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JORPRES (Jurnal Olahraga Prestasi), 20 (2), 2024, 34-45

Development of IoT-based footwork ability test using ESP32 camera for badminton athletes

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Abstract
Badminton requires open and fast movements towards the shuttlecock, but there is no specific agility test for badminton players with specific movements to assess the athlete's footwork ability. This leads to a lack of objective indicators to know the progress of the results of the exercises. Researchers aim to produce useful technology to measure the agility of badminton athletes as a tool of Footwork Test and Training. The method used is Research & Development (R&D). The test involved 26 badminton athletes in Bandung. After going through the validity test by experts (expert judgment) shows that the validation technology performed by 3 validators get a value of 95% can be categorized as very good. The accuracy of the score calculation system of 99.96% is in the very high category. The results showed that footwork ability test technology received a positive response from athletes and coaches, this tool can also serve as a trainer tool to guide athletes in carrying out footwork exercises. Thus, footwork ability test technology has been declared worthy of use as a medium of tests and exercises.
Keywords: Badminton; Footwork; Agility; Technology

INTRODUCTION

Badminton is one of the popular sports in Indonesia that is in the spotlight in the world today. According to the Indonesian Survey Scale, badminton is ranked as the second most popular sport in Indonesia. The achievements that have been achieved by badminton players are a source of pride, so many people like badminton and are even in demand (Septian Williyanto, 2016). Therefore, athletes are motivated to train from an early age to adolescence to improve high-level skills. In addition, the achievements of the best athletes in developing countries who set world records cannot be separated from the role of science, technology and engineering (Frevel, Beiderbeck & Schmidt, 2022). Therefore, one of the goals of performance analysis-related research is to help improve players' skills and performance efficiency during matches (Leong & Krasilshchikov, 2016).

Currently, badminton achievements in Indonesia over the past 5 years have experienced ups and downs, obtained from BWF ranking data which shows that athletes have not been able to maintain their achievements. In addition, this is also supported by real facts from interviews with badminton athletes and coaches obtained from the PBSI official website. It is known that one of the causes of athlete defeat is due to lack of footwork skills (Karyono & Paluris, 2022; Zaidan et al., 2024). A player who does not have good footwork will have difficulty in mastering the game, the key to playing badminton is good footwork, so that indirectly athletes who have good footwork will quickly master the basic techniques of the game (Ngadiman & Kusuma, 2020). In general, to improve players' footwork, coaches often use exercises by placing the ball (shuttlecock) at different corners of the court, and players are tasked with reaching the ball and placing the ball/cock back to another corner. Researchers call this the conventional footwork training system. Of course, behind the achievements that are inscribed,

ISSN 0216-4493 (print), ISSN 2597-6109 (online)

of course, cannot be separated from the problems of athletes in training. One of them is the use of technology in sports that has not been maximized.

The role of technology in terms of achievement development is minimally used so that training is only applied manually, as a result there are no objective indicators to determine the progress of the training results (Ngadiman, Kusuma, & Widhi Nugraha, 2019). Through the results of research conducted by (Endang Sepdanius, 2019), data were obtained which showed that training activities were not objective, badminton is going well, but in terms of technology utilization it is still small. The use of technology in sports will greatly assist coaches and athletes in implementing the desired training program, especially in honing technical, physical, and tactical skills (Ababil, Adi, & Fadhli, 2019). In badminton, the aspects that influence the game are technique and physicality which influence each other on the quality of play (Kusuma & Jamaludin, 2020). Badminton involves strokes that require speed and explosive power combined with agile footwork (D. Liu, 2017). Players who can perform fast movements tend to dominate in badminton tournaments (BIDIL et al., 2021). Therefore, badminton players' footwork during fast movements is an important basis for determining agility (Frederick et al., 2020). Badminton-specific footwork training is a major component of agility training.

Therefore, in order to improve sports performance in badminton games, training is needed. According to (Muthiarani & Lismadiana, 2021) training aims to improve physical quality in general, develop specific physical potential, add and perfect techniques and strategies. During training, the use of technology can be done to increase the variety of exercises, changes in efficiency and effectiveness in training depending on the training model provided (Williyanto, Wiyanto & Santoso, 2021). Training footwork techniques to improve agility will be an advantage for badminton players (Hamid & Aminuddin, 2019). Therefore, to improve the ability that conditions agility, technology is needed to control the intensity of training more accurately.

At this time, there has been technological research and innovation that develops tools in practicing footwork in badminton. Some related research includes, among others, research (Maryati, Sri & Sugiawardana, 2017) namely, the development model of a microcontroller-based footwork trainer tool on badminton skills was developed to improve footwork required for a badminton athlete. Research (Williyanto & Wira Yudha Kusuma, 2018), namely, the development of badminton skill test instruments for athletes in the age group range of children to adolescents. Research (Kusuma, 2019), namely, the application of the blocked practice method and technology-based footwork media in an effort to improve badminton playing skills. Research (Ababil et al., 2019), namely, has developed an android application-based badminton basic technique training media for novice athletes. Research Ngadiman, Kusuma & Widhi Nugraha (2019), namely designing footwork training aids in badminton games based on microcontroller technology as a measuring tool for the success rate of an athlete in training. Research Endang Sepdanius (2019), namely the development of footwork training aids in android-based badminton to test the effectiveness of badminton sports training tools. Research (Rusdiana, 2021) namely, the development of agility training devices, coordination, and reaction time with infrared sensors and Arduino WiFi modules in badminton.

Some of the development research that has been done, there is no camera feature that can be streamed to evaluate training results. The technology developed will be able to detect footwork movements made by athletes through an embedded camera, which will be connected to an application that can stream during training so that it can be used to evaluate training results. In addition, there is a center sensor that will detect footsteps to count the number of footsteps that have been taken.

Based on existing problems, researchers provide solutions in the form of IoT-based Footwork Ability Test technology using ESP32 Camera to Measure Agility of Badminton Athletes. The application of this technology is intended for badminton coaches who have

ISSN 0216-4493 (print), ISSN 2597-6109 (online)

similar problems and want to develop potential and improve footwork training techniques, as a problem-solving solution in developing the achievements of badminton athletes. This technology is designed in a simple, practical form, and according to user needs. The advantages of this technology will be able to detect footwork movements made by athletes through an embedded camera, which will be connected to an application that can be streamed during training so that it can be used to evaluate training results, and the use of a center sensor to detect footsteps. If this technology is applied to footwork technique training for badminton athletes, it is hoped that the training process can be carried out in a more varied, optimal and efficient manner.

METHOD

The method used is the research and development research method because the final result of this research will produce a footwork ability test product. The technology trial was carried out through several stages: (1) the test subjects were badminton athletes in Bandung City as many as 36 samples (10 small group samples) (26 large group samples) using purposive sampling method, (2) data collection instruments using expert questionnaires, (3) the type of data used is qualitative data, (4) and data analysis techniques using Likert scale assessment criteria.

The method used in this research is the research and development method because the end result will produce an IoT-based footwork ability test product using the ESP32 Camera for badminton athletes. The research subjects consisted of 36 badminton athletes in Bandung City, who were taken using purposive sampling method, with a division of 10 small group samples and 26 large group samples. Data was collected through a questionnaire prepared by technology and sports experts, and analyzed using Likert scale assessment criteria to measure the level of satisfaction and user perception of this tool.

The tool usage stage begins with the preparation and installation of the ESP32 Camera at strategic points in the training area to record athletes' footwork movements. After that, an initial calibration was carried out to ensure the accuracy of data collection and initial trials with several athletes to ensure the device was functioning properly. During use, athletes were instructed to perform a series of footwork exercises according to the prescribed procedure, while the ESP32 Camera recorded and collected movement data in real-time. The collected data is sent to the server for analysis using IoT-connected software, which then generates a footwork performance report. An assessment of the effectiveness of the tool is conducted using a Likert scale based on feedback from athletes and coaches, which is then used to provide performance improvement feedback to athletes.

The product's advantages include high accuracy due to its high video resolution ESP32 Camera, real-time analysis that enables immediate feedback, and IoT integration that simplifies data collection and analysis. It is also designed with a user-friendly interface, simple standard operating procedures, and increases the efficiency and effectiveness of footwork assessment, reducing the need for time-consuming manual assessment. Thus, this research method provides a comprehensive overview of the development and implementation of an IoT-based footwork ability test for badminton athletes.

Implementation Stage

This development procedure adapts the steps written by (Sugiyono, 2014). The following is a picture of the flow of research and development research design:

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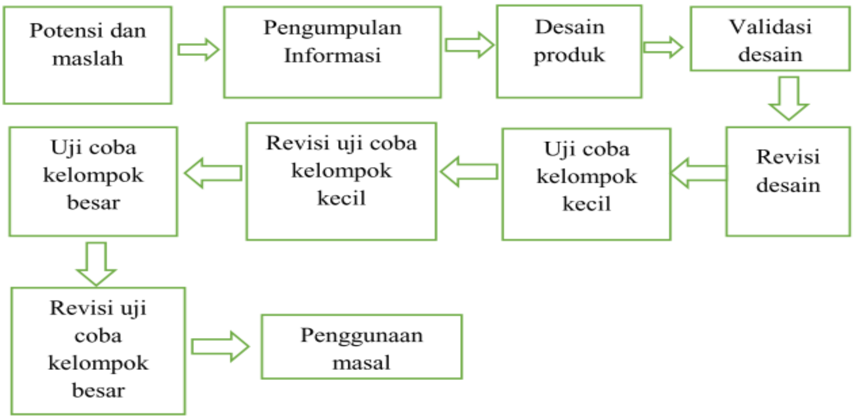

Figure 1: Steps of the Research and Development Method

Design Technology

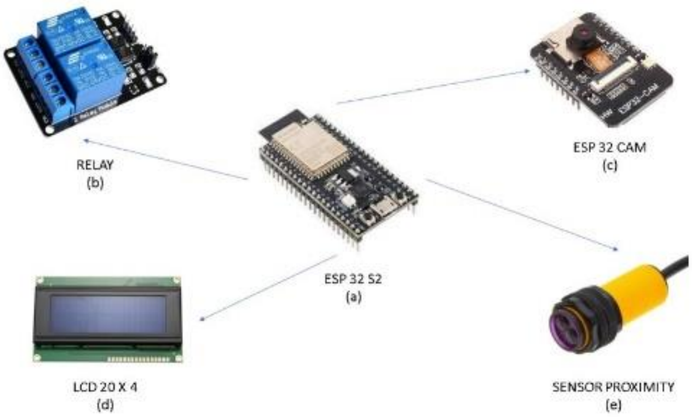

Figure 2. System Architecture

The technology design in Figure 2 consists of several supporters, namely: (a) ESP 32 S2 functions to read sensor results and connect the device with a smartphone, (b) relay as a conductor of response to the LED, (c) ESP 32 CAM functions to monitor movements through an embedded camera, (d) 20 X 4 LCD functions to display realtime data during training, and (e) Proximity Sensor functions to detect movements with a maximum distance of 6 cm.

Innovative Work Product

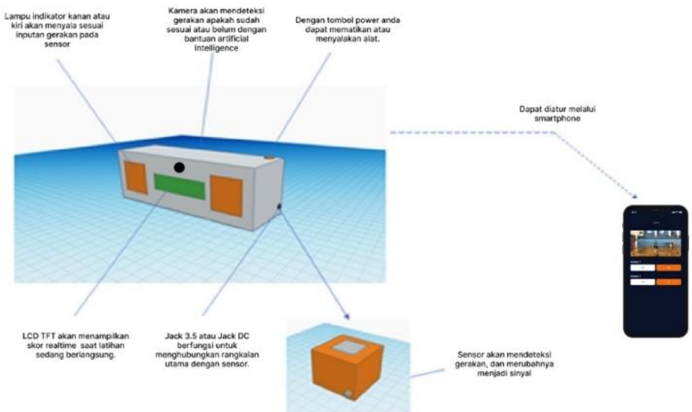

Figure 3. Innovative Work Product

In Figure 3, the initial prototype of the innovative work product before it was made. In the main box there is a camera as a movement monitor, left and right sensor lights as a support system for movement direction response, LCD score counter. The small sensor box as a reference for footwork movements and there is a supporting application to help trainers operate the tool.

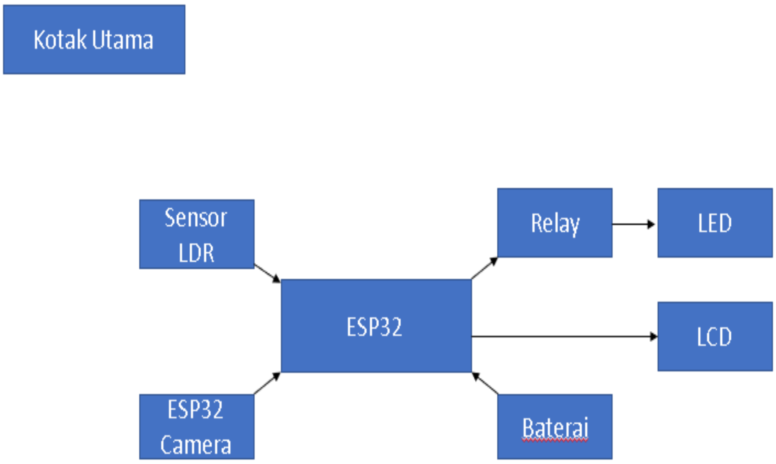

Figure 4. Main Box Block Diagram

The main box is supported by several components, sensors that function as a score calculation system based on the incoming light. Then the data from the input will be processed by ESP32. The output of the data processing results will turn off and turn on the sensor. Then the score will appear on the LCD. The power source of this tool is a 5V9000Mah battery.

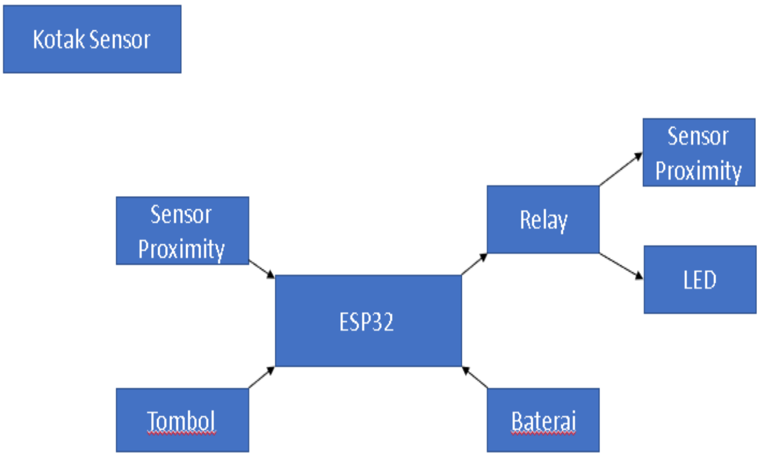

Figure 5. Sensor Box Block Diagram

The sensor box has several supporting components such as sensors and buttons as motion detection inputs. Data from the input will be processed by ESP32, the results of data processing can turn off and turn on the sensor and led. The power source of this circuit is a 5V 6000Mah battery.

Production Process

The production process is carried out by people who are experts in their fields with approximately 3 months (June-August) online and offline (blended). Starting from the preparation of technical design, manufacturing footwork ability test products (FPTK UPI electro lab), product implementation (UPI sport hall and badminton club in Bandung City), and evaluation by applying health protocols in each manufacturing process.

ISSN 0216-4493 (print), ISSN 2597-6109 (online)

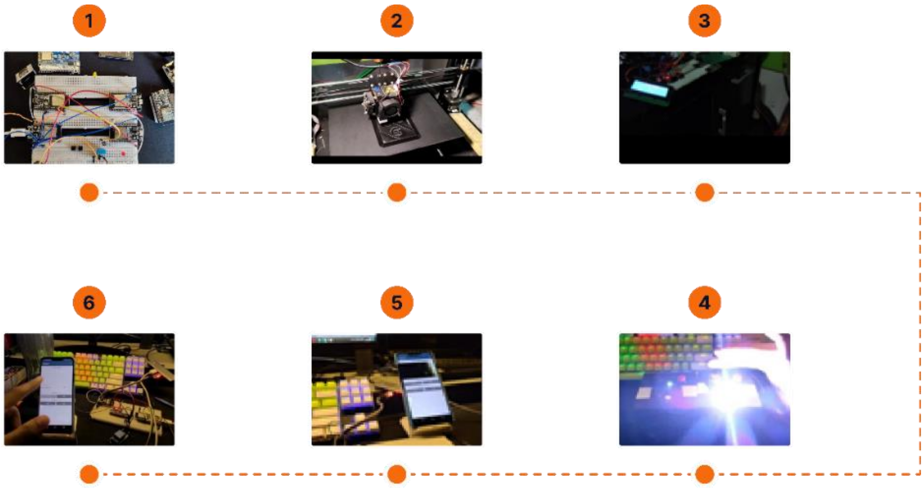

Figure 6. Production Process

Figure 6 explains the stages of tool production; (1) simulation of the tool using a breadboard aims to connect several ESP32s so that they can connect to each other and send data to the gateway, (2) making the casing using a 3D printer. So that it can make the casing as needed, (3) LCD counter simulation aims to program the LCD so that it can add scores from sensor detection, (4) motion detection and indicator lights to detect movement on the racket, and on the sensor box there are indicator lights for athletes to know which sensor box to go to and is active, (5) simulation of camera streaming aims to program the camera so that it can stream when footwork training is being carried out, so that the coach can find out where the athlete's mistake is during training, (6) making android applications aims to make it easier for coaches and users when training. In the application we made, there are several features, namely being able to turn on and off indicator lights, streaming video during training, and monitoring incoming scores.

Testing

Technology feasibility testing was validated by 3 expert judgement, namely, material experts, technology experts, and bulutagkis academics (trainers). Through interviews and filling out questionnaires. After that, test the product in the field to the target user.

The following small-scale field test of UPI Badminton UKM is shown in Figure 7:

Figure 7. Small Scale Field Test (UPI Badminton UKM)

ISSN 0216-4493 (print), ISSN 2597-6109 (online)

Through the results of small-scale field trials, it is known that the durability of the tool for one hour of use can function properly in the application of the exercise. Obstacles occur when the signal used is less stable, so a supporting device (wifi network) is needed. Then the calculation of the score with the center point sensor has not been able to calculate the footsteps properly because the laser position is below, so it is necessary to place the sensor position more accurately to be effective in operating the device.

The following large-scale field test of the SGS Club of PLN Bandung City is shown in Figure 8:

Figure 8. Large Scale Field Test (SGS PLN Club Bandung City)

Through the results of large-scale tests at the SGS PLN Badminton Club in Bandung City, the tool can be used properly and the score calculation is accurate, thus getting a positive response from athletes and coaches. The initial trial obstacles have been overcome in the large-scale field test by adding a wifi LAN network to support network stability, adding a tripod to the midpoint sensor and the main box to calculate footsteps to be more accurate. In addition, it also functions to adjust the height of the athlete to suit his needs.

The following is the product feasibility presentation assessment range shown in table 1:

Table 1. Category Feasibility Percentage

No.	Score in percentage	Feasibility category
1	< 40%	Not Feasible
2	40 % - 55 %	Less Feasible
3	56 % - 75 %	Quite Feasible
4	76 % - 100 %	Feasible

Source : Sugiyono, (2014)

Evaluate

Evaluation is carried out after the feasibility assessment by experts, then conducting field trials and final demonstrations on technology. Evaluation that has been carried out from start to finish from the technology development stage to training and assistance to users, the results show that this tool is 100% feasible and ready to use. Thus, the footwork ability test technology is ready for mass production.

ISSN 0216-4493 (print), ISSN 2597-6109 (online)

RESULT AND DISCUSSION

Results

The technology developed is a footwork training tool in the form of a footwork test and training. The resulting technology is called the "Footwork Ability Test" to provide convenience in badminton training. If this technology is applied to the training of footwork techniques in badminton athletes, the test and training process can be carried out in a more varied, optimal and efficient manner. Overview of the resulting operation-ready functional product:

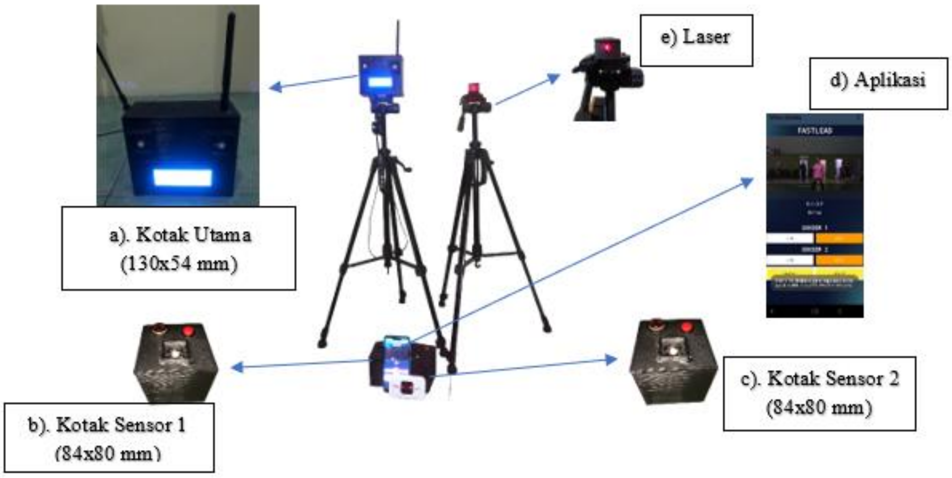

Figure 9. Fastlead Innovative Products

The main tool consists of ESP32 as a microcontroller controlling the LCD display and the life of the LED indicator on the main module with ESP32 allowing the tool to connect to the WiFi network and bluetooth so that it can be connected to a smartphone. In supporting the process of making this tool, several components are needed including ESP32 S2 which functions to read the output of the sensor, process data and connect between the tool and the smartphone, ESP32 Cam is used to take pictures or videos that can determine whether the movement is wrong or right with several parameters, in reading the movement using two sensors including a remote sensor or PIR and a PROXIMITY proximity sensor so as to minimize movement reading errors, to visualize in real time using a 3.5 inch LCD that can display scores and as a timer when training takes place. The casing of this tool is made using a 3D printer.

The way the tool works is adapted to training and footwork tests in badminton. Here are the steps of how the Footwork Ability Test works:

(1) When the hand is placed above the sensor will detect footsteps,

(2) There is a center sensor to count the number of footsteps that have been taken,

(3) And there is an ESP32 camera feature for coaches to monitor athletes in streaming on the application.

The following flow of application usage is shown in Figure 10:

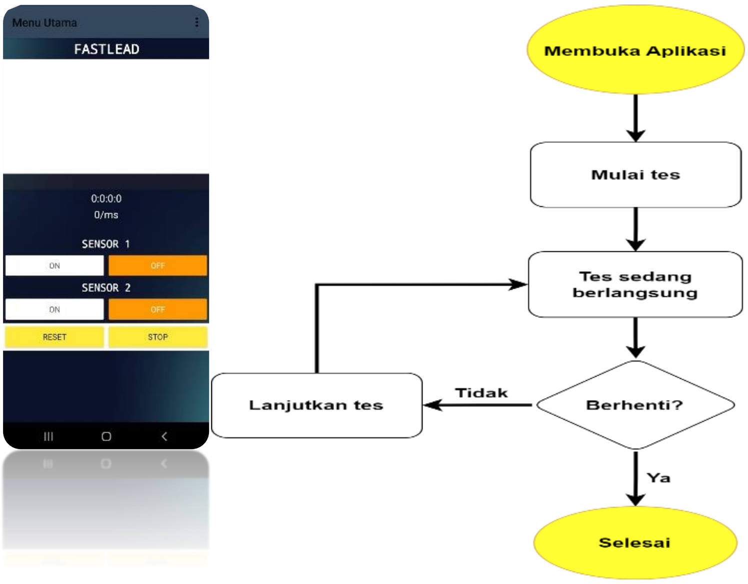

Figure 10. Flowchart of Application Usage

The following are the results of product feasibility after the validity test of 3 expert judgment shown in table 2:

Table 2. Expert Assessment Validity Results

No.	Testers	Asessor	Percentage of expert views
1.	Technologist	100	34 %
2.	Material Expert	100	34 %
3.	Badminton Academics	85	27 %
Total:		285	95 %

The results show the feasibility of the footwork ability test technology at 95%.

The following score calculation system accuracy results are shown in table 3:

Table 3. Score Calculation System Accuracy

No	Time	Tempo	Retrieved	Unaccounted For	Accuracy (%)
1	30s	120	64	1	99.98
2	30s	100	52	0	100
3	30s	80	41	0	100
4	30s	60	32	0	100
5	30s	40	21	0	100
Total:					**99,96%**

The results show the accuracy of the footwork ability test technology is 99.6%.

DISCUSSION

Based on the results of the research, the IoT-Based Footwork Ability Test Using ESP32 Camera, is an appropriate technological innovation in the footwork training process that can be

ISSN 0216-4493 (print), ISSN 2597-6109 (online)

used in badminton athletes, because this technology is designed in a simple, practical form, and according to user needs. The development of this technology is relevant to the opinion (Williyanto et al., 2021) that during training the use of technology can be done to increase the variety of exercises, changes in efficiency and effectiveness in practicing depending on the training model provided. In the development of this technology, it also contains the right method or technique when conducting tests in line with research (Endang Sepdanius, 2019), namely the development of footwork training aids in android-based badminton to test the effectiveness of badminton sports training tools, and also research (Rusdiana, 2021), namely the development of agility, coordination, and reaction time training devices with infrared sensors and Arduino WiFi modules in badminton, The development of this technology also answers the theory put forward by (Ngadiman et al., 2019) that the role of technology in terms of the development of agility, coordination, and reaction time with infrared sensors and Arduino WiFi modules in badminton, 2019) that the role of technology in terms of achievement development is minimally used so that training is only applied manually, as a result there are no objective indicators to determine the progress of the training results. This theory is also in line with (Hamid & Aminuddin, 2019) that to improve abilities that condition agility, technology is needed to control the intensity of training more accurately. So it can be concluded that mastery of techniques including mastery of footsteps in playing badminton is very important.

After testing the Footwork Ability Test technology runs very well, the durability of the tool can last long enough, which is approximately 1 hour. Then the sensor can detect movement and successfully send a signal to the main box. The center point sensor is able to count the number of movements made by the athlete. The ESP32 Cam functions to display athlete movements so that the coach can evaluate the training that has been done.

The advantages of the Footwork Ability Test product are an appropriate technological innovation in the footwork training process that can be used in badminton athletes, because this technology is designed in a simple, practical form, and according to user needs. During training, the use of this technology can add variety to training, increase efficiency and effectiveness in practicing footwork in badminton. Compared to training models and tests that are still carried out conventionally commonly used by coaches, namely (illionis agility, T run, and six points). Footwork Ability Test can provide more advantages because it has special specifications for training and measuring footwork of badminton athletes.

Footwork Ability Test can facilitate the test and training process, a variety of training models, get data on the results of exercise evaluation, training becomes more fun and increases the enthusiasm of athletes in footwork training with playing methods so that it is effective for improving footwork skills in athletes.

Seeing the potential advantages of the products produced, development will continue to be carried out to improve the quality of innovation in the product. In addition to having the advantages of this “Footwork Ability Test” technology, there are weaknesses in this product including: additional sensor points (to 6 points), updated application features have more supporting features to produce more accurate training data, the appearance of the tool is less attractive, needs to be tested with more samples for making training norms, and needs to be done SII feasibility. Some of these weaknesses are expected to be a concern in further development efforts, to obtain better technological results. This fact will further open up opportunities for further improvements.

CONCLUSION

The “Footwork Ability Test” technology innovation has been produced to measure the agility of badminton athletes in the process of footwork tests and training. The test results show

ISSN 0216-4493 (print), ISSN 2597-6109 (online)

that the technology is very feasible to use, has a very high accuracy value, can add to the variety of exercises, increase efficiency, and effectiveness in practicing badminton footwork. In addition to being used by badminton coaches in tests and training, this tool is also ready for mass production.

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