An incident detection for indoor activities of independent person through far infrared imaging

Mayuko Kitazume [a], Shunji Katahara [b], Masayoshi Aoki [c]

[a, b, c] *Department of Computer and Information Science, Faculty of Science and Technology, Seikei University ,Tokyo, Japan*

Abstract

An incident for indoor activities of independent person has a potential risk not to be found for some time. To save lives and give timely treatments, it is very important to detect such situation as early as possible. In this paper we propose an indoor scene analyzing system to detect incidents or hazardous situations of one person's independent activities. We utilize far infrared image sequences obtained from fixed position camera with a fixed line of sight direction. Human area candidates detected by background subtraction are tracked in image sequence. We detect an incident using shape and motion cue, such as head and body relative position, sudden jerky motion or very little motion. Through preliminary experiments, we are convinced that the proposed system is very promising. We will show some experimental results to show the feasibility of the proposed system.

Keywords

incident detection, independent indoor activities, far infrared image

1 Introduction

We are entering an aging society quite rapidly. In an aging society, many people have to live alone. This will causes very severe situation that is an incident occurred one person living alone independently will not be detected for some time or not be detected at all. There are many reports of so-called "solitude death"(died without noticed by relatives or other person). This could happen for not only one person living alone independently but also elderly couple. Generally speaking, for an ordinary person working in a private room without co-worker(s) has the same risk that some misshapen to himself/herself will not be noticed for some time, specifically in night time. Another risk area example is a bathroom. Since it is private and temperature, water pressure, slippery conditions act in some complex combined manner.

Therefore detection of an incident of one person during his/her independent indoor activities is very important and urgently and desperately required in these days. Vital physical life signals, such as breathing, heartbeat can be used to detect critical situation of a human. Signals from wearable sensors can be used by a standalone diagnosis device and a critical situation will be sent to an emergency center. These signals can also be sent to a telemeter center for centralized diagnosis. However, wearable sensors are very cumbersome for daily use and not realistic for the general public. For a specific application, such as a doze detection of a driver, stand alone wearable devices are available on the market. For the detection of incident of a human in advance, his/her conducts or behaviors should be analyzed to detect signs of some irregularities. For this purpose, non-contact device is a must to become into wide use.

One promising solution for non-contact analysis of human behavior or conduct seems to exist in an image sequence analysis. For example, driver's blinking pattern is used to detect a doze of a driver. Visible ray and near infrared ray have been experimented for these purposes. Some systems have been commercially introduced to warn low level of driver alertness and falling asleep. It is possible to exploit visible ray image to detect indoor incidents. Visible ray image could have lots of complex textures and we need sophisticated algorithm[1]. Another shortcomings for visible ray imaging is that we need illumination to get stable result. In a low or no contrast, image processing has nothing to do with.

We would like to propose a non-contact far infrared image analysis system for indoor incident detection. Any object whose temperature is not absolute zero (-273 Celsius) emits far infrared ray. If there is enough temperature difference between two objects, resulting far infrared image has a good contrast and we can easily separate these two objects. Under normal conditions, temperature of human body can be assumed to be higher than the surrounding indoor environment. This means human body will comes out as high temperature region in far infrared image with a good contrast. This character is very useful to detect human body using simple image processing procedure. One most important advantage of far infrared imaging is that there is no need for illumination and human body comes out almost the same in different circumstances. These merits are also useful for pedestrian detection[2～5], driver monitoring[6], security surveillance[7], since it will be possible to utilize day and night without illumination.

In this paper, we show the usefulness of far infrared imaging for indoor incident detection by way of preliminary experiments. This paper we will be consist of, "Far infrared imaging", "Incident detection scheme", "Experimental results", "Discussion", and "Conclusion".

2 Far infrared imaging

Human body emits far infrared ray with peak power wave length about 10μm. There exists so cold atmospheric window between 8 to 14μm and infrared ray can propagate without gaseous molecule absorption. This means that infrared ray from human body can be used for imaging in atmospheric environment. Since human body emits infrared ray spontaneously and we need not any illumination for imaging, therefore infrared ray imaging seems to be very attractive for the imaging of human body. The far infrared image can be considered as a two dimensional thermometer and human body area can be extracted from far infrared image by temperature range slicing.

Far infrared imaging devices had been very expensive for some time ago. The main reason was that we had to use cooling system to cope with thermal noise of the detecting elements. The introduction of uncooled technology changed the situation drastically and the price went down so that we can use far infrared imaging for practical application, such as on board pedestrian detection devices.

Figure 1 through Figure 3 are typical examples of far infrared images of independent person indoor activities.

Figure 1 Indoor walking

Figure 2 Reading a book on a couch

Figure 3 Working with PC

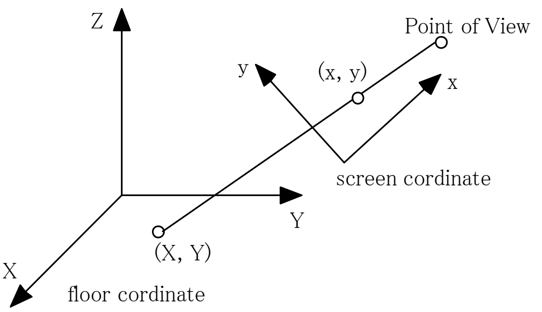
3 Incident detection scheme

3. 1 Human body extraction

Under normal conditions, we can assume that human body temperature is higher than the surrounding indoor environment. Since a far infrared image can be considered as a thermal image, we can detect a human body region applying simple thermal thresholding or temperature range slicing. For indoor surveillance, a camera position and direction are fixed. We can exclude static high temperature object other than human body using background subtraction. Combination of binalization, connected region extraction, merging, and noise reduction, we will get whole body region. The top of this region can be considered as a crown and the bottom region as foot. We can use width, height and occupancy ratio as important shape parameters. The time sequence of the center of gravity of the extracted region indicates rough motion and gives primary motion information. The object could raise hands over the head or move like a shadow boxing. Sometimes the object could raise its leg in a high kick motion. However these situation is not so often.

3. 2 Position on the floor

The floor position of a body plays an important role in indoor motion description. If we assume a single person is walking in a room with no furniture, there will be no occlusion on human body image. The whole body comes out as a single connected entity in a thermal image. Further more, if the person is bare footed, like in a Japanese "Tatami (glass mat)" room, bottom position of body image corresponds to floor position of the person. Even he/she wears a pair of shoes, that is the case in western room, the bottom position of body image will give a good approximation of foot position. The primary floor position information can be easily calculated applying projectional transformation. The relationship between 2-D image coordinate and floor 2-D coordinate is given by simple ratio of two linear expressions of image coordinates. This is illustrated in Figure 4 as an transformation from one plane coordinate to other plane coordinate. Even when one stands on a single leg, raising his/her another leg, the foot position is on the vertical line which goes through the center of gravity. This is a simple physical fact.



$$X = \frac{a_x x + b_x y + c_x}{a_0 x + b_0 y + 1}, \quad Y = \frac{a_y x + b_y y + c_y}{a_0 x + b_0 y + 1}$$

Figure 4 Projectional transform (relationship between screen coordinate and floor coordinate)

3. 3 Head detection

We assume that in a normal situation upper body is in a upright posture. We interpret this as a head position is above the body position. Therefore it is very important to detect a head position. Head shape in 3-D is considered as a sphere and its projection to 2-D screen results in a circle shape. We search for a circular shape region from the top of body region. In this model, the top of the whole body region is a candidate of the crown, and circular shape beneath the crown is head and which situated above the body part. Instead of applying circular template matching, we examine sequence of horizontal run length. For a circular shape, the run length (corresponding width) has local maxima around the head center and shows local minimum at the neck position, as illustrated in Figure 5. If the run length sequence shows this feature, we decide the y coordinate of head center position at this maximum and x coordinate of head center position at the center of this horizontal run. If there is no such feature or there are multiple horizontal runs in one horizontal line, we apply these scheme to vertical runs. In this case the object could be lying in some posture and head position search will be done from right most and left most position of the connected region. If there is no circular region satisfying the criteria including maximum run length, there is a possibility that the object posture is not normal, ie indicating a possibility of incident. This will be discussed in the next paragraph.

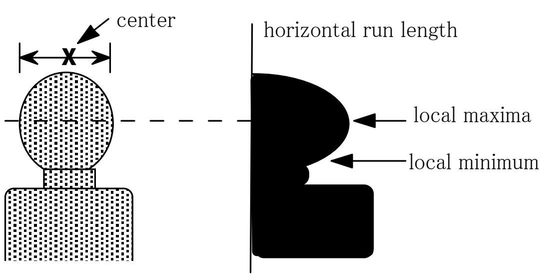


Figure 5 Horizontal run length and head detection

3. 4 Decision scheme for incident

In each single frame, we estimate object's posture as a still image and decide the possibility of incident situation. If a head is found normally satisfying a criterion and its position is above the body center, we consider that there is no irregularities. If a head is not found at all, this is considered as an indication of some incident or irregularities. If a head is found but its vertical position is not above the whole body center, it is considered that the object is lying nearly horizontally.

For the verification and confirmation of the single frame decision result, we use time sequence of head and whole body center position. No head found and no motion means a very critical situation. Since the position of desk and chair will be given before hand, collapsing on one's desk or falling down from the chair will be detected by the position and motion of head.

4 Experimental results

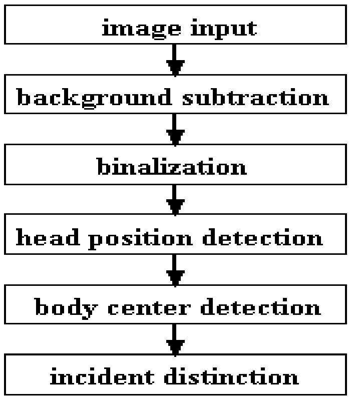


Figure 6 simplified flow chart for incident detection

4. 1 Position on the floor

As a preliminary experiment, we calculated floor position of walking person from bottom of legs in far infrared image.(As illustrated in Figure 4)

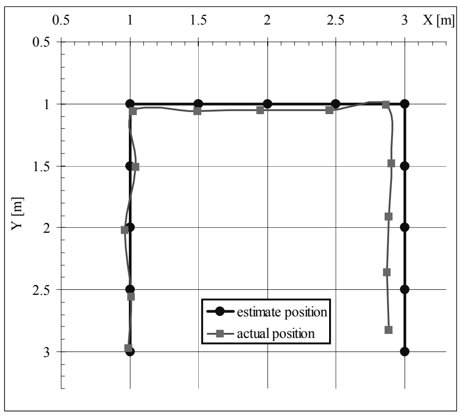


Figure 7 Floor position estimation result

4. 2 Hypothesized head position by local run length maxima

We applied background subtraction, binalization, connected region extraction, noise reduction for Figure 1 through Figure 3. Then we detected head position by local run length maxima, as a hypothesized head position.(As illustrated in Figure 5) We assume half head width as a vertical distance of head position from the top(crown). As explained in 3.4, we interpret the situation as normal if the head position if above the center of gravity of whole body. We also use a criterion that head width should be small enough compared to the whole body height.

Figure 8 through Figure 10 satisfy these criteria and categorized as normal.

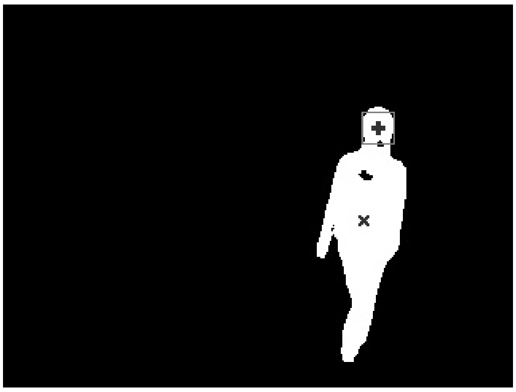


Figure 8 Head(+) and body(×) position of Figure 1 ("normal")

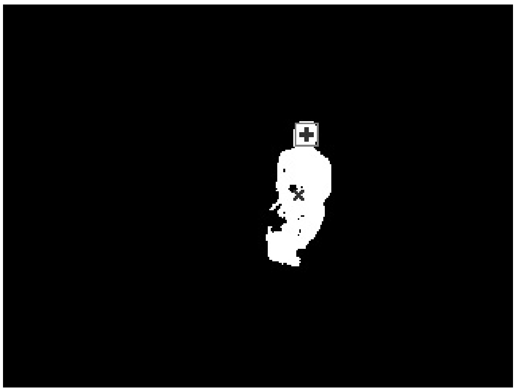


Figure 9 Head(+) and body(×) position of Figure 2 ("normal")

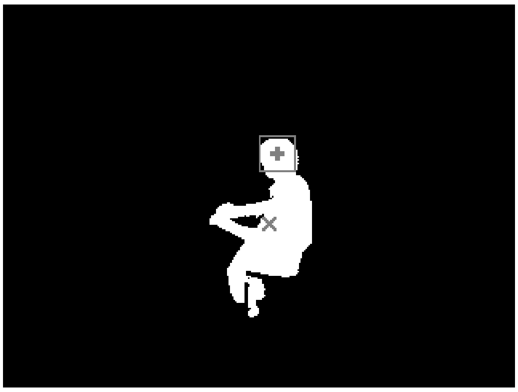


Figure 10 Head(+) and body(×) position of Figure 3 ("normal")

4. 3 Incident detection by vertical position of whole body gravity center and hypothesized head position

Figure 11 through Figure 13 are examples categorized as incident. In these examples, hypothesized head positions are not above enough from the center of gravity of the whole body and head width are relatively large compared to the height of the whole body.

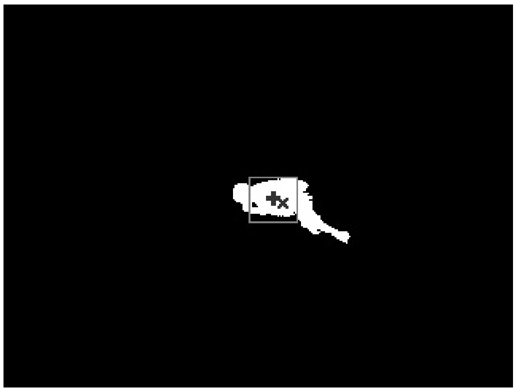


Figure 11 Head(+) and body(×) position (lying on the floor "incident")

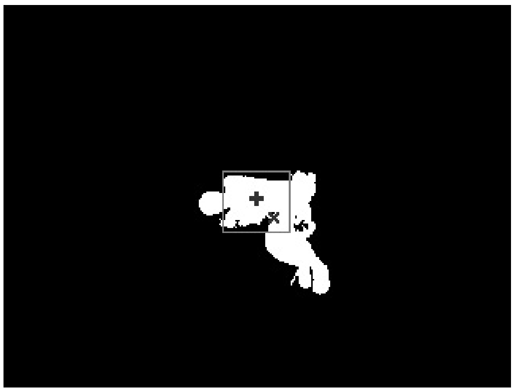


Figure 12 Head(+) and body(×) position (lying on the couch "incident")

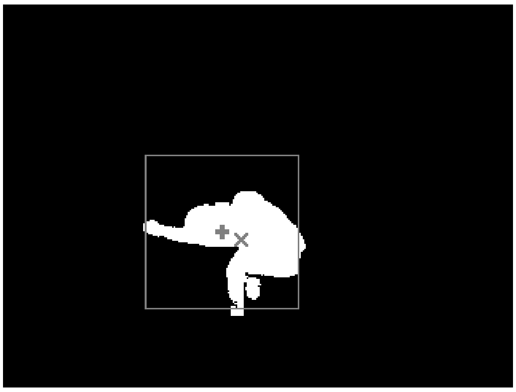


Figure 13 Head(+) and body(×) position

(fall asleep on the desk "incident")

5 Discussion

Position on the floor:
In this very simplified condition, no furniture and no occlusion, floor position can be calculated from the bottom of body on the image. Bare footed legs can easily found in the far infrared image. Even for a person with shoes on, we can estimate approximate foot position. For a room with furniture which causes occlusion, if the layout of the furniture is not so complicated, we can expect some frames without occlusion.

Hypothesized head position by local run length:
We assume that in a normal or natural situation, one's head is above its body. In this situation, the hypothesized head position is detected by local run length maxima. The center of gravity of whole body position is estimated below the head vertical position. This is a very useful information to determine normal situation. To cope with lying body posture, we can apply a similar algorithm using vertical run length. In this case, we have to search from right and left side both. To detect head position, head template matching or circle detection Hough transform could be other alternatives, for shape feature introduction.

Incident detection by the whole body gravity center and hypothesized head position:
If the head position is not found at all, for example too large, this indicates some incident situation. In our preliminary experiment, the hypothesized head position is defined the local maxima of horizontal run length searched from the top. The head size is simply assumed twice the distance of the local maxima from the top. Therefore, the size of the hypothesized head candidate could become large for non head case. For a lying body posture, algorithm using vertical run length is promising and give a good approximation of head position. This will work well to distinguish normal situation from incident one by position comparison

6 Conclusion

In this paper, we showed the effectiveness of far infrared image in detecting incident of independent person's indoor activities. In a simplified condition, head position and the center of gravity of whole body works quite well to distinguish incident situation from normal one. By refining the algorithm, far infrared image become a very useful and powerful tool in monitoring indoor activities of independent person. Combination of far infrared based image processing and other techniques will contribute enforcing the safety of coming aging society.

The proposed approach could be applied for remote sensing of "aliveness" such as 1) the housebound elderly, including falls detection, 2) baby monitoring.

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