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Intelligent Recognition Method of Infant Sleeping Position Based on Thermal Infrared Imaging

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Abstract

The sleeping position monitoring of infant is a very important component of baby safe custody. Existing infant sleep monitoring mainly rely on human duty, which is usually easy to cause urgent infant events not to be timely detected and treated, especially when the guardian is sleeping at night. In this paper, we propose an intelligent recognition method of infant sleeping position based on thermal infrared imaging, aiming to overcome the deficiencies of the prior art on infant sleep monitoring. Firstly we capture real-time thermal infrared images on infant sleeping with thermal imager, in a non-touch way. Then we detect the position of infant's nose or mouth as well as the position of infant's head area. Next we discriminate the sleeping position of infant's head according to the relative position of nose or mouth to the detected head area. Finally when the recognized sleeping position is dangerous or with a security risk to infant, we remind the guardian through triggering early warning module to generate alarm. Real data have been used to test the proposed approach and very good results have been achieved, validating it.

Keywords: *Infant Sleeping Position; Intelligent Recognition; Thermal Infrared Imaging*

1. Introduction

In real life, parents or guardians should pay more attention to baby safe custody [1], where the sleeping position monitoring is its important component. During the sleeping monitoring, guardian should promptly and effectively discover and deal with some very important events such as the infant's face is covered by clothing or the infant sleeps in the prone, since these events are extremely easy to suffocate infant [2-6]. Existing infant sleep monitoring is mainly carried out by human monitoring or video surveillance [7-9]. Actually, video surveillance requires the guardian to always keep active attention focused on the display terminal. Both human monitoring and video surveillance rely on human duty, which is usually easy to cause urgent infant events not to be timely detected and treated, especially when the guardian is sleeping at night.

This paper proposes an intelligent recognition method of infant sleeping position based on thermal infrared imaging, aiming to overcome the deficiencies of the prior art on infant sleep monitoring.

The remainder of this paper is organized as follows. Section 2 illustrates the framework of proposed approach on intelligent recognition of infant sleeping position. Section 3 elaborates the detailed flowchart of proposed approach on intelligent recognition of infant sleeping position. Section 4 provides the experimental results. Finally, the paper is concluded in Section 5.

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2. The Framework of Proposed Method

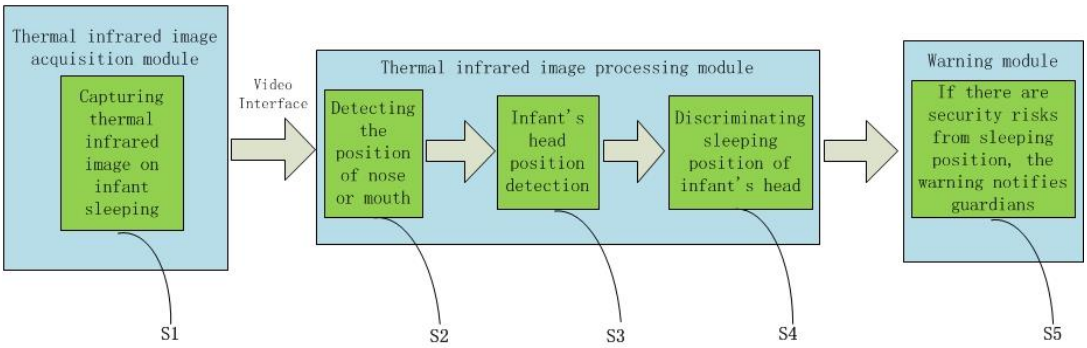


Figure 1. The Framework of Proposed Approach on Intelligent Recognition of Infant Sleeping Position

The framework of proposed method is illustrated in Figure 1.

The proposed sleeping position intelligent identification method and the corresponding device involves thermal infrared image acquisition module, video interface, thermal infrared image processing module and warning module. Thermal infrared image acquisition module captures real-time thermal infrared images on infant sleeping with thermal imager [10]. The captured thermal infrared images are transmitted to thermal infrared image processing module via video interface. The alarm output from thermal infrared image processing module is connected to warning module. Thermal infrared image processing module detects the position of nose or mouth, the position of infant's head area, and discriminate sleeping position of infant's head according to the relative position of nose or mouth to the detected head area. When the recognized sleeping position is dangerous or with a security risk to infant, such as the infant's face is covered by clothing or the infant sleeps in the prone, early warning module is triggered to generate alarm and remind the guardian. Warning module uses shock reminder as well as sound and light alarm.

3. Intelligently Discriminate Infant Sleeping Position Based on Thermal Infrared Imaging

The proposed method in the paper intelligently discriminates infant sleeping position based on thermal infrared imaging, and consists of the following key steps.

S1) capture thermal infrared images on infant sleeping

S2) detect the position of infant's nose or mouth

S3) detect the position of infant's head area

S4) discriminate sleeping position of infant's head according to the relative position of nose or mouth to the detected head area

S5) remind the guardian when the recognized sleeping position is dangerous or with a security risk to infant

Figure 2 shows the flowchart of the proposed method.

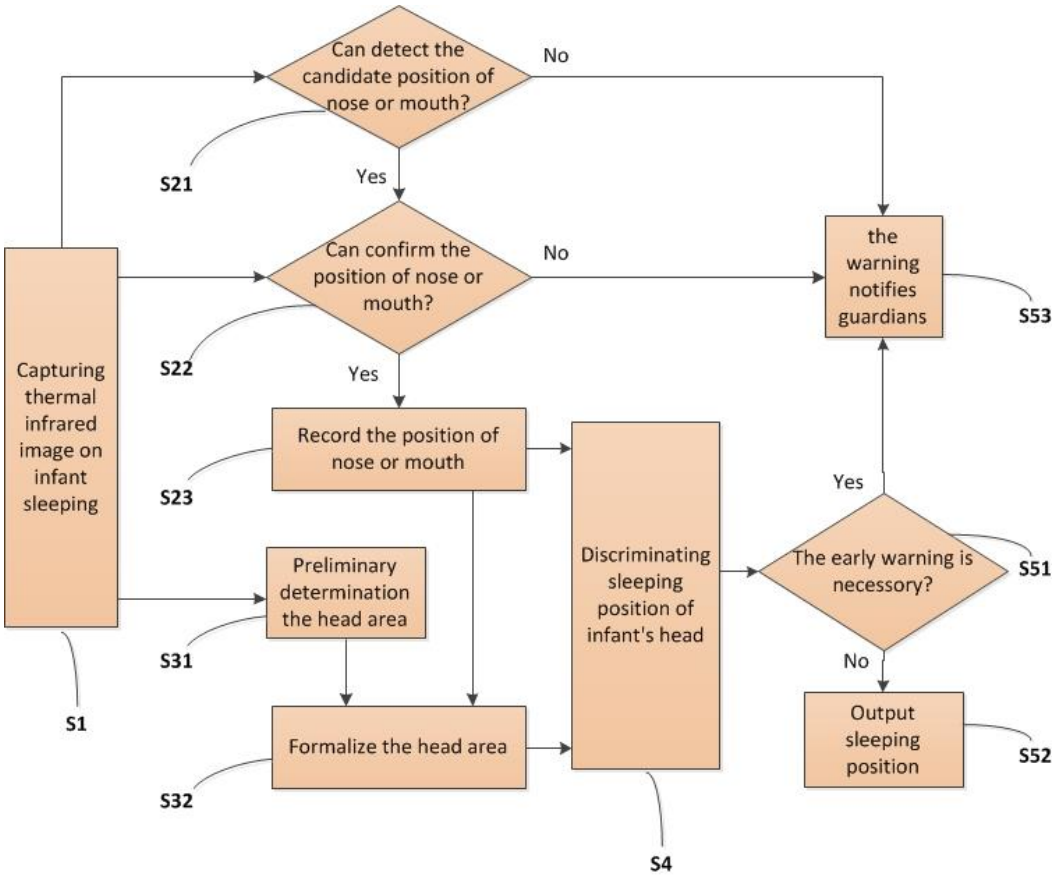


Figure 1. The Flowchart of Proposed Approach on Intelligent Recognition of Infant Sleeping Position

In step S1, capturing thermal infrared images on infant sleeping is completed by thermal imager, in a non-touch way.

As shown in Figure 2, step S2 includes three following sub-steps.

S21) Can detect the candidate position of nose or mouth? Human respiratory physiological process includes inhale, exhale and other processes. When people exhale, there is a difference between the temperature of exhaled CO_2 airflow and the temperature of surrounding environment. Physiological process of human respiratory will make the temperature near nose or mouth vary regularly with rise and fall. The temperature of exhaled CO_2 airflow as well as the temperature of surrounding environment can be obtained from thermal infrared imaging video signal. Thus the candidate position of nose or mouth can be detected by searching for the area with regular fluctuation of temperature from successive multi-frames of thermal infrared imaging video signal.

In the specific implementation, we scan the thermal infrared video signal area, and for every point we determine whether the area including this point is an area with regular fluctuation of temperature from successive multi-frames. In detail, this practice example of implementation is illustrated as follows.

(1) Find the local maximum values of this point in the most recent 30 frames by virtue of the function findpeaks( ) of Matlab, and find the max of this point through the function max( ) of Matlab. Then remove those local maximum values whose difference with the max is too large (such as greater than 5), and remain the effective local maximum values and their time positions.

(2) Find the local minimum values of this point in the most recent 30 frames by virtue of the function findpeaks( ) of Matlab, and remain the effective local minimum values and

their time positions. In the specific implementation, we need to take negative values of the series of temperatures of this point, and find the local maximums of these negative values in the most recent 30 frames by virtue of the function findpeaks( ) of Matlab just like in step (1). Thus we can find out the local minimum values of the original temperature series.

(3) According to the time positions of the effective local maximum values as well as the effective local minimum values, check if almost every minimum value is right located between two maxima from the view of time position. If so, the area including this point is an area with regular fluctuation of temperature from successive multi-frames. If we can seek out this kind of area, the candidate position of nose or mouth is determined, and step S22 is executed. Otherwise, this kind of area isn't successfully found, which means that the sleeping position of infant is dangerous or with a security risk to infant, such as the infant's face is covered by clothing or the infant sleeps in the prone. So step S53 is executed and early warning module is triggered to generate alarm and remind the guardian.

S22) Can confirm the position of nose or mouth? Based on the operation that the thermal infrared video signal is narrow band-pass filtered, we determine whether to confirm the position of the nose or mouth. When people exhale, the concentration of exhaled CO_2 is 3.7%, and CO_2 has high absorption effect on infrared signal with a wavelength of 4.26um. Through the narrow band pass filtering for the thermal infrared video signal by virtue of a filter with center frequency of 4.26um wavelength, we can judge if to successfully find the nose or mouth position according to the filtering result. If we can confirm the position of nose or mouth, step S23 is executed. If not, it indicates that the candidate position of nose or mouth in the step S21 is not effective position. That is to say, actually we don't successfully detect the position of the nose or mouth in the step S21, which means that the sleeping position of infant is dangerous or with a security risk to infant, such as the infant's face is covered by clothing or the infant sleeps in the prone. So step S53 is executed and early warning module is triggered to generate alarm and remind the guardian.

S23) Record the position of the nose or mouth.

As shown in Figure 2, step S3 includes two following sub-steps.

S31) Preliminarily identify the head area. Body temperature is usually higher than the ambient temperature. Especially the temperature of the head or face is often higher than the ambient temperature since the head or face is not covered by the clothing in the normal case. Accordingly, we can initially identify the position of the head region. Specific method is described below. For thermal infrared images, firstly we conduct automatic generation of wavelet denoising threshold selection through the function ddencmp( ) of Matlab, and then implement image noise reduction globally while effectively preserving the border of region by virtue of the function wdencmp( ) of Matlab. Thus we complete image enhancement for thermal infrared images. Next we carry out high-pass filtering for thermal infrared images according to the fact that the temperature of the head or face is often higher than the ambient temperature, and initially split head area boundary and determine the location of the head region. In addition, find the horizontal and vertical direction of the head according to the direction of the body.

S32) Based on the fact that the position of the nose or mouth should be contained within the head region, we can officially determine the position of the head region according to the position of the nose or mouth recorded in the step S23.

As shown in Figure 2, sleeping position of infant's head is discriminated in step S4 as follows. We discriminate sleeping position of infant's head according to the relative position of nose or mouth to the detected head area, which includes supine, prone, lying on the left side, or right side, and lying to compromise with head tilting to one side and back lying on the bed surface etc. In detail, if the position of nose or mouth is in the intermediate area of the head region in the horizontal direction, the infant sleeps in the supine. If the position of nose or mouth is in the boundary area of the head region in the

horizontal direction, the infant is lying on the left side or right side. If the position of nose or mouth is between the intermediate area and the boundary area of the head region in the horizontal direction, the infant is lying to compromise. If we cannot successfully detect the position of nose or mouth, the sleeping position of infant is dangerous or with a security risk to infant, such as the infant's face is covered by clothing or the infant sleeps in the prone.

In fact, if we want to judge if the sleeping position of infant is dangerous or with a security risk to infant, we only just need to pay attention to checking the status of nose or mouth, which is implemented by detecting the position of nose or mouth as well as the head region from the thermal infrared imaging video signal in our proposed approach. Since we only detect the position of nose or mouth and the head region, discriminating the sleeping position and its correct rate is not affected by the factors such as how many clothes infant has on or how many quilts infant is covered. This is an advantage of our proposed approach, which overcomes the deficiencies of the prior art on infant sleep monitoring.

As shown in Figure 2, step S5 includes three following sub-steps.

S51) Determine if it is necessary to generate alarm according to the discriminated sleeping position. If it isn't, step S52 is executed. If it is, step S53 is executed and early warning module is triggered and reminds the guardian.

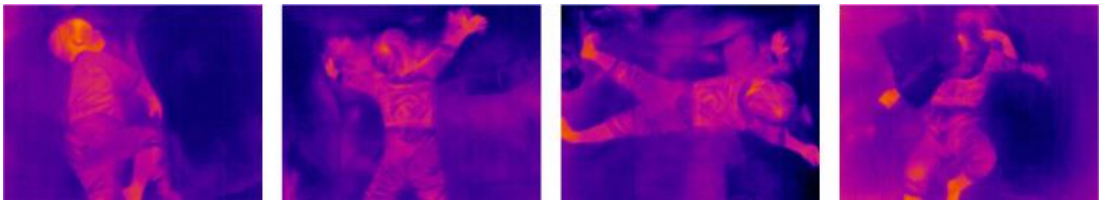
S52) Output the discriminated sleeping position of infant.

S53) Remind the guardian. If the discriminated sleeping position of infant is dangerous or with a security risk to infant, such as the infant's face is covered by clothing or the infant sleeps in the prone, early warning module is triggered to generate alarm and remind the guardian. Early warning module is implemented by using shock reminder as well as sound and light alarm. In non-emergency situations, shock reminder can be used to remind the guardian to help infant correct sleep position without affecting infant's sleeping. At the same time, in the case of an emergency such as the infant's face is covered by clothing or the infant sleeps in the prone which is extremely easy to suffocate infant, both shock reminder and sound and light alarm are used to timely remind the guardian promptly deal with the situation, in order to ensure the safety of infant.

4. Experimental Results

To validate the proposed intelligent recognition method of infant sleeping position based on thermal infrared imaging, we took real images to confront it with the real world. As shown in Figure 3, we select eight typical cases of intelligent recognition on infant sleeping position in the paper due to space limitation, which involve different sleeping positions including sleeping in the supine, or prone, lying on the left side, or right side, lying to compromise with head tilting to one side and back lying on the bed surface, and face being covered by clothing, for illustrating the extensive application of our method.

(a) case 1 (b) case 2 (c) case 3 (d) case 4



(e) case 5 (f) case 6 (g) case 7 (h) case 8

Figure 3. Eight Cases of Intelligent Recognition on Infant Sleeping Position Based on Thermal Infrared Imaging

In every case, we discriminate the infant sleeping position using our proposed method. In detail, we capture thermal infrared images on infant sleeping by thermal imager, in a non-touch way, and only one frame is shown in Figure 3 for each case. Then we detect the candidate position of nose or mouth by searching for the area with regular fluctuation of temperature from successive multi-frames of thermal infrared imaging video signal. Through the narrow band pass filtering for the thermal infrared video signal by virtue of a filter with center frequency of 4.26um wavelength, we can judge if to successfully find the nose or mouth position according to the filtering result. Next, according to the fact that the temperature of the head or face is often higher than the ambient temperature, we initially split head area boundary and determine the location of the head region. And based on the fact that the position of the nose or mouth should be contained within the head region, we officially determine the position of the head region according to the position of the nose or mouth. After that, we discriminate the sleeping position of infant's head according to the relative position of nose or mouth to the detected head area. The results of intelligent recognition on infant sleeping position are summarized by Table 1. According to the obtained results in Table 1, the infant sleeping position is correctly detected in each case using our approach. In case 6, case 7 and case 8, the early warning module is triggered to generate alarm and remind the guardian since the discriminated sleeping position of infant is to sleep in the prone or infant’s face being covered by clothing and with a security risk to infant. Thus our proposed method about intelligent recognition of infant sleeping position based on thermal infrared imaging has been validated.

Table 1. The Obtained Results of Intelligent Recognition on Infant Sleeping Position Using the Proposed Approach for Every Case in Figure 3

Cases	Infant Sleeping Position
case 1	lying on the right side
case 2	lying to compromise with head tilting to right side and back lying on the bed surface
case 3	sleeping in the supine
case 4	lying to compromise with head tilting to left side and back lying on the bed surface
case 5	lying on the left side
case 6	sleeping in the prone
case 7	sleeping in the prone
case 8	The infant’s face is covered by clothing

5. Conclusion

In this paper, we proposed an intelligent recognition method of infant sleeping position based on thermal infrared imaging. The proposed approach on intelligent recognition method of infant sleeping position mainly involves the following key steps. In the first,

the thermal infrared images on infant sleeping are captured by virtue of thermal imager. The captured thermal infrared images are transmitted to thermal infrared image processing module via video interface. Then in the thermal infrared image processing module, we detect the position of infant's nose or mouth. Otherwise, we also detect the position of infant's head area. Next we discriminate sleeping position of infant's head according to the relative position of nose or mouth to the detected head area. Finally, when the recognized sleeping position is dangerous or with a security risk to infant, such as the infant's face is covered by clothing or the infant sleeps in the prone, early warning module is triggered to generate alarm and remind the guardian. Experimental results showed that the achieved results of intelligent recognition on infant sleeping position closely match the real scenes and are consistent as well as accurate. The good results from the experiments illustrated the practicability and effectiveness of our proposed intelligent recognition method of infant sleeping position, validating it.

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