Multi-sensor recognition of human pressure

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Abstract. At present, skin pressure ulcers are a common problem in the care of bedridden patients. Solving this problem usually involves turning the patient over regularly, which requires a lot of manpower and material resources. This paper designs a human body pressure recognition model, which can solve the problem of human pressure ulcers very well in combination with intelligent nursing beds. This paper collects the bone data of the human body by using the Kinect sensor, and then processes the collected data. The film pressure sensor is used to collect the pressure information of the human body, and the pressure information is matched with the bone data of the human body, so as to obtain the pressure of the corresponding part of the human body, and judge the current posture of the human body through the pressure information. When the pressure of the compression part of the human body reaches the threshold, the intelligent nursing bed automatically turns over to reduce the pressure of the compression part of the human body.

1. Introduction

For long-term bedridden patients, long-term bed rest can cause muscle atrophy, venous thrombosis, pressure ulcers and other diseases, which seriously endanger the patient's health. The emergence of intelligent nursing beds has greatly reduced the pressure on patients' families and nursing staff. The intelligent nursing bed has basic functions such as raising the back, bending the leg, and turning over, and can solve some basic nursing problems of long-term bedridden patients.

Aiming at the pressure ulcers problem of long-term bedridden patients, this paper designs a human body pressure recognition model to control the movement of the intelligent nursing bed. The recognition model uses Matlab software to fit the bone data collected by the Kinect sensor with the pressure data collected by the film pressure sensor to identify the pressure of the pressured part of the human body and the current lying position of the human body, which is used as an output signal to control intelligent care Movement of the bed.

2. Recognition model design

The work flow of the human body pressure recognition model designed in this paper is shown in Figure (1). The work flow is: collect the subject’s bone data information through the Kinect sensor and collect the subject’s pressure information through the film pressure sensor, and then compare the collected data. The bone data is used to screen bone points and coordinate transformation, fit human bone data and pressure data to obtain the pressure of the corresponding part of the human body, and identify the current posture of the human body according to the pressure information of the human body, and finally output the signal to control the intelligent nursing bed movement.
3. Bone data collection and processing

3.1. Data collection
In order to obtain the data set required for training the neural network, this paper collected the human bones of 10 normal subjects (3 women and 7 men, aged between 25-60 years and height between 1.55-1.90 m) data information. When collecting data in this experiment, the Kinect sensor was set on the left side of the bed, and the subjects lying on the smart nursing bed showed five postures: lying flat, raising the back, bent legs, and lying on the left and right sides, collected by the KinectV2 sensor. The bone data information of the human body, each posture is maintained for 10 seconds. As shown in Figure (2).

3.2. Selection of bone points
By using the Kinect sensor and the corresponding development software, the spatial coordinates (x, y, z) of the standardized bone joints of 25 human bodies can be obtained. As shown in Figure (3). Based on the reliability of the purpose of this research and the consideration of recognition speed, this paper screens the number of bone joints and reduces the number of bone joint points from 25 to 11. As shown in Figure (4), the selected 11 joint points are: head(1), spine shoulder(2), shoulder left(3), shoulder right(4), spine base(5), hip left(6), hip right(7), knee left(8), knee right(9), ankle left(10), ankle right(11).
3.3. Coordinate transformation

In order to determine the subject's position on the smart care bed, and at the same time avoid the Kinect sensor to capture the human bone data outside the smart care bed, coordinate transformation of the 11 selected bone joint coordinates is needed to transform them into the absolute reference system (x, y, z) with the intelligent nursing bed as the reference. According to the imaging theory, the world coordinate system $o_{w-xw}y_wz_w$ can be converted to the imaging coordinate system $o_{j-xj}$ through $o_j = R o_w + T$, where $T$ is the transition matrix and $R$ is the rotation matrix. In Kinect sensor, the coordinate transformation model can be represented by Figure (5).

![Coordinate transformation model](image)

Converting the world coordinate system to the depth system and the RGB system can use equation (1) and equation (2).

$$ o_d = x_d y_d z_d = R_d o_w + T_d $$

$$ o_{rgb} = x_{rgb} y_{rgb} z_{rgb} = R_{rgb} o_w + T_{rgb} $$

In the imaging system, the RGB image coordinate system $[u_{rgb}, v_{rgb}, 1]^T$ can be described by equation (3).

$$ [u_{rgb} \, v_{rgb} \, 1]^T = \frac{1}{z_{rgb}} H_{rgb} [x_{rgb} \, y_{rgb} \, z_{rgb}] $$

The depth imaging system can be described by equation (4).

$$ [u_d \, v_d \, 1]^T = \frac{1}{z_d} H_d [x_d \, y_d \, z_d] $$

Among them, $H_{rgb}$ and $H_d$ are the original parameters of the sensor. Through the above four formulas, the transformation from the form $[u_{rgb}, v_{rgb}, 1]^T$ to $[u_d, v_d, 1]^T$. Since the distance between the color camera and the depth camera of the Kinect sensor is very close, it can be assumed that $z_d \approx z_{rgb}$, so:

$$ [u_d \, v_d \, 1]^T \approx H_d H_{rgb}^{-1} R_d R_{rgb}^{-1} [u_{rgb} \, v_{rgb} \, 1] + (T_d - R_d R_{rgb}^{-1} T_{rgb}) $$

Since the Kinect sensor is a standardized production equipment, solving the spatial mapping problem can be solved with the calibration parameters of Kinect sensor [10]. When solving the joint point $J(u_{rgb}, v_{rgb})$ in the color image, it can be used to obtain the depth image map $J(u_d, v_d)$. In the depth camera coordinate system, the depth value of $P'$ is $z_d$. So far, the three-dimensional coordinates are based on the world The coordinate system $J (x_w, y_w, z_w)$ is obtained with respect to $J (u_{rgb}, v_{rgb})$ according to equations (2) and (3).
4. Pressure data collection

4.1. Laying of film pressure sensor

According to the body size of Chinese adults released by the National Bureau of Technical Supervision, the detailed data of human body parts are as follows:

![Figure 6. Human standing diagram](image)

| Age (gender) | 35-60 years old (male) | 35-55 years old (female) |
|--------------|------------------------|--------------------------|
| Percentile   | 50 90 95               | 50 90 95                 |
| x Height     | 1680 1752 1774         | 1593 1660 1679           |
| y Upper arm length | 313 333 338   | 284 303 308             |
| z Forearm length | 237 253 258   | 213 229 234             |
| o Thigh length | 465 496 505         | 438 467 476             |
| p Calf length | 369 396 403          | 344 370 376             |

Select the men’s 90th percentile height value for calculation reference, that is, \( h=1752 \text{mm} \).

Pressure is the main factor causing skin pressure ulcers. In this paper, film pressure sensor is used to collect human pressure. Through calculation, the body is easy to produce pressure sore parts for laying.

According to the relationship between bedding size and human body in ergonomics, the length of nursing bed is:

\[
L = h \times (1+0.05) + 150 = 1989.6 \text{mm}
\]  

(6)

Therefore, the length of the bed surface of the intelligent nursing bed is 2000mm. Taking into account the distance between the top of the user’s head and the head of the bed and the foot and the bed, respectively take this distance as \( a=100 \text{mm} \) and \( e=100 \text{mm} \).

Because long-term bed rest is most likely to cause pressure ulcers on the head, back, buttocks and feet. Therefore, pressure sensors are laid for these four body parts, the laying position of the head pressure sensor \( a \), the laying position of the back pressure sensor \( b=(L-e-o-p)/2+a \), the laying position of the hip pressure sensor \( o=L-e-o-p \), the foot \( d=L-e \). As shown in Figure (7).
4.2. Obtain human body pressure data

Because the film pressure sensor is laid according to the size of the human body, combined with the processed bone coordinates, and fitted with Matlab software, the pressure of the corresponding part of the human body can be obtained.

Taking the length of nursing bed as Y-axis as reference, the coordinate point of head in the Y-axis direction is $y_1$, the coordinate point of Spine Shoulder in the Y-axis direction is $y_2$, the coordinate point of HIP left in the Y-axis direction is $y_3$ and the coordinate point of hip right in the Y-axis direction is $y_4$, the Y-axis coordinates of the ankle left is $y_5$ and the Y-axis coordinates of the ankle right is $y_6$.

As a result of the human body there is a difference, but in the use of the scope of little difference. Therefore, in the process of fitting, it is necessary to redefine the film pressure sensor and the bone coordinates after treatment. When $\frac{a}{2} \leq y_1 \leq \frac{3a}{2}$, judge the value of the left head pressure sensor and the right head pressure sensor, and take the maximum value as the head pressure data collected by the head pressure sensor. When $\frac{3b+a}{4} \leq y_2 \leq \frac{5b-a}{4}$, judge the value of the left back pressure sensor and the right back pressure sensor, and take the maximum value as the back pressure data collected by the back pressure sensor. When $\frac{3c+b}{4} \leq y_3 \leq \frac{5c-b}{4}$, the data collected by the pressure sensor on the left hip is regarded as the pressure on the left hip. When $\frac{3d+b}{4} \leq y_4 \leq \frac{5c-b}{4}$, the data collected by the right hip pressure sensor is regarded as the right hip pressure. When $\frac{5d-L}{4} \leq y_5 \leq \frac{3d+L}{4}$, the data collected by the left foot pressure sensor is regarded as the left foot pressure; When $\frac{5d-L}{4} \leq y_6 \leq \frac{3d+L}{4}$, the data collected by the right foot pressure sensor is regarded as the right foot pressure.

After fitting by the above method, the pressure information of each part of the human body can be accurately obtained. When the human body is lying flat, the collected pressure information of each part is shown in Figure (8). In addition, when the human body is lying on the left side, the pressure data collected by the pressure sensor on the left side is significantly greater than that on the right side, and it can be judged that the human body is lying on the left side; when the human body is lying on the right side, the pressure data collected by the right pressure sensor Obviously larger than the left side, it can be judged that the human body is lying on the right side; when the back and head pressure value is less than 500, it can be judged that the human body is in a raising the back state; when the pressure on the left and right feet of the human body is less than 500, the human body can be judged In a bending the leg state.
5. Conclusion
Most of the current nursing beds are adjusted by fixed time and remote control, so as to relieve pressure ulcers, can not be adjusted in real time according to the information of the human body. In this paper, by using the Kinect sensor combined with the film pressure sensor, the pressure of the corresponding parts of the human body can be more accurately obtained, and the limitation is small, the scope of application is wide, and the current position of the body can be accurately identified, combined with the nursing bed, greatly alleviates the formation of pressure ulcers.

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