Optimal Dual Cameras Setup for Motion Recognition in Salat Activity

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Abstract: *Motion recognition has received significant attention in recent years in the area of computer vision since it has a wide range of potential application that can be developed. A wide variety of algorithms and techniques were proposed in the context of developing human motion recognition systems. This paper investigated optimal dual sensors setup in motion recognition for salat activity by using multisensor which has remained unexplored. Existing works in the related field are able to recognise few salat movements, but not from the multisensor perspective which is important for better recognition and analytic results. This research proposed a solution that is relevant to the current scenario where we deal with one of the fundamental activities required for every Muslim which is salat. Not only carrying out salat with the right actions will help strengthen our relationship with Allah Subhanahu Wa Taʿala (SWT), but also enable the formation of a positive personality, mental well-being, and physical health. Firstly, this research identified the best position setup of a dual sensor. Then, Hidden Markov Model was used to classify all movements in salat activity and the data were trained before the testing phase. This study led to a new way of learning for salat activity which can be further explored and developed. This research contributed a new way of learning by incorporating new interaction in human-computer interaction. The outcome of this research will be very useful in validating the salat movements of every Muslim.*

Keywords: *Motion recognition, Salat activity, Multisensor, Hidden Markov model, Human-Computer Interaction.*

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1. Introduction

Motion recognition has attracted global scrutiny because it covers an extensive scope of areas including medical, surveillance [14], sport, and human-computer interaction. In recent years, marker-based motion recognition has existed to model a wide range of human motion [2]. This system requires specially composed connected sensor motes to measure the effectiveness of human motion. Then, there are wireless sensor-based to improve the existing sensor in motion recognition [19]. However, markers and the corresponding sensor-based are not always desirable for natural user interaction.

This study aims to examine optimal dual sensor setup for motion recognition in salat activity using Kinect sensors and Hidden Markov Model (HMM). Salat is one of the obligations that must be completed by every Muslim five times daily. Practicing salat correctly is crucial for Muslims since proper salat will assist in becoming better Muslims. By using multisensor, the posture and movement for salat activity can be ensured to be correct.

Salat requires physical movement and our minds to be focused on Allah Subhanahu Wa Taʿala (SWT). In performing salat, each Muslim must comply with the behaviours and established standardised movements based on the laws of salat. Several existing techniques have been proposed to recognise human motion in daily activities. However, no research has focused on salat movements on multisensor which is one of the unexplored areas in human motion recognition.

Carrying out salat with precise movements will not only improve the connection with Allah but also help promote mental well-being, enhance positive personality, and boost physical health. The current literature has presented techniques and algorithms which can only be employed for human motion recognition. This study has identified that the algorithms from previous studies cannot be used directly in situations that require complex motions such as salat. This limitation occurs since salat movement necessitates cooperative multisensor, motion recognition, and analysis of study salat movement according to the laws of salat. Hence, the aim of this research is to provide a solution to the issue and to identify the best position for dual sensor setup.

The remaining sections are arranged as follows. Section 2 reviews related works on multisensor research. Section 3 discusses the methodology employed to achieve the objective of this paper. Section 4 shows the result and provides a discussion on the experiments to identify the optimal places for sensors to track motion for salat movement. Lastly, Section 5 concludes the finding from the experiments and offers recommendations for future works that can be done to obtain more comprehensive results.

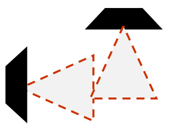
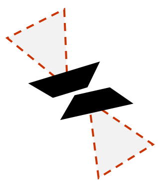
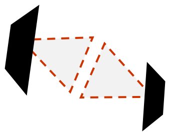
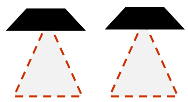
2. Related Work

Before describing the method used in conducting this research, related studies which have been done using multiple Kinect sensors are presented. Kinect is one of the popular depth sensors. It was released in November 2010 by Microsoft and jumpstarted many improvements in computer vision research. The release of open source Kinect Software Development Kit (SDK) for developers has attracted many researchers to explore the capability of Kinect sensor since it is one of the affordable marker-less motion tracking sensors [11, 18].

Many researches were conducted using multiple Kinect sensors which had been sorted by Berger [3] in different research fields, i.e., motion estimation, reconstruction, recognition, and tracking. In Berger's paper, there are five typical capturing setups using multiple Kinect sensors. Firstly, Kinect sensors are uniformly positioned in a virtual circle around the scene centre. The second setup is multiple Kinect sensors which are in line to seize a volume with a huge side length. The third setup is multiple sensors which are compared and placed in a position that do not face each other. The fourth is dual Kinect sensors facing each other and the fifth setup involves multiple uncalibrated moving Kinect sensors.

Since our focus is to find the optimal setup for dual cameras, more research using dual camera were elaborated. Dual Kinect sensors were used due to Kinect SDK limitation; thus, the setup was done as simple as possible. Since Kinect sensors are affordable, dual Kinect is one of the solutions to solve occlusion and ambiguity. Different setup using dual camera is depicted in Table 1.

Table 1. Research using dual Kinect.

Camera Setup	Characteristic	Advantages	Disadvantage	Context	Author
	• Cameras placed orthogonal • Principal and secondary camera • Enhanced skeleton problem using constrained optimization	• Real time human motion captured • Efficiency algorithm •	• Unmatched joints for each camera • Unable retrieve correct joint positions	Motion Capture	Yeung *et al.* [21]
	• Uncalibrated moving sensors • Recognise people by using appearance cue	• Covering wide area • No calibration needed • Online re-identification over a camera network	• Self-occlusion	Surveillance	Satta *et al.* [18]
	• Camera place facing each other	• Support any number of Kinect sensor • Flexible human surface modelling method	• IR interference	Motion Estimation	Zhang *et al.* [23]
	• Camera place in line, parallel in each other	• Easy calibration • Simple setup	• Wide space needed	Position Tracking	Saputra *et al.*[17]

Several research approaches were employed using dual sensors to ensure accurate, stable, and real-time application. The previously available motion recognition application requires users to wear custom or sensor to help the system recognise activity or motion. This is known as marker-based application which is not attractive and applicable towards natural interaction for users.

Marker-less motion tracking and recognition are more desirable in these recent years. This is the reason why research for marker-less motion tracking has rapidly progressed. Dual sensors resolve occlusion and ambiguity problems that usually occur using a single sensor.

Hidden Markov Model was used in speech recognition in early years before it was applied to motion recognition recently. HMM is an effective pattern recognition which has been used in previous research [13] to prove its efficiency in recognition. Figure 1 shows a simple probabilistic parameter of HMM where S represents state and a represents state transition probabilities.

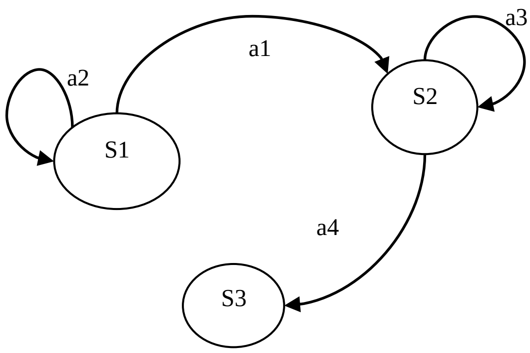


Figure 1. Probabilistic parameter of HMM.

Traditionally, HMM is defined as following the quintuple:

$$\lambda = (S, T, A, B, \pi) \quad (1)$$

Where

- S is the number of states for the model.
- T is the number of distinct observation symbol per state.
- A is the SxS state transition probability distribution in the form of matrix A={aij}.
- B is the SxT observation symbol probability distribution given in the form of matrix B={bj(k)}.
- π is the initial state distribution vector π={πi}

If we opt out the structure parameters S and T, we have the often-used compact notation:

$$\lambda = (A, B, \pi) \quad (2)$$

Recently, many researches combined HMM and Kinect sensors. There are many researches on motion tracking using multiple sensors [1, 4, 10] as Kinect sensor is an affordable marker-less 3D scanning for motion capture solutions [7]. This sensor attracts more attention as there are many rapid project developments.

Table 2 lists the research that combined Kinect sensor and HMM. Most of the research is in the context of recognition as HMM is a powerful pattern recognition. The combination of Kinect and HMM will expand the area of research in the tracking and recognition tracking.

Generally, in the case of salat movement, some early studies showed that performing salat correctly will be beneficial to health [8, 16] whereas others [6] have done salat action recognition using a single camera. It is clear that there is still insufficient research for motion recognition in salat movement activity using dual cameras. Therefore, it is interesting to explore the need, analyze and identify the optimum dual camera setup for motion recognition in salat movement. Consequently, the goal of this study can fill some of the many gaps that remains in the field of motion recognition.

Table 2. Research using Kinect sensor and HMM.

Author	Techniques	Number of Kinect	Context
Xu and Lee [20]	• Improved Hidden Markov Model Algorithm	1	Gesture Recognition
Piyathilaka and Kodagoda [15]	• Gaussian Mixture Modal based Hidden Markov Model	1	Motion Recognition
Yin and Davis [22]	• Salience Detection • Concatenated Hidden Markov Models	1	Gesture Recognition
Jaafar *et al*. [9]	• Hidden Markov Model	2	Motion Recognition
Dubois *et al*. [5]	• Three States Hidden Markov Model	1	Mobile Object Tracking

3. Methodology

This paper investigates optimal dual sensors setup motion recognition for salat activity using Kinect sensor and HMM. Two Kinect sensors are placed at different pre-defined positions and angles to obtain a multi-view in a single space as shown in Figure 2.

Multiple sensor setup is involved in our experiments. For each setup, two Microsoft Kinect sensors are connected to a single computer. The input from these sensors needs to be synchronised to enable motion recognition to be processed correctly.

Joint position provided by Kinect SDK was used to determine the joint position for tracking purposes. From the skeleton information provided, the important joints that have significant movement during salat activity have been selected as features for the training and testing processes.

The important joints that have been selected are right and left wrist, head, middle spine, and bottom spine. These joints are selected because:

- The wrist, head, and spine move a lot during salat. The combination of these joints produces distinctive values for every salat movement. This will increase the accuracy of movement recognition during the testing stage.
- The wrist has a better position compared to the hand because the hand has an additional feature which is the grab and release state. These states may add additional noise to the joint position.
- The head is the easiest position to track. It is not obstructed by other joints during salat movement. There are certain salat movements which require head to move, making it one of the best features to be tracked.
- Spine has similar advantages as the head. It moves in most of the salat movements. Spine position is also required to calculate the angle of the human body during certain movements.

This study focused on upper body more than lower body because most of the movement involves the upper body and wrist as previously mentioned. Lower body joints do not significantly affect significantly the recognition process for salat movement activity. Moreover, the results from append experiments identified an increase in the number of joints, the feature extraction effect could be improved, and boost the recognition accuracy. Nevertheless, the rate of training time amplified.

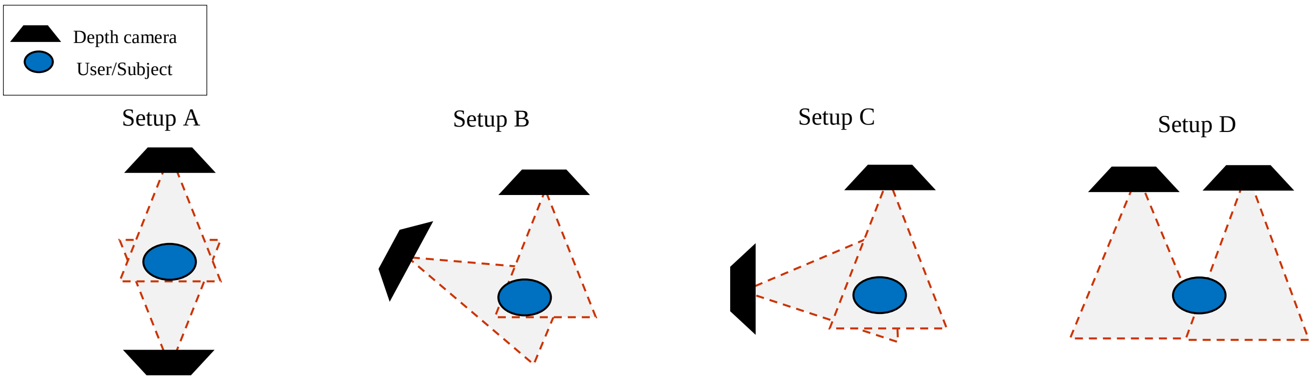


Figure 2. Multiple Kinect setup for experiments.

Figure 3 provides a visualisation of how the system works. Kinect sensor had been setup with different positions to find the optimal setup. The selected joints are same for all different sensor setup. After that, all movements will be recorded.

The current databases are inadequate and there are insufficient action samples which hinder further assessment on the performance of human motion-based. For our study, no human motion databases were reported to support salat motions. Thus, the data for the motions in salat activities were manually collected for each dual sensor setup.

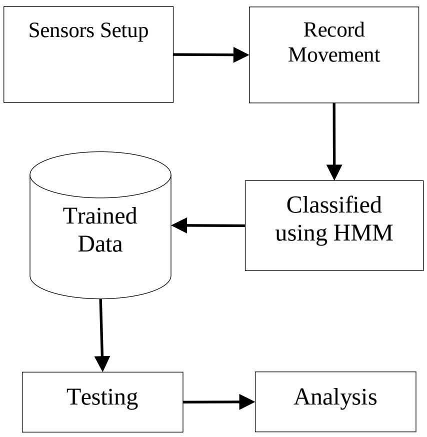


Figure 3. System framework.

The documented movements were categorised in accordance with HMM function from Accord.NET library and are then deposited into a database. Figure 4 demonstrates HMM function throughout the motion categorisation process. Motion data refers to the input sequence for the HMM function while the output projected from this function is known as motion classifier. Every motion data is categorised into five main movements, namely, takbir, ruku', i'tidal, sujud, and sit.

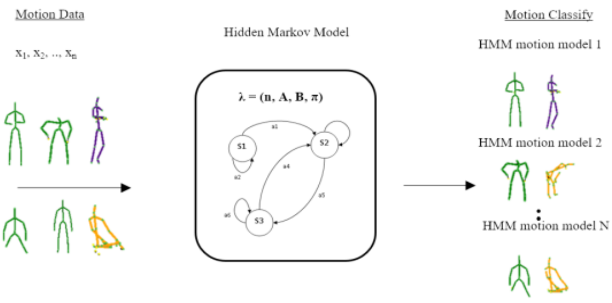


Figure 4. HMM function.

Data were manually gathered by different dual sensors setup for salat activity as there is no dataset in salat motion. Each movement is tracked and recorded for 20 times. Then, the recorded data were classified and trained using HMM function before stored in the database as a dataset.

The dataset in the database will be reused to recognise the performed salat movement during the testing process. In the testing process, all recognised motion will be stated in the confusion matrix as shown in Table 3.

Table 3. Confusion matrix table.

		Predicted	
		Movement 1	**Movement 2**
Actual Outcome	**Movement 1**	True Positive	False Positive
	Movement 2	False Negative	True Negative

The accuracy of motion recognition was calculated during this process for all four-different setup. The motion recognition accuracy can be calculated using the following Equation:

$$\text{Accuracy} = \frac{\sum \text{True positive} + \sum \text{True negative}}{\sum \text{Test outcome positive} + \Sigma \text{ Test outcome negative}} \quad (3)$$

In our case,

$$Accuracy = \frac{\sum TT + \sum TR + \sum TI + \sum TSj + \sum TSt}{\sum Total\ Testing\ Movement} \quad (4)$$

Where

- *TT* is True *Takbir*
- *TR* is True *Ruku'*
- *TI* is True *I'tidal*
- *TSj* is True *Sujud*
- *TSt* is True Sit

Lastly, an analysis was done based on the testing result of varies setup to identify the best position for sensor setup for motion recognition in salat activity. More result and finding will be discussed in next section.

4. Result and Discussion

In this paper, one raka'ah of salat movement was tested to determine the best dual sensors setup to recognise this activity. All trained data were evaluated in the testing process to find the best setup to recognise motion in salat activity. The movements were divided into five main movements and for each movement, 10 samples were performed to test the recognition. This step is repeated for each different sensor setup and the confusion matrix was visualised in Tables 4, 5, 6, and 7.

Table 4. Confusion Matrix for Salat Recognition Setup A.

	Takbir	*Ruku'*	*I'tidal*	*Sujud*	Sit
Takbir	0.9	0.0	0.0	0.1	0.0
Ruku'	0.1	0.9	0.0	0.0	0.0
I'tidal	0.0	0.0	1.0	0.0	0.0
Sujud	0.0	0.0	0.0	1.0	0.0
Sit	0.0	0.0	0.0	0.0	1.0

Table 5. Confusion Matrix for Salat Recognition Setup B.

	Takbir	*Ruku'*	*I'tidal*	*Sujud*	Sit
Takbir	1.0	0.0	0.0	0.0	0.0
Ruku'	0.0	1.0	0.0	0.0	0.0
I'tidal	0.0	0.0	1.0	0.0	0.0
Sujud	0.0	0.0	0.0	1.0	0.0
Sit	0.0	0.0	0.0	0.0	1.0

Table 6. Confusion Matrix for Salat Recognition Setup C.

	Takbir	*Ruku'*	*I'tidal*	*Sujud*	Sit
Takbir	1.0	0.0	0.0	0.0	0.0
Ruku'	0.0	1.0	0.0	0.0	0.0
I'tidal	0.0	0.0	1.0	0.0	0.0
Sujud	0.0	0.0	0.0	1.0	0.0
Sit	0.3	0.0	0.0	0.0	0.7

Table 7. Confusion Matrix for Salat Recognition Setup D.

	Takbir	*Ruku'*	*I'tidal*	*Sujud*	Sit
Takbir	1.0	0.0	0.0	0.0	0.0
Ruku'	0.0	1.0	0.0	0.0	0.0
I'tidal	0.0	0.0	1.0	0.0	0.0
Sujud	0.0	0.0	0.0	1.0	0.0
Sit	0.3	0.0	0.0	0.0	0.7

From the recognition results in Tables 4, 5, 6, and 7, it can be seen that the accuracy of every setup varies. Setup B in Table 5 shows the highest accuracy as all the movement can be tracked in all test outcome.

This experiment was done to find the optimum camera setup for salat activity. However, the best value is not the same for all setup. Every setup has different joints tracked in each camera and this proves that the position of cameras plays an important role in motion recognition processes and results.

Table 8 presents the outcomes of the research experiment and that the accuracy system can reach to track motion for salat movement with respect to sensors position and the number of joints tracked in every movement.

The Table shows that most of the movement can be recognised by the system after the training phase with HMM with an accuracy percentage rate of between 94% and 100%. Previous research done using HMM proves that HMM is one of best classifiers in motion recognition.

Martinez-Contreras *et al*. [12] have performed human action recognition by employing silhouette-base HMM with a recognition rate of 99.92%. Xu and Lee [20] have studied continuous gesture recognition by utilising the improved HMM algorithm with an overall recognition rate of 93.83%.

Kinect SDK itself has a limitation where it was trained to recognise human in standing position. Yeung *et al*. [21] have stated that Kinect SDK database does not include squatting pose, thus, the position estimated by Kinect SDK is not good. The same thing happened for ruku', sujud, and sitting position in our case.

During these non-standing positions, few occlusion problems occurred as Kinect SDK tends to make assumptions. When ruku' movement was performed, Kinect SDK makes the assumption of spine position because the head and spine are parallel to each other. For the sujud and sitting movements, knee and foot position cannot be tracked due to the Kinect SDK limitation. The Kinect SDK tried to arrange those knee and foot joints as in a standing position.

To overcome this problem, multisensor was used to generate and improve skeleton information by joining two Kinect together. By sharing Kinect information, the inferred skeleton joint will be supported by the other tracked skeleton in different cameras. This will reduce the number of inferred joints and improve the tracking and recognition process.

Based on Tables 4, 5, 6, and 7 in section 4, it can be concluded that standing movements like takbir and i'tidal experience no problem in the recognition process. Table 8 shows that the highest number of joint tracked are from like takbir and i'tidal movements. As previously mentioned, Kinect SDK was trained for standing position. This shows that the number of tracked joint plays an important role in recognition accuracy.

However, HMM is a powerful pattern recognition agent. When sujud movement is performed, the total number of tracked joint drastically reduced in all setup but HMM can classify it as sujud due to the significant inferred joints pattern.

Table 8. Outcomes of research experiments.

Camera Setup		*Takbir*		*Ruku'*		*I'tidal*		*Sujud*		Sit		Mean	Mean	Accuracy
		Tracked	Inferred	Tracked	Inferred	Tracked	Inferred	Tracked	Inferred	Tracked	Inferred	Tracked	Inferred	
A	1	20	0	15	5	20	0	10	10	16	4	15.9	4.6	0.96
	2	17	4	13	8	21	0	14	7	13	8			
B	1	20	0	15	5	20	0	10	10	16	4	15.9	4.6	1.00
	2	20	1	15	6	17	4	11	10	15	6			
C	1	20	0	15	5	20	0	10	10	16	4	14.9	5.6	0.94
	2	17	4	12	9	16	5	12	9	11	10			
D	1	19	1	15	5	19	1	10	10	14	6	16.1	4.4	0.94
	2	21	0	15	6	21	0	11	10	16	5			

The experiment was conducted to check the optimal camera setup to recognise human motion in salat activity. In setup A, there are confusions in recognising takbir and ruku'. This is because the secondary sensor was confused about the back tracking since Kinect sensor database was trained for front tracking. This makes setup D to be the most advantageous setup to track motion.

In setup D, the number of joint tracked is highest compared with other setups. However, this setup does not solve the occlusion problem as the angles for both sensors are the same. In this setup, HMM experienced confusion in the tracking sit position. This situation occurred because the primary sensor could not track many joints in the sitting position.

A similar situation happened in setup C. The secondary sensor has the lowest joint tracked compared with other setups that might affect the tracking result. setup B has the highest result in recognition accuracy. This is because setup B was able to overcome most of the occlusion problem compared to other setups.

The secondary sensor was able to place most joints in 3D space correctly and overcome problem faced by the primary camera in mapping joint based on body posture. For example, during the *ruku'* movement, the head and spine are parallel to each other. The primary sensor was not able to map the joint, but the secondary sensor was able to overcome this problem and map the joint correctly (refer Figure 5).

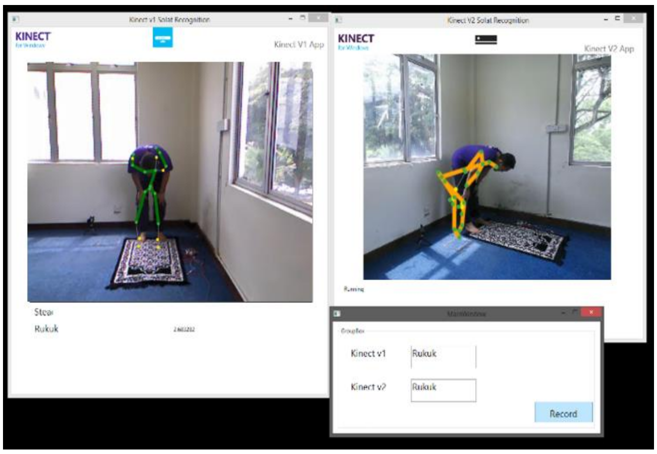


Figure 5. Ruku' movement in Setup B.

The experiment found that setup B is the optimum sensors setup for motion recognition in salat activity. Although setup D identified the highest number of joint tracked, setup B helped HMM function to recognise motion better as it overcomes most of the occlusion problems during the non-standing position.

Kinect sensor is trained to track human from the front and in the standing position. Figures 6 and 7 below show that most joints are tracked for setup A and D during the *takbir* position. This is because these two-setup users stood right in front of the camera.

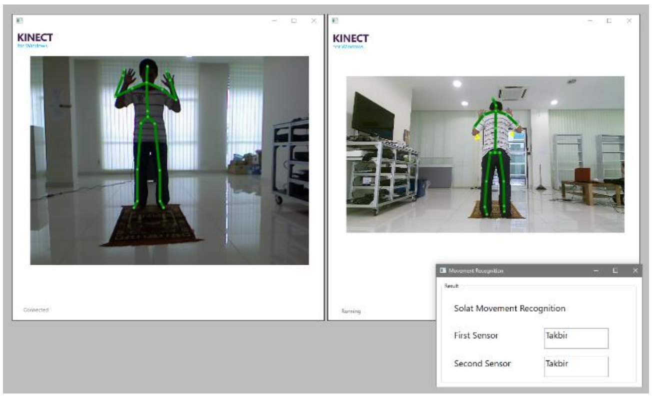


Figure 6. Takbir movement in Setup A.

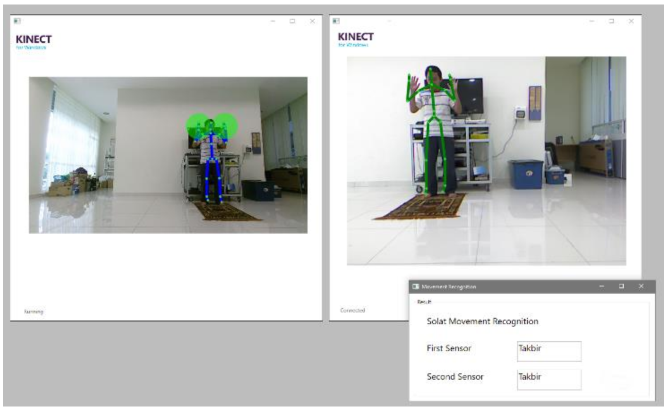


Figure 7. Takbir movement in Setup D.

5. Conclusions and Future Work

The objective of this study was to identify the optimal sensors setup to track motion for salat movements by using the widely popular and affordable Kinect sensor and HMM as pattern recognition agents. The experiments showed that some setups are not suitable to recognise all movements in salat activity.

In addition, the number of joints detected in skeleton information plays an important role to ensure the movement can be recognised by the system. HMM was able to classify the correct movements during the training phase. From the experiment results, it can be concluded that setup B is the optimal sensor setup to recognise motion in salat activity. Furthermore, this experiment proved that not all sensor setups are suitable for motion recognition in salat activity.

Based on the results, the dataset for salat movements was developed using a dual sensor. The dataset was customised with lots of variations for the testing process. The work presented here can classify the main movements in salat activity such as takbir, ruku', i'tidal, sujud, and sitting movements. Many future works can be done to improve this system including:

- Determine the angle of the face, hand, and spine to ensure the position is correct.
- Improve the skeleton position to handle complicated movement in salat activity.

Thus, it is believed that the findings from this study will lead to a new development of learning. Dual sensors technology can be used in educational technology and a new method in Islamic education can be established. The method in dual sensors can be performed to recognize errors in the salat actions and deliver comprehensive instructions in order to assist individuals who are learning to pray, enhance the quality of salat, and strengthen the most critical pillar of Islam

In addition, more experiment can be tested to determine the optimum camera setup for motion recognition in other complex activities such as dancing and sports. It is interesting to test for other activities that required bigger joint movements compared to salat activity that only limited to one single space.

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