Determination of Anatomy Joint Position in Human Body
Combining Human Contour Image Feature Algorithm

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Abstract. How to extract the feature information related to human body structure from image sequences and complete human motion analysis including human posture recognition is highly important research work. In this paper, an algorithm for determining the position of human joints based on human contour image features is proposed. Firstly, the virtual skeleton of the human body is extracted from the human contour using the energy function. Subsequently, the position of joints is determined based on three rules to identify whether a point in the human virtual skeleton is a joint point given in the standard human skeleton model as well as the related knowledge of human anatomy. The experimental results show that the proposed algorithm has no restrictive conditions attached to the human body in the image in the aspects of motion and color, etc. At the same time, it also has an excellent suppression effect on the noise in the human contour image. Attributing to this feature, it has a relatively low requirement for the extraction accuracy of human contour, with relatively good performance in complex backgrounds.

Keywords: Contour Image Feature, Joint Position, Contour, Virtual Skeleton

1. Introduction
How to extract the feature information related to human body structure from image sequences and complete human motion analysis including human posture recognition is highly important research work [1-2]. As this research has a broad application prospect, it is currently receiving more and more attention. Its typical application areas include the following: restoration and reconstruction of three-dimensional human body structure, athlete motion analysis, safety and security, medicine, robotics, human-computer interaction, and video retrieval.

To implement the analysis of human motion based on image sequences, the following two methods are traditionally adopted: ① Motion analysis is implemented by installing sensors on the joints and
other parts of the controlled object \[3-4\]; ② The obtained image sequence is used for motion analysis to recover 3D human structure and motion information from the correspondence between features \[5-6\].

In this paper, an algorithm is proposed based on the human contour image feature to determine human joint position. In this method, the outline of the target human body is first extracted from the image. Subsequently, the energy function is used to obtain a virtual skeleton like the real human skeleton. Then, the position of the joint is determined. The proposed method has the following advantages: it does not need to restrict the motion and color information of the research object, and it has a high degree of automation; at the same time, because the energy function used has a good suppression effect on noise, the accuracy of human body contour extraction is low, and the algorithm It also has better performance in relatively complicated backgrounds.

2. Human contour extraction

The method of skeleton extraction is based on the target of human contour. The specific process is as follows:

1) Perform a different operation on two adjacent frames of images, extract their moving parts, and count the gray information of the moving parts.

2) Use the gray information of the moving part to obtain the human contour based on the result of Step 1.

3) After the outline of the human body is extracted, the source image is binarized.

\[
g(x, y) = \begin{cases} 
0, & drop(x, y) \in \text{Contour area} \\
1, & drop(x, y) \notin \text{Contour area}
\end{cases}
\]  

(1)

A binary image of the human contour is obtained according to Eq. (1).

Figure 1 shows the result of extracting human contours from a specific human moving image sequence.

(a), (b) are two adjacent original images, (c) is a differential image, and (d) is a binary image of the human contour corresponding to image (a)

Figure 1. Extraction of human contours

1) Definition of the virtual skeleton

After obtaining a binary image of the human contour, a virtual skeleton is further extracted on this basis. Hence, the human body is regarded as a combination of long strip parts (arms, thighs, etc.) and joints (shoulder joints, hip joints, etc.). The corresponding bar model and joint model are shown in Figure 2.
(a) is a long model, (b) is a joint model, (c) and (d) are long models and joint models after deformation

Figure 2. shows two models of various parts of the human body

The strip model includes a deformable rectangle and two circles connected to it. The rectangle indicates its shape, and the circles at both ends are used to connect the joint model. The joint model is a deformable circle.

2) Extraction of the virtual skeleton

It is assumed that before performing human skeleton extraction. We define the following energy function, as shown in Eq. (2):

$$
\varepsilon(x, y, r) = \int \int \left( r - \sqrt{u^2 + v^2} \right) I(x+u, y+v) \, du \, dv - \frac{r^\alpha}{\alpha}
$$

Among them, $\alpha$ is a constant, which is used to adjust the influence of the radius $r$ of the circular integral area on the energy function. Its value is related to the average gray level of the image, and generally takes 2 or 3. When the values of $x$, $y$, and $r$ make the energy function $\varepsilon(x, y, r)$ to a minimum, and the value of the radius $r$ makes the outer edge of the circle tangent to the contour of the human body. Hence, a point $P(x, y)$ on the virtual skeleton can be determined.

The starting point of the search is determined as follows: the human contour binary image is searched line by line from top to bottom to find the uppermost region in the human contour binary image, and then the method mentioned above determines a point $P(x, y)$.

The above $P(x, y)$ is used as the seed points, and all points on the human virtual skeleton are determined according to the following steps:

1. It is assumed that a point $P_n(x_n, y_n)$ on the virtual skeleton has been determined, and now search $P_{n+1}$ based on $P_n$. Hence, let $P_n$ be the center point of the joint model shown in Fig. 2 (d), and calculate the length $d_i$ of $m$ ray segments from $P_n$ with the angle $\Theta_i$ between these ray segments and the horizontal direction as a parameter ($i = 0, 1, \cdots, m - 1$). If $d_i$ has a maximum value
only at $\theta_{\text{max}}$, then use $\theta_{\text{max}}$ as the search direction and search $P_{n+1}$ based on $P_n$. If $d_j$ has multiple local maximums, a search is conducted in the direction of taking these local maximums.

2. Make $\hat{P}_{n+1}(x_{n+1}, y_{n+1}) = (x_n + \Delta \cos \theta_n, y_n + \Delta \sin \theta_n)$ a candidate for $P_{n+1}$ ($\Delta$ is the search step). If the image value at $\hat{P}_{n+1}$ is 0, use $\hat{P}_{n+1}$ as the center of the circle to make a circular area; use the coordinate values of the points in this area as the first two parameters. If the image value at $\hat{P}_{n+1}$ is 1, the point $\hat{P}_{n+1}$ is out of the contour, and the search process corresponding to the skeleton branch ends at this point.

Finally, all the skeletal points searched according to the above method are connected one by one in the search order to obtain the corresponding virtual skeleton of the human contour binary image.

3) Determination of joint position

Firstly, a standard human skeleton model shall be defined.

The joint point corresponding to rule 3 is a special type of joint point. At this point, there is no branching of the skeleton, and the slope may not change significantly. Obviously, the location of such joint points cannot be determined using the previous two rules.

The joints in the two cases (1) and (2) are referred to as referred to as the “dominant joints”, and the joints in the third case are referred to as “recessive joints”. To determine the location of the “recessive joint”, the anatomical ratio between the various parts of the human body must be used.

4) Determination of joint position

The above-mentioned knowledge of human anatomy is used to determine whether the extracted virtual skeleton point $P_n$ meets the above three rules. If $P_n$ meets one of the conditions, it is determined that it is a joint point; otherwise, $P_n$ is not determined as a joint point. In this way, it is possible to determine whether the virtual skeleton point is a joint point while it is extracted.

Firstly, the position of the “dominant joint” in the virtual skeleton is located:

1) Assuming that n virtual, calculate $k(i) = \frac{y_i - y_{i-1}}{x_i - x_{i-1}}, i = 1, 2, \ldots, n$.

2) The selection of K value is related to the error of the contour image of the human body and the motion amplitude of the target human body. If the error of the binary image is small, the amplitude of human motion is large, and K takes a smaller value; otherwise, a larger value is taken for K. In general, the value for K is between [0.05, 0.15].

3. Experimental Results and Analysis

According to the algorithm described above, we conducted experiments on some single images and sequence images. Figure 5 shows the experimental results of images taken in a laboratory environment. The white points in Figure 3 (f) are the positions of the real joints of the human body, and the red points are the joint points determined by this method. small.
(a), (b) are two adjacent frames, (c) is a differential image, (d) is the extracted human contour, (e) is the position of the extracted virtual skeleton and joint points, and (f) is the same as the real Comparison of joint positions. $\alpha = 3$, $K = 0.08$

**Figure 3.** Experimental results of images taken in a laboratory environment

At the same time, the following conclusions are obtained:

1. The energy function taken when extracting the virtual skeleton has a good suppression effect on point noise and linear noise in the binary image, but block noise has a certain effect on the result.

2. Scale parameter is used to determine the position of the recessive joint, but there is a certain error between the parameters of different individuals, which has some impact on the results.

3. As it is impossible to extract the contour of the human body corresponding to the occluded part, the situation of joint concealment and occlusion has a relatively significant influence on the results and may even generate wrong results.

4. **Conclusions**

In this paper, an algorithm for determining the human joint position based on the human contour image feature is proposed. In this method, the contour of the target human body is first extracted from the image. Subsequently, the energy function is used to extract a virtual skeleton similar to the real human skeleton and determine the joint position. The experimental results show that the algorithm has no restrictions on the motion and color of the human body in the image. At the same time, it also has an excellent suppression effect on the noise in the human contour image. Attributing to this feature, it has a relatively low requirement on the extraction accuracy of the human contour, with good performance in complex backgrounds.

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