CHAPTER I
INTRODUCTION

1.1. Background of the Study

The development of Internet of Things (IoT) technology has provided significant opportunities in the field of modern agriculture, particularly in sensor-based plant management and smart systems [1]. This technology enables the automatic monitoring and control of environmental conditions through the integration of hardware, sensors, and artificial intelligence algorithms [2]. In the context of urban farming and plant conservation, IoT plays an important role in creating a suitable growing environment despite being outside of its natural habitat [3]. This becomes increasingly relevant given the limitations of land and climate change, which demand innovative solutions in maintaining plant survival.

One of the plants facing cultivation challenges is Drosera Sessilifolia, a carnivorous plant that naturally can only grow in outdoor environments with specific light conditions, water levels, and air temperatures [4]. Problems arise when this plant is grown indoors, due to the limited natural light intensity, water level regulation, and air temperature stability that do not correspond to its natural habitat. Without proper environmental management, the growth of Drosera Sessilifolia will be hindered, and it may even be at risk of dying [5].

The results of previous studies indicate that the Fuzzy PID method is capable of maintaining more stable temperature and humidity, increasing water use efficiency through automatic irrigation, and improving the quality of plant lighting. This small-scale smart greenhouse system has also proven effective in creating a suitable environment for plant growth, with a faster response to changes in environmental conditions compared to conventional methods. This study discusses the system integrating various sensors (temperature, relative humidity, soil moisture, and light intensity) with actuators such as fans, irrigation pumps, and LED lights, and uses Fuzzy PID control compared with manual methods [6].

Meanwhile, other previous research discusses the application of smart control in isolated greenhouses used to grow vegetable crops such as tomatoes and

peppers. This study applies a Takagi-Sugeno model based on Interval Type-2 Fuzzy (IT2-FLC) within a Model Predictive Control (MPC) framework to manage temperature and humidity. This approach is designed to overcome model uncertainties and external disturbances, such as outdoor temperature fluctuations and solar radiation variations. Simulation and real-world experiment results show that the IT2 method is more robust compared to Fuzzy Type-1, as it is able to reduce control errors to below 5% and keep environmental conditions optimal despite significant environmental variations. This proves that IT2-FLC can be a more adaptive solution in modern greenhouse management, particularly in facing environmental dynamics that are difficult to predict [7].

The results of various previous studies show that the application of Fuzzy Type-2 in agricultural IoT systems has great potential in creating a stable and adaptive environment for plant growth. However, the majority of studies still focus on horticultural and food crops such as tomatoes, peppers, or hydroponic vegetables [7]. This opens up opportunities for new research examining the utilisation of similar technology for carnivorous plants, specifically Drosera Sessilifolia, which has unique environmental needs. The urgency of this research is increasingly high given the limitations of the natural habitat of the Drosera Sessilifolia plant and the continuously growing public interest in cultivating carnivorous plants for both collection and conservation purposes [8]. Referring to the findings [9] that Interval Type-2 Fuzzy Logic is superior in dealing with temperature and light intensity variability in photovoltaic systems compared to Type-1, it can be assumed that the application of a smart control system based on Fuzzy Type-2 also has the potential to increase the success of indoor cultivation.

Although the application of Fuzzy Type-2 has proven effective in overcoming sensor data uncertainty in greenhouse systems, to date, no research has been found that specifically applies it to Drosera Sessilifolia. This plant differs from vegetables or other horticultural crops because it is highly sensitive to certain environmental parameters such as light intensity, water levels, and air temperature [10]. This research gap serves as a crucial point, as technology that has proven

effective on food crops cannot necessarily be directly adapted to carnivorous plants with more specific ecological needs [11].

Based on this background, this study aims to design and implement an IoT system based on Fuzzy Type-2 that can monitor and control three main parameters, namely light intensity, water level, and air temperature, in order to create optimal environmental conditions for the indoor growth of Drosera Sessilifolia. The contribution of this research is to provide innovation in the field of carnivorous plant cultivation through a smart farming approach, expand the application of Fuzzy Type-2 in the field of precision agriculture, and support conservation efforts and the development of plants that are difficult to cultivate. Furthermore, the results of the study are expected to serve as a reference for the development of similar smart control systems for other types of plants with specific environmental needs.

1.2. Problem Formulation

Based on the background described, the problem formulation in this study is as follows:

1. How is the implementation of an Internet of Things (IoT) system based on Interval Type-2 Fuzzy Logic using an ESP32 microcontroller in automatically monitoring and controlling the air temperature, light intensity, and water level in the growing environment of Drosera Sessilifolia?
2. How is the performance of the Interval Type-2 Fuzzy Logic method in generating actuator control decisions (heater, peltier, light, pump, and fan) based on environmental parameter changes detected by the sensors?
3. How is the effectiveness of the IoT-based monitoring system through the Blynk platform in presenting environmental condition information and actuator status in real-time to support the monitoring of the Drosera Sessilifolia growing environment?

1.3. Research Objectives

Based on the formulated problems, the objectives of this study are as follows:

1. To design and implement an Internet of Things (IoT) system based on Interval Type-2 Fuzzy Logic using an ESP32 microcontroller to automatically monitor and control the air temperature, light intensity, and water level in the growing environment of Drosera Sessilifolia.
2. To analyse the performance of the Interval Type-2 Fuzzy Logic method in processing sensor data and generating actuator control decisions, such as heater, peltier, light, pump, and fan, based on detected environmental conditions.
3. To evaluate the effectiveness of the IoT-based monitoring system through the Blynk platform in presenting environmental condition information and actuator status in real-time to support practical and sustainable monitoring of the Drosera Sessilifolia growing environment.

1.4.Scope and Limitations

To ensure that this research remains within a clear scope, the problem limitations are determined as follows:

1. The research is solely focused on one type of carnivorous plant, namely Drosera Sessilifolia.
2. The control of water level, light intensity, and air temperature is conducted using Type-2 Fuzzy logic.
3. The IoT system is designed using an ESP32 microcontroller with the integration of sensors and actuators.
4. The monitoring and control system is carried out in a small-scale indoor environment.
5. Testing was conducted in February and in 2 locations, namely the front porch and inside the house.
6. The use of a battery as a backup electrical source does not apply to the peltier actuator.

1.5. Significance of the Study

This research is expected to provide benefits for various parties, both theoretically and practically, as follows:

1. For the Author

   This research provides practical benefits for the author in developing technical skills in the field of designing microcontroller-based automatic control systems, applying Type-2 Fuzzy logic, and utilising IoT technology for remote monitoring. The author also gains a deeper understanding of how to maintain the stability of the microenvironment for plants with specific ecological needs, in this case, Drosera Sessilifolia, through the control of main parameters such as light intensity, water level, and air temperature. With the application of Type-2 Fuzzy, the author can design a system that is adaptive to uncertain sensor data variations, while simultaneously contributing to the development of smart farming based on intelligent technology.

2. For Future Research

   This research can serve as a foundation or reference for future research interested in the development of environmental control systems for plants with specific ecological needs using IoT and Type-2 Fuzzy approaches. The results of this study open up opportunities for the development of similar methods, either by adding other environmental variables such as pH, soil moisture, and CO_2 levels, or by integrating more complex artificial intelligence technologies. Thus, this research not only contributes to the development of more adaptive control systems but also encourages the emergence of further innovations in the fields of precision agriculture, urban farming, and rare plant conservation.

3. For Drosera Sessilifolia Owners

   Drosera Sessilifolia owners can utilise the results of this research as a practical solution in caring for the plant in indoor environments. The designed system helps maintain the stability of environmental conditions according to the plant's needs, thereby minimising the risk of stunted growth

or even death due to unsuitable conditions. Furthermore, the information generated from this IoT system can be used to monitor plant conditions in real-time, plan routine care, and take preventive measures when environmental changes occur. Thus, this research not only supports the health and survival of Drosera Sessilifolia but also makes it easier for owners to maintain the quality of cultivation sustainably.