BAB V
CONCLUSIONS AND SUGGESTIONS

5.1 Conclusions

Based on the design, implementation, and testing results of the Internet of Things (IoT)-based Fire-Belly Newt paludarium monitoring and control system utilizing the Interval Type-2 Fuzzy Logic method, the following conclusions can be drawn:

1. The IoT-based paludarium monitoring and control system was successfully designed and implemented using an ESP32 microcontroller, DS18B20 temperature sensor, LDR sensor, and turbidity sensor as input devices, as well as a Peltier cooler, lamp, and buzzer as output actuators. The system is capable of monitoring environmental conditions in real time through the Blynk platform, enabling users to remotely observe the paludarium conditions.
2. The Interval Type-2 Fuzzy Logic method was successfully implemented for the temperature, light intensity, and water turbidity parameters through the stages of fuzzification, inference, type reduction, and defuzzification. The use of the Lower Membership Function (LMF) and Upper Membership Function (UMF) effectively represents uncertainties in sensor measurements caused by noise and environmental fluctuations, resulting in a more adaptive and stable decision-making process compared to conventional fuzzy approaches.
3. The functional testing results demonstrated that all sensors and actuators operated according to the predefined system rules. Based on 27 testing scenarios involving combinations of temperature, light intensity, and turbidity conditions, the system successfully executed the expected automatic actions with a 100% success rate.
4. The testing results of the DS18B20 temperature sensor indicated a high level of accuracy, achieving an accuracy of 99.69% with an error rate of 0.31%. Therefore, the sensor is considered capable of accurately measuring water temperature in accordance with the actual conditions of the paludarium.

5. Based on the environmental parameter analysis, the turbidity sensor exhibited a very high level of stability with a coefficient of variation of 0.16%, while the LDR sensor demonstrated responsiveness to real-time changes in ambient light intensity with a coefficient of variation of 4.29%. These results indicate that the system is capable of performing environmental monitoring in a stable manner while remaining adaptive to changing environmental conditions.
6. The developed system is capable of maintaining paludarium environmental conditions within ranges suitable for the Fire-Belly Newt through the automatic control of temperature, lighting, and water turbidity levels. Consequently, the system can help reduce the risk of stress caused by environmental fluctuations while improving the efficiency of long-term paludarium monitoring and maintenance.

5.2 Suggestions

Based on the results of this study, several recommendations are proposed for future research to further enhance and optimize the system, as follows:

1. Future studies are recommended to incorporate additional environmental parameters, such as water pH, dissolved oxygen (DO), air humidity, and other water quality indicators, to create a more comprehensive monitoring and control system that more closely resembles the natural habitat conditions of the Fire-Belly Newt.
2. The system may be further developed by implementing more advanced control methods, such as adaptive fuzzy logic, neuro-fuzzy systems, or the integration of machine learning techniques, to improve automated decision-making capabilities and enhance adaptability to environmental changes.
3. The actuator control mechanism can be improved by implementing multi-level control using technologies such as Pulse Width Modulation (PWM) or MOSFET-based control, allowing temperature and lighting regulation to operate with greater precision and efficiency rather than relying solely on ON/OFF control.

4. Future research is encouraged to conduct testing over a longer period to evaluate the long-term stability of the system, the durability of the hardware components, and the impact of the system on the health and behavior of the Fire-Belly Newt in greater detail.
5. The monitoring interface can be enhanced by incorporating features such as historical data storage, monitoring graphs, automatic notifications, and cloud-based data storage, enabling users to analyze environmental conditions more easily and systematically.
6. The system may be expanded for larger-scale applications or adapted to other semi-aquatic habitats, allowing the outcomes of this research to extend beyond Fire-Belly Newt paludariums and contribute to fields such as conservation, education, and the cultivation of other semi-aquatic species.