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An Analytical Method of Human Motion by Image Processing

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This paper deals with an analytical method of human motion by image processing to make a model of the scooping process. Firstly, the scooping tool is the spoon, and while the scooping process is performing, the movement of the mouth center position and the spoon top position are measured by two cameras. As the amount of substance is over the uppermost area of the cup, the spoon is stuck obliquely into the substance. Then the spoon is rotated and lifted up to the mouth. Secondly, we recognize the mouth center from the characteristic of the face image data and calculate the spoon top position to extract two points on the spoon handle from the time series images by two cameras. Finally, we describe the method of recognizing the coordinate of the mouth center and estimating the coordinate of the spoon top to analyse the scooping process.

1. INTRODUCTION

The interface for information transmission from the human to the computer is carried out by using mainly the simple devices such as the touch panel, the keyboard and the mouse which are using to treat the input information one by one (1). The transmission volume of information is considerably few, in comparison with the volume of the visual information of the three dimensional human motion. It is necessary to develop the human-interface by take the visual information into the input device. And the analysis and quantization of various human motion are important to materialize the visual human-interface.

The relation between the human and the machine should be made simply by using the computer with the progress of technology. To make the high flexibility of the input of the information that fits the sense of the human, the information should be taken directly into the machine by using the human motion as the gesture (2).

By the way, the care work for the aged and disabled people should be assisted by human in the present situation (3). The necessity of the care work will increase more and more in the future (4). The supporting device is able to be handled with the will of the person that needs help, if the information is treated and analyzed by using an easy body action as visual human-interface (5).

In this paper, we propose an analytical method of human motion by image processing to make a model of the scooping process. This method composes of two phases, such as; the recognition of mouth center from the characteristic of the face image data and the measurement of the spoon position on the scooping process. Therefore, the movement of mouth center will be used to select the food and, the scooping process will be able to use to control the meal support robot system (6,7).

Section 2 outlines our proposed analytical method. Section 3 shows the experiment at condition of the scooping process.

2. OUTLINE OF ANALYSIS METHOD

This method composes of two phases, such as; (1) the recognition of mouth center from the characteristic of

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the face image data and (2) the measurement of the scooping process by using the spoon. It is assumed that the head moves to the front side in the scooping process. The procedure of this method is explained as follows.

2.1 Recognition Method of Mouth Center

2.1.1 Input Image

The system configuration of image processing device is shown in Fig. 1. The face image data and the scooping process by using the spoon is taken at short intervals continuously by setting at the front camera (C_1) and the side camera (C_2), so that the upper half of the body can be imaged in the screen of the video monitor in Fig. 2. We set the three-dimensional coordinates, such as; the direction of the lens of camera (C_1) is set as X-axis, the direction of the camera (C_2) is set as Y-axis then Z-axis is set as the upper direction in the image of C_1 and C_2. The image data from two cameras are taken into the personal computer through two full-color frame buffer boards. The board has 400 pixels on the horizontal axis and 640 pixels on the vertical axis with 256 levels each 3 colors (red, green and blue). The image data from camera C_ℓ ($\ell=1, 2$) at time t is denoted as follows.

$$0 \leqq R_{\ell ij}(t) \leqq 255, \quad 0 \leqq G_{\ell ij}(t) \leqq 255, \quad 0 \leqq B_{\ell ij}(t) \leqq 255, \quad 0 \leqq i \leqq 399, \quad 0 \leqq j \leqq 639, \quad t=1,2,\cdots,n.$$

2.1.2 Calculation of coordinate of mouth center

The coordinate of the mouth center is calculated by the value that is obtained by the extraction of the face area. The face area is restricted in the area of $0 \leqq i \leqq 399$, $0 \leqq j \leqq 320$ that is the face area is put as the half top of the input image show in Fig. 3-(1). The binary image $F_{1jk}(t)$ of C_1 and $F_{2ik}(t)$ of C_2 are given by the Eq. (1) and (2). Where, the constant value TF_1 and TF_2 are put as the threshold values.

$$F_{1jk}(t) = \begin{cases} 1 \mid R_{1jk}(t) > TF_1, \\ 0 \mid R_{1jk}(t) \leqq TF_1, \end{cases} \quad 0 \leqq j \leqq 399,\ 0 \leqq k \leqq 320. \tag{1}$$

$$F_{2ik}(t) = \begin{cases} 1 \mid R_{2ik}(t) > TF_2, \\ 0 \mid R_{2ik}(t) \leqq TF_2, \end{cases} \quad 0 \leqq i \leqq 399,\ 0 \leqq k \leqq 320. \tag{2}$$

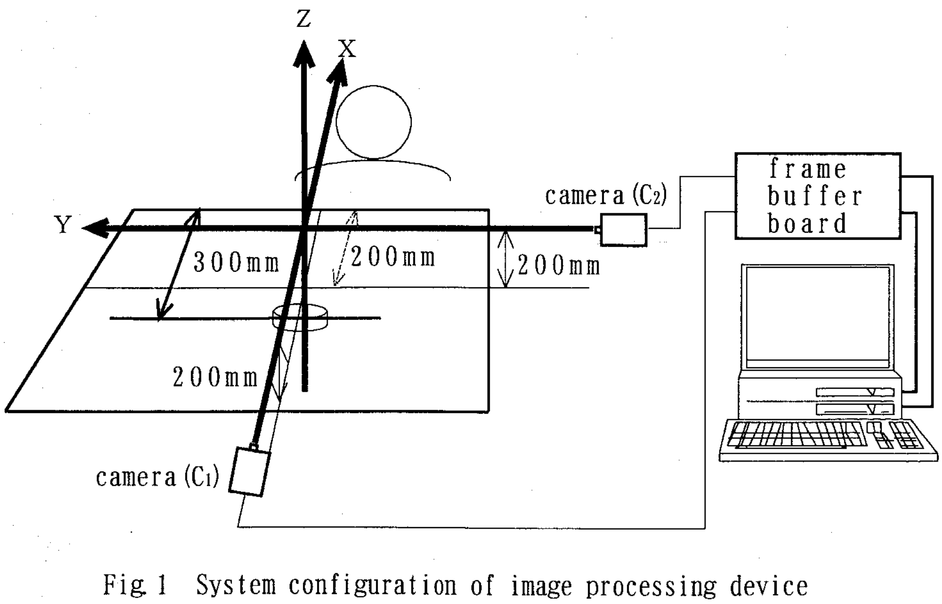


Fig. 1 System configuration of image processing device

The horizontal face area is put as the area between the minimum value $JFN(t)$ and the maximum value $JFX(t)$ of binary image $F_{1jk}(t)$, $JFN(t)$ and $JFX(t)$ are given by the Eq. (3).

$$\begin{cases} JFN(t) = min\ \{j \mid F_{1jk}(t) = 1\}, \\ JFX(t) = max\ \{j \mid F_{1jk}(t) = 1\}, \end{cases} \quad (3)$$
$$0 \leqq j \leqq 399,\ 0 \leqq k \leqq 320.$$

The vertical face area is put as the area between the minimum value $KFN(t)$ and the maximum value $KFX(t)$, $KFN(t)$ and $KFX(t)$ are given by the Eq. (4).

$$\begin{cases} KFN(t) = min\ \{k \mid F_{1jk}(t) = 1\}, \\ KFX(t) = max\ \{k \mid F_{1jk}(t) = 1\}, \end{cases} \quad (4)$$
$$0 \leqq j \leqq 399,\ 0 \leqq k \leqq 320.$$

The vertical center line $KFC(t)$ and the horizontal center line $JFC(t)$ are shown in Fig. 3– (1), $KFC(t)$ and $JFC(t)$ are given by the Eq. (5).

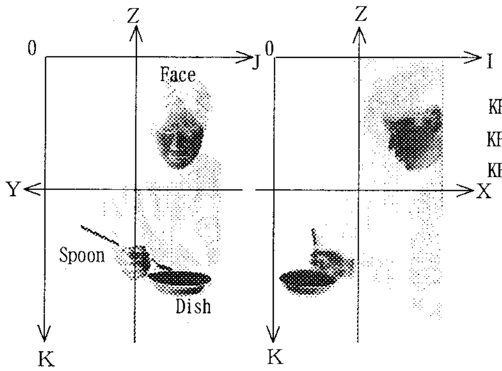
$$\begin{cases} KFC(t) = (KFN(t) + KFX(t))/2, \\ JFC(t) = (JFN(t) + JFX(t))/2. \end{cases} \quad (5)$$

It is assumed that the mouth center position $M(JM(t), KM(t))$ is located on the horizontal center line $J = JFC(t)$.

The contour line (8) of the face is extracted from the area of $0 \leqq i \leqq 399$, $KFC(t) \leqq k \leqq KFX(t)$ in Fig. 3– (2). The chin position $C(IC(t), KC(t))$ and the nose top position $N(IN(t), KN(t))$ in C_2 are obtained from this contour line. The mouth center position $M(IM(t), KM(t))$ make an intermediate position between the chin position $C(IC(t), KC(t))$ and nose top position $N(IN(t), KN(t))$ by the Eq. (6).

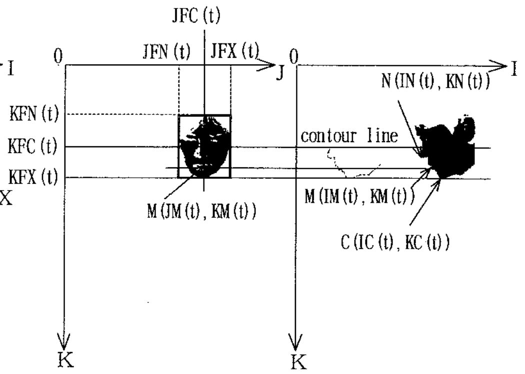
$$\begin{cases} IM(t) = (IC(t) + IN(t))/2, \\ KM(t) = (KC(t) + KN(t))/2. \end{cases} \quad (6)$$

Therefore, three dimensional coordinate $M(IM(t), JM(t), KM(t))$ of the position of a mouth are obtained. Also, we are able to judge that the spoon comes at the mouth, because the length of the contour line of the face in the case that the spoon enters to the mouth is longer than the length in the case that the spoon does not enter.



(1) Camera (C_1) (2) Camera (C_2)

Fig. 2 Input Image



(1) $F_{1jk}(t)$ (2) $F_{2ik}(t)$

Fig. 3 binary image of the face

2.2 Measurement Method of Scooping Process

2.2.1 Extraction of the range of the blue stick

The spoon is attached the blue stick at the part of the spoon handle to measure the its position in Fig. 4. The length $LS1$ of the blue stick is 100 mm and the diameter is 7 mm. The length $LS2$ of the spoon is 150 mm. Three dimensional coordinate of top of the spoon are able to calculate from the coordinate of point A and point B. Point A is the top coordinate of the blue stick, and point B is the coordinate of attachment point between the blue stick and the spoon.

The area of the blue stick is obtained from the area where satisfies the Eq. (7) of the camera C_1 at t=1 in Fig. 5- (1). Because, in the area of the blue stick, the blue component value is bigger than the red and the green component value.

$$S_{1jk}(1) = \begin{cases} 1 \mid B_{1jk}(1) - R_{1jk}(1) > TH_1 \text{ and } G_{1jk}(1) - R_{1jk}(1) > TH_2, \\ 0 \mid B_{1jk}(1) - R_{1jk}(1) \leqq TH_1 \text{ and } G_{1jk}(1) - R_{1jk}(1) \leqq TH_2. \end{cases} \quad 0 \leqq j \leqq 399,\ 320 \leqq k \leqq 639 \tag{7}$$

where, the constant value TH_1 and TH_2 are put as the threshold values.
Likewise, the area of the blue stick is obtained from the camera C_2 at t=1 in Fig. 5- (2).

2.2.2 The calculation of 3 dimensional coordinate of the spoon top

The contour line in Fig. 5- (1) is extracted from the area of the blue stick. The data of this contour line is shown with $CL_1(J_r, K_r)$, $(0 \leqq r \leqq L_1)$. The value L_1 is the number of pixels on the contour line. The curvatures CC_{1r}, $0 \leqq r \leqq L_1$ in Fig. 6- (1) are calculated by using three points $CL_1(J_r, K_r)$, $CL_1(J_{r-d}, K_{r-d})$ and $CL_1(J_{r+d}, K_{r+d})$ on the contour line by the Eq. (8). Where the value d is determined from the experimental data.

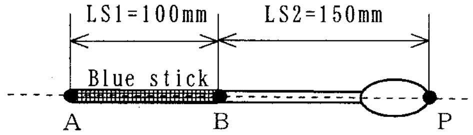


Fig. 4 Spoon

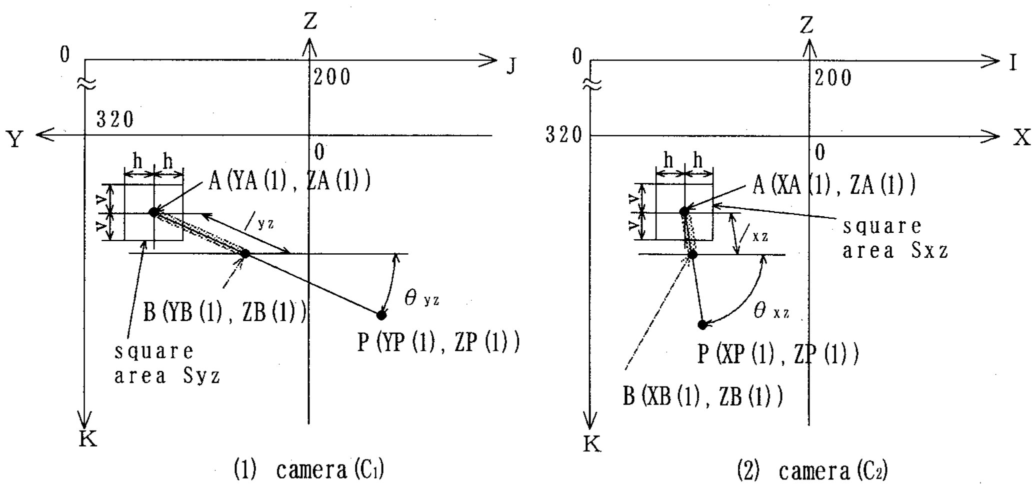


Fig. 5 Binary image of the spoon

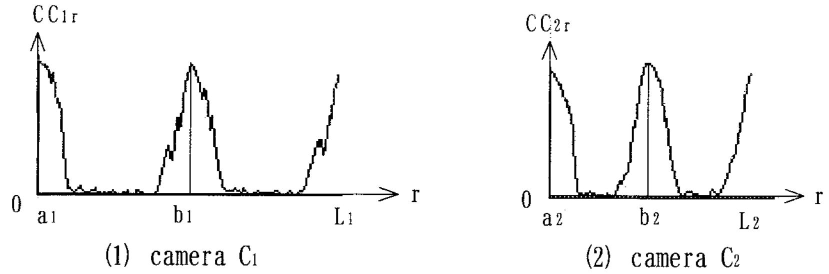


Fig. 6 Curvatures on the contour line

$$CC_{1r} = \tan^{-1}\frac{K_{r-d}-K_r}{J_{r-d}-J_r} - \tan^{-1}\frac{K_r-K_{r+d}}{J_r-J_{r+d}},\ r=d,\cdots,L_1\text{-}d. \quad (8)$$

Two dimensional coordinate of point $A(YA(1), ZA(1))$ is given from $r=a_1$, and $B(YB(1), ZB(1))$ is given from $r=b_1$ on the maximum value of the curvature. Likewise, the contour line $CL_2(I_r, K_r)$ $(0 \leqq r \leqq L_2)$ is able to extract from the area of the blue stick by the camera C_2. Two dimensional coordinate of point $A(YA(1), ZA(1))$ and $B(YB(1), ZB(1))$ are given from $r=a_2$ and $r=b_2$ on the maximum value of the curvatures CC_{2r}, $0 \leqq r \leqq L_2$ in Fig. 6– (2).

The area of the blue stick at $t=2$ is able to obtain from the square area Syz $(YA(1)-h \leqq y \leqq YA(1)+h,\ ZA(1)-v \leqq z \leqq ZA(1)+v)$ of the centering on point A at $t=1$ in Fig. 5– (1). The area of the blue stick at $t=n$ is able to extract from the square area Syz at $t=n-1$. Likewise, The area of the blue stick from the camera C_2 at $t=n$ is able to obtain from the square area Sxz $(XA(n-1)-h \leqq z \leqq XA(n-1)+h,\ ZA(n-1)-v \leqq z \leqq ZA(n-1)-v)$ at $t=n-1$ in Fig. 5– (2). Here, the value h and v are determined from experimental data. The processing time is able to be reduced by setting up the square area Syz and Sxz.

Three dimensional coordinate of spoon top $P(XP(t), YP(t), ZP(t))$ are given by the Eq. (9) from three dimensional coordinate of point $A(XA(t), YA(t), ZA(t))$, $B(XB(t), YB(t), ZB(t))$ of the blue stick.

$$\begin{cases} XP(t) = XA(t) + LS1\cdot(\ell_{yz}/LS2)\cdot\cos\theta_{yz}, \\ YP(t) = YB(t) + LS1\cdot(\ell_{yz}/LS2)\cdot\sin\theta_{yz}, \\ ZP(t) = ZB(t) + LS1\cdot(\ell_{xz}/LS2)\cdot\sin\theta_{xz}. \end{cases} \quad (9)$$

Here, ℓ_{yz}, ℓ_{xz}, θ_{yz} and θ_{xz} are shown as follows.

$$\ell_{yz} = \{(XA(t)-XB(t))^2 + (YA(t)-YB(t))^2\}^{1/2},$$
$$\theta_{yz} = \tan^{-1}\{(YA(t)-YB(t))/(XA(t)-XB(t))\},$$
$$\ell_{xz} = \{(ZA(t)-ZB(t))^2 + (YA(t)-YB(t))^2\}^{1/2},$$
$$\theta_{xz} = \tan^{-1}\{(YA(t)-YB(t))/(ZA(t)-ZB(t))\}.$$

3. EXPERIMENTAL RESULT

In the experiment, the subject eats with the spoon. The condition of food is (1) liquid state thing (water), (2) grain state thing (wheat chocolate) and (3) rice. The position of the mouth, the extraction of the blue stick and the coordination of the spoon top are calculated by the proposal method. Fig.7 shows the inclination angle θ_{yz} of the spoon from camera C_1. Fig. 8 shows the point of the spoon top are obtained from camera C_1 and C_2 images for each food. Here, the threshold value put as $v=100$, $h=100$, $TF_1=150$, $TF_2=150$, $TH_1=30$, $TH_2=30$ and d=10. As the spoon arrives at the mouth after scooping was about 1.7 seconds, 0.8 seconds, 1.2 seconds in each food.

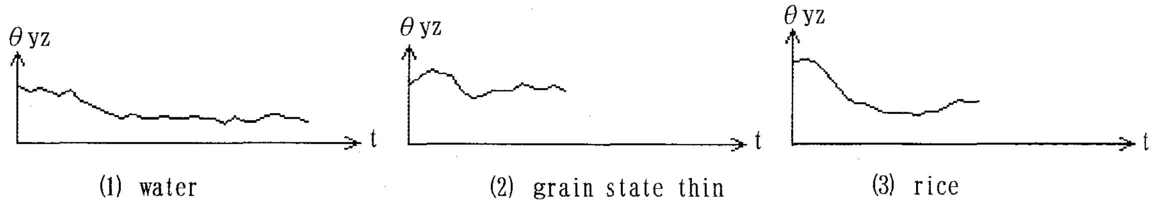


Fig. 7 Inclination angle of the spoon

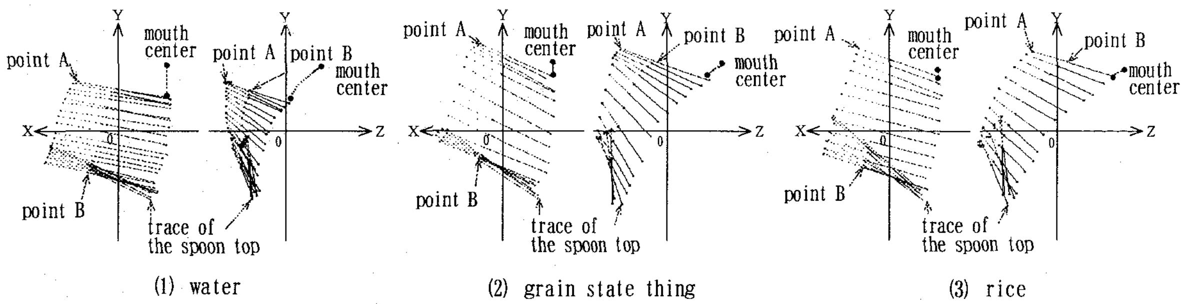


Fig. 8 Movement of mouth center and the spoon

In the case of water, the variable quantities of the inclination angle θ_{yz} of the spoon less and the movement of the spoon is slower than other food comparatively. Also the position of the mouth center is moving as it approaches to the spoon in the case that the spoon is moved slowly. The person is changing the inclination of speed of spoon in the condition of food. In this experiment, the coordinate of the spoon top can be calculated at the rate of about 10 times in one second.

4. CONCLUSION

We propose the analytical method of human motion by the image processing to make a model of the scooping process. The mouth center is recognized from the characteristic of the face image data and the measurement of the scooping process of the spoon. The following points are made clear.

(1) The coordinate of the mouth center is calculated by the characteristic of the face image data .

(2) The scooping process of the spoon can be analyzed in nearly real time.

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