CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions obtained from the entire research process that has been conducted, starting from the design, implementation, testing, and validation stages of the motion detection system for Internet of Things-based home security using PIR sensor and Fuzzy Logic Simplified Mamdani method with Telegram notifications. The conclusions are based on the analysis of testing data that has been collected in Chapter IV, referring to the problem statement and research objectives established in Chapter I. In addition, this chapter also contains constructive recommendations that are expected to serve as guidelines for subsequent research in developing Internet of Things-based home security systems that are more reliable, comprehensive, and adaptive to various environmental conditions.

5.1 Conclusions

Based on the design, implementation, testing, and validation results that have been conducted on the motion detection system for Internet of Things-based home security using PIR sensor and Fuzzy Logic Simplified Mamdani method with Telegram notifications, several conclusions can be drawn as follows:

1. The Internet of Things-based motion detection system was successfully designed and built using the ESP32-CAM AI Thinker module as a single processing unit that integrates microcontroller, camera, and WiFi communication functions in one device. The PIR HC-SR501 sensor connected to GPIO 13 successfully detected infrared radiation changes emitted by the human body with a 100% success rate at distances of 1 to 4 meters, and 80% at 5 meters which is the maximum detection range limit, so the overall average detection success rate reached 96% from 25 total trials. This result proves that the components and configuration designed in this research are correct and suitable for use as an Internet of Things-based home security system.
2. The implementation of the Fuzzy Logic Simplified Mamdani method on the system was successfully carried out with a condition classification accuracy

of 100% across all five testing scenarios that include Aman condition, buffer zone, Waspada, Bahaya, and delayed notification mechanism. The application of step function-shaped membership functions with an Waspada threshold of 3.50 and a Bahaya threshold of 7.00 proved capable of classifying threat levels accurately and consistently. The buffer zone mechanism in the value range of 0 to 3.50 proved effective in filtering environmental disturbances such as small animal movement, mechanical vibration, and sudden light changes, so the system's false alarm rate reached 0% from six tested disturbance scenarios. This proves that the application of Fuzzy Logic provides real contribution in improving the accuracy and reliability of motion detection system compared to conventional PIR sensor-based systems without further processing.

3. The system successfully sent warning notifications in real-time to users through the Telegram application with an average response time of 2,050 ms under stable WiFi connection conditions. Notifications in Bahaya condition are accompanied by transmission of two photo frames automatically captured by the ESP32-CAM camera as visual documentation of the threat, while notifications in Waspada condition use a delayed notification mechanism that only sends one notification after motion ceases to prevent notification spam. The buzzer connected to GPIO 14 was also successfully activated as a local physical alarm for 5 seconds in every Bahaya condition. The integration of all these components results in a home security system that is responsive, efficient, layered, and can be accessed remotely through a smartphone.
4. System validation conducted against eight points of needs and research objectives showed that all points are declared Valid with a 100% validation success rate, and validation against eight Fuzzy Logic input parameters also showed all valid results..

Therefore, the Internet of Things-based motion detection system using the Fuzzy Logic Simplified Mamdani method is proven to meet all functional requirements and technical specifications that have been established, making it suitable to be presented as an affordable, reliable, responsive, and easily implementable home security solution for the general public. However, the system

designed by the researcher still has several limitations such as only detecting the presence of motion without identifying the type of object. This presents an opportunity for future researchers to further develop features regarding object classification that function to improve threat detection accuracy.

5.2 Recommendations

Based on the research results and system limitations that have been identified, there are several recommendations for further development in subsequent research:

1. The system in this research only uses one PIR HC-SR501 sensor that has a detection angle of approximately 70 degrees so the monitoring area coverage is limited to one direction. Subsequent research can develop the system by adding several PIR sensors at different angles or combining PIR sensors with ultrasonic sensors to expand the monitoring area coverage and improve detection accuracy.
2. The current system performance depends entirely on the availability and stability of internet connection because all notifications are sent through a cloud-based Telegram platform. Subsequent research can add local storage mechanism using microSD card as a fallback when internet connection is unavailable, or develop an MQTT-based system with a local broker so the system can still operate on a local network without dependence on the internet.
3. Testing in this research was only conducted in a controlled indoor environment, so the system performance under outdoor conditions with more extreme variations in temperature, humidity, and light intensity cannot yet be confirmed. Subsequent research is recommended to conduct testing in more diverse outdoor environments, as well as examine the possibility of applying Type-2 Fuzzy Logic method which is more capable of handling dual uncertainty in more dynamic and complex environmental conditions.