IOHIVE: Design Requirements for a System that Supports Interactive Journaling for Beekeepers During Apiary Inspections

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Abstract. In this paper, we present an ongoing project that focuses on designing interactive systems and their respective interfaces for monitoring and journaling of apiculture information acquired in the actual field during apiary inspections by the beekeepers. Initially, the paper provides a brief overview of the concepts and technologies found in the domain. Next, it examines the scenarios to be used for the design of interactions related to the actual beehive inspections and desktop use in the office. The paper mainly focuses on the design requirements based on user research. It provides a review of interaction techniques that can be implemented for journaling in the workplace of the apiary, briefly outlines the infrastructure and gives a system overview at its current state of development. Finally, the paper discusses future work including, guidelines towards the development of the various system components for journaling and a preliminary evaluation plan for the case studies that will follow.

Keywords: Journaling for beekeeping · Beehive inspection · Apiculture · IoT · Interaction design · Agriculture science · Bee management practices · Modern beekeeping

1 Introduction

In recent years there has been an increasing interest in the design of technologies for the agricultural and more specifically apiculture/beekeeping sectors. Graphical User Interfaces (GUIs) still dominate as the main user interface platform used in outdoor workplaces (field/farm), while non-traditional interfaces such as speech-based, gestural, haptics, multimodal, etc. are also incorporated more frequently in terms of human work interaction in pervasive and smart work environments [1, 2]. These interfaces create a natural link with the users' working environment and promote user performance in multitasking contexts where agricultural activities take place [3]. Researchers agree that there is a need to further investigate technology use in agriculture. Toward this goal, great

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attention is given to making it more efficient, easy to access and understand. Moving beyond the well-established GUI interaction [4], the new direction is to focus on the relation of the user, the technology, and the actual environment where most agricultural activities are taking place [5].

The general objectives of the project are the design and development of technological infrastructures and services for a) Remote hive monitoring of beekeeping data including bee biometrics, hive development in relation to local climatic conditions, honey production and other hive products, b) supporting beekeeping practices and management techniques that are aiming at the development and population expansion of the bees, c) supporting the utilisation of all products that are being produced by beekeeping. The quantitative and qualitative data that will be produced, will be gathered, processed, and presented in order to increase efficiency and improve the quality of the produced products [6]. In this paper, we focus on the design of the logging/journaling mechanisms that will be introduced to support inspection notetaking in an apiary. The paper also describes the methodology towards the general systems' design and architecture.

1.1 Precision Beekeeping/Apiculture

The field of agriculture that needs to follow this path is beekeeping. Beekeeping is a labour-intensive practice that focuses on preserving the health and productivity of bee colonies [6]. To monitor the progress of the hive, beekeepers inspect the frames of each hive almost daily, depending on the season and the goals that a beekeeper has. By journaling the practices and the data that were observed during the field visit, beekeepers can be drawn to conclusions regarding the state of the hive and be able to make predictions about the future of its state. It is also a way to verify that a practice is effective and aligned with beekeeping protocols, by monitoring its progress and results based on the journaling activity [6–8]. Journaling during the process of the beekeeping inspection can be distracting and difficult to follow because of the tools and processes involved. Beekeepers have been using empirical methods and tools such as paper journals, in order to take notes based on signs, symbols, and numbers [9], during or after the process of the inspection (Fig. 1).

Fig. 1. Empirical methods for note-taking in an apiary: journaling on paper, stones and other objects placed on the beehives to indicate an event of action (e.g. missing queen), markings on the frames (e.g. newly introduced frame since last inspection)

This type of method makes it extremely difficult to track the plurality and complexity of data that have been gathered during practices that took place over a beekeeping period.

A technological system could help to organise and keep track of the activities performed and evaluate their effectiveness. Remote monitoring, telemetry, and analysis of sensor data of a beehive isn't the only option to secure the colony strength and thus identify crucial factors for the productivity and the health of the bees. Often the observed hives might be in distant places, increasing the travelling costs and the time consumed [10]. Digital sensors installed on a beehive provide valuable data that can be stored and used in near real-time to assist in collecting data that can be later used to study the health and behaviour of individual honey bees and their hives [11–13]. This project supports the idea that this type of automated monitoring does exclude a large part of beekeeping, namely human observation, and intervention during beehive inspections. For this reason, the IOHIVE project focuses on designing a comprehensive system that affords both automated monitoring and logging of human empirical observation. Monitoring will be based on IoT sensor data, including commonly used in-hive sensors such as temperature, humidity, weight, sound etc., as well as environmental and weather data from weather stations either in the wider region or ones closely located to the apiaries that capture the microclimate of the area. The core idea of the project is to support beekeeper workers to log data while inspecting or intervening on a beehive. The purpose is to provide them with a usable interface/device that affords simple data entry interactions in the farm/field during actual work. This information can later become more valuable in terms of correlation with data sourced from sensors and other monitoring devices.

2 Related Work

There are several different systems and practices focusing on assisting beekeepers in the apiculture domain in journaling, keeping logs or diaries of their activities related to inspecting and intervening in a beehive.

2.1 Logging and Journaling Apiculture Practices

Hive inspection is one of the main tasks performed by beekeepers to manage their colonies. With this activity beekeepers try to turn a set of stimuli and scattered data into meaningful understanding about their colonies [14]. It is a practice that is usually taught by a more experienced beekeeper to beginners by collaborating over their inspections. To successfully manage a beehive, the amateur beekeeper needs to become more attentive, have the capacity to monitor certain information, and adapt their responses to situations that arise. There are certain lists and categories of information that one might look for in an inspection, although the more experienced a beekeeper becomes, the quicker it is to inspect a hive and to go further on what they observe during that time. Hive inspections can be taking place weekly, fortnightly, monthly, or even daily during harvesting season [15, 16]. Beekeepers usually assess the status of brood condition, the population size, they consider giving additional space to the hive during the flowering season or reducing it during winter, check for food reserve, queen's existence, or tendency to swarm [9, 15]. As it is a practice that is carried out regularly in every hive of an apiary, the amount of data produced in only one inspection can be overwhelming. To be able to manage this information, beekeepers keep records of hive inspections which can be helpful in order to follow colony progress and to plan for future work in the apiary [17]. This type of manual recording takes place in various ways, such as making notes on a hive, marking a hive with a rock, and keeping notes on paper [9, 17].

Beekeeping Diaries and Inspection Notebooks. Beekeepers started journaling those inspections, in order to manage this information and be able to make predictions about the well-being of the hive. Organizing this data makes it easier to verify that a practice is effective and aligned with beekeeping protocols, instead of having to memorize them. This task takes place during or after beehive inspections, preferably as soon as possible so that all qualitative and quantitative data can be recorded. They use paper journals or take notes based on signs, symbols, and numbers regarding usually the number of frames that have brood (eggs), the presence of the queen, and the number of frames that have food reserves (honey or pollen) [9]. Beekeepers are particularly interested in those data because they can indicate potential future problems. They also keep notes of abnormalities in hives or statuses that trouble them, in order to take further action about those hives in their next inspection. They keep comments on more abstract observations as well, given a reason exists, but this is not the usual case since there is a lack of time.

The main problems with keeping notes during hive inspections is that it is time-consuming, and the environment is not conducive to writing down observations. If the notes are written down after the inspections, the quality and quantity of the information that ends up in the journal is significantly lower than what was observed at the apiary. Traditionally, beekeepers solve this problem using empirical methods, marking hives with information that will be useful to them during their next inspection or at a later visit. This is only a short-term solution, as this type of recording is not stored somewhere and is often lost immediately after the next inspection to be updated with the new data. If the notes are written down during the inspections, the beekeeper must do so while wearing protective gear.

2.2 Related Systems and Software

Beehive Journaling. There is a wide range of systems, services and applications that focus on note-taking or journaling for inspections alongside monitoring from sensors [18]. These include research and commercially available systems and services, as well as mobile applications easily found on most mobile market stores. The two most well-known open-source systems that have attempted to address journaling more specifically include Beep App online webservice with its accompanying Beep Scale [19] and OSBee-hives application accompanied by the BuzzBox beehive monitoring system [20]. Both system services support beekeepers' diary functionality. The user can keep notes after creating each hive, about the current status, treatments, changes that have been made during the inspections etc. Moreover, monitoring from sensors is stored on databases and presented to the user through various visualisation techniques (graphs, charts, widgets etc.). Both services classify the information properly according to inspection lists, well known in the beehive community [21]. As both systems are under heavy development, their graphical user interfaces and core functionality are continuously updated, allowing users to navigate quickly through their mobile and desktop devices.

Beehive Monitoring. Manual journaling from the beekeeper is often accompanied by automation systems that monitor the current data of an apiary including the beehives and the microclimate of the area. Monitored data is captured and analysed by a number of systems and techniques including: audio / acoustics or sound analysis [22–25], motion/track analysis [26–29], population estimation and variability [30–34], behaviour analysis [35], vibration [36, 37], image analysis and computer vision for detecting diseases and parasites [38], energy consumption [39], environmental data [40] etc. A number of systems have also been developed to monitor combinations of the aforementioned data based on multi-sensor arrays that also fall within the domain of IOT. These usually monitor temperature, humidity, weight, audio, video, vibrations etc. Some recent examples are BeePi [41], Beemon [12], an IoT concept for precision beekeeping [42], and an IoT project of a low-power beekeeping safety and conditions monitoring system [43].

3 Methodology

One of the most important tasks of this project is to design interaction and interactive interfaces that afford the logging and journaling of specific beekeeping practices/tasks performed by the respective workers/beekeepers in the actual field/apiary. The methodology we follow in this project focuses to support several levels of design and development ranging from the design of the interactions based on user research to the analysis and outline of data architecture, to the development of the infrastructures, systems and services. We follow a user centered design approach for establishing the user requirements and establishing the interaction techniques to be used in the various interfaces [44, 45]. In terms of systems and services we follow a Service Oriented Architecture (SOA) for web service applications which defines an important stage towards the evolution of the actual application development and integration [46]. Therefore, the different layers of the project will be developed as independent sets of interacting services offering well-defined interfaces to their potential users. The technologies involved will be available in such a way to allow sub-component developers to browse collections of systems, technologies, and services, select those of interest, and combine them to create the required functionality in terms of user research and pre-established design requirements [47, 48]. The challenge here is to apply the SOA architecture for an IoT service-oriented architecture that takes into account a user centered design approach [49]. The IoT SOA architecture layers for this project include the following layers: Application Layer, Domain Services Layer, Common Services Layer, Infrastructure Layer. In combination with the user centered approach described earlier, the generic architecture of this focusing on: a) desktop research and stakeholder interviews for identifying the domain requirements, b) user (beekeepers and researchers) research for establishing requirements, c) design and development of infrastructure systems and services, d) design and development of common systems services, including the iterative design process of establishing working interactive prototypes and e) the evaluation of the various sub-systems and services in terms of a pilot case study. For the purposes of this paper, we will focus on the analysis of the user research, the interaction techniques and the architecture components implemented at the current state of the project.

3.1 User Research

Initially, the research focused on understanding beekeeping and its practices, the work environment that beekeepers experience in an apiary, the challenges they face during work, and the tools they use. The main part of beekeeping concerns hive inspections. It is craftsmanship where the beekeepers must understand the nature and the needs of the bee colonies, receive stimuli during their visit about the current status, and develop a plan of future actions [9, 10]. To better understand this process and identify the difficulties that arise due to the complexity of this work environment, the research and design team of the project conducted a set of field visits. We interviewed beekeepers and researcher by using semi-structured interviews. We also observed and recorded beehive inspections in the apiary on the basis of structured and semi-structured scenarios. The participants were asked a range of questions covering topics related to their activities. The purpose was to learn about the data they observe during the inspection, which of those they journal, what methods they use to record them, when they record them and how often they consult them. Some of the most important findings during the interviews were the following:

1. It is almost impossible to document all the practices each beekeeper follows, as they are often structured in terms of empirical knowledge,
2. due to the lack of appropriate tools, beekeepers only record a general review of their observations when and if they journal,
3. problematic situations are preferred to be solved on the spot, if not, beekeepers keep notes in order to remember to take further actions about those hives in their next inspection (e.g. disorder, missing queen etc.),
4. time and task completion are important factors and affect most of their decisions, as it is limited during their field visits,
5. journaling most of the times does not take place right after the individual beehive inspection,
6. depending on the season, their focus shifts, but during inspections they mainly observe the status of the brood, the food reserves, and the queen presence.
7. beekeepers manage how they are going to spend their time and what actions they are going to follow in their next inspection, before going to the field. They have a general overview of their hives and based on the season; they make plans about their actions. Even if they don't journal each hive's progress, they manage to filter the most important information and act on it. Each hive's status concerns them on a high level during the inspection, but after they are done with their actions, if it doesn't appear to have an abnormality, they keep a minimum amount of information about the hive.
8. Beekeepers are creative in inventing new ways to communicate this information, using signs, letters, objects to solve as fast and efficiently as possible. Although they manage to achieve their goal without the use of specifically designed tools for their work, these issues must be addressed.

Researchers of the field face similar issues; even though they have the time to observe and journal, there is not a user-friendly digital tool available to help them organize their observations. The data that they are recording must be accurate, consistent, and gathered in one place. It appears thorough user research in the available tools has yet to be done to take their needs and the field into account.

Finally, both beekeepers and researchers are using monitoring systems as a way to indicate important marks on their apiaries. Such systems do not seem to cover their needs as they can only monitor some parameters of a few hives that do not actually indicate what is happening in the hive. During the structured scenario, the beekeepers were questioned about the date, practices, and goals of the previous inspection, the goals, and practices during the present inspection and the tools they are going to use, as they approached the hive to follow certain steps to perform an inspection. Those steps were part of an inspection protocol, designed to understand how beekeepers would journal an observation, as well as their hand and body position, by giving the same instructions to multiple beekeepers. The tasks assigned to them included: 1) using the smoker and the hive tool during the inspection, 2) carrying out practices in the hive, 3) observing the frames, 4) moving around with and without the tools, 5) announcing what they observed in each frame regarding the hive population, brood status (egg and capped brood) and food reserve (honey, pollen) in percentages, as well as if there was a queen presence, while they were able to add any other comment (Fig. 2).

Fig. 2. Use of tools and hand interaction during beehive inspection

Through the structured scenario what was discovered was that although beekeepers could follow the instructions, they often preferred to follow a different workflow based on their way of working. Their attention was on the events that take place in the hive with the bees and not on their tools or the position of their hands. Although they were guided to leave their tools on the side while observing a frame, the hive tool seemed to be a part of their hand during the whole inspection. Both of their hands were busy most of the time, trying to perform quickly but steady what was requested.

They also mentioned that putting their tools far away or on the ground is an action they would avoid, so as to reduce their physical fatigue. According to the unstructured scenario, it was detected that the focus of the beekeepers was aimed inside the hives and not on the peripheral environment. They were mainly dedicated in observing, while acting almost instinctively. Their actions were fast but cautious and efficient, while using both hands and always holding the hive tool in one hand. Every tool and part of the hive was placed on a close range from the hive they were inspecting, in order to avoid large movements, bending over or lifting weights, as they wanted to minimize their physical effort per hive. Due to the weather conditions (cold, wind), beekeepers also reduced the information they were looking to keep for later and focused on minimizing the time they would keep the hive open.

Inspection Scenarios. Beehive inspection will possibly take place in two phases: a) by opening the beehive and identifying the current status, b) after finishing up the inspection. Before the next visit, the beekeepers review the data they have recorded so that they can properly prepare the inspection. To meet these requirements, the system must include all of the actions listed in these two stages. The data that the beekeeper will record per hive will include the number of frames, the population, the bees' behaviour, the quantity of brood and the stage it is in, the honey / pollen stocks, the presence of a queen, disorder identification, and food consumption. Thus, during a visit to inspect food consumption in their apiary, the beekeepers can approach a hive and check its condition using data collected by the sensors. They can then begin the inspection based on the protocol chosen and check the frames in relation to the food reserves. During the process, if they notice that there are fewer reserves of honey and pollen from the previous visit, they can proceed to feed them. They can journal the new hive's status in food consumption about food reserves (honey, pollen), and brood status before moving on to the next hive. After finishing the inspection, they return home and have an overall view about the apiary's food consumption during this month.

3.2 Interaction Requirements and Interaction Techniques

Beekeepers, like other agri-food workers, are often required to deal with painful everyday practices for the human body, like lifting and lowering brood and honey boxes that may harm their lower back in the long run [16]. Therefore, they need small and lightweight assistive technologies, as well as interactions that do not restrict their movement in the field. The interface's dialogue with the beekeeper via audiovisual notifications must be carried out carefully. Beekeepers feel it is necessary to use both their mind and their eyes to document the overall situation inside and outside the hive. Any distraction can result in incomplete journaling and, as a result, affect future beekeeping practices. Among the key insights provided by beekeepers during the field research were the inability to hold more tools or objects during beekeeping practices. As a result, it is not surprising that most of them suggested hands-free interactive tools during beekeeping inspections. Another vital requirement they highlighted is instant access to the history of all the beehive health data via GUIs, with an emphasis on previously critical data, particularly when inspecting beehives in a large-scale apiary. The information that was previously memorised or noted through the use of signs, must also be included in the digital journaling process, since a potential data loss or an incorrect interpretation of a past event may determine the future of a bee colony. Bare-hand interaction with touchscreens could not be considered a best practice, primarily because most beekeepers tend to avoid being stung and therefore wear uniforms and thick gloves that prohibit touch interaction, and secondarily because they will have traces of bee products on their bare hands that also makes difficult to interact with any touchscreen device. Furthermore, wearing thick or dirty gloves may make it difficult to perform subtle movements such as typing, tapping on options, or using a touchscreen or traditional keyboard in general. Consequently, multimodal user interfaces that combine tangible and voice interfaces might be an option when time is limited and adverse field conditions, such as low visibility, occur.

Web and mobile application interfaces are mainly used in order to keep beekeepers informed through charts and alert notifications about beehive health status and weather conditions either during apiary inspections or later on in the office [42–44]. Smartwatch interfaces for beekeeping, which are currently in a conceptual design phase, emphasize on displaying real-time changes in the beehive and alerts for the node's battery level [40]. On the other hand, no particular development has been observed in the use of smart emerging technologies, so that the beekeepers can maintain their own digital journal for the beehive inspection with Wearables and Augmented Reality technology. Nowadays, the design of interactive applications for this purpose is limited to the use of common user-platform interaction techniques, allowing beekeepers to type notes, create, input, edit, and delete information about their hives and apiaries, with the use of their keyboard from a desktop computer or a mobile device [45]. Portable devices, combined with the evolutionary capabilities of interaction like tangible interactions, speech recognition and gesture-based interactions are the proposed styles of interaction that can potentially evolve as the future interactions for beekeeping practices. A description of the existing types of interactions and their possible contribution to journaling during beekeeping inspection is mentioned below.

Wearable Interaction. Wearable Technology, wearable devices or wearables are small electronic gadgets with wireless communication capability, which are usually worn on the human body, or easily integrated into accessories and clothing [50, 51]. Physiological and kinematic parameters can be measured, so that users are able to enhance their perception about their performance, or even the conditions of their surroundings and the environment [52].

Ometov et al. (2021) presented a detailed classification of wearables based on the device technology, managing to name 27 different device types. Personal notification devices, Smart watches, Wearable cameras, Smart clothes, Smart contact lenses, Smart gloves, Smart rings, E-Textiles (smart fabrics) and AR devices, are some examples of the wearable technologies mentioned. Recognizing how many options are available and how many combinations could be used in beekeeping practices, we can get a taste of the innumerable ways we can provide the user to interact with both the environment and the interface.

Wearables can also be categorized into the following three types, based on how much energy they consume: low-power, medium-power, and high-power wearables. Devices with displays typically consume more power than those without a graphical output interface [53].

In terms of data collection, the following sensing techniques are already used in wearables: Participatory (active) sensing (gathering information through the user's action), Opportunistic (passive) sensing (gathering time-based or distance based data), and Opportunistic mobile social networks (point-to-point networks of devices that share information with one another) [50].

In this paper, wearables are considered as extremely useful for journaling during the inspection process. As previously stated, beekeepers frequently have their hands full and are usually unable to hold another item. Small smart devices are also easier to carry on the human body. Immediate access to charts of live data collected by sensors, combined with available technologies for manual data input, like speech-based [54] and gesture interaction, would increase presence and add significant value to user experience design.

Physical Object Manipulation and User Experience. Physical objects are characterized by shape, colors, ergonomy, metaphors, mobility, weight, texture, plasticity, functionality, indications, aesthetics and size. Using physical objects could activate innate spatial reasoning skills of the beekeepers, while simultaneously expanding the range of gestures with grasping behaviors [55]. Moreover, the manipulation of a physical object would enhance their user experience with the feeling of touch and response [56]. An interesting challenge when designing interactions is keeping users engaged with the feeling that they are actively participating in the process. Interacting with a physical object, would give beekeepers the feeling that the journaling process is still under their control.

Physical object interactions are based on the way users hold, move, touch an object and transform it. As mentioned above, subtle movements like typing may not be possible during beehive inspections whereas, moving, rotating and tapping on larger tangible interfaces can potentially provide more flexibility in data entry of simple values. Aside from important elements, such as form and functionality, user experience could also be improved with detailed design of other elements placed on the object, like colourful indicators, lighted surfaces, and symbols representing beekeepers' semiotics during beehive inspection.

Gesture-Based Interaction. Recent advances in real-time gesture recognition algorithms have resulted in the development of algorithms that are quite adaptable to different types of hands and have overall recognition accuracy rates greater than 94% [57]. A wider range of available gestures could lead to a more realistic and detailed journal about the behaviour of bees, the condition of each frame and the overall health of the beehive. Given the fact that difficult conditions may prevail during journaling, together with the inability of the beekeeper to grasp other things, wearables with eye-tracking interaction, can be potential alternatives for data input [50].

3.3 Basic Architecture and Infrastructure

This section aims at presenting a high-level overview of the IOHIVE architecture and its connection with the journaling sub-system. Starting from the user side, a user can interact with the IOHIVE platform both through a wearable/tangible device and a web application for visualising data in terms of mobile or desktop interfaces. Through the wearable/tangible interface, the user can record observed inspections. When the user moves away from the actual apiary, he/she can interact with the web application in order either to configure his/her hives for next inspection or to monitor them based on the installed IoT sensors and devices. Every hive has been associated with a list of devices including weather stations, temperature and humidity sensors in/outside the hive, scales, sound sensors etc.

The open and extensible architecture of the IOHIVE platform is designed to facilitate the integration of different end devices for remote beehive monitoring, acquisition of weather/environmental data as well as inspection data. Measurements such as a) the weight of a hive, b) the temperature inside/outside a hive, c) the humidity and d) the sound inside the hive provide valuable information about the status of bee colonies. Environmental or weather data provide a good valuable source of wide area climate and microclimate around the apiaries. In addition to the aforementioned, beehive inspection data, provided by the beekeepers, offer a valuable additional layer of information. This type of empirical data is based on observation or experience and is a subjective measurement of phenomena, as directly experienced by the beekeepers. This data is thus valuable and cannot be ignored. It can be further utilised in terms of correlation with sensed data from the instruments and sensors.

A brief description about the end devices that have been already integrated in the platform is presented on the following Fig. 3:

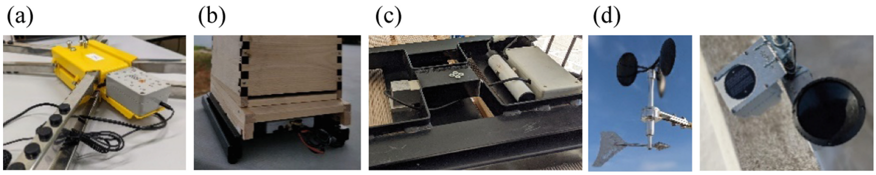

Fig. 3. IOHIVE end devices. a) BEEP base, b) SaveBees SMS scale, c) Kudzu scale based on Sprout, and d) MeteoHelix IoT Pro weather station MeteoWind IoT Pro wind sensor.

The focus of this project, according to the design requirements and research gathered at the early stages of its implementation, is to invest on IoT technologies that provide long-range wireless communications at a low bitrate among the connected objects, such as sensors that operate on a battery (Fig. 4).

Fig. 4. Gateway overview at TTN. At this stage six gateways deployed at Syros and Paros Islands. These include custom made TTN Gateways based on RPi (3), Beaglebone (1) microcontrollers and LoRank (2).

Thus, the majority of devices used in this project operate over the LoRa low-power wide-area network modulation technique. A few node devices support 3G/4G connectivity for coverage in areas with limited network access or LoRa coverage and communicate through Simple Message Service (SMS) technology via an SMS gateway. In this way the absence of LoRa coverage at the area can be tackled. Therefore, the main goal is to have devices installed in the apiaries which are low power wide area (LPWAN) LoRa nodes that connect to the nearest LoRa gateway [58, 59]. The gateways forward the data to The Things Network (TTN) [60]. Using appropriate payload decoders and web hooks the payload is supplemented with a unique device ID and timestamp and is being pushed to the IOHIVE Service described in the following section (Fig. 5).

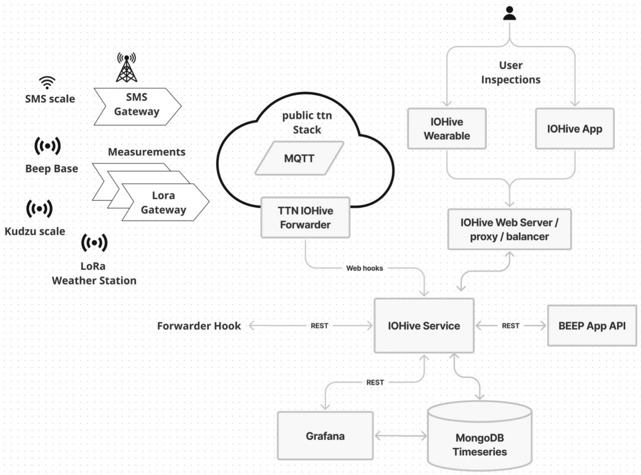

Fig. 5. High-level overview of the IOHIVE architecture

Finally, it is important to note that the data derived from the sensors is being persisted in a MongoDB database [61]. Currently, the latest Mongo 5 database offers timeseries collections combined with a powerful aggregation framework.

The IOHIVE Service

The IOHIVE service provides three distinct APIs:

- IOHIVE Sensor (Data) API - responsible for the integration of sensor data
- IOHIVE Weather (Data) API - responsible for the integration of weather data
- IOHIVE Inspection (Data) API - responsible for the integration of inspection data

The IOHIVE service is responsible for pre-processing the data (validate, format etc.) and store them into the database. The service has been implemented using NestJS/NodeJS technology. Apart from the push API, the service exposes endpoints to allow retrieval/aggregation of data by the IOHIVE App. Grafana has been used as the main framework for generating charts and embedding them into the IOHIVE App. The combination of MongoDB aggregation framework and Grafana offers a flexible framework for developing charts aiming at extracting useful insights about the data. So, data originating from continuous monitoring of a beehive and its surrounding environment can be correlated in time with data coming from inspections. For every cycle of an inspection (finished inspection → start new inspection) a data window can be extracted and analysed. Through appropriate visualization techniques the user has insights about what went wrong during the last inspection period and plans corrective actions (Fig. 6).

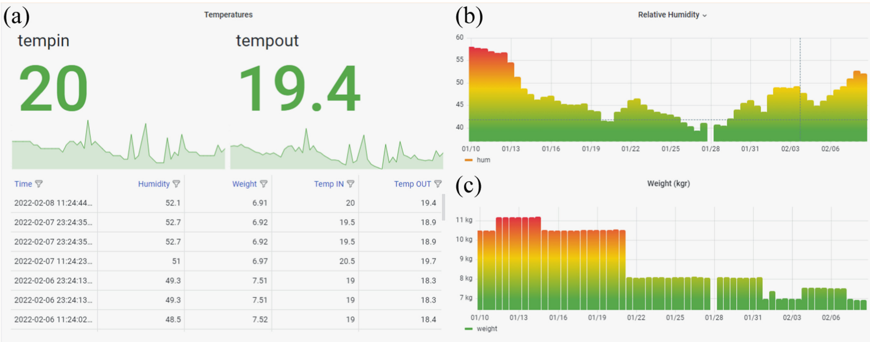

Fig. 6. Visualization of sensor data using charts and tables. Measurements from an SMS scale: a) temperature in/out, b) relative humidity, c) weight.

Furthermore, BEEP app and BEEP base have been integrated in our architecture [19]. Data from the different sensors are being forwarded to the BEEP app through the IOHIVE Service. In addition to them the IOHIVE wearable/tangible device will also feed with inspection data initially the IOHIVE API service and its forwarding services. Based on the user research described above, several inspection checklists will be developed. A data transformation layer, part of the IOHIVE Service, is responsible for transforming data from different sources to the suitable formats for an optimized consumption by the different interfaces. This allows for dynamic/configurable checklists based on the end user needs.

4 Future Work and Directions

Future work will focus on the design of the wearable/tangible system that will support journaling for beehive inspections. This will include the actual design of the physical product, the electronics and the interaction techniques. The design team will also focus on designing the web interfaces, the user roles and the visualisation mechanisms for providing charts and graphs to the end users. Moreover, further development is needed for the completion of the Sensor, Weather and Inspection APIs.

Another important task for the research and design team is to outline and organise the evaluation plan for the case studies that will follow the actual development of the prototypes.

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