security and conditions occurrence reaction and the executives frameworks are introduced (Komasilovs, Zacepins, Kviesis, Fiedler, & Kirchner, 2019).

Apiary foundation wellbeing is the main worry of the beekeeping business. Beehive dangers can be arranged into three classifications: 1. Human burglary and intercession, 2. Vertebrate assaults and 3. Wasp assaults, bugs or multitude state occurrences, for example, sovereign demise, extraordinary conditions, hunger or even thirst. Security is principally detailed in the writing as human robbery or warm blooded creature assaults, while wasps, parasites, and illnesses are synthetically stood up to. The third classification of occurrences are likewise considered as condition security dangers with no current episode reaction framework out on the lookout. Beekeeping establishment wellbeing from creature dangers and human burglary is a significant string in a movement beekeeping exhibit. In any case, existing security frameworks don't offer total and precise episode mindfulness and reaction security arrangements (Komasilovs, Zacepins, Kviesis, Fiedler, & Kirchner, 2019).

The most ordinarily utilized frameworks for these kinds of dangers are advanced weight scales with GPRS or IEE802.15.4 transponders. These gadgets give hive weight estimations and caution frameworks if these estimation patterns are out of scale. On the off chance that the beehive's weight varies above edges, beekeepers are told through SMS, or email or even 3G/4G HTTP pop-up messages. The weight scale caution framework's huge disadvantage is the absence of precision, since it requires a level even base to work accurately, letting the gadget estimations to change even on wind blows. Honey bee shop presented a beehive observation camera pack, like EyeSon. This framework camera recognizes developments and catches photographs or records video, sending them to the beekeeper's cell phone. The framework incorporates battery pack, SD memory card and requires 3G LTE availability. This arrangement the best wellbeing mindfulness item introduced in the market that can likewise react to condition security dangers. In any case, it presents critical energy utilization and quick battery consumption set off by bogus movement location alarms. For static and moving apiaries, electrified barrier portions around the beehives are likewise utilized. Notwithstanding, such arrangements don't offer powerful human robbery security usefulness. An illustration of beehive is presented in Figure 4 (Zogović, Mladenović, & Rašić, 2017)

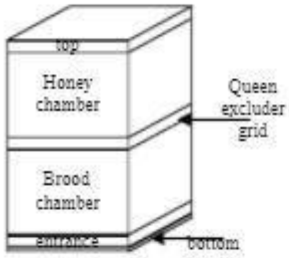

Figure 4: Beehive structure (Zogović, Mladenović, & Rašić, 2017)

APISAFE and other comparable market items, for example, Beebot, Hive-Tech and HiveMind, and Arnia framework, aside from hive conditions checking (temperature, dampness and ecological readings), suggest an elective component for protecting beehives, like the instrument utilized by armada the executives frameworks. That is, GPS hostile to robbery GPS beacons. Beekeepers quickly get advised during the direct of beehive burglary occurrences. The gadget gives consistent post-burglary following by sending GPS facilitates over 3G or SMS (utilizing 1–5 min occasional time periods area changes) for exact planning of the cheat's area.

The battery self-governance of these frameworks is promoted as 2–3 months yet has been tentatively estimated by creators to work effectively for close to 25 days for a 10,000 mAh battery, for 1 min occasional GPS estimations transmission. Besides, such frameworks are protected and innocuous for the honey bees. GPS against burglary GPS beacons have been demonstrated as not a decent strategy for protecting beehives, because of their high complete organization cost to a beehive exhibit. GPS beacons are then again utilized in a couple of hives for each exhibit and whenever spotted by criminals can be handily killed without a ready criticism. In the event of creature assaults, GPS beacons don't offer critical assurance, since creatures just cup side or break the beehives, without moving them around. Besides, GPS transponders don't have the granularity to recognize little developments (under 6 m) and trigger cautions appropriately.

Except for the web system that the author proposes, an addition is the development of mobile applications and a smart watch. Those two products can be essentials for every beekeeper that wants to be informed about changes that can happened in the apiary (Figure 5) (Zacepins, Kviesis , Pecka, & Osadcuks, 2017)

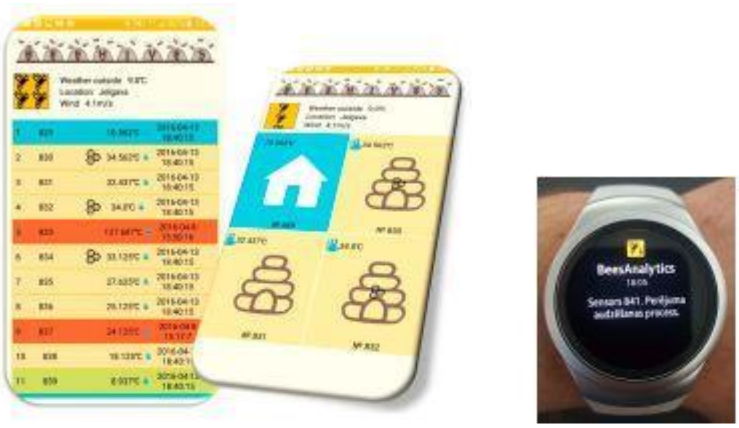

Figure 5: Prototypes of app and smartwatch (Zogović, Mladenović, & Rašić, 2017)

Zeroing in on the beehive business conditions checking frameworks, various them have just been proposed and are industrially accessible: Beebot, Hive-Tech, HiveMind, EyeSon, Arnia framework, B-product framework and BuzzBox. The vast majority of them screen the ecological conditions inside and outside the beehive. The conditions that are frequently detected are temperature, mugginess, radiance inside and outside the hive, just as miniature atmosphere ecological conditions including readings of precipitation, wind speed and air pressure. What's more, there are no known frameworks in the writing that can analyze infections and honey bee sicknesses, for example, varroa bugs and produce cautions. Having tactile contribution with the assistance of information mining – A.I. calculations, the above frameworks offer roundabout choices about hive status, nectar profitability, taking care of prerequisites, sovereign imperativeness, province size decrease, and infection rebellion. In the accompanying sections, the most dependable IoT frameworks and the IoT innovations utilized are plotted.

The B-product framework screens a beehive's exact weight and encompassing temperature. It is set under every beehive and constantly sends information to a Monitoring System by means of a neighborhood Data Collector. The framework underpins up to 100 hives with a most extreme distance of 50 m between the hive's neighborhood Data Collector. The information is sent through Bluetooth Low Energy (BLE). A sunlight based board gives sufficient energy to the nearby Data Collector (Catania & Vallone, 2019).

The Arnia distant hive checking framework is another condition of the executives framework that screens brood temperature, hive moistness, temperature, acoustics and vibration. CO2 estimations and meteorological information, for example, precipitation, temperature and daylight, are likewise accumulated. All the information gathered from the hives' sensors are moved remotely to a nearby escape, which sends the information to a cloud administration for preparing an introduction on UIs. The Hivemind observing framework reports the in-hive moistness, within and outside temperature, the quantity of honey bees entering or leaving the hive, and the heaviness of the hive, just as precipitation and GPS area. All the information from close by beehive sensors are assembled to a center point concentrator gadget which advances the information to a cloud administration. Another honey bee screen framework is EyeSon. It utilizes a camera and PC to outwardly screen honey bee movement and measures the quantity of flying honey bees, following their flight conduct. State movement designs are followed over the long haul by utilizing electronic video examination. EyeSon gives video playback and alarms through a suitable web application (Catania & Vallone, 2019).

The BuzzBox beehive checking framework is another IoT observing framework that records indoor and outside temperature and mugginess, pressure, GPS area, wind speed and bearing and acoustics. It moves information to a cloud administration from a neighborhood Fi passageway. Hive-Tech is additionally a beehive, the board framework that continually screens the hive's sound, temperature, dampness, weight and aromas. The GPS position, the power and the range of the surrounding light, nature of air, oxygen and carbon dioxide are additionally checked. Post-preparing of this information produces data about efficiency, brood, sovereign imperativeness, inescapable amassing, supplied nectar, and infection uprising. The recorded information are communicated to the cloud by means of Bluetooth or the GSM organization. The far off beehive the executives framework Beebot likewise assembles fundamental data about temperature, stickiness, acoustics and weight changes of the beehive. Information are shipped off the cloud by means of the Wi-Fi network where handling gives data about the wellbeing and the efficiency of the honey bee provinces (Komasilovs, Zacepins, Kviesis, Fiedler, & Kirchner, 2019).

The entirety of the above IoT frameworks move their information to the neighborhood remote door by means of 2.4 GHz Wi-Fi or Bluetooth Low Energy (BLE). The proposed IBSMC framework engineering portrayed in the accompanying segment is a novel IoT occurrence reaction framework that incorporates the most basic temperature and stickiness condition IoT sensors just as dynamic hive the board components (IoT actuators and robotized measures) for the cycle of mugginess and temperature guideline in basic condition occasions. Besides, the proposed IBSMC framework utilizes the Low Power Wide Area (LPWA) organizing convention LoRaWAN. This convention is prepared to do wide reach inclusion of up to 12 km away from the hives, for the cycle of information transmission in the free ISM RF band of 868 MHz. The IBSMC low energy information transmissions and minimal effort framework sensors and actuators empowers the capacity of mechanized extraordinary conditions intercessions combined with a hearty wellbeing and episode revealing instrument for a wide range of security occurrences. The proposed ability of identifying beehive condition changes and response is performed with the utilization of minimal effort and low energy utilization actuators sent in all beehive cells. Besides, information transmissions are acted in the ISM band without pointless LTE supplier costs for the beekeeper (Komasilovs, Zacepins, Kviesis, Fiedler, & Kirchner, 2019).

Chapter 3: Methodological Analysis

3.1. Human – centered Design

In general, users of a system are not only considered to be those who are going to operate it directly by interacting with its input-output devices. The system designer should record and analyze all direct and indirect users whose activities may be affected by the introduction of the system and who may influence its acceptance and successful operation. Thus, users include, among others, those who interact directly with the system, those who control or manage the direct users, those who receive the results (output) of the system, those who make financial decisions in relation to the system and those who use competing systems.

According to Macaulay (1995), the following three categories of users are distinguished:

1. Primary users are those who are going to interact frequently, directly with the system. These users will be greatly affected by the introduction of the new system. They may have to significantly change the way they used to perform certain tasks. As a result of automating some of their tasks, they may need fewer people to perform the same task, and overall performance may increase.

2. Secondary users are those who use the system less frequently or through an intermediary. A typical case is the management of an organization and the maintenance staff of the system. The introduction of the system may increase the dependence of these users on the computer system. Also, with the introduction of the system, information that until now belonged only to them, may now be available to a larger number of people, resulting in changes in their power in the organization.

3. Tertiary users. These users never use the system directly, but are affected by its introduction, as they are forced to change some of their tasks in order to adapt to its requirements. Customers of a company, for example, may be affected by the introduction of a new computer system as the issuance of receipts and invoices may require the introduction of additional information and delays in the issuance of such documents.

Other views on the initial analysis phase suggest that all stakeholders be recorded and brought to the attention of the design team. Stakeholders are all those who have a direct or indirect investment in the introduction and use of the system (MacAulay, 1995). The categories of stakeholders are:

1. Those responsible for its design and development, technical staff, developers, analysts, manual writers, etc.

2. Those who have financial interests related to the development or purchase of the system, such as the sales manager of the company that develops the product or its buyer.

3. Those responsible for its introduction, installation and maintenance within an organization, such as those responsible for equipment maintenance, staff training, etc.

4. Those interested in its use, i.e. the management of a company as well as the three user categories mentioned immediately before.

After identifying the user groups, it is necessary to record their characteristics, which include:

1. Individual characteristics: age, physical abilities / peculiarities, learning ability, cognitive ability, experience-skills, motivations and ambitions, cultural background, phobias, personality, etc.

2. Computer-related features: previous experience in software and operating systems, experience in using devices, predisposition towards computers and IT, etc.

3. Group characteristics: group goals and mission, cohesion and homogeneity of group members, autonomy, dependence on other groups, structure and dynamic characteristics, prestige, voluntary or forced participation.

It is also important to record the goals, tasks and the environment in which users will work, as the new system is built precisely to support some tasks in a specific user interface. However, it should be noted that this recording is particularly difficult as users often can not explain what they need to achieve their goals and in many cases can not even formulate those goals. Job analysis includes techniques for this very purpose and is described in the next section. Regarding the user environment, among the information that is typically recorded are the following:

1. Working environment: noise, cold, humidity, cleanliness, use of dangerous toxic substances.

2. Workplace organization: user communication channels, organizational structure, effect of automation on work practice and work content, recording potential skills losses, job loss, changes in power structure, decentralization / concentration of power.

3. User employment conditions: fill in a description of a typical day in the employee's life with comments on how it will change when the proposed system is introduced. Then each of the following key tasks should be analyzed: a) organizational analysis: importance of work, safety issues, motivation to perform work, required level of ability to do it, dependence on other tasks, b) analysis of time constraints: performance, average time required to complete the task, preparation time, segmentation, ability to perform it in distinct sections, and c) analysis of human involvement: mandatory / optional, stress induced, performance criteria.

These characteristics should be recorded before the introduction of the new system and it should be described how they are expected to evolve after its introduction.

Thus, this stage included the registration of the users who are supposed to use the system, which is mainly the beekeepers and secondarily the technicians and the employees. But as beekeepers are the main users, the application will be tailored to their requirements, and as the researcher in the beekeeping industry has experience, recording design requirements on the part of the user has been easier.

3.1.1 Usability Heuristics of User Interface Design

The main goal of HCI researchers is to develop techniques into their computer systems in order to make them useful and easy for users. In order to achieve that they use usability tests. Although, the question is what usability really is and how it is delimited (Maunder, Marsden, & Tucker, 2006). The answer comes from the 10 usability heuristics by Jacob Nielsen.

The first rule is about "visibility of system status". The design of a system is either a computer interface or a smartphone application should keep informed at any time its user about the process that is going on. By this way users know how to work with the system and be helped by its design. They know the operation and which are the required moves in order to have results. The general idea is that users can be informed from the system with feedback in terms of text, video, icons etc. An example is the icons on a map that indicate user location or the location of a shop/cafeteria.

The second rule and a requirement in modern systems is the “match between the system and the real world”. In another world the design of an application must use the same language of the user. This means that it is important for a system to use words, phrases, and concepts familiar to its user and not rather than specialized vocabulary or technical terms. It is also important that the information will appear in a logical order. The elements from simple buttons to the icons must be appropriate for the audience that will use the system.

The third rule is “user control and user freedom”. A characteristic of people is that they always make a kind of mistake during the procedure. For this reason they need a way to solve it or to skip it without going back to the point that they started an action. Freedom is when the user can skip or undo an action that he made because he was not careful enough. Buttons like undo, redo, exit and cancel are now necessary for all the devices and applications. The rule is that: “*Digital spaces need quick “emergency exits,” just like physical spaces do”*.

The fourth rule is “consistency and standards”. The systems that a designer makes need to have internal and external consistency, easy to learn and have clear commands. If a user spends much of his time in order to understand that two words in an application have the same meaning then the game is lost. For this reason there are many standards, platforms and conventions that a new designer can follow.

The fifth rule is about “error prevention”. Users according to user control and freedom have the choice to undo an action that they consider as wrong but in some cases a wrong move means a lot more. An element that differentiates a good for a bad system is error prevention messages and confirmation options. For Nielsen there are two types of mistakes: slips that are unconscious errors due to lack of attention and can be solved when an application offers constraints and mistakes that are conscious errors when a user does not understand an application’s particular design. In this case designers provide users with commands like undo and warn messages.

“Recognition rather than recall”: an important rule that helps users to remember or recall information as he has it in front of him in the interface with the help of menus. It is known that people have short-term memories. So designers have to deliver a visible helpful menu with orders, labels and buttons. The main idea here is that less information is good information.

“Flexibility and efficiency of use”. Today, all computer users have some favorite shortcuts like ctrl+C on a Windows computer instead of ordering “copy”. That does not mean that designers must delete the regular ones. Instead, they must provide users with all the options and let them decide which one is appropriate and easy for them. The success key customization, that allows users to make their own shortcuts that help them be more productive.

Another one rule is to design “aesthetically and minimalistic design” in the same time. Interfaces must contain only information that is relevant to the tasks and preferences of users. Any irrelevant items and designs make users feel confused and it is a sign of a bad design. Designers have to be always by the side of users and do not distract them from their goals with their work on an interface.

The ninth rule is about “helping users with errors”, recognize it and try to recover from it. It is about error messages that should follow a simple form, not code at all in a normal language, indicate the problem with necessary detail and give users alternatives solutions. The presentation of error messages must be in a form that is hard for users to avoid like in a bold red text, in a pop up message etc.

Last rule, “help and documentation”. In some cases, it is better that the application provides users with additional information so they can understand how to complete their tasks. It is crucial that both documentation and help can be found easily from the users having a concise form divided into concrete steps (Nielsen, 1992).

A sum up of all the heuristic that this dissertation discussed is presented in Figure 10

Figure 6: 10 Usability heuristics (https://www.interaction-design.org/, n.d.)

3.2. Primary research: Observation-Ethnography

User observation is an ethnography method that enables researchers to study people in their physical environment while they are working, eating etc. The method includes a researcher who observes users as they work and keeps track of the activity being performed. Ethnography is useful in the early stages of researching and recording user specifications to obtain quality data. It is also useful for studying existing tasks and procedures (Baker & Trends, 2006).

The observation can be either direct, where the researcher is present during the execution of the activity, or indirect, where the activity is observed by other means, such as through video recording. It can also take place either in the physical space where the activity takes place (ethnographic studies or field observation) or in laboratory conditions. Furthermore, the observation may take a few hours, as in the case of micro-ethnography, or several days. Finally, it may involve the observation of individuals or groups. Co-discovery learning is an example of a method where a researcher observes two people exploring an idea or product together and discussing it (Nielsen, 1993).

The observation process includes setting objectives and information requirements, selecting observers and recording models, conducting observation pilot sessions, informing participants and securing their consent, and finally analyzing and summarizing the data. collected. Central to the process is the recording model, which must be followed by all observers involved in the process, be appropriate for the activity under study and serve the purposes of observation. For example, there are recording models that support the observation of children in outdoor play activities (outdoor play observation scheme, Bakker, Markopoulos, & de Kort, 2008), the recording of experiences and emotions (Isomursu, Tahti, Vainamo, & Kuutti, 2007).

While conducting the user observation, some indicative questions that helped in the recording are: What is the participant doing now? What is he trying to achieve? Who else is present? When does the activity take place? How is it integrated into the wider ecology? Where does the activity take place? What does body language reveal to us? What are the similarities and differences observed in different people doing the same job?

Finally, there are various user observation strategies and protocols:

1. Passive: the observer monitors and records without interfering. Passive monitoring can be done remotely with the researcher trying not to be perceived, an approach known as 'fly-on-the-wall'. For example, the researcher goes to the halls of a museum and watches what is happening. This minimizes the intrusion into the observed activity, but makes it practically difficult to record its details. Another approach to passive observation is the so-called "anthropic shadow", according to which the researcher closely follows the participant in the research, after first obtaining his permission. For example, the researcher follows a doctor to a hospital during a day on duty. This approach allows the researcher to study the activity in depth (e.g. to record conversations, objects used, etc.), but may create problems in the execution of the work or raise privacy issues for the participant or the organism.
2. Conversational: the researcher observes the user during the execution of the task, but during the observation, and when there is a need, he interrupts and converses with him to understand the thoughts, beliefs, motivations, emotions, way of thinking, etc. There are several methods that belong to this category depending on the protocol that is followed. The Think Aloud Protocol requires

users to speak aloud while performing the task, and the researcher's intervention is limited to encouraging them to speak aloud. In contrast, in Contextual Inquiry the researcher has the role of 'learner' and whenever he deems necessary he asks questions to the user, who has the role of 'teacher'. The main advantage of these methods is that they provide information about the user's mental model, and are therefore particularly useful in activities with intense mental work. However, it is often very difficult for some users to describe what they are doing (e.g. children, experienced users). Also, the description of thoughts when performing a task can disrupt the user's concentration. Retrospective Think Aloud solves this problem by separating the observation phase from the discussion phase, but at least doubles the time required.

3. Participant: the researcher assumes a specific role and participates in the execution of tasks together with the user. For example, it assumes the role of the customer in a product store. This approach is particularly useful in tasks performed by experienced users who, due to the development of automation in the execution of the task, find it difficult to explain verbally the actions they take to complete the task. Also, this approach is used when observing group activities in order to understand how the team is organized and the cooperation of its members to achieve its goal. However, this approach is highly intrusive for the human activity under study, and may require specialized knowledge and time-consuming training of the researcher (DeMonbrun, Finelli, & Shekhar, 2015).

More specifically, the method of observation used in the context of this dissertation was conversation observation. A visit was made to two beekeeping beehives, one by one the procedures and the needs of the beekeepers were observed, which were clarified through discussion with them and recording in a notebook. The notes were then collected, cleared and formatted the design steps and processes to be implemented.

3.3 Primary research: Interviews

A very important and interesting way in collecting data by primary research is the method of interview. It is about qualitative research and can urge the participant to respond to specific questions that are valuable for the researcher, helping them collect facts. Many times interviews are compared to questionnaires about their validity and efficiency. Although a big advantage of questionnaires is that they address a wider audience, interviews give more insights in a specific topic, they are more precise and help the researcher understand more about his topic (Wei & Moyer, 2008).

There are different types of interviews according to the method used each time. Depending on the research design and the goal of its survey there is a classification in three types of interviews for qualitative research: structured, unstructured and semi structured (Rowley, 2012). Unstructured interviews are interviews that have some questions or in many cases they do not have any, it is upon the interviewer to make the right questions. It is more a form of a conversation that studies the point of the research. There is no standard protocol for the interview and the form is less formal. However, it needs a lot of attention as the interviewee can easily go out of topic. On the other hand, semi structured interviews use a protocol as a guide to help the researcher with the progress of the interview and get more precise answers about the research question.

In this form there is a structure for the conversation so the researcher can gain more details as it is a more flexible form. There is no great need for an additional round of interviews due to lack of elements but in some cases some questions they may not have answered in the first round. Furthermore, there is the third type, structured interviews. This type of interview has predefined questions based on a particular layout. It stands out from the questionnaires because it uses open-ended questions. As a result, there are not a lot of opportunities for participants to open new topics as they have to answer grid questions. This method benefits researchers that have a list of questions, as it helps them to target the specific phenomenon and investigate it in depth. One time is enough for this type of interview as it gathers the correct information. No follow up interviews are needed (Bryman, 2001).

Every type of interview has some advantages and disadvantages, it is up to the researcher and the goal he wants to achieve which interview he will use. In our case a semi structured interview was selected in order to gather data and ideas that the prototype of the application will have.

3.3.1 Questions for the interview

After careful study of the literature and some observation days from the life of beekeepers this section presents the questions for the interview:

- How experienced are you as a beekeeper?
- How many hives do you currently hold?
- How many times had you visited your hives last month?
- How many times do you transfer your hives each year?
- Where do you place beehives?
- How many types of bees are available in nature?
- What dangers does a beekeeper deal with?
- Does climate change affect the profession of beekeeping?
- How does a beekeeper be informed about his profession?

Those are some questions that concern the profession of beekeeper in an attempt to understand what he does and which factors mostly for the external environment can affect his job. In order to understand if the idea with an application would help those professional the interviewer will continue with the following questions:

- From which media do you get information?
- Do you use a smartphone?
- Do you keep a diary to help you in your job? If not, in which way do you recall information about your hives?
- How many times do you visit websites about farming and beekeeping?
- What data beekeepers are missing today?
- What is your opinion as a beekeeper about sharing data with other beekeepers?
- Do you use an application that could help you in your job?
- What requirements do you expect of such an application?
- How do you imagine the ideal application?

The interview took place in a place near the hives of beekeepers. It has three participants, all men. The two of them were professional beekeepers with 30 apiaries each and visited their beehives 6-8 times per week while the other one dealt with the beekeeping as an amateur for three years. The purpose of the interview was to select valuable information and insights about the requirements that an application for beekeepers must have.

As the interview showed, beekeepers are informed mostly from television about the weather and the latest news on their profession. All of them are users of smartphones and they only use them to keep an eye on weather changes and on newsfeed about the latest news of rural areas. One of the participants who was older argued that he is using a diary to keep track of his hives and of the procedures he has to do like the transform of hives, the collection of the honey etc. The other two are using some signs like small stones or parts of wood. All participants agree that they are visiting many websites about their field on the internet to be informed about changes on beekeeping on a regular basis like three days per week. They also state that beekeepers nowadays do not have fully information about places that they can transfer their hives, climate information about each region or knowledge about the existence of other beekeepers near them.

In general beekeepers are not keen on sharing their data with others because as they characterized it “it is a very is a profession that has its own secrets that need years of practice in order to be unlocked”. To the question “Do you use an application that could help you in your job?" The amateur one said that it uses an application that help him with weather forecasts and temperatures but not something indicative for his hives. As for the requirements that he want for an application about beekeeping, he believe that the ideal application must have predictions about weather in each location, a map with the location of beehives, a list with his beehives and personal notes about each beehive, a news feed about the latest news that concern the field. The other two participants do not use any kind of application.

This type of interview was a good approach to requirements that a system for beekeeping must have. In a nutshell those requirements are:

- ✔ A friendly interface
- ✔ A news feed about beekeeping topics
- ✔ A section about weather forecast
- ✔ A map that is focused on locate the spots of each beehive
- ✔ A section in which beekeepers can keep track of their daily routine and important notes about their activities.

3.3. Design-Mockups

The waterfall design model was used in the design of this application. According to this model, the development process follows successive stages. In the initial stage, a general description of the problem and the proposed solution is given. The result of this phase is the initial "Application Description". In the second stage, also known as problem analysis, the application requirements are collected and recorded, which eventually take the form of an official document of the

"Requirements Specifications". Based on this document, a contract of obligations is drawn up between those who define the initial problem and those who undertake the development of the application. Based on this contract, the next phase of product design begins, which ends with the "Design Specifications" which are a detailed description of the final product sufficient for its development. Finally, based on the "System Design Specifications", the product development takes place, which is the last phase of the process. In particular, this phase concerns the development of the application code, databases, writing manuals, etc., and the result is the "Final Product".

Each of the stages of this development model is completed with a test that focuses a) on whether the representation is in line with customer requirements and b) on whether the representation is consistent with the specifications of the previous phase. In the waterfall model we observe that each development phase is distinct from the others and that the transition from one phase to another is done through documents, which are successive, increasingly detailed, representations of the application that end up in the final product.

The waterfall model has the advantage of clearly describing the development phases of a product, which are inevitable to be encountered in any design process. It is also an easy-to-understand process by all involved and ostensibly facilitates project management (schedules, deliverables, assignment of tasks based on specialty). However, strict adherence to the model presents problems. The most important of these problems is the impossibility of detailed specification of a product before its implementation. In practice, it has been shown that the development of detailed specifications often results in the forced modification of requirements that have already been drawn up and the implementation of the product results in the forced subsequent modification of detailed specifications. This problem can be addressed by developing prototypes during the analysis and design phase, i.e. draft, small-scale, versions of the product that reveal details of the final system. This will be done in the context of this dissertation.

3.4. Prototype

The source of information about user interface objects is task analysis. It describes the activities of users and the objects they handle and know. Other relevant information can be found in the application definition, in the business objective, in the user analysis as well as in other texts that have been collected during the recording of the requirements specifications. According to Roberts (1998), the objects recorded are tangible objects, people who are subjects or objects of the user's actions, forms or other printed and abstract objects.

In the context of object recording, a text description of these objects should be written, which will contain a short paragraph for each object. The description should include the characteristics of the objects and refer to their use in the context of the work of each specific group of users.

Object relationship diagrams should also be constructed. There are many ways to represent object relationships, such as entity-relationship diagrams, object class diagrams, etc., known from software systems design techniques. These representations help to understand the scope and design of the information system. In this process, decisions must also be made about the classification of a concept in the category of the object or in the category of the property of an object according to the emphasis that the application places on that concept.

The description of the syntactic structure of the human-computer interaction, the so-called "dialogue", is useful in case the system is quite complex and the team of designers has more than one member, and it is necessary for the clear description of the system to those who will undertake its implementation.

The simplest choice of language for writing such specifications is natural language, but it lacks the precision and clarity required to describe a complex computational system.

Thus, standard languages with strict syntax have been developed for this purpose, a practice that has been used successfully in circuit design, in the creation of specifications for programming languages, etc. These languages are divided into diagrammatic and text-oriented.

Diagrammatic specifications tend to be less stringent, but are easier to understand and better describe direct control interfaces. These place less emphasis on the serial structure of the dialogue and rely more on "events" triggered by the user's actions. Examples of diagrammatic descriptions are state transition networks (STNs), Jackson structured diagrams (JSDs), Petri networks, etc.

Examples of text-driven techniques for drafting specifications include: the BNF (Backus Naur Form) notation, known for its use for syntactic description of programming languages; the production rules; with serial and parallel behavior, and is used in the description of telecommunication protocols and other similar systems; finally, the symbol UAN (user action notation) has been proposed, which allows the detailed description of both user actions and interface feedback, at the level of keystrokes. The reader wishing to delve into the field of user interface specification languages can refer to Dix, Finlay, Abowd, and Beale (2004), which cover the field in detail.

In terms of the present thesis we will use Screen Prototyping. The design of screens involves many intermediate stages. Designers must first make decisions about: a) the interaction style, b) the interaction devices, and c) the dominant metaphor to be used in the system. Then they have to design a prototype so they have to make decisions about d) the virtual content and the layout of the screens, e) the flow of the dialogue and g) the navigation model. Here the designer must refer to the requirements analysis material which may include analysis of other similar systems as well as analysis of user work. Also important aids for the activities of this phase are the design principles, the rich bibliography of detailed instructions, as well as the interaction technology concerning the selection of appropriate interaction devices and development tools environment.

3.5. User Feedback collection

User feedback is the information that potential users of a product or participants in a survey provide designers with. It measures the level of satisfaction or dissatisfaction of users as they test the prototype. Any opinion is important because it can help the research team to make corrective moves that will perfect the prototype and turn it into a useful product or service (Fu, et al., 2013).

Rikke Friis Dam and Teo Yu Siang list six ways in which a researcher can gather user feedback and maximize learning (Dam & Siang , 2020):

1. Solicit feedback: It is a good start to exist several versions of the prototype that the users are going to test in order to gather feedback. This is a way to solicit critical feedback due to the fact that many times participants in a survey tend to hold back on overtly criticizing prototypes. When there are many alternatives, participants can compare the different prototypes, express their views more freely so the feedback becomes more honest.
2. Right people for test: The usefulness of the feedback about the prototype depends upon the team of participants. In the early stage of the design project when a simple feedback is needed some team-mates is the appropriate sample. On the other hand, in the end of the project in which the prototypes are more detailed and get the final form it needs a wider audience for more relevant feedback.
3. Right questions: One step before the testing of the prototypes it is obvious that researcher must know what is testing in terms of usability, user friendly etc. you should therefore be sure about what **exactly you are testing for**.. Subsequently, in an interview after the testing period the questions must be relevant to the goal of the survey.
4. Neutrality in the presentation of ideas: In the presentation of the main idea the researcher must highlight the advantages and disadvantages of the solution that the prototype offers. Also, a better user feedback is obtained when the creator of the prototype is not attached in his initial idea and is receptive even to negative criticism

5. Adoption in testing: The test period in the prototype needs a flexible mindset from their creators in order to perceive the elements that draw attention away from the core functions of the prototype and be able to change or delete them.
6. Contribution from users: Users should be free to contribute to the prototype with changes and proposals that will make it better. It is the only way that HCI can work under the approach of human to human.

Chapter 4: System Overview

This dissertation presents a prototype application about the management and inspection of beehives and apiaries. It is known that many beekeepers especially in Greece use traditional ways to take care of their bees (Gounari, 2020). Although, with the evolution of technology it is a good idea to mix methods: the traditional way of books and the technology with the applications and software systems.

4.1 BeePal: The prototype

The name of the prototype is BeePal. It is an application with simple functions that can be used by a novice or a professional beekeeper. Except for the interviews with beekeepers that helped in the design of the particular prototype many applications were tested in order this prototype achieve a realistic interface and function. Some of them were BeeKeePal an apiary management software that applies in any form of beehives, BeeKeePal CheckInspect, a version of beekeeping application that uses weather forecast so beekeepers choose where to put their beehives and BeeKeepQuiz, a game made for all the bee lovers that want to learn more about this topic and educate other users (BeeKeepClub, 2021).

The prototype was designed with the use of Adobe XD tool that gives users the ability to create easy to use interfaces that seem like originals one from a professional application. The whole idea is based on an application with three main functions that every beekeeper needs: management of beehives and apiaries, beehive inspection and use of weather forecast. As it is understandable these main functions have many subcategories with every detail and function that a modern beekeeper needs.

In Figure 7 is illustrated the first screen that the user sees when he opens the application. The icon with the bee is the main symbol for the application. This interface needs to be simple and clear so as not to confuse the user. The main color that was used is a color similar to one of bees and honey to refer subconsciously to the user about the use of the application. There are two choices: a user that has installed the app for a long time has already account so he can *login* whereas a user that use the app for the first time he has to sign up in order to create his account.

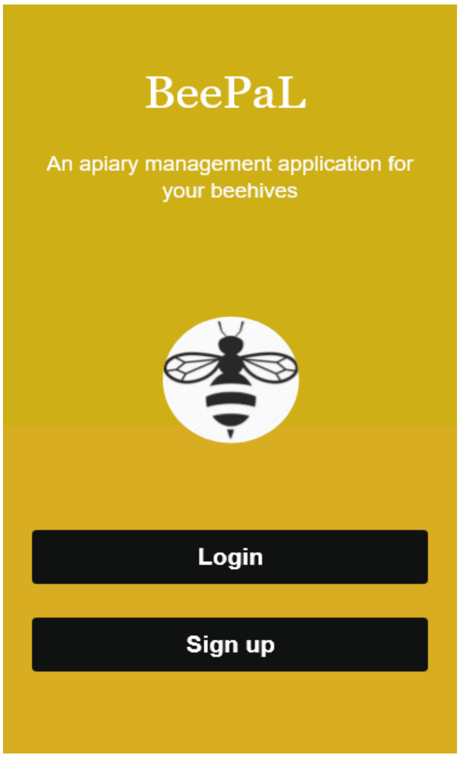

Figure 7: BeePal

After the first screen there are two other different screens (Figure 8) that are a result of user choice and condition (if it is a user for the first time or vice versa).

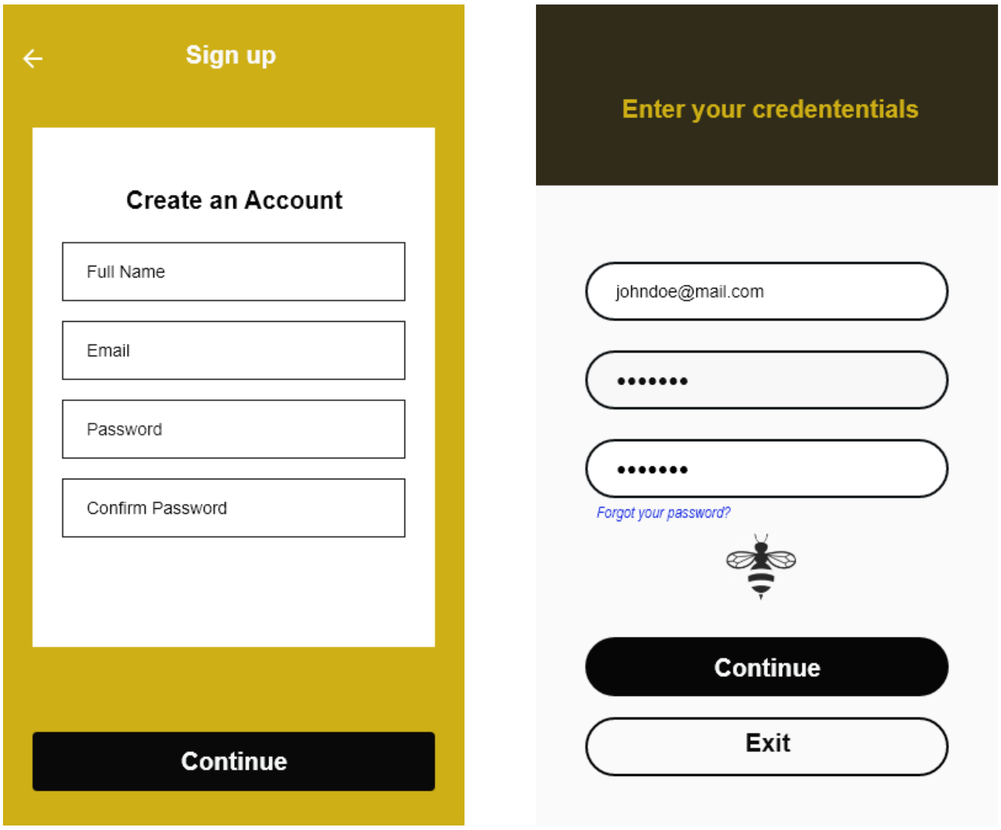

Figure 8: Sign up and Login screens

For the sign up process the application asks the user for some basic information such as his full name, email and a password. More detailed information can be added from the user when he has done with the sign up process and proceed in the application. Following all the principles of usability from Chapter 3 this screen is simple and gives the user the ability to confirm his password in order to avoid typing error, gives the choice to continue with the process or leave the application by clicking on the left arrow in the upper left side of the screen. As far as it concerns a daily user of the BeePal the application needs his email and typing two times his password for security reasons as the application gives access to all of the beekeeper's information. In the case that the beekeeper does not remember his password he can continue by clicking on "Forgot your password?" link. Again there are two different choices: continue or exit.

4.2 Main menu

After the sign up or login process the user is transferred to the main menu screen. Here there are the main functions for the beekeeper like management and inspection of beehives, weather forecast and the essential choice with the application settings. Every category has many subcategories, BeePal follows the strategy of simplification for this reason it gives main categories where it has gathered many other commands. There are also different colors for each one of the choices in order the user has a sense of difference in the commands (Figure 9).

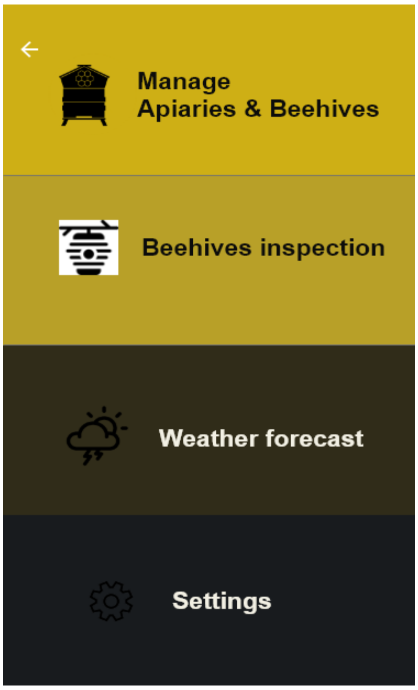

Figure 9: Main menu

Icons are placed next to commands in order to make this particular interface beautiful and help users understand its function better. Every time that the user wants to exit from this screen all that he has to do is to click on the left arrow in the upper side of the screen.

4.3 Hamburger menu

This application is user centered. For this reason it helps users with all the possible ways to navigate through the main functions and at the same time be able to have any menu function he wants accessible. The hamburger menu exists on every basic function screen and helps users to go back to every main function wants (Management of Apiaries, Beehives inspection, Weather forecast and Settings) or sign out. In Figure 11 there is a screenshot of this function while the user is on the screen of Newsfeed. There is also the choice to minimize the menu from the orange arrow.

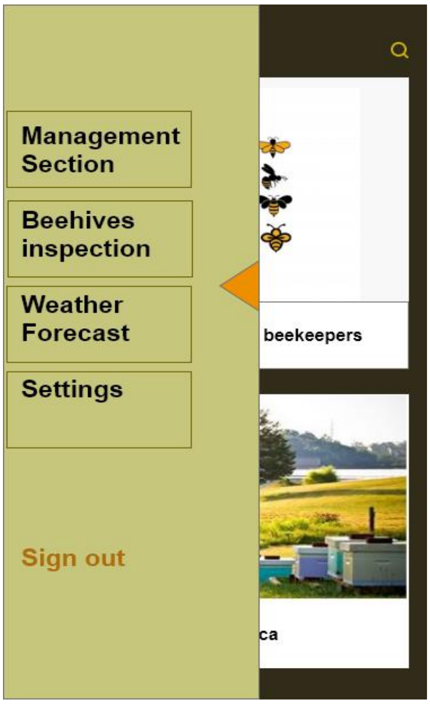

Figure 11: Hamburger menu

4.4 Settings

The settings page is divided into two sections, the one that concerns the network (Wi-Fi connection, Bluetooth, Data Usage) and the other part is about the device (alerts, sound, notifications, connectivity with different apps and storage).

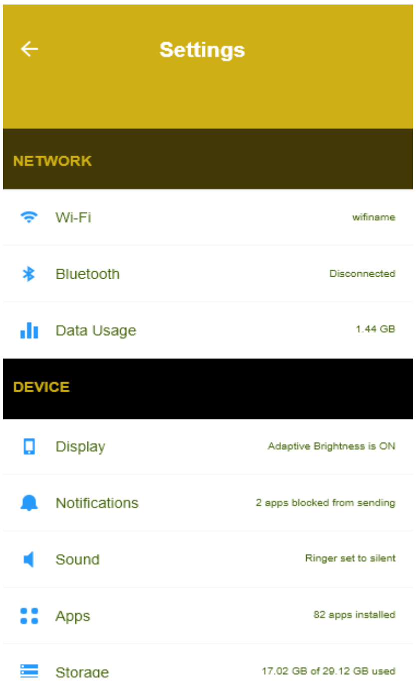

Figure 12: Settings

4.5 Management of Apiaries and Beehives

In this function users can give names to their apiary and start managing it. They can enter information about the apiary including the number of beehives that are in each apiary, and its exact location. They can also write down some important notes for them. This feature is great for beekeepers with apiaries located in different places. Beekeepers can add or delete their apiaries. They can also manage their beehives as well in the same way. When they are in this screen all they have to do is to select the appropriate icon and the relevant section arises (Figure 13).

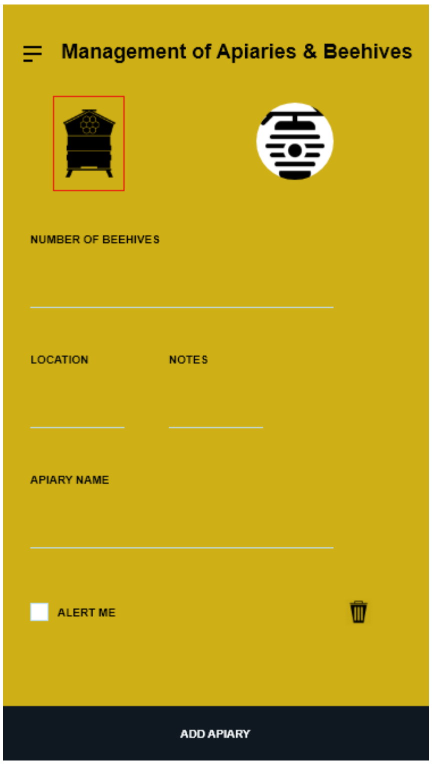

Figure 13: Management of apiary

There is also an "Alert me" option that is a command which alerts the user with notifications about the certain apiary or beehives every time something changes like the weather or the beekeeper transfers his apiary from one spot to another. If the user does not want to receive notifications, he does not check the dialogue box. As far as it concerns beehives management, this choice is about entering information and managing it for each individual beehive. It takes all the important information such as inspections, production (Figure 14).

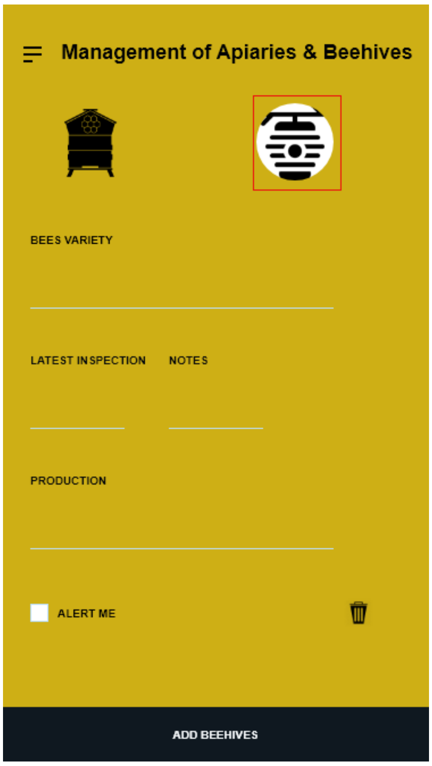

Figure 14: Management of beehive

4.6 Inspection of Beehives

The second main function of the application is the ability that gives to its user to inspect beehives. This interface includes a map that shows all the locations with the apiaries and beehives. In the bottom of the screen there is information about the exact location from the selected apiary. In the upper section of the screen there are four choices (Figure 15). One is the “Explore” in which users can enter the name or the location of the apiary and the search comes back with results. “Beehives” open a screen with a list of all the beehives that the user has entered (Figure 16). “Add” is another way for users to add apiaries or beehives alternatively to the menu “Management of Apiaries and Beehives”. There is also a choice called “Friends”. This links all the connections of the mobile phone of the user with the users of the app. If the beekeeper has two friends with their numbers on his phone and if they have installed the application too then they have been registered on the device as friends.

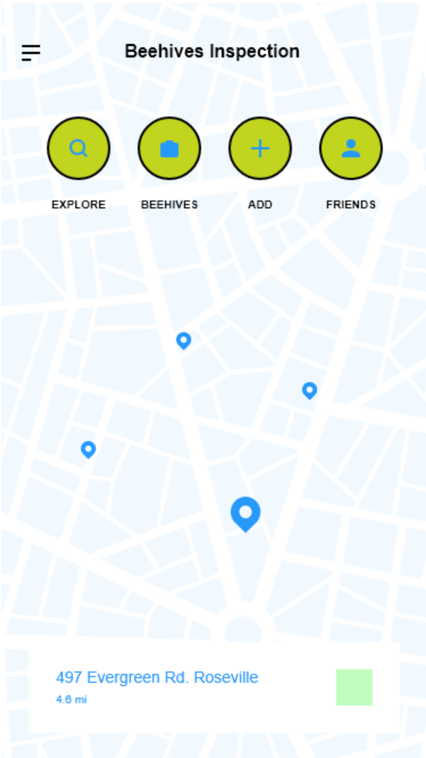

Figure 15: Beehive inspection

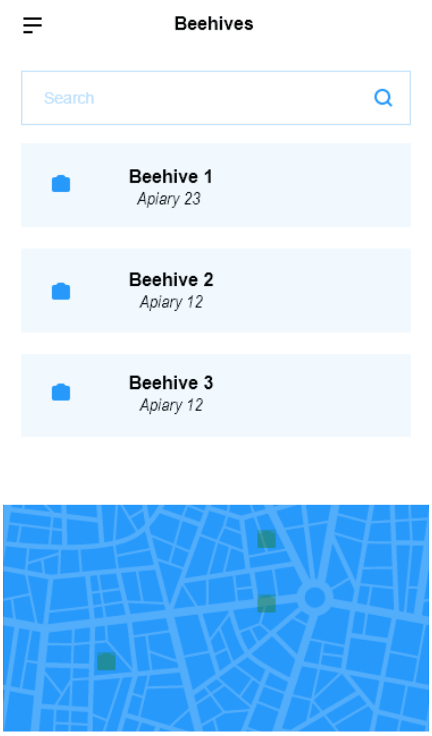

Figure 16: Beehives list

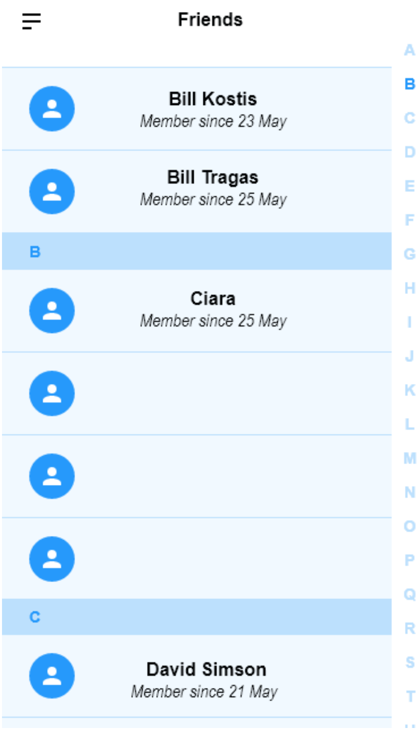

Figure 17: Friends list

The reason why those choices are not in the main menu is due to the fact that this interface does not aims to confuse user but to provide him with simple choices at first that include all the other inside of them in a logical sequence

4.7 Weather Forecast

This function is linked to the user's mobile data and location and provides all the information about weather like temperature, moisture and wind in a form of diagrams and words (Figure 18). There is also a calendar icon in the bottom of this screen in which user can select a different date and take all the important information that he needs (Figure 19)

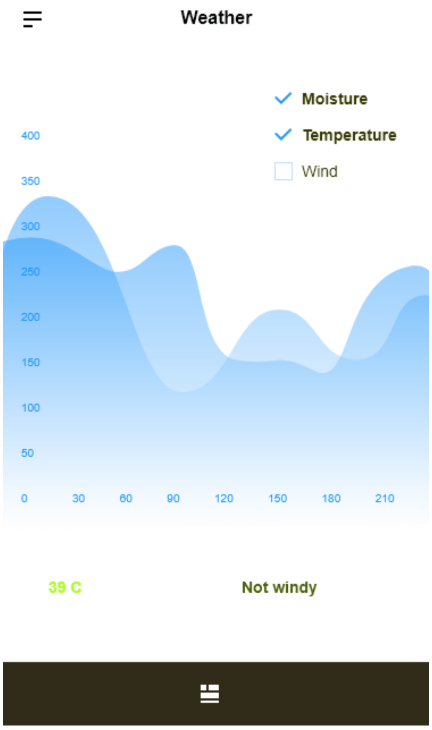

Figure 18: Weather forecast

Figure 19: Weather calendar

Chapter 5: The process of evaluation

The process of testing a prototype and developing its design is a very important part of the design process. Testing and evaluation phase are basic tools that ensure researchers and designers that the product will work as it is supposed to or it needs some changes to catch its full potential. The viability of a design can be done through the testing process. With tests clients and customers are able to view the functionalities of a prototype and propose some ideas for further development.

The evaluation process of the BeePal was carried out with the help of five participants, one from the beekeepers that joined the interview about requirements and four other persons all of them were university students. The evaluation was based on the basic heuristic of Nielsen. Each problem that arise were graded from participants with a severity score from 0-5 according its importance (Figure 20).

Severity Ranking	
Rating	Definition
0	Violates a heuristic but doesn't seem to be a usability problem.
1	Superficial usability problem: may be easily overcome by user or occurs extremely infrequently. Does not need to be fixed for next release unless extra time is available.
2	Minor usability problem: may occur more frequently or be more difficult to overcome. Fixing this should be given low priority for next release.
3	Major usability problem: occurs frequently and persistently or users may be unable or unaware of how to fix the problem. Important to fix, so should be given high priority.
4	Usability catastrophe: Seriously impairs use of product and cannot be overcome by users. Imperative to fix this before product can be released.

Figure 20: Severity ranking for problems

In order participants recall the main heuristics, they were provided with an illustration that provided all of them and when they spotted an error or something that did not like on the design they write done what category of heuristic was violated and designer took notes about recommendations for a better reform.

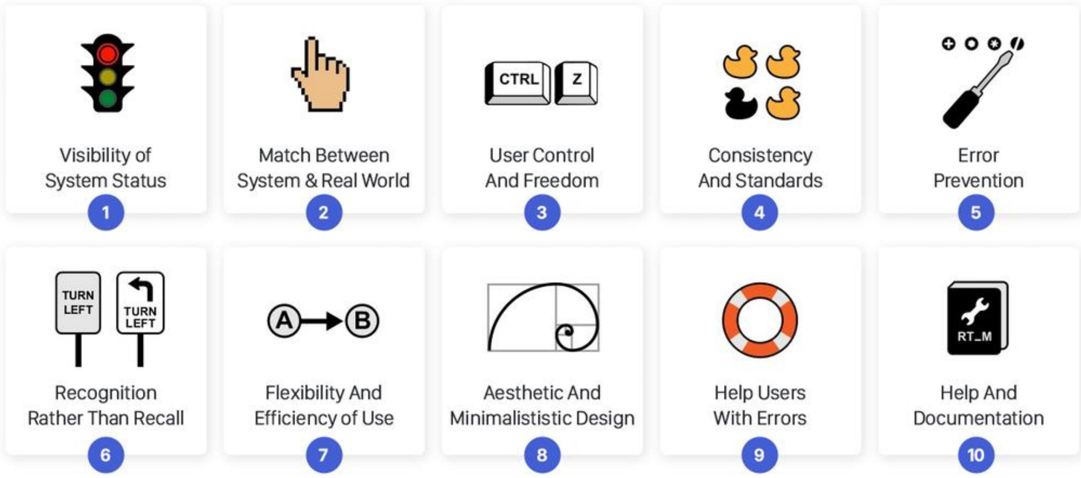

Figure 21: Illustration of Nielsen's Heuristics (adamfard, 2020)

5.1 Issue No. 1

In the section with the main menu participants noted that a choice for users that enables the return to the home page was missing. The heuristic that was violated was that of **user control and freedom** as well as **help users with errors**. The proposal was the creation of a backward arrow. *Problem severity 5*.

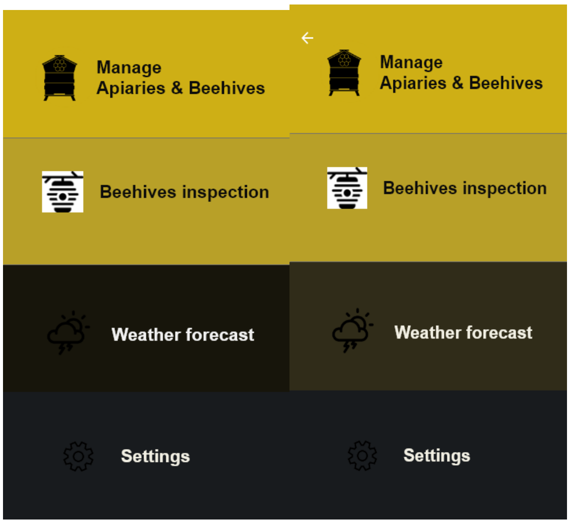

Figure 22: Main menu before and after evaluation

5.2 Issue No. 2

Another problem arises in the screen about the management of apiaries and beehives. The user had the ability only to add a product but not the ability to delete it. This affected **the flexibility and efficiency to use** and also the heuristic about **error prevention** as a user may want to delete one apiary or beehive. The designer chose to put a trash bin icon as a choice for deleting products. *Problem severity was 4.*

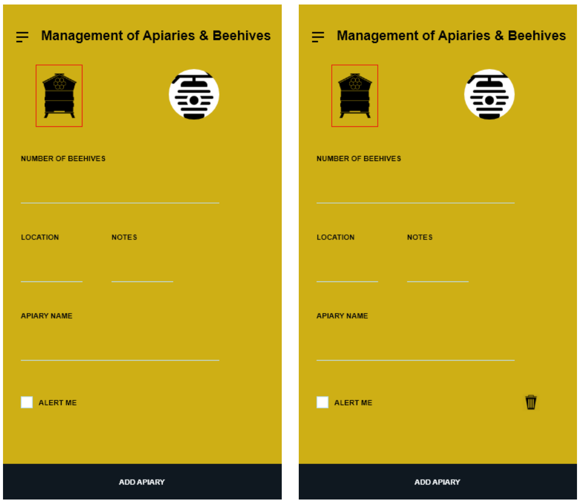

Figure 23: The addition of trash bin icon

5.3 Issue No. 3

The section about settings was not clear to users because there was no main title. Participants only perceive this section like a setting screen because of its elements. The recommendation in this case was the addition of a title. The heuristic violated was **visibility of system status**. *Problem severity 4.*

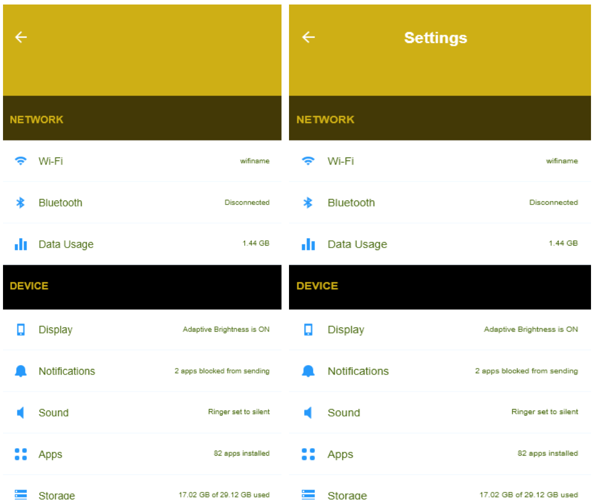

Figure 25: Settings screen before and after evaluation

5.4 Issue No. 4

One of the most important heuristic of all that was violated was that of **aesthetic design** as the application prototype had not at first a title. *The severity score here was 5* because the title of the app, its name is its identity.

In general, the prototype had no other major issues to solve as it was based on already existing applications and combined many elements in the appropriate order.

Chapter 6: Conclusion & Future work

The HCI field is so wide that it can find applications in any situation. Something that before many years would be unlikely to happen. This happens because the field of HCI focuses on the interaction between humans and computers and in the 21st century technology continues to grow and is constantly involved in people's lives. One of the sectors that can be affected by new technologies is agriculture. This thesis studies how a certain activity of agriculture, beekeeping can be affected by the HCI field and proposes the creation of an application for beekeepers in a prototype form. The utilization of precision agriculture permits beekeepers to have the control of their hives and bees in times that are in other areas or they can visit their hives.

The world of Internet of Things endorses the strategy of HCI for a better interaction between humans and computer systems. There are applications that enable the measurement for remote monitoring Bee hives. The innovative application makes it possible to remotely manage the cell, offering beekeepers all the necessary tools and data to save time, resources and reduce travel, ensuring improved business operation and better quality of life. The user - honey producer uses IoT technology and an easy to use and versatile web portal, to monitor the humidity remotely, the internal and external temperature and the weight of the cells in the field, controls their condition and honey production by bees, and knows them production trends. The measuring equipment allows the user to locate the cell, while in case a cell moves, opens or reaches the weight to which honey must be collected, send him the corresponding notice.

Monitoring systems have advanced in a great number because they make use of remote sensor organizations (WSNs). A WSN consists of implanted gadgets that can secure information from various sensors, measure them, and speak with a PC with a cloud data set. This technology is essential for IoT and can be used for monitoring beehives. While all those technologies exist the field of beekeeping especially in Greece lacks in the part of technology and applications. Beekeepers grow their hives by traditional methods and by doing this they do not reach the full potential of their job and productivity.

This dissertation studies the relevant literature about the new technologies and how they can be developed in the agriculture field. Starting with the examples from applications and platforms that have developed globally about beekeeping propose the same idea for an application that can be used in Greece and in every other country. The goal of the proposed application is to provide beekeepers with the opportunity to keep track of their activities around the hives, monitor their hives from distance, connect with other beekeepers in an area, be informed in real time about climate and weather changes as well as be informed about the latest new on beekeeping field.

6.1 Limitations of the study

The thesis has to deal with some limitations. First, the number of the participants in the first interview that concerned beekeepers was low. This happened because the situation in which the survey took place was difficult. Due to COVID-19 pandemic travel in distant areas was not permitted so the only participants were some family friends who are active in nearby cities of Patras. If there was a bigger number of participants the requirements for the application maybe would be more and would in this way contribute to the refinement of the prototype.

Another limitation was that the prototype is not fully functional as it is about prototypes of the final version that the author proposes. The full implementation of the application would require more time and a great number of participants that would had to use it for a long period like six months or more in order to obtain data for their use and the behavior of users against it. A final limitation of this thesis was that there is not enough literature that refers to individualized applications and systems that have to do with the beekeepers and their activities. There are some examples and references in some applications and platforms but not an extensive bibliography that could help in requirement analysis of such systems.

6.2 Future work

This study can be a stimulus for further research in HCI field about beekeeping and modern technology that can make the daily life of a farmer easier. One proposed for future work is the use of ethnography. Ethnography is a method of observational research that is used in the HCI field to a great extent. In this topic an ethnography could be used to monitor the work of a beekeeper or a team of beekeepers in an area. In this way the daily activities of the beekeepers will be recorded and by observation the researcher will be able to continue with a better implementation of a system for monitoring and caring for the hives.

A future work that would be added in the application is an activity feed function. One of the purposes for the creation of BeePal is for beekeepers to be informed about the latest news from the world of beekeeping. In the activity screen would be appeared the most relevant and recent news that would be refreshed in every time that beekeeper would use his internet connection on his smartphone. This screen could be combined with further choices like pinning the favorite articles or saving an interesting website.

Another idea for further extension would be the creation of a system that would be able with the use of specific sensors to understand radio waves from telephone antennas. When the application understands that an area is full of radio waves it will alert its user about the radioactivity rates and will suggest another area that it is appropriate to put the hives. Hives but also the bees themselves are affected by radioactivity and in some cases are completely destroyed, something that no one in the beekeeping field wants. This idea will be integrated like another one as another function of the existing application.

A last idea is the implementation of a system that can perceive dangerous gases in the air. This category includes fertilizers, insecticides and other toxic forms of gases that farmers use in order to protect their fields from various diseases and insects. An extra function in the BeePal application would alert the beekeeper to remove his beehives from a certain area that is near a field which is sprayed with those gases.

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