BAB I

INTRODUCTION

1.1 Background of the Study

Fire-Belly Newt (Cynops orientalis) is one of the salamander species that is commonly kept as a pet and for educational purposes. This species originates from temperate to cold regions in eastern China, making it naturally adapted to relatively cool and stable aquatic environments[1]. The species requires specific environmental conditions, including an ideal temperature range and water quality that must be carefully maintained. Fire-Belly Newts are highly sensitive to drastic environmental changes, where fluctuations in environmental conditions may cause stress and even increase the risk of mortality[1]. In practice, manual maintenance has limitations in maintaining environmental parameters consistently over time. Therefore, a monitoring system that is more consistent and accurate is required to lowize potential disturbances to the animal's health. In addition, lighting also plays an important role because it affects the growth of plants that contribute to maintaining ecosystem balance within the paludarium. Therefore, the use of a light sensor is necessary to monitor light intensity in order to ensure suitable conditions for aquatic plants, thereby maintaining a stable environment for the Fire-Belly Newt. In practice, Fire-Belly Newts are generally kept in paludariums to replicate the conditions of their natural habitat.

A paludarium is an artificial ecosystem that combines aquatic and terrestrial elements, replicating natural conditions for amphibians and plants that inhabit both environments[2]. In a paludarium inhabited by Fire-Belly Newts, the aquatic area plays a more dominant role because this species spends most of its time in the water.[1] Although the terrestrial area is still required as a place for resting or perching, its influence on the animal's health is not as significant as the aquatic factors. Therefore, the regulation of environmental parameters is more focused on maintaining water quality. Manual monitoring is often time-consuming and prone to errors, making a more efficient method necessary to maintain the balance of this ecosystem.

In this study, the environmental parameters focused on are temperature, light intensity, and water turbidity. The selection of these three parameters is based on their dominant roles in influencing the stability of the paludarium ecosystem. Temperature plays a role in regulating the physiological conditions of organisms, light intensity affects the growth of aquatic plants that contribute to maintaining ecosystem balance, while water turbidity reflects the quality of the living environment related to the level of environmental cleanliness [3]

Environmental stability is a crucial aspect in the maintenance of Fire-Belly Newts. Uncontrolled environmental parameters may lead to a decline in health conditions and even mortality, which not only affects the survival of the organisms but may also result in losses for the keeper. Therefore, a more accurate and consistent environmental monitoring and control system is required to maintain environmental stability. [4]

The Internet of Things (IoT) has become one of the technologies widely utilized in the fields of environmental monitoring, environmental control, and animal management[5]. With the support of various sensors, such as the DS18B20 sensor for detecting water temperature, a turbidity sensor for monitoring water turbidity, and a light sensor for measuring the light intensity required by aquatic plants, the data collection process can be performed in real-time and with greater accuracy compared to conventional methods. The collected data not only provide information regarding current environmental conditions but can also be analyzed to detect patterns or anomalies that may affect the health of the organisms. Furthermore, IoT integration enables remote control through connected devices, allowing users to directly adjust environmental conditions[6]. Therefore, IoT facilitates faster, more precise, and data-driven decision-making while also improving the efficiency of monitoring and controlling the stability of artificial ecosystems such as paludariums.

Research on the implementation of Type-2 Fuzzy Logic has also demonstrated advantages in handling high levels of uncertainty in environmental systems. One study developed an IoT-based humidity control system using a Type-2 inference mechanism, which was proven to provide potentially more stable control responses compared to conventional methods and Type-1 Fuzzy Logic[7]. The main advantage of Type-2 lies in its ability to handle a wider footprint of uncertainty and improve system robustness against fluctuations in sensor readings. However, the study focused only on a single parameter, namely air humidity, and therefore did not address the complexity of multi-parameter conditions in aquatic environments.

Type-1 Fuzzy Logic (T1) and Type-2 Fuzzy Logic (T2) are two approaches in fuzzy logic used to handle uncertainty in control systems. T1 utilizes a single membership value for each element, making it suitable for systems with low levels of uncertainty. In contrast, T2 employs interval-based membership values, allowing a more complex and flexible representation of uncertainty. Therefore, T2 has greater potential in handling uncertainty in sensor data and environmental conditions.[8]

In the implementation of sensor-based monitoring and control systems, one of the main challenges is the uncertainty in sensor reading data. Environmental sensors, such as temperature, light intensity, and water turbidity sensors, possess a certain degree of uncertainty due to noise and fluctuations in sensor readings. The Type-1 Fuzzy Logic approach is considered insufficient to optimally represent such uncertainty because it only utilizes a single membership function. Therefore, this study employs Type-2 Fuzzy Logic, which incorporates a Footprint of Uncertainty (FOU) to represent uncertainty in the membership degrees generated from sensor readings, allowing data variations and noise to be modeled more flexibly.[9] Nevertheless, the implemented control system still represents system outputs in a discrete form (ON/OFF), adjusted to the characteristics of relay-based actuators through defuzzification and thresholding processes. Thus, the application of Type-2 Fuzzy Logic in this study is focused on improving the quality of control decision-making rather than generating multilevel outputs.

This study aims to develop an IoT-based paludarium monitoring and control system capable of performing automatic control and real-time monitoring, thereby ensuring that environmental conditions can be maintained optimally at all times. In its implementation, the Interval Type-2 Fuzzy Logic method is utilized to regulate temperature, light intensity, and water quality precisely according to the requirements of Fire-Belly Newts. Through this system, the risk of stress and mortality caused by unstable environmental conditions can be lowized, while also providing convenience for users in monitoring environmental conditions accurately and continuously.

1.2 Probelem Formulation

- How can the Type-2 Fuzzy Logic method be implemented to regulate temperature, light intensity, and water turbidity parameters in order to maintain stability according to the ecological requirements of the Fire-Belly Newt paludarium?
- How can a microcontroller- and IoT-based system enable remote monitoring and control of Fire-Belly Newt paludarium conditions?
- How does the performance of a Type-2 Fuzzy Logic-based monitoring and control system contribute to creating optimal semi-aquatic microclimate conditions that support the health and survival of Fire-Belly Newts?

1.3 Research Objectives

1) To implement the Interval Type-2 Fuzzy Logic (Type-2 Fuzzy Logic) method in regulating temperature, light intensity, and water turbidity parameters in order to maintain stability according to the ecological requirements of Fire-Belly Newts.
2) To develop a microcontroller- and IoT-based system that enables remote monitoring and control of Fire-Belly Newt paludarium conditions.
3) To evaluate the performance of the Type-2 Fuzzy Logic-based monitoring and control system in creating optimal semi-aquatic microclimate conditions that support the health and survival of Fire-Belly Newts.

1.4 Scope and Limitations

1) The physical scope of the system is limited to a small-scale paludarium measuring 40 × 20 × 20 cm, where all experiments were conducted within the paludarium environment, and is not intended for commercial or outdoor applications.
2) The monitoring system can only be accessed through an internet network and depends on the stability of the internet connection.

3) System testing was conducted over a period of one month; therefore, the system performance evaluation was focused on functional aspects.

1.5 Research Benefits

1) For the Author

This study provides practical benefits for the author in developing technical skills in the field of microcontroller-based monitoring and control system design, the implementation of Interval Type-2 Fuzzy Logic (Type-2 Fuzzy Logic), and the utilization of IoT technology for remote monitoring and control. The author also gains a deeper understanding of maintaining the stability of a semi-aquatic microenvironment that is suitable for the ecological requirements of Fire-Belly Newts, particularly through the regulation of temperature, light intensity, and water turbidity parameters.

2) For Future Researchers

This study can serve as a foundation and reference for future research related to the development of environmental monitoring and control systems for semi-aquatic animals using IoT and Type-2 Fuzzy Logic approaches. The results of this study provide opportunities for the development of similar methods, either by adding other environmental variables such as dissolved oxygen levels and more detailed water quality parameters, or by integrating more advanced technologies. Therefore, this study not only contributes to the development of more adaptive monitoring and control systems but also encourages further innovation in the fields of wildlife conservation, artificial ecology, and smart habitats.

3) For Fire-Belly Newt Owners

Fire-Belly Newt owners can utilize the results of this study as a practical solution for maintaining these animals in a paludarium environment. The designed system helps maintain stable semi-aquatic conditions according to the ecological requirements of Fire-Belly Newts, thereby lowizing the risks of stress, disease, and mortality caused by unstable environmental conditions. In addition, the information generated by this IoT-based system can be used to monitor paludarium conditions in real-time, plan routine maintenance, and take preventive actions when environmental changes occur. Thus, this study not only supports the health and survival of Fire-Belly Newts but also assists owners in maintaining sustainable and high-quality animal care.