Measuring the Sequence of Steps in Martial Art Techniques using Frame-Based Rules Ranges of the Motion Templates

Wan Mohd Rizhan Wan Idris, Ahmad Rafi, Azman Bidin, Azrul Amri Jamal

Abstract: Martial arts (MAs) can be considered as a preserved heritage. Motion capture (MoCap) techniques have been used in various applications of MAs preservation, such as: producing 3D models; performance testing results; and system platforms development. MoCap requires motion recognition (MoRec) technique to translate the motions executed into meaningful forms. MoRec measures accuracy of rules towards certain movements which is in perspective of machine learning algorithm without emphasizing aspects to be assessed in MA perspective. Sequence of steps is one of the important aspects in measuring the effectiveness of MA techniques. The sequence of steps may reflect certain MA technique due to the accuracy of consecutive steps being executed. Incorrect steps in MA technique may cause harm and even fatal injuries. In this paper, Frame-Based Rules-Ranges (FBRR) approach is proposed to measure the sequence of steps in MA technique. Implementation and evaluation of FBRR for templates of MA techniques are discussed by experimenting FOUR SSCM techniques. The results show that the templates with FBRR have reduced redundant and irrelative rules in the sequence that leads to a better measurement of the sequence of steps. These templates with FBRR are ready to be tested to the other MA practitioners including trainers and trainees in order to validate and verify their techniques.

Keywords: Motion capture; Motion recognition; Motion template; Frame-Based Rules Ranges; Seni Silat Cekak Malaysia.

I. INTRODUCTION

Martial Art (MA) is a general term that describes the art of combat and self-defense [1] which normally combines offensive and defensive techniques [2].There are various styles of MAs practiced in the world with their distinct history, philosophy and set of techniques [1].People nowadays regardless of age and gender have been practicing MAs for different purposes. Most practitioners enroll in MAs in order to construct high self-confidence and self shields, to evade the practitioners from negative aspects. Some enroll in order to preserve the original cultures and religious aspect of MAs [3], and some to maintain their health and fitness [4].

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In addition, MAs can be considered as a preserved heritage primarily due to fact that MAs represent certain level of identities and cultures.

This cultural heritage may provide a foundation for the uniqueness of the nation and its people [5]. Nevertheless, many traditional and cultural values of MA have been forgotten with the appearance of advanced technologies[5]. This preserved heritage will be lost in the near future if immediate acts to preserve MAs were not taken.

Current teaching and learning as well as evaluation of MAs are still rely on conventional method [6]. During trainings, a teacher or master uses observation and verbal respectively to examine the movements and to reprimand about the movements executed. Meanwhile the test is also judged and evaluated by a jury who is among MAs master, teacher or trainer [7]. Among the assessed aspects in certain MA techniques evaluation are existence of the technique patterns, speed of accomplishing the techniques, and level of confidence. The existence of the technique patterns can be examined through sequence of steps executed by the practitioners. It is because the execution of accurate sequence of steps will reflect to particular MA techniques. Therefore, inspection of the sequence of steps is crucial to evaluate the MA techniques.

Human motion capture, the research area to capture and analyze human motion is rapidly due to the large number of potential application and its inherent complexity. Apart from its usage in biomechanics research, the source of motion data is important for computer animation as well as education, training, and sports [8]. Motion capture (MoCap) is the process of recording a live movement event to obtain a single 3D representation of the performance by translating it into usable mathematical terms using tracking a number of key points in space over time [9]. In MAs, MoCap techniques have been used in various applications to produce 3D models, performance testing results and system platforms development whether using marker-based or marker-less MoCap techniques.

MoCap normally requires motion recognition technique to translate the motions executed into meaningful forms [10]. Common approaches to motion recognition are using statistical methods, neural networks, fuzzy sets, optimal path finding, semantic methods, finite state machines, and natural user interface [11]. These approaches however have limitations in terms of requiring very large training and validation sets which might be unintuitive for a skilled system user because the techniques have to be manually tuned and difficult to add new gesture to be recognized without additional intensive training of the classifier [12]. Furthermore, none of these approaches have been studied and designed for MAs which certainly compose of fast and complex movements. Gesture Description Language (GDL) and Reversed-GDL (R-GDL) approaches have been tested and evaluated for MAs techniques. Both approaches are natural user interfaces-based which are suitable for non-technical users [14].GDL is a classifier which is capable for real-time human body gestures recognition [15][16][17]. R-GDL is an automatic scripts generator for gesture descriptions using unsupervised learning method [14].In work of Wan Idris et al., [18], R-GDL has been applied to develop motion templates of MA techniques while GDL has been used as evaluation to test the created motion templates' validities.

In GDL approach, the outputs of GDL are in forms of rules sequence. The sequence of rules shows the existence of steps in the movements. However, the sequence may also consist of redundant, unsorted, and irrelative rules. The redundancies rules can be triggered by scenarios as follows:

- Whenever the motions of steps are similar to the particular rules. While the motions are still relevant to the steps, the rules are continuously produced in the sequence as GDL outputs. This scenario results a sequence of rules (frequent rules) for such triggered motions.
- During the transition of motions from one step to another. The system still detect the previous rules during the transitions of the motions until the motion is completely different or transitioned from the previous step. This is caused by the speed of motions in which MoCap sensor device and motion classifier cannot track and translate exactly in-between steps. This scenario may cause the rules in the sequence detected in scattered.
- The system detects rules for irrelative motions done by the performers which are quite similar to the rules. Even the motions are inconsistent to the steps in the techniques of MA, the system still detect and record the rules. This scenario may lead to over detect the rules in the sequence which are inconsistent to the steps in the techniques of MA.

The second and third scenarios cause the detected rules in redundant, scattered and irrelative respectively due to the rules inconsistency and irrelevancy to the steps in the techniques executed. The redundancies of rules for the same postures are not supposed to happen. By improving the GDLs, each rule shall recognize one posture of movement at a time.

The redundant and scattered rules are difficult to determine the accuracy of movements. Therefore, the sequence of rules was not suitable to be a mean for score in order to evaluate the effectiveness of the techniques execution. In MAs, such evaluation based on only the recognition rate or accuracy is insufficient to evaluate MAs techniques executed especially in term of sequence of steps. This is because perspective of machine learning becomes main focus to measure the accuracy of rules towards certain movements performed without emphasizing the aspects in MA perspective. The sequence of steps in MA techniques is one of the important aspects to measure the effectiveness of MA technique execution. The sequence of steps may reflect certain MA technique due to the accurate continuity of steps executed. Instead, the incorrect steps may cause dangerous and fatal injuries [19].In this paper, a new approach to measure the sequence of steps in MA technique called Frame-Based Rules-Ranges (FBRR) is presented and discussed.

II. MATERIALS AND METHODS

A framework of extrinsic feedback evaluation using motion capture system (EFE-MoCap) has been referred for developing motion templates for MA techniques; developing Rules-Ranges for the created motion templates which are in forms of Gesture Description Language Scripts (GDLS);as well as developing score rubric assessment for MA techniques. In general, the framework consists of three designs to do such purposes including Templates Design; Frame-Based Rules Ranges (FBRR) design; and Score Rubric Assessment (SRA) design as illustrated in Figure 1. The templates design has been presented in International Conference on Informatics, Computing and Applied Mathematics [13] and published theoretically [20] and technically [18]. In this paper, FBRR design is presented to develop Rules-Ranges for the created motion templates and to evaluate using validation tests in order to measure the sequence of steps and publish EF for the MA techniques.

FBRR design in EFE-MoCap framework

As illustrated in Figure 2, FBRR design involves Rules-Ranges model for developing Rules-Ranges for the created motion templates (in development environment) while MoCap model, MoRec-Classifier model and Steps Sequence model for evaluating the motion templates with FBRR approach using validation tests (in evaluation environment).

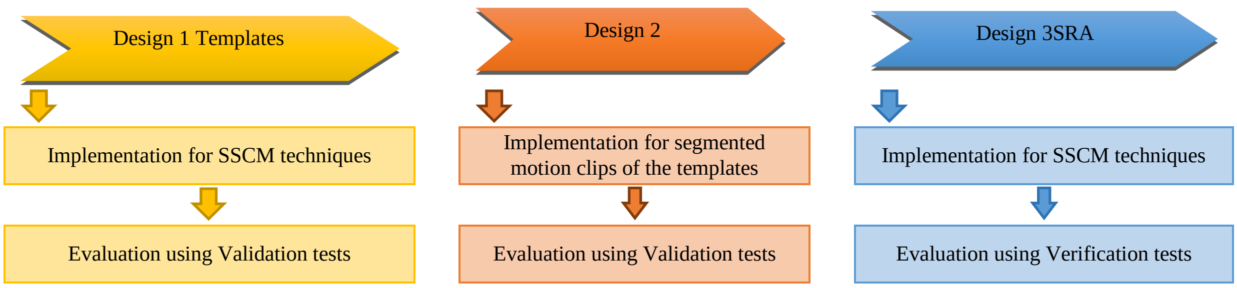

Fig. 1 EFE-MoCap System Framework

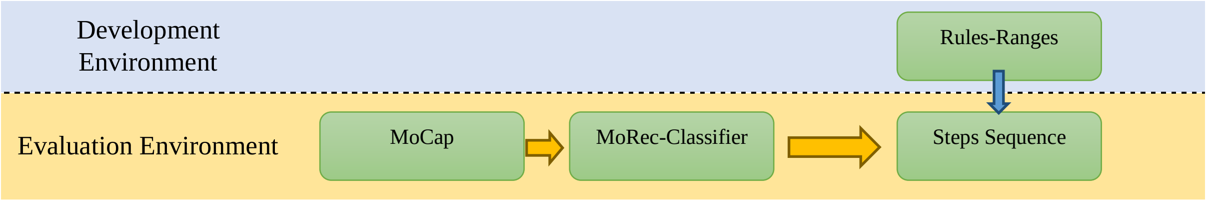

Fig. 2 Models involved in FBRR design

In the development environment, the segmented motion clips for validating the created motion templates in the Templates design [18] have been reused as inputs in this environment. Rules-Ranges model functions to produce the Rules-Ranges for the created motion templates using the segmented motion clips. This model consists of loading motion clips, plotting key frames, calculating minimum (Min), maximum (Max),average (Avg),and calculating rules-ranges operations. The outputs of this model are$Range1_R$, $Range2_R$ and $Range3_R$ for all steps in the movements of the motion clips.

In the evaluation environment, performers who are among MA Trainers have participated in these experiments and their live motions have become inputs in this environment in order to test and validate the published Rules-Ranges of the motion templates. Besides, the created motion templates which are in forms of GDLS have also become inputs. MoCap model purposes to accurately capture or track human bodies for generating skeleton, finding focused target, and recording human motions in the repository. The outputs of this model are the performers' motion data in form of skeleton data. This skeleton data will be transferred to MoRec-Classifier model for instant classification purpose.

Motion recognition classifier (MoRec-Classifier) model operates to recognize the performers' motions executed based on the generated GDLS loaded previously. In this model, the live performers' motions have been captured in form of skeleton data as inputs to be classified. To implement such purpose, GDL approach has been adopted in this model. This model consists of loading skeleton data and GDLS operation as well as motion classifier operation using GDL approach which contained functions of forward-chaining reasoning and memorizing conclusions. The outputs of this model are GDL Output containing a sequence of detected rules along with their frame numbers for the motion executed.

Steps Sequence (SS) model mainly functions to measure the sequence of steps. This model uses the Rules-Ranges of the motion templates created in the development environment to be main references for determining and comparing the new published Rules-Ranges for the performers' motion skeleton data in this environment. This model analyses and processes the outputs produced from MoRec-Classifier model which were in form of GDL Output. Determining and comparing between both Rules-Ranges in this model allows the redundant and unsorted rules in the sequence to be minimized and at the same time published SS for the motions executed by the performers. In order to publish SS, FOUR operations in this model are determining rules-ranges, collecting rules-ranges, sorting and listing frames and getting frequency of rules.

III. IMPLEMENTATION

Development environment

The development environment purposes to produce the Rules-Ranges for the created motion templates. The experiments in this environment involve the reuses of the Seni Silat Cekak Malaysia (SSCM) Teacher's motion data executed for creating the motion templates in the previous design [18]. The Teacher's motion data consists of FOUR selected techniques in SSCM including *Buah Jatuh Pertama*, *Buah Jatuh Ali Patah Sudah (II)*, *Buah Jatuh Kilas Hadapan*, and *Buah Jatuh Hempok (II)* from *Kaedah*(Clusters) A, B, C, and D respectively. The Teacher's motion data has been segmented because each motion data contains TEN times of the continuous same motions. Each technique motion data has been segmented and stored into TEN different motion clips with skeleton file format (**.SKL*). Due to space limitation, only *Buah Jatuh Pertama* technique is discussed in this paper. Table 1 shows the loaded motion clips for *Buah Jatuh Pertama* technique with times, frame No., total of frames taken, tracked joints, inferred joints and total of tracking. In this environment, GDL Studio 2 platform has been utilized as a main platform with several modified and enhanced interfaces to publish the Rules-Ranges of the *Buah Jatuh Pertama*motion templates.

Table. 1 TEN motion clipsfor Cluster A: Buah Jatuh Pertama

Motion clips	Time (Sec)	Frames	Total Frames	Tracked Joints	Inferred Joints	Total Track
T_1C_0	4	88:218	130	3119 (93.8%)	206 (6.2%)	3325
T_1C_1	4	306:426	120	2841 (92.4%)	234 (7.6%)	3075
T_1C_2	4	536:666	130	3015 (90.7%)	310 (9.3%)	3325

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T_1C_3	4	772:902	130	3083 (92.7%)	242 (7.3%)	3325
T_1C_4	4	973:1096	123	2891 (91.8%)	259 (8.2%)	3150
T_1C_5	4	1195:1315	120	2881 (93.7%)	194 (6.3%)	3075
T_1C_6	4	1389:1509	120	2821 (91.7%)	254 (8.3%)	3075
T_1C_7	4	1587:1717	130	3016 (90.7%)	309 (9.3%)	3325
T_1C_8	4	1777:1890	113	2687 (92.7%)	213 (7.3%)	2900
T_1C_9	4	1964:2087	123	2876 (91.3%)	274 (8.7%)	3150

Publishing Rules-Ranges process

In each motion clip loaded, the key frames for certain steps in the MA technique have been plotted in order to collect all important postures in the MA. In a certain technique, there is a sequence of steps. The steps in this platform are represented by rules. A step or a rule represents a key frame in the sequence which is a frame number. The next step or next rule will represent another ahead key frame (onward frame number).

As shown in Figure 3, plotting the key frames for the main postures allows the ranges between step-by-step (or rule-by-rule) to be determined.

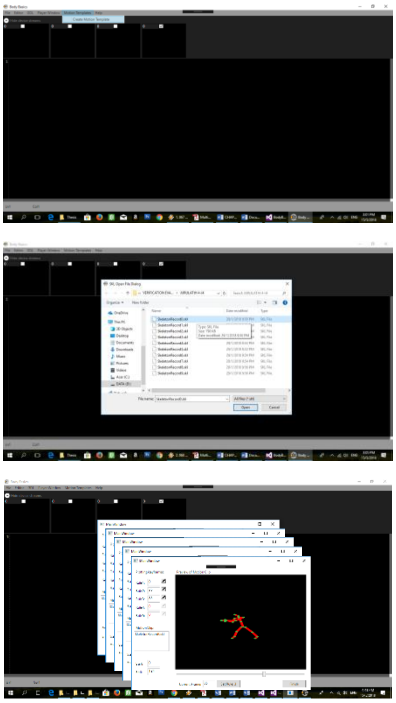

Fig. 3 Interfaces for loading motion clips and plotting key frames to calculate Min, Max and AVG as well as rules-ranges operations

After plotting the key frames for the main postures in all loaded motion clips, values of Max, Avg and Min of the collected key frames have been determined for each step or rule in this operation.

Given T = technique (1, 2, 3 and 4), m = techniques {1, 2, 3 and 4} and n = clips {1, 2, 3, 4, 5, 6, 7, 8, 9 and 10}. Min refers to the lowest frame number in the sequence for each step or rule, Max denotes to the highest frame number in the sequence for each step or rule while Avg refers to the mean between the lowest and highest frame number in the sequence for each step or rule. Min, Max and Avg of key frames plotted for each step or rule can be produced using the equations as follows:

$$MinFrame_R = Minimum(T_mC_n) \quad (1)$$
$$MaxFrame_R = Maximum(T_mC_n) \quad (2)$$
$$AvgFrame_R = Average(T_mC_n) \quad (3)$$

Min, Max and Avghave been utilized in calculating the Rules-Ranges for the motion templates because allowing the variety of motions speed executed by the Teacher to be considered and calculated. Then Rules-Ranges consisting of $Range1_R$, $Range2_R$ and $Range3_R$ for each step or rule can be calculated using the equations as follows:

$$Range1_R = AvgFrame_R - MinFrame_R \quad (4)$$
$$Range2_R = MaxFrame_R - AvgFrame_R \quad (5)$$
$$Range3_R = MaxFrame_R - MinFrame_R \quad (6)$$

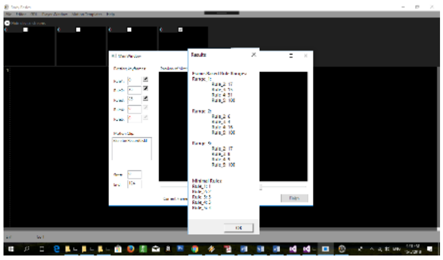

Fig. 4 Outputs of Rules-Ranges of the motion templates

The outputs in this operation which are$Range1_R$, $Range2_R$ and $Range3_R$for all steps in the motion templates as illustrated in Figure 4will be used for evaluation environment.

Evaluation environment

For the evaluation environment, the created motion templates of FOUR selected techniques with FBRR approach (Rules-Ranges) have been tested and validated using other experts' motions. The experiments have been participated by a SSCM Trainers who is expert in this field. He is experienced Trainer (28 years) who has practiced, taught and trained Trainees in a co-curriculum subject in a local public university, Universiti Sultan ZainalAbidin (UniSZA).

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The Trainer is also experienced as a jury to evaluate the Trainees during several level tests including Basic Level Test and Down Level Test. Table 2 shows the biography the Trainer who has participated in these experiments.

Motion capture process

Motion capture process in this design functions to accurately capture or track human bodies for skeleton generation, find focused target and record human motions in the repository. This process consists of skeleton tracking, focused target and skeleton recording operations.

Due to practicality and portability factors, a standard Microsoft Kinect for Windows Version 2 and Kinect SDK 2.0 have been utilized to capture, track and record the executions of the selected technique in the experiments. In term of practicality, the performer especially the SSCM Trainer involved in this experiment does not need to wear any marker which can limit their movements and performance [21]. The tool used is based on marker-less technique. Furthermore, the Trainer does not need to attend in static studio for motion capture since the tool is easier to carry. The experiments have been conducted indoor. During the experiments, the Teacher has stood at the distance 2.65m from the device since the distance is suitable to track the whole body even if some techniques executed require the performer to step forward or backward [22].

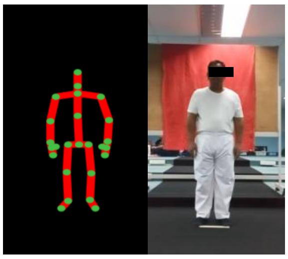

Fig. 5 Skeleton tracking for the posture of the SSCM Trainer

Figure 5 shows skeleton tracking for the posture of the SSCM Trainer during the experiments. Microsoft Kinect for Windows Version 2 has successfully tracked the whole body of the Trainer to generate the skeleton consisting of 25 joints including *SpineBase*, *SpineMid*, *Neck*, *Head*, *ShoulderLeft*, *ElbowLeft*, *WristLeft*, *HandLeft*, *ShoulderRight*, *ElbowRight*, *WristRight*, *HandRight*, *HipLeft*, *KneeLeft*, *AnkleLeft*, *FootLeft*, *HipRight*, *KneeRight*, *AnkleRight*, *FootRight*, *SpineShoulder*, *HandTipLeft*, *ThumbLeft*, *HandTipRight* and *ThumbRight*[18][20].

The Trainer's skeleton and motions aretracked in skeleton form using GDL Studio 2 platform. This platform has been enhanced in order to record the tracking status such as tracked and inferred joints, frames and times for future agendas. Player Window Interface in this platform is also modified so that this interface can be accessed when needed especially for other purposes. In the skeleton file, data of time period, clip edges, hand left confidence, hand left state, hand right confidence, hand right state, restriction and tracking status of body, lean, lean tracking state, joints' orientation and position as well as tracking status have been stored along with the frames list. The Trainer's motion data will be transferred live to the next process in order to translate the motions.

Motion recognition process

MoRec-Classifier process operates to recognize the transferred Trainer's motion data based on the generated loaded previously. To implement such purpose, GDL approach has been adapted in this model [23][24][15].GDL approach has been implemented real-time on the skeleton data captured and tracked using MoCap process. To perform the function of forward-chaining reasoning, GDL uses inference engine towards the rules in GDLS [25].This function determines whether the rules are satisfied with the motions executed or not.

If a rule is satisfied, its conclusion is memorized in memory stack which is implemented in the function of memorizing conclusions. The conclusion a sequence of detected rules called GDL Output. Together with the detected rules, the rules frame numbers are also recorded so that the next agenda can be processed.

Table. 2 Biography of Trainer

	Age	Gender	Training Experience	Teaching Experience	Highest Level	Height (cm)	Weight (kg)
Trainer	53	Male	32 years	28 years	Finish	166	68

Steps sequence process

The steps sequence (SS) process functions to measure the sequence of steps. This process uses the Rules-Ranges of the motion templates created previously in the development environment to be references for determining the Rules-Ranges for the performers' motion skeleton data in this environment.

Using the Rules-Ranges of the motion templates as the references, the Rules-Ranges for the performers' motions based on the GDL Output from MoRec-Classifier process can be determined. In this operation, only the frames in the Rules-Ranges of the motion templates are taken while the rest is ignored due to it is out of ranges. Based on the GDL Output, the performer's ranges which are P_Range1_R,P_Range2_R and $P_Range3_R$can list all frames containing R^{th} rules in the respective ranges in this operation as shown in equations as follows:

$$P\_Range1_R = \{Range1_R\}$$
$$P\_Range2_R = \{Range2_R\}$$
$$P\_Range3_R = \{Range3_R\}$$

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Therefore, each rule has three ranges and each range contains a list of frames occupied from GDL Output.

Then the frames in all Performer's ranges are collected based on R^{th}rules using *Union()*function. This function is also purposed to remove the redundant R^{th}rules containing the same value of frames in all respective ranges. The output from this operation is a list of frames without rules redundancy for each rule as allocated in $UnionFrame_R$.

$$UnionFrame_R = P\_Range1_R \cup P\_Range2_R \cup P\_Range3_R$$

After collecting the frames for all R^{th}rules, sorting frames operation has been implemented for $UnionFrame_R$ to sort the values in ascending using *Sort()* function. The sorted values in $UnionFrame_R$are presented in $SortedFrame_R$. After sorting operation, *List()* function has listed all sorted frames for each respective rule in $FList_R$.

$$SortedFrame_R = Sort(UnionFrame_R)$$
$$FList_R = List(SortedFrame_R)$$

Then, the frequency of R^{th}rule in $FList_R$ has been implemented through *Count()* function. There are four conditions to obtain the frequency of rules as follows:

Condition#1:

IF $FList_R.First()$ is greater than $FList_{prevR}.Last()$ THEN
SET $FilteredFrame_R$ by counting the frequencies of rules from $FList_R.First()$ till $FList_R.Last()$.

If the first frame of current rule is greater than the last frame of previous rule, the frequency of R^{th}rule which is$FilteredFrame_R$ can be obtained by counting from the first frame of current rule,$FList_R.First()$ as starting point until the last frame of current rule,$FList_R.Last()$. The frequency of the R^{th} rule is in between of $FList_R.First() \geq FilteredFrame_R < FList_R.Last()$. If this condition is false, the next condition is considered.

Condition#2:

ELSE_IF $FList_R.First()$ is equal or smaller than $FList_{prevR}.Last()$ AND $FList_R.Last()$ is greater than $FList_{prevR}.Last()$ THEN

SET $FilteredFrame_R$ by counting the frequencies of rules from $FList_{prevR}.Last()$ till $FList_R.Last()$.

If the first frame of current rule is equal or lower than the last frame of previous rule and the last frame of current rule is greater than the last frame of previous rule, the frequency of R^{th}rule which is$FilteredFrame_R$can be obtained in between of $FList_{prevR}.Last() \geq FilteredFrame_R < FList_R.Last()$. $FilteredFrame_R$is counted from the last frame of previous rule, $FList_{prevR}.Last()$ as starting point till the last frame of current rule, $FList_R.Last()$. If this condition is false, the next condition is considered.

Condition#3:

ELSE_IF $FList_R.First()$ is equal or smaller than $FList_{prevR}.Last()$ AND $FList_R.Last()$ is equal or smaller than$FList_{prevR}.First()$ AND$FList_{prevR}.First()$ is not equal to *0* THEN
SET $FilteredFrame_R$ by counting the frequencies of rules from $FList_R.First()$ till $FList_R.Last()$.

If the first frame of current rule is equal or lower than the last frame of previous rule and the last frame of current rule is also equal or lower than the first frame of previous frame, the frequency of R^{th}rule which is$FilteredFrame_R$ can be obtained by counting from the first frame of current rule, $FList_R.First()$ as starting point until the last frame of current rule,$FList_R.Last()$. The frequency of the R^{th} rule is in between of $FList_R.First() \geq FilteredFrame_R \leq FList_R.Last()$. If this condition is also false, the final condition is considered with R^{th}rule is claimed as non-exist as shown below:

Condition#4:

ELSE
SET$FilteredFrame_R$ as *0*
END_IF

IV. RESULTS AND DISCUSSIONS

Based on the implementation of the development and evaluation environments for FBRR approach, analysis and results can be discussed as follows:

Analysis and results for development

Analysis in this paper only discusses about *Buah Jatuh Pertama* technique. Other techniques will be shown as final results. Using the segmented motion clips loaded for *Buah Jatuh Pertama* technique, the analysis and results for the motion templates with FBRR approach can be seen based on plotted key frames, Rules-Ranges for the motion templatesof *Buah Jatuh Pertama* technique.

The produced results for this development environment will become as main references in the evaluation environment.

Plotted key frames

Table 3 illustrates values of key frames plotted for each step in all segmented motion clips. Blank fills in the table indicated the uncertainty of key frames for certain step. The values for this situation can be blank fills. Even there are the blank fills for certain rules, their values can be supported by the other motion clips' values because of having ten segmented motion clips to be plotted. Based on the equations 1, 2 and 3, values of maximum, minimum and average for each rule have been produced.

Rules-Ranges for motion templates

Based on the values of Min, Max and Avg, the Rules-Ranges of *Buah Jatuh Pertama* techniqueusing FBRR approach can be calculated and produced using equations 4, 5, and 6as shown in Table 4.To calculate the Rules-Ranges, the first and last rules respectively representing the first and the last steps can be ignored because both steps may take long time before starting the real action in the technique and ending the last step. Therefore, in-between rules are crucial for such calculation with the second rule becomes the main trigger indicating the actions have been performing. Let *x* becomes the triggered frame number for the second rule.

All ranges for Rule_1 can be ignored due to the frames can be too long for other activities such as preparation, warming up and getting set before beginning the action of the technique. As well as the last rule which is Rule_5, the frames for all ranges can be too long due to the performers may stay the last step too long. Therefore, the ranges can be considered starting with Rule_2 and ending with Rule_4. The formulas for the Rules-Ranges for the motion templates of *Buah Jatuh Pertama* technique can be written as follows:

Range1: x ≤Rule_2> x+6, x+6 ≤Rule_3> x+6+4, x+6+4 ≤Rule_4> x+6+4+16, x+6+4+16 ≤Rule_5> x+6+4+16+8;
Range2: x ≤Rule_2> x+11, x+11 ≤ Rule_3> x+11+11, x+11+11 ≤ Rule_4> x+11+11+15, x+11+11+15 ≤ Rule_5> x+11+11+15+9;
Range3: x ≤Rule_2> x+17, x+17 ≤Rule_3> x+17+15, x+17+15 ≤Rule_4> x+17+15+31, x+17+15+31 ≤Rule_5> x+17+15+31+17

The results of Frame-Based Rules Ranges for the motion templates of other techniques are shown in Table 5.

Table. 5 Rules-Ranges for the motion templates of other techniques and their formulas

Buah Jatuh Ali Patah Sudah (II) technique

	Range_1	Range_2	Range_3
Rule_1	-	-	-
Rule_2	6	7	13
Rule_3	6	8	14
Rule_4	9	12	21

Range_1: x ≤Rule_2> x+6, x+6 ≤Rule_3> x+6+6, x+6+6 ≤Rule_4> x+6+6+9;
Range_2: x ≤Rule_2> x+7, x+7 ≤ Rule_3> x+7+8, x+7+8 ≤ Rule_4> x+7+8+12;
Range_3: x ≤Rule_2> x+13, x+13 ≤Rule_3> x+13+14, x+13+14 ≤Rule_4> x+13+14+21;

Buah Jatuh Kilas Hadapan technique

	Range_1	Range_2	Range_3
Rule_1	-	-	-
Rule_2	7	15	22
Rule_3	16	26	42
Rule_4	13	18	31

Range1: x ≤Rule_2> x+7, x+7 ≤Rule_3> x+7+16, x+7+16 ≤Rule_4> x+7+16+13;
Range2: x ≤Rule_2> x+15, x+15 ≤ Rule_3> x+15+26, x+15+26 ≤ Rule_4> x+15+26+18;
Range3: x ≤Rule_2> x+22, x+22 ≤Rule_3> x+22+42, x+22+42 ≤Rule_4> x+22+42+31;

Buah Jatuh Hempok (II) technique

	Range_1	Range_2	Range_3
Rule_1	-	-	-
Rule_2	5	8	13
Rule_3	6	8	14
Rule_4	13	15	28
Rule_5	17	17	34

Range1: x ≤Rule_2> x+5, x+5 ≤Rule_3> x+5+6, x+5+6 ≤Rule_4> x+5+6+13, x+5+6+13 ≤Rule_5> x+5+6+13+17;
Range2: x ≤Rule_2> x+8, x+8 ≤ Rule_3> x+8+8, x+8+8 ≤ Rule_4> x+8+8+15, x+8+8+15 ≤Rule_5> x+8+8+15+17;
Range3: x ≤Rule_2> x+13, x+13 ≤Rule_3> x+13+14, x+13+14 ≤Rule_4> x+13+14+28, x+13+14+28 ≤Rule_5> x+13+14+28+34;

Analysis and results for evaluation

Based on the Rules-Ranges for the motion templates of *Buah Jatuh Pertama*produced in the development environment, evaluation using the other experts' motions has been implemented. This evaluation has tested the validities of the created motion templates with FBRR approach.

Motion data

Motion data tracked for Trainer during MoCap process with times, frame number, total of frames taken, tracked joints, inferred joints and total of tracking is shown in Table 6.

Table. 3 Plotted key frames for relative steps in TEN motion clips of Teacher's motions for *Buah Jatuh Pertama*

	T_1C_0	T_1C_1	T_1C_2	T_1C_3	T_1C_4	T_1C_5	T_1C_6	T_1C_7	T_1C_8	T_1C_9	MIN	MAX	AVG
Step_1	1	1	1	1	1	1	1	1	1	1	1	1	1
Step_2	-	15	-	15	30	25	13	13	-	-	13	30	19
Step_3	62	48	-	-	-	50	47	49	-	51	47	62	51
Step_4	89	-	-	-	-	-	58	-	-	-	58	89	74
Step_5	95	93	91	95	95	78	79	79	78	80	78	95	86

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Table. 4 Calculation of Rules Ranges for the motion templates of Buah Jatuh Pertama

	Rule_2	***Rule_3***	***Rule_4***	***Rule_5***
Range1	$Range1_{Rule2}$= $AvgFrame_{Rule2}$ – $MinFrame_{Rule2}$ = 19 - 13 = 6	$Range1_{Rule3}$= $AvgFrame_{Rule3}$ – $MinFrame_{Rule3}$ = 51 - 47 = 4	$Range1_{Rule4}$= $AvgFrame_{Rule4}$ – $MinFrame_{Rule4}$ = 74 - 58 = 16	$Range1_{Rule5}$= $AvgFrame_{Rule5}$ – $MinFrame_{Rule5}$ = 86 – 78 = 8
Range2	$Range2_{Rule2}$= $MaxFrame_{Rule2}$ – $AvgFrame_{Rule2}$ = 30 – 19 = 11	$Range2_{Rule3}$= $MaxFrame_{Rule3}$ – $AvgFrame_{Rule3}$ = 62 – 51 = 11	$Range2_{Rule4}$= $MaxFrame_{Rule4}$ – $AvgFrame_{Rule4}$ = 89 – 74 = 15	$Range2_{Rule5}$= $MaxFrame_{Rule5}$ – $AvgFrame_{Rule5}$ = 95 – 86 = 9
Range3	$Range3_{Rule2}$= $MaxFrame_{Rule2}$ – $MinFrame_{Rule2}$ = 30 - 13 = 17	$Range3_{Rule3}$= $MaxFrame_{Rule3}$ – $MinFrame_{Rule3}$ = 62 - 47 = 15	$Range3_{Rule4}$= $MaxFrame_{Rule4}$ – $MinFrame_{Rule4}$ = 89 - 58 = 31	$Range3_{Rule5}$= $MaxFrame_{Rule5}$ – $MinFrame_{Rule5}$ = 95 – 78 = 17

Table 6. MoCap for Cluster A: *Buah Jatuh Pertama* technique executed by Trainer

	Sec.	**Frames**	**Total Frames**	**Tracked Joints**	**Inferred Joints**	**Total Track**
Trainer	6	291:475	184	4545 (97.2%)	130 (2.8%)	4675

GDL Output

GDL Output has been recorded and produced from MoRec-Classifier process using GDL approach. Table 7 shows the frequencies of relative rules in GDL Output (*FreqRules*) for *Buah Jatuh Pertama* technique executed by the Trainer.

Table. 7 Frequencies of rules in GDL Output for Buah Jatuh Pertama technique

	Rule_1	Rule_2	Rule_3	Rule_4	Rule_5
FreqRules	74	16	56	60	45

The results of the detected rules with the frame numbers for *Buah Jatuh Pertama* executed by the Trainer can be seen in Figure 6. The Trainer has executed all steps properly by firstly standing up straight (Rule_1). Step 2, the performer has performed *Kaedah A* with left hand to fend off opponent's attack. At the same time, the performer's right leg and right hand respectively have been located at behind opponent's knee (Step 3) and punched opponent's rib (Step 4). Steps 2, 3 and 4 have been performed simultaneously due to these steps are *Segerak* movements (Rule_2). In Step 5 (Rule_3), the performer has stepped his right leg on the opponent's behind knee. The performer has slapped the opponent's right arm to fall using right hand in Step 6 (Rule_4). The last step (Rule_5), Pemakan or punching has been executed to the opponent.

This result shows that even GDL approach has successfully recognized the steps executed by the Trainer through producing rules in GDL Output, there are many redundant and unsorted rules in the sequence.

The effectiveness of executing MA technique cannot be measured through this sequence of rules. To solve this issue, FBRR approach has been implemented.

Rules-Ranges for performer's motions

For the Trainer's motion, frame 368 has been detected for Rule_2 and it becomes the main trigger (*x*) in the next operation. Therefore, the Rules-Ranges of the motion templates can be published as follows:

Range1: 368 ≤Rule_2>368+6, 368+6 ≤Rule_3>368+6+4, 368+6+4 ≤Rule_4>368+6+4+16, 368+6+4+16 ≤Rule_5>368+6+4+16+8;
Range2: 368 ≤Rule_2>368+11, 368+11 ≤ Rule_3>368+11+11, 368+11+11 ≤ Rule_4>368+11+11+15, 368+11+11+15 ≤ Rule_5>368+11+11+15+9;
Range3: 368 ≤Rule_2>368+17, 368+17 ≤Rule_3>368+17+15, 368+17+15 ≤Rule_4>368+17+15+31, 368+17+15+31 ≤Rule_5>368+17+15+31+17

Therefore, the Rules-Ranges for the performers in the sequence of rules recorded in GDL Output can be determined as follows:

P_Range_1: 368≤Rule_2>374, 374≤Rule_3>378, 378≤Rule_4>394, 394≤Rule_5>402;
P_Range_2: 368≤Rule_2>379, 379≤Rule_3>390, 390≤Rule_4>405, 405≤Rule_5>414;
P_Range_3: 368≤Rule_2>385, 385≤Rule_3>400, 400≤Rule_4>431, 431≤Rule_5>448;

As shown in Table8, the frames within *P_Range_1*, *P_Range_2* and *P_Range_3* have successfully been detected. However, there are so many redundant and irrelative frames.

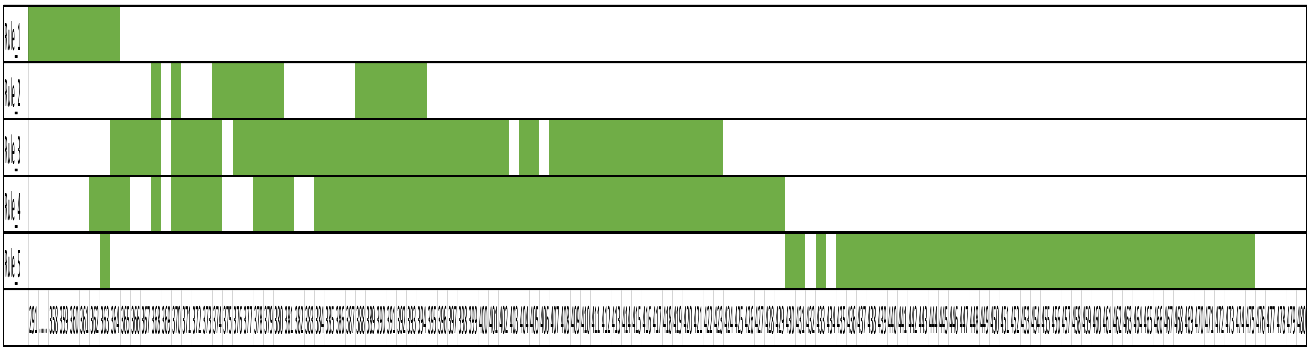

Fig. 6 The positions of relative rules in frames for *Buah Jatuh Pertama* executed by the Trainer

Table. 8 Frames within *P_Range_1*, *P_Range_2* and *P_Range_3* for the performer's motions

	P_Range1	P_Range2	P_Range3	Total
Rule_1	74 {291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364}	74 {291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364}	74 {291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364}	222
Rule_2	7 {368, 370, 374, 375, 376, 377, 378}	9 {368, 370, 374, 375, 376, 377, 378, 379, 380}	2 {368, 370}	18
Rule_3	11 {379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389}	15 {385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399}	3 {374, 376, 377}	29
Rule_4	15 {390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404}	30 {400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429}	14 {378, 379, 380, 381, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393}	59
Rule_5	44 {430, 431, 433, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475}	43 {431, 433, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475}	44 {430, 431, 433, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475}	131

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Table. 9 Frequencies of rules using Union() function for Buah Jatuh Pertama technique

	TOTAL	FRAMES LIST ($FList_{Rule}$)
$UnionFrame_{Rule\_1}$	74	291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364
$UnionFrame_{Rule2}$	9	368, 370, 374, 375, 376, 377, 378, 379, 380
$UnionFrame_{Rule3}$	24	374, 376, 377, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399
$UnionFrame_{Rule4}$	50	378, 379, 380, 381, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429
$UnionFrame_{Rule5}$	44	430, 431, 433, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475

Table. 10 Frequency of rulesusing FOUR conditions

	COND.	TOTAL	FRAMES ($FilteredFrame_{Rule}$)
Rule_1	-	74	291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364
Rule_2	#1	9	368, 370, 374, 375, 376, 377, 378, 379, 380
Rule_3	#2	19	381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399
Rule_4	#2	30	400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429
Rule_5	#1	44	430, 431, 433, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475

Reductions of redundant rules

Using *Union()* function, the redundant R^{th}rules which contain the same value of frames in all respective ranges have been removed as shown in Table9.

Then, the frequency of R^{th}rule based on FOUR conditions has been counted as *FilteredFrame* to remove the irrelative rules in the sequence for the technique executed as shown in Table 10.Therefore, the frequencies of Rule_1, Rule_2, Rule_3, Rule_4 and Rule_5 for Trainer using FBRR respectively are 74, 9, 19, 30 and 44. The frequencies show the existence of all steps in the sequence for *Buah Jatuh Pertama* technique executed by Trainer.

Table 11shows the comparisons of the frequencies for the relative rules between *FreqRules* produced using GDL approach and *FilteredFrame* produced using FBRR approach.

Table. 11 Comparisons of frequencies rules between GDL approach and FBRR approach for *Buah Jatuh Pertama* technique

	FreqRules	*FilteredFrame*	Redundancies Reduction
Rule_1	74	74	0 (0.0%)
Rule_2	16	9	7 (43.8%)
Rule_3	56	19	37 (66.1%)
Rule_4	60	30	30 (50.0%)
Rule_5	45	44	1 (2.2%)

GDL has detected 74, 16, 56, 60 and 45 iterative rules respectively for Rule_1, Rule_2, Rule_3, Rule_4 and Rule_5 containing relevant and irrelevant rules for the steps executed by Trainer. Using FBRR approach, the redundancies of rules have been reduced at 9 (Rule_2), 19 (Rule_3), 30 (Rule_4) and 44 (Rule_5) which containing only relevant rules. Therefore, our method successfully reduces the redundancies of irrelative rules at 43.8%, 66.1%, 50% and 2.2% respectively for Rule_2, Rule_3, Rule_4 and Rule_5. By removing the redundant and irrelative rules in the sequence, the listed rules in the sequence are more accurate and suitable for measuring the effectiveness of MA technique.

Meanwhile, the frequencies of R^{th}rule for other techniques have also been done. Table 12 shows the comparisons of the frequencies for the relative rules between *FreqRules* produced using GDL approach and *FilteredFrame* produced using FBRR approach for other techniques in SSCM executed by the same Trainer. In overall, the redundant and irrelative rules in the sequence for all selected techniques successfully have been reduced using FBRR approach (*FilteredFrame*) compared to GDL approach (*FreqRules*).

Table. 12 Comparisons of frequencies rules between GDL approach and FBRR approach for other techniques executed by the Trainer

Buah Jatuh Ali Patah Sudah (II) technique			
	FreqRules	FilteredFrame	Redundancies Reduction
Rule_1	80	80	0 (0%)
Rule_2	95	7	88 (92.6%)
Rule_3	13	6	7 (53.8%)
Rule_4	59	58	1 (1.7%)
Buah Jatuh Kilas Hadapan technique			
	FreqRules	FilteredFrame	Redundancies Reduction
Rule_1	76	76	0 (0%)
Rule_2	23	14	9 (39.1%)
Rule_3	34	14	20 (58.8%)
Rule_4	55	49	6 (10.9%)
Buah Jatuh Hempok (II) technique			
	FreqRules	FilteredFrame	Redundancies Reduction
Rule_1	54	54	0 (0%)
Rule_2	5	5	0 (0%)
Rule_3	23	17	6 (26.1%)
Rule_4	0	0	0 (0%)
Rule_5	6	6	0 (0%)

V. CONCLUSION

In this paper, FBRR design has been discussed to develop Rules-Ranges for the created motion templates and to evaluate using validation tests in order to measure the sequence of steps the MA techniques. In the development of Rules-Ranges for the motion templates environment, ten motion clips of *Buah Jatuh Pertama* technique in Seni Silat Cekak Malaysia (SSCM) executed by a SSCM Teacher have been reused and discussed. In order to publish the Rules-Ranges of the motion template of *Buah Jatuh Pertama*, the operations of plotting key frames for all loaded motion clips, calculating Min, Max and Avg of the collected key frames and calculating $Range1_R$, $Range2_R$ and $Range3_R$ have been performed. These Rules-Ranges may reduce the redundant and unsorted rules in the sequence produced by GDL approach.

The Rules Ranges for the motion templates of other techniques including *Buah Jatuh Ali Patah Sudah (II)*, *Buah Jatuh Kilas Hadapan*, and *Buah Jatuh Hempok (II)*have also been published (Table 5). For the evaluation, the created motion templates of FOUR selected techniques with FBRR approach (Rules-Ranges) have been tested and validated by a Trainer who is very experienced (28 years) and has practiced, taught and trained the Trainees in a co-curriculum subject in a local public university (University of Sultan ZainalAbidin). The Trainer is also experienced as a jury to evaluate the Trainees during several level tests including Basic Level Test and Down Level Test.

During the motion capture process, a standard Microsoft Kinect for Windows Version 2 and Kinect SDK 2.0 have been utilized to capture, track and record the executions of the executed technique in the experiments.Motion recognition classifier (MoRec-Classifier)process operates to recognize the transferred Trainer's motion data based on the generated GDL script (GDLs) loaded previously. To implement such purpose, Gesture Description Language (GDL) approach has been used. The result shows that even GDL approach has successfully recognized the steps executed by the Trainer through producing rules in GDL Output, there are many redundant and unsorted rules in the sequence. The effectiveness of executing MA technique cannot be measured through this sequence of rules. To solve this issue, steps sequence process in FBRR approach has been implemented.

The steps sequence process functions to measure and produce the sequence of steps. This process uses the Rules-Ranges of the motion templates created previously in the development environment to be references for determining the Rules-Ranges for the performers' motion skeleton data in this environment. Based on the Rules-Ranges of the motion templates, the frames within Trainer's ranges (*P_Range_1*, *P_Range_2* and *P_Range_3*) have successfully been detected. However, there are so many redundant and irrelative frames. Using *Union()*function, the redundant R^{th}rules which contain the same value of frames in all respective ranges have been removed. Then, the frequencies of R^{th}rule based on THREE conditions have been successfully implemented to remove the irrelative rules in the sequence for the technique executed.By removing the redundant and irrelative rules in the sequence, the listed rules in the sequence are more accurate and suitable for measuring the effectiveness of MA technique.

As future works, this research is planned to implement FBRR approach to other SSCM techniques.

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Other experts including Trainers and Trainees will be invited to test and validate the created motion templates with FBRR approach. Developing Score Rubric Assessment is also in planning which will be marked by the jury to evaluate MA techniques. This SRA can be used as verification purpose by comparing the results from FBRR and SRA approaches in order to evaluate the accuracy of the approaches developed. Comparing both approaches may contribute in publishing the extrinsic feedback for the MA techniques.

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