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A Microcomputer-Based Assistive Device for Visually Impaired Athletes in Track and Field Events, Specifically in Sprinting

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Abstract

The aim of this research is to develop an innovative device as a substitute for a guide runner for visually impaired runners. The method used is Research and Development (RnD) with the ADDIE model. The population in this study consists of visually impaired athletes participating in the national running championships, and the sample is obtained using purpose sampling, resulting in a sample size of 3 individuals. Data collection techniques involve interviews with athletes and coaches, as well as speed calculations before and after athletes use the microcomputer-based device. The results of the implementation show that athletes adapt more quickly when using the microcomputer-based device compared to adapting with a guide runner. The running speed of athletes with the microcomputer-based device indicates faster times compared to running with a guide runner. Therefore, the microcomputer-based device can assist visually impaired athletes in running independently without the aid of a guide runner.

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INTRODUCTION

In the execution of Paralympic athletics, specifically in track and field sprinting events, visually impaired athletes are always accompanied by a guide or companion. Guide runners cannot be selected randomly; they must go through a phase of living together and training together to build synchronized steps and movements between the athlete and guide runner (Peiris et al., 2016). During the execution, the hands of the visually impaired athlete and the companion are tied together at their respective wrists (Al-Zayer et al., 2016; Nagahara, 2021). The difference in speed between the athlete and the companion is a significant issue, often causing the companion to fall behind the athlete or vice versa due to the difference in running abilities between the two (Nagahara, 2021). These factors can have a fatal impact when the companion crosses the finish line before the visually impaired athlete, as it would result in the athlete's disqualification. This dependence on a companion is what makes the career of visually impaired athletes reliant on their guides (Andajani et al., 2020; Nababan et al., 2015).

In Indonesia, the development of equipment for visually impaired athletes is still underdeveloped. This is evidenced by the fact that our country lacks advanced technology and sports experts who collaborate with technology experts (Nababan et al., 2018). From interviews with coaches of NPCI (National Paralympic Committee of Indonesia) athletes in Bandung, it was mentioned that the presence of a guide runner has a significant impact on the career of visually impaired athletes. If a guide runner is absent during training, athletes do not practice. Moreover, if a guide runner is not present during a competition, the athlete may face disqualification.

The infrastructure and equipment needed for visually impaired individuals should be tailored to provide feedback through auditory or tactile/proprioceptive information (Cho et al., 2021; Gkanidi & Drigas, 2021). Technological advancements and innovations have been made to address these needs. Mestika & Sriwano (2014) introduced an innovative device using line follower technology, which can be used for short-distance running tracks up to 100 meters. Machado & Carvalho (2021) developed an innovation for visually impaired individuals using Android smartphone technology through wireless connections, suitable for short distances of up to 100 meters. Peiris et al. (2016) created an innovation called "eye vista" using the Open Source Computer Vision method, primarily aimed at real-time computer vision, which functions up to 100 meters and weighs 250 grams.

Based on the information provided, the researchers were motivated to create an innovative solution for the challenges faced by visually impaired athletes. This solution is a microcomputer-based device designed to replace the need for a guide runner in track and field sprinting events. The microcomputer-based device draws inspiration from Tesla's advanced automotive technology, particularly its Autopilot feature, which allows for full self-driving capabilities through software updates designed to enhance functionality over time.

The microcomputer-based device is designed to provide accurate audio and tactile information to visually impaired athletes autonomously. It can be used on various track and field conditions, ideally suited for sprinting events. High-quality materials, adhering to ISO and SNI standards, are used to create the device. The device has a simple interface, is lightweight, and comfortable for visually impaired athletes to use during their runs. When the visually impaired athlete is in the correct position or on the appropriate track, the microcomputer-based device provides feedback in the form of vibrations on the front chest area. If the athlete deviates from the track, the device provides feedback on the shoulder and side of the chest, aligning with the direction of the deviation.

This microcomputer-based device serves to improve upon existing equipment and is characterized as advanced, ergonomic, and cost-effective. It enables visually impaired athletes to run comfortably without the need for a partner or guide runner.

METHOD

The research method used in this study is Research and Development (R&D) with the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Rafi'y, 2022). This method is employed to create a specific product and test its feasibility or effectiveness. The sampling technique chosen is purposive sampling, where visually impaired athletes are specifically selected to implement the microcomputer-based device. The sample consists of visually impaired athletes from NPCI Kota Bandung who have participated in the national games and achieved first place in those competitions.

Data collection in this study involves interviews with athletes and coaches, and conducting pre-test and post-test measurements on the athletes to assess their speed before and after using the microcomputer-based assistive device. The interview results with visually impaired athletes and coaches are transcribed and coded in a narrative format. Data validity is ensured through triangulation techniques involving all the informants.

1. Analyze

Visually impaired track and field athletes are divided into two categories based on their level of vision: low vision and blind vision. In the case of blind vision athletes, they rely on a guide or companion both during training and Paralympic events. The companion must be someone accustomed to training alongside the athlete. When the guide runner is unable to attend, the athlete cannot conduct training sessions or participate in competitions. This issue was conveyed by informant Y, who is a blind vision athlete.

"When the guide runner is absent, visually impaired athletes cannot run independently."

"*Adapting with a guide runner takes a very long time."*

"There are not many people willing to become guide runners."

"Turn your weaknesses into the key to success and view your limitations as a form of struggle towards success."

"The difference in speed often causes visually impaired athletes or guide runners to fall behind."

"Elementary school-level running competitions often have physical education teachers serving as guide runners because of the lack of individuals willing to take on the role."

The potential solution identified from the aforementioned issues is to create a microcomputer-based device through a combination of literature research and improved interviews with coaches. Interviews with coaches of visually impaired athletes in NPCI Bandung revealed that the adaptation process between guide runners and athletes varies significantly. Adaptation can be built through engaging in various activities together, with the average adaptation period ranging from three to six months. Moreover, being a guide runner is not a primary profession, leading to irregular attendance during training sessions. Consequently, athletes' training schedules depend on the availability of guide runners. In light of these issues, the researcher recognizes the necessity to develop a microcomputer-based device capable of substituting the role of a guide runner. This device would enable athletes to conduct their training and participate in competitions independently.

2. Design

The planning phase of this research begins with technical design development, component assembly, product programming, 3D design creation, vibrator wiring, chest strap fabrication, and the packaging of the microcomputer-based device product.

a. Technical Design Development

The block diagram for the system design can be observed in this device, which employs real-time line detection based on a microcomputer using the histogram algorithm. The operation of this device involves detecting the running track using a Raspberry Pi Noir camera.

b. Component Assembly

The component assembly begins with gathering references and collecting the necessary components for the creation of the microcomputer-based device product. The components used for the microcomputer-based device product include:

1) Components for the Microcomputer-Based Device Product: Raspberry Pi Zero 2W, Lithium polymer battery 3800 mAh, Charger module, Micro SD card, ULN2003 module, Raspberry Pi Noir Camera, Fan Cooler, Audio output, Vibrator motor. In Figure 1, the components of the device product are illustrated.

Figure 1. Components of the microcomputer-based device

2) The Programming Process for the Microcomputer-Based Device. The programming process for the microcomputer-based device involves using the PyCharm software and employs the OpenCV-based Open Computer Vision method. It uses algorithms for perspective analysis and histogram to detect the running track. This process aims to overcome limitations from previous systems, such as identifying curved and steep path lines. The method consists of two main components: the camera and computer vision. Computer vision utilizes image processing techniques along with perspective and histogram algorithms to understand the digital images and videos captured by the camera.
3) The Creation of the 3D Design for the Microcomputer-Based Device. The creation of the 3D design for the microcomputer-based device is carried out using Autodesk Fusion 360 software. The 3D design of the microcomputer-based device is tailored to meet the needs of visually impaired athletes, ensuring it is comfortable to use. Figure 3 represents the process of creating the 3D design for the microcomputer-based device product.

a. Wiring the vibrator. The wiring process for the vibrator is performed using a soldering tool and tin solder. The vibrator wiring is connected in parallel at each of its parts to ensure that the vibration function operates optimally.
b. Creation of the chest strap. The creation of the chest strap begins with gathering the necessary materials such as elastic webbing and other components. The chest strap is then crafted by a tailor, following a design provided by us to ensure it meets the needs of visually impaired athletes. Figure 5 illustrates the process of creating the chest strap.
c. Packaging of the microcomputer-based device product. The packaging of the Blind Run product involves assembling all components. The Raspberry Pi Zero 2W, which has been programmed and combined with other components, is placed inside the Blind Run casing. Once everything is assembled according to the design, the device is ready for use. Figure 6 represents the packaging process of the microcomputer-based device product. In Figure 2, The microcomputer-based device product.

Figure 2. The microcomputer-based device product.

3. Development

The development of the device is conducted to assess the comfort and ergonomics of the microcomputer-based device product. Validation of comfort and ergonomics is carried out through interviews with athletes and coaches. From the interviews with athletes and coaches, the following information was obtained.

a. The validity of comfort. From the information obtained from the informants, it is reported that using the microcomputer-based device product, there is a sense of comfort. Respondents mentioned that the microcomputer-based device product is comfortable to use, without the feeling of tightness experienced during running.
b. The validity of ergonomic aspects. The information obtained from the informants indicates that when using the Blind Run product, there is ergonomic comfort in the body position, and it does not disturb the athlete while running.

The microcomputer-based device is validated by equipment experts, including one design expert, one technology expert, and one field expert. The assessment conducted by the validators evaluates the product based on two aspects: comfort, ergonomics, and simplicity. The validation of the product is determined by the average score for each aspect obtained from the validators using the formula:

$$\text{Percentage} = \frac{\text{The obtained scores}}{\text{the maximum score}} \times 100\%$$

The presentation criteria can be found in Table 1 which defines the validity interval criteria.

Table 1. Validity Interval Criteria

No	The Interval of the Average Scores	Response Categories
1	85-100	Very feasible
2	75-84	feasible
3	65-74	Quite feasible
4	<65	Less feasible

4. Implementation

The implementation phase of the microcomputer-based device is divided into two stages: implementation with the team and implementation with visually impaired athletes.

a. Implementation with the team, the use of the device begins with the production team assessing the functionality of the Blind Run product that has been designed. The initial use of the device is to ensure that the microcomputer-based device is safe and functions properly when used by the end-users.
b. Implementation of the microcomputer-based device with visually impaired athletes. The implementation of the microcomputer-based device product with visually impaired athletes is carried out by national athletes, and this implementation process begins with the adaptation of the microcomputer-based device with visually impaired athletes.

5. Evaluation

The evaluation phase is conducted by examining the results of the programmed product's functionality. These results are then presented to compare the speed of a visually impaired athlete when running with a guide and running with a microcomputer-based device. This evaluation process is carried out to assess the outcomes produced by the product, allowing us to evaluate the functionality of the microcomputer-based device.

RESULTS

From the implementations conducted, the researcher has obtained results. These results are described in this section.

Comfort Validation

Comfort validation is carried out to assess how comfortable users are when using the microcomputer-based device product. Comfort validation can be seen in Table 2.

Table 2. Comfort Validation

Assessment aspects	Assessment indicators	Assessment scores	Categories of Respondents
Design	Product attractiveness	90.6%	Very feasible
Materials	Material quality	93.2%	Very feasible
Average Score		91.90%	Very feasible

The table results indicate that the average score for the comfort validation assessment by the design expert is 91.90%, with the category being "very feasible." This pertains to the comfort aspect. The design aspect with the product attractiveness indicator obtained a score of 87.5%, categorized as "very feasible." The design aspect with the material quality indicator received a score of 93.2%, also categorized as "very feasible."

Ergonomic Validation

Ergonomic validation is performed to assess how ergonomic the device created in the microcomputer-based device product is. This validation can be seen in Table 3.

Table 3. Ergonomic and simplicity validation

Assessment Aspect	Assessment score	Categories of Respondents
Simplicity	90.6%	Very feasible
Ergonomic	93.2%	Very feasible
Average score	91.90%	Very feasible

The table results indicate that the average score for the comfort validation assessment by the design expert is 91.90%, with the category being "very feasible." This pertains to the comfort aspect. The design aspect with the product attractiveness indicator obtained a score of 87.5%, categorized as "very feasible." The design aspect with the material quality indicator received a score of 93.2%, also categorized as "very feasible."

Based on interviews with coaches of visually impaired athletes, the adaptation of athletes with guide runners takes three to six months to build chemistry in order to synchronize their steps and running speed. Figure 9 illustrates the comparison of adaptation between using a guide runner and the microcomputer-based device product.

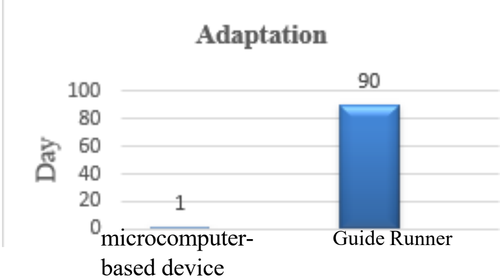

Figure 3. Comparison of Athlete Adaptation with a Guide Runner and the Microcomputer-Based Device Product.

Microcomputer-Based Device Product.

Based on Figure 3, it is evident that the adaptation of athletes with a guide runner takes approximately three months, while adaptation with the microcomputer-based device allows athletes to adapt after just two uses in a single day.

Speed Difference Analysis

After assessing the adaptation of athletes with the microcomputer-based device, the researcher analyzed the speed of the athletes. Before using the microcomputer-based device, the athlete's speed while running with a guide runner was 8.73, while when the athlete used the microcomputer-based device, the athlete's speed was much faster by 0.2 seconds compared to running with a guide runner. These results can be seen in Figure 4, the graph of the athlete's speed difference.

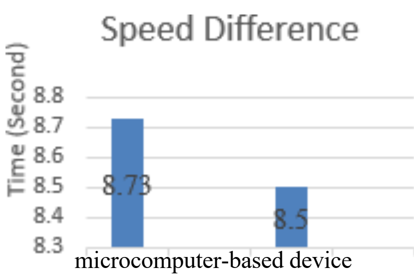

Figure 4. Athlete Speed Difference without a Guide Runner, with a Guide Runner, and Using the Microcomputer-Based Device

Microcomputer-based assistive devices can be used to facilitate independent training for athletes. This device consists of several components that can assist athletes in running independently, and these components can be seen in Figure 5.

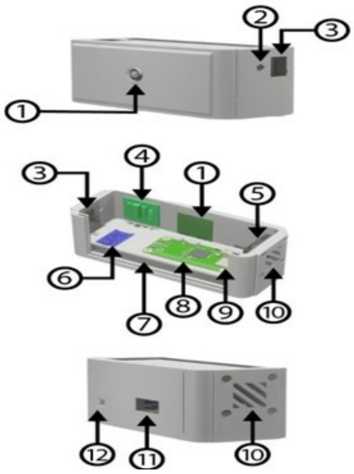

Figure 5. Components of the Microcomputer-Based Device

Explanation:
1. Camera
2. Indicator light
3. SPST (switch)
4. ULN 2003 Stepper Motor Driver Module
5. Fan
6. Charger Module
7. 3800 mAh Lithium Ion Battery
8. Rasberry Pi Zero 2W
9. Micro SD
10. Fan Ventilation
11. Connector hole
12. Charger hole

How to use the microcomputer-based devise:
1. Attach the microcomputer-based device to the body
2. Press the SPST switch to the turn on the microcomputer-based device, and the LED indicator light will illuminate.
3. Head to the track, and the vibration is the middle, the device is functioning properly
4. Turn off the SPST when it is no longer needed.

DISCUSSION

Based on the research results presented in the graphs, the researcher has developed an innovative microcomputer-based device that can be used for a 400m running track. From the data processed by the researcher, it is evident that with a guide runner, athletes need to adapt for about three months, as they have to build chemistry and synchronize their steps to ensure a smooth run. On the other hand, when athletes adapt to the microcomputer-based device, they can adapt within one day by performing adaptation trials two to three times to understand the information provided by the device. During the speed difference test, the distance was determined through an agreement between the researcher and the research subject to minimize unexpected events, given that athletes will participate in significant competitions. In the test conducted, both the researcher and the subject agreed to perform a 100m test. The results are presented in the graph above, which shows that using the microcomputer-based device results in faster running times compared to running with a guide runner. This is because running with a guide runner requires time to build chemistry and synchronize steps for a synchronized running pace (Hiemstra & Rana, 2023; Mertala & Palsa, 2023).

Based on the findings of this research, it provides a novel contribution to previous research. In this study, the researcher successfully developed an innovative microcomputer-based device designed with perspective analysis and histogram algorithms that can detect the running track and be used for up to 400m in real time. Previous research conducted by Mestika & Sriwarno (2014) developed a vest with a line follower system using the CMUcam sensor to enable visually impaired individuals to train independently for up to 100m. Additionally, Peiris et al. (2016) created an innovative vest using open-source computer vision programming functions mainly aimed at real-time computer vision, which can be used up to 100m. Furthermore, Machado & Carvalho (2021) developed an innovation for blind athletes using

Android smartphones through wireless networks. This innovation can control athletes outside the field using a smartphone but requires assistance from someone outside the field and an internet connection to connect to the innovation. Therefore, the results of this research may differ from previous research due to the differences in the methods used.

The operation of the microcomputer-based device starts with the camera, which sends visual information (images) to the Raspberry Pi, serving as the brain of the microcomputer-based device. Visual information undergoes a filtering or filtration process in which the video is converted to black and white using the Histogram algorithm. Blindrun can detect the athlete's running track and the finish line using Open Computer Vision through the Python programming language. Subsequently, the program issues commands to the microcomputer-based device, which generates output in the form of vibrations through the vibrator module and sound through Bluetooth earphones.

Visual impairment is a common term used to describe a condition in which an individual experiences a disturbance or impairment in their sense of sight (Hendryadi et al., 2022; Kusumo & Purwoko, 2022; Pratama et al., 2016). A person with visual impairment is an individual who has weak vision or visual acuity less than 6/60 after correction or has no vision at all. According to Setiawan & Charles (2017), visually impaired individuals are those whose visual senses (both of them) do not function as a means of receiving information in their daily activities, as in the case of sighted individuals.

Based on their abilities, athletes with disabilities are divided into two categories. First, there are those with low vision (partial vision), and second, there are those who are blind (completely visually impaired). Individuals with low vision are characterized by having some degree of vision that allows them to see their surroundings, although they may still require visual aids such as glasses, among other things, to assist their vision. Those considered blind are individuals who cannot use their vision and cannot perceive their surroundings, necessitating the assistance of others or visual aids to carry out their daily activities (Triyono et al., 2020).

The inability to see the surrounding environment among athletes with visual impairments results in the reception of stimuli/ information through other senses (besides the eyes). Therefore, in carrying out their mobility, individuals with visual impairments often use a cane (Solekha et al., 2023). When it comes to participating in sports activities, athletes with visual impairments typically cannot engage in sports independently due to the lack of visual cues and information from their environment. This is especially true for sports like running, where athletes with visual impairments require a companion or guide runner to complete their activities (Peiris et al., 2016; Folmer, 2015). Dependency on a guide runner is a constraint for athletes to engage in sports and their daily activities (Rahmawati & Sunandar, 2018). In order to improve physical fitness and mobility, athletes need to undergo significant training programs to achieve their set goals. Training programs should be modified according to individual habits, physical function, health status, training responses, and stated objectives (Resmayanti & Rochmania, 2020).

The most important aspect of improving the fitness and mobility of athletes is ensuring their safety during their activities (Esatbeyoğlu et al., 2022). Therefore, it is crucial for athletes with visual impairments to have assistive devices that can help them with their mobility and daily activities.

CONCLUSION

Based on the research conducted, it can be concluded that by using the microcomputer-based device, athletes can adapt in a very short time and achieve faster speeds compared to running with a guide runner.

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