Fall Detection – Vision-Based Indoor Environment

Conference Paper · November 2014

1 author:

Dnon Dnon
Memorial University of Newfoundland

Fall Detection – Vision-Based Indoor Environment

Younis E. Abdalla, M. Shehata, T. Iqbal
Memorial University of Newfoundland
St. John's, NL, Canada. A1B3X5
yea764@mun.ca, mshehata@mun.ca, tariq@mun.ca

Abstract -- **Recent statistics show that the population of elderly people who live alone is increasing at a fast rate. Automatic monitoring systems for elderly people can help automatically detect falls and speed emergency response authorities and help reduce the number of injuries, and subsequent fatalities that occur as a result of falls. Most current vision-based approaches extract geometric information on the moving human from a live video stream, such as orientation, centroid, velocity, and other dynamic object features. These techniques suffer from a high false detection rate in specific postures. This paper presents an algorithm for fall detection that has high accuracy of fall detection in all postures.**

Keywords **– Fall detection, Vision Algorithms, Elderly, Healthcare.**

I. INTRODUCTION

According to recent statistics, 30% of elderly people fall at least once a year, resulting in 70% of accidental deaths [1]. The dramatic increase in the population, particularly the increasing number of older people, is resulting in an increase in the number of individuals who live alone; therefore, offering automatic monitoring of human activities will improve their environments and can assist automatically detect falls and speed emergency response authorities and help reduce the number of injuries and deaths resulting from sudden and harmful falls, in addition to reducing healthcare costs [2]. Indeed, in today's society, the young generations are busier than ever before because of jobs and entertainment. Younger people are more occupied than ever, decreasing the attention they give to older people, even those who live in the same house as them. Automatic tracking systems are important for those who have an old person living with them in the same house, and of course the system has become very important in hospitals and seniors' homes. The consequence of the increasing number of elderly people, who frequently stay in hospitals and health care centers, makes individual monitoring a hard job for nurses and other healthcare providers. In case of a sudden fall or unexpected illness, the system will ensure that the older individual is in a safe situation [3]; otherwise, it will send an alarm. Thus, fall detection systems have become the alarm systems most used when dangerous falls occur, and it may be become the main emergency caller to escalate the level of auto care. Finally, because the computer vision-based system shows more accuracy by providing real time tracking and can save time for people in the private sector who are willing to use this system, we propose an algorithm that uses multiple factors and the decision belts on voting function.

This paper is organized as follows: first, it gives an overview of related works, and the next section will illustrate the proposed algorithm processing. The discussion of the results will be presented after that. At the end we will conclude the work and propose future work directions.

II. RELATED WORK

The main important categories of falls detection are: wearable device, ambience device and vision-based [4], [5], [6]. Wearable devices are basically designed to be attached to the targeted object, and they use embedded sensors to monitor the activity of the body by using accelerometers, whereas the ambience device captures the posture of the body based on either sound or audio to detect falls. Vision-based is the most increasing research area nowadays, and it has the most advantages over the two above approaches [6].

In this paper we will state three main problems: an increase in the number of injuries and deaths among elderly people who live alone due to harmful and sudden falls, failure to provide classic 24-hour monitoring system functions and delays and/or the inability to manually trigger alarms by the fallen elderly individual. The proposed algorithm is our participation in the attempt to solve these problems. The criteria of the solution will be following four steps: detecting the person, tracking the motion, detecting the falls and sending an alarm.

III. System Overview

The system input and the methodology follow the chart shown in Fig. 1

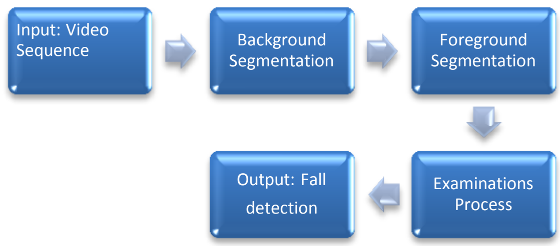


Figure 1: System Frame work

In this paper we use pre-recorded video. The system requirements are divided to two parts. The first part is the hardware, such as the computer, camera and the environment of the work. In this work we used a laptop has a processor Intel(R) core (TM) vi3 CPU M330 @ 2.13GHz, RAM 4.00GB. The second part is the software: Windows 7 and Matlab 2012.

In order to apply the same experiment on the real time process, we need a USB 2.0 camera. In this case we should carefully choose the right position to fix the camera in and determine the camera calibration before starting the tracking. The environment of tracking in this work is proposed to be a single room, as you see in Fig. 2, with a non-busy background; for example, a private hospital room.

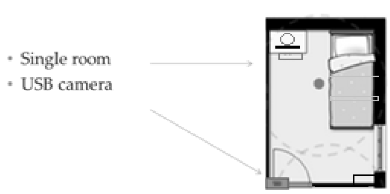


Figure 2: Projected environment

IV. Solution Methods

To achieve good results in this project, we considered four factors to determine the fall action. In fact, this processing part is responsible for making the decision based on the applied formula. In Fig. 3 the examination part shows the main factors used in this algorithm.

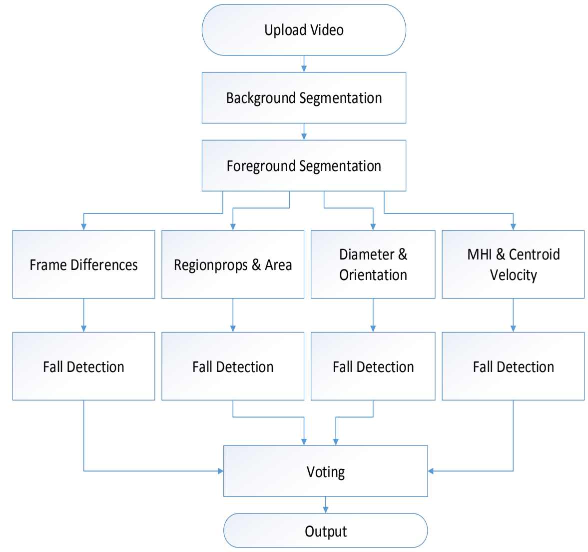


Figure 3: Block diagram of the system presented the examination and voting tasks

A. *Frame Differences*

We demonstrate that the joint use of frame by frame differences with a specific frame as a constant background and apply a subtraction function for this purpose. In fact, it gives a strong and fast pixels foreground classification and without the need of previous background [7].

The strategy was used is to find if the frame has a horizontal gesture, which represents a fallen human body, and then we used this frame as a background subtraction frame. By looping all the video frames by frame and specifying the suitable threshold, we can determine where the fall happens. The equation (1) summarises the idea, as you can see in Fig. 4.

$$Fall = [\ \sum_{n=0}^{n-1}(frame_n - frame_c) < Threshold >] \qquad (1)$$

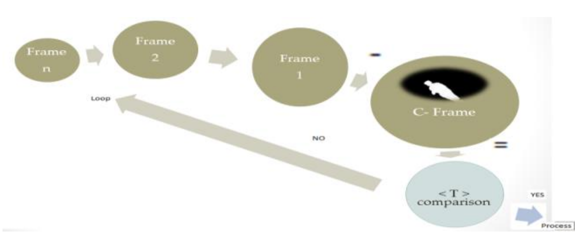


Figure 4: Frame differences algorithm

B. *Region-Props Area*

IT presents the actual number of pixels in the region. (This value might differ slightly from the value returned by bw-area, which weights different patterns of pixels differently.) See Fig. 5

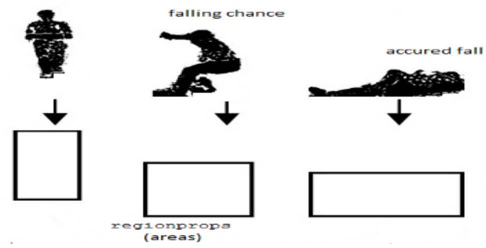


Figure 5: The regionprops area for different human positions [8]

C. Orientation

The angle (in degrees ranging from -90 to 90 degrees) between the *x*-axis and the major axis of the ellipse that has the same second-moments as the region. This property is supported only for 2-D input label matrices [9] See Fig. 6

By:- using Regionprops property

>> stats = regionprops(bw,'Orientation');

Or: by using centroid

$$m_{p,q} = \sum_{(x,y)\in R} x^p y^q \, f(x,y) \quad (2)$$

$$C = \frac{2M_{11}}{M_{20} - M_{02}} \quad (3)$$

$$Theta = 0.5 \times \tan^{-1}(C) \quad (4)$$

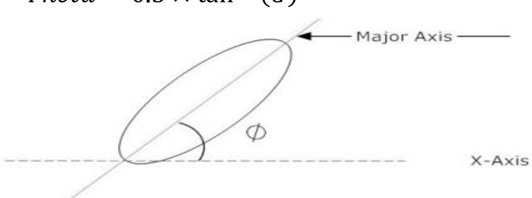


Figure 6: Theta between major and X axis represents the orientation of the ellipse

D. Motion History Image (MHI)

We can use two methods to find the frames that have only moving objects. One way is to extract the foreground object from the background and use the entire object as an input signal. We have actually found this, and that is more forceful than defined frame differencing but it requires having a background image to remove. To compute the frame difference MHI, we first need to compute the frame difference sequence. This can be done by using the binary image $f_t(x,y)$ which is defined simply as [10]:

$$f_t(x,y) = \begin{cases} 1 & if \ \left(f_t(x,y) - f_{t-1}(x,y)\right) \geq theta \\ 0 & if \quad otherwise \end{cases} \quad (5)$$

Why MHI is used:

- To compute the person's motion velocity.
- To represent how motion is moving.
- It could be applied by the next function.

$$C_{motion} = \frac{Gray\ frame_{(pixel's\ No.)}}{Gray\ frame_{(pixel's\ No.)} - White\ frame_{(pixel's\ No.)}} \quad (7)$$

The gray pixels and white pixels can be represented by the Fig. 7 where the figure shows the stable object on the left side and it has only the white pixels. On the other hand, the object on the right side has both gray and white pixels.

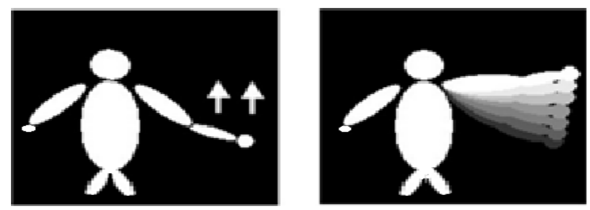


Figure 7: Presents the MHI

When we apply the function (7), will get the C as the following: $0 \leq C_{motion} \leq 1$.

Where: -

- 0 :- Centroid velocity in zero
- 1 :- High velocity
- C_{motion} :-
  - Low centroid velocity (Rotating around)
  - Medium centroid velocity (Walking)
  - High centroid velocity(Falling)

Zhengming Fu et al. [11] show the centroid velocity in different situations of human activities.

V. RESULT AND DISCUSSION

In this work we pass through different sequences of processes to get the targeted output (Full Detection). In the following we will try to summarise this process.

A. Foreground Processing

After the reading is done, we convert the video stream to a frames sequence to deal with each frame as an individual image, so we can apply the next steps: First, transfer each frame from the RGB model to gray scale. Second, apply different types of filters to achieve good quality for the image before applying the segmentation. We applied a special filter: (medfilt2(vid_Obj, [3 3])). In order to make good segmentation, we transfer the gray scale image to a binary image, so they will have only ones and zeroes in the frames (im2bw). Next, connective components are applied later in order to have one complete object in processing tasks. The minimum object will appear assigned by a threshold equal to 300 pixels. The next few steps are to ensure the filtering stage on the object. Foreground segmentation is applied by using a Gaussian filter and detector function. In this step in particular we assumed the threshold to be 0.78. Finally, we display the foreground object as a mask. See Fig. 9

Figure 9: Full foreground segmentation for the tracking object

B. Background Processing

Handling the background takes common steps with foreground processing. In fact, to achieve very high acquisition to the foreground, we have to obtain very good background segmentation, as in Fig. 10, where we can easily do that based on the binary image as we mentioned above.

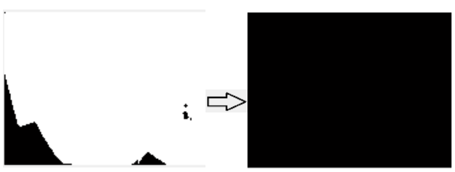


Figure 10: The transformation of the background from black and white to a binary image and application of the segmentation

VI. IMPLEMENTATION AND OPTIMIZATION

Processing a long and verity pre-recorded videos is computationally expensive and confusing. In fact this paper uses samples of 30 sec duration. Depending on of the system classification, as mentioned above, the actual time for the same samples is run by Matlab for five times. This time span is called minimum trail, which is the time from 59 sec to 67.8 sec. Between 18sec to 19.5 sec is the time consumption to finish the fall including fall detection time which consumes 6 sec at maximum. Analyses show that the key performance is the computational processing time with the system accuracy.

VII. EVALUATION OF THE RESULTS

As we mentioned above, there much progress has been made in the way to achieve the final goal, which is fall detection. However, there were some difficulties in finishing this work. For example, some parameters take longer to compute and that is because of the Matlab toolbox size. On the other hand, the impact of doing this work gives good a resolution about the vision methodology and concepts. This evaluation will be focused on the main steps and the optimal solution from our angle of view.

First, once the foreground task has been done, the rest of the work will be based on this factor. Thus, the quality of the foreground segmentation will affect all the results of the application. Pre-recorded video samples were used in the tests, so the camera's information will not be considered, as well as the camera calibration.

Second, based on the information from the proposal solution techniques there are different techniques to detect falls. For instance, using Orientation of the body by using X & Y axes as defined by major and minor axes, Centroid event, Motion History Image (MHI), and the Hidden Markov Model (HMM). In our work, we suggested to apply four joint parameters, as we discussed above.

Next, the voting part is ensuring that the final decision will be applied by a complex (IF) condition function in this algorithm. In case the voting does not satisfy the threshold, however, the voting value was close enough from the actual threshold, so we take this case as falling chance and it will be automatically reported by our application to give an overview of the object activities. In fact, this is one way to accomplish two goals. First, from a technical perspective, it opens a window to use to view the accuracy of the algorithm and provides a way to escalate the proficiency of the system in the future. Second, from the healthcare perspective, it helps to identify some health problems with the person at an earlier time.

Finally, we will present some screen snapshots about the outputs we obtained in Fig. 11, 12, 13, 14.

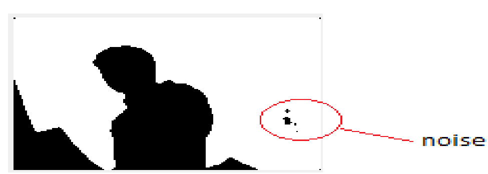


Figure 11: B&W image with some noise before the filtering process

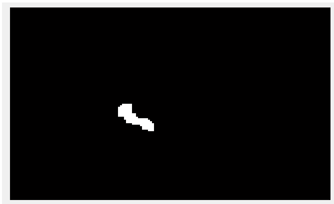


Figure 12: Final action of the fallen body in a foreground representation, noise-free

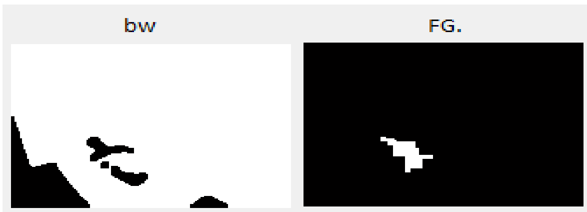
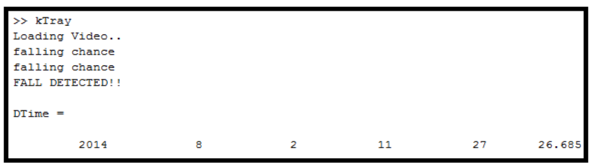


Figure 13: Presenting the fall in a BW frame and FG Frame



```
>> kTray
Loading Video..
falling chance
falling chance
FALL DETECTED!!

DTime =

        2014        8        2        11        27        26.685
```

Figure 14: The final output shows the fall decisions, date and time of fall

VIII. CONCLUSION AND FUTURE WORK

An automatic fall detection system was successfully developed. In fact, the automatic monitoring system uses more parameters, which make it more accurate than some of the existing systems. Indeed, the system creates a file which includes a report for each fall detection details and saves it in a specific location, so it could be used in the person’s health history. Finally, the prerecord video which was used for all experiments simulated a real time process successfully. Future work can be done by using open CV software for real time processing, using a real time video stream and using a 3D depth camera to fix the light alteration problem.

REFERENCES

[1] A. Fern'ndez-Caballero, M. Sokolova, J. Serrano-Cuerda, J. Castillo, V. Moreno, R. Castineira and L. Redondo, "HOLDS: Efficient Fall Detection through Accelerometers and Computer Vision," *Intelligent Environments (IE), 2012 8th International Conference, IEEE computer society,* pp. 367 - 370, 26-29 June 2012.

[2] N. Thome, S. Miguet and S. Ambellouis, "A Real-Time, Multiview Fall Detection System: A LHMM-Based Approach," *Circuits and Systems for Video Technology, IEEE Transactions,* vol. 18, no. 11, pp. 1522 - 1532, 2008.

[3] G. Feng and Q. Lin, "Design of Elder Alarm System Based on Body Posture Reorganization," *Anti-Counterfeiting Security and Identification in Communication (ASID), International Conference . IEEE,* vol. 3, pp. 249 - 252, 2010.

[4] X. Yu, "Approaches and Principles of Fall Detection for Elderly and Pationt," *e-health Networking, Applications and Services, 2008. HealthCom 2008. 10th International Conference,* pp. 42 - 47, 2008.

[5] N. Noury., A. Fleury., A. Bourke, G. O. Laighin, V. Rialle and J. Lundy, "FallDetection - Principles and Methods," *Proceedings of the 29th Annual International Conference of the IEEE EMBS Cité Internationale, Lyon, France,* pp. 1663 - 1666, 2007.

[6] M. Mubashir., L. Shao. and L. Seed, "A survey on fall detection: Principles and approaches," *Neurocomputing 100,* pp. 144 - 152, 2013.

[7] M. M. a. M. N. Davide A. Migliore, "A Revaluation of Frame Difference in," in *Santa Barbara*, California, USA, 2006.

[8] F. V. A. Edgcomb, “ww.cs.ucr.edu/~vahid/assistivemonitoring/," UCR: Assistive monitoring, 2013. [Online]. [Accessed 26 7 2014].

[9] MathWorks, "www.mathworks.com/help/images/ref/regionprops.html#bqkf8ji," MathWorks. [Online]. [Accessed 24 7 2014].

[10]"http://www.cc.gatech.edu/~afb/classes/CS4495-Fall2012/ProblemSets/PS7/ps7-descr.pdf," 14 December 2012. [Online]. [Accessed 23 July 2014].

[11] Z. Fu, T. Delbruck, P. Lichtsteiner and E. Culurciello, "An Address-Event Fall Detector forAssisted Living Applications," *Biomedical Circuits and Systems, IEEE Transactions ,* vol. 2, no. 2, pp. 88 - 96 , 2008.

[12] M. Shehata, "www.mun.ca," 4 2014. [Online]. [Accessed 5 2014].