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Motion recognition technology based remote Taekwondo Poomsae evaluation system

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Abstract This paper finally aims to make the public confident, fair and objective Taekwondo evaluation environment through development of publically certified remote Taekwondo Dan(Poom) promotion evaluation platform and, further vitalize Taekwondo and arrange the base for popularization and distribution of remote Taekwondo Poomsae promotion evaluation system. For this, this paper proposed the remote Poomsae evaluation system which may judge and evaluate the accuracy of motion comparing Taekwondo Poomsae motion of the evaluator to that of black belt player using the motion recognition technology which may recognize Taekwondo Poomsae motion through the trace of certain joint regions. In addition, the researcher investigated the accuracy of each algorithm for the date of relatively simple motions trained using the various motion recognition technologies. Also, the final establishment platform was proposed based on the system configuration, module architecture and the entire process according to the remote Taekwondo Poomsae evaluation platform to be implemented in future.

Keywords Motion recognition · Remote evaluation system · Taekwondo Poomsae · KINECT sensor

1 Introduction

They call Karate, Kung Fu and Taekwondo as the martial art in USA. Poomsae of Taekwondo, the beauty motion of the body completes the beauty, which is the ultimate purpose of the martial art through the discipline and enlightenment of martial artists. Theotria (ideology and

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logic) exists in Techne (Practice: gesture) in Poomsae, the physical action of Taekwondo beauty. Therefore, Taekwondo is a performance are and also a sports which has both theory and practice. Taekwondo had an international status as a regular event of Olympic Game in Sydney 2000 and has received many interests and supports from each country for win the medals. Now, it is ranked as No. 10 in member countries (190 member countries, approx 65 million members) under International Sports Federation (IF) and is a regular event of Olympic Game [12]. Taekwondo mainly includes Poomsae and Gyeorugi.

Gyeorugi of Taekwondo reduced the wrong decisions with relatively accurate grading method comparing to the past adopting the electronic body protect but still lacks the objectivity since insufficient number of examiners visually evaluate many candidates in Dan(Poom) promotion examination conducted by Kukkiwon. If it is possible to secure the objectivity and fairness of practical evaluation of 'Kibon Dongjak' and 'Poomsae' of Taekwondo equipped with IT technology in order to solve such problem, they may obtain the objective information by tracing the physical skeleton of the candidate and provide the objectivity to the examination of Taekwondo Dan(Poomsae) based on such information. Further, this will contribute to the scientification, standardization and globalization of practical evaluation of Taekwondo. Figure 1 shows Gyeorugi [6, 12].

Poomsae of Taekwondo refers to the figure of hand and feet motion and the motion posture consisting of various defense and offense technologies in order to practice even without the competitor in preparation of various virtual offenses. Through this, they may practice the fighting train assuming various situations by practicing muscle training, breath adjusting, weight shift, power control and smooth motion as well as improving Gyeorugi technology. Poomsae consists of Taegeuk Chapter 1~8, Koryeo, Keumgang, Taebaek, Pyeongwon, Sibjin, Jitae, Cheonkwon, Hansoo, Ilyeo etc. For example, Poomsae of Taegeuk Chapter 1 consists of Kibon Dongjak such as Momtong Makki, Momtong Jireugi, Arae Makki and Abchagi. Figure 2 shows Motion Recognition of Taekwondo Poomsae [6, 12].

Since the acquisition of Poomsae is decided mainly based on the grading of the examiners in Dan(Poom) promotion examination of Taekwondo, it is difficult to avoid the argument that such examination lacks the objectivity due to the visual evaluation [9]. In addition, the expenses required for leasing the examination venue and gathering the examiners, supervisors and applicants for Dan(Poom) examination in the same place are significantly big. Introduction of automatic evaluation system of Taekwondo practice may save the costs and expenses

Fig. 1 Gyeorugi of Taekwondo

Fig 2 Motion Recognition of Taekwondo Poomsae

required for the entire Dan(Poom) promotion examination process by reducing the time and spatial restrictions required for Dan(Poom) promotion examination.

This paper finally aims to make the public confident, fair and objective Taekwondo evaluation environment through development of public confident remote Taekwondo Dan(Poom) promotion evaluation platform and, further vitalize Taekwondo and arrange the base for popularization and distribution of remote Taekwondo Dan(Poom) promotion evaluation system. For this, Section 2 shall describe the case studies and related algorithms of local and overseas application technologies, and Section 3 proposed the entire block diagram, technology of each module and Poomsae measuring methods, and finally Section 4 described the conclusion.

2 Related studies

2.1 Motion recognition technology

Gesture based recognition is to recognize the posture by tracing the specific joint regions appearing during the motion when it is difficult to discriminate the postures in the specific frame [9]. There is a case where they used the eyes of the player and the target object as the context information by connecting the target motion with the target object in the previous studies. This method improved the recognition rate comparing to the method that uses the trace information of joints only. It is possible to discriminate the motions by one specific posture only during the motion process to be recognized. For example, a posture which stretches out one foot and an arm of the other side appears in Abchagi motion, through which it is possible to recognize the motion by a posture in a certain moment. The method to recognize the motion by a posture in a certain moment refers to the posture based recognition [9].

2.1.1 Microsoft 'KINECT'

KINECT which Microsoft developed in order to use for its game console Xbot 360 has been acknowledged to be the most successful terminal in the world. KINECT is a non-contact motion recognition controller which may trace the movement of the people in the image taken

by camera by mounting the camera which is able to detect the depth through the infrared ray projector. It show an accuracy which may recognize not only the arm and leg motion but also the facial expression of the people, and is mainly utilized for the dance game and fitness game of Xbot 360 [6, 10].

2.1.2 iPiSoft

iPi Desktop Motion Capture is a technology which may capture the motion directly from the desktop of animator without mark. With this, they don't need to operate the studio but only need to shoot the motions using the webcam or cheap digital camera and convert the files to 3D by PC. This is a technology for the people including the freelancers and animators who operate the small studio or are interested in the motion capture technology [9].

2.1.3 Optitrack

Optitract optical motion capture equipment is developed in order to reduce the unnecessary elements and use the equipment easily. It is very easy to use since Arena Software and Arena Expression for capturing the face allow the user to follow the works such as attaching the mark, skeleton set up and capture using Magician function. In addition, it is easy to install and move due to the simple configuration of the equipment [9].

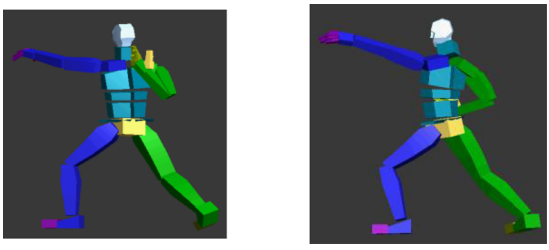
2.1.4 Comparison of motion recognition technology

The result indicated on Fig. 3 was obtained using KINECT, iPi Soft and Optitract which are frequently used for comparison of Kibon Dongjak of Taekwondo Poomsae with above motion recognition solutions. The result of Fig. 3(a) shows the cheap cost but low quality of motion recognition while Fig. 3(b) shows the high quality, easy use and utilization of motion recognition.

2.2 Related algorithm

2.2.1 Multilayer Perceptron (MLP)

MLP is a perceptron which added a hidden layer between the input layer and output layer and implements the learning changing the weight value between each algorithm most suitable to the data using Back-Propagation learning algorithm [4, 8] (Fig. 4).



(a) Result of using iPiSoft

(b) Result of using KINECT and Optitrack

Fig 3 Comparison of Motion Recognition Technologies **a** Result of using iPiSoft **b** Result of using KINECT and Optitrack

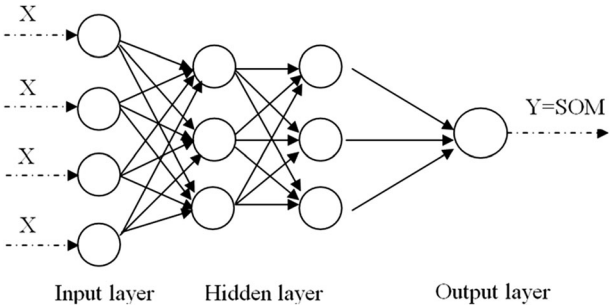


Fig 4 MLP algorithm structure

2.2.2 Naive Bayes

This is a classification method based on Bayes' Theorem while Naïve Bayes is an algorithm which defines the class of document using the statistic method. Naïve, a name of Naive Bayes means that it uses Bayes technology but does not consider the possible dependence [4, 8]. This algorithm is useful for creating a mining model quickly which searches the relation between the input rows and predictable rows. It is possible to create the additional mining models with more complicated and accurate algorithm applying the result after exploring the initial data. The classification process of Naive Bayes could be shown as following formula:

$$\text{classify}(f_1, f_2 \cdots . f_n) = argmax p(C = c) \prod_{i=1}^{n} (F_i = f_i | C = c) \tag{1}$$

2.2.3 Decision tree

When they plan and implement a system, a certain type of system shall be decided considering the usefulness and value. However, various ways are considered in implementing such decision and one decision brings other various problems. In addition, it needs to estimate the result by such decision [4, 5, 8]. They call this Decision Tree shown as the tree branches. This is very useful for implementing the system since the progress of logic becomes clear and comparison of decision methods is available. The formula of Decision Tree is as follows:

$$\begin{aligned} \text{Gain}(\text{S}, \text{A}) \equiv \text{Entropy}(\text{S}) - \sum_{values} \frac{|S_v|}{|S|} Entropy(Sv) \\ \text{H} \quad (\text{x}) \quad = \quad - \int p_x(x) \log_2 p_x(x) dx \end{aligned} \tag{2}$$

2.2.4 Algorithm comparison

The recognition rate of motion recognition test result with above algorithm and the details of relevant motion are as follows: [Table 1(a)] shows a simple motion comparison and [Table 2(b)] shows a relatively simple motion comparison. The learning was made using Weka [1] while the motions of [Table 1] were learned giving the values of total 300 features to Weka determining 20 joint values by each frame selecting five frames while the motions are implemented. The gestures of [Table 2] were learned with total 72 features selecting 24 frames while total motions were implemented by separating the coordinate values of fingertip. In addition, the learning date were tested with 10-

Table 1 Result of algorithm comparison

Algorithm	Accuracy
(a) Simple motion comparison	
MLP	97.2 %
Naive Bayes	100 %
Decision Tree	100 %
(b) Complicate motion comparison	
MLP	96.3 %
Naive Bayes	90.5 %
Decision Tree	79.67 %

fold cross-validation giving 400 data to each motion. Decision Tree was learned with J48 algorithm and MLP conditions were hidden layer =2, Learning Rate=0.3, Momentum=0.2.

3 Poomsae evaluation system platform

3.1 Entire system configuration

Remote Taekwondo Poomsae Evaluation System consists of the image input sensor, motion recognition part which recognizes the motion analyzing the image input and Poomsae evaluation module which conducts Poomsae evaluation comparing the accuracy of Poomsae motion analyzed through the motion recognition module and the accurate Poomsae motion DB information. The image input sensor part in the left side of Fig. 5 used the motion recognition sensor in order to analyze the motion recognition of the applicant by detecting and tracing the physical area of the applicant.

Motion recognition and evaluation S/W of right side of Fig. 5 was designed in order to analyze the accuracy of overall physical skeleton recognition recognized by the images and motion recognition sensor from the input area of images and Poomsae postures while Poomsae examination standard DB was designed in order to utilize the evaluation value of Poomsae postures as the comparison data by advanced DB work receiving the image of accurate Poomsae postures of Taekwondo black belt players and the motion recognition analysis module was designed in order to provide the function which may evaluate the accuracy of applicant's Poomsae postures by comparing the applicant's Poomsae postures analyzed by motion recognition and evaluation S/W and Poomsae information stored in Poomsae motion DB [1–3, 7, 11, 13]. In addition, the user interface (examination result and video) consists of the screen which stores and displays the video so that the applicant could check the information input and motion analysis screen of the applicant (Figs. 6, 7 and 8).

3.2 Poomsae motion extraction module

The motions shall be extracted from the image data input from two units of motion recognition sensors through Open NI Framework [10] as follows:

① Remove the background from the image input.
② Detect the physical joints and poses using Skeleton and Pose function.

Table 2 Taekwondo Poomsae DB

Type of Poomsae	Evaluation focus point
Arae Makki	Arm Degree
Momtong Makki	Arm Degree
Momtong Jireugi	Arm Degree
Abchagi	Foot Degree
Eolgul Makki	Arm Degree
Sonnalmok Chigi	Arm Degree
Sonnal Makki	Arm Degree
Yeonsok Makko Chigi	Arm and Leg Position and Consecutive Motions
Chago Yeonsok Jireugi	Accuracy of Consecutive Motions
Sonnal Momtong Makki	Arm Degree
Pyeonson Qeut Jireugi	Arm Degree
Jebi Poommok Chigi	Arm Position
Yeop Chagi	Foot Degree
Momtong Baqqat Makki	Arm Degree
Hansonnal Eolgul Baqqat Makki	Arm Degree
Dolyeo Chagi	Foot Degree
Eolgul Baqqat Makki	Arm Degree
Batang Sonmok Makki	Arm Degree
Deung Jumeok Eolgul Apae Chigi	Arm Degree
Sonnal Arae Makki	Arm Degree
Batang Son Geodeuleo Makki	Arm Degree
Bojumeok Gawi Makki	Arm Degree
Mureup Chigi	Arm and Foot Degree
Montong Hyecheo Makki	Arm Degree
Jechin Dujumeok Momtong Jireugi	Arm Degree and Consecutive Motions
Eotgeoleo Arae Makki	Arm Degree and Consecutive Motions
Pyojeok Chigi	Arm Degree
Yeop Jireugi	Arm Degree
Dubal Dangsang Baqqat Mok Momtong Geodeuleo Baqqat Makki	Arm and Foot Degree and Consecutive Motions
Oisanteul Makki	Arm Degree
Teok Jireugi	Arm Degree
Geodeuleo Arae Makki	Arm Degree
Tuieo Chagi	Foot Degree and Consecutive Motions
Palgup Dolyeo Chagi	Arm Degree and Consecutive Motions

③ Classify the side and front images analyzing the images and poses from two devices.
④ Classify the completion of motion by distinguishing the images before the motions were changes as a single motion according to the scenario defined in Taekwondo Poomsae evaluation.
⑤ Judge the motion comparing Poomsae motion according to Poomsae evaluation grade.

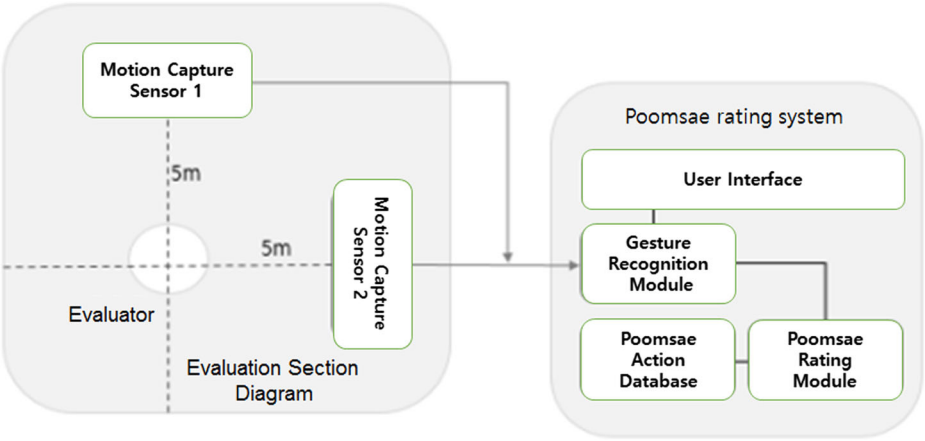


Fig 5 Entire system configuration

3.3 Feature extraction module

Measure the degree of the legs and arms with different base points according to types of Taekwondo Poomsae out of the list extracted as Skeleton in order to extract the features of

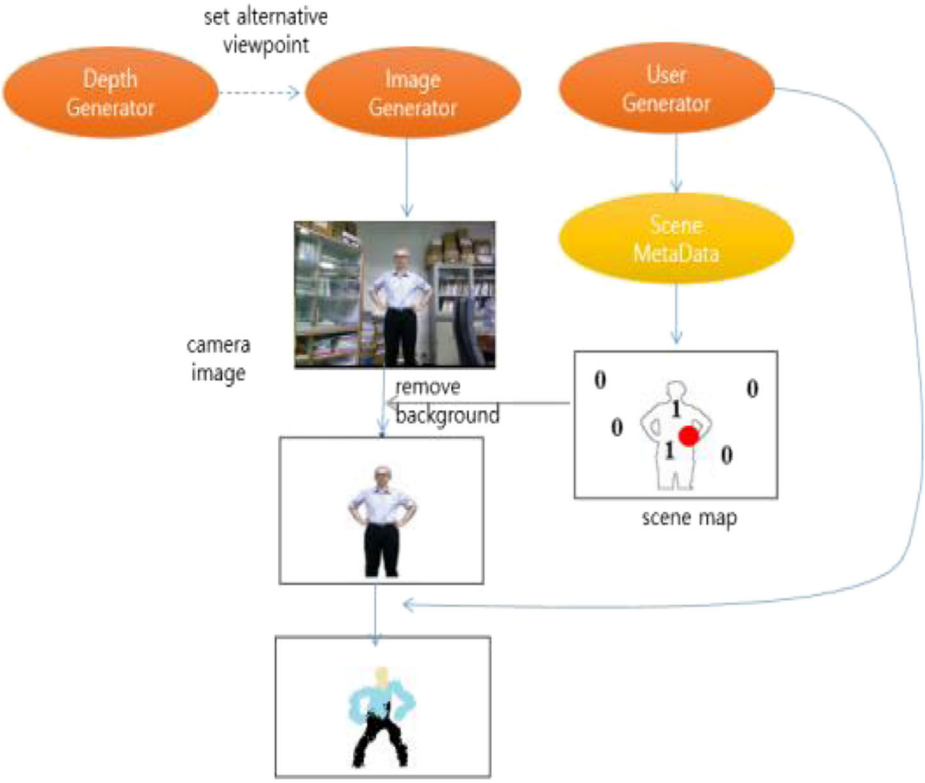


Fig 6 Background removal model

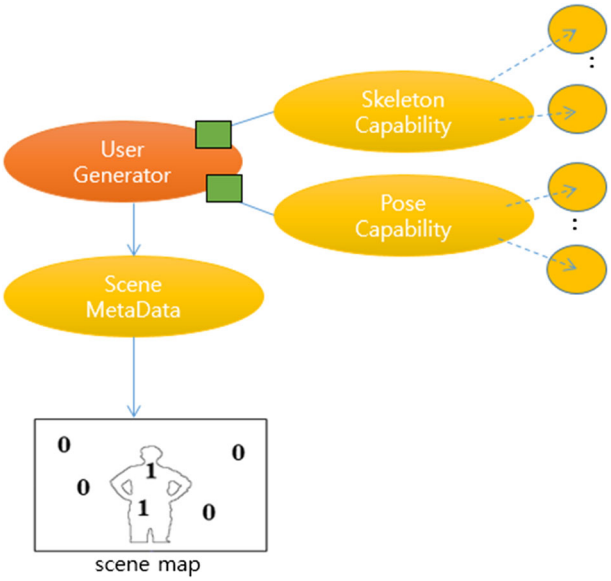


Fig 7 Skeleton and pose analysis model

Poomsae. For example, measure the degree between the left foot and right foot with the torso as the center.

① Measure the degree of the arms and legs according to the type of Poomsae distinguished through the motion recognition module in order to extract the features.
② In case of the complicated motion more than 2 motions, measure the arm and leg degree by each motion and measure the consecutive time.

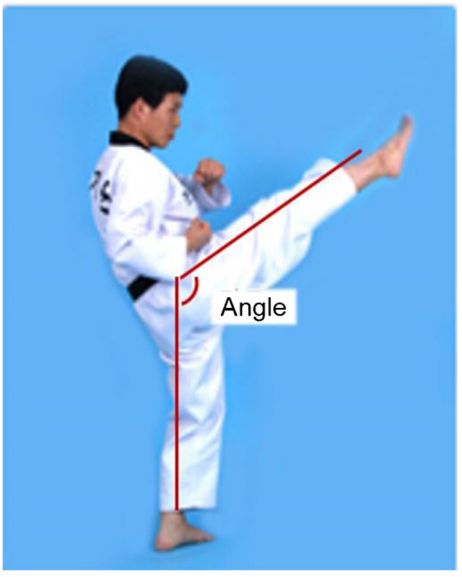


Fig 8 Example of Leg degree

3.4 Motion comparison module

① Compare the arm or leg degree bringing the same motion from Taekwondo Poomsae DB already defined according to types of Poomsae through the motion recognition module.
② Extract the difference between the arm and leg degrees defined in Taekwondo Poomsae DB and the evaluated evaluation index values.
③ Calculate the evaluation value applying the discriminated point subtraction according to difference of the degrees. (Apply the point subtraction by 0.1 point per 1 degree)

3.5 Poomsae comparison module

Evaluate Poomsae considering the accuracy of motion according to order of Poomsae motion. In addition, evaluate the same applying the weight according to the grading standards defined in the rules of Taekwondo Poomsae competition. The formula of Poomsae evaluation was applied as follows:

Poomsae evaluation point (Based on 10 points as the perfect score)=A+B+C+D ——————— (Formula 3)

- A: Whether or not the evaluation was conducted in order according to the types of Poomsae (Max. 2 points)
- B: Accuracy of the motion (Max 4 points)
- C: Speed and balance (Max 2 points)
- D: Harmony (Strength and smooth, Tempo, Rhythm) (Max 2 points)

  Evaluate the standard of D calculating the completion time by Poomsae (Definition of completion time by Poomsae: For example, Taegeuk Chapter 1 shall be completed within 1.5 min)

3.6 Poomsae evaluation motion DB

Establish Poomsae Evaluation Motion DB by extracting and defining the specific values to evaluate according to the motions after understanding and analyzing the types of Taekwondo Poomsae. The types of Taekwondo Poomsae include from the beginning stage, Taegeuk Chapter 1~8 to the senior stage, Koryeo~Ilyeo. However, in this paper, Poomsae DB from Taegeuk Chapter 1 to Chapter 8, the beginning stage was considered as Table 2. Table 3 defined the user information DB.

3.7 User interface and reliability verificarion

User interface provides the user convenience based interface which the user may easily check the result. Figure 9 shows the user interface example.

To verify the reliability of the Poomsae remote-assessment system using the motion recognition technology proposed in this paper, the expert assessment by 10 black belt holders of the National Taekowndo Institute was performed subjecting three target examinees. Based on the expert assessment points, their skills were compared using the iPiSoft, Kinect and Optitract motion recognition technologies. The assessment items were the front and the side

Table 3 User information DB

Field	Description
Applicant's ID	Input the applicant's ID
Applicant's name	Input the applicant's name
Applicant's gender	Input the applicant's gender
Applicant's age	Input the applicant's age
Applicant's address	Input the applicant's address
Name of Taekwondo Club	Input the name of Taekwondo Club under evaluation
Current grade	Input the grade acquired before
Poomsae grade evaluation	Evaluate the new Poomsae Grade
Date of Poomsae evaluation test	Input the date of evaluation test
Evaluation result	Input the result of Poomsae evaluation

motions of each skill based on the basic Taekwondo Poomsae presented in Table 2. Figure 10 shows the assessment result of the motion recognition technology based on the experts' assessment. Wherein, Fig. 10(a) shows the comparison on the front motion assessment in Table 2, and Fig. 10(b), the side motion, separately.

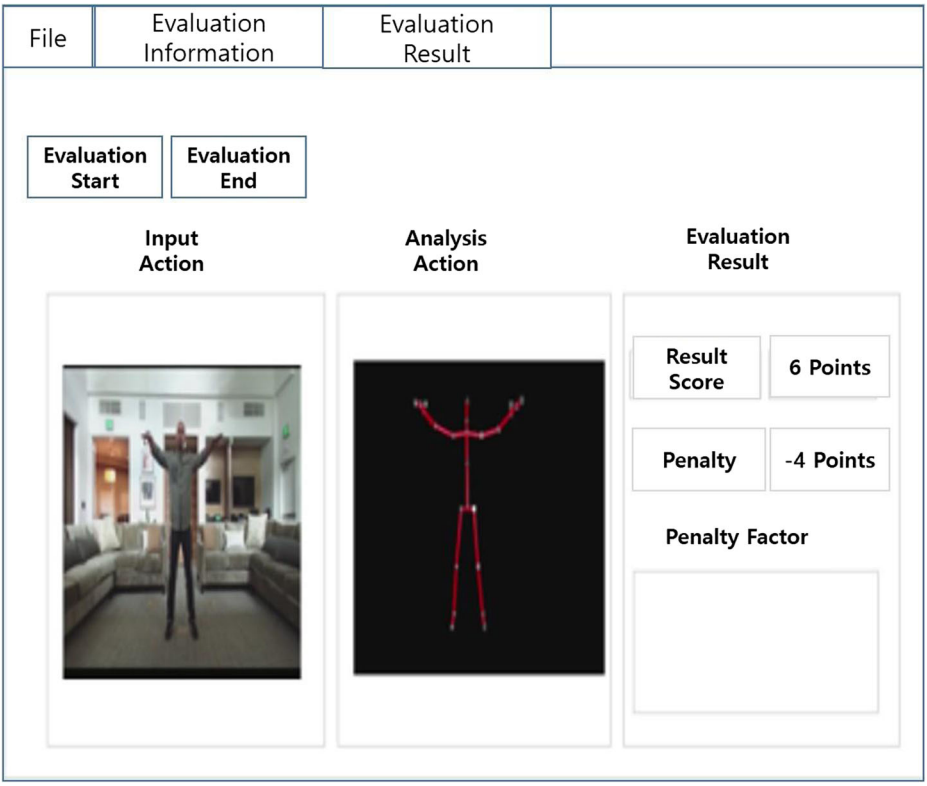
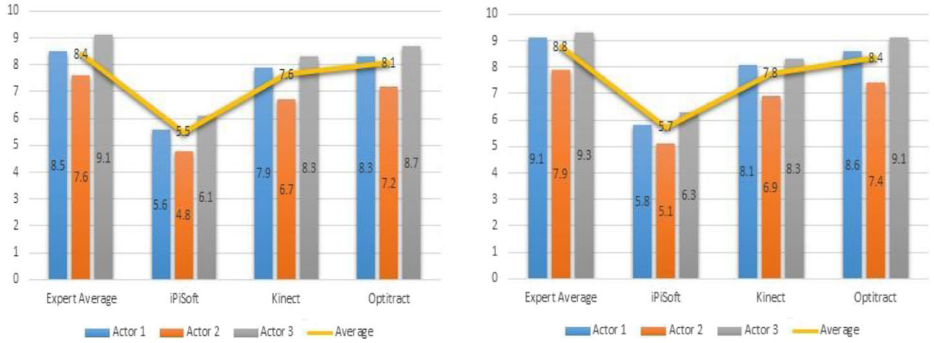


Fig 9 Example of user interface



(a) Comparison of the poomsae front motion (b) Comparison of the poomsae side motion

Fig 10 Comparison of the poomsae motion recognition assessment **a** Comparison of the poomsae front motion **b** Comparison of the poomsae side motion

Based on the basic Poomsae in Table 2, the average point of the front motion by the 10 taekwondo assessment experts was 8.4. The result compared with those of the Poomsae remote assessment methods appeared as; the iPiSoft method presented 65.5 %, Kinect, 90.5 %, and Optitract, 96.4 %, respectively. On the other hand, the average point of the side motion of the assessment experts was 8,8, Based on such, the accuracies of each method compared with that of the Poomsae remote assessment method appeared as; the iPiSoft method, 64.8 %, Kinect method, 88.6 %, and Optitract, 95.5 %, respectively.

4 Conclusion

This paper proposed a platform of remote Taekwondo Dan(Poom) promotion examination system in order to make the public confident, fair and objective Taekwondo evaluation environment through development of publically certified remote Taekwondo Dan(Poom) promotion evaluation platform and further vitalize Taekwondo and arrange the base for popularization and distribution of remote Taekwondo Dan(Poom) promotion evaluation system. The platform proposed designed the entire system block diagram, motion technology of each module and Poomsae measuring method and Poomsae motion DB and established the example of the user interface.

In addition, 2 KINECT units, OptiTrack and iPiSoft were used for camera's motion detection in order to test the remote Poomsae Evaluation System using the motion recognition technology and MLP(Multilayer Perceptron), Naive Bayes, Decision Tree were used as for the motion analysis algorithm. In addition, the remote Poomsae evaluation system was established using the real time server and Web service technology.

The objectivity and fairness of Kibon Dongjak and Poomsae practice evaluation of Taekwondo equipped with IT technology could be secured through this proposal, and

the objective information was obtained by tracing the physical skeleton of the applicant and the objectivity could be given to Taekwondo Dan(Poom) promotion examination based on foregoing. This shall contribute to scientification, standardization and globalization of Taekwondo practice evaluation.

The researcher would like to develop an objective real time remote Poomsae evaluation system through establishment and analysis of professional Poomsae motion big data through the reliable motion recognition using the various motion recognition sensor technology in future study.

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