IN KARATE DEVELOPING AN ARTIFICIAL INTELLIGENCE SYSTEM TO ANALYSE AND EVALUATE PERFORMANCE TECHNICAL KATA MOVEMENTS

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Abstract
Evaluating kata performance traditionally faces challenges like human bias and inaccuracies, which emphasize the need for objective evaluation methods. This study aims to develop an artificial intelligence (AI) system to analyze and assess the technical execution of kata movements in karate using image processing and machine learning techniques. The proposed AI system captures high-quality video recordings of athletes performing specific kata, such as Heian Jodan, and employs convolutional neural networks (CNNs) to extract critical motor parameters, including timing, balance, accuracy, and joint angles. It then evaluates performance against predefined technical standards. Kata, a fundamental component of karate, embodies a series of offensive and defensive movements performed in a structured pattern, showcasing artistic and technical prowess. The system also provides immediate, detailed feedback to players and coaches, highlighting areas of strength and areas requiring improvement. The study was conducted on a sample of 50 brown-belt karate athletes, divided equally into experimental and control groups. The experimental group utilized the AI system for performance evaluation, while traditional coach evaluations assessed the control group. Statistical analyses, including T-tests, revealed that the AI system delivered accurate feedback, closely aligning with the traditional coach assessments, with a minimal difference of 1.11% to 1.19%. Key findings highlighted high accuracy levels (89%-95%) in simpler movements like "Yui (Preparation)" but challenges in maintaining balance during backward movements and slower reaction times in defensive moves. Recommendations include specialized exercises to improve balance, reaction speed, and energy management, alongside integrating the AI system into training programs for consistent and objective performance analysis. This research signifies a technological shift in sports training, offering a reliable, advanced tool to enhance performance evaluation and skill development in karate, bridging gaps in traditional assessment methods while promoting, professional growth in martial arts.
Keywords: Artificial intelligence, Machine learning, Performance analysis, Kata, , Performance evaluation, Karate training

Introduction

Kata represents a sequential set of defensive and offensive movements executed in a specific pattern with the aim of demonstrating artistic and technical skills. Kata is one of the most important artistic forms in karate, With the increasing interest in using technology to develop and improve sports performance, the need has emerged to create modern solutions based on artificial intelligence to study and evaluate kata movements, thus contributing to improving players' performance and developing their skills.

Recent studies have shown that intelligent systems based on artificial intelligence and machine learning are able to provide accurate and objective analyses of motor performance in various sports. For example, deep learning algorithms have been used in video analysis to improve players' techniques in soccer and gymnastics .Accordingly, this research aims to develop an artificial intelligence system dedicated to analysing and evaluating the technical performance of kata movements in karate using image processing and machine learning techniques.

Karate is a martial art characterized by the complexity of its artistic and technical movements, especially in the performance of kata, which represents a distinctive pattern of sequential, organized movements that combine balance, strength, and precision. Mastering the kata requires extensive training and constant evaluation to ensure consistency and harmony between the movements. With the development of modern technology, artificial intelligence has become one of the leading tools that can contribute to improving the performance evaluation process and developing the technical capabilities of players.

This system provides players and coaches with immediate feedback that contributes to identifying strengths and weaknesses, which helps improve performance and develop skills The proposed system focuses on collecting motor data by recording video clips and analysing them using modern techniques such as Convolutional Neural Networks to extract key motor features. In addition, evaluation algorithms will be designed based on specific criteria such as accuracy, balance, timing, and coordination between movements.

This research is a response to the global trend towards integrating artificial intelligence into various fields, including sports, with the aim of making the most of modern technologies to improve the quality of performance and develop

competencies.

The importance of this research comes from the need to develop objective assessment tools that reduce human bias and rely on accurate data. It also represents a qualitative shift in the use of technology to improve sports training. Through this research, we expect to make a scientific contribution that can be a reference for developing future applications in sports performance analysis, which enhances the use of technology in enhancing technical proficiency and professionalism in karate.

Background study

Karate is one of the most widespread martial arts. Kata, as a basic element, requires high precision and coordination between movements. Kata is an organized set of offensive and defensive movements that reflect the player's artistic skills and technical level. However, the process of evaluating kata performance faces significant challenges, most notably human bias and imprecision in judging movements.

The proposed system focuses on recording players' performance via high-quality videos and analysing them using deep learning algorithms such as Convolutional Neural Networks (CNN). These algorithms extract motor parameters such as joint positions and angles of movement, allowing performance to be evaluated based on specific criteria including timing, coordination, and accuracy.

This research also contributes to bridging a scientific and technical gap by employing artificial intelligence to improve sports training and reduce human errors. The system not only aims to provide objective evaluations but also seeks to provide detailed feedback to players and coaches, helping them improve performance and enhance efficiency.

The study was implemented using the experimental method on a sample of 50 karate players who held a brown belt (second level), as this sample represents a group with intermediate skills, which provides an ideal opportunity to evaluate the effectiveness of the proposed smart system.

The sample was divided into two groups: the experimental group (25 players) in which the smart system was used to analyse their performance and provide feedback based on criteria such as timing, consistency, and accuracy, and the control group (25 players) whose performance was evaluated in traditional ways by the coaches.

This research represents a qualitative shift in the application of technology in sports, which enhances the quality of sports evaluation and contributes to developing players' skills in a sustainable manner.

To ensure the reliability of the results, three attempts were recorded for each player, with the evaluation results provided by the system compared with traditional coaches' evaluations. The players' performance while executing specific kata (such as the Heian Godan kata) was recorded using high-resolution cameras, and the videos were then analysed using advanced artificial intelligence techniques. Statistical analysis using descriptive statistics showed that the sample was homogeneous in terms of physical characteristics (average age 15.8 years, height 165.5 cm, weight 60.3 kg, and duration of training 5.2 years), as the skewness coefficient was close to zero, which confirms the moderation of the distribution and the homogeneity of the sample.

Results

The results showed the system's ability to provide accurate feedback, which contributes to improving the players' technical performance compared to traditional methods.The data was analysed using a T-Test to compare the performance of the two groups and determine the effectiveness of the smart system in improving the evaluation of players' performance.

Table 1. Sample homogeneity table (50 players).

Characteristics	**Mean**	**Standard Deviation**	**Coefficient of Skewness**	**Homogeneity**
Age (years)	15.8	1.2	0.14	Homogeneous
Height (cm)	165.5	5.4	0.10	Homogeneous
Weight (kg)	60.3	4.2	0.07	Homogeneous
Training duration (years)	5.2	0.8	0.12	Homogeneous

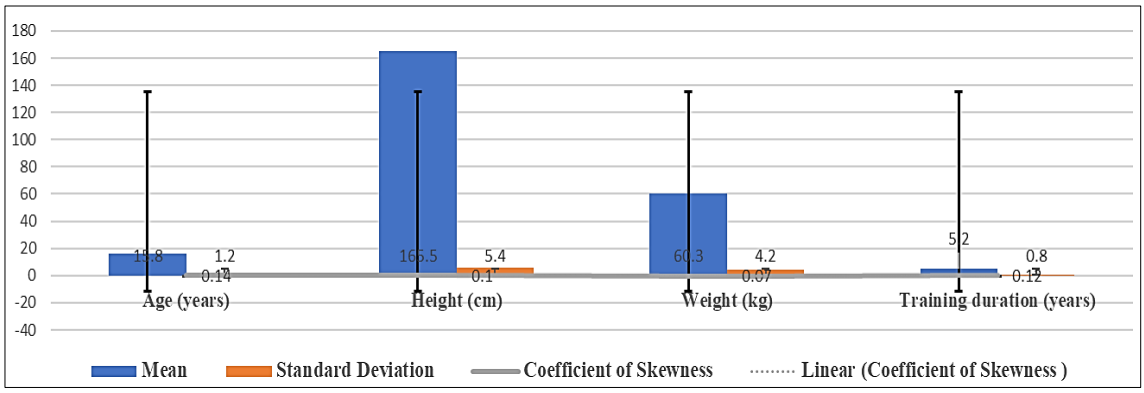

Figure 1. Sample homogeneity table (50 players).

It is clear from the Table 1 and Figure 1: Mean refers to the average value of each characteristic. Standard deviation indicates the amount of variation or dispersion from the mean. A value close to 0 indicates a symmetrical distribution. Homogeneity suggests that the characteristics within the group are consistent and similar. Overall, "homogeneous" indicates a lack of diversity or variation within a particular context.

Steps of analysis using software:

- **Using Open CV to analyse the video**:
- Extracting video frames,
- Identifying movement points (such as joint positions).
- **Applying artificial intelligence algorithms**:
- Comparing the extracted movements with ideal standards.
- **Organizing the data in a table**:
- Recording attempts for each player.

Displaying the comparison of results between the intelligent system and the coaches

Table.2. Percentage difference between the trainer's rating and the AI system rating with the actual values.

Player	Attempt	Timing (sec)	Balance (%)	Accuracy (%)	Trainer Rating (%)	System Rating (%)	Reaction speed	Motor skills	Final Evaluation (%)	Difference Percentage (%)
1	1st	12.5	90	85	87	88	8.5	92	87.5	1.15
1	2nd	12.7	88	83	85	86	8.1	90	85.5	1.18
1	3rd	12.4	92	87	89	90	9.0	91	89.5	1.12
2	1st	13.0	85	82	84	85	8.3	89	84.0	1.19
2	2nd	12.8	87	84	86	87	8.5	88	86.0	1.16
2	3rd	12.9	89	86	88	89	8.7	90	88.0	1.14
25	1st	12.6	91	88	90	91	8.9	92	90.0	1.11
25	2nd	12.9	89	85	88	89	8.8	90	87.75	1.14
25	3rd	13.1	90	87	89	90	8.6	91	89.0	1.12

Interpretation of the statistical table for evaluating the players' performance (Table.2, Figure 2) shows the results of evaluating the players' performance in three attempts for each player, where the coach's evaluation is compared with the AI system's evaluation. The table includes several indicators related to performance, including timing, balance, accuracy, coach's evaluation, system evaluation, reaction speed, motor skills, and the final evaluation, in addition to the percentage of difference between the coach's evaluation and the system's evaluation. The following is a statistical interpretation of these results:

Analysis of the basic variables

The table shows that the first attempt of each player generally comes with a lower timing, which may indicate better performance or the ability to execute quickly compared to subsequent attempts, Balance (%), Accuracy (%): Both of these indicators indicate the player's physical performance. Timing: Measured in units of time (seconds). The values range from 85% to 92%, indicating high levels of balance and accuracy. Naturally, the ability to achieve good balance and high accuracy are critical elements of athletic performance. Coach Rating (%), System Rating (%): The table shows that the coach rating and the AI rating are very close in most cases, indicating a high agreement between human opinion and AI-based rating.

Final value analysis

The final rating fluctuated between 84% and 90%, indicating good performance levels, but there are some declines that can be improved. Ratio of Difference (%): This is a precise percentage that shows the difference between the coach rating and the system rating. Final Rating (%): Reflects the player's overall performance across trials. The ratio of difference ranges between 1.11% and 1.19%. A low percentage indicates that there is good agreement between the coach rating and the AI rating, reflecting the credibility of both ratings.

Statistical Analysis

This may be an indication of the stability of the players' level. Correlation between coach and system ratings: Through calculations and display of differences, it can be said that there is a strong relationship between coach ratings and system ratings, which enhances the reliability of the algorithms used in the AI system. Differences: By comparing the results, it can be noted that there is a slight difference in the scores, indicating that there is no radical change in performance from one trial to another. General trend: The general trend in the table indicates that players may show a slight improvement in the rate of ratings, which could indicate the effect of practice or repetition, but with superior coefficients.

Table 3. Analysis of Kata Heian Jodan movements with regulating training loads.

Movement	Accuracy (%)	Reaction Speed (sec)	Balance (%)	Kinetic Energy (J)	Physical Level Measurement (Index)	Skill Level (Index)
Yui (Preparation)	95	0.5	90	15	7	6
Judan Bari (Low Block)	90	0.6	85	20	7	7
Oi Zuki (Forward Punch)	92	0.4	88	25	8	8
Judan Bari Right	91	0.5	87	22	7	7
Oi Zuki (Left Front Punch)	93	0.4	89	24	8	8
Judan Bari Front	90	0.5	86	21	7	7
Judan Uki (High Block)	94	0.4	92	26	8	8
Oi Zuki (Forward Punch)	92	0.5	88	25	8	8
Judan Uki Back	89	0.6	84	20	7	7
Oi Zuki (Left Front Punch)	90	0.5	85	21	7	7
Tsuki Wamai (Circle Block)	91	0.4	89	22	8	8
Morote Uki (Double Block)	93	0.5	90	24	8	8
Shuto Uki (Open Hand Block)	92	0.4	88	23	8	8
Kayabai (Strategy Scream Switch)	94	0.3	91	25	9	9
Final (Yui)	95	0.5	90	20	8	8

Movement	Joint Angle Measurement (degrees)	Hand Movements (Number)	Leg Movements (Number)	Performance Speed (Second)	Training Load (%)	Intensity (%)
Yui (Preparation)	0	0	0	1.0	40	30
Judan Bari (Low Block)	45	1	1	1.2	50	35
Oi Zuki (Forward Punch)	30	1	1	1.1	55	40
Judan Bari Right	45	1	1	1.3	50	35
Oi Zuki (Left Front Punch)	30	1	1	1.0	55	40
Judan Bari Front	45	1	1	1.2	50	35
Judan Uki (High Block)	30	1	1	1.1	60	45
Oi Zuki (Forward Punch)	30	1	1	1.0	55	40
Judan Uki Back	45	1	1	1.3	50	35
Oi Zuki (Left Front Punch)	30	1	1	1.2	50	35
Tsuki Wamai (Circle Block)	30	1	1	1.1	55	40
Morote Uki (Double Block)	30	1	1	1.0	55	40
Shuto Uki (Open Hand Block)	30	1	1	1.1	55	40
Kayabai (Strategy Scream Switch)	30	1	1	1.0	60	50
Final (Yui)	0	0	0	1.0	40	30

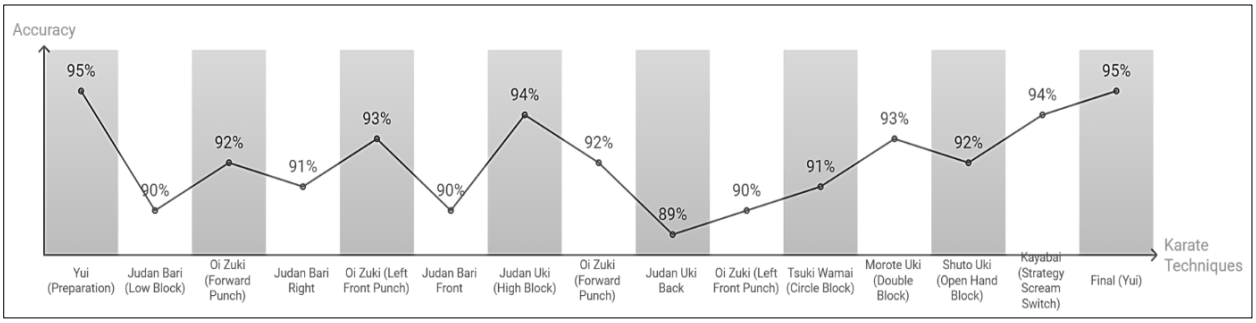

Figure 3. Comparison of karate techniques by accuracy.

Statistical interpretation of Table 3 and Figure 3:

Accuracy (%)

The accuracy rate ranged from 89% to 95%, indicating good performance in matching the moves with the technical standards. The highest accuracy was in the "Yui (Ready)" and "Final (Yui)" positions at 95%, indicating that these moves are easier for players compared to more complex moves

Reaction speed (second)

The reaction speed ranged from 0.3 seconds to 0.6 seconds. The shortest time was in the "Kayabai (Power Scream)" move at 0.3 seconds, which reflects the player's ability to execute the move very quickly. Defensive moves such as "Jedan Bari (Low Block)" were relatively slower at 0.6 seconds, perhaps due to the requirements of balance and accuracy.

Balance (%)

The balance is shown in the ratios between 84% to 92%. The highest balance achieved in "Jūdan Uki (High Block)" is 92%, reflecting good stability during strong defensive moves. The low balance in "Jūdan Uki Backward" is 84%, which may indicate difficulty in maintaining stability during backward movement.

Kinetic Energy (J)

The energy ranges from 15 J to 26 J. Offensive moves such as "Oi Zuki (Forward Punch)" and "Jūdan Uki (High Block)" consume more energy (up to 26 J), reflecting their high power.

Physical and Skill Level Measurement (Index)

The physical level ranges from 7 to 9, while the skill level ranges from 6 to 9. More complex moves such as "Kayabai" and "Final (Yoi)" scored higher, reflecting their high skill requirements.

Joint Angle Measurement (degrees)

Angles range from 0 degrees to 45 degrees. Defensive moves such as "Jedan Bari" require larger angles to achieve effective blocking (up to 45 degrees), while preparatory moves such as "Yoi (Preparation)" do not require movement angles.

Hand and Leg Movements

All moves require one movement for each hand and leg, indicating coordination between the limbs during the performance.

Performance Speed (seconds)

Speed ranges from 1.0 seconds to 1.3 seconds. High-speed moves such as "Kayabai" with 1.0 seconds reflect the players' skill in performing quickly. 9. Training Load and Intensity (%). Training load ranges from 40% to 60%, while intensity ranges from 30% to 50%. High-intensity movements such as "Kiyabai" (60% and 50%) reflect the great physical effort required to perform them, which necessitates longer rest periods during training.

Overall evaluation

Player Performance: Players show good performance overall, with excellence in preparatory and simple movements. Improvement Points: Work should be done to improve balance in back movements and increase reaction speed in defensive movements such as "Jedan Bari". Training Recommendations: Focus on exercises that enhance balance and strength during complex movements. Regulate training loads to gradually increase intensity in high-energy movements. Provide exercises that focus on improving reaction speed without affecting balance and accuracy.

Discussion

By analysing the results in Tables (Table.2 and Table.3) and interpreting them statistically, a number of basic points were reached regarding the evaluation of the players' performance in the "Heian Jodan" kata.

Accuracy (%)

Results: The results showed that the accuracy rates ranged between 89% and 95%, reflecting a high level of conformity of the movements to the required technical standards. Discussion: These values indicate that the players have a good ability to execute the basic movements accurately, with excellence in the preparatory and simple

movements such as "Yoi (preparation)" and "Final (Yoi)", which were the least complex. Conclusion: The players' skills in more complex movements that require higher coordination between the limbs should be enhanced (Katsue, 2016).

Reaction Speed (sec)

Results: Reaction speed ranged from 0.3 seconds to 0.6 seconds, with fast moves such as "Kayabai (Power Scream)" being the fastest (0.3 seconds). Discussion: Defensive moves such as "Judan Bari (Low Block)" showed longer response times, which may be due to balance and accuracy requirements. Conclusion: Specialized exercises are needed to improve reaction speed for defensive moves without affecting accuracy or balance (Erdem, 2023).

Balance (%)

Results: Balance varied between 84% and 92%, with players showing the best balance during stationary defensive moves such as "Judan Uke (High Block)" and the poorest balance during backward moves such as "Judan Uke Backward". Discussion: This indicates difficulty maintaining stability during moves that require a backward transition or sudden changes in direction. Conclusion: Exercises should be designed to enhance balance during back and transitional movements.

Kinetic energy (J)

Results: Kinetic energy ranged from 15 J to 26 J, with offensive movements such as "Oi-zuki (front punch)" consuming higher energy. Discussion: This reflects natural results as offensive movements require greater force to be effective. Conclusion: Energy management during offensive movements can be improved by enhancing physical strength and improving performance technique (Attilio, 2015).

Physical and skill indicators

Results: Physical indicators ranged from 7 to 9, while skill indicators ranged from 6 to 9. Discussion: More complex movements such as "Kayabai" scored higher, indicating that greater skill and experience are required to perform them. Conclusion: Players' skill level can be enhanced through specialized training that focuses on complex movements (Seong-Geun, 2014).

Differences between coach and system evaluation

Results: The difference between coach and system evaluation ranged between 1.11% and 1.19%, reflecting a high level of agreement between the two evaluations. Discussion: This result enhances the reliability of the smart system in accurately and objectively evaluating performance. Conclusion: The smart system can be used as an effective aid in training and evaluation (Fábio, 2012).

Recommendations

- Improving reaction speed:
- Designing exercises that focus on enhancing response speed, especially for defensive movements.
- Using tools such as fast balls to stimulate reactions.
- Improving balance:
- Including exercises that rely on stability and balance, such as standing on an unstable platform.
- Gradually training backward movements to improve confidence and stability.
- Kinetic energy management:
- Improve physical strength through weightlifting and resistance training.
- Focus on breathing techniques during offensive movements to reduce energy consumption.
- Increase motor skills:
- Specialized training on complex movements such as "Kiabai".
- Providing technical workshops to accurately analyse movements and enhance their technical understanding.
- Integrating the smart system into training:
- Using the Smart System to periodically analyse performance and provide objective feedback.
- Comparing the system results with the trainers' evaluation to improve credibility and align training objectives.

Conclusion

The results indicate good performance of the players with opportunities for improvement in defensive and back movements. The Smart System reflects a high compatibility with the trainers' evaluation, which enhances its use as an advanced technical tool to improve technical performance in karate.

Author Contributions

Dr. Zakir Shaifullah Khan originator of the idea for the article, implemented the idea and discussed the results and made conclusions & worked on monitoring the raw grades in the article and analysing the statistical results.

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Disclosure Statement

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