Copycat Arm

- An aping arm mimicking human motions without delay -

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1 Introduction

The proposed system is capable of estimating the "shape or posture of the human hand" with a high speed and accuracy by means of a single high-speed camera, regardless of the differences among individuals, such as finger size, length of the bones, skin color, and state of creases, as well as differences in the lighting environments. In addition, this system can also estimate the accurate posture of a hand performing three-dimensional motions such as rotations of the wrist and shoulder by using a single camera, without having to install multiple cameras surrounding the hand, i.e., the object to be photographed. The error in the estimation is approximately 5 to 6 degrees in the finger joint angle, thus achieving an accuracy level almost identical to that of the conventional technology. This system realizes a processing speed of more than 100 fps, even when a single notebook personal computer with ordinary specifications is used.

Our research group made an exhibit of a "Copycat Hand" [1]–[2] at Siggraph Emerging Technologies in 2006. Although this system achieved a high processing speed of 150-160 fps, it could not necessarily make an accurate estimation of the motions of the fingers during three-dimensional motions such as rotations of the wrist and shoulder. In other words, a very low accuracy was achieved in the estimation of the hand posture when the palm of the user was aligned sideways with respect to the camera or when the user performed waving motions, for example, saying 'good-bye.' On the other hand, the "Copycat Arm" introduced this year can estimate the posture of a hand with high accuracy, even if the user moves his hand or arm freely before a high-speed camera. The secret lies in saving the contour information of a large number of hand shapes in advance in a database; this enables us to identify similar images among unknown images (this function was also adopted for "Copycat Hand"). Further, it is also advantageous to save the "slenderness ratio" of the hand images in the database and to hierarchically rearrange the data set of the database in advance, depending on the degree of similitude. If one practices gymnastics or dances in front of a high-speed camera, the "Copycat Arm" imitates the motions of the person's upper limbs without delay so that he/she can enjoy interactive communications with it. Therefore, this system is also known as the "Aping Arm."

2 System configuration

Human hand images and joint angle data were acquired as a set for preparing the database. The characteristics were calculated with respect to a reference point and its vicinity using a higher order local autocorrelation function

Clustering was conducted by means of a self-organizing map in order to collect data with mutually similar slenderness ratios of the hand images and joint angles. The large-scale database was divided into an approximately uniform number of classes and data in order to achieve uniformity in the estimation time.

3 Hand posture estimation

A subject held up a hand roughly 1 m away from the high-speed camera and moved his hand and fingers freely. The hand was allowed to move in all directions.

The estimated results showed that the finger angles have possibly been estimated with a high precision during continuous hand and fingers movements (Fig.1). It is also apparent that this system can estimate the accurate posture of a hand performing wrist rotation. The system operates at a rate faster than 100 fps. It also realizes a processing speed of more than 100 fps, even when a single notebook personal computer with ordinary specifications is used.

When the estimation results are transmitted to a humanoid robot arm with a hand (designed by our research group), which can pinch a small, thin, or fragile object using its fingertips, the dexterous hand can mimic the motions of the human hand with high accuracy at a processing speed of 100 fps or more, as shown in Fig. 2.

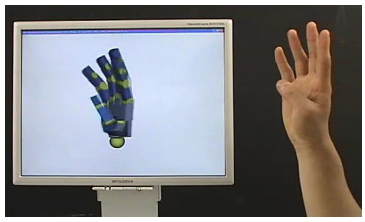

Fig. 1: An example of hand posture estimation.

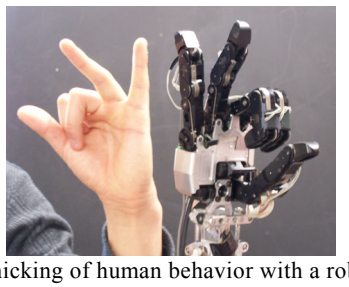

Fig. 2: Mimicking of human behavior with a robot hand.

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