ENTRY RESTRICTED SECURITY SYSTEM FOR A SMART HOME

Inspiring Excellence

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DECLARATION

We, hereby declare that this thesis is based on the results found by ourselves. Materials of work found by other researcher are mentioned by reference and through citation. This thesis, neither in whole nor in part, has been previously submitted for any degree.

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ABSTRACT

This report represents a new personal identification method for entry restricted security system. In this proposed method skeleton recognizing feature of Kinect is being used to identify human. Human identification has been done by comparing 19 body segment's length and 8 angles of different body joints with the saved lengths and angles. Fuzzy C–means (FCM) algorithm is used to compare new data with the data in the database. The system will decide whether to restrict or allow any person depending on the comparison result of FCM algorithm. Experimental results show that the proposed method exhibited 100% accuracy for our tested dataset.

CHAPTER 01

INTRODUCTION

1.1 Motivations

In the 21st century, security is the biggest concern. Now a day people's life is becoming more and more confidential, so security is needed in every sector of their life in order to maintain privacy. Sometimes woman, children and elder person stay alone in home. Again, security of home in absence of home owner is a big issue. Security system is being developed with the improvement of technology, but at the same time security broken technique is also improving [1]. 86% people around the world use many other home security tools to secure their home and 95% people are in favor of advanced smart security system [2]. While researching we came up with the idea that most of the time main door is the place to entry in a home. It is seen that most of the time people open the door without knowing who is outside of the door; especially the children do this work. These issues encouraged us to think about an improved and reliable security system. To insure the security of home we need to insure that the door does not open for unknown persons. Moreover to identify known and unknown person we need such a system which can find out known and unknown person. We come with the idea of Entry Restricted Security System for a Smart Home using Kinect.

1.2 Contribution Summary

In our proposed method, we have come up with a system which can identify human and give permission to the authorized person based on person's body segment's length and joint's angle from their skeleton information using Kinect. Kinect is a device that can identify human body joint points [3]. Kinect can give the co-ordinate of 19 points from human skeleton [4], using the co-ordinate of these points we can calculate body segment's length and joint's angle. Some segment's length and joint's angle are different for each person. We save all the information of authorized person to match while any person tries to enter through the door. If the information matched then the door will open. The main strength of our system is skeleton information of any person cannot be copied. This proposed method has following features:

- ✓ Body point recognition.
- ✓ Body segment’s length calculation.
- ✓ Body joint’s angle calculation.
- ✓ Match the database information using FCM algorithm.
- ✓ Allow or disallow human.
- ✓ Save the data of the new person.

1.3 Thesis Orientation

The rest of the paper is organized as follows- Chapter 2 represents background study. Chapter 3 provides a detailed overview of proposed model. Chapter 4 describes about experimental result and analysis. Finally, Chapter 5 has information about future work and also concluded our report.

CHAPTER 02

BACKGROUND STUDY

2.1 Literature Review

A number of researches have proposed several security models using different technology. For example, in [5], authors proposed a GSM based security [5] system. An ultrasonic sensor based security system is proposed in [6], where authors mainly detect motion and search for a result. A method of security system using finger print recognition system is presented in [7]. The main limitation of finger print based security system is the copy of individual's finger print with the help of modern technology. According to [8], gait refers to the style of walking of an individual based on the principal component analysis (PCA).The paper describes an approach to recognize human using individual's gait information from their walking style; but walking style of individual person sometimes can defer because of many reasons, so it cannot detect human every time if the information does not match with previous data. In [9], Molina *et al.* Develop a software prototype based on biometrics of human with a gait analysis, for identification and verification of individual person using Kinect. In [10], a security system has been developed such that any voice command which is identifiable by the system's database if issued by the user then the system will allow a person to enter, but this type of system has limitation that modern technology can easily copy voice command of any person. There is a security system based on the pattern of the human iris. Now a day's iris pattern can copy to contact lens and it can use to break this type of security system [11].

2.2 Hardware knowledge

In this project the main hardware we have used Kinect version 1[12], developed by Microsoft Kinect which is a very popular electronic device that basically used by the gamer for hand free gaming, but Kinect has lots of other applications too[13]. Kinect provides a Natural User Interface (NUI) for interaction using body motion and gesture as well as spoken commands[14] and thus it can detect human from their various skeleton information. Color camera, Infrared (IR) emitter, IR depth sensor, Tilt motor, Microphone array, LED are some key components of Kinect sensor[14], Kinect device also include a power adapter for external power supply and a USB adapter to connect with a computer. Figure 1 is showing some key components of Kinect.

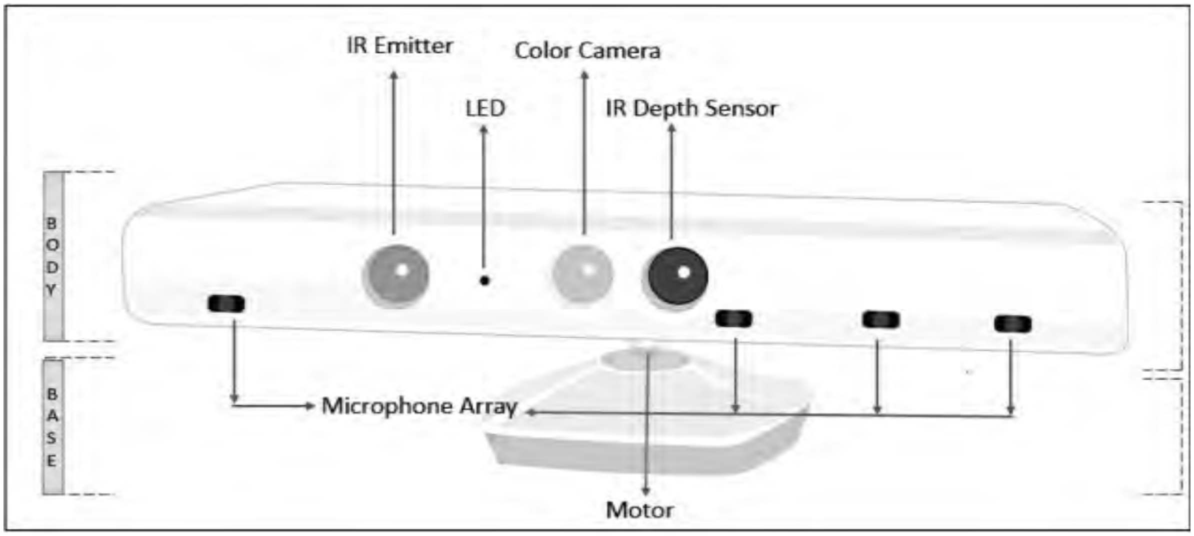

Figure 1: Kinect with key components.

In this project the skeleton body joint tracking application of Kinect had been used and developed to reach the goal of this project.

2.3 Software knowledge

In order to make the Kinect usable for this project we need one pc or laptop which has Microsoft visual studio 2010 installed in it. Microsoft visual studio 2010 had been used for the coding purpose of this project. The reason behind using Microsoft Visual Studio Integrated Development Environment (IDE) is that it has the full language support for Kinect version 1.In the coding part the language we have used is C# with Windows Forms Applications (WFP) [15], which has the advantage of developing smart console and user interface.

2.4 FCM Algorithm

FCM algorithm is one of the most popular fuzzy clustering techniques, was originally proposed by Dunn [16] in 1973 and had been modified by Bezdek [17] in 1981.The reason behind choosing FCM algorithm over other clustering algorithm is it has a function called membership function denoted as 'm' which allows every data point to get at least one cluster. FCM algorithm is based on the formula:

$$J(U,V) = \sum_{i=1}^{n}\sum_{j=1}^{c}(u_{ij})^m \,||x_i - v_j||^{\,2} \tag{1}$$

where J is the identifier which actually identify the perfect person from the database for each length and angle , N is the number of frames we get for a single body parts or joints length or angle , C is the number of person we have in the database, u_{ij} is the membership for i^{th} data to j^{th}person which we can find by the formula:

$$u_{ij} = \frac{1}{\sum_{k=1}^{c}(distance_{ij}/distance_{ik})^{(\frac{2}{m-1})}} \tag{2}$$

where$m$ is the fuzzyness co-efficient which can vary from more than 1 to infinity, V_j is the cluster center which will be a unique value for each cluster, we can find V_j calculating the formula:

$$V_j = \frac{(\sum_{i=1}^{n}(u_{ij})^m x_i)}{(\sum_{i=1}^{n}(u_{ij})^m)} \,, \forall_j = 1,2,3,\ldots\ldots\ldots c \tag{3}$$

by using equation number (2) & (3) in equation number (1) we calculate the error.

CHAPTER 03

PROPOSED MODEL

3.1 Introduction

Figure 2 demonstrates a detailed work flow of our proposed model. The system work flow consists of three major segments including initialization, input, matching and final output. The main objective of this paper is to identify a human being using skeleton information. We used Microsoft Kinect to take human skeleton information because it can track human skeleton better than other sensors which are available in the market. To identify a human, it perfectly takes the data of each authorized person and saved it in the system's database after processed by Kinect skeleton tracking function. After that when a person arrives and wants to enter into a secured place, this system matches the new data with database and tries to identify that person. The main goal of this project is to ensure the entrance of authorized person in restricted area.To achieve this, a person has to:

- ✓ Have his/her skeleton information in system database.
- ✓ Stand properly in the specific position.
- ✓ Stand for certain period of time.
- ✓ Stand in a lighted place so that Kinect can detect.

Our system needs to complete some vital steps to fulfill its goal and achieve the success. By performing all the necessary steps properly system will able to give us a perfect result as output bywhich it can identify a person properly.

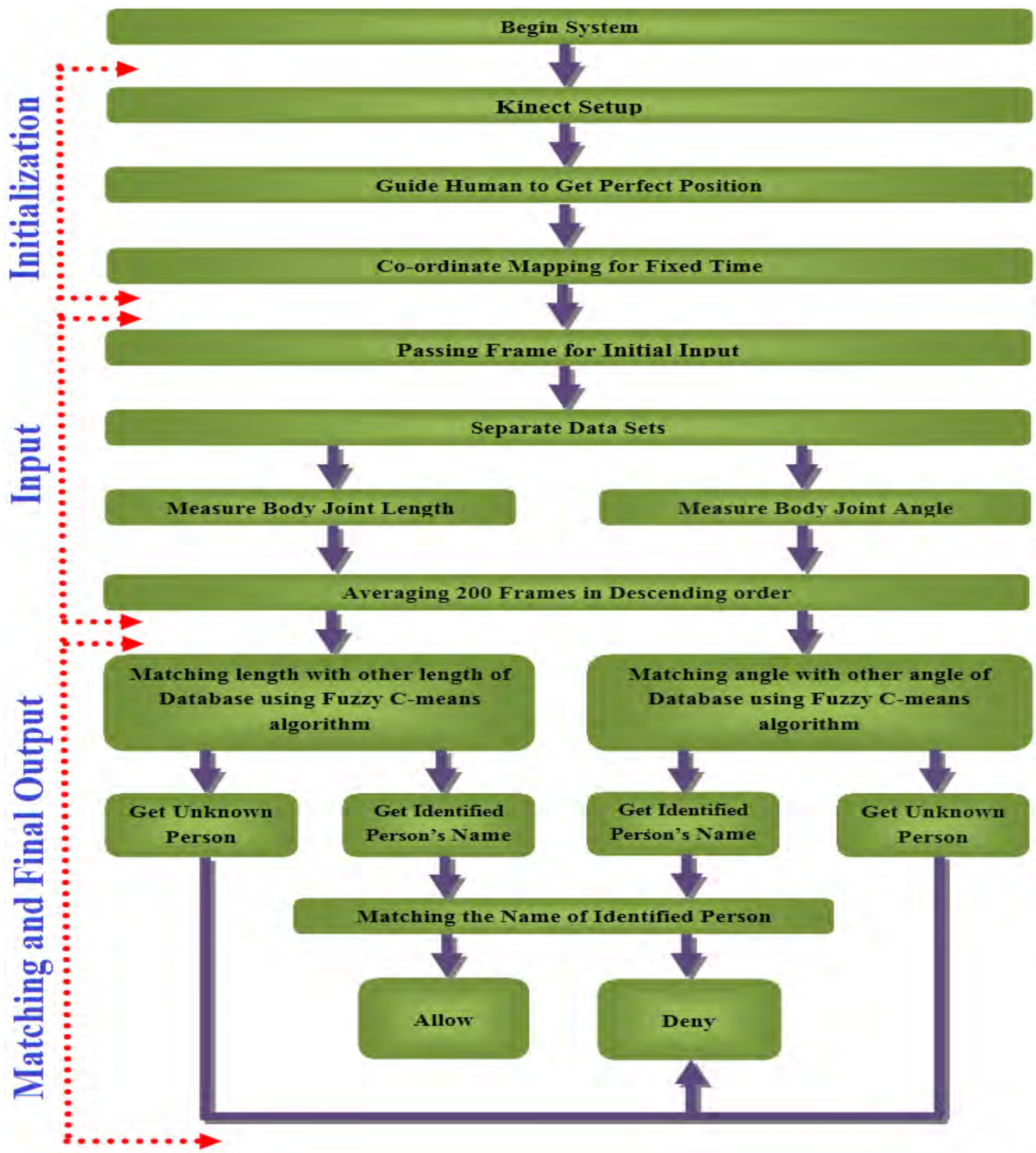

Figure 2: System work flow of proposed model.

3.2 Initialization

First, we use the Kinect as a human skeleton information taking sensor. We set the viewing angle of Kinect at 15 degree from the ground and the distance from Kinect to the experimented person at 3.2 meter. We fix the value of angle and distance by trial and error method.

Second, our system searches for human skeleton in front of the door by using the Kinect sensor. When it gets a human in front of the door it will guide the human to get perfect position.

Third, the Kinect sensor will do the coordinate mapping for 10 seconds by passing 300 frames and get all the information of human skeleton points. Here Kinect passes 300 frames for getting more accurate value during experiment. After that system saves that information in its memory for further calculation.

3.3 Input

Kinect can deliver the still image frame within a range of 12 to 30 frames per second (Kinect for windows) [18]. Each frame contains some data of still image. We take frames for 10 seconds and take the data of 300 frames and consider last 200 frames as initial input data.

After getting the initial input data by passing frames, system creates separate database for length and angle from raw input data.

By using initial input data, our system creates values for each body length and angle by averaging the initial input data, which will be our clustering centre during match.

At the end, the system utilizes an algorithm to find out the value of each body part and also find out the value of each angle. According to our experiment, for better data reliability we take the average of last 200 frames data of each body part and angle individually. Finally, system stores the data in the memory as an input of a person.

3.4 Matching and Final Output

When the system gets the final input of a person in its memory then it starts doing comparison with database using FCM algorithm. First, it takes the final data set of body length from the memory and tries to match with the first person's body length of database. If final data set of body length matches with the body length of database then system gets the name of that person from database and stores the name. If the final data set of body length do not matches with the first person of database then system continues and tries to match the final data set of body length with the next persons' of the database. System will compare final data set of body length with each and every person's body length. If system fails to get any match then system will stop and will not get any name as output. After that system store the final data set of body length in database as an unknown person.

And then system first checks the comparison results of body length. If it does not get name then system stop doing comparison for angle. Else system takes the final data set of angle from the memory and compares it with the database persons angle one by one just like body length. And if it matches with any person's angle then the system stores the name as output otherwise system will stop and will not store any name.

After that the system will have 2 outputs of body length and angle. System compares them and if system gets same name then it will allow the person otherwise system will not allow the person to enter into the home.

Finally, the system will clear its memory and make space for itself for further calculation for the new person and makes it ready for taking new input.

CHAPTER 04

EXPERIMENTAL RESULTS AND ANALYSIS

In order to implement the proposed model some hardware and software setup is needed, after setting up all the necessary things implementation will be started. In this section full description of experimental setup will be described.

To implement our proposed model, we setup an experiments using Kinect version 1 developed by Microsoft, which can detect human from their various skeleton information.

In order to make the Kinect usable for this model, we need a computer having Microsoft visual studio[19]. In our implementation, Microsoft visual studio 2010 is used. The reason behind the use of Microsoft Visual Studio Integrated Development Environment (IDE) is that it has the full language support for Kinect version 1. In addition, in the coding we have used is C# with Windows Forms Applications (WFP)[15].

4.1 Position setup

In order to complete this project perfectly Kinect sensor has to be used properly. The initial goal of this project is to get all the skeleton joint point's co-ordinate. It is known that Kinect can give 12 to 30 frames per second, so the X, Y and Z co-ordinate of each point varies frame to frame. To control the fluctuation rate we make the distance from Kinect to user static at 3.2 m and also fixed the movement angle of Kinect at 15 degree. Again in the computation time we keep the Kinect device always in the ground so that the height from the ground to Kinect is always fixed. Before starting the computation we make the Kinect sensor on and skeleton sensor enable so that it can take the skeleton data perfectly. We keep the Kinect sensor on for 10 seconds to get the data of 300 frames and we compute the data of last 200 frames, we skip 1st 100 frames because of initial fluctuation. Figure 3 is showing our idea about experimental setup.

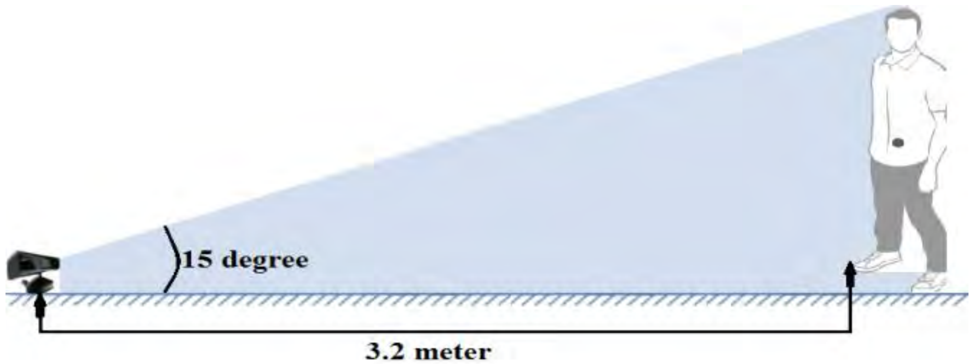

Figure 3: Experimental position setup.

4.2 Input taking process

In this section the description of input taking process will be described. While using this system, user will stand in front of Kinect at a particular position and a particular pose as dissipated in figure 4.

Figure 4: Human standing pattern in front of Kinect.

When user stands in front of Kinect, it scans whole body and identifies the 19 joints from the skeleton of the body which is shown in figure 5.

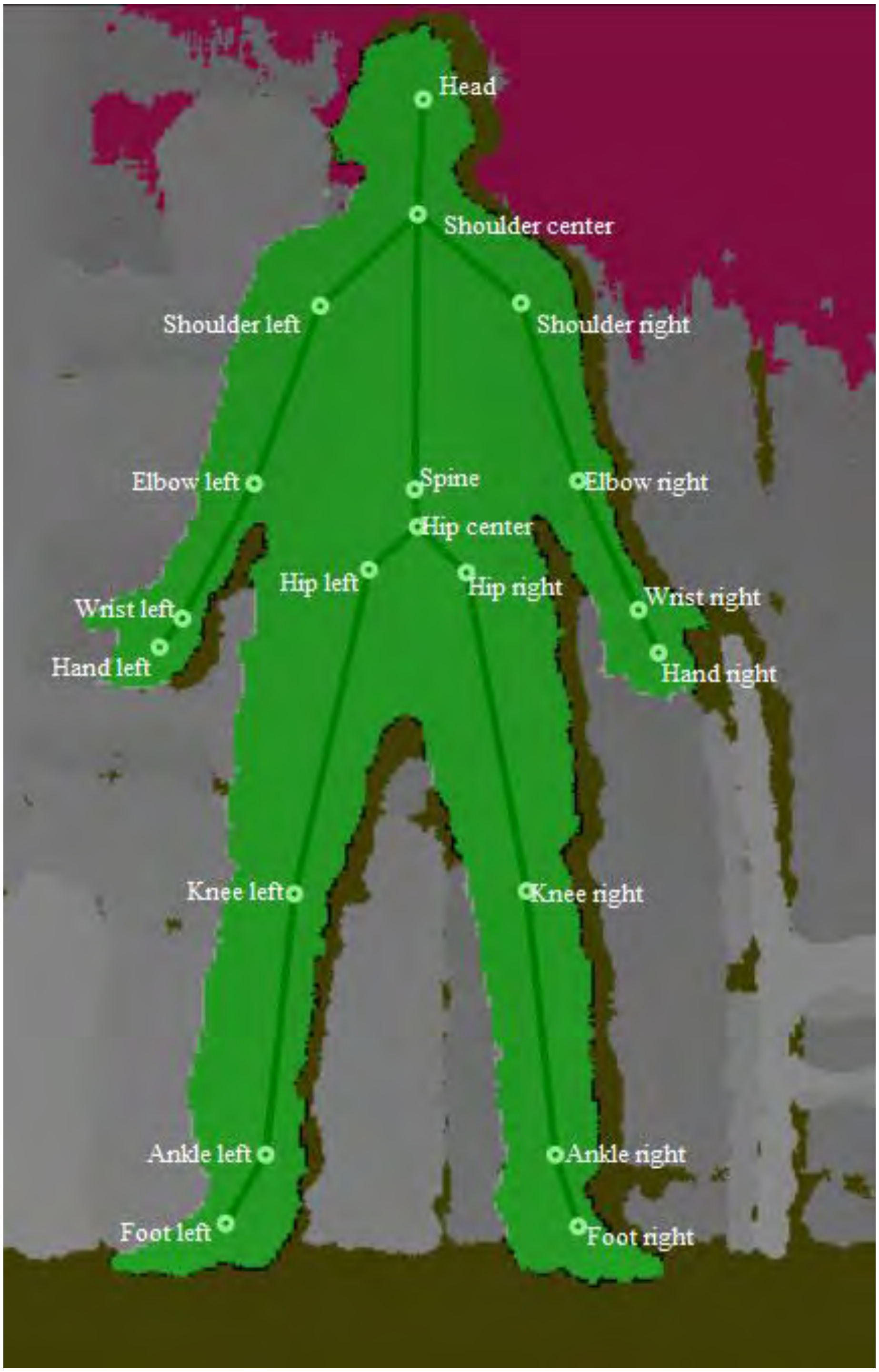

Figure 5: Human detection by Kinect.

After identify the joints Kinect gives us X, Y and Z co-ordinate of those joints which will be the primary input of our system. Table 1 is showing the co-ordinate of 19 joints of a single frame.

Table 1: Sample data of a person's body points

Body points	**X co-ordinate**	**Y co-ordinate**
Shoulder center	315	116
Head	317	67
Shoulder Right	352	152
Shoulder Left	272	146
Elbow Right	357	219
Elbow Left	251	209
Wrist Right	361	272
Wrist Left	241	261
Hand Right	357	291
Hand Left	241	280
Hip Right	324	246
Hip Center	306	227
Hip Left	286	243
Knee Right	319	362
Knee Left	271	358
Ankle Right	310	453
Ankle Left	264	447
Foot Right	309	471
Foot Left	241	280
Spine	308	211

If we draw the co-ordinate of 19 joints in the graph we will see a shape of human skeleton which is showed in figure 6. Each skeleton joints co-ordinate varies in every frame and every time there will be a new skeleton shape if we draw them in the graph. To get the skeleton shape we have to convert Y-axis value into negative value. And then we draw the skeleton on fourth co-ordinate where the value of X is positive and value of Y is negative to get a perfect skeleton of human using points value.

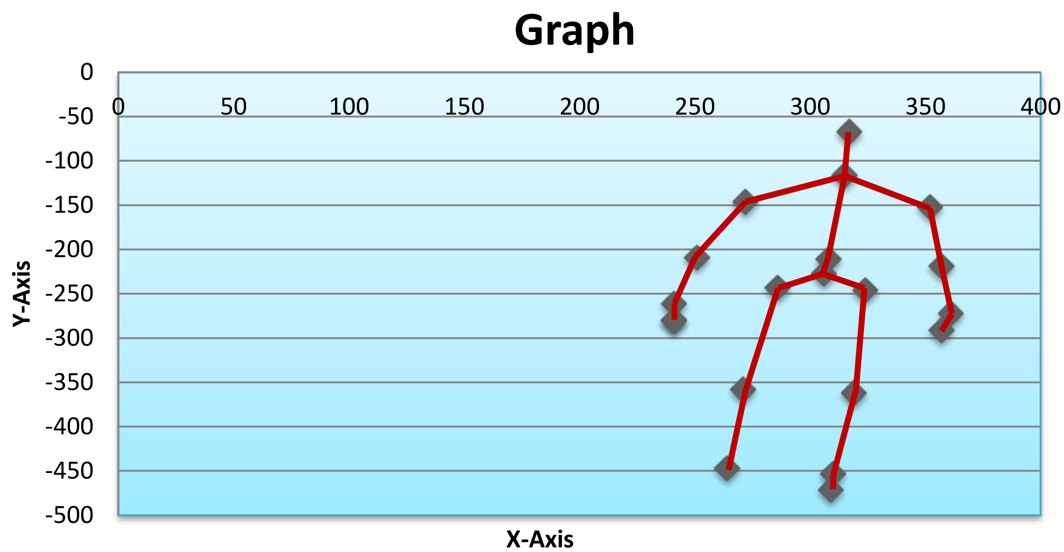

Fig 6: Graphical representation of skeleton points.

Our system is based on two important criteria, one is measuring body length and other one is calculating joint's angle which are calculated from the co-ordinate positions of 19 body joints. Next section describes the length and joint's angle calculation process.

4.3 Calculating body segment length

To calculate the length of one body segment, the first and last point's X, Y and Z co-ordinate value is needed where X indicates the position of user across the X axis, Y co-ordinate indicates user position across the Y axis and Z co-ordinate indicates the distance of user from Kinect. After getting all three co-ordinate value of end points, length can be calculated using Eucldean distance rule[20]:

$$(\sqrt{(X1 - X2)^2 + (Y1 - Y2)^2 + (Z1 - Z2)^2}) \tag{4}$$

Here X1, Y1, Z1 is the co-ordinate of first point and X2, Y2, Z2 is the co-ordinate of last point. Figure 7 is representing the length of different body segments.

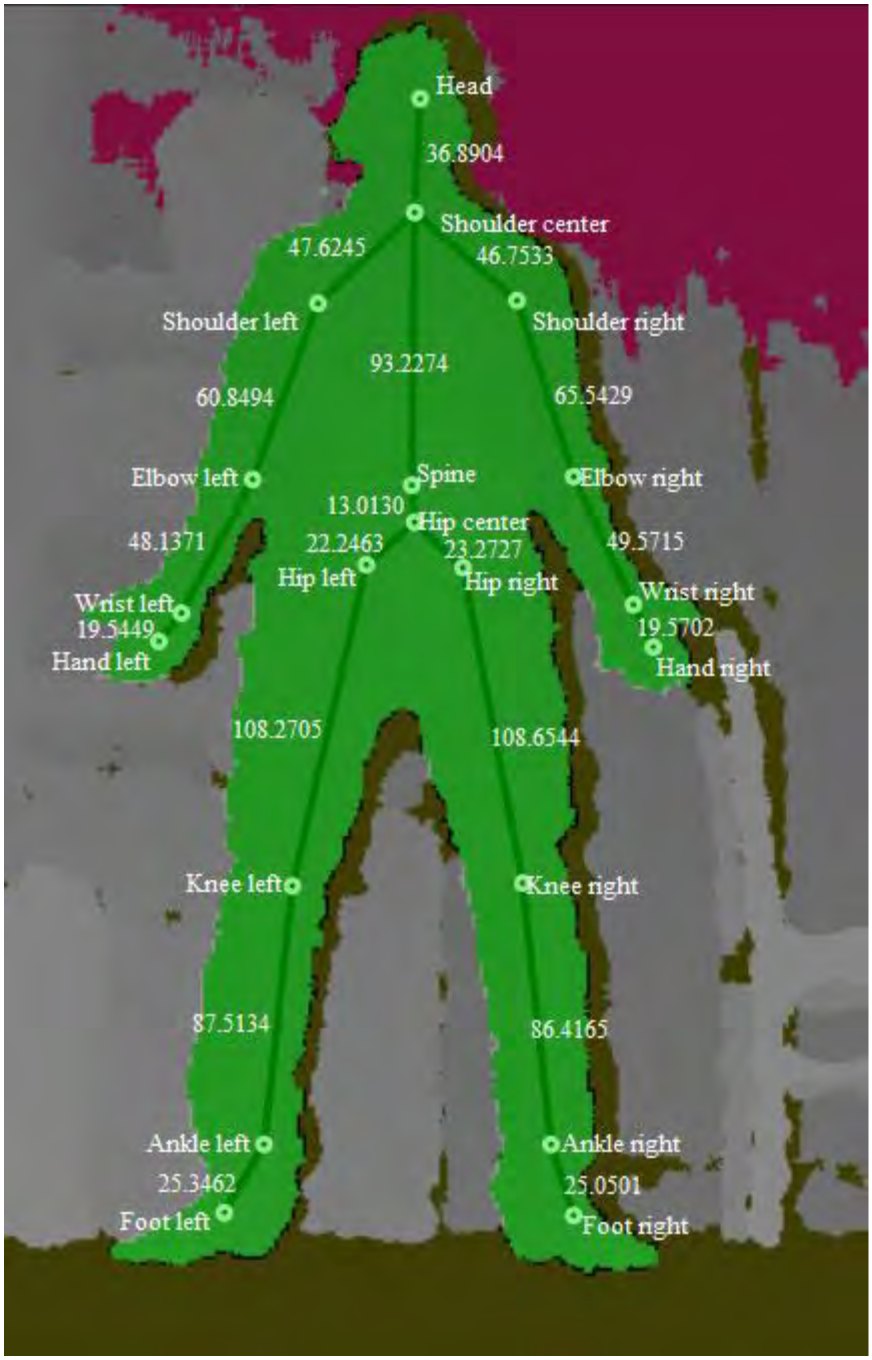

Figure 7: Human skeleton with body segment's length.

In this system we have calculated body segment's length of authorized person. Table 2 is representing an example database of calculated length of four authorized person.

Table 2: Length of different segments

Body part	Person1	Person2	Person3	Person4
Head To Shoulder center	40.235	35.693	36.890	44.157
Shoulder center To Shoulder Right	46.467	43.152	46.753	45.154
Shoulder center To Shoulder Left	50.600	47.167	47.625	48.411
Shoulder Right To Elbow Right	62.185	65.891	65.543	65.318
Shoulder Left To Elbow Left	60.991	60.366	60.849	60.656
Elbow Right To Wrist Right	48.494	50.824	49.572	51.303
Elbow Left To Wrist Left	49.988	51.518	48.137	50.080
Wrist Right To Hand Right	13.776	15.586	19.570	14.865
Wrist Left To Hand Left	13.567	15.638	19.545	16.742
Hip Center To Spine	12.236	15.114	13.013	11.501
Hip Center To Hip Right	23.147	22.012	23.273	23.329
Hip Center To Hip Left	23.625	23.996	22.247	23.294
Hip Right To Knee Right	118.475	112.752	108.654	130.179
Knee Left To Ankle Left	88.704	68.263	87.513	89.678
Hip Left To Knee Left	118.282	113.072	108.271	131.772
Knee Right To Ankle Right	88.185	73.461	86.417	91.594
Ankle Right To Foot Right	26.572	25.488	25.050	25.948
Ankle Left To Foot Left	27.654	25.181	25.346	27.040
Spine To Shoulder center	94.599	99.812	93.227	98.871

4.4 Calculating body segment angle

Before describing how we did the angle calculation let’s discuss about why we did angle calculation in this project. If we think properly it will be clear that angle between two body segment sometimes can indicate the thickness of some portion of our body[21]. Suppose the larger angle between the segment make by hip-center and hip-left and the segment make by hip-center and hip-right is indicating the fatter waist. To calculate angle firstly we have calculated the dot product and cross product between two segments (considering them as vector)[22] after that we have calculated angle using the formula:

$$\text{Theta}=\tan^{-1}\left(\frac{Dotproduct}{Crossproduct}\right) \quad (5)$$

Figure 8 is an example of how angle is related with body thickness.

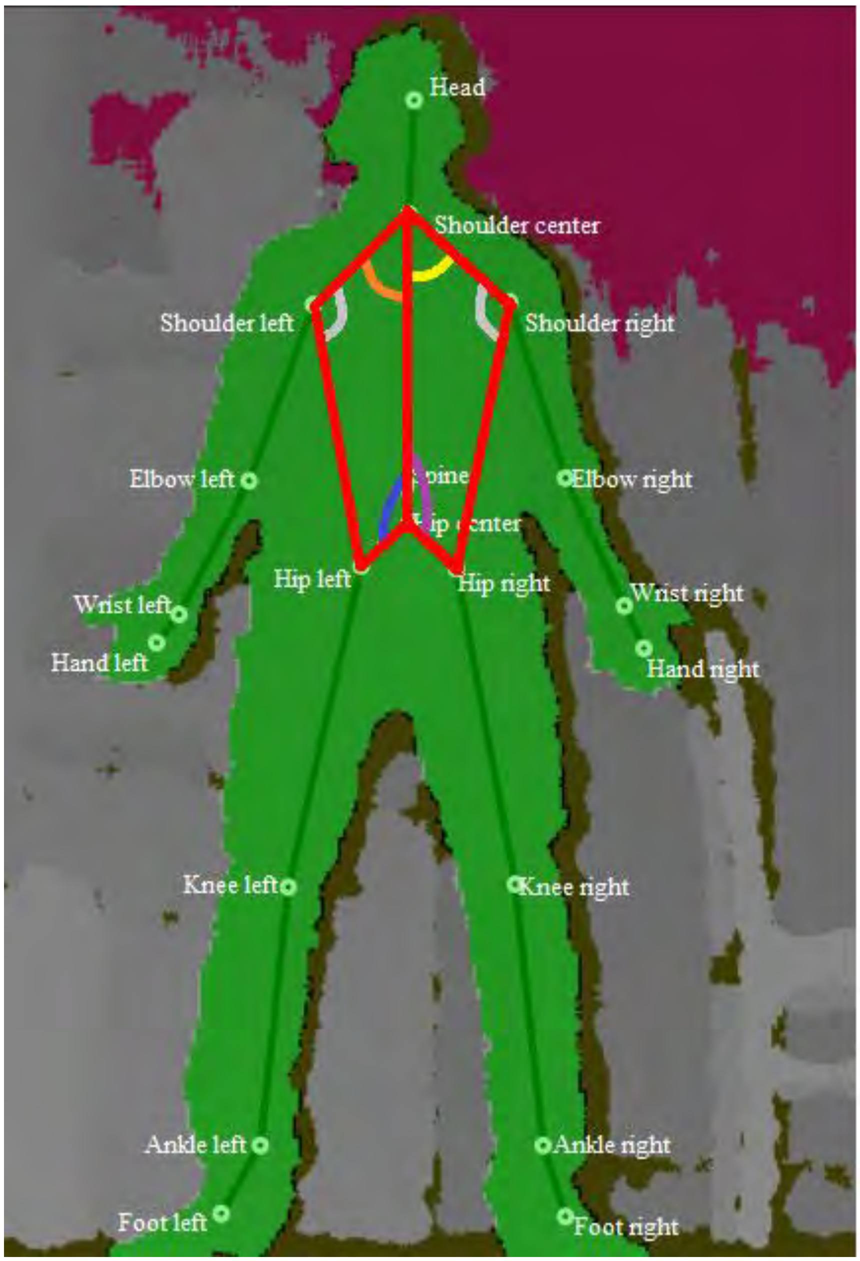

Figure 8: Human skeleton with body joint angle.

In this system we have also calculated body segment's angle of authorized person. Table 3 is representing an example database of calculated angle of four authorized person.

Table 3: Angle Data of different Segments

Body joint angle	**Person 1**	**Person 2**	**Person 3**	**Person 4**
Shoulder right + Shoulder center To Spine	231.741	232.383	232.937	230.737
Shoulder left + Shoulder Center To spine	126.976	131.982	129.438	125.749
Spine to Shoulder center + Spine to hip center	184.926	176.308	174.652	181.349
Spine to hip center + hip center to hip right	304.476	316.848	318.028	307.564
Spine to hip center + hip center to hip left	44.552	52.125	56.889	43.645
Shoulder right to hip right + Shoulder center to Shoulder	120.283	116.688	117.343	121.583
Shoulder left to hip left + Shoulder center to Shoulder left	242.696	240.649	241.875	240.928
Shoulder right to hip right + hip center To hip right	301.426	302.227	302.959	301.744
Shoulder left to hip left + hip center To hip left	59.151	61.065	62.854	58.928

4.5 Matching With Database

In this section, we will describe how a new person's data have been matched with the data exist in the database. It is known that every time when user stands in front of Kinect for giving input, the input data will be different much than the previous data and this is a big problem for matching. To get rid from this problem we have used Fuzzy C Means (FCM) algorithm. This helps us by calculating error value and error tolerance label.

Table 4: Datasheet of matching error and identify person using FCM.

Name of Joint	Tolerance	Unknown Person 1			Unknown Person 2		
		Value	Matching person	Permission	Value	Matching person	Permission
Head - Shoulder center	1.5	2.3	Person 2	0	1.37	Person 1	1
Shoulder Center-Shoulder Right	0.5	1	Person 3	0	0.07	Person 3	0
Shoulder Center-Shoulder Left	1.0	1.4	Person 1	0	2.14	Person 2	0
Shoulder Right-Elbow Right	0.5	0.8	Person 5	0	0.23	Person 4	0
Shoulder Left-Elbow Left	0.5	1.2	Person 2	0	1.4	Person 2	0
Elbow Right-Wrist Right	0.5	1.1	Person 3	0	2.3	Person 3	0
Hip Center-Spine	0.5	1.2	Person 1	0	0.19	Person 1	1
Elbow Left-Wrist Left	1.0	0.5	Person 3	1	2.99	Person 1	1
Wrist Right-Hand Right	1.0	1.5	Person 4	0	6.82	Person 1	0
Wrist Left-Hand Left	1.5	1.9	Person 2	0	4.46	Person 1	0
Hip Center-Hip Right	0.5	0.2	Person 1	1	10.2	Person 2	0
Hip Center-Hip Left	0.5	0.9	Person 3	0	0.3	Person 1	1
Hip Right-Knee Right	2.0	2.5	Person 4	0	12.9	Person 1	0
Knee Left-Ankle Left	0.5	0.9	Person 5	0	0.33	Person 1	1
Hip Left-Knee Left	1.5	1	Person 3	1	13.3	Person 1	1
Knee Right-Ankle Right	1.0	1.4	Person 1	0	3.93	Person 1	0
Ankle Right-Foot Right	0.5	1.1	Person 4	0	0.42	Person 1	1
Ankle Left-Foot Left	0.5	1	Person 5	0	0.33	Person 1	1
Spine-Shoulder Center	1.5	1.9	Person 4	0	6.46	Person 2	0

FCM algorithm calculates error from the difference of saved data and new data for each point. This algorithm calculate the difference of a particular point's new value with all the saved values of same point, after that it finds out the lowest difference which is the error, at the same time it saves the name of the person who has the same point with lowest difference from new value and thus this algorithm finds out the error and the matched person's name for each point.

For the development of our project we have also calculated the error tolerance label for each point using above algorithm. To find the tolerance we have matched the saved person's data with all data of all people for 10 times and we save the highest error of matched point and thus we have calculated the tolerance label for each point. To accept a person by our system length value of at least 8 segments and at least 4 angle values should be matched with the database.

As depicted in Table 4, we have the experimental tolerance label for each point. We also have two person's error value. 1st person has maximum 4 matched with the known person 4 but in all cases it has crossed the tolerance label. On the other hand 2nd person has maximum of 8 matched with the known person 1 and all 8 values have the error between tolerance labels. Therefore, 2nd person has the greater possibility to be accepted by this system, to be sure we have to match the angle of 2nd person with the known person 1 if it will match too then 2nd person will be accepted.

CHAPTER 05

CONCLUSIONS AND FUTURE WORKS

5.1 Conclusion

This project presents an entry restricted security system which can be applied in entrance of different places where security is a major concern. In the proposed model skeleton information of human body is used for personal identification. Kinect version 1 is used to get skeleton information. The lengths between joint points of skeleton and selected angle's value between some joint parts are used to recognize a person. For improving reliability, in matching we use FCM algorithm. Experimental results show that the proposed model can correctly detect the person. Every system has some advantages. People try to use most advanced system. Our system also has some advantages which will attract people to use it in various purposes.

People use figure print scanner, eye scanner to ensure security. Those systems have limitation. Now a day's finger print and eye scan could be copied, but in our system, body points cannot be copied. So, our system is very reliable.

This system is not online based. So, it wouldn't be hacked through online. Input taking, data save and matching all procedures is locally processed. So, it is more secured than any other online based security system.

Authorized person can be identified without any touch. This system detect person from a specific distance and identify accurately. In other system, people use lock in their door but key may be lost or theft. Our system ensures the most secure security system.

There is no system exist in the world without limitation. Some systems have more and some have fewer limitations. There are some limitations in our system. In this system; there is a fixed position to take input of a person. The distance is also fixed from Kinect to specific position. If a person does not stand in the fixed position, Kinect will not take input. Person must stand in front of the Kinect. Otherwise this system would not be able to identify human and run its process. Authorized person's skeleton information should be in the database, otherwise Kinect will not allow authorized person. In this system, people have to stand in front of Kinect for specific period of time. Then Kinect will take the input data. person have to stand a lighten area. Without lighted place, Kinect cannot detect human.

5.2 Future Work

First of all, we will use this security system to allow or disallow human to enter a home. We will also give notification to an authorized person when any human will allow or disallow. This will help to be more secure for home.

After that we can also use this system for bank, Govt. office or any other organization. It can be used for authorized person to enter in the office. We will also track the face of those people who were rejected by the system to enter. This image of face will be saved in the authorized person's computer for further security purpose.

We will use this system to track number of people entered in the office; if this system placed in the front door. This will also track when people come in the office and when they left the office. Database can identify who are staying in the office. At that time this system can perform as an attendance and tracking human device. Higher authorized person can check the database anytime and will be updated about all people who are in the office, when they come and when they left. This system will be very helpful for government and non-government organizations. This will ensure better security.

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