Development of a Multi-Modal Agility Ladder System for Sports Training

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Background: Recent advancements in various technologies have led to an increase in user-centered services, and in the sports field, user-centered service activities are steadily increasing through the application of various tools developed through the convergence with ICT technology. In particular, personalized training based on accurate information measured through ICT convergence tools is being provided in sports training methods. However, in the field of basic physical training such as agility ladder training, related research is still insufficient. Therefore, this study aims to design a multi-modal agility ladder system that includes a sensor-based step detection and visual feedback module.
Method: The multi-modal agility ladder system consists of an agility ladder body, a step data collection module, and an integrated control module. The agility ladder body can be placed on the floor like existing products to carry out exercise drills, and this study adds a function for visual feedback. The step data collection module collects data related to the time and success of steps during the exercise drill.
Findings: The agility ladder main body and the step data collection module are connected to the integrated control module. The integrated control module is responsible for transmitting information about the feedback display situation of the agility ladder body and the collected step information to the trainer. The integrated control module is connected to the trainer's smartphone or PC, and delivers the collected information. Conversely, the trainer can send commands to the integrated control module through the application, allowing control of the feedback device built into the agility ladder main body.
Improvements: The system designed in this paper focuses on the common areas where agility ladder training is needed, regardless of the sports event, and designs an advanced design from the existing training tools. In future research, it is expected that system design research that can diversify training for each event where agility ladder training is critically important will be needed.

Keywords: Multi-modal Agility Ladder System, Sports Performance Training, Smart Sports Training, Training System, Sports Performance, Sports Training props.

1. Introduction

In sports activities, how much technical performance can be implemented for the

corresponding sports event is a very important part. Securing basic physical strength for basic human movements is positioned as a basic step for implementing such technical performance, and basic physical training using various exercise tools is being conducted to improve game skills and physical functions in various sports[1]. In particular, step ladder training is widely applied in sports such as soccer, basketball, and tennis, where the utilization of steps is high[2-4].

Agility ladder training refers to a training where the exerciser moves in a specific direction by placing ladder-shaped exercise tools on the floor[5]. The ladder-shaped tool distinguishes the areas to step on and the areas not to step on, and the exerciser trains to step on fast and accurate steps by distinguishing those areas. The purpose of this training is to improve the ability to use fast and accurate steps unconsciously. Agility ladder training is a basic physical training that is well known for its importance to the extent that it is necessarily included in the training program of sports that emphasize stepping[6-8]. However, due to the limitations of the training result measurement method, instructors are having difficulty providing quantitative feedback on the training content.

Agility ladder training primarily measures results by using a stopwatch to measure the start and end times. However, this method has limitations in providing feedback by dividing the training content, such as whether accurate steps were used for each divided step area, how much time it takes to use one step, and whether similar time was spent on all the steps walked during one training. Since agility ladder training requires fast and accurate steps, if feedback can be provided step by step, it can be expected that the diversification of the agility ladder training program and strategic step training based on quantitative information will be possible.

With the recent advancements in ICT technology [9-18], the provision of user-centered services is increasing, and in the sports field, user-centered service activities are steadily increasing through the application of various tools developed through the convergence with ICT technology. Especially, in sports training methods, personalized training is provided based on accurate information measured through ICT convergence tools. However, in the field of basic physical training such as agility ladder training, related research is still insufficient. Therefore, this study aims to design a multi-modal agility ladder system that includes a sensor-based gait detection and visual feedback module. Through this, it is possible to measure the accuracy and time of steps that were difficult to measure with the existing training measurement method and provide visual feedback on the results.

2. Multi-modal Agility Ladder System Design

To design a multi-modal agility ladder system, an analysis of the existing agility ladder training program is necessary. Through the analysis of the training program, the sensors and feedback elements for developing the agility ladder system can be determined, and a design that allows for the same exercise performance as the existing training program can be established.

2.1. Exercise Analysis for Multi-modal Agility Ladder System Design

The exercise performed in agility ladder training aims to improve physical performance through repetitive training[10-12]. Agility ladder exercise involves repeatedly traversing the step area of the ladder laid on the ground in various patterns [13-15]. [Figure 1] shows the

exercise training that is conducted in agility ladder training.

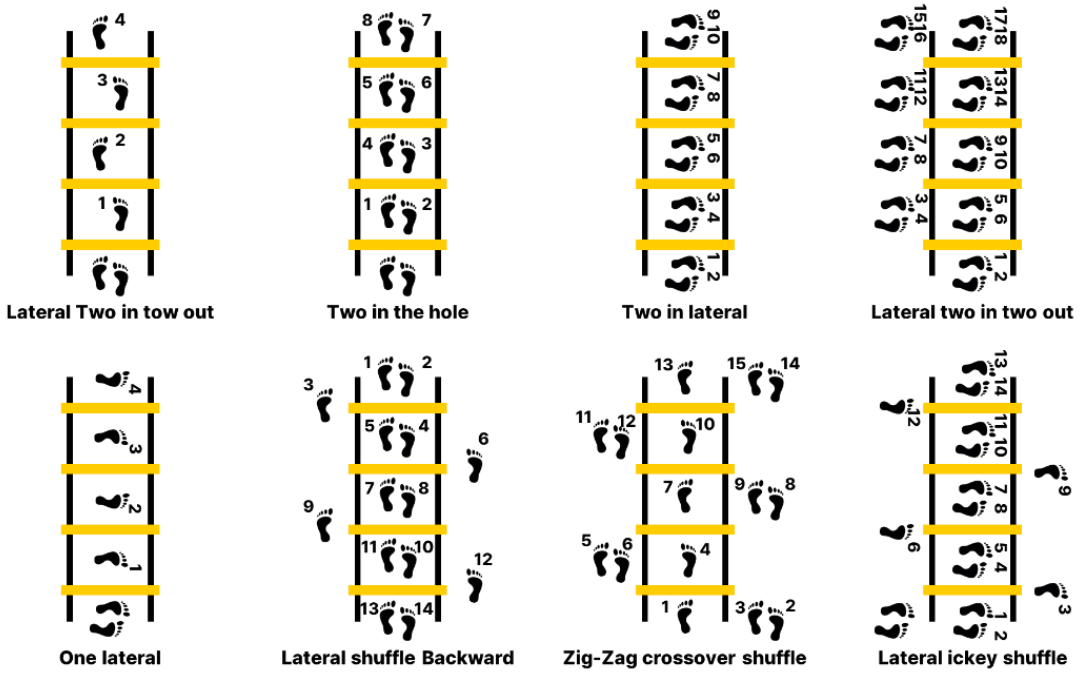

Figure 1. Agility Ladder Exercise Drills

When analyzing the patterns of agility ladder drills, it can be observed that the exercise involves stepping on the inside and outside areas of the ladder placed on the ground. To collect information about the steps, it is necessary to apply a variable design that can measure or detach both the inside and outside areas of the agility ladder. Furthermore, providing visual feedback around the steps is essential for effective execution of the exercise while confirming the position of each step. Lastly, to create a variety of patterns for ladder drills, it is important to consider placing the agility ladder in a design that encompasses not only forward, backward, left, and right movements but also diagonal directions.

2.2. Multi-modal Agility Ladder System Configuration

The multi-modal agility ladder system consists of the agility ladder main body, step data collection module, and integrated control module, as shown in the [Figure 2].

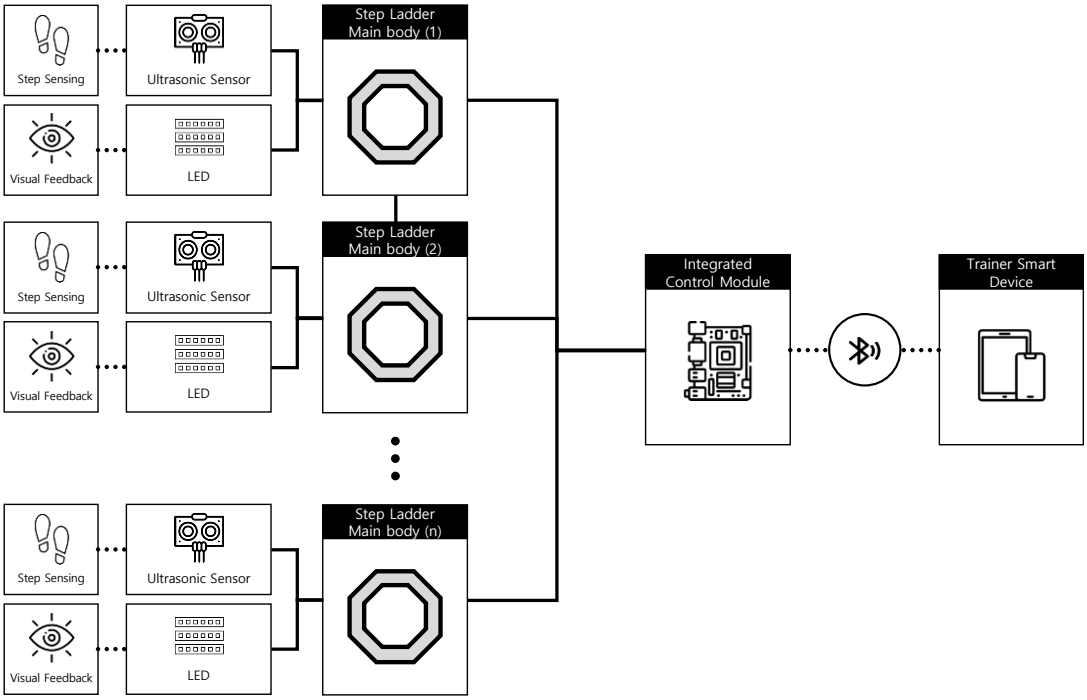

Figure 2. Multi-modal Agility Ladder System Configuration

The agility ladder main body is placed on the floor, similar to existing products, allowing for the execution of ladder drills. In this study, additional features are incorporated for visual feedback. The step data collection module collects data related to the timing of steps and the success of each step during the execution of ladder drills. The agility ladder main body and the step data collection module are connected to the integrated control module. The integrated control module is responsible for transmitting information about feedback display situations of the agility ladder main body and the collected step data to the trainer. The integrated control module is connected to the trainer's smartphone or PC to transmit the collected information, and conversely, the trainer can control the feedback device embedded in the agility ladder main body through commands sent to the integrated control module via an application.

2.3. Multi-modal Agility Ladder System Design

To design the agility ladder main body and step collection module for the multi-modal agility ladder system, it is important to consider various patterns by incorporating designs that encompass forward, backward, left, right, and diagonal directions, depending on the execution of ladder drills. Therefore, the agility ladder main body is designed in a square shape, allowing for versatility in arranging different patterns. Additionally, to provide visual feedback, LEDs are attached to the edges of the agility ladder main body.

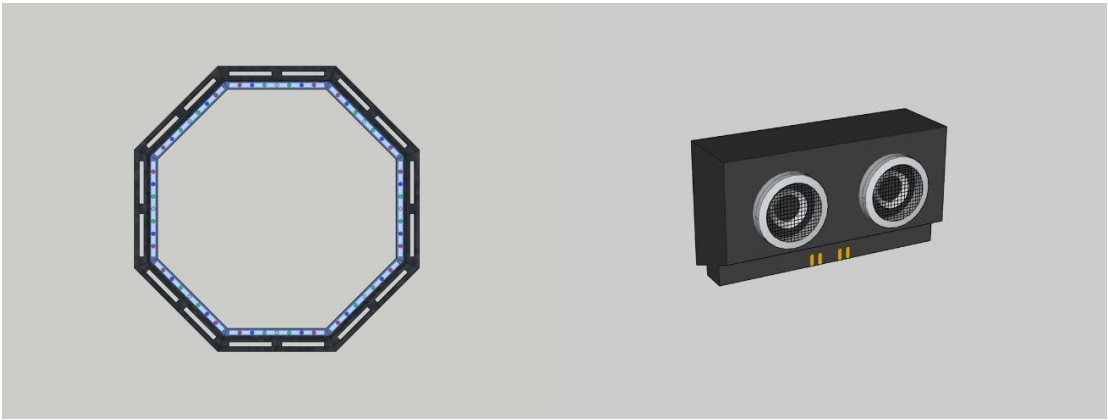

Figure 3. Multi-modal Agility Ladder Main Body and Step Data Collection Module Design

The step data collection module is designed to be detachable and can be freely attached to and detached from the agility ladder main body. Observing the execution of ladder drills, steps are taken either on the inside or outside of the agility ladder. Therefore, the step data collection module is designed with a detachable feature to collect information about desired steps, whether they are on the inside or outside of the ladder. Additionally, the step data collection module utilizes ultrasonic sensors to accurately detect only the steps located within a specific area. This allows for measuring the accuracy and timing of steps by measuring the distance to steps within a certain range. The design of the agility ladder main body and step data collection module is depicted in the [Figure 3].

3. RESULTS AND DISCUSSION

In this chapter, we will develop the agility ladder main body and the step data collection module based on the previously designed multi-modal agility ladder system.

3.1. Multi-modal Agility Ladder Main Body Development

The agility ladder main body is designed in a rectangular shape to allow placement on the floor in various patterns such as forward, backward, sideways, and diagonal, enhancing the diversity of exercise drills. The perimeter of the agility ladder main body features a space where the step data collection module can be attached and detached. Additionally, it is equipped with built-in LEDs to provide visual feedback. A total of 60 LEDs are embedded, and when a step is detected by the step data collection module, the color of the LEDs is displayed to indicate the success of the step. The LED colors are sequentially changed to red, blue, green, and yellow. This allows the agility ladder on the floor to be displayed in the same color, enabling easy visualization of the success of the steps during the exercise drill. Furthermore, the multi-modal agility ladder can be connected to a smartphone or PC, allowing specific colors to be displayed on a specific agility ladder main body. This can be used as a way for trainers to guide exercise drills.

3.2. Step Data Collection Module Development

The step data collection module is developed using ultrasonic sensors to detect steps located

in a specific area. The diameter of the step area on the agility ladder main body is 30cm. The step data collection module, which is attached to the agility ladder main body, detects the presence of an object within a defined accurate step area of up to 20cm at a rate of 1ms. When an object is detected within the 20cm range, it is recognized as a step, and the information regarding step recognition is collected and transmitted to the integrated control module. Additionally, when steps need to be detected outside the step area of the agility ladder main body, the step data collection module can be rotated and attached to face the outside area. Even in this case, steps must be placed in a position similar to the step area of the agility ladder main body to be recognized as steps within the 20cm range. The areas where the internal and external steps of the agility ladder main body are detected and situations where objects are detected through the ultrasonic sensor are depicted in the [Figure 4].

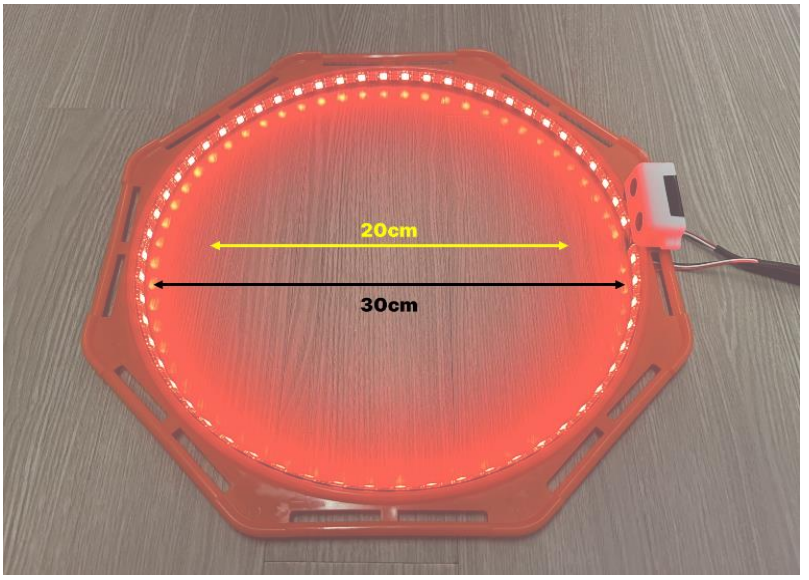

Figure 4. Multi-modal Agility Ladder Main Body and Step Data Collection Module Design

3.3. Multi-modal Agility Ladder System

The Multi-Modal Agility Ladder System is composed of multiple agility ladder bodies, an equal number of step data collection modules, and an integrated control module. Configured in this way, the Multi-Modal Agility Ladder System operates according to the algorithm process depicted in the [Figure 5].

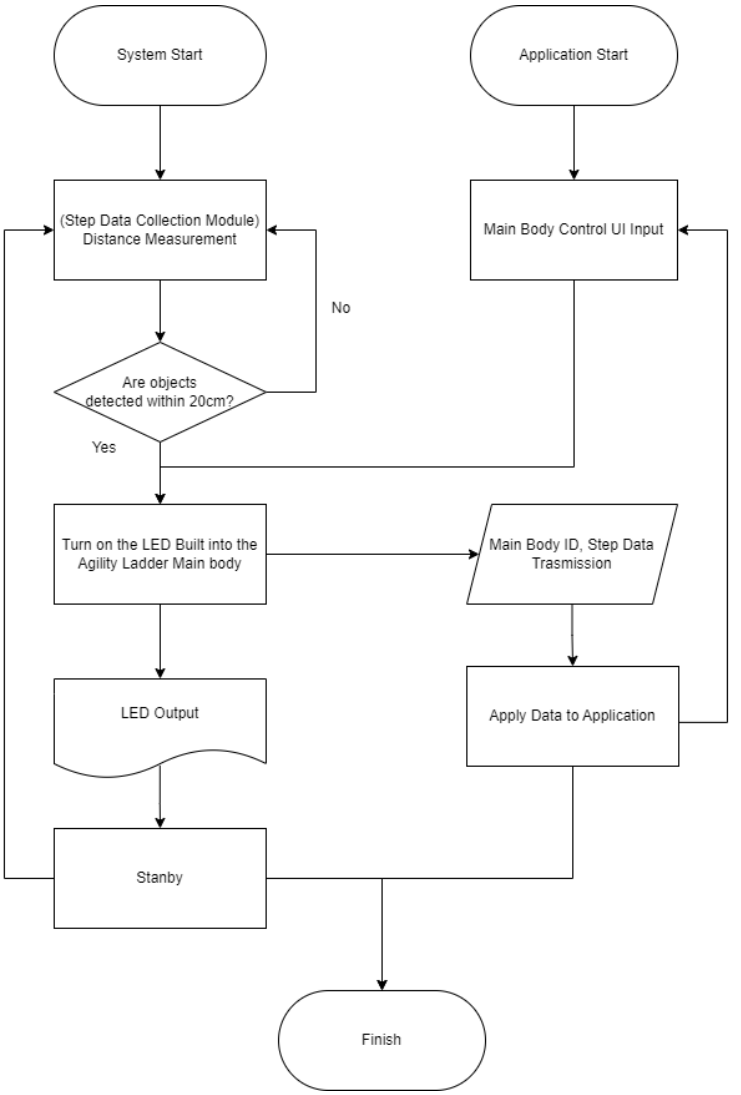

Figure 5. Multi-modal Agility Ladder System Flow Chart

To conduct exercise drills, the step data collection modules are attached to the agility ladder bodies arranged in a specific pattern. The attached step data collection modules detect steps within the step area of the agility ladder bodies. When steps are detected in the precise area, the built-in LEDs on the agility ladder bodies display specific colors in sequential order.

The collected step information is transmitted to the trainer's smartphone or PC through the integrated control module. The transmitted information is then provided to the trainer through the application's user interface (UI), which is installed on their smartphone or PC. The UI displays the step time and indicates whether the steps were successful or not. Additionally, the application allows the trainer to control the LEDs within the agility ladder bodies. This enables them to dynamically change the exercise drill program in real-time or provide exercise guidance to the participants.

3.4. Multi-modal Agility Ladder Contents

The content of the Multi-Modal Agility Ladder system is provided through a PC or mobile application connected to the system. The representative contents consist of Time Attack and Color Match Drill, which add fun to the training by adding rules to the existing agility ladder drills. This helps in collecting and recording data on the existing agility ladder drills, which aids in the design of progressive training programs. Additionally, Custom Contents are provided, which allow trainers to control the agility ladder.

3.4.1. Contents 01 : Time Attack

The Time Attack content is designed to reflect the agility ladder's exercise characteristics, which can improve the speed of steps. In the Time Attack content, a target completion time is set, and participants aim to complete the exercise drill within that specified time. To engage in this content, you would need to configure the target time, the number of agility ladder bodies arranged, and the number of cycles in the exercise drill, as depicted in the [Figure 6].

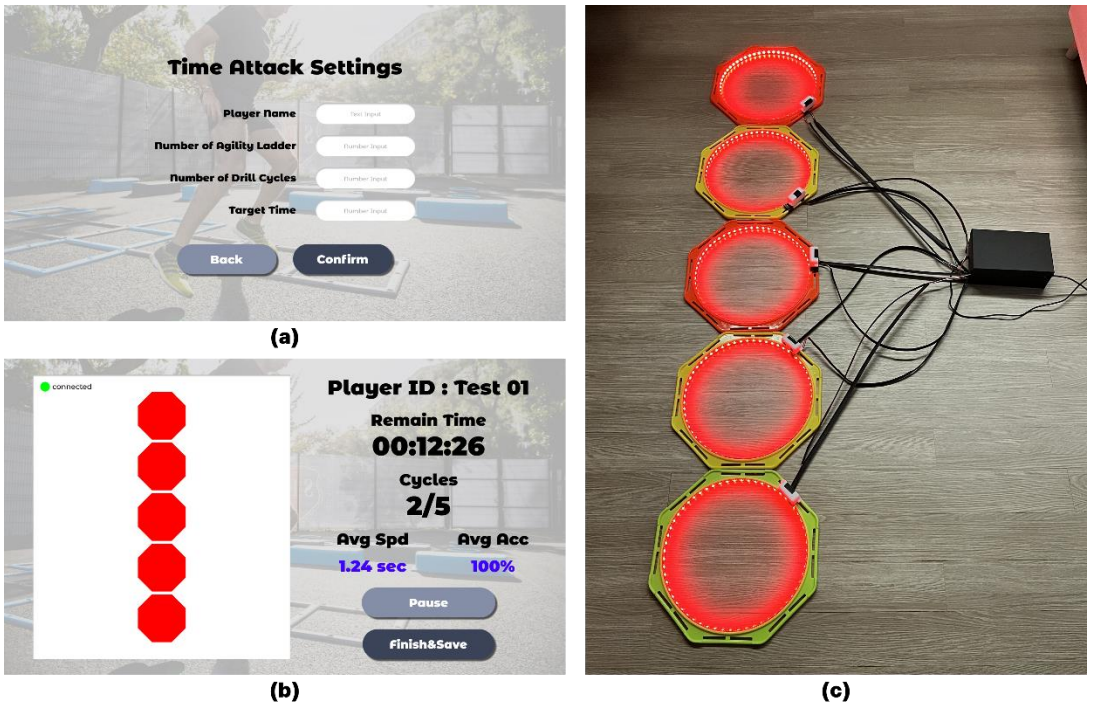

Figure 6. Multi-modal Agility Ladder Time Attack Contents

((a) : Setting Screen, (b) : Play Screen, (c) : Visual Feedback Result)

When a step is detected on the first agility ladder body, time starts counting, and it continues to elapse until the last step is detected after completing the set number of exercise drill cycles. At that point, the time stops and the record is saved. The recorded time can be used as a competitive record to compete with others. It allows you to create leaderboards for multiple individuals and can serve as a motivating factor in training.

In the Time Attack content, not only the execution time of the exercise drill is required, but also the accuracy of the steps. Even if the exercise drill is performed quickly, if the steps are not accurately executed, 2 seconds per step error will be added to the final record. This can be set in the application according to the trainer's preference.

3.4.2. Content 02 : Color Match Drill

The Color Match Drill content is designed to reflect the agility ladder's exercise characteristics, aiming to improve the accuracy of steps. In the Color Match Drill, you set the number of cycles for the desired exercise drill and strive to execute precise steps. After each cycle, the LED module of the agility ladder body displays specific colors alternately. For example, if you set the exercise drill to have 4 cycles, the LED will display colors in the following sequence: yellow, red, blue, green. Once a cycle is completed, the LED resets for the next cycle to proceed.

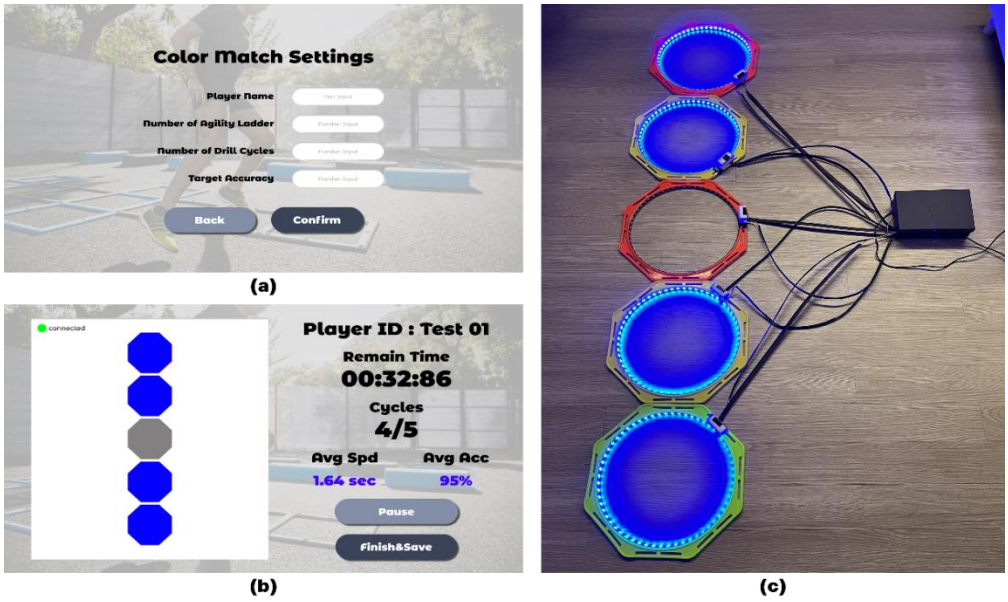

Figure 7. Multi-modal Agility Ladder Color Match Contents

((a) : Setting Screen, (b) : Play Screen, (c) : Visual Feedback Result)

The Color Match Drill content is conducted by inputting the number of agility ladder bodies arranged and the number of cycles for the exercise drill. You can also set the colors of the LED to be displayed for each cycle. During the content, if there are step errors on an agility ladder body, the corresponding LED will not light up, as depicted in the [Figure 7]. The Color Match Drill content records information about the accuracy of steps and can provide motivation for exercise through leaderboards, just like other content.

3.4.3. Custom Contents

Custom Contents provides the ability for trainers who want to utilize a multi-modal agility ladder to control the ladder in real-time through a connected PC or smartphone. When the content is executed, the number of agility ladder units can be inputted, and the connected

agility ladder UI is displayed on the screen based on the inputted information.

Custom Contents allows for various modifications to exercise drills performed in predefined patterns and can provide guidance for exercise execution. Additionally, in Custom Contents, the trainer can change the color of the agility ladder units on the PC screen, and the corresponding changes are reflected in the actual agility ladder units, as shown in the [Figure 8].

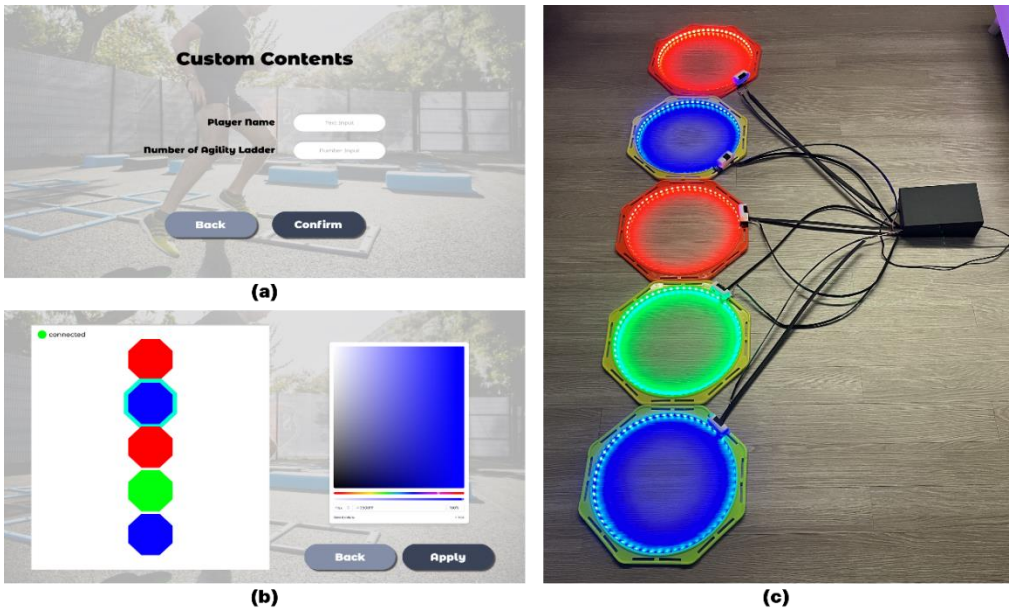

Figure 8. Multi-modal Agility Ladder Custom Contents

((a) : Setting Screen, (b) : Play Screen, (c) : Apply Result)

Through Custom Contents, trainers can create their own exercise drills tailored to individual players and their characteristics. Furthermore, the changing LED colors of the agility ladder units can be used to indicate specific situations to the players, and the players have the opportunity to improve their coordination skills through the color changes of the LEDs.

4. CONCLUSION

This paper describes the development of a multi-modal agility step ladder system. The multi-modal agility step ladder system consists of an agility step ladder body, a step data collection module, and an integrated control module. The agility step ladder body is equipped with built-in LEDs, which provide visual feedback by displaying the collected information from the step data collection module. The step data collection module incorporates ultrasonic sensors to gather information about the steps during agility ladder exercises. It detects whether accurate steps are performed in the inner and outer step areas of the agility step ladder body, verifying the step accuracy. Furthermore, it calculates the time taken for the steps to be recognized, enabling the measurement of the exerciser's agility and speed. This system allows for the

provision of quantitative exercise information, appropriate feedback, and even the provision of content utilizing existing exercise drills.

The multi-modal agility step ladder system developed in this paper has limitations in that it can only collect information about steps. There is a need to collect additional information such as exercise posture to quantitatively measure the overall exercise performance. Furthermore, research on providing more diverse feedback methods beyond visual feedback is required. In future studies, the system will be further developed to measure exercise posture and provide effective feedback. This is expected to be a method of transitioning from traditional analog exercise environments to digital environments and improving the quality of sports training environments through strategic training based on quantitative exercise data.

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