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# INTEGRATED SMART REAL TIME SCORING PENCAK SILAT BASED ON INTERNET OF THINGS (IOT)

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**Abstract-** Pencak Silat is a relic of our ancestors and one of the cultural heritages. This sport still competes in sports competitions. The current score calculation is still using the manual method. A touch of technology is needed to increase the validity in calculating the score of the Pencak Silat sport that can be used as a decision support system for athletes during training or referees during matches. The purpose of the study is to propose a solution that can be used as a support system to calculate Pencak Silat scores in real-time and Internet of Things (IoT) based. Stages of the research stage were the design process (hardware and software), system integration, and testing process. The experimental results show that the use of a system equipped with RFID has higher accuracy in determining the score, namely 99.8% in identifying punches, while the accuracy in identifying kicks is 99.4%. The AUC value generated by the first system is 0.996 in identifying punches, and 0.944 in identifying kicks. This system is expected to assist referees in determining scores in matches and also assist athletes in improving their performance.

**Keywords:** Pirates, Pencak Silat, Power, Punch, Kick, Identification, IoT.

## 1. INTRODUCTION

Pencak Silat is one of Indonesia's cultural heritages, where this sport is not only focused on strength and also intrinsic beauty [1]. Pencak Silat contains the ancestor's noble values, which motivates its athletes to always do good [2]. This is what underlies the sport of Pencak Silat that must be maintained in order not to become extinct as Indonesian culture.

Pencak Silat is an example of a martial sport. Research on evaluating punches using vision and inertial sensing systems. The system uses an IC sensor 3140 accelerometer implanted into a punching bag for dynamic acceleration measurement, and 2 GoPro Hero 3 cameras [3]. The introduction of punches in karate using acceleration sensors and Convolution Neural Networks, results show that the system can recognize punches well based on the developed models [4]. The kinematic measurement characteristics of the punch in boxing sport were carried out using a Neural Network, the results showed the level of punch recognition [5, 6].

Some of the technologies used in martial sports include virtual reality, tracking systems, the use of sensor technology, etc. The punch tracker recognition was developed for boxing, experimental results show that the recognition of punches in a sequence is recognized better [7]. Developing of kick testing and movement speed measurement is investigated and demonstrated results show that the developed system is reliable for use in specific martial arts fields [8].

Virtual Reality Technology is also used in martial sports training, the learning results show that the student's score is 15% higher when compared to traditional learning [9]. The application of IoT for wushu martial sports shows that the training process using this system increases the athlete's level of effectiveness by 7.8% higher [10]. Technology to observe movement in martial sports has also been applied [11]. Virtual Reality in Pencak Silat has been researched and got a positive response from users where the level of pleasure after playing the media was 78.47%, and curiosity was 80.56% [12].

One of the technologies used to preserve Pencak Silat is implemented computer-based technology in Pencak Silat training process. The results of this study indicate that the implementation of this technology has a good impact on learning outcomes achievement [13]. Another implementation is using similarity for the selection of athletes who will participate in the Indonesian National Sports Competition, and the results of the study show that the method can be decision support in selecting athletes who have the potential to compete in the competition [14].

Pencak Silat is a sport of competition between 2 (two) athletes. The element of Pencak Silat is attack and defense, the things that can be done are hitting, kicking, parrying, dodging, attacking, and possibly knocking down opponents with various techniques and tactics.

Pencak Silat matches are led by a referee and assisted by 5 judges in determining the decision. The referee's task is to lead the match and technical achievements based on the regulations. The jury also has the right to reduce the assessment of a fighter who commits a violation [15].

Body protectors are commonly used by Pencak Silat athletes to protect themselves from opponent attacks. The function of body protectors is to protect the athlete's chest, abdomen, and ribs. The existing rules only mention that the size used by athletes must be following the athlete's body size, this is intended so as not to disturb the athlete when making movements [15].

One of the studies is body protectors designed for 10 to 16 years athletes, but it does not simultaneously calculate Pencak Silat match score automatically [16]. Previous research on the placement of sensors where the results of this study is that the placement of sensors is very influential on the recognition of punches and kicks made by athletes [17].

The calculation of scores in Pencak Silat matches is needed as decision support for referees. Scores calculation of this sport allows using Internet of Things (IoT) technology. IoT has been implemented in many fields, for example in education, smart agriculture, accessing and operating appliances in the home (smart home), smart city, etc. The use of IoT is possible because this sport is active and mobile so data can be sent via the internet.

The purpose of this research is to propose the Pencak Silat sports score counter which is integrated with smart pirates' athletes' Internet of Things (IoT) based. This research expected could display scores automatically based on kicks and punches made by athletes. This system uses sensors that can identify kicks and punches that are connected to the MCU Node. So that users can access the results, the system is designed IoT based. Data from the FSR 402 sensor is sent to the server, and the user can access the required information. The limitation of this research is that it still has not considered the parry movements carried out by athletes.

## 2. METHODS

The category of Pencak Silat matches consists of sparring, singles, doubles, and teams [18]. This study is still focused on single-match category matches, where the game consists of 2 athletes competing against each other.

### 2.1. System Design

The research stages were design process (hardware and software), system integration, and testing process. The design stages include hardware and software requirements identification needed in this system and also hardware and software design. System integration stage aims to integrate mechanics, hardware, and software so that the system can work well and harmoniously. System performance analysis needs to be done by conducting a testing process

The resulting score depends on the type of action of resistance, whether the resistance is a punch or a kick. So, the determination and identification of punches and kicks is the key to determining the score. The initial stage in this research is how to identify punches and kicks that hit the opponent's body accurately so that the score obtained will be the same with the actual conditions.

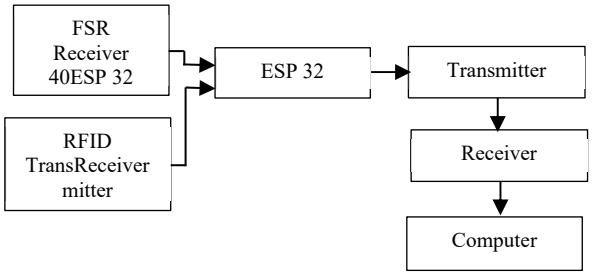


Figure 1. Smart pirates' hardware design

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The sensor used in this study is a force sensor FSR-402, this sensor has been used in several previous studies in various fields [19]. In addition, Node MCU 8622 is used so that the sensor can send data to the server via the internet. The MCU 8622 node has also been implemented with remote monitoring [20], patient monitoring [21], home security [22], fire safety and air quality monitoring [23], etc. This means that Node MCU 8622 is common and safe to use for remote monitoring and measurement.

The design of this research is depicted in Figure 1, the FSR-402 force sensor is connected to multiplexer 4051. The use of the multiplexer 4051 because the analog pins on the MCU 8622 node are limited, with the multiplexer, these 24 sensors can transmit data via pin A0 on the MCU 8622 node. This type of multiplexer has also been used in previous studies in designing electrical impedance tomography for biomedicine, lighting settings, and other applications. The server will receive the data sent by the MCU node and the user can access this information through a specific address.

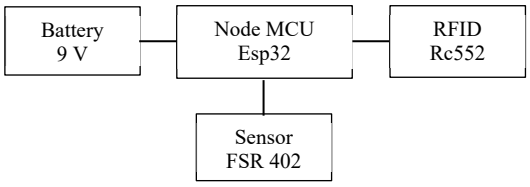


Figure 2. Circuit design

The circuit design is depicted in Figure 2, there are 2 types of systems proposed in the study. The first system is not equipped with a Radio Frequency Identification (RFID) reader, and the second design is equipped with an RFID reader [24]. This is done to know the performance of each of the designs.

### 2.2. Algorithm of The System

The algorithm implemented in this research is figured in Figure 3. The sensor will detect when the athlete makes a punch or kick. The detected power is valuable information to identify whether it is a type of punch or kick. Based on this, the root score is determined by the system following the provisions. If the user wants to know the athlete's score, he can access it via the user's gadget according to the specified address.

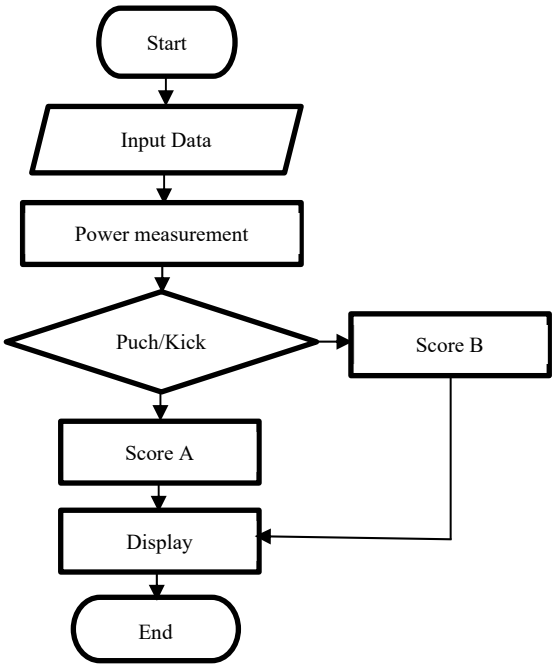


Figure 3. Algorithm of this system

### 2.3. Evaluation

The initial evaluation was carried out by statistical analysis by identifying punches and kicks. This analysis was carried out by involving 1000 times of data collection. To evaluate this system, the first design is tested without being equipped with RFID and the second design is equipped with RFID. Performance evaluation is carried out by accurate value calculation, ROC analysis, and Area Under the Curve (AUC) analysis.

## 3. RESULTS AND DISCUSSION

The design has been implemented so that a force sensor FSR 402 arrangement is obtained as shown in Figure 4. This sensor has been arranged and implanted in the Pencak Silat pirates. This sensor arrangement contains 24 force sensors FSR 402 that can detect punches and kicks. This sensor arrangement applies to the first design and the second design.

This sensor is implanted into the pirates/body protector as shown in Figure 5. The sensor arrangement is implanted with attention to the athlete's safety, where the position of the sensor is arranged in 3 layers. The first layer consists of a sponge that is useful for protecting athletes and their sensors and electrical circuits, the second layer is an arrangement of sensors, and the third layer in which there is an electrical circuit and a sponge as a protector.

A visualization of the integration of the three layers is depicted in Figure 6. The integrated sensor array is implanted in the athlete's pirates. These pirates will be able to identify the athlete's punches and kicks.

The IoT system used is by designing servers and the web according to the needs of this research. Smart pirates are designed to have different colors, in this study red and blue. This is to distinguish one athlete from another. If the FSR 402 sensor sends information from pirates that are red or blue, it will send a unique ID so that the data can be sent to the server.

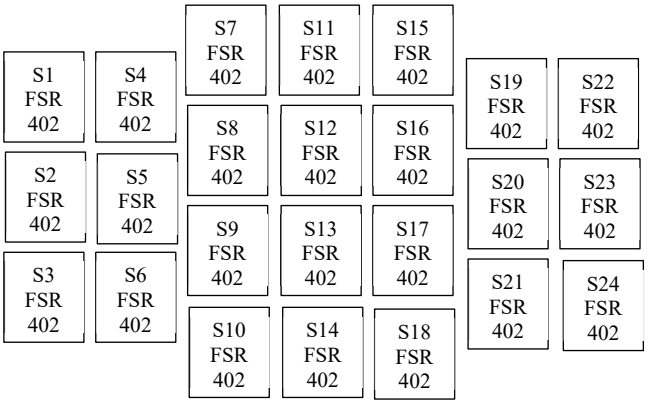


Figure 4. Arrangement of sensor FSR 402 on pirates

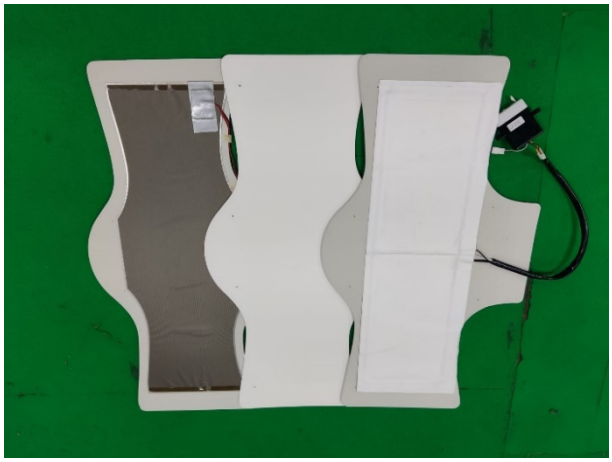

Figure 5. The sensor arrangement implanted where the position arranged in 3 layers

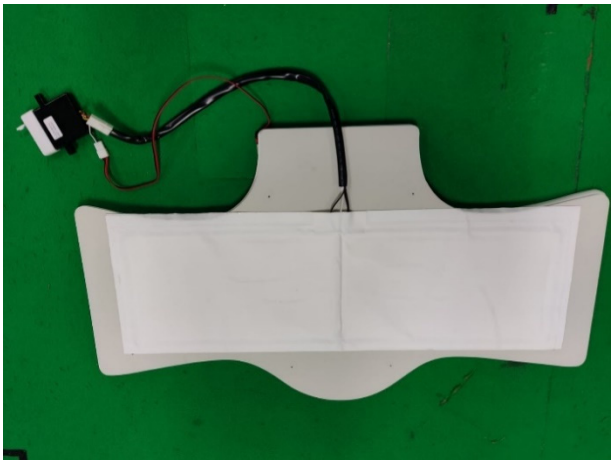

Figure 6. Integrated real-time scoring Pencak Silat with smart pirates athletes

This generated ID consists of information from where the signal was received (red or blue pirates), information on kicks (represented by label 1) or strokes (represented by label 2), and no kicks or punches occurred (represented by label 0). In addition, the ID also contains information about the amount of force hitting the opponent. With this unique ID, the system will read properly and be accessed through a predetermined address can [25] [16], the display of this score is depicted in Figure 7.

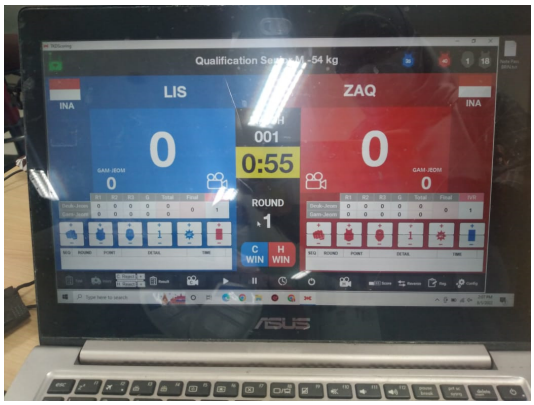


Figure 7. System scores display

Figure 7 shows the display of the score when accessed by the user. Pencak Silat IoT-based match score display which is equipped with a test mode feature for checking tools before the match starts, participant point details, match point acquisition data, match start information, match pause button, timer, match finish button, participant position change information, frequency registration body protector with receiver, scoring settings, total score and violation for each round, receiver indicator connected to PC, competing participant points, match time, and body protector indicator connected to receiver.

Figure 8. Integrated real time scoring Pencak Silat with smart pirates athletes based on IoT

It has been explained previously that the system being tested is a smart pirate's system without using RFID and a smart pirates system equipped with RFID. The system without RFID in determining kicks and punches uses a threshold value obtained from data retrieval 1000 times by 10 athletes, where each athlete kicks and punches 100 times which is carried out gradually in distinguishing between punches and kicks. The visualization of this smart pirate is depicted in Figure 8. The results of the punch and kick analysis are shown in Figure 9.

The FSR 402 sensor converts the amount of force (gr) into resistance (kΩ). The conversion from force to resistance in this study is illustrated in Figure 9. The distribution of punches and kicks in Figure 9 is carried out by 10 people and each person kicks and punches 100 times, so a total of 1000 kicks and 1000 punches. The graph for the y-axis shows the magnitude of the resistance and the x-axis shows the number of punch or kick.

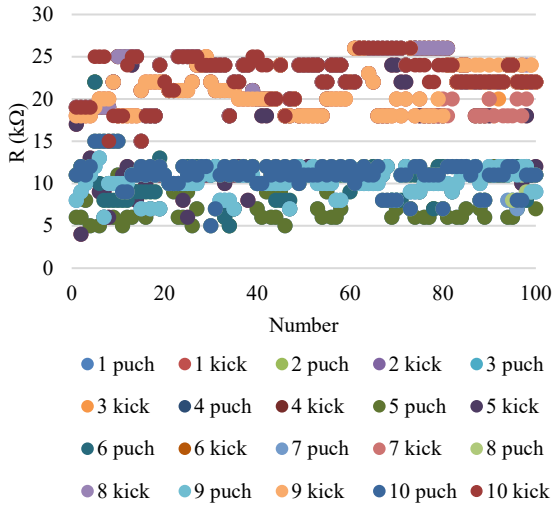


Figure 9. Spread the resistance value of punches and kicks

Figure 10 is the result of data collection carried out by 10 people, each person did 100 kicks and 100 punches, and data collection is carried out in stages. The data obtained is the conversion value of the resistance to the input force received by the FSR 402 sensor. This graph shows the average, minimum, and maximum values of kick and punches resistance values.

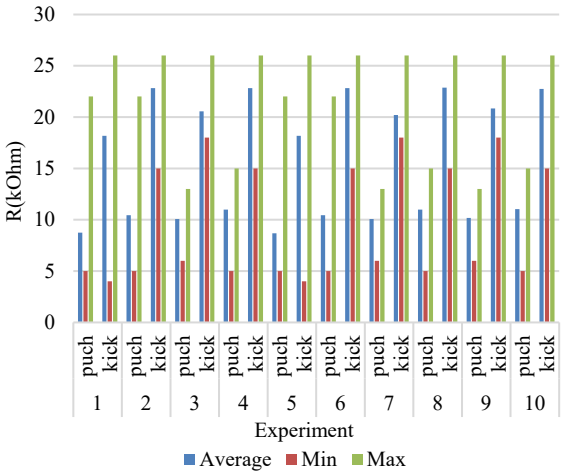


Figure 10. Average, minimum, and maximum values of punches and kicks

Figure 10 represents the minimum, maximum, and average values of punches and kicks. This value is then used as the basis for determining the threshold value for kick and punch identification. Determination of the threshold is obtained by calculating the middle distance between the kick and punch average, the formula used is as in Equation (1).

$$T = \frac{(\bar{x} + \bar{y})}{2} \quad (1)$$

where, $\bar{x}$ is the average value of kick resistance and $\bar{y}$ is the average value of punch resistance.

Based on Figure 11, the average value of kick resistance is 21.200 kΩ and the average value of the stroke is 10.162 kΩ. When calculated the middle value of these

two values obtained a threshold value of 15.681 kOhm. So that the threshold value is used as a benchmark to identify between kicks and punches. This threshold value has been implemented, and the system accuracy is obtained for 1000 data carried out by 10 people as shown in Figure 12.

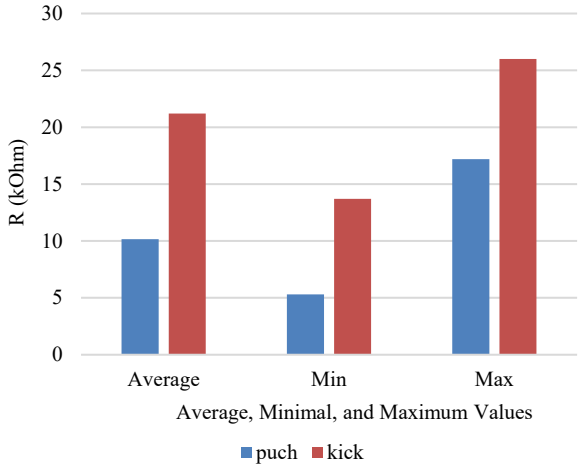


Figure 11. Average, minimum, and maximum values of punches and kicks

One method to measure system performance can be to use accuracy values based on experimental results. Based on Figure 12, the calculation of the accuracy of the system without RFID compared to ground truth obtained an accuracy value of 99.6% for punches and an accuracy value of 94.0% for kicks. The accuracy formula used in this study is as in formula 2.

$$Acc = 100\% - err \quad (2)$$

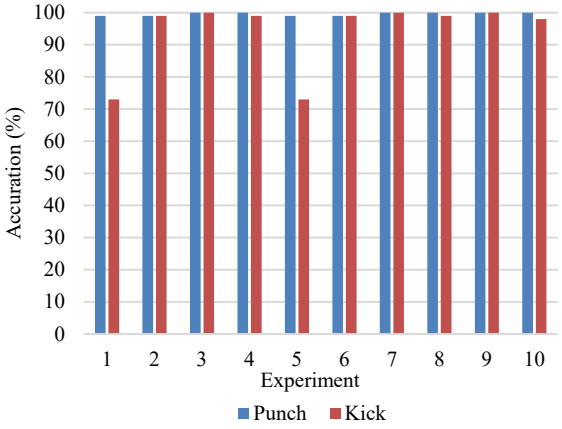


Figure 12. Accuracy of the system without RFID

The next process is to calculate the receiver operating characteristic curve (ROC). Several previous researchers have used ROC in measuring system performance [26]. The calculated ROC is the ROC from the identification of punches and kicks. The results of ROC strokes are obtained as shown in Figure 13a. Meanwhile, the kick ROC is depicted in Figure 13b. Figure 13 shows that the accuracy in identifying punches compared to grown truth is higher than in identifying kicks. This is because there is a condition where a kick with a force lower than the predetermined threshold value is identified as a hit.

One of the system performance evaluation methods can also be done by calculating the area under the curve (AUC) value, the curve referred to as ROC. Several studies have used AUC to measure the performance of the resulting system [27]. The calculation of the AUC value for punches was 0.996 while the AUC value for accuracy in identifying kicks was 0.943.

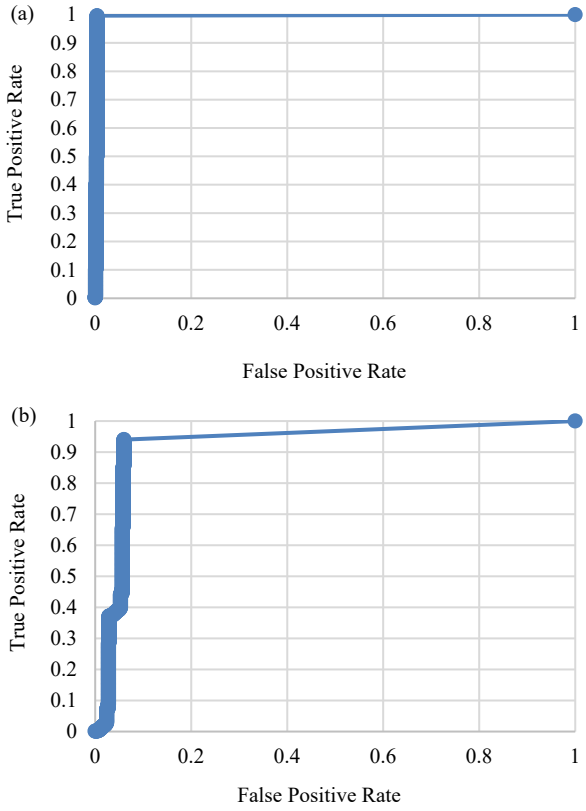


Figure 13. (a) ROC System without being equipped with RFID, (b) ROC System equipped with RFID

The results of the identification analysis of punches and kicks on the system equipped with RFID are depicted in Figure 15. The results of the analysis of the identification of punches and kicks in the second system are expected to overcome the limitation of the first system and increase value. The second system is designed to be equipped with RFID in the foot so that the kick can be recognized accurately. RFID is a device consisting of an antenna and chip [33]. RFID tags are also called transponders that function the same as barcodes, namely as identification of objects or assets with numbering on the Electronic Product Code (EPC). This research is used to identify the kick that occurs.

RFID uses an identification system with radio waves. So, it takes two devices, namely tags and readers. When the reader catches the signal from the RFID tag. The tag can be read if the user takes a kick. RFID is water and friction resistant; this is one of the reasons why RFID is implemented in recognizing kicks. The calculation of the accuracy obtained is depicted in Figure 14.

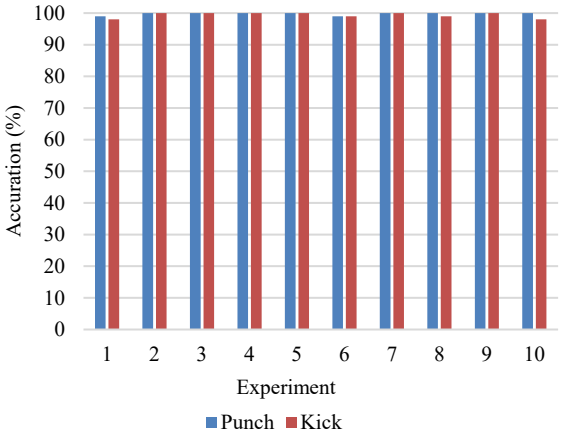


Figure 14. Accuracy of the system equipped with RFID

Analysis of the accuracy results according to Figure 15, the accuracy of the resulting system both in identifying punches and kicks is higher than the system without equipped with RFID. The accuracy obtained is 99.8% in identifying punches, while the accuracy value in identifying kicks is 99.4%. This is because when the foot touches the opponent's body during the kicking position, with the presence of RFID kick can be quickly recognized.

The results of ROC analysis in identifying punches and kicks on a system equipped with RFID are depicted in Figure 15(a) to identify punches, and Figure 15(b) to identify kicks. Based on this ROC, the AUC value is calculated. The calculation method of the AUC value is the same as the first system. The results of the analysis of the AUC value in determining the hit on the system equipped with RFID is 0.998, while the AUC value in kick identification is 0.994.

The results of the identification of punches and kicks that have been identified by the system will be used as the basis for scoring. This score will be accessible to users with certain addresses with a display as shown in Figure 8. This system works in real-time so it is expected that it can be used as decision support in score determination in Pencak Silat matches.

The system without being equipped with RFID has the advantage that this system is simpler in integrating the system. However, what needs to be considered is that the determination of this threshold value is largely determined by the initial data collection. If there is someone who punches and kicks less than the average value or who exceeds the average value, the identification of punches and kicks will not match the real conditions.

The results of the analysis show that the Integrated Real Time Scoring Pencak Silat system with Smart Pirates Athletes Based on IoT equipped with RFID can identify punches and kicks very well. This is because RFID provides information to the system that indicates a kick has occurred. Another benefit is that punches and kicks can be identified quickly. The disadvantage of a system equipped with RFID is that the system becomes more complex including hardware, software, and IoT systems. Future research to improve accuracy in identifying punches and kicks can also implement artificial intelligence in this system [28, 29].

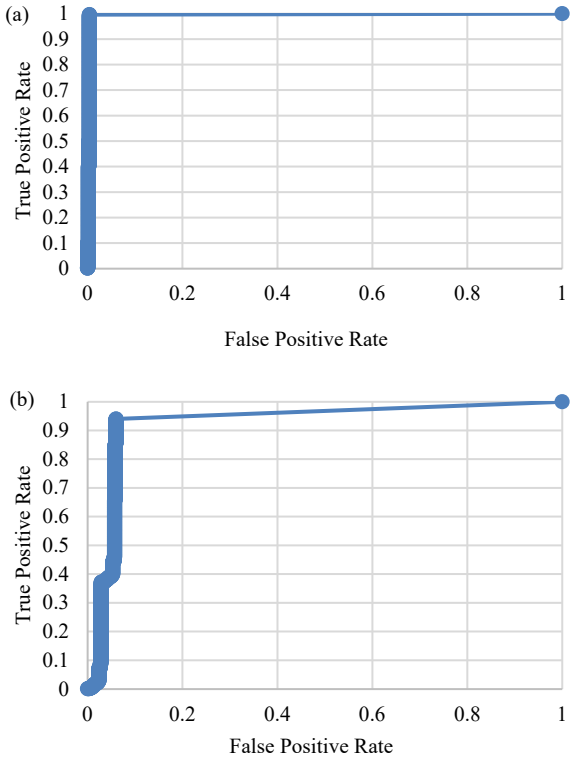


Figure 15. ROC analysis results on systems equipped with RFID: (a) punch identification (b) kick identification

## 4. CONCLUSION

The results of the implementation of the first and second systems have been able to work well. The first system implemented without being equipped with RFID has a system accuracy value of 99.6% to identify punch, while the accuracy in determining kick is 94.0%. The second system equipped with RFID has a system accuracy of 99.8% in identifying punches, while the accuracy in identifying kicks is 99.4%. The AUC value generated by the first system is 0.996 in identifying punches, and 0.944 in identifying kicks. While the AUC value of the second system is 0.998 in identifying the punches, and 0.994 in identifying the kicks. This shows that the system can be implemented by analyzing the advantages and consequences of its use. When using the first system, the user must always update the threshold value every time a match is made. This is because the threshold value depends on the match class. If the threshold value analysis is not carried out, the consequence is that the stated score will not match the actual conditions. The second system is more practical and accurate in its implementation. Another advantage of the second system can be implemented in all types of matches.

## APPENDICES

### Appendix 1. FSR-402

FSR-402 is a force sensor that can convert the amount of force into resistance. The data that will enter the embedded system is the amount of resistance.

**Appendix 2. NodeMCU ESP8266**

One of the developments of the ESP8266 is the NodeMCU ESP8266. The function of this module is almost the same as arduino but the difference is that the NodeMCU ESP8266 module facilitates connecting to the internet.

**Appendix 3. Radio Frequency Identification (RFID)**

The chip part is capable of storing 2,000 bytes of data. Labels or RFID tags are called transponders that function the same as barcodes. The working principle of RFID is a wireless identification system that allows data retrieval without having any touch between devices.

## NOMENCLATURES

**1. Acronyms**

| | |
|---|---|
| AUC | Area Under the Curve |
| EPC | Electronic Product Code |
| IoT | Internet of Things |
| RFID | Radio Frequency Identification |
| ROC | Receiver Operating Characteristic Curve |

**2. Symbols / Parameters**

$T$: The number of thresholds
$\bar{x}$ : The average value of kick resistance
$\bar{y}$ : The average value of punch resistance
$Acc$: Accuration (%)
$err$: Error rate (%)

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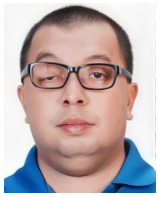

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