Automated Monitoring System for Fall Detection in the Elderly

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Abstract

Falls are a major problem for the elderly people living independently. According to the World Health Organization, falls and sustained injuries are the third cause of chronic disability. In the last years there have been many commercial solutions aimed at automatic and non automatic detection of falls like the social alarm (wrist watch with a button that is activated by the subject in case of a fall event), and the wearable fall detectors that are based on combinations of accelerometers and tilt sensors. Critical problems are associated with those solutions like button is often unreachable after the fall, wearable devices produce many false alarms and old people tend to forget wearing them frequently. To solve these problems, we propose an automated monitoring that will detects the face of the person, extract features such as speed and determines if a human fall has occurred. An alarm is triggered immediately upon detection of a fall.

Keywords: Fall Detection; Monitoring System; Face Detection; Elderly; Webcam.

1. INTRODUCTION

Falls and sustained injuries among the elderly are a major problem worldwide. The proportion of people sustaining at least one fall during one year varies from 28-35% for the age of 65 and over. The risk of falling increases with age, and in 2 cases out of 3 it happens at home. People that experience a fall event at home, and remain on the ground for an hour or more, usually die within 6 months. In the last years there have been many commercial solutions aimed at automatic and non automatic detection of falls [1][2][3][4] like the social alarm, which is a wrist watch with a button that is activated by the subject in case of a fall event, and the wearable fall detectors that are based on combinations of accelerometers and tilt sensors. Critical problems are associated with those solutions; the main problem in the first solution is that the button is often unreachable after the fall especially when the person is panicked, confused, or unconscious. In the second solution, the problem is that these devices produce many false alarms, and old people tend to forget wearing them frequently [5][6][7]. To solve these problems, we propose a framework for the monitoring of elderly people, including fall detection capabilities, by using a webcam system without any user intervention. Cameras in in-home assistive system present several advantages over different sensors: they are less intrusive because installed on building (not worn by users), they are able to detect multiple events simultaneously and the recorded video can be used for post verification and analysis.

This paper presents an automated monitoring system based on image processing of the person's movement in real-time; this system will detects the face of the person, extract features such as speed and determines if a human fall has occurred. An alarm is triggered immediately upon detection of a fall.

In this paper, we present an automated monitoring system based on image processing in real time; this system detects the face of a person in a given area, collects data such as the speed of movement of the person, and determines whether the person has suffered a fall; an alarm is triggered immediately upon the detection of a fall.

2. WEBCAM MONITORING SYSTEM

This section describes the monitoring system, as well as its main functions. The system detects the face, extracts features (speeds, distance face-webcam, face presences), determines if a fall occurred and triggers an alarm upon fall detection.

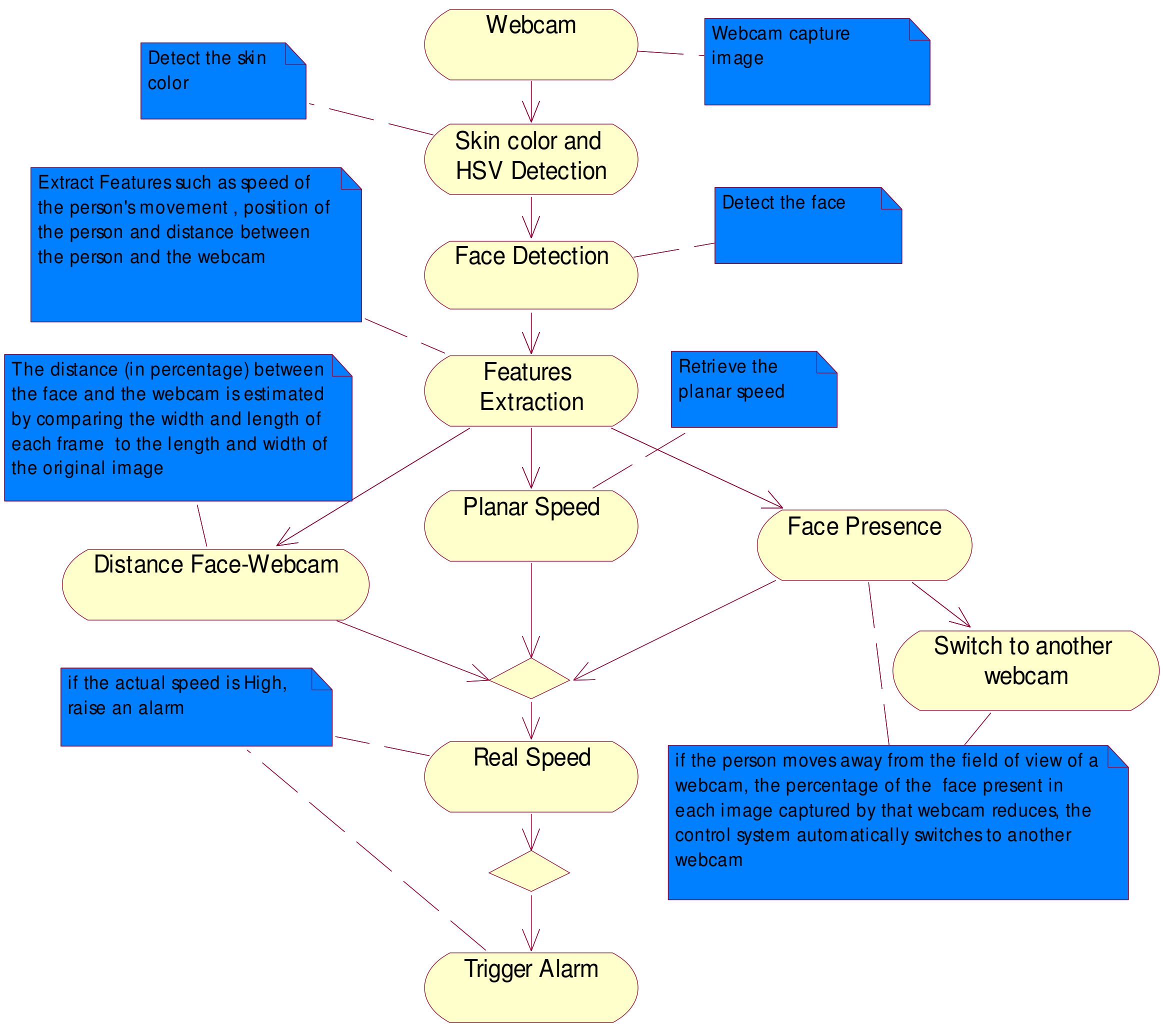

FIGURE 1: Monitoring System Architecture

2.1 Webcam

The Webcam is the entry point of the monitoring system. It detects the person's movement. Notes that we will have more than one webcam in order to cover all the area. Based on the presence of the face according to the webcam, a switch will be done to the other webcam. So at this phase, we have images of the person's movement that will be processed later.

2.2 Skin color and HSV detection

After having images of the person catched by the webcam, the system will proceed to the detection of skin color, which is an effective way often used to define a set of areas that could contain a face or hands. In addition, it can be accomplished easily based on thresholds in an appropriate color space. Different color spaces are used as skin color pixels: RGB, RGB standard, HSV (or HSI), YCrCb ... HSV is used which provides very good results. After detection of skin color, image filtering will be applied (erosion and dilation).

2.3 Face detection

After identifying skin areas, it is also necessary to distinguish the face, for this, the correlation is done between the detected object and the ellipse. The correlation technique is very effective and efficient. This technique is based on an approach using the comparison with an ellipse.

2.4 Features Extraction

After detecting the face of the person, features properties are needed to be extracted (speed, position, and distance from webcam) in order to determines if a human fall has occurred.

2.4.1 Distance Face-Webcam

After extracting the properties of the detected face, we can determine the distance face-webcam. By comparing the width and length of each frame to the length and width of the original image we obtain the percentage of this distance.

First, knowing the width and length of the first frame, we calculate the area (Area = length * width) in order to know the distance (%) in the initial image (we assume 50,000 pixel as maximum area). Secondly, we determine the following:

- X=width/width0
  where width is the width of the detected face for each frame
  Width0 is the width of the detected face for the initial frame

- Y= length/length0
  where length is the length of the detected face for each frame
  Length0 is the length of the detected face for the initial frame

Third, according to the value of X or Y, we obtain the percentage of the distance for the current frame.

The purpose is to take the nearest value of 1; if the person detected by the camera turned his face to the right / left or up / down, only one parameter will change: if the move is left / right, the width varies from initial width (width0) while the length is very close to the initial length (length0). If the face moves up or down, in this case the length varies and the width is close to initial width.

2.4.2 Face Presence

For the fall detection and surveillance of an elderly person, we should use more than one webcam as this person may changes his position to become in an area not covered the webcam. To handle this problem, the percentage of the presence of the face for a webcam should be calculated. So if the person moves, the control automatically turns the webcams depending on the percentage of the presence of the face calculated for each webcam. This percentage is obtained by using the following expression:

Z= X/Y = (width/width0)*(length0 /length)

2.4.3 Planar Speed and Real Speed

The planar speed is calculated based on the following formula:

Speed = distance/time (pixel/sec)

Distance: is distance between two faces in consecutive frames (pixel)
Time: processing time between two consecutive images

The fall detection depends on the speed and the distance face-webcam at the same time. We therefore define the real speed as:

Real speed = planar speed *(1/Z) (Z is defined in section 4.2)

Having the real speed, we can adopt the classification below:

- Low speed : 0-200
- Normal speed : 200-400
- Medium speed: 400-600
- High speed: 600 and up

3. RESULTS

In this section, we present the results obtained using the proposed monitoring system.

3.1 Distance between face and webcam

Frame	Width	Length	X = width/ width0	Y = length/ length 0	Zoom (zoom %)	Planar Speed (pixel/s)	Actual speed
1	113	159	1	1	35.93 %	-	
5	104	148	0.920	0.930	33.44 %	6.3434	18.97
7	94	133	0.831	0.836	30.05 %	21.211	70.59
9	81	114	0.716	0.716	25.76 %	0	0
15	56	81	0.495	0.509	18.30 %	6.2192	33.98
16	55	78	0.486	0.490	17.62 %	8.6235	48.94

TABLE 1: Planar and actual speeds calculated on basis of distance between face and webcam

In the above table, frames 5 and 15 have almost the same planar speed but different zoom (z) values. Therefore, the actual speeds are different.

3.2 Face presence

By considering 6 frames detected by the webcam, we obtained the following results:

Frame	**Width**	**Length**	**X = width/ width0**	**Y = length/ length 0**	**Zoom (zoom %)**	**Face presence (%)**	**Remarks**
1	157	203	1	1	63.74 %	100 %	
4	131	193	0.834	0.950	60.59 %	87.76 %	
7	73	172	0.421	0.847	54.01 %	54.88 %	Switch to another webcam
10	101	189	0.64	0.931	69.34 %	69.09 %	
14	132	192	0.840	0.945	60.29 %	88.89 %	
16	140	198	0.891	0.975	62.17 %	91.42 %	

TABLE 2: Face presence

3.3 Fall detection

3.3.1 Results With 8 frames

By considering 8 frames detected by the webcam, we obtained the following results:

Frame	Width	Length	X = width/ width0	Y = length /length0	Zoom (zoom %)	Planar Speed (pixel/s)	Actual speed
1	84	85	1	1	14.28 %	-	
2	102	91	1.214	1.070	15.28 %	80.67	527.97 Medium
3	83	90	0.988	1.058	15.12 %	63.76	421.72 Medium
4	82	91	0.976	1.070	15.29 %	40.32	263.72 Normal
5	75	86	0.982	1.011	14.45 %	85.85	594.15 Medium
6	80	76	0.952	0.894	13.60 %	29.57	217.43 Normal
7	81	89	0.964	1.047	14.95 %	57.80	386.64 Medium
8	80	85	0.952	1	14.28 %	87.83	615.10 High ALARM

TABLE 3: Fall detection with 8 frames

3.3.2 Results With 5 frames

By considering 5 frames detected by the webcam, we obtained the following results:

Frame	Width	Length	Surface	X = width/ width0	Y = length /length0	Zoom (zoom %)	Planar Speed (pixel/s)	% of presence	Actual speed
1	82	90	7380	1	1	14.7 %	-	100 %	
2	83	85	7055	1.01	0.94	14.9 %	13.3	100 %	89.24 Low
3	94	99	9306	1.14	1.10	16.2 %	58.2	100 %	358.5 Normal
4	83	98	8134	1.01	1.08	14.9 %	32.0	92.96 %	214.8 Normal
5	88	85	7480	1.07	0.94	15.8 %	64.0	100 %	404.3 Medium

TABLE 4: Fall detection with 5 frames

From the table above, for frames 2 and 4, we have two very different areas with same zoom (effect of turning left or right, in this case the percentage presence will be very different).

3.4 About the results

As mentioned in the tables above, having the distance between the face and the webcam, with the face presence and the planar speed, we were able to retrieve the actual speed and detect a fall. All the calculations are based on the formulas/expressions mentioned in the previous sections.

4. DISCUSSION, CONSLUSION & FUTURE WORK

Elderly people represent the fastest growing segment of the population around the world. The public health services institutions will have budget problems with more pressure to limit costs. In addition, Elderly people are not used to new technologies and electronic services, and their acquisition process is always more difficult that in young people. This will justify the demand on services oriented to elderly people to help them live longer in their home increasing their quality of life. The first step in the design of this system has been to clearly identify the elderly people's requirements and the lack in the existing products to meet these requirements. The most important requirements implemented by the proposed monitoring system are:

4.1 Reliability of the system

One of the main aims of the monitoring system is to give more confidence to elderly people in their daily life, and such objective will be achieved with such highly reliable system. Elderly people do not want false detections neither they want falls not detected.

4.2 Functionalities and services to be implemented

A wide offer of services can be implemented in such a platform. However, according to elderly people, the most important service for them to be implemented is the automatic fall detection without the need to push a button to raise the alarm. The automatic detection is continuously real time carried out while the elderly person performs any activity in its daily life. The implemented algorithm detects when a fall occurs based on fall patterns. The monitoring system is able to differentiate daily activity from falls, and so to avoid false alarms. The activity monitoring classifies the activity according to 4 levels: low, normal, medium and high level activity. An alarm will be raised when the system detects high level activities.

The proposed monitoring system offers complete activity monitoring and automatic fall detection and allows detecting distress situation and triggering an alarm upon fall detection. Tests and results show that the system is reliable and meets well the requirements. The proposed system in the paper can be treated as a strategy to be followed for any other future work in the same domain. Such system has a lot of applications; it reduces the hospitalization costs and improves life conditions for elderly peoples.

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