A Humanoid Robot for Table Tennis Playing

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Humanoid robot has been one of the most active research topics in the field of robotics. Their human-like form and configuration gives it advantages in working in human-interactive environment. The bipedal walking capability makes them possible to step over and onto obstacles, providing accessibility and mobility in cluttered space. The multi-DOF design of arms and legs enables them assist or replace humans in their normal tasks, making human life easier and safer. Humanoid robots, with their human-like outlook, also bring better interactive experience and are expect to play a part in people's daily life and help the elderly and the children.

Given the resent advancement on humanoid robot research, stable locomotion and various functionalities have been studied and implemented on many prototypes. Yet it's still challenging for humanoid robots to achieve a human-level performance due to limited sensory, poor actuation and lack of intelligence to interact with the environment. Compared with the static application condition which industrial manufacturing robots usually rely on, the service-oriented humanoid robots face much more difficulties caused by dynamic environment and complicated task objectives: ground may be uneven or slipped, human may walk around, obstacles or manipulable objects may be replaced or removed at any time, unexpected external force may cause the robot tick over, complex task requires delicate dynamics planning for whole body actuators, etc.

We take the table tennis playing as an entry point to exploit the techniques in the field of humanoid robotics. The table tennis playing is a challenging task but an ideal demonstration for an intelligent humanoid robot system. It involves following key points:
(1) Flexible mechanism design. It is essential to develop a robust and flexible humanoid robot both for walking and playing table tennis.
(2) Real time control. It not only demands on the efficiency of the planning and control algorithm, but also on the control cycle time due to the quick respond requirement. To get an instant control, minimize the cycle time is important.
(3) Accurate perception that includes identifying the moving ping-pong, predicting its motion and localizing the robot itself precisely in realtime.
(4) Robust balance maintenance, that is keeping balance dynamically during high-speed arm motion. Currently, the humanoid robot we built, named Kong, can perform constant rallying with a human table tennis player.

The robot is designed as a completely independent humanoid robot that can interact with human beings and the environment. It has a height of 160cm, a weight of 55Kg and 30 degrees of freedom (DOF). Compared with TOPIO, Kong is shorter and lighter, but more identical to common human beings.

There is an onboard vision system on the robot. It consists of two cameras mounted on head with a working frequency of 60fps and a base line of 10cm. However, due to the body vibration in playing table tennis and the short baseline between the two cameras, with such an onboard vision system the accuracy of the ball's locating result is not good enough. Thus, an external vision system consisted of the same two cameras hanged upside down from the roof with a base line of 110cm is adopted. The task of the external vision system is to identify the ball, locate the ball, predict the moving trajectory of the ball and find the best hitting time, pose and velocity of the paddle, while the task of the onboard vision system is to localize the robot itself at the beginning and in the playing interval.

When playing the table tennis, the robot stands on one side of a standard ping-pong table which is 2.74m long, 1.525m wide and 76cm high, with a 15.25cm high net in the middle of the table. The external vision system sends the hitting planning to the robot through a 802.11n wireless network. When the main controller on the robot receives the hitting plan from the external vision system, it plans each joints motion, generates compliance and compensation motion of whole body and sends control commands to the motor drivers. At the beginning and in the playing interval, the robot sends data requirement to the onboard vision system, then adjust its pose or update its pose information on the external vision system according to the data received.

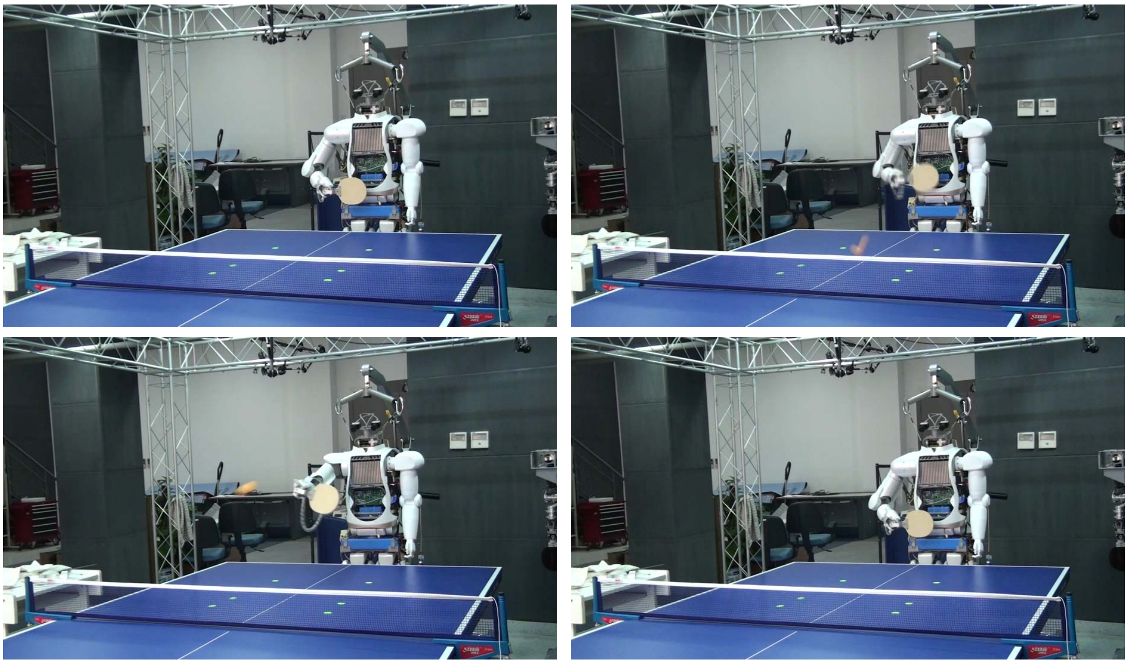

Fig 1. The robot plays table tennis