

IoT-Based Smart Jacket with Multimodal Sensors for Autism Monitoring

Aulia Darnilasari^{1*}, Matalangi^{2*}, Muslim^{3**}, Selsiana^{4*}, Hasnia Arruan^{5*}

* Department of Artificial Intelligence, Universitas Kristen Indonesia Paulus

** Department of Informatics Engineering, Universitas Handayani Makassar

auliadarnilasari97@gmail.com¹, matalangi18@gmail.com², muslim@handayani.ac.id³, selsiana553@gmail.com⁴,
tallulembang019@gmail.com⁵

Article Info

Article history:

Received 2026-08-20

Revised 2026-10-09

Accepted 2026-10-15

Keyword:

Autism,
Internet of Things,
Multimodal Sensor,
Smart Jacket.

ABSTRACT

Autism is a neurodevelopmental condition characterized by difficulties in verbal and non-verbal communication, as well as challenges in regulating certain activities and behaviors. One of the challenges faced by families when individuals with autism engage in activities outside the home or are left unsupervised is the difficulty of continuously monitoring their activities and health conditions. Therefore, this study aims to integrate multimodal sensors into a smart jacket for Internet of Things (IoT)-based activity and health monitoring of individuals with autism. The proposed smart jacket integrates a multimodal sensor system comprising an Inertial Measurement Unit (IMU) sensor for activity detection, a tilt sensor for detecting body inclination, a sound sensor for detecting vocal stimming, a DHT22 sensor for monitoring the temperature inside the jacket, a vibration sensor for detecting body vibration frequency, a pulse sensor for monitoring heart rate, and an oximeter sensor for measuring blood oxygen saturation. An ESP32 microcontroller is employed for data acquisition and processing, while a web-based IoT platform is used to transmit information from the smart jacket to family members' smartphones. The experimental results demonstrate that the developed smart jacket can transmit activity and health-related information of individuals with autism to family members, including activity status, anomalous activities, vocal stimming, temperature, heart rate, and blood oxygen saturation.



This is an open access article under the [CC-BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license.

I. INTRODUCTION

Autism is a condition characterized by difficulties in communication and social interaction, which may be accompanied by repetitive behavioural patterns and varying levels of support needs across individuals. These characteristics may require individuals with autism to receive specialized supervision and assistance from parents or caregivers, particularly in monitoring changes in daily activities, behaviour, and health conditions. Wearable technology has emerged as a promising approach for obtaining objective information on behavioural and physiological responses in individuals with autism, including motor activity, behavioural patterns, emotional regulation, and physiological responses [1]. Furthermore, the integration of physiological sensors into wearable devices has

demonstrated potential for monitoring stress levels and internal physiological conditions in individuals with autism, although challenges remain regarding inter-individual physiological variability, user comfort, and the need for sensor personalization [2]. The advancement of Internet of Things (IoT) technology further enables the integration of wearable devices with communication and remote monitoring systems, allowing activity and physiological data to be transmitted and accessed in real time by parents or caregivers [3]. Therefore, this study aims to develop a smart jacket integrated with a multimodal sensor system for IoT-based monitoring of activities and health conditions in individuals with autism.

Research on the application of technology for monitoring activities and health conditions in individuals with autism has

been investigated by several researchers. Albinali et al. developed an accelerometer-based system combined with a pattern recognition algorithm to detect stereotypical motor movements in children with autism in classroom environments [4]. Their study demonstrated that motion data acquired from wearable sensors can be used to objectively identify activities such as hand flapping and body rocking. Subsequently, Amiri et al. developed WearSense, a smartwatch- and Internet of Things (IoT)-based system for detecting stereotypical behaviors in children with autism [5]. The system utilizes an accelerometer embedded in a smartwatch to recognize several types of activities and transmit the collected information through a communication device to support the monitoring process. In another study, Sarker et al. developed a smartwatch-based system integrating accelerometer and gyroscope sensors to detect stereotypical motor movements, including hand flapping, head banging, and other repetitive activities [6]. The findings demonstrated the potential of wearable technology for real-time detection of motor activities in individuals with autism. Furthermore, Billeci et al. developed an integrated wearable technology approach to monitor brain and autonomic nervous system responses in children with autism during therapy [7]. The proposed system utilizes physiological parameters, including cardiac activity, to obtain information on changes in physiological conditions and levels of engagement during therapeutic sessions.

Research on wearable technology for monitoring individuals with autism has continued to evolve. Di Palma et al. evaluated the use of wearable technology to monitor autonomic responses in children with autism during sociocognitive tasks [8]. Their study demonstrated that physiological information acquired from wearable devices can serve as an additional indicator for assessing individual responses during specific activities. Subsequently, Zwilling et al. evaluated a commercially available wireless cardiovascular monitoring device for measuring and transmitting physiological responses in real time in children with autism [9]. Their findings indicated that wearable monitoring of cardiovascular parameters has the potential to support the assessment of physiological conditions in individuals with autism, although user comfort and individual sensory characteristics should be carefully considered. In addition, Nuske et al. developed and validated a smart wearable shirt-based system for predicting challenging behaviors in individuals with autism [10]. The system utilizes physiological data acquired from the smart garment to identify changes in the user's physiological state and provide information that can assist caregivers in anticipating potentially emerging behaviors. Furthermore, Gangaraju et al. developed an IoT-based sensory data acquisition system for autism monitoring by integrating wearable sensing with an IoT network [11]. The system utilizes multimodal data, including motion, temperature, and skin conductance, and employs unequal clustering and reinforcement learning

approaches to improve the efficiency of sensory data acquisition.

Based on previous studies, several researchers have developed human activity monitoring systems, particularly for elderly individuals, using accelerometer and gyroscope-based approaches [4]–[6], physiological response-based approaches [7], [8], [10], and smart T-shirt-based systems for predicting surrounding challenges [9]. However, based on the findings reported in these previous studies, no research has yet specifically developed a smart jacket designed to monitor the activities of individuals with autism. Therefore, the novelty of this study lies in the development of a smart jacket for monitoring the activities and physiological conditions of individuals with autism through the integration of multimodal sensors and the Internet of Things (IoT). The proposed monitoring system is capable of detecting various activities and behavioral conditions, including walking, sitting, lying down, screaming, and other abnormal activities, while also monitoring physiological parameters such as body temperature and heart rate.

II. METHOD

To address the research problem, a systematic problem-solving approach was developed to enable parents or family members to remotely monitor the activities and health conditions of individuals with autism through the integration of multimodal sensors into an IoT-based smart jacket. Figure 1 illustrates the architecture of the proposed system.

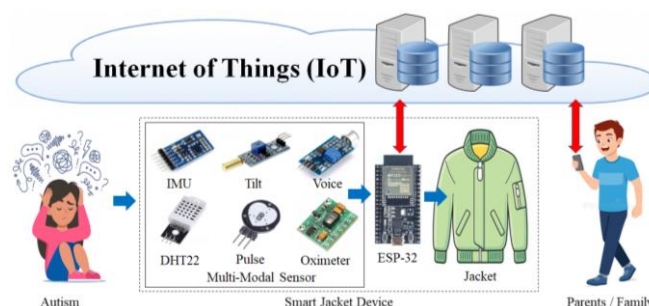


Figure 1. Systems architecture

The proposed smart jacket consists of several interconnected components that form an integrated monitoring system. The individual with autism serves as the primary subject of the study, while the smart jacket functions as the wearable sensing device equipped with a multimodal sensor system comprising an Inertial Measurement Unit (IMU) sensor, tilt sensor, sound sensor, DHT22 sensor, pulse sensor, and oximeter sensor. An ESP32 microcontroller serves as the central control unit for acquiring and processing sensor data before transmitting the collected information to a web-based IoT cloud platform. At the application level, parents or family members can remotely access the platform to monitor the activity and health conditions of the individual with autism. Based on the proposed system architecture,

Figure 2 presents a detailed block diagram of the circuit configuration and component interconnections used to implement the smart jacket developed in this study.

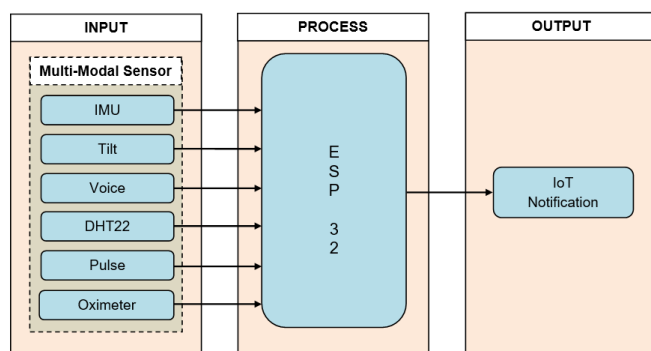


Figure 2. Circuit block diagram

Based on the system architecture design presented in Figure 2, the circuit block diagram consists of three main sections used to develop the smart jacket, namely the input, processing, and output sections. The input section comprises several sensors integrated into a multimodal sensing system, which consists of multiple sensing devices combined into a single module [12]. These sensors include an Inertial Measurement Unit (IMU) sensor for detecting the angular motion of the subject [13], a tilt sensor for detecting body inclination [14], a sound sensor for detecting vocal sounds [15], a DHT22 sensor for monitoring the temperature inside the jacket [16], a pulse sensor for measuring heart rate [17], and an oximeter sensor for measuring blood oxygen saturation [18]. In this study, the IMU, tilt, and sound sensors are employed to detect the activities of children with autism, whereas the DHT22, pulse, and oximeter sensors are used to monitor their health conditions.

In the processing section, an ESP32 microcontroller serves as the central data processing unit responsible for processing the sensor inputs acquired from the multimodal sensing system and converting them into activity and health monitoring information for children with autism. The processed information is then transmitted to the smartphones of parents or family members through the Blynk IoT platform. The ESP32 is a microcontroller equipped with integrated Bluetooth and Wi-Fi connectivity, making it well suited for Internet of Things (IoT) applications [19]. Meanwhile, web-based platforms provide an effective means of receiving and presenting data from embedded systems on mobile devices through Internet connectivity, thereby supporting remote monitoring in IoT-based systems [20].

Referring to the information presented in Figures 1 and 2, the initial step in addressing the research problem was to integrate all multimodal sensors required for monitoring the activities and health conditions of individuals with autism into the smart jacket. Subsequently, a program was developed for the ESP32 microcontroller to acquire and process data from all multimodal sensors and transmit the resulting activity and

health information to parents or family members through an IoT-based web platform over a wireless Internet connection.

In practical use, when parents or family members need to leave home to attend to important activities, the smart jacket is worn by the individual with autism and activated to enable the transmission of activity and health information through IoT technology. Once the parents or family members are away from home, they receive notifications when the individual exhibits activities outside their usual behavioral patterns and can remotely access activity and health information through the monitoring platform. The monitored activity information includes sitting, standing, walking, running, lying down, abnormal or uncontrolled activities, and vocal activity, while the monitored health parameters include body temperature, heart rate, and blood oxygen saturation. Figure 3 presents the flowchart of the algorithm employed in this study to detect the activities of individuals with autism.

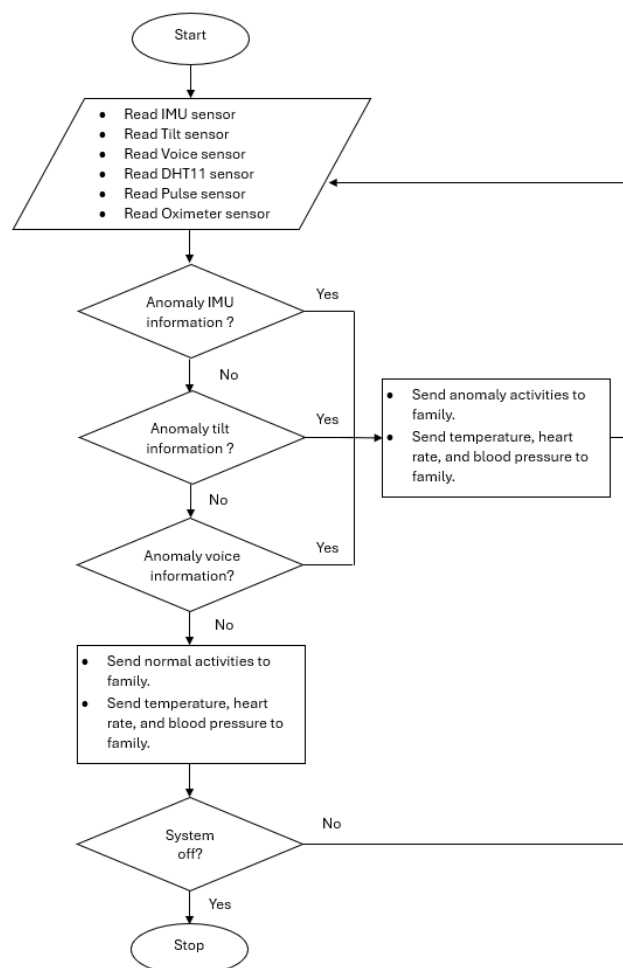


Figure 3. Algorithm for detecting activities of individuals with autism.

As illustrated in Figure 3, the proposed method translates the sensor data acquired from the IMU, tilt, and sound sensors to detect abnormal activities in individuals with autism. When the data patterns obtained from the IMU, tilt, and sound sensors remain within the predefined normal activity ranges,

the system classifies the individual's condition as normal. In contrast, when these sensors detect higher-intensity activity patterns, particularly from the IMU and tilt sensors, the system identifies the activity as potentially abnormal or excessive. Furthermore, when the sound sensor detects a high-intensity vocal signal, the system interprets the condition as screaming. In addition to activity-related information, the proposed system also transmits physiological information related to the individual's condition, including the temperature inside the jacket, heart rate, and blood pressure.

III. RESULTS AND DISCUSSIONS

The smart jacket device for monitoring the activities and health conditions of individuals with autism was implemented and evaluated in this study. The researchers conducted trials of the smart jacket with individuals with autism to assess its effectiveness in monitoring their activities and health conditions during daily activities. Figures 4 and 5 present the integration of all hardware components installed inside the jacket, showing the front and rear views, respectively.



Figure 4. Interior of the jacket, front view



Figure 5. Interior of the jacket, rear view

Based on the information presented in Figures 4 and 5, several hardware components are interconnected within the jacket to enable the implementation of the smart jacket for monitoring the activities and health conditions of individuals with autism. Figure 4 shows the ESP32 microcontroller,

which serves as the central processing unit for acquiring data from the multimodal sensors, processing the collected data, and transmitting information regarding the individual's condition to family members through an IoT-based communication system. The system also includes a Wi-Fi modem that provides Internet connectivity, a power supply that supplies power to the entire system with a 5 V DC output, an on/off switch for activating and deactivating the device, and a charging port for recharging the smart jacket's power supply battery. In addition, a pulse sensor is used to detect heart rate, while an oximeter sensor is employed to measure blood oxygen saturation and related blood oxygen parameters in individuals with autism.

Furthermore, Figure 5 shows the IMU sensor, which is used to detect the movements of individuals with autism during sitting, standing, and lying positions. The sound sensor is used to detect vocalizations when the individual exhibits uncontrolled screaming. The DHT22 sensor is used to monitor the temperature inside the jacket as an indirect indicator of the individual's body temperature. Meanwhile, the tilt sensor is used to detect body inclination during sitting and standing activities. Based on the implementation of the proposed smart jacket, Figure 6 presents the completed smart jacket from the exterior view.



Figure 6. External view of the smart jacket.

Based on Figure 6, all hardware components integrated into the proposed smart jacket are concealed from external view, as the components are installed inside the jacket. This configuration allows the system to acquire data related to the activity and health conditions of individuals with autism while maintaining the overall appearance and usability of the garment. In this study, the smart jacket is designed primarily for children and adolescents with autism aged approximately 8–15 years, as the physical dimensions of the developed jacket are tailored to this age range. Furthermore, the effectiveness of the proposed smart jacket was evaluated through a series of trials involving individuals with autism to assess its capability to detect activity conditions in indoor and outdoor environments, monitor daily activities, and monitor health-related parameters. Figures 7, 8, and 9 present the implementation of the smart jacket in individuals with autism during indoor activities, including sitting, walking, and lying down, respectively.



Figure 7. Activities of individuals with autism while seated



Figure 8. Activities of individuals with autism while walking



Figure 9. Activities of individuals with autism while lying down

Referring to the information presented in Figures 7, 8, and 9, individuals with autism can use the proposed smart jacket under various activity conditions, including sitting, walking, and lying down. In this study, a multimodal sensor system is integrated into the smart jacket to detect activities and monitor

the health conditions of individuals with autism in real time through IoT connectivity. This enables family members or caregivers to continuously monitor the individual's activities and conditions remotely while the individual is at home or engaged in activities outside the home. Table 1 presents the relationship between the integrated sensors and the IoT-based monitoring of activities and health conditions in individuals with autism.

TABLE I
THE ROLE OF MULTI-MODAL SENSORS IN IoT-BASED ACTIVITY AND HEALTH MONITORING FOR INDIVIDUALS WITH AUTISM

Monitoring	Multimodal Sensors	Function
Activities	IMU	Detect the condition of individuals with autism while sitting, standing, walking, and lying down.
	Tilt	Detection of anomalous movement in individuals with autism.
	Voice	Detecting the sound of an autistic person screaming uncontrollably.
Healthy	DHT22	Reading the temperature of an autistic person wearing a smart jacket.
	Pulse Rate	Reading the heartbeat
	Oximeter	Measures oxygen levels in the blood

Based on the information presented in Table 1, the multimodal sensors integrated into the smart jacket are designed to monitor the activities and health conditions of individuals with autism. The monitoring information is obtained from the data acquired by each sensor to identify the individual's condition based on body movements and activities performed while wearing the smart jacket. In this study, an IoT-based web application was developed to monitor the activities and health conditions of individuals with autism while using the smart jacket. The proposed platform facilitates remote monitoring by enabling family members or caregivers to access information about the individual's activities and health conditions while away from home in real time.

In this study, the sensor data corresponding to normal and anomalous conditions were analyzed using the IMU, tilt, and sound sensors. Figures 10, 11, and 12 present the respective data analysis graphs used to identify normal and anomalous activities in individuals with autism.

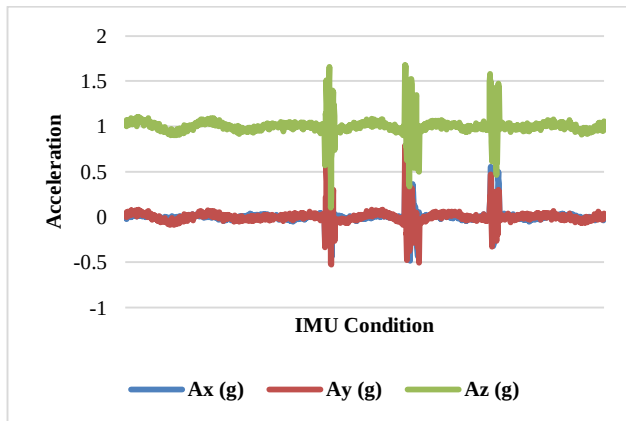


Figure 10. IMU sensor data analysis

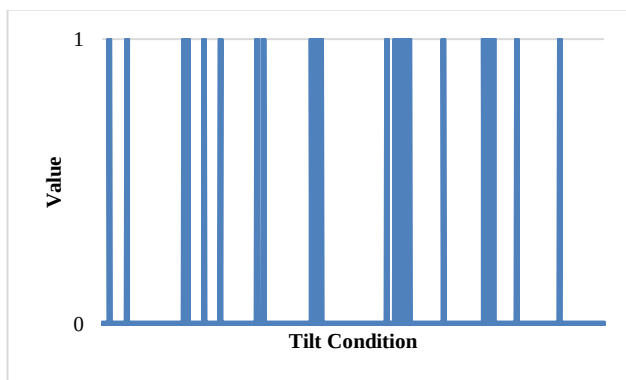


Figure 11. Tilt sensor data analysis

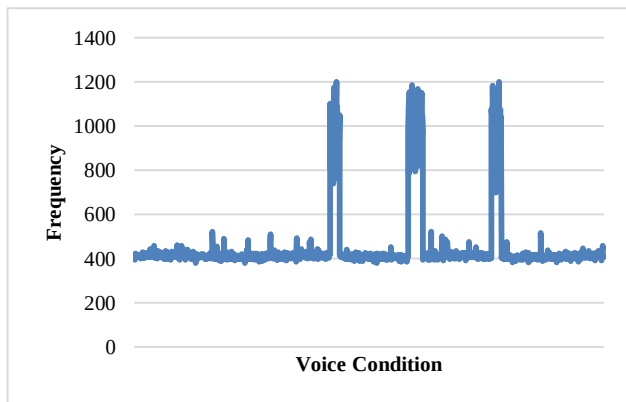


Figure 12. Voice sensor data analysis

Based on the data analysis presented in Figures 10, 11, and 12, the sampling frequency and corresponding threshold ranges can be observed over a one-day time interval for detecting activities of individuals with autism. Under normal conditions, the sensor data remain within a relatively stable value range. In contrast, when the sensors detect anomalous activity, the resulting sensor data exhibit highly dynamic patterns with significant temporal variations. These substantial changes in the sensor readings provide an indication that the individual with autism is engaged in an anomalous activity.

As shown in Figure 13, family members or caregivers can remotely monitor several parameters, including activity status, anomalous activities, vocal stimming, temperature inside the jacket, heart rate, and blood oxygen saturation. During practical implementation, when family members or caregivers need to monitor the individual's activities and health conditions, they can access the monitoring platform through an Internet-connected website. The system then displays real-time information on a smartphone according to the individual's current condition. Figure 13 presents the implementation of the web-based software for displaying IoT-enabled activity and health monitoring information for individuals with autism.

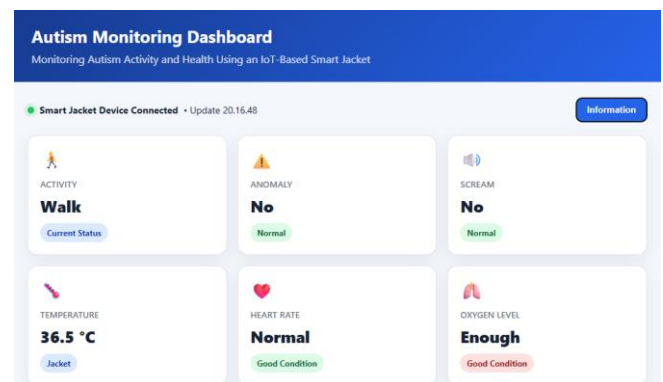


Figure 13. Activity and health information of individuals with autism.

Referring to the information presented in Figure 13, the system displays several parameters representing the activity and health conditions of individuals with autism during daily activities. Table 2 presents the activity and health conditions of individuals with autism displayed through the IoT-based web monitoring system.

TABLE 2
INFORMATION DISPLAYED ON THE IOT WEBSITE IS BASED ON THE
ACTIVITIES OF INDIVIDUALS WITH AUTISM WHILE WEARING THE JACKET.

Condition	Information	Message
Activity	Walk	Current Condition
	Stand	Current Condition
	Lie Down	Current Condition
Anomaly	No	Normal
	Yes	Need Attention
Scream	No	Normal
	Yes	Need Attention
Temperature	Temp Value	Jacket
Heart Rate	Normal	Good Condition
	Low	Damage
Oxygen	Enough	Good Condition
	Low	Damage

Based on the information presented in Table 2, the IoT-based web monitoring system provides several output parameters for displaying the activity and health conditions of individuals with autism. These parameters provide real-time information regarding the individual's current activities and

health status. Furthermore, the proposed system incorporates an alert mechanism to provide early warnings to family members or caregivers when potentially abnormal or undesirable conditions are detected. In addition to enabling family members or caregivers to monitor activity and health conditions in real time, the developed system also records the individual's activity data while wearing the smart jacket. This activity history enables family members or caregivers to review previously recorded activities when an unexpected event occurs.

In this study, an experimental evaluation was conducted to assess the effectiveness of the proposed smart jacket for monitoring the activities of an individual with autism. The experiment involved one participant and was conducted over a one-week period. The monitored activities consisted of the participant's daily activities while staying at home. Activity and physiological data were acquired at one-minute intervals. The data transmitted from the smart jacket to the family member's smartphone consisted of activity and health-related information, which was presented through a web-based interface. Regarding data privacy and security, the current implementation does not yet employ an authentication mechanism, allowing family members to directly access the activity and health information of the individual with autism through the web interface without logging in. Therefore, data security and privacy should be considered in future development to protect sensitive information related to the participant. Furthermore, Figure 14 presents the recorded activity history of the individual with autism, with activity data logged at 5-second intervals.

History						
TIME	ACTIVITY	ANOMALY	SCREAM	TEMPERATURE	HEART	OXYGEN
22.12.45	Walk	No	No	36.6 °C	Normal	Enough
22.12.40	Stand	No	No	37.3 °C	Normal	Enough
22.12.35	Stand	No	No	37.1 °C	Normal	Enough
22.12.30	Walk	No	No	36.4 °C	Normal	Enough
22.12.24	Lie Down	No	No	36.8 °C	Damage	Enough
22.12.19	Lie Down	No	No	37.3 °C	Normal	Enough
22.12.14	Stand	No	No	37.0 °C	Normal	Enough
22.12.08	Lie Down	No	No	37.3 °C	Normal	Enough

Figure 14. Information on the activity and health history of individuals with autism.

Referring to the information presented in Figure 14, several different activities performed by the individual with autism can be observed at 5-second intervals. These variations occur because the individual may occasionally exhibit relatively vigorous or uncontrolled movements, resulting in changes in the detected activity information. Therefore, the

recorded activity history enables family members or caregivers to review the individual's previous activities, providing useful contextual information for assessing the individual's condition and supporting the investigation of unexpected events. Furthermore, this study evaluated the effectiveness of the proposed system in detecting the activities of the individual with autism, including standing, walking, and lying down. Figure 15 presents the confusion matrix obtained from the evaluation.

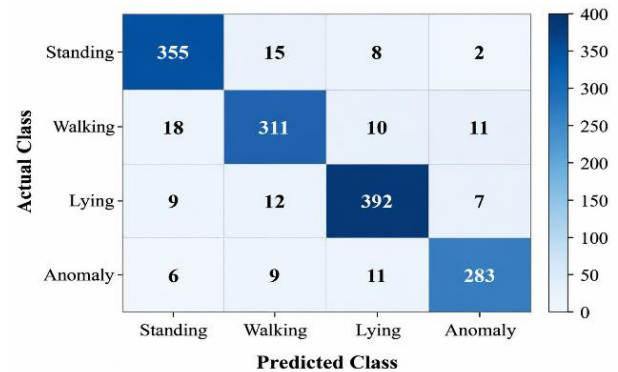


Figure 15. Confusion matrix of this research.

Referring to the results presented in Figure 15, the system was able to classify four activity categories, namely Standing, Walking, Lying, and Anomaly, with most predictions located along the main diagonal, indicating correct classifications. The system correctly identified 355 Standing samples, 311 Walking samples, 392 Lying samples, and 283 Anomaly samples, while the misclassifications mainly occurred between Standing and Walking, as well as between Anomaly and Lying. These results indicate that the combination of IMU, tilt, and sound sensors is capable of distinguishing activity patterns and detecting anomalous conditions, although some activities exhibit overlapping sensor characteristics. Furthermore, this study evaluated the accuracy, precision, recall, and F1-score for each activity category. Figure 16 presents the results of this evaluation.

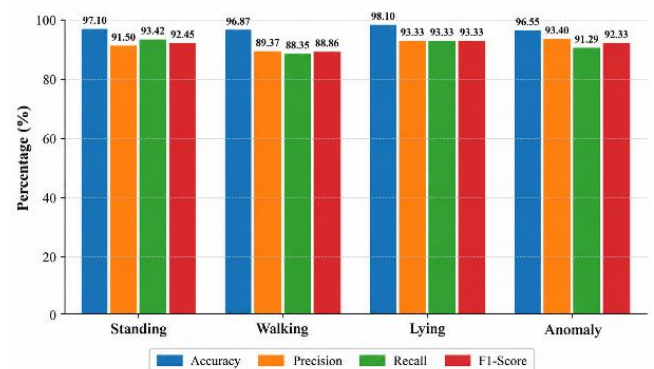


Figure 16. Accuracy, Precision, Recall and F1-Score of this study.

As shown in Figure 16, the system demonstrates relatively good classification performance across all activity categories, achieving accuracies of 97.10% for Standing, 96.87% for

Walking, 98.10% for Lying, and 96.55% for Anomaly. The Lying category achieved the highest accuracy of 98.10%, with precision, recall, and F1-score each reaching 93.33%. In contrast, the Walking category exhibited relatively lower performance, with a precision of 89.37%, recall of 88.35%, and F1-score of 88.86%. For the Standing category, the system achieved a precision of 91.50%, recall of 93.42%, and F1-score of 92.45%, whereas the Anomaly category achieved a precision of 93.40%, recall of 91.29%, and F1-score of 92.33%. Overall, these results indicate that the integration of IMU, tilt, and sound sensors provides consistent classification performance in distinguishing normal activities from anomalous conditions. Furthermore, this study analyzed the True Positive (TP), False Positive (FP), and False Negative (FN) outcomes to further assess the accuracy of the proposed system in detecting the activities of individuals with autism. Figure 17 presents the TP, FP, and FN analysis results obtained in this study.

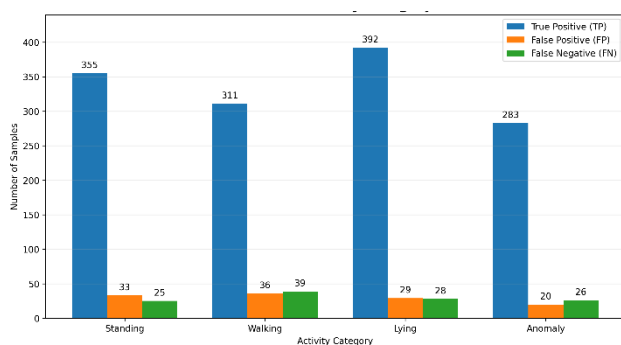


Figure 17. Analysis of True Positif, False Positif, and False Negatif of this research

Referring to the analysis presented in Figure 17, the TP values are substantially higher than the FP and FN values across all activity categories. The Lying category recorded the highest TP value of 392, followed by Standing with 355, Walking with 311, and Anomaly with 283, indicating a relatively high number of correctly classified samples. Meanwhile, the highest FN value was observed for Walking (39), indicating that some Walking samples were still misclassified as other activity categories, while the highest FP value was also observed for Walking, with a value of 36. The Anomaly category yielded TP = 283, FP = 20, and FN = 26, indicating that most anomalous conditions were successfully detected by the system, with relatively fewer classification errors. Overall, the comparison of TP, FP, and FN values demonstrates that the system achieves good classification performance across the four activity categories, although some misclassifications remain, particularly in distinguishing between Standing and Walking and between Walking and other activity categories.

In addition to evaluating the successful transmission of activity and health information from the smart jacket, this study also analyzed the data transmission latency between the smart jacket and the family member's smartphone over an

Internet-based web platform. Figure 18 presents the results of the latency analysis for transmitting activity and health information from the smart jacket to the family member's smartphone, as measured over a one-day period.

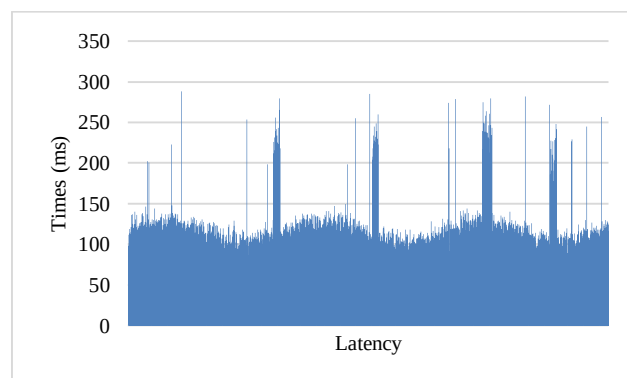


Figure 18. Latency analysis of IoT data transmission.

Based on the IoT data transmission latency results presented in Figure 18, several data transmissions exhibited relatively high latency. This condition was primarily attributed to the unstable Internet connection between the smart jacket device and the family member's smartphone.

Based on the results of this study, the implementation of the smart jacket for monitoring the activities and health conditions of individuals with autism was successfully demonstrated. The proposed system integrates a multimodal sensor system comprising IMU, tilt, voice, DHT22, pulse rate, and oximeter sensors to monitor activity and health-related parameters. In addition, Internet of Things (IoT) technology was employed to transmit activity and health information to family members or caregivers through a web-based monitoring platform over an Internet connection. Although each sensor can be implemented independently, this study integrates multiple sensing devices into a single system to support the research objectives through a multimodal sensing approach. User comfort is an important consideration in the implementation, as the jacket contains multiple interconnected electronic components that may cause some discomfort, particularly when an individual with autism lies down or sleeps. Therefore, future development should pay greater attention to the placement and arrangement of the electronic components within the jacket to improve user comfort. In addition, further research should conduct long-term durability and reliability testing of the device to evaluate its performance over extended periods and ensure the reliability of the proposed system.

In the present study, clinical trials involving individuals with autism were not conducted. Instead, the data were collected from real-world observations of the participant's daily activities. Future research will involve collaboration with medical professionals to conduct more comprehensive assessments, particularly for evaluating the overall health conditions of individuals with autism. For future development, the proposed system could be integrated with

Artificial Intelligence techniques to enhance the intelligence of the smart jacket and improve the accuracy of activity detection in individuals with autism. Furthermore, future research should consider developing a more compact, lightweight, and comfortable jacket design, as well as an adjustable and flexible garment size that can accommodate individuals with different body sizes and age groups.

IV. CONCLUSION

The implementation of a smart jacket for monitoring the activities and health conditions of individuals with autism through the integration of multimodal sensors and Internet of Things (IoT) technology was successfully demonstrated in this study. The multimodal sensing system comprises an Inertial Measurement Unit (IMU) sensor for detecting activities such as walking, standing, and lying down; a tilt sensor for rapidly detecting body inclination and movement variations associated with anomalous activities; a sound sensor for detecting vocalizations when an individual with autism exhibits screaming; a DHT22 sensor for monitoring the temperature inside the jacket; a pulse-rate sensor for measuring heart rate; and an oximeter sensor for measuring blood oxygen saturation. The proposed system successfully monitored several activity and health-related parameters, including walking, standing, and lying-down activities; anomalous movement conditions; vocalizations associated with screaming; temperature inside the jacket; heart rate; and blood oxygen saturation. Furthermore, the developed system can transmit activity and health information to family members through a web-based IoT platform and maintain an activity history with data recorded at 5-second intervals. Furthermore, the results of this study demonstrate that the proposed system was able to classify four activity categories, namely Standing, Walking, Lying, and Anomaly, with most predictions located along the main diagonal of the confusion matrix, indicating correct classifications. The analysis further showed that the system achieved relatively good classification performance across all activity categories, with accuracies of 97.10% for Standing, 96.87% for Walking, 98.10% for Lying, and 96.55% for Anomaly. The Lying category achieved the highest accuracy of 98.10%, with precision, recall, and F1-score each reaching 93.33%. In contrast, the Walking category exhibited relatively lower performance, with a precision of 89.37%, recall of 88.35%, and F1-score of 88.86%. For the Standing category, the system achieved a precision of 91.50%, recall of 93.42%, and F1-score of 92.45%, whereas the Anomaly category achieved a precision of 93.40%, recall of 91.29%, and F1-score of 92.33%. The analysis of True Positive (TP), False Positive (FP), and False Negative (FN) values further showed that the Lying category recorded the highest TP value of 392, followed by Standing with 355, Walking with 311, and Anomaly with 283, indicating a relatively high number of correctly classified samples. Meanwhile, the highest FN value was observed for Walking (39), indicating that some Walking samples were

still misclassified as other activity categories. The highest FP value was also observed for Walking, with a value of 36. The Anomaly category yielded TP = 283, FP = 20, and FN = 26, indicating that most anomalous conditions were successfully detected by the system with relatively few classification errors. Future research should incorporate Artificial Intelligence techniques to enhance the intelligence and performance of the proposed system, particularly for improving activity classification and anomaly detection. In addition, further development should focus on designing a more flexible, lightweight, and comfortable smart jacket that can accommodate variations in body size and provide greater comfort during prolonged use by individuals with autism.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the Ministry of Higher Education, Science, and Technology for providing financial support and the opportunity to conduct and complete this Beginner Lecturer Research project through the BIMA research funding program. The authors also gratefully acknowledge Universitas Kristen Indonesia Paulus and the community for their valuable support and assistance, which contributed to the successful completion of this research within the timeframe.

REFERENCES

- [1] D. Ahuja, A. Sarkar, S. Chandra, and P. Kumar, "Wearable technology for monitoring behavioral and physiological responses in children with autism spectrum disorder: A literature review," *Technology and Disability*, vol. 34, no. 2, pp. 85–98, 2022.
- [2] S. Cano, C. Cubillos, R. Alfaro, A. Romo, M. García, and F. Moreira, "Wearable solutions using physiological signals for stress monitoring on individuals with autism spectrum disorder (ASD): A systematic literature review," *Sensors*, vol. 24, no. 24, Art. no. 8137, 2024.
- [3] K. Gangaraju, Y. H. Kadegowda, and S. Sangani, "Energy- and behavior-aware sensory data collection for ASD monitoring over IoT using unequal clustering and reinforcement learning," *Discover Internet of Things*, vol. 6, Art. no. 24, 2026.
- [4] M. Albinali, A. Goodwin, and S. S. Intille, "Detecting stereotypical motor movements in the classroom using accelerometry and pattern recognition algorithms," *Pervasive and Mobile Computing*, vol. 8, no. 1, pp. 103–114, Feb. 2012, doi: 10.1016/j.pmcj.2011.04.006.
- [5] A. M. Amiri, N. Peltier, C. Goldberg, Y. Sun, K. M. Hiremath, and colleagues, "WearSense: Detecting autism stereotypic behaviors through unequal clustering and reinforcement learning," *Healthcare*, vol. 5, no. 1, Art. no. 11, 2017, doi: 10.3390/healthcare5010011.
- [6] H. Sarker, A. Tam, M. A. Foreman, N. Fay, M. Dhuliawala, and A. K. Das, "Detection of stereotypical motor movements in autism using a smartwatch-based system," in *AMIA Annual Symposium Proceedings*, 2018, pp. 952–960.
- [7] L. Billeci, A. Tonacci, G. Tartarisco, A. Narzisi, S. Di Palma, D. Corda, G. Baldus, F. Cruciani, S. M. Anzalone, S. Calderoni, G. Pioggia, F. Muratori, and the Michelangelo Study Group, "An integrated approach for the monitoring of brain and autonomic response of children with autism spectrum disorders during treatment by wearable technologies," *Frontiers in Neuroscience*, vol. 10, Art. no. 276, Jun. 2016, doi: 10.3389/fnins.2016.00276.
- [8] S. Di Palma, A. Tonacci, A. Narzisi, C. Domenici, G. Pioggia, F. Muratori, and L. Billeci, "Monitoring of autonomic response to sociocognitive tasks during treatment in children with Autism Spectrum Disorders by wearable technologies: A feasibility study,"

- Computers in Biology and Medicine*, vol. 85, pp. 143–152, Jun. 2017, doi: 10.1016/j.combiomed.2016.04.001.
- [9] M. Zwilling, A. Romano, H. Hoffman, M. Lotan, and R. Tesler, "Development and validation of a system for the prediction of challenging behaviors of people with autism spectrum disorder based on a smart wearable shirt: A mixed-methods design," *Frontiers in Behavioral Neuroscience*, vol. 16, Art. no. 948184, Nov. 2022, doi: 10.3389/fnbeh.2022.948184.
- [10] H. J. Nuske, M. S. Goodwin, Y. Kushleyeva, D. Forsyth, J. W. Pennington, A. J. Masino, E. Finkel, A. Bhattacharya, J. Tan, H. Tai, Z. Atkinson-Diaz, C. P. Bonafide, and J. D. Herrington, "Evaluating commercially available wireless cardiovascular monitors for measuring and transmitting real-time physiological responses in children with autism," *Autism Research*, vol. 15, no. 1, pp. 117–130, Jan. 2022, doi: 10.1002/aur.2633.
- [11] K. Gangaraju, Y. H. Kadegowda, and S. Sangani, "Energy- and behavior-aware sensory data collection for ASD monitoring over IoT using unequal clustering and reinforcement learning," *Discover Internet of Things*, vol. 6, Art. no. 24, 2026, doi: 10.1007/s43926-026-00287-w.
- [12] I.W. Suparno., dan A. Jalil, "Implementasi Sensor Multi-Modal Menggunakan Raspberry Pi dan Roobot Operating System Pada Sistem Keamanan Rumah," *Jurnal Electro luceat*, Vol. 7, No. 2, pp. 86-95, 2021. DOI: <https://doi.org/10.32531/jelekn.v7i2.405>.
- [13] M.F. Ridho., A.Z. Abidin., dan B Septian, "Integrasi Odometri LIDAR dan Sensor IMU Untuk Peningkatan Lokalisasi Pada Robot Bergerak Indoor," *Blend Sains Jurnal Teknik*, Vol. 2, No. 4, pp. 287-297, 2024. DOI: <https://doi.org/10.56211/blendsains.v2i4.470>.
- [14] Q. Zhang, Y. Chen, Y. Tang, Y. Yao, J. Guo and X. Zhang, "A High-Resolution Tilt Sensor Utilizing Grooved Arch Beam-Assisted EFPI for Large Angle Measurement," in *IEEE Sensors Journal*, vol. 24, no. 22, pp. 36846-36853, 15 Nov.15, 2024, doi: 10.1109/JSEN.2024.3467122.
- [15] Cakra., M.S.Said., dan Henny, "Sistem Kontrol Lampu Menggunakan Sensor Suara," *Jurnal Sistem Informasi Dan Teknik Komputer*, Vol. 8, No. 1, pp. 77-82, 2023. DOI: <https://doi.org/10.51876/simtek.v8i1.218>.
- [16] A. R. Nair, A. Mohan, P. V. Moncy, V. Vinod, L. R. Mathew and J. Jayakumari, "Smart Air Quality Monitoring System for Pulmonary Disease Management - OSA," *2024 International Conference on Futuristic Technologies in Control Systems & Renewable Energy (ICFCR)*, Malappuram, India, 2024, pp. 1-6, doi: 10.1109/ICFCR64128.2024.10763385.
- [17] W. Panjaitan, "Sistem Monitoring Detak Jantung Menggunakan Pulse Heart Rate Sensor dan Nodemcu," *Merkurius: Jurnal Riset Sistem Informasi dan Teknik Informatika*, Vol. 3, No. 2, pp. 63-72, 2025. DOI: <https://doi.org/10.61132/mercurius.v3i2.712>.
- [18] S.R. Sunarto., A. Situmeang., dan V.E. Kristianti, "Prototipe Pengukur Detak Jantung, Saturasi Oksigen, dan Suhu Tubuh Manusia Secara Portable," *Jurnal JTS*, Vol. 3, No. 2, pp. 84-93, 2024. DOI: <https://doi.org/10.56127/jts.v3i2.1535>.
- [19] M.F. Azhar., dan L. Narpulaela, "Implementasi Penggunaan ESP32 Sebagai IoT Pada Project Smart Charger di PT. Pasifik Satelit Nusantara Bekasi," *JATI*, Vol. 8, No. 4, pp. 7248-7253, 2024. DOI: <https://doi.org/10.36040/jati.v8i4.10201>.
- [20] J. B. Ajith, R. Manimegalai and V. Ilayaraja, "An IoT Based Smart Water Quality Monitoring System using Cloud," *2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE)*, Vellore, India, 2020, pp. 1-7, doi: 10.1109/ic-ETITE47903.2020.450.