IoT-Based Instrumentation Development for Reaction Time, Kick Impact Force, and Flexibility Index Measurement

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***Abstract*—This paper presents an Internet of Thing (IoT)-based instrumentation development using vibration sensor, force sensor, and Blynk app to obtain the reaction time, kick impact force, and flexibility index based on visual stimulants. Besides the Blynk app, vibration, and force sensors, other main components of the prototype are the Arduino NodeMCU microcontroller, and three LEDs (yellow, red, and green). The developed prototype was able to record the reaction time, kick impact force, and flexibility index. These outputs could be viewed not only on the Organic Light Emitting Diode (OLED) display but also on the smartphone via the Blynk app interface. To evaluate the performance of the developed prototype, four male Silat athletes weighing between 61kg to 80kg were recruited for this experiment. They were requested to undergo a Simple Reaction Time (SRT) task which requires them to perform three trials of the front kick. From the SRT findings, it can be deduced that 75% of the participants reacted faster towards green LED with the fastest reaction time recorded was 1485.2±126.7ms compared to yellow and red LEDs. In the future, the design of the hardware in terms of circuitry and hardware casing will be improved for a better prototype presentation. Secondly, a big sample size of subjects and different branches of combat sports will be recruited to assist in further analysis. Furthermore, the sound stimuli will be included in future studies. Lastly, further research should be conducted to assess the effect of colored stimuli on the reaction time of the athletes.**

***Index Terms*—Internet of Things, reaction time, kick impact force, flexibility index**

I. Introduction

There is no consensus on the exact definition of agility within the world of sports science. One of the proposed definitions of agility is a rapid reaction of whole-body movement with a change of velocity or direction in response to the stimulus. Agility comprises physical qualities that can be trained, such as power, strength, flexibility, and technique, as well as cognitive components, such as visual processing techniques, visual processing speed, anticipation, and pattern recognition [1]. An athlete, who has an advantage on their physical and cognitive skills, is said to give better performance, and this performance is evaluated by the reaction time of the athlete itself. Athletes who have better reaction time are said to have an ideal performance than others [2]-[6].

Silat performers are required to make use of their eyes, hands, and feet to execute defense and attack techniques. At present, there are hardly any devices that measure the reaction time, kick impact force, and flexibility altogether, especially in Silat sport. Therefore, in this study, a developed prototype that can display the reaction time, kick impact force, and flexibility index of the Silat practitioner will provide significant data for the coaches to plan the training programs to achieve great performance success. The flexibility of the athletes is important as it can help to prevent sports injuries [7].

Based on the current limitation, the objectives of this research are formulated. The first objective is to develop an IoT-based instrumentation device for measuring the reaction time, kick impact force, and flexibility index of Silat athletes based on Simple Reaction Time (SRT) task. The second objective is to evaluate the performance of the developed device on Silat athletes by requesting them to perform the front kick on the prototype. To achieve the objectives of the research, the scopes of the research are divided into three phases. The first phase is the development of Internet of Thing (IoT)-based instrumentation, which measures reaction time (milliseconds), kick impact force (Newton), and flexibility index (dimensionless). The main components of the device consist of Arduino NodeMCU, vibration sensor, force sensor, and three-light emitting-diodes (LEDs). Besides, the circuit design is simulated by using Proteus software for circuit operation testing. The second phase is the integration of all parameters with the (IoT) platform. In this study, the Blynk is chosen as the IoT platform. Through the integration with the Blynk platform, the data obtained can be viewed in the Blynk app and it can be stored in the Blynk server for later analysis. The final phase of this study is the data collection on the participants. This study is carried out on Silat athletes who were highly skilled and had participated in the regional tournament. The experiment

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was conducted in the outdoor environment for participant's comfortability and according to the usual training environment. The prototype was attached to the kicking pad, and the participants were required to perform the experiment task known as Simple Reaction Time (SRT). The prototype was designed to be able to withstand the impact of the kicking force so that any major damages to the prototype can be avoided.

II. Development of IoT-Based Instrumentation

Fig. 1 shows the overall block diagram of the proposed IoT-based instrumentation. The Arduino NodeMCU is used as the microcontroller to communicate with the vibration sensor and the force sensor, as well as for the integration with the IoT platform (Blynk app). The selection of the visual stimulants (yellow, red, and green LEDs) was controlled via the IoT-based stimulant controller buttons, which were developed in the Blynk app. Each time the visual stimulant is selected, the reaction time in milliseconds will start counting until the subject performs the front kick on the kick pad. The vibration sensor will stop the reaction time counting when it detects vibration while the force sensor will measure the amount of force exerted by the athlete's front kick. The flexibility index will be calculated when the data of the maximum kick range of the subject and the height of the subject are inserted in the Blynk app on the smartphone. Then, the data of reaction time, kick impact force and flexibility index will be displayed on the organic light-emitting diode (OLED) display and later will be saved into the Blynk server. In addition, a reset button widget in the Blynk app is used to reset the previous data collected.

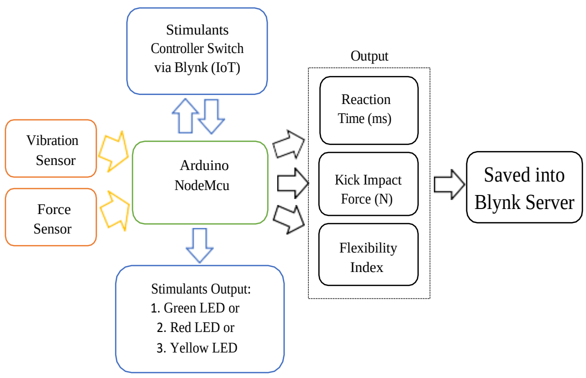

Fig. 1. The overall block diagram of IoT-based instrumentation.

A. Participant Consideration

This research work was approved by the Ethical Research Committee from the Research Management Centre (RMC) UTHM to conduct subject testing. A total of four male subjects from the Silat background, which weighted between 61kg to 80kg was recruited in this study. All of them were high achievers in various Silat tournaments at the university level. The subjects were asked to fill in the consent form first before participating in the SRT task. Next, the subjects were requested to perform the front kick for three times trials to ensure the data collected is valid and constant during the experiment task. The front kick is one of the Silat kicking skills usually performed during their training and, hence it has been selected in this study.

B. IoT Blynk Application

Blynk is an IoT platform that can work with iOS and Android operating systems. It allows controlling electronic devices over the Internet. It provides a digital dashboard, whereby users can build a graphic interface using different widgets by the simple act of dragging and dropping the widgets [8]. Blynk can also read, store and display sensor data. There are three main components in Blynk, which are the Blynk app, server, and libraries. The Blynk app helps to build the interface for remote control, as well as monitoring and the server provides communication between the Blynk app and the hardware. The libraries allow the communication for the hardware with the server through the use of coding [9], [10].

In this research, there were several widgets selected to control and monitor the reaction time, kick impact force, and flexibility index parameters, which are Superchart widget, Value Display widget, Numeric Input widget, and Button widget. The Superchart and Value Display widgets were used to monitor the data collected from the sensor, whereas the Button widget was used to control the visual LED stimulants (yellow, red, and green). The numeric input widget was used to accept the key-in value of the maximum kick range (cm) and the height of each participant (cm) for the determination of the flexibility index (FI) (dimensionless) [11], described as

$$FI = \frac{\text{Maximun kick range}}{\text{Body height}}$$

Fig. 2 shows the coding that allows Arduino NodeMCU to interface with the Blynk app. The #include <ESP8266WiFi.h> is the NodeMCU library, which enables Arduino NodeMCU to interface with the Blynk app, whereas Blynk.begin(auth, ssid, pass) is a command that enables Blynk to recognize the device and to initiate the connection.

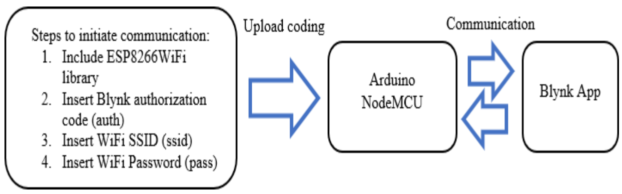

Fig. 2. Steps to initiate communication between Arduino NodeMCU and the Blynk app.

Fig. 3 illustrates the flowchart of the IoT-based instrumentation for reaction time, kick impact force, and flexibility index. The communication between Arduino NodeMCU and the Blynk enables the control of visual stimulation at one's fingertips. Through the Blynk app, the LEDs can be triggered with a single tap on the button widget. In this study, the Simple Reaction Time (SRT) task is designed to assess the athlete's reaction time based on the visual stimuli (yellow, red, or green LEDs) by asking the athletes to perform the front kick on the prototype as soon as the stimulus is presented.

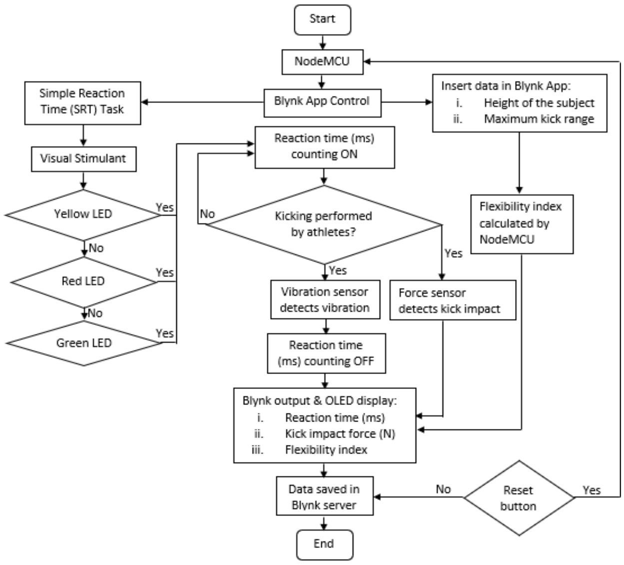

Fig. 3. The flowchart of IoT-based instrumentation.

For example, when the red LED turns on (visual stimulus is triggered), the subject will execute the front kick on the kick pad. Then, the red LED will turn off as soon as the vibration sensor detects the vibration that is caused by the front kick impact. Next, the reaction time will be measured between the starting time of the LED lit up and the LED turn off time. Simultaneously, the force sensor will detect the force of the kicking applied by the subject. As for the flexibility index, the maximum kick range of the subject and the subject's height will be manually inserted into the Blynk app. The resulted flexibility index as well as the reaction time and the kicking force will be displayed on the OLED display and the Blynk app. All the data will be saved into the Blynk server for data storage. A reset button widget can be triggered to reset the previous data collected for the next trial.

C. Experimental Protocol for Simple Reaction Time (SRT) Task

Fig. 4 shows the flowchart of the SRT experiment protocol. First of all, the subjects were briefed on the experiment protocol in detail. A written consent form was distributed to all participants to fill up their personal information required in the experiment. The athletes were requested to do warm-up to prevent any injury from happened during the experiment. This research consists of a Simple Reaction Time (SRT) task, which requires the participant to react towards the visual stimulus. During the SRT task, the subject will stand on the starting line, which is two meters away from the kick pad. Then, the subject is required to focus on the visual stimuli and react by performing the zigzag step before executing the front kick on the kick pad when the stimuli are presented. The visual stimuli will be randomly presented without any notice, hence the subject has to be alert at all times. After performing the first kicking, the subject must move back to the starting line as soon as possible and wait for the same stimulus to be presented again for the second kicking. Thus, one trial of the experiment required the subject to perform two kicking actions on the kick pad. An average value was taken for each trial performed. For the measurement of kick impact force, the participant was required to kick on the force sensor attached to the kick pad as shown in Fig. 5. Each participant was requested to perform three trials for each stimulus. However, thirty seconds of resting time were given to the subject before proceeding to the next trial. A repetition of the trial would be conducted should any technical problem occurred.

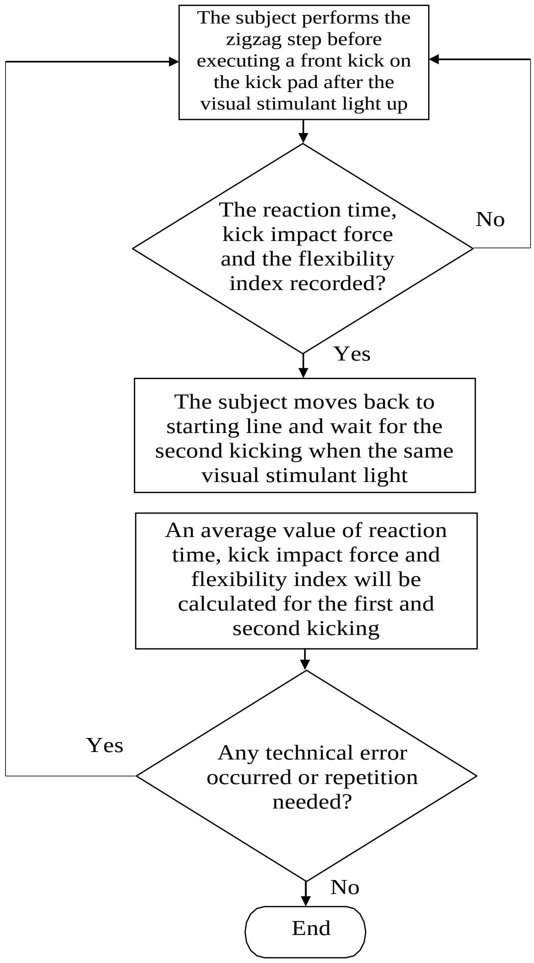

Fig. 4. The flowchart of SRT experiment protocol

III. RESULTS AND DISCUSSIONS

This section presents the IoT-based instrumentation development and data analysis on the collected data based on reaction time, kick impact force, and flexibility index.

A. IoT-Based Instrumentation for Reaction Time, Kick Impact Force, and Flexibility Index

Fig. 5 shows the front view of the IoT-based prototype with the hardware design attached to the top surface of the kick pad. The hardware components were placed in a Perspex box and the box was adhesively attached to the top surface of the kick pad. The OLED display and the three LEDs (yellow, red, and green) were placed on the top of the Perspex box, whereas the force sensor was attached to the kicking surface of the kick pad that acted as the target for the participant during the experiment. Table I summarized the functions of each numbering item corresponding to Fig. 5.

TABLE I: FUNCTION FOR EACH NUMBERING LABEL BASED ON FIG.5

No	Name	Descriptions
1	LEDs	Consists of yellow, red, and green LEDs,which acts as visual stimuli
2	OLED	Display of reaction time, kick impactforce, and flexibility index values
3	Kick Pad	Standard kick pad size used by Silatathlete in the experiment
4	Force Sensor	Acts as a target for the subject to focus their front kick and measurement of kick force

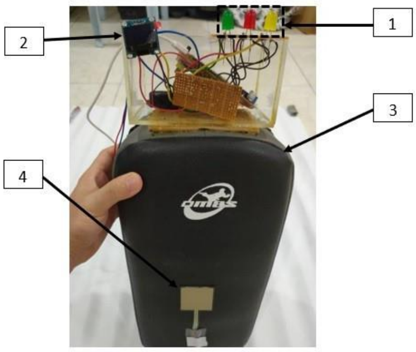

Fig. 5. The front view of the IoT-based prototype.

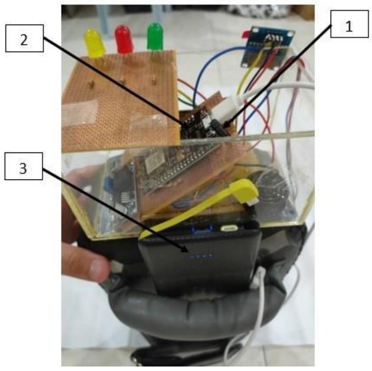

Fig. 6. The back view of the IoT-based prototype.

TABLE II: FUNCTION FOR EACH NUMBERING LABEL BASED ON FIG.6

No	Name	Descriptions
1	Vibration Sensor	Used to detect vibration for reactiontime counting
2	Arduino NodeMCU	The microcontroller is used to process the input and the output of data as well as communication with the Blynk platform
3	Power Bank	The power supply of 5V for Arduino NodeMCU

Fig. 6 shows the back view of the IoT-based prototype with the power supply attached to the back of the kick pad. A power bank of five volts was used to supply power for the Arduino NodeMCU. The Arduino NodeMCU was soldered on the stripboard along with the vibration sensor. The vibration sensor was used to sense the vibration caused by the kicking force of the subject, which triggered the reaction time to stop counting. Table II summarized the functions of each numbering item corresponding to Fig. 6.

Fig. 7 shows the resulted interface of the IoT application through the Blynk app. There were several main indicators such as the visual stimulant control buttons which were used to control the visual stimuli (yellow, red, and green LEDs), the reset button for resetting the Blynk app, three main parameters displays; reaction time, kick impact force as well as flexibility index. It can be seen that the reaction time shown was 1106ms, whereas the kick impact force and the flexibility index were displayed as 47.97N and 0.62 (dimensionless), respectively. The same values displayed in the Blynk app were also shown on the OLED display as depicted in Fig. 8.

Fig. 7. The Blynk app interface for the developed prototype.

Fig. 8. The organic light-emitting diode (OLED) display.

B. Analysis of Reaction Time, Kick Impact Force, and Flexibility Index

The data analysis was carried out on four Silat athletes, which were high achievers in the Silat tournament. Each of them was weighted between 61kg to 80kg. In this research, a small sample size of the subject was recruited due to the insufficient number of Silat athletes available. Nonetheless, the number of subjects was adequate because the athletes were intended to test whether or not the prototype could function as the initial expectation. The subjects were required to conduct three trials of the SRT experiment.

Fig. 9 shows the average means and standard deviation of reaction time of the subjects in yellow, red, and green LEDs. Based on Fig. 9, it can be seen that Subject D has the fastest reaction time, which was 1762.8±89.7ms and the slowest reaction time was exhibited by Subject B, which was 2170±124.7ms in the yellow LED stimulus. For the red LED stimulus category, Subject C has the fastest reaction time, which was 1560±146.5ms and the slowest reaction time came from Subject A, which was 2044.3±70.2ms. In the green LED stimulus category, it can be deduced that Subject C has the fastest reaction time, which was 1485.2±126.7ms, whereas Subject A has the slowest reaction time, which was 2067±53.1ms.

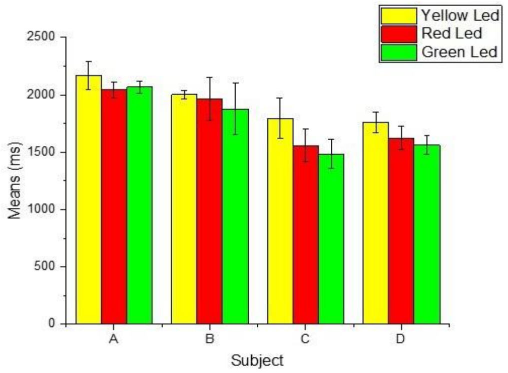

Fig. 9. The average means and standard deviation of reaction time in yellow, red, and green LEDs.

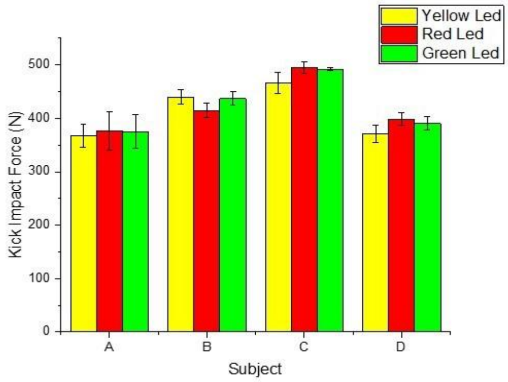

Fig. 10. The average means and standard deviation of kick impact force in yellow, red, and green LEDs.

TABLE III: THE FLEXIBILITY INDEX OF EACH PARTICIPANT

No	Subject	Weight (kg)	Flexibility index
1	A	67	0.503
2	B	77	0.508
3	C	70	0.592
4	D	68	0.573

Fig. 10 illustrates the average means and standard deviation of the kick impact force of the subjects based on the visual stimuli (yellow, red, and green LEDs). Subject C has the highest kick impact force, which was 466.6±19.8N as compared to others and the lowest kick impact force came from Subject A, which was 367.7±21.7 N for the yellow LED stimulus. As for the red LED stimulus, Subject C has the highest kick impact force, which was 494.7±11N in comparison with others, whereas Subject A has the lowest kick impact force of 376±36.1N. In the green LED stimulus category, Subject C dominated its peer with the highest kick impact force of 492.3±3.3N, whereas Subject A has the lowest kick impact force of 374.9±31.5N.

The analysis of the subjects' flexibility index had shown that Subject C has the highest flexibility index, which was 0.592 followed by Subject D (0.573), Subject B (0.508), and Subject A has the lowest flexibility index of 0.503 as tabulated in Table III. Higher flexibility index indicated that one is more flexible as compared with others [9]. In this case, Subject C was the most flexible, whereas Subject A was the least flexible among the subjects.

To sum up the analysis, Subject C has the overall fastest reaction time in the SRT task with the fastest reaction time achieved in green LED stimulus, which was 1485.2±126.7ms. In comparison, Subject A has the slowest reaction time throughout the SRT task with the slowest reaction time achieved, which was 2044.3±70.2 ms in red LED stimulus. Meanwhile, Subject C also dominated its peer in kick impact force measurement with the highest impact force of 494.7±11N in red LED stimulus. In contrast, Subject A possessed the lowest kick impact force in the whole SRT task with the lowest kick impact force of 367.7±21.7N in yellow LED stimulus. The deduced reason why Subject A obtained the lowest kick impact force might perhaps be due to the weight difference among the subjects whereby Subject A has the lowest weight of 67kg as compared with Subject B (77 kg), Subject C (70kg), and Subject D (68kg). For the flexibility index, Subject C has the highest flexibility index of 0.592, which indicated that Subject C was the most flexible in comparison with the others. Thus, to summarize all the analyses, Subject C has the fastest reaction time, highest kick impact force, and the most flexible among the subjects recruited, whereas Subject A has the slowest reaction time, lowest kick impact force, and lowest flexibility index throughout the whole SRT task. In addition, Subject C achieved the highest kick impact force might be due to the highest flexibility of the leg as there was a significant relationship between the force of the leg and the leg's flexibility [12]. Besides that, it can be concluded that 75 % of the participants were more responsive towards green LED as compared with yellow and red LEDs in the SRT task in terms of reaction time. This result corresponded to the findings from the previous studies [13], [14], which indicated that the reaction for green color stimuli was significantly less than the reaction time for red color stimuli. The deductions on why most of the subjects responded faster towards the green LED are the green light has a shorter wavelength and carries greater energy than the yellow and red lights in the same quantum [14]. However, another study, which presented inconsistent results that showed the reaction time for red color stimuli was significantly less compared to green color stimuli [15]. Therefore, further research would be needed to assess the effect of colored stimuli on the reaction time of the athletes. Last but not least, this developed instrument provides IoT functions, which enabled remote control of the device during the SRT task and the data collected can be saved in the Blynk server, besides measuring reaction time, kick impact force, and flexibility index.

IV. CONCLUSION

In conclusion, an IoT-based instrumentation prototype for measuring the reaction time, kick impact force, and flexibility index of Silat athletes based on Simple Reaction Time (SRT) task was successfully developed. The developed device was able to measure the reaction time, kick impact force, and flexibility index of each subject, and the data was successfully saved in the Blynk server for later analysis. There are some limitations, which cause the collected data to be inconclusive. Firstly, the physical and mental states play an important factor in collecting the reaction time, kick impact force, and flexibility index data. Some of the subjects could only participate in the experiment after their busy schedules. Secondly, this study recruited a small sample size of subjects. Nevertheless, this sample size was sufficient since the subjects were recruited to test the performance of the developed prototype. Lastly, it can be concluded that 75% of the participants were more responsive towards green LED as compared with yellow and red LEDs in the SRT task in terms of reaction time. As for future works, several recommendations can be done. Firstly, the design of the hardware in terms of circuitry and casing can be improved for a better prototype presentation. Secondly, a big sample size of subjects and different branches of combat sports can be recruited to assist in further analysis. Furthermore, the sound stimulus can be included in future studies. Lastly, further research should be conducted to assess the effect of colored stimuli on the reaction time of the athletes.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Dr. Nur Anida led the conducted research and edited the paper. Mr. Ng Chun Keat developed the prototype, analyzed the data, and wrote the paper. All authors had approved the final version of the paper.

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