Utilising Iot Technologies To Improve Beekeeping Through Remote Hive Monitoring

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Abstract
Internet of Things (IoT) technology on beekeeping, with a particular emphasis on remote hive monitoring. The use of IoT has changed beekeeping, which is vital for pollination and honey production. Beekeepers now have access to real-time data on hive conditions. The study highlights the value of remote monitoring in proactive hive management and early detection as a means of addressing issues that conventional beekeeping techniques encounter. The elements of vibration, audio, temperature, humidity, hive weight, and other sensors that are part of remote monitoring systems are explained. Together, these sensors add to a thorough knowledge of the behaviour and health of hives. Beekeepers may take rapid, well-informed decisions thanks to real-time data transmission to centralized platforms, which encourages proactive interventions and improves overall hive management. The benefits of remote monitoring are emphasized, including improved production, resource efficiency, and early problem discovery. Early detection of diseases and pests reduces the impact on bee colonies, and resource efficiency results from a decreased need for frequent physical inspections. Optimized hive management based on real-time data analytics leads to increased production. There are recognized difficulties, including data security, implementation costs, and the requirement for education among beekeepers. The symbiotic relationship between conventional beekeeping knowledge and cutting-edge Internet of Things advancements, pointing to a peaceful and sustainable future for apiculture. This study highlights the critical role that remote hive monitoring plays in improving beekeeping techniques, protecting the health of bees, and promoting ecological balance through increased sustainability and productivity.

Keywords: Internet of Things (IoT), beekeeping, Early detection, apiculture, hive management

INTRODUCTION

In the agricultural field of beekeeping, *Apis Mellifera* bees are bred specifically to harvest honey and other products from the hive. Since ancient times, *Apis Mellifera*, a semi-domestic species, has been extensively utilized for its significant role in pollination, particularly of vegetable and fruit crops, as well as for the production of honey, wax, and pollen. The monitoring of environmental conditions is one significant application of the Internet of Things (IoT) technological integration that has changed different sectors. This technological development has become of special significance in industries like agriculture where accuracy and current data are essential. Monitoring environmental conditions is essential in this situation as it helps with resource optimization and well-informed decision-making. One of the most active species on earth is bees.

However, the honeybee is the most significant member of the bee family since it serves as the main pollinator of numerous horticultural and agricultural crops in addition to producing honey and bee wax. Honey can be made artificially, a process known as beekeeping, or spontaneously **(Pandimurugan *et al.*, 2021).** Approximately 75–80% of honey produced naturally comes from hilly or forested regions, and beekeepers use specially constructed wooden boxes known as honey boxes. According to a BBC story, there is a huge global demand for honey, yet there isn't enough of it in the world. The average annual honey consumption of Europeans is 0.7 kg (1.5 lbs), and the EU is the world's largest importer, purchasing in approximately 200,000 tons; behind China, it is the world's second-largest producer of honey. Now, most farmers are concentrating on beekeeping in order to supply the enormous demand for honey. The artificial boxes that are constructed by humans are used to domesticate and properly care for colonies of bees (**Burma, Z. A. 2023).** Farmers could have 500–1000 honey boxes in their bee yard at any given time. For this reason, it is challenging for farmers to give each hive a same amount of concentrate. Globally, dynamic factors like population increase and shifting consumer needs are causing a constant process of development and transformation in the food production and agricultural sectors. A major component of this change is beekeeping, which has significant ecological and economic value. In today's world, beekeeping is seen

as an activity that combines plant resources, bees, technological knowledge, and labour force. It holds significant economic and ecological value. Since ancient times, beekeeping has been a significant human endeavour. It attempts to preserve the natural balance of life while also generating honey and other honey products that support the economy **(Kady *et al.*, 2021).**

Beekeeping is a significant source of both jobs and revenue. Bee keeping's digital transition will be a hope for raising output and national income. Beekeeping lies at the crossroads of sustainable agriculture and environmental preservation. Bee pollination is essential to the preservation of plant diversity and the enhancement of agricultural product productivity. As a result, bee keeping's efficiency and sustainability are essential to the agriculture industry's general health. But in recent times, the beekeeping industry has encountered several difficulties. Globally, threats to the health and survival of bee colonies include habitat deterioration, pesticide use, disease transmission, and climate change. Beekeepers experience crop losses as a result of these risks, and the health of the ecosystem declines. Nevertheless, despite these difficulties, we live in a technological age when the beekeeping industry has a lot of potential thanks to digital transformation powered by developing technologies **(Mohseni *et al.*, 2022).**

During this time, waving the quality and efficiency of beekeeping will benefit agriculture as well as beekeeping. observe the emergence of digital transformation in beekeeping as a ray of hope for the industry's ability to solve these issues. In order to meet the growing demand for food, raise farmer living conditions, ensure agricultural development, and increase productivity in production elements, beekeepers must embrace new technology **(Gürer & Akyol, 2018).** Recent years have seen a fast change in technology. In agriculture, production techniques and technologies are always evolving. Farmers are given the opportunity to employ innovative ways at different phases of production. Agricultural farms generally Favor keeping things as they are. Farmers find it difficult to adopt new ideas and implement them gradually **(Kaya, 2022).**

OVERVIEW OF TECHNOLOGY

The rise in popularity of the Internet of Things (IoT) is a result of advancements in contemporary wireless communication technologies. This concept's fundamental building block is the creation of applications that make life easier for people by allowing items to speak with one another **(Guisto *et al.*, 2010)**. End users are connected to various communication systems using the conventional internet communication infrastructure. Thanks to recent technological advancements, a multitude of sensor devices can be connected to the internet via WSN (Wireless Sensor Networks) systems **(Akyıldız *et al.* 2002)**. IoT refers to the capability of addressable things and objects built on standard communication protocols to communicate online (Bassi & Horn, 2020). In this manner, production will continue around the clock, even throughout the night, and a wide range of items, including electronics, furniture, and printed documents, will be linked to the internet. Products of this technology include robot vacuums, air fryers, smart kitchen appliances, and smart home gadgets that we have been accustomed to using on a daily basis and cannot live without. According to **Aktaş *et al.* (2014)**, the Internet of Things is a network structure that allows machines or devices to communicate with one another, gather data, and make decisions based on that data without the need for manual data entry or human intervention. The term "smart" is now applied to numerous sectors where the Internet of Things is deployed. the start for most people. These include smart applications for the house, smart cities, smart banking and finance, smart scientific research, smart energy, smart public sector, smart agricultural production, smart health, and smart applications for smart home and city. Digital transformations are occurring in all these domains, encompassing the shift from traditional procedures to technological ones.

Using plant resources, bees, and labour, beekeeping is a nature-dependent livestock breeding activity that produces living materials like queen bees and swarm bees as well as goods like honey, beeswax, pollen, royal jelly, propolis, and bee venom **(Aksoy and Öztürk, 2012).** Bees are significant organisms that have numerous positive effects on the environment and the agricultural industry. According to Einstein, "man would have only four years to live if bees disappeared from the earth." Bees are necessary for fertilization, without which there would be no plants, animals, or humans. The pollination process, which is essential for the reproduction of fruits, vegetables, flowers, and other plant species, is carried out by bees. Bees also carry the pollen from plants. In the absence of bees, many Plant species would be incapable of procreating. In a similar vein, low pollination would result in reduced plant yield, or production. As a result, bees are essential to both natural ecosystems and agriculture. The pollination of many agricultural crops by bees is responsible for their growth and productivity. Wildlife also heavily depends on bees as a food source. Particularly, bats, birds, and certain insects feed on bees. Bee-produced honey is a tasty and nutritious food source. Humans ingest honey and use it for certain medical purposes. Bees gather pollen from plants, which are used to make goods like medications and dietary supplements. Bees eliminate organisms that degrade. This preserves the harmony and cleanliness of the natural world. Plant diversity is increased by bees. The global environment is enhanced and new plant species are promoted. One industry that boosts the economies of many nations is beekeeping. Bee products like honey, beeswax, propolis, and venom are sold to make money. Research in the medical field has focused on bee venom and other compounds. Particularly, bee venom is utilized to treat certain medical conditions. Apitherapy is used in alternative health healing. Bees are essential to the health of our ecosystems and have numerous advantages, including the production of food and the preservation of the natural environment. Thus, it is imperative that bees are safeguarded and lead healthy lives for the benefit of both humans and the environment.

IoT IN BEEKEEPING

IoT is rapidly taking centre stage as a catalyst for the creation of novel and disruptive (remote) monitoring systems, drawing on writers like **Symeonaki *et al.* (2022)**. These systems are built around sensing nodes that are constantly connected, scalable and adaptable in terms of adding updates when new requirements arise, and globally interoperable.

Moreover, numerous examples of IoT-based frameworks, ontologies, applications, and approaches may be found in the literature that is now in publication **(Chukkapalli *et al.,* 2020, Farooq *et al.,* 2020, Symeonaki *et al.,* 2022).**
IoT-driven remote agriculture monitoring the term "4.0" describes the use of Internet of Things (IoT) technology for remote management and monitoring of agricultural operations **(Abbasi *et al.,* 2022)**. In order to gather and send data from several sources, it entails integrating sensors, devices, and networking technologies. assets related to agriculture, including soil, cattle, crops, and machinery. From a more pragmatic standpoint, IoT-based remote monitoring is seen as an enabler of real-time data acquisition and analysis when applied to the agriculture 4.0 paradigm. This provides farmers, livestock breeders, poultry farmers, pig farmers, goat farmers, beekeepers, and many other industry players with valuable insights for making decisions, maximizing resource usage, and enhancing overall efficiency. IoT sensors, network connectivity, data processing, and visualisation tools are among the system's essential elements **(Araújo *et al.,* 2021, Maffezzoli *et al.,* 2022).**
In order to record and gather data, IoT sensors are used in agricultural settings **(Roy and De, 2022)**. Numerous parameters, including as temperature, humidity, soil moisture, pH levels, nutrient content, rainfall, air quality, and livestock behaviour, can be measured using these sensors. They are able to be installed in machinery, greenhouses, animal housing, and fields to continuously monitor important variables influencing agricultural productivity (Swain et al., 2021). According to **Miranda *et al.* (2019)**, the data gathered from Internet of Things (IoT) sensors is transferred to a centralized platform or cloud infrastructure for storage and analysis using wireless networks like Wi-Fi, cellular networks, or Low-Power Wide-Area Networks (LPWAN).
It is possible to analyse the data from IoT-based remote monitoring systems using sophisticated analytics methods and algorithms. To find patterns, spot abnormalities, and get useful insights, machine learning and data modelling techniques can be used **(Pyingkodi *et al.*, 2022)**. Predictive analytics, for instance, can assist in anticipating weather patterns, disease outbreaks, or agricultural growth phases, allowing for resource allocation and preventive interventions **(Xu *et al.*, 2022)**. Tools for visualisation, like Dashboards and data visualisations facilitate consumers' intuitive comprehension of the gathered data. These tools enable farmers to quickly assess the state of their agricultural operations and react to new possibilities or difficulties by providing real-time data, historical patterns, and alarms in an easy-to-use manner. According to **Zhao *et al.* (2020)**, IoT-based monitoring can therefore lead to the development of decision support systems that rely on real-time data gathering, analysis, and visualisation to assist farmers in their daily decision-making and strategic planning.
Improved production, lower costs, more sustainability, and better resource management are some advantages of IoT-based remote monitoring in Agriculture 4.0. By consistently tracking important metrics, farmers may maximize their use of fertilization, irrigation, and pest control techniques, improving resource allocation and reducing environmental influence. Furthermore, losses can be avoided and total production and animal welfare can be enhanced by early detection of anomalies or deviations in crop health or livestock behaviour **(Maffezzoli *et al.,* 2022).**
So, based on the previously mentioned points, IoT-based remote monitoring in Agriculture 4.0 makes use of connectivity, sensor technology, data processing, and visualisation to facilitate real-time monitoring and agricultural operation decision-making. With the help of this strategy, farmers will be able to more effectively manage their resources, react quickly to changing circumstances, and implement precision agriculture techniques for profitable and sustainable farming.

PARAMETERS FOR MONITORING BEEHIVES

Bee populations have significantly decreased recently as a result of a number of environmental issues as well as the possibility of colony collapse disorder. Beehive monitoring has become a viable answer to this problem, aiding beekeepers in their endeavours to save these vital pollinators **(Anwar *et al.,* 2023)**.
Utilizing cutting-edge technology, beehive monitoring collects data and insights in real time from beehives. Beekeepers may keep an eye on vital indicators like temperature, humidity, weight, and sound by installing a variety of sensors inside the hive. These sensors give beekeepers important information on the general health and well-being of the colony, enabling them to take fast action when needed **(Abdollahi *et al.*, 2022, Bellino *et al.,* 2022)**.
One of the main advantages of beehives monitoring is the process of identifying possible problems early. For instance, abrupt changes in humidity or temperature may be signs that the hive is stressed. In this case, quick action is needed to determine and treat the underlying issue, which could be a disease or pests **(Zaman and Dorin, 2023).** Beekeepers can gain valuable insights into honey production and ascertain the best time to collect honey by monitoring the hive's weight. This ensures that the honey yield is maximized while still providing sufficient honey for the bees to survive **(Robustillo *et al.,* 2022)**.
According to studies by authors like **Ntawuzumunsi *et al.* (2021) and Szczurek *et al.* (2023)**, evaluating a beehive's general health and productivity (perspectives) requires efficient and effective multi parameter monitoring. The relevant research also reveals a number of Indicators that are frequently employed for monitoring systems in apiaries and beehives that are intended to provide information on the occurrence of critical changes that may suggest that human intervention is necessary to maintain the colony include.

Weight
Keeping an eye on the weight enables beekeepers to provide the necessary information regarding a hive's condition **(Meikle *et al.*, 2016)**. The almost real-time availability of this data allows for the emergence of reliable assessments of the hive's condition. The hive's weight decreasing tends to symbolize the occurrence of events for which it is vital to determine the cause and magnitude of the overall impact produced. A few instances of these occurrences are changes in the colony's population number and the presence of unfavourable environmental circumstances. that may have caused swarming, the necessity to provide food, or the act of collecting honey itself **(Cecchi *et al.,* 2020, Fitzgerald *et al.,* 2015, Hong *et al.,* 2020)**. Therefore, without upsetting the colony, weight monitoring gives beekeepers' exact information to assess the state of the hives and determine whether harvesting or human intervention is necessary.

Temperature
In order for honeybee reproduction to occur, the air temperature inside the hive must stay constant and, at worst, hover between + 15 and + 35ºC. In order to maintain the stability of the mentioned temperature, bees produce metabolic heat by forming clusters in the event of low temperature or by carrying water into the interior of the hive in the event of high temperature, which increases humidity. Stability of temperature is a crucial sign of the health of the colony **(Edwards-Murphy *et al.,* 2016).** As per **Zacepins *et al.* (2016)**, temperature rise is also a significant sign of swarming, a natural occurrence that can have detrimental effects on profitability if beekeepers do not control.

Humidity
Keeping an eye on the hives' relative humidity is important for assessing the health of the colonies and directly affects output **(Mohamed and Mansor, 2023).** The literature currently in publication has demonstrated that temperature and humidity differ depending on the subspecies of bees **(Gil-Lebrero *et al.*, 2020)**. For example, **Hong *et al.* (2020)** state that in order to improve egg hatching, the hive's relative humidity needs to be between 90% and 95%. Nevertheless, writers like According to **Andrijević *et al.* (2022),** beehives have a greater chance of ensuring sustainable growth over time when they maintain a temperature of 35ºC and a humidity percentage of about 75%. Based on the foregoing, it is imperative to provide long-term monitoring of the hive's relative humidity since, in addition to temperature, it helps to trigger the beekeeper's rapid intervention.

Sound
The general health and vigor of a hive can be inferred from the sound that bees make. The characteristic noises that a robust and healthy hive makes are usually connected to the labor of the worker bees. As a result of potential problems that need to be addressed, such as illnesses, foraging activities, swarming, or other colony events, weak or stressed colonies, on the other hand, may display distinct sound patterns **(Abdollahi *et al.,* 2022).** Therefore, keeping an eye on the A hive's sound will therefore enable the gathering of information that the beekeeper can utilize to, in conjunction with the definition of alarm mechanisms, be able to respond in advance of the happening of events or circumstances that jeopardize the hive's sustainability and health **(Kulyukin *et al.,* 2018, Murphy *et al.,* 2015).**

Number of People
The population size is also mentioned in a number of works as a sign of the health and productivity of the hive. The survival of honeybee colonies can be compared to complex systems, with each individual bee's quality, adaptability, and resistance to different stresses playing a crucial role. The death of colonies is probably caused by a variety of stress factors interacting with one another **(Requier, 2019).** Therefore, by guaranteeing effective oversight of the amount of the colony, beekeepers are able to proactively predict major problems that could jeopardize the beehive. A variety of methods are proposed in the literature to count or estimate the number of bees in a beehive at a given time. These methods range from systems that use RFID tags attached to the back of the bees to allow detection at the entrance of the hive **(Schneider *et al.,* 2012)** to an array of photoelectric or infrared sensors on both sides of the individual holes in the hive entrance that, by detecting the sequence of the interruption of the radiation beams, can give information about the movement of the bees (i.e., leaving or entering the hive) that is ultimately used to estimate the population size **(Struye *et al.,* 1994).** Real-time imaging systems that can identify every person within the hive through a series of analyses to a collection of captured photographs **(Ngo *et al.,* 2019).**

ADVANTAGES OF BEEKEEPING WITH REMOTE MONITORING
Early Problem discovery
Having instant access to real-time data helps minimize the effects on the bee colony by facilitating the early discovery of issues like pest infestations or diseases.

Proactive Management
By utilizing real-time data, beekeepers may optimize variables such as temperature, humidity, and hive weight to achieve optimal productivity from their hives.

Efficiency of Time and Resources
By reducing the need for frequent physical inspections, remote monitoring conserves both time and resources. Instead of doing routine inspections, beekeepers can concentrate on focused interventions.

Enhanced Productivity and Sustainability
Remote monitoring helps to promote sustainable beekeeping methods and higher honey production by maximizing hive conditions and quickly resolving problems.

MAJOR CHALLENGES OF IoT TECHNOLOGIES

The benefits of integrating advanced technologies into beekeeping practices are substantial, several challenges must be addressed to ensure a successful transition. One prominent concern revolves around data security, as the implementation of technology often involves the collection and management of sensitive information. The safeguarding of data against potential threats is crucial to maintaining the integrity of beekeeping operations and ensuring the privacy of valuable information.

Another significant hurdle is the early installation costs associated with adopting technological solutions in beekeeping. The initial investment required for acquiring and implementing these technologies may pose a barrier for some beekeepers, particularly those operating on limited budgets. Overcoming this financial obstacle is essential to encourage widespread adoption and allow beekeepers of various scales to harness the benefits of technological advancements.

Moreover, addressing the educational needs of beekeepers is imperative for the successful integration of these technologies. Providing comprehensive training and educational programs will empower beekeepers to understand, utilize, and optimize the technology effectively. This educational focus is essential to bridge the knowledge gap and equip beekeepers with the skills required to navigate the intricacies of modern beekeeping technologies.

Looking ahead, future advancements in beekeeping technologies should prioritize ensuring a seamless integration with traditional beekeeping operations. Striking a balance between innovation and the preservation of established practices is key to fostering acceptance and adoption within the beekeeping community. Additionally, efforts should be directed towards increasing the accessibility of these technologies, making them more readily available to beekeepers across diverse geographic and economic contexts.

CONCLUSION

Beekeeping techniques have advanced significantly with the use of IoT in remote hive monitoring. IoT technology enable beekeepers to make educated decisions, increase production, and support the general health of bee colonies by giving real-time information into hive conditions. The combination of cutting-edge discoveries and conventional wisdom suggests a viable future for beekeeping as technology advances. In conclusion, beekeeping techniques have advanced dramatically as a result of the use of IoT technologies for remote hive monitoring. Real-time data collection on vital parameters like temperature, humidity, hive weight, and even vibration and sound patterns provides beekeepers with previously unheard-of insights into the behaviour and overall health of their colonies. There are numerous advantages to remote monitoring. Continuous data streams enable early problem diagnosis and proactive action, which reduces the impact of pests and diseases on bee colonies. Proactive maintenance not only improves the hive's general health but also boosts productivity by improving pollination efficiency and honey production. There are significant time and resource savings via remote monitoring. Beekeepers are able They now focus on targeted treatments rather than merely doing routine physical inspections, allocating their efforts more wisely. This creates opportunities for sustainable beekeeping methods while also conserving resources. Issues like data security, the initial expenses of implementation, and the requirement for education among beekeepers must be addressed. In order to overcome these obstacles and make IoT technology more widely available and easily incorporated into conventional beekeeping methods, future advances should focus on these issues.

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