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The monitoring system for Imperial Eagles within the concept of Industry 4.0

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***Abstract* – This paper presents some ideas that could contribute to the conservation and further reproduction of Imperial Eagles and other birds. Industry 4.0 enables us to achieve complete automation of the monitoring process of eagle reproduction in real-time using a specific application, as well as significant resource savings.**

Keywords—Industry 4.0; Smart sensors; ESP32; Smart cameras; IoT.

I. Introduction

The most powerful predator in the sky, yet the most vulnerable on the ground, no other species is as endangered. This bird is on the Serbian flag, the least it deserves is for all of us to protect it together. A formidable raptor, at the top of the food chain in nature. What the brown bear is on the ground, it is in the sky. We have taken it as our national symbol. Imperial Eagles are the rarest bird of prey in Serbia. In the Red List of Birds of Serbia, they are classified as critically endangered species due to their extremely low numbers and the great threats to their survival in nature [7]. The Imperial Eagle on our coat of arms dates back to the Byzantine era. With one head looking towards the heavens and the other towards the earthly realm. Thanks to its hunting abilities, it is unrivaled in nature. With a wingspan of up to 2.15 m, a length of up to 84 cm, and a weight of up to 4.5 kg. Its strongest weapon is its sight, eight times better than that of a human. It swoops down at a speed of 171 km/h. The muscles in its eyes adapt, retaining focus and depth perception, seeing the tiniest detail, rarely missing prey. Its main food sources are mammals, mice, and ground squirrels. They used to inhabit Fruška Gora, Deliblatska peščara, and Vršački breg. It was threatened primarily by poaching, poisoning, and the disappearance of ground squirrels. We were left with only one pair nesting and still nesting today, in the north of Banat, near the village of Srpski Krstur. It wasn't until ornithologists, biologists, and volunteers got more involved that the situation improved. Today, we have 8 nesting pairs, whereas in 2016, we were left with only one nesting pair of Imperial Eagles. They are the selectors of who should survive and who should not, and they do it unfailingly, always choosing the stunted individuals from nature.

The period when eagles lay eggs poses a challenge, especially due to the need for constant monitoring. If the eagles get disturbed or sense human presence, there is a risk of them abandoning the nest, exposing the eggs to the danger of cooling or takeover by other birds. This monitoring process lasts about 120 days per year, from the moment the eggs are laid until the young eagles begin to fly. During March and April, the female lays several eggs, and the young eagles leave the nest after 60-80 days [1].

Fig. 1. Imperial Eagle on the flag of the Republic of Serbia

Every day, a dedicated person monitors the Imperial Eagle nest during the critical period of their development and reproduction. They carefully observe when the Imperial Eagle most frequently leaves the nest to determine the optimal time to

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deploy the drone. They track every moment when the birds exit the nest, recording their activities and behavior. These regular observations enable the creation of a detailed picture of the life and habits of the Imperial Eagles. The current approach, where a person visits and monitors the nest daily over an extended period, can be enhanced by implementing Industry 4.0. This technology enables continuous monitoring and tracking of various parameters 24 hours a day. One of the goals of this project is to make this system accessible to everyone, allowing easy use without the need for prior knowledge or training.

Bird monitoring should bring benefits to both humans and birds. This monitoring should enable efficient use of human time, providing access to data from the comfort of the office or any other location where humans are present. This eliminates the need for daily field visits to observe the birds. Through this observation process, we could better understand what is more acceptable to the birds, how they behave during different periods of the year, how they feed, and when they leave their nests. This deeper understanding of their lives would enable us to improve the development of Imperial Eagles for future generations.

Fig. 2. Imperial Eagle

Tracking of Imperial Eagles in Serbia began for the first time in 2021, with the help of satellite transmitters. This will allow ornithologists from the Bird Protection and Study Society to obtain a large amount of real-time information that can ensure the survival of this species. Two young Imperial Eagles were marked with satellite transmitters for the first time in Serbia, sending valuable information that will help to better understand and protect their species.

Fig. 3. Satelite transmitter attached to a young Imperial Eagle [2]

The transmitter features a small solar panel, while the battery within the device regularly receives power. The device communicates with the GSM network, sending data about its location. Additionally, the device communicates with a satellite and transmits information once or twice during the day, depending on its configuration. It determines the bird's altitude, measures its speed and body temperature. Crucial information includes the bird's location; if the bird remains stationary, it may be assumed to be poisoned, killed, deceased, or simply detached from the transmitter. Since we know its location, we can locate it and assess the situation. Furthermore, we have information about the date, time, battery charge level, magnetic field strength, and ambient light. Data updates can be performed via GSM, GPRS, 3G, or 4G networks. SMS messages are sent when GPRS or 3G are unavailable. Recorded data is stored in memory if the phone network is unavailable [3].

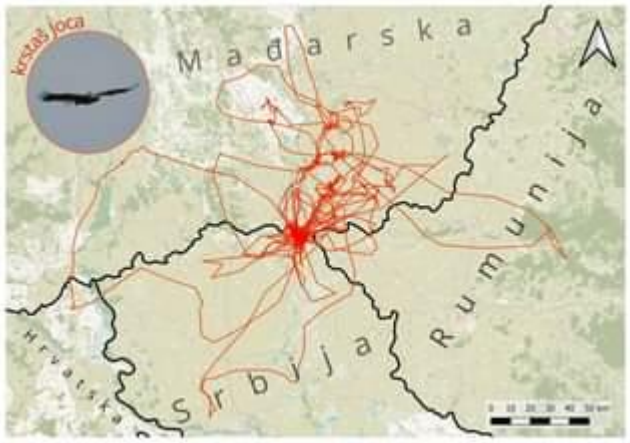

Fig. 4. Movement of the marked Imperial Eagle named Joca [2]

II. Real-time measurement and monitoring of imperial eagle development

With the advent of Industry 4.0, sensors begin to play a crucial role as componnts that collect information about the state and operation. For this reason, they must gather a large amount of data in real time while remaining energy-efficient. The development of metrology has enabled us to utilize such technologies, which are crucial for the development of Imperial Eagles. This aspect of Industry 4.0 requires constant measurements, data collection from sensors, as well as interconnectivity and communication among the sensors themselves. Metrology and smart sensors are expected to significantly advance this branch of industry by facilitating the implementation of various advanced technologies, such as the Internet of Things, Cloud computing, and others, thus undoubtedly streamlining production processes. The data collected from smart sensors enable us to draw new conclusions aimed at the preservation and further breeding of Imperial Eagles. With all the accumulated data, new insights into the developmental processes of various bird species can be gained. The introduction of smart sensors and IoT solutions is not meant to completely exclude humans from this process but rather to enhance efficiency and productivity. IoT plays a role in providing efficient access to data over long distances. Some fundamental questions related to the contribution of real-time measurements are:

1) What benefits would the introduction of such measurements bring?

The introduction of such a measurement system would represent a significant step towards better understanding and protecting the Imperial Eagles. It involves identifying weather conditions that best suit them, understanding their food intake needs during different seasons, which is crucial for maintaining optimal bird health. Monitoring bird behavior during key stages such as egg laying and raising young helps detect potentially stressful situations. This enhanced understanding allows for measures to reduce the impact of stress on birds. Detailed monitoring of the periods when birds leave the nest enables an understanding of their habits and needs during these crucial moments. This can contribute to more effective nest management and increase the chances of successful breeding. Such a measurement system not only enables a better understanding of bird behavior but also provides a basis for the preventive implementation of protective measures, contributing to long-term preservation.

2) Would we save time and money by implementing real-time measurements?

Implementing real-time measurements would bring significant savings in both time and money, especially during the critical period of 120 days during reproduction. Currently, a person is present daily, for several hours a day, throughout this period to observe activities in the nests. The implementation of real- time video surveillance would greatly facilitate this process. This system would enable precise monitoring of when the bird leaves the nest, how much time it spends outside, and during which part of the day these exits most frequently occur. Knowing these details opens up the possibility of efficient drone usage. For example, if it is noticed that the bird regularly leaves the nest at a certain time, a drone can be deployed during that time to check for a new brood or to assess the condition of the chicks. With this approach, besides saving human time, there is also the opportunity for quicker responses to key events in the birds' life cycle, contributing to more efficient and precise monitoring of their behavior.

3) Would the results of the measurements contribute to the development and reproduction of birds?

The measurement results should have a significant contribution to the development and reproduction of Imperial Eagles. Although reproduction is to some extent a natural process, understanding the conditions under which it occurs plays a crucial role in adapting and improving their environment. Measurements would provide insights into the specific conditions optimal for the reproduction of Imperial Eagles. This information would be invaluable as it could anticipate what exactly suits them best, thereby adapting the environment accordingly. This approach enables the creation of better conditions for reproduction, ultimately contributing to the preservation and development of future generations of Imperial Eagles.

III. Proposal for problem solution

Within the initiative to preserve and develop the population of Imperial Eagles, the implementation of an automated system has been proposed as one of the possible solutions. This innovative system would be designed with the primary goal of protecting these magnificent birds, representing a blend of nature and advanced technology. The main feature of this system would be its ability for continuous remote monitoring, available 24 hours a day. The use of Industry 4.0, which heavily relies on automation and digitalization, allows us to create intelligent monitoring systems. The proposed system would consist of sensors deployed at key locations in the habitats of Imperial Eagles. These sensors would collect various types of data. The data collected by the sensors would be further processed and analyzed to identify the behavior patterns of Imperial Eagles and detect potential threats to their survival. The system would consist of two main parts.

The first part would consist of temperature and humidity sensors, as well as air quality sensors. The main component of this part of the system would be the ESP32 microcontroller, which would process the data and have the ability for wireless communication via WiFi networks. The ESP32 microcontroller can communicate via WiFi over distances ranging from several tens of meters to even several hundred meters, meaning that internet access nearby would be necessary. This would enable remote real-time data monitoring, providing insights into environmental changes. For additional energy efficiency and independence from power sources, solar power would be utilized. It would allow for long-lasting and reliable operation in remote areas. All these components would be housed in a compact and durable box designed for easy installation in the natural environment. The data collected by the ESP32 microcontroller from the sensors would be sent via WiFi to the IoT Cloud. The Cloud would serve as a data repository where data analysis and processing would take place. The processed data would then be transported to an IoT application where users could utilize the processed data. This would demonstrate the full value of IoT and give it a more practical application. It would allow us to monitor temperature, humidity, and air quality in real-time on smartphones, tablets, or computers [4].

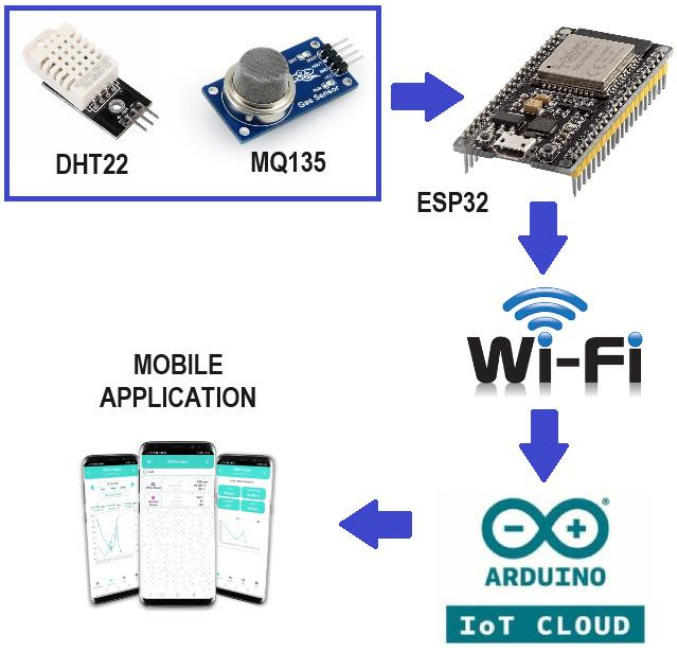

Fig. 5. Representation of the first part of the solution, from data collection to data display on a mobile phone [4]

Fig. 6. Model of the box where the first part of the solution would be placed [6]

The second part would consist of a system for monitoring Imperial Eagles, equipped with a WiFi camera, providing a unique opportunity to peek into the world of these magnificent birds. The WiFi camera would be positioned at a certain distance from the nest, featuring solar-powered operation to ensure continuous recording of events around the nest. The camera selected for its solar-powered function is the EufyCam 3. It would capture precious moments when the Imperial Eagle leaves the nest and returns. The WiFi camera would enable real-time monitoring via an application on a mobile phone, tablet, or computer. This should be a good way to study and preserve Imperial Eagles, discovering their world in a completely new way, tracking every flight and moment of their lives [5].

Fig. 7. Nest Monitoring System [5]

IV. Discussion

The proposed system brings a number of significant benefits, primarily in saving human time and improving efficiency. The ability to access real-time data allows access to information available anytime, anywhere. Based on the collected data, the needs and behavior of Imperial Eagles during key periods of their development can be better understood. This enables better adaptation of conditions to their environment. Through improved understanding of their behavior and needs, we can develop strategies and measures that will support the survival and prosperity of future generations of Imperial Eagles.

While this system brings certain advantages, there are also drawbacks that require attention. This initial idea serves as a foundation with great potential for enhancement and improvement. It is possible to expand monitoring by adding new parameters or developing an application that would allow the display of sensor data as well as live camera feed in one, as shown below, in the pictures. The box containing the sensors and microcontroller could be better designed to improve functionality, durability, and aesthetics. Adding GPS to the box may be useful for tracking location, in case of theft or unforeseen situations such as falling branches or trees. Also, before adding additional sensors, it is necessary to carefully assess the capacity of the ESP32 microcontroller to avoid technical obstacles. In case of unavailability of information from the microcontroller, there are several potential reasons that could cause it. The microcontroller may be exposed to power supply problems if the battery powering is not in optimal condition or if its power has weakened. Signal problems can cause loss of communication between the microcontroller and sensors. There is a possibility that the entire box with the microcontroller has fallen or been damaged in some other way, such as falling into water. Disconnections within the box can lead to interruptions in communication or the functioning of the microcontroller. Sensors that are malfunctioning or damaged can cause loss of relevant information or interruption in their collection. All of these situations can lead to temporary or permanent loss of data or communication with the microcontroller, requiring urgent problem-solving to ensure normal system operation. Also, with the camera, a potential problem could be exposure to external weather conditions. Any severe weather can compromise the integrity of the camera or even cause it to detach from its mount. Potential limitations of the system may arise if the nest is located in an area with poor signal, which can affect the reliability of data transmission.

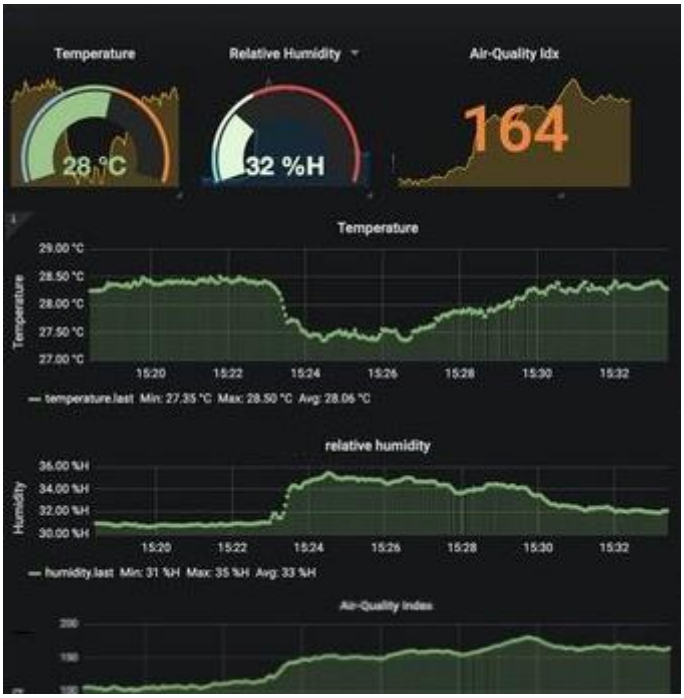

Fig. 8. Model of how the application could look, first part [4]

Fig. 9. Model of how the application could look, second part [4]

The displayed images provide an example of how the application would look, providing real-time information about sensors and nest recordings. This initial idea can be further developed to allow users to access information about a specific nest of their choice upon entering the application. By introducing GPS functionality, users could see the exact location of the nest on the map, providing additional convenience and accuracy in tracking activities. This concept represents the beginning of creating a useful application that would enable efficient tracking and analysis of nest data in real-time.

V. Conclusion

The conclusion of this paper emphasizes the dynamic advancement of technology and provides valuable ideas for improvement. The concept presented in this paper would not be limited solely to Imperial Eagles but could be expanded to other bird species, and perhaps even some animals. This indicates broader applicability and potential for the development of similar projects. The assessment of this concept as a good idea for further project development confirms its significant potential. It is crucial to achieve a positive balance between benefits and losses during the design phase. The project makes sense only if it has a positive impact and contributes to the community, rather than the other way around.

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