On Vector Autoregressive Model for Action of Human Arm's

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Abstract

Human arm's pose is determined by the angles of the shoulder and the elbow. In this paper, we will estimate the relation between the angles of the arm in action using a vector autoregressive model.

1 Introduction

Recently, analysis of human pose and action becomes important in the fields, such as medical treatment, welfare and robotics. The authors proposed the fuzzy models to describe the human-like arm's pose. There wear two types of fuzzy models which depended on the domain's where the hand moved.

In this paper, we propose a vector autoregressive model to estimate the action of the arm.

2 The model of an arm's pose

2.1 Description of the arm's pose

By using the D-H method, we can build the virtual posture model to human's upper limbs. We set coordinates to the body, shown in Figure 1. The arm's pose can be described by the angles of the joints. Considering the constraints of the joints, human-like arm's model is estimated.

a_1 shows the breadth of its shoulders. a_2 shows the length from the shoulder to an elbow. a_3 shows the length from the elbow to the wrist. d_1 shows the length of the body.

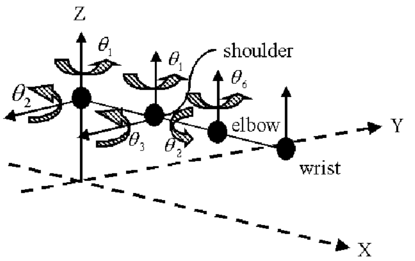

Figure 1: Coordinates of D-Hmethod length between the neck and the shoulder

2.2 Relation between a hand position and each joint angle

Hand position is denoted by (X, Y, Z). Each joint angle is denoted $\theta_i (i = 1 \cdots 6)$. The relation between the hand position and each joint angle is shown below.

$$X = a_3(C_{12}C_{34}C_5 - S_{12}S_5) + a_2C_{12}C_3 + a_1C_1 \quad (1)$$

$$Y = a_3(C_{12}C_{34}C_5 + C_{12}S_5) + a_2S_{12}C_3 + a_1S_1 \quad (2)$$

$$Z = a_3S_{34}C_5 + a_2S_3 + d_1 \quad (3)$$

where

$$C_i = \cos\theta_i, S_i = \sin\theta_i,$$
$$C_{ij} = \cos\theta_i + \theta_j, C_{ij} = \sin\theta_i + \theta_j$$

Angle γ and δ are set such that Figure 2 shows.

The coordinates of the hand, the elbow, and the shoulder are (x_h, y_h, z_h), (x_e, y_e, z_e), (x_s, y_s, z_s), respectively.

The distances A, B, C, and D shows in Figure 2 is as follows.

$$A = \sqrt{(x_e - x_h)^2 + (y_e - y_h)^2} \quad (4)$$

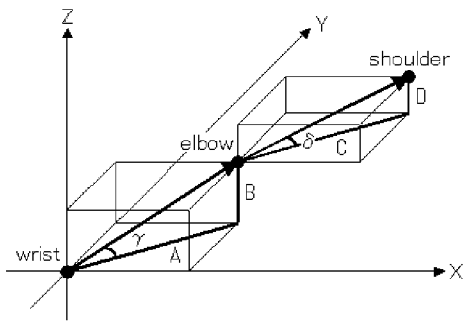

Figure 2: The angles of hand, elbow, and shoulder

$$B = | z_e - z_h | \tag{5}$$

$$C = \sqrt{(x_s - x_e)^2 + (y_s - y_e)^2} \tag{6}$$

$$D = | z_s - z_e | \tag{7}$$

From (4) and (5),we get

$$\tan\gamma = \frac{z_e - z_h}{\sqrt{(x_e - x_h)^2 + (y_e - y_h)^2}} \tag{8}$$

$$\gamma = \tan^{-1} \frac{z_e - z_h}{\sqrt{(x_e - x_h)^2 + (y_e - y_h)^2}} \tag{9}$$

From (6) and (7),we get

$$\tan\delta = \frac{z_s - z_e}{\sqrt{(x_s - x_e)^2 + (y_s - y_e)^2}} \tag{10}$$

$$\delta = \tan^{-1} \frac{z_s - z_e}{\sqrt{(x_s - x_e)^2 + (y_s - y_e)^2}} \tag{11}$$

3 Vector autoregressive model

$X(n) = (x_1(n), \cdots, x_k(n))$ denote the time series. $U(n)$ is white noise sequence. Vector autoregressive model is as follews. It is shown in (12).

(1)The autoregressive model

$$X(n) = \sum_{m=1}^{M} A(m)X(n-m) + U(n) \tag{12}$$

$$A(m) = \begin{bmatrix} A_{11}(m) & \cdots & A_{1k}(m) \\ \vdots & \ddots & \vdots \\ A_{k1}(m) & \cdots & A_{kk}(m) \end{bmatrix} \tag{13}$$

(2)Autoregressive coefficient

The Mth coefficient is decided by (14).

$$c_i(m) = A_{ii} \qquad m = 1, \cdots, M \tag{14}$$

Cofficients $A(m)$ is estimated by Levinson-Durbin Algorithm.

(3)Impulse response function

The impulse response function from $x_j(n)$ to $x_i(n)$ is calculated by (15) and (16).

$$a_{ij}(m) = A_{ij}(m) + \sum_{k=1}^{m-1} c_i(k)a_{ij}(m-k) \tag{15}$$

$$a_{ij}(m) = \sum_{k=1}^{M} c_i(k)a_{ij}(m-k) \tag{16}$$

Variable $x_i(n)$ is obtained by (17).

$$x_i(n) = \sum_{j=1}^{k}\sum_{m=1}^{M} a_{ij}(m)x_j(n-m) + u_i(n) \tag{17}$$

The frequency response function from $x_j(n)$ to $x_i(n)$ is calculated by (18).

$$a_{ij}(f) = \sum_{m=1}^{M} a_{ij}(m)e^{-2\pi imf} \tag{18}$$

The power spectrum of noise($u_i(n)$) is set to (19). σ^2 is variance of $u_i(n)$.

$$P_{ui}(f) = \frac{\sigma^2}{| 1 - \sum_{m=1}^{M} c_i(m)e^{-2\pi imf} |^2} \tag{19}$$

$$A(f) = \begin{bmatrix} 1 & -a_{12}(f) & \cdots & -a_{1k}(f) \\ -a_{21}(f) & 1 & \cdots & \cdots \\ \vdots & \vdots & \ddots & \vdots \\ -a_{k1}(f) & \cdots & \cdots & 1 \end{bmatrix} \tag{20}$$

The power spectrum of $x_i(n)$ can be decomposed into (21) and K ingredients. (22) is the noise portion of $x_i(n)$. (23) can calculate the rate of noise contribution.

$$P_{ii}(f) = \sum_{j=1}^{k} | b_{ii}(f) |^2 \, P_{uj}(f) \tag{21}$$

$$q_{ij}(f) = | b_{ij}(f) |^2 \, P_{uj}(f) \tag{22}$$

$$r_{ij}(f) = \frac{q_{ij}(f)}{P_{ii}(f)} \tag{23}$$

4 Experiment

4.1 Measurement conditions

Experiments are performed as follows.

1. A subject is sat down in the chair.
2. The subject moves his hand on a desk.
3. The height of a desk is same as the height of his navel.
4. Positions of his right shoulder, his right elbow, his right-hand head, his navel, and his throat are mesured by motion capture.
5. Sampling interval of observation is 0.0084[ms].
6. Repetition operation is measured in the domain where the subject moves his hand easily.
7. Same action is repeated 50 times.

It is shown in Figure 3.

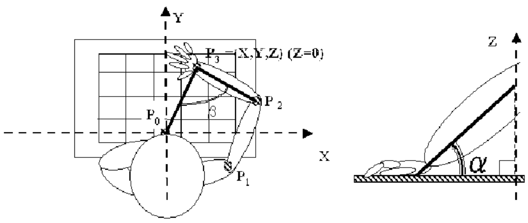

Figure 3: The situation of the experiment

4.2 The measured waveform

The measured waveform is shown in Figure 4, 5, and 6. The number of data is 2000. The angle γ and δ are calculated from these date and are shown in Figure 7, 8.

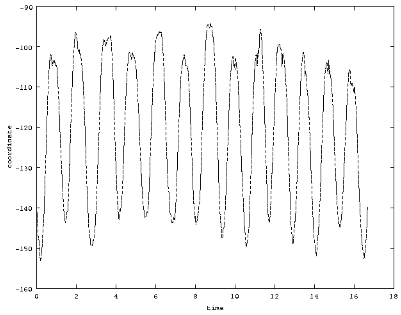

Figure 4: Coordinates x of the wrist

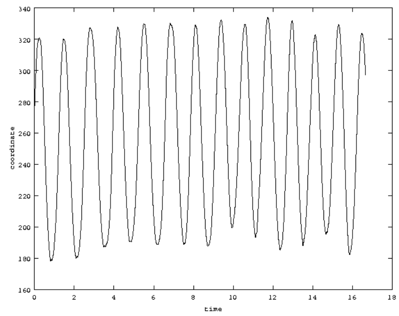

Figure 5: Coordinates y of the wrist

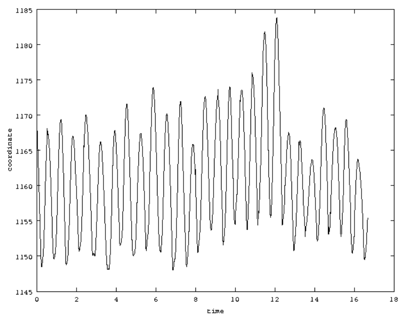

Figure 6: Coordinates z of the wrist

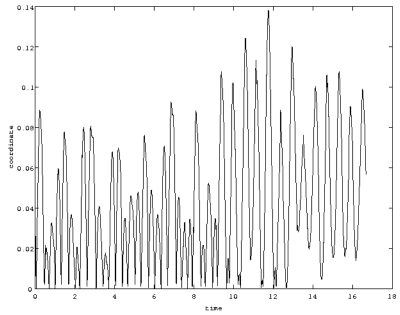

Figure 7: Angles γ

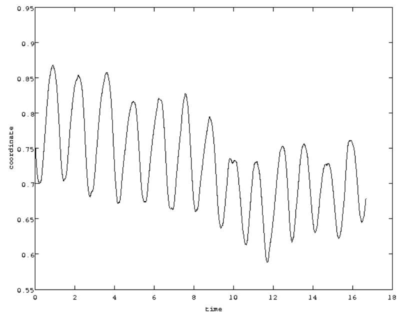

Figure 8: Angles δ

4.3 Application of vector autoregressive model

The relation between angle γ and δ is estimated by vector autoregressive model. The order of the model is determined by AIC.

It was decided that we would be the 10th order. The rate of contribution is calculated from (7) and (8). A result is shown in Figure 9.

The motion of the wrist and the motion of an elbow are interlocking. If frequency becomes high, the tendency for which a motion of an elbow depends on a motion of a wrist will become strong.

5 Conclusion

We estimated the pose of the upper limbs in action by using vector autoregressive model. Estimated model described the relation between the angles of the wrist and the elbow. And gave the contribution rate to show the dependence between the movement of the wrist and the elbow. In this experiment, the action was performed only in the domain where the subject move his arm easily.

In the future, we will determine the model of the action out of this domain.

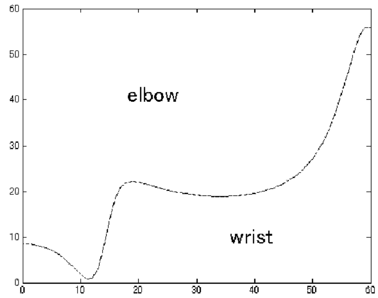

Figure 9: The rate of contribution

References

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