On the Validity of the Knowledge Transferring Assessment of the Knowledge-based System for Training Long Jump Athletes: The Approach-Run Phase

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Abstract: Precise measurements of maximum speed and position of maximum speed during sprinting have essential inferences for planning and improving the individual performance of long jump athletes. Coaching in the approach-run phase is somewhat difficult because the athlete’s movement is very fast. Therefore, the aim of this study was to evaluate the validity of the knowledge transferring of Knowledge-Based System (KBS) for training long jumpers in the approach-run phase which was compared with the Tracker video analysis software. Twelve healthy adults (Average age=27.58 years old, SD=9.67, Variance=93.53) were randomly selected for data collecting. The participants performed walking, jogging, running and fast running trials and static starts at about 20-25 m. distance from a take-off board. Descriptive statistics, Cross-tabulation and Spearman’s Rho were employed for statistical analysis. The results showed strong significant relationship between both systems at Spearman’s Rho Correlation = 0.916, p-value <0.01. The results also indicated that the proposed KBS could be used to accurately evaluate transferring of knowledge in the approach-run phase.

Keywords: Knowledge-based system, knowledge engineering, knowledge transfer, approach-run, long jump biomechanics, computer vision, validity.

INTRODUCTION

According to the Ministry of Education, Thailand has a number of students in Middle and High secondary schools at approximately 4.3 million. About 4,000 pupils are studying in the sport schools of the Institute of Physical Education [1]. Eleven sport schools are distributed at all regions of Thailand, such as Northern, Central, Eastern and Southern. Athletic is one of 31 sport types that is contained into the sport curriculum for studying in all sport schools. Nearly 700 students are studying in Athletic, nevertheless, just about 10-15 students are interested in the long jump for each sport school. Therefore, overall of students from sport schools in Thailand who choose to learn long jump are only approximately 150 [2].

Due to the long jump biomechanics which includes four phases as the approach-run, the take-off, flight and landing to complete the excellent performance [3], the existing coaching methods of the long jump are monitored during the jump and then corrected and recommended to the long jump athletes. Unfortunately, most long jumpers still lack the standard long jump biomechanics suggestions from coaches to correct the right principle for practising, thus, long jump athletes are unable to increase their skills to the high level of their long jump performance. Besides, IAAF certification expert for long jump is rare in Thailand. There are only five professionals who got Level III (Coach level). IAAF (International Association of Athletics Federations) is the international governing body for the sport of athletics [4].

The main problem of long jump teaching is motion analysis of long jump during approach-run to take-off until flying and landing into the pit. Some coaches use just a digital camera or tablet for recording
movement of an athlete, then correct and suggest their movements. Nevertheless, it is somewhat difficult to analyse by only human visual system because the approach-run phase is very fast. Coaches cannot know the exact maximum speed and position of maximum speed of the long jump athlete, therefore, the requirement of them is a device or a system for detection of speed of movement, analyse and also suggest the right action of all phases of the long jump biomechanics [5]. In order to generate good long jump distance, the maximum speed and position of maximum speed is a very important influence to long jump performance. In addition, athletes have to make a fast run-up, reaching approximately 95-99 per cent of their maximum speed at the end of the run-up, about 2-3 last strides before take-off [6], [7]. In addition, in the optimum take-off technique, long jump athletes have to run-up as fast as possible in the long jumping [8].

Currently, computer vision techniques are employed to help several studies for developing automatic systems as well as analysing the human movement [9], for example, the approach-run to the take-off kinematic data analysis [10], an automatically-detected motion of standing long jump [11], an automatic human detection, tracking and acting recognition of athlete finding [12], an automating detection of both arms and legs of swimming biomechanics [13], vehicle tracking and speed measurement system [14], etc. These researches used computer vision techniques for analysing human movement and improving performance skills of athletes.

Knowledge-based system (KBS) has root from artificial intelligent (AI) field, that is, a recognition of distinct human quality. Knowledge from human (human expert knowledge) is to be initiated in the computer system and in the form of IF-THEN rule, that is called ‘inference engine’ [15], [16]. Developing the KBS, furthermore, is to contain the knowledge engineering technique (capturing knowledge from experts) and typical software engineering practices [17], and also, KBS can transfer explicit knowledge and reuse explicit knowledge to improve humans’ knowledge [18].

The knowledge-based system framework for practising long jump athletes was designed that comprises: video motion capture, recognize action, expert system, domain experts, training image dataset, suggestion action and summary report [19], [20]. The Knowledge-Based System (KBS) for training long jump athlete: approach-run phase was developed for testing maximum velocity and also position of maximum velocity in the approach-run phase of the individual long jump athlete. The purpose of this study is the validity of knowledge transferring of the KBS in the approach-run phase comparison with the Tracker video analysis software. Tracker is a free Java video analysis and modelling tool from Open Source Physics [21].

Contribution of this paper to the literature, this paper contributes to validate the knowledge-based system (KBS): case of approach-run phase for transferring long jump experts’ knowledge to long jump athletes with a video analysis software tool. Furthermore, analysis of association of the long jump experts’ suggestion between the KBS and a video analysis software tool.

**MATERIALS AND METHODS**

**Participants**

In this study, participants were twelve healthy adults aged 18 to 42 years who were recruited by random selection method from Chiang Mai University, Chiang Mai province, Thailand. The participants performed walking, jogging, running for ten trials (C1-C10) and static starts far from a take-off board approximately 20-25 m. All participants had no experience in the long jump biomechanics.
Protocol

Capturing data in this phase, the Maximum velocity \( (V_{max}) \) and Maximum velocity’s position \( (V_{maxPosition}) \) were performed for a total of all conditions on the synthetic running track, flat and dry. The protocol of this phase consisted of 4 located markers as M1: at the starting point of the long jump sand pit, M2: at the take-off position, M3: at the 5 meters far from the take-off position and M4: at the 10 meters far from take-off position. The camera’s position far from the take-off position (M2) about 10 meters and 18-20 meters from the marker (M4). The camera was fixed on the tripod and 3-way head at the height from the floor about 1.5 meters. Furthermore, each participant wore a black sport suite. The white passive circular marker about 2.5 inches was then placed at the body’s centre of mass (COM) of participants for capturing. The protocol is shown in Fig. 1.

Procedures

This study focused on the validity of the proposed system to transfer knowledge to athletes in the approach-run phase of the long jump biomechanics. The procedure diagram of this study is shown in Fig. 2.

Data collection

The movement of participants was recorded with a stationary video camera (Nikon 1 J1) at the rate of 60 fps and 10 mm lens. A video format is MOV. A resolution of 1280 x 720 pixels was performed for all videos. The participant did one trial of each condition with ten conditions which comprised:

- C1: Walking at a comfortable speed from the beginning to the end
- C2: Jogging from the beginning to the end
- C3: Jogging and then gradually increasing speed
- C4: Jogging and then gradually decreasing speed
- C5: Running at medium speed from the beginning to the end
- C6: Running at medium speed and then gradually increasing speed
- C7: Running at medium speed, then gradually decreasing speed and walk
- C8: Running at medium speed, then gradually increasing to fastest speed
- C9: Running at the fastest speed, then gradually decreasing speed
- C10: Running at the fastest speed from the beginning to the end

Data Analysis

All captured videos from the standard video camera (120 videos) were transferred to a personal computer, then these videos were analysed by the proposed system (KBS) and also Tracker video analysis software (Tracker). The KBS was established using Matlab R2015a in combination with the Image Processing Toolbox and the Computer Vision System Toolbox. The proposed method comprises 6 stages that are (1) Video motion capture, (2) Motion segmentation, (3) Feature extraction, (4) Maximum velocity detection, (5) Maximum velocity position detection and (6) Knowledge experts’ suggestion.

The variables such as the maximum velocity \( (V_{max}) \) and the position of maximum velocity \( (V_{maxPosition}) \) were calculated using the KBS algorithm and also the Tracker video analysis software. Additionally, IF-THEN rule in this phase from long jump experts was employed for correction of Rule result of each condition of both KBS and Tracker.

In this study, experts were professionals of the long jump biomechanics who had participated in the IAAF Level III training [4]. They recommended that the inference IF-THEN rules of the approach-run phase should be separated into 3 rules:

- 1\textsuperscript{st} rule the position of maximum velocity is at the take-off board to 5 meters from the take-off board (around the last 2 to 3 strides).
- 2\textsuperscript{nd} rule the position of maximum velocity is at longer than 5 meters from the take-off board to 10 meters from the take-off board.
- 3\textsuperscript{rd} rule the position of maximum velocity is at longer than 10 meters from the take-off board to the starting position.
Table 1: Inference Rule from long jump experts.

<table>
<thead>
<tr>
<th>Rule</th>
<th>Vmax (m.s(^{-1}))</th>
<th>Vmax position (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule 1</td>
<td>&gt;=4</td>
<td>0.5</td>
</tr>
<tr>
<td>Rule 2</td>
<td>&gt;= 4</td>
<td>&gt; 5.10</td>
</tr>
<tr>
<td>Rule 3</td>
<td>&gt;= 4</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>Low speed</td>
<td>&lt; 4</td>
<td>No consideration</td>
</tr>
</tbody>
</table>

Besides, experts suggested that if the maximum velocity was less than 4 m.s\(^{-1}\), running was not appropriate for the approach-run. Therefore, to generate the longest distance, the long jumper had to produce the maximum velocity (Vmax) around the last 2 to 3 strides or around 5 meters before take-off as shown in Table 1. The inference IF-THEN rules of the approach-run phase were determined to produce rule-based (inference engine) for correcting the long jump running. Rule result, additionally, is the result of the suggestion checking (KBS compare with Track) using Algorithm 1: Approach-run phase as shown in Fig. 3.

Statistical Analysis

IBM SPSS Statistics Version 21 for Windows (SPSS Inc., Chicago, IL, USA) was performed for analysing data. P-Value < 0.05 was considered as statistically significant. Descriptive statistics (means, SD and variance) were used for the demographic characteristics. Mean of the maximum velocity of each condition and Pearson Correlation was performed for evaluation of the correlation between maximum velocity (Vmax) of KBS and Tracker.

Statistical Analysis

Besides, the correction of Rule result, Cross-tabulation was used to present the frequency of Rule result from KBS and Tracker of all conditions (C1-C10). Moreover, to examine the KBS validity against the Tracker, Spearman's Rho was employed to evaluate the correlation between Rule result of KBS and Rule result of Tracker.

A significant association was assumed when the probability value (p-value) was 0.05.

RESULTS

Descriptive Statistics

Ten conditions (C1-C10) were successfully completed by 12 participants without incident. The participants’ demographic characteristics indicated that the sample of this study comprised relatively healthy groups of 6 males and 6 females without cognitive impairment. The average of age was 27.58 years (SD=9.67, Variance=93.53), weight was 61.08 kg (SD=12.36, Variance=152.81), height was 1.70 m (SD=0.07, Variance=0.01) and Body Mass Index (BMI) was 17.89 kg.m\(^{-2}\) (SD=3.18, Variance=10.14).

Table 2: Correlation of maximum velocity (V\(_{\text{max}}\)) of KBS and Tracker (N=120).

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>Variance</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBS</td>
<td>1.0</td>
<td>8.1</td>
<td>4.21</td>
<td>1.7</td>
<td>3.08</td>
<td>.995*</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracker</td>
<td>1.0</td>
<td>8.0</td>
<td>4.24</td>
<td>1.7</td>
<td>3.08</td>
<td>.995*</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed).**

Furthermore, Table 2 presents the descriptive statistics of maximum velocity of both KBS and Tracker. There was a strong significant positive relationship between KBS and Tracker at the P-value < 0.01 level (2-tailed).
Algorithm 1: Approach-run phase

Input: $V_{\text{Max}}$, Position of $V_{\text{Max}}$

Output: Result_Run, Result_suggestion

1 Begin
2 if $V_{\text{Max}} < 4$ then
3 Result_Run = "Sorry your maximum velocity ($V_{\text{max}}$): $V_{\text{MAX}}$ m/s$^{-1}$. That is not suitable for long jump. The maximum speed should be more than 4 m/s$^{-1}$."
4 Result_suggestion = "Suggestion:
1. You should try again with more speed-up.
2. You should practise your speed performance."
5 elseif Position of $V_{\text{Max}} = 0$ || Position of $V_{\text{Max}} < 5$ then
6 Result_Run = "Very Good: You are at the Rule #1
Maximum velocity ($V_{\text{max}}$): $V_{\text{MAX}}$ m/s$^{-1}$.
Maximum velocity position ($V_{\text{max}}$ position): Position of $V_{\text{Max}}$ m."
7 Result_suggestion = "Suggestion:
1. This is good running but you have to control the velocity to take-off.
2. Your maximum velocity is this position, so you should control the speed for take-off.
3. Please do not reduce your speed and keep this speed level or increase your speed-up before the next jump.
4. You should move the starting-point equivalent lose space to the take-off board from the last starting-position but the speed still the same with each running attempt."
8 elseif Position of $V_{\text{Max}} = 5$ || Position of $V_{\text{Max}} < 10$ then
9 Result_Run = "Almost good: You are at the Rule #2
Maximum velocity ($V_{\text{max}}$): $V_{\text{MAX}}$ m/s$^{-1}$.
Maximum velocity position ($V_{\text{max}}$ position): Position of $V_{\text{Max}}$ m."
10 Result_suggestion = "Suggestion:
1. Before reaching to the take-off board, you should have two check makes.
2. You have to shift in from start point to take-off board.
3. Good, but you should keep this maximum speed to take-off board. The controlled maximum speed should be less than 5 meters from the take-off board.
4. If the real competition situation, you will adjust the new marker using around 14-17 soles (2 strides of running) come to take-off board.
5. You should move the starting-point equivalent lose space to the take-off board from the last starting-position but the speed still the same with each running attempt.
6. Do not take more long stride or short stride of a leg before take-off"
11 elseif Position of $V_{\text{Max}} > 10$ then
12 Result_Run = "Try again: You are at the Rule #3
Maximum velocity ($V_{\text{max}}$): $V_{\text{MAX}}$ m/s$^{-1}$."

Maximum velocity position (V_{max} position): \textit{Position of V_{Max} m.}"

\textbf{13 Result suggestion} = “Suggestion:

1. Number of stride ratio of all distance from the start point to the first check mark should be more than the last period before reaching to the take-off board.

2. You should slightly increase to the take-off board. It is unable to use this speed for taking-off. You should practise the approach-run again.

3. You may start with over fast running that why V_{max} appears in this period. It affects to the athlete that is unable to preserve and control speed for taking-off.

4. You should start with around 10–20 m. with long stride from the take-off board, then each stride adjusts your speed at 5–10 m, and the maximum speed should be around 0–5 m. from the Take-off board.

5. You should gradually increase speed from starting position to check mark point, then perform the fastest speed around 0–5 m from take-off board.

6. Increasing speed, the jumper gradually straightens up and run become more upright and go along with a smooth stride pattern.

7. Rhythm in each approach increase your pace at the same rate and take care to keep the degree of muscle contraction uniform.

8. One checkmark at a distance which is the midpoint of the run is usually sufficient.”

\textbf{14 end if}
\textbf{15 end}

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Fig. 3. KBS: Approach-run phase algorithm.

### Table 3. Cross-tabulation of each condition (C1-C10) with Rule results of KBS and Tracker (N=120).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean (m.s^{-1})</th>
<th>SD (m.s^{-1})</th>
<th>Minimum (m.s^{-1})</th>
<th>Maximum (m.s^{-1})</th>
<th>Variance (m.s^{2})</th>
<th>Total Sum (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KBS Tracker</td>
<td>KBS Tracker</td>
<td>KBS Tracker</td>
<td>KBS Tracker</td>
<td>KBS Tracker</td>
<td>KBS Tracker</td>
</tr>
<tr>
<td>C01</td>
<td>1.52 1.56</td>
<td>.25 .28</td>
<td>1.03 1.05</td>
<td>1.83 1.86</td>
<td>.06 .06</td>
<td>3.6 3.7</td>
</tr>
<tr>
<td>C02</td>
<td>2.62 2.66</td>
<td>.51 .56</td>
<td>1.87 1.96</td>
<td>3.53 3.66</td>
<td>.27 .31</td>
<td>6.2 6.3</td>
</tr>
<tr>
<td>C03</td>
<td>4.34 4.40</td>
<td>1.08 1.11</td>
<td>2.68 2.64</td>
<td>6.19 6.00</td>
<td>1.17 1.24</td>
<td>10.3 10.4</td>
</tr>
<tr>
<td>C04</td>
<td>2.70 2.72</td>
<td>.65 .70</td>
<td>1.60 1.63</td>
<td>3.57 3.68</td>
<td>.42 .49</td>
<td>6.4 6.4</td>
</tr>
<tr>
<td>C05</td>
<td>4.45 4.48</td>
<td>1.25 1.24</td>
<td>2.52 2.46</td>
<td>6.35 6.23</td>
<td>1.57 1.55</td>
<td>10.6 10.5</td>
</tr>
<tr>
<td>C06</td>
<td>5.38 5.37</td>
<td>1.18 1.24</td>
<td>3.38 3.20</td>
<td>6.87 6.77</td>
<td>1.40 1.54</td>
<td>12.8 12.7</td>
</tr>
<tr>
<td>C07</td>
<td>3.87 3.91</td>
<td>.94 .93</td>
<td>2.66 2.57</td>
<td>5.47 5.40</td>
<td>.88 .87</td>
<td>9.2 9.2</td>
</tr>
<tr>
<td>C08</td>
<td>5.60 5.63</td>
<td>1.37 1.38</td>
<td>3.28 3.27</td>
<td>7.68 7.58</td>
<td>1.87 1.89</td>
<td>13.2 13.3</td>
</tr>
<tr>
<td>C09</td>
<td>5.55 5.59</td>
<td>1.16 1.09</td>
<td>3.95 4.10</td>
<td>7.25 7.20</td>
<td>1.36 1.18</td>
<td>13.2 13.2</td>
</tr>
<tr>
<td>C10</td>
<td>6.06 6.13</td>
<td>1.31 1.24</td>
<td>4.02 4.23</td>
<td>8.10 8.01</td>
<td>1.70 1.55</td>
<td>14.4 14.5</td>
</tr>
<tr>
<td>Total</td>
<td>4.21 4.24</td>
<td>1.76 1.76</td>
<td>1.03 1.05</td>
<td>8.10 8.01</td>
<td>3.08 3.08</td>
<td>100.0 100.0</td>
</tr>
</tbody>
</table>
Table 3 shows mean of the maximum velocity of each condition (C1 - C10) with KBS and Tracker. The results illustrated that mean of C01, C02, C04 and C07 were less than 4.00 m.s\(^{-1}\) whereas C03, C05, C06, C08, C09 and C10 had the maximum velocity higher than 4.00 m.s\(^{-1}\).

Besides, Table 4 shows the Rule results that were divided into four rules as Rule 1, Rule 2, Rule 3 and Low speed. Cross-tabulation was performed to present the conditions' Rule results of KBS and Tracker. The result shows that condition C1, C2 and C4 were Low speed around 30% of all attempts. It means that the proposed system could check the movement of participants as walking or jogging. In addition, C3, C5 and C7 were Low speed approximately 15% of all attempts. It was walking or jogging as well, but there were some participants that made jogging or running at medium speed. However, in this study, around 55% of all attempts were running at medium speed and running at the fastest speed.

 Besides, Table 5 shows the similarity of KBS and Tracker with 'Yes' and 'No' Rule results. The result indicated that the similarity of Rule result 'Yes' was 85% whereas Rule result 'No' was 15%.

### RULE RESULTS VALIDITY

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### The Knowledge Transferring of KBS Validity

Table 6 presents the association of knowledge transferring (experts' suggestion inference rules) between KBS and Tracker. The result shows a strong significant positive relationship at Spearman's Rho Correlation = 0.916 and p-value <0.01.
DISCUSSION

The results of this study suggested that the KBS: approach-run phase could be used to accurately measure the maximum speed of each trial which the correlation was strongly significant at Pearson Correlation = 0.995 and p-value < 0.01. And also, the transferring knowledge to the individual long jump athlete was strongly significant at Spearman’s Rho Correlation = 0.916 and p-value < 0.01. Our findings for using both KBS and Tracker to detect maximum speed of the athletes gave very good results. Both systems can detect the maximum speed and imply that the athlete is walking (C1, C2, C3, C7), jogging (C4, C5, C6), running (C5, C6, C8) or fast running (C8, C9, C10). Moreover, both of the systems can also detect the maximum speed position of the long jump athlete and then can precisely suggest through the Algorithm 1 as about 85 per cent. The proposed system has numerous advantages over video analysis software tools. The primary advantage is that it provides not only an automatic detection of maximum velocity (Vmax) of working until fast running of the human movement, but also an automatic detection of maximum velocity position (VmaxPosition). The second advantage, especially important for coaching, the suggestions from experts were embedded into the proposed system. Coaches can read the suggestion feedback and the results of each athlete from the system immediately. The third advantage, friendly use of the system, the proposed system provides the flexibility for unfamiliar using with information and computer technology. The user is not necessary to plot, draw, setup or mark into the video source that is different from the video analysis software. The proposed system was designed for easy use with just one step or two steps and then the results will show within a few minutes. Additionally, the fourth advantage, a low cost standard video camera can be used in the proposed system, but it has to be fixed on the camera tripod or an adjustable desk. The fifth advantage, markerless motion capture, the proposed system can capture movement data without an attachment of any device or marker in the athlete’s body. As a result, the athletes can move their body in a natural manner that represents the real performance. However, the proposed system has some limitations. Firstly, the capture volume depends on the camera position, for instance, if we need to capture the athlete running around 30 m, we will have to set the camera approximately 25 m from the athlete’s body. So, we have to consider about an area for using of the proposed system. Secondly, the colour of athlete’s suite, due to the real environment, the system was set for detection of just lower value of colour such as dark gray and black. Hence, the suitable athlete’s suite is dark gray or black colour whereas other colours are restricted to use. Finally, the proposed system is unable to capture under low light environment. It works at normal illumination.

CONCLUSIONS

In this study, we have presented the validity of the KBS: the approach-run phase with Tracker video analysis software and also the correcting rule results of both systems was performed using the inference IF-THEN rule from experts’ knowledge (Algorithm 1: Approach-run phase). Statistical analysis, moreover, Descriptive statistics, Cross-tabulation and Spearman’s Rho were employed for analysing data. The results have demonstrated that the knowledge-based system (KBS) for training long jump athletes: the approach-run phase can be used for accurate knowledge transfer. The future work should examine the combination of approach-run phase and take-off phase of the long jump biomechanics for suggestion of the individual long jump athlete’s skills.

Practical Implications

The maximum speed (V\text{max}) and the position of maximum speed (V\text{max,position}) can be detected with high accuracy using the knowledge-based system (KBS) for training long jump athletes: the approach-run phase.
The KBS: the approach-run phase can be transferred knowledge with high precision comparing with the standard video analysis software (Tracker). **Acknowledgments:** This study was supported by the Graduate School, Chiang Mai University, Chiang Mai, Thailand. Besides, the authors would like to convey their gratitude to the Student Development Division of Chiang Mai University for supporting the main stadium. Moreover, the authors would like to thank Assoc. Prof. PermsakSuriyachanand also Mr. KittisakSukon (the long jump coach of Thailand national team) for supporting knowledge of the long jump techniques. Besides, the authors would like to thank Assoc. Prof. Dr. SirinunBoripuntakul for supporting the protocol designing and statistical analysis.

**Conflicts of Interest:** The authors declare no conflict of interest.

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