Combination of Motion History Image and Approximated Ellipse Method for Human Fall Detection System

Elvira Sukma Wahyuni[1], Mohd Brado Frasetyo[2], Hendra Setiawan[3]

Electrical Engineering
Universitas Islam Indonesia
Yogyakarta, Indonesia
Elvira.wahyuni@uii.ac.id[1], 14524030@students.uii.ac.id[2], hendra.setiawan@uii.ac.id[3]

Abstract **- Indonesia has a high number of elderly people, who live alone without any family at home. This matter has a high risk for elderly in biological aspect, in case something goes wrong like fall, therefore a fall detection systems is needed for monitoring elderly conditions at home. This paper propose a human fall detection system using combination of Motion History Image (MHI) and Approximated Ellipse. These method works by generating C_{motion} that represents object motion and $Sigma\_\theta$ and $Sigma\_\rho$ that represents object movement direction. The result showed, this research obtain a good performance in fall detection from a moving object with accuracy is 83.33%.**

Keywords - Image processing; Motion History Image; Approximated Ellipse

I. INTRODUCTION

Indonesia has a high increased number of elderly, in 2010 Indonesia is predicted has higher elderly population than other countries [1]. It is important to notice that 9.66% of elderly live alone without any family at home. It has a high risk for elderly coused by physical endurance reduction, especially in biological aspect such as fall [2]. From the condition, we need a system that can detect the movement of a person especially for unusual movements.

There are some methods that usually used for fall detection system, such as the installation of a device on the body of the object [3] and using camera (Image Processing) [4]. In Indonesia, fall detection using device on objects body is not effective, elderly's memory is usually weak so that the sensor has a risk of damaged or loss. Moreover, Indonesian averages populations are moslem[5], so that the device will often be released when elderly wanting to pray. Fall detection using camera is one of solution for detecting object movement, the system can detect the movement without a direct contact to object. This method uses image processing to process the images taken from the camera then detects movement based on changes in the pixels of the image.

Motion History Image (MHI) is one of image processing method to detect the movement of the object, the recorded video is divided into several images to form a sequence image, these images will be processed to know the movement of the object that is from the pixel changes, in normal activity image pixel does not change greatly, whereas in abnormal movements such as fall, pixels will experience a very rapid changes [4].

Fall detection system using Motion History Image (MHI) have been done by some researchers before, among others are.

Research by Caroline Rougier et al, this research about how to detect someone fall by using computer vision system. The method used is using Motion History Image (MHI) and Human Shape Variation which detects pixel changes in video sequence images so that it can detect a person's movement changes, when the movement is very fast and suddenly stop then someone is considered to fall. The result is the system can detect people falling and can differentiate with daily movement. However, this system uses only 1 camera so that not all object movement can be detected properly [4].

Research conducted by Nuttapong Worrakulpanit et al, this research is on how to detect someone fall by looking at changes in movement speed and changes of object's body position. The method used is Motion History Image (MHI), the fall detection algorithm based on the change of two parameters ie C_{motion} and $Sigma\_\theta$. However, the $Sigma\_\theta$ value is not enough to detect a person's body position change because it only detects changes in movement parallel to the camera's optical axis [6].

Another study conducted by Suad Albawendi et al, this study also uses Motion History Image (MHI) as a motion detection object. However, in this study they use a camera that is placed exactly in front of the object, therefore the camera visibility that they use is limited [7].

II. ALGORITHM REVIEW

A. Motion History Image

Motion History Image is a method to detect the movement of objects, this method detects movement based on pixel changes. The movement of an object is taken from a video that has been divided into several sequence images.

Motion History Image (MHI) was first introduced by Bobick and Davis [9]. Step of MHI is first extract the binary sequence of the object movement D (x, y, t) from the original image I (x, y, t) using the image-differencing method [4]. second compute H_t each pixel using equation 1, in time range t (1 ≤ τ ≥ n).

$$H_\tau(x,y,t) = \begin{cases} \tau & if\ D(x,y,t) = 1 \\ \max(0, H_\tau(x,y,t-1) - 1) & otherwise \end{cases} \quad (1)$$

Note :

x = The position of pixels in x coordinates
y = The position of pixels in y coordinates
$H_\tau(x,y,t)$ = Motion History Image (MHI)
$D(x,y,t)$ = Motion of binary sequense from object

The result is a scalar value of the image where the movement of the object will change to white, the following is the result of Motion History Image, Showed in figure 1.

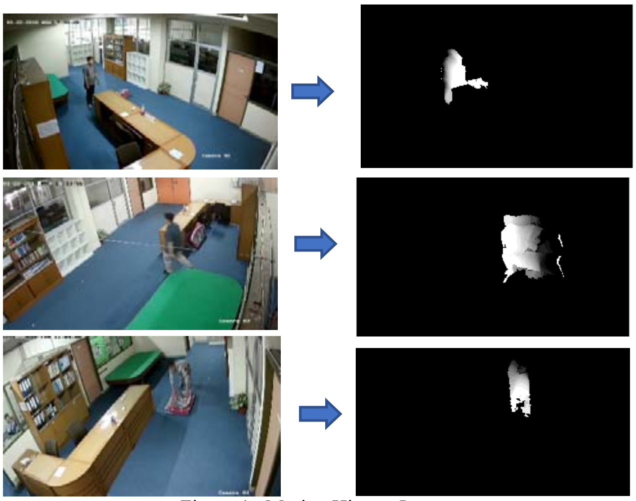

Figure 1. Motion History Image.

B. Approximated Ellipse

Objects will be predicted using ellipse using moments. An ellipse is defined by centroid (x, y), orientation, and major semi-axis a and minor semi-axis b [4]. For a continuous image, the moments values are derived from equation 2:

$$m_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x^p y^q f(x,y)\,dx\,dy \quad (2)$$

Note :

m_{pq} = Moments value
p,q = 0,1,2

Centroid of ellipse is obtained by calculating the coordinates of the center of mass with first and zero spatial order moments using equation 3:

$$\bar{x} = \frac{m10}{m00};\ \bar{y} = \frac{m01}{m00} \quad (3)$$

Note :

$\bar{x}$ = Centroid in x coordinates.
$\bar{y}$ = Centroid in y coordinates.

Centroid (x, y) is used to calculate central moments using equation 4:

$$\mu_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x-\bar{x})^p (y-\bar{y})^q f(x,y)\,dx\,dy \quad (4)$$

Note :

μ_{pq} = Central moments

The angle between the main axis of the object and the horizontal axis x gives the orientation of the ellipse, and can be calculated by the central moments of order 2 from equation 5:

$$\theta = \frac{1}{2}\tan^{-1}\left(\frac{2\mu_{11}}{\mu_{20}-\mu_{02}}\right) \quad (5)$$

Note :

θ = Ellipse orientation

To get the major semi-axis a and minor semi-axis b of ellipse, we must calculate Imin and Imax, ie the smallest moment of inertia and the moment of greatest inertia [4]. This value can be calculated by evaluating the eigenvalue of the covariance matrix from equation 6:

$$J = \begin{pmatrix} \mu_{20} & \mu_{11} \\ \mu_{11} & \mu_{02} \end{pmatrix} \quad (6)$$

Note :

J = Covariance matrix

The eigenvalue of the matrix J is Imin and Imax which is calculated by equation 7 :

$$I_{min} = \mu_{20} + \mu_{02} - \frac{\sqrt{(\mu_{20}-\mu_{02})^2 + 4{\mu_{11}}^2}}{2}$$
$$I_{max} = \mu_{20} + \mu_{02} - \frac{\sqrt{(\mu_{20}-\mu_{02})^2 + 4{\mu_{11}}^2}}{2} \quad (7)$$

Note :

I_{min} = Minimum value of moment inertia
I_{max} = Maximum value of moment inertia

Then the major semi-axis a and minor semi-axis b calculated by equation 8 :

$$a = \left(\frac{4}{\pi}\right)^{\frac{1}{4}} \left(\frac{(I_{max})^3}{I_{min}}\right)^{1/8}$$
$$b = \left(\frac{4}{\pi}\right)^{\frac{1}{4}} \left(\frac{(I_{min})^3}{I_{max}}\right)^{1/8} \quad (8)$$

Note :

a = Major semi-axis a
b = Minor semi-axis b

With a and b we can determine the ratio of ellipse by equation 9 :

$$\rho = \frac{a}{b} \quad (9)$$

Note :

ρ = Ratio of ellipse.

III. Proposed System

A. Research Flow

This human fall detection has several stages, each stage has its own function to complete the system. Figure 2 is a block diagram of the system.

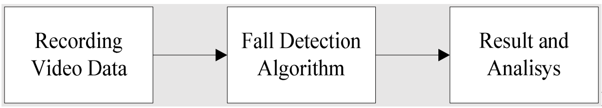

Figure 2. Research Flow Diagram

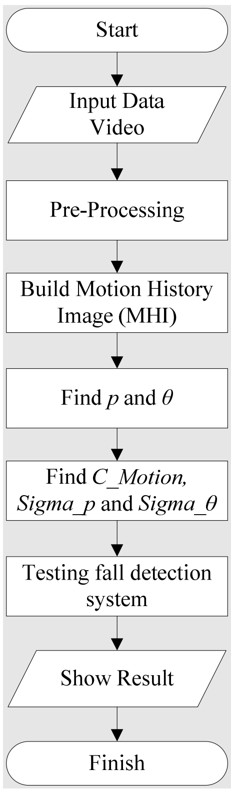

Figure 3. Diagram of Hunam Fall Detection System

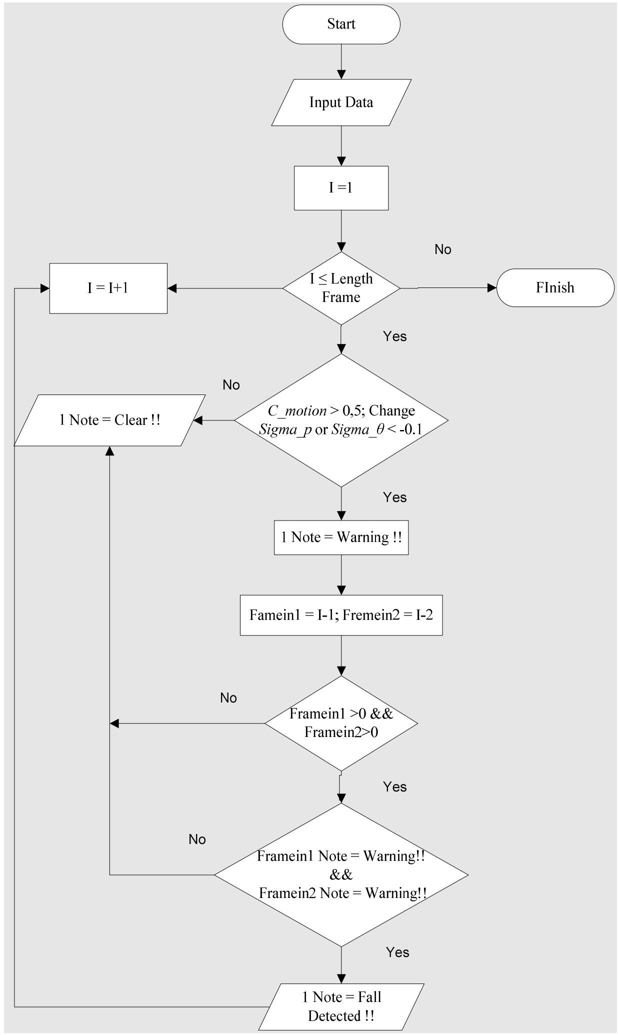

Figure 4. Fall Detection System Algorithm

B. Recording Video Data

The first stage in this research is to take video data as data input of fall detection system using 4 CCTV cameras that have been installed at every corner of the Computer Programming Laboratory UII. The amount of video data used in this study is 30 data, each 15 fall data and 15 not fall data. The video resolution is 1280 x 720 pixels.

C. Design of Human Fall Detection System

Fall detection system is designed using MATLAB 2017. Figure 3 show the system flow diagram.

The first step is we put in the recorded video data, the data will be converted into several frames then through pre-processing process, that is foreground detection and filtering blob. Afterward, we build motion history image and calculate rho and theta value using approximated ellipse. After MHI and approximated ellipse are obtained then we will get parameter C_{motion} , $Sigma\_\theta$ and $Sigma_{\rho}$. Furthermore, all these parameters will be used as a reference to the fall detection algorithm. Finally, we show the results of the human fall detection system.

D. Algorithm

The previously captured video data will be analyzed using the fall detection system algorithm, which is based on the speed of the object movement (C_motion > 0.6) [4], and the change of body shape of the object (Change of Sigma_ ρ or Sigma_ θ < -0.1). The threshold is designed by looking at the parameter response of some video data, then selecting the value with the highest accuracy. To calculate the value of C_motion is using this equation 10 :

$$C_{motion} = \frac{\sum pixel_{(x,y)} \in blob\ H_{\tau}(x,y,t)}{\#pixels \in blob} \quad (10)$$

Note :

C_{motion} = Coefficient of object motion
blob = *blob* of pixel that representing the person.

After C_{motion} calculated, next step is calculate the value of $Sigma\_\rho$ and $Sigma\_\theta$, where the value is obtained from equation 11 :

$$Sigma\_\theta = \sigma_{\theta}$$
$$Sigma\_\rho = \sigma_{\rho} \quad (11)$$

Note :

$Sigma\_\theta$ = The orientation standard deviation
$Sigma\_\rho$ = The orientation standard deviation

If a person falls perpendicularly to the camera optical axis, than the orientation will change significantly. If a person fall parallel to the camera optical axis, than the ratio will change significantly. Flow chart of the fall detection algorithm system is represented in Figure 4.

The flow chart explains that if all of the parameters are qualify, it will generate a "*Warning !!*". Therefore, if three times sequential "*Warning* !!" is occurred, the data will be considered as a fall data. Data will be analyzed from the first frame to the last frame of the video.

IV. Result and Discussion

A. Testing CCTV Camera.

This step we recording data using 4 CCTV cameras that have been installed in every corner of the room. Figure 5 is a data view object that has been recorded using all CCTV.

Figure 5. Result of Recorded Data From 4 CCTV Camera

B. Motion History Image Conversion (MHI)

We converting the data of each video frame into MHI. This process has several stages which is foreground detection, filtering blob, and build MHI. Figure 6 shows the process of converting video frame data into MHI.

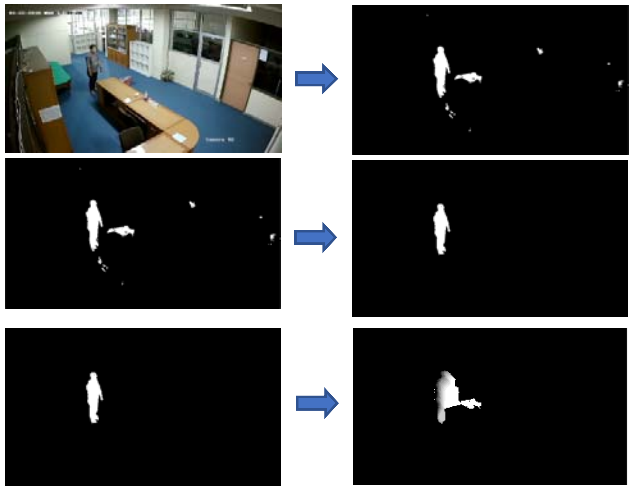

Figure 6. Motion History Image Conversion Process

C. Testing Algorithm on Different Condition

We testing this fall detection system algorithm on different conditions which aims to test whether the fall detection system has a good performance. First, we testing the algorithm for the different fall positions shown in Figure 7 below.

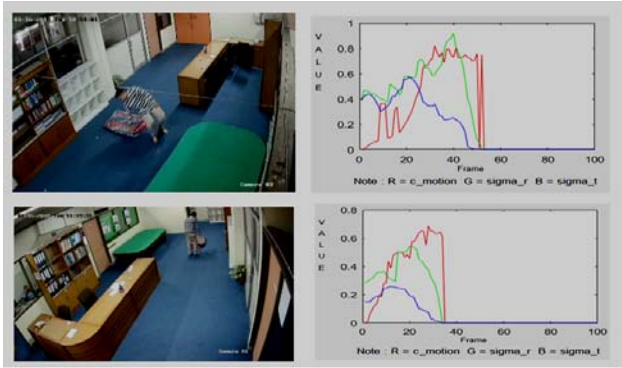

Figure 7. System's response on different fall posistion

The results indicate that the position of object in the middle of the room is the most ideal position to detect the fall, this is because all movement of object can be seen clearly by all the cameras, so the parameter data obtained becomes more accurate. Whereas when object is too far away from the camera, accuracy will slightly decrease because object causes the pixel change only in the small area. Next we testing the algorithm on the different falling movements as in figure 8 below.

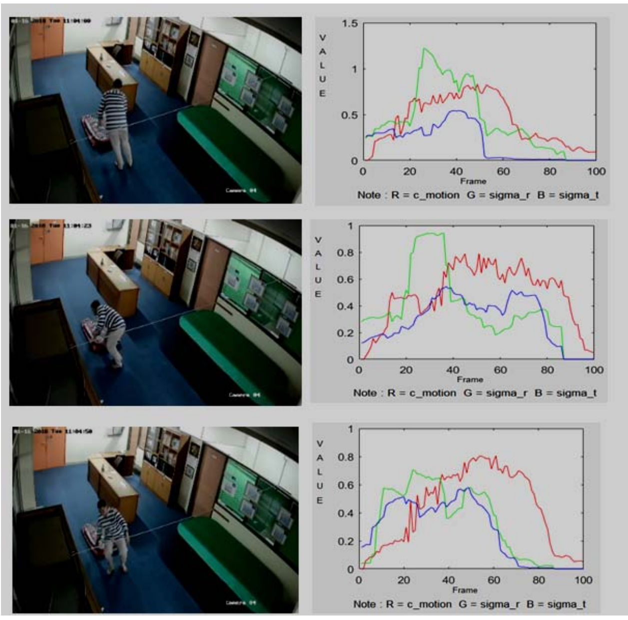

Figure 8. System's response on different fall movement direction

The results show that all falling motions can be detected using fall detection algorithm. The resulting parameters is similar despite the different falling movements, as the falling movements have a similar motion that starts from a standing position, moves rapidly, falls asleep and stays quiet.

Next we testing the fall detection algorithm against the different light intensity of the room as shown in Figure 9:

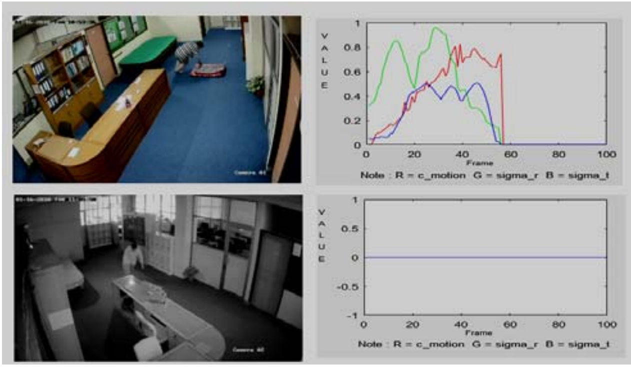

Figure 9. System's response on different light intensity

The results show that when intensity of light is bright algorithm can detect fall well, because the camera can catch the parameter changes more clearly and only get a little disturbance from the shadow object, so the parameters generated become more accurate. But when light intensity is dark, fall can not be detected. This is because the pixel data is not captured by the camera so the C_{motion} parameter does not appear.

D. Result

We testing fall detection algorithm with 30 data, Table 1 show the result of fall detection system with 15 fall data and 15 non-fall data.

TABLE 1. RESULT OF HUMAN FALL DETECTION SYSTEM TEST

No	Data	Cam 1	Cam 2	Cam 3	Cam 4
1	Fall	×	×	✓	✓
2	Fall	✓	✓	×	✓
3	Fall	✓	✓	✓	×
4	Fall	×	✓	✓	✓
5	Fall	×	✓	×	✓
6	Fall	×	×	✓	✓
7	Fall	×	✓	✓	✓
8	Fall	✓	✓	✓	×
9	Fall	×	✓	✓	×
10	Fall	×	×	✓	✓
11	Fall	×	✓	✓	×
12	Fall	×	✓	✓	×
13	Fall	×	✓	×	×
14	Fall	✓	×	×	✓
15	Fall	×	✓	✓	✓
16	Non-Fall	×	×	×	×
17	Non-Fall	×	✓	✓	✓
18	Non-Fall	×	✓	×	×
19	Non-Fall	✓	✓	✓	✓
20	Non-Fall	×	×	×	×

No	Data	Cam 1	Cam 2	Cam 3	Cam 4
21	Non-Fall	✓	×	×	×
22	Non-Fall	×	×	✓	✓
23	Non-Fall	×	×	×	×
24	Non-Fall	×	×	×	×
25	Non-Fall	×	✓	×	✓
26	Non-Fall	×	×	×	×
27	Non-Fall	×	×	×	×
28	Non-Fall	×	×	×	×
29	Non-Fall	×	×	×	✓
30	Non-Fall	×	×	×	×

Note : ✓ = Fall Detected ; × = No Fall Detected.

The result indicating the system accuracy is equal to 83.33%. This result is considered using threshold "If fall is detected on ≥ 2 camera" then the data will be considered as falling data. The condition is used because it is considered better than other conditions, ie when using the condition "If fall detected ≥ 1 camera", the status of other cameras will be more dominant. Whereas when using the condition If fall detected ≥ 3 camera or 4 camera", fall detection accuracy going reduced. There is an error that is caused by the movement that have a similar changes of parameter like a fall, that is object runs quickly then stops, the object sits extremely, or presence of excessive shadow intensity.

V. CONCLUSION

Fall detection system is influenced by some conditions that cause the performance of the algorithm to be disturbed, namely the distance between the camera with the object too far or too close, the existence of other objects that block the object to be detected, the speed of falling objects and light intensity of the room.

Fall detection system has a good performance against the difference direction of fall and difference color between objects and background. This human fall detection system has an accuracy of 83.33%, using experimental fall and non-falling data.

ACKNOWLEDGMENT

The authors would like to thank to directorate research, technology and general high education (RISTEKDIKTI) Indonesia for supporting this project.

REFERENCE

[1] Central Bureau of Statistics. "Statistical elderly population." *Central Bureau of Statistics, Jakarta – Indonesia,* 2015.

[2] Ministry of Health R.I. "The Elderly Situation (Elderly) in Indonesia: May 29-National Elderly Day." *InfoDATIN Data and Information Center Ministry of Health RI,* 2016.

[3] Kwolek, Bogdan, and Michal Kepski. "Improving fall detection by the use of depth sensor and accelerometer." *Neurocomputing* Vol.168, 2015.

[4] Central Bureau of Statistics. "Citizenship, ethnicity, religion, and colloquial Indonesian citizens: Results of the 2010 population census." *Central Bureau of Statistics, Jakarta – Indonesia,* 2011.

[5] Rougier, Caroline, et al. "Fall detection from human shape and motion history using video surveillance." *Advanced Information Networking and Applications Workshops, 2007, AINAW'07. 21st International Conference on*. Vol. 2. IEEE, 2007.

[6] Worrakulpanit, Nuttapong, and Pranchalee Samanpiboon. "Human fall detection using standard deviation of C-motion method." *Journal of Automation and Control Engineering* Vol.2 No.4, 2014.

[7] Albawendi, Suad, et al. "Video based fall detection with enhanced motion history images." *Proceedings of the 9th ACM International Conference on Pervasive Technologies Related to Assistive Environments*. ACM, 2016.

[8] T.Sutoyo, Edy Mulyanto et all "Digital Image Processing Theory" *Andi & Universitas Dian Nuswantoro- Semarang*, 2009.

[9] Bobick, Aaron F., and James W. Davis. "The recognition of human movement using temporal templates." *IEEE Transactions on pattern analysis and machine intelligence*. Vol.23 No.3, 2001.

[10] Kim, Kyungnam, et al. "Real-time foreground–background segmentation using codebook model." *Real-time imaging* Vol.11 No.3 2005.