Dynamical Robotic Interaction Using High-speed Visual Feedback and High-speed Robot Hand

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Abstract—In this paper, we focus on dynamical robotic interaction with high-speed visual feedback and high-speed robot hand. This paper describes two human–robot interactive tasks; the first one is Janken (rock-paper-scissors) robot as an example of non-contact type human–robot interaction and the second one is carrying object robot as an example of contact type human–robot interaction. To achieve these tasks, we briefly explain the proposed method and show experimental results.

I. INTRODUCTION

Robot technologies for manipulation and human–robot interaction have been proposed. These technologies contribute to automation of object handling by a robot and assistance of manual handling by a human. Recently, a fusion of manipulation and human–robot interaction has been actively studied for improving the working efficiency and the task performance. In the conventional technologies, the camera recognition of the object and the manipulation by the robot takes a long time, and these factors are the disadvantages of the conventional technologies.

Thus we apply the high-speed robot technology to the manipulation and the human–robot interaction. In particular, this paper describes the concrete applications in the human–robot interaction.

A. Related Work

Until now, there has been a lot of researches on human–robot interaction. Especially, in order to carry an object in the human–robot interaction, the task was successfully performed by Yokoyama et al. [1], an assistive system was developed by Hayashibara et al. [2], and a guidance system was proposed by Stücker and Behnke [3].

High-speed robot systems using a high-speed image processing technique with a high-speed camera (1,000 fps), which is beyond human eye (30 fps), were developed in our laboratory. Also, dynamic manipulations and other applications were achieved [4], [5]. We considered that high-speed robot technology can be applied to human–robot interaction.

B. Purpose

We describe Janken (rock-paper-scissors) robot as one example of non-contact type human–robot interaction. Also we explain object carrying robot as one example of contact type human–robot interaction. These tasks, which require the high-speed performance, are considered to be dynamical robotic interaction using high-speed visual feedback and high-speed robot hand (Fig. 1). Moreover, we show the possibility of the applications of the high-speed robot system to dynamic human–robot interaction, which means the robots react to the human action immediately.

II. HIGH-SPEED ROBOT SYSTEM

Our robot system consists of a high-speed robot hand, a high-speed vision system and a real-time controller. The real-time controller receives the image-processing result and controls the high-speed robot hand at 1 kHz.

A. High-speed Robot Hand

We developed the high-speed robot hand [6] whose joints can be closed at a speed of 180°/0.1 s. The high-speed robot hand has three fingers, and each finger has a top link and a root link. In the development of the high-speed robot hand, a miniature and high-power servo motor was also developed based on a new design concept of the servo motor.

B. High-speed Vision System

We used a high-speed vision system with a high-speed camera and high-speed image processing technique to recognize the state of a measurement target in real time. Only the image-processing results are sent to the real-time controller. By proposing the appropriate image processing to each task, the high-speed image processing can be performed.

III. JANKEN (ROCK-PAPER-SCISSORS) ROBOT

We show Janken (rock-paper-scissors) robot as the first application. This task is considered to be non-contact type human–robot interaction.

A. Method

We divided the task into the following two steps:
1) The hand shape (rock, paper or scissors) of the human is recognized using high-speed vision in real time.
2) The robot hand is quickly controlled to win the human.
By repeating the above two steps every 1 ms, the robot can always win the human.

1) **Hand Shape Recognition**: In order to appropriately recognize the shape (rock, paper or scissors) of the human hand at high-speed, we proposed a new algorithm for recognizing the shape [7]. In the proposed method, we can recognize the hand shape robustly and quickly.

2) **Robot Hand Control**: According to the recognition result of the hand shape, we give the reference joint angles of the robot hand and control the robot hand so as to beat the human.

**B. Result**

Fig. 2 shows continuous photographs of the experimental result. Also, a video of the experimental result is available on our web site [8]. From the experimental result, we achieved the Janken (rock-paper-scissors) robot with 100% winning rate.

**IV. OBJECT CARRYING ROBOT**

Here we explain an object carrying robot as the second application. This task is considered to be contact type human–robot interaction via an object to be handled. The details of our proposed method are given in [9].

**A. Method**

We also divided the task into the following two steps:

1) The position and orientation of the object are measured using high-speed vision in real time.
2) The robot hand is quickly controlled according to the position and orientation of the object.

By repeating the above two steps every 1 ms, the object carrying task can be successfully achieved.

1) **Measurement of Position and Orientation of Object**: In order to measure the position and orientation of the object, we tracked four corners of the object (a rectangle board) using the high-speed vision and the high-speed tracking algorithm [10], in which a marker was attached to each corner. From the information of the four corners, we measured the position and orientation of the object.

2) **Robot Hand Control**: According to the position and orientation of the object, the robot hand was controlled using PD (proportional-derivative) control. The reference joint angles of the robot hand were obtained by the inverse kinematics.

**B. Result**

Fig. 3 shows continuous photographs of the experimental result. Also, a video of the experimental result is available on our web site [11]. From the experimental result, we achieved the object carrying task using the high-speed robot system.

**V. CONCLUSION**

In this paper, we focused on dynamical robotic interaction with a high-speed robot system. Our system is specialized in the speeds of robots, visual feedback rate and reaction of robot. The proposed method was also executed by a high-speed vision system including high-speed image processing and a high-speed robot hand. As examples of the human–robot interaction, we developed and demonstrated Janken (rock-paper-scissors) robot and object carrying robot.

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**REFERENCES**