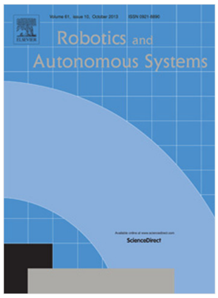
Accepted Manuscript



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PII: S0921-8890(17)30692-9
DOI: https://doi.org/10.1016/j.robot.2017.12.004
Reference: ROBOT 2962

To appear in: *Robotics and Autonomous Systems*

Received date : 2 October 2017
Revised date : 21 November 2017
Accepted date : 11 December 2017

Please cite this article as: Y. Liu, L. Liu, Accurate real-time ball trajectory estimation with onboard stereo camera system for humanoild ping-pong robot, *Robotics and Autonomous Systems* (2017), https://doi.org/10.1016/j.robot.2017.12.004

Accurate Real-time Ball Trajectory Estimation with Onboard Stereo Camera System for Humanoid Ping-Pong Robot

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Abstract—**In this paper, an accurate real-time ball trajectory estimation approach working on the onboard stereo camera system for the humanoid ping-pong robot has been presented. As the asynchronous observations from different cameras will great reduce the accuracy of the trajectory estimation, the proposed approach will main focus on increasing the estimation accuracy under those asynchronous observations via concerning the flying ball's motion consistency. The approximate polynomial trajectory model for the flying ball is built to optimize the best parameters from the asynchronous observations in each discrete temporal interval. The experiments show the proposed approach can performance much better than the method that ignores the asynchrony and can achieve the similar performance as the hardware-triggered synchronizing based method, which cannot be deployed in the real onboard vision system due to the limited bandwidth and real-time output requirement.**

Keywords: Humannoid Ping-pong robot, onboard vision, trajectory estimation;

1. Introduction

The task to build the onboard vision system for the humanoid Ping-Pong robot[1], shown in figure 1, is a challenge, as the vision system equipped on the robot will be constant vibration when the arm hitting the ball. Thus the vision system needs to estimate its 6DOF pose related to the table quickly and localizes the ball's coordinates related to the table by the triangulation and then estimates the trajectory of the ball to further predict the ball's arriving time, velocity and position for the visual servo planning of the arm. In the designated vision system, the multiple-camera pose estimation algorithm [1] is used to estimate the pose in real-time and a Kalman filter [2, 3] based estimation method to predict the status of the ball. Then the accurate real-time ball trajectory estimation becomes the critical point for the onboard stereo vision system.

In the normal rallying, the processing of the ball flying through the table only takes less 600ms. The arm needs to occupy about 400ms to start its motion and move to the hit point, and the prediction will cost 50ms, there are only less 150ms left for the ball's trajectory estimation. Thus two difficulties for the trajectory estimation come up.

The first difficulty is to design the optimal capture software and hardware system that can consider both the accuracy and the capability of real-time performance. In the designated vision system, two cameras[2] working at a resolution of 640x480 pixel, 60 frame/s are used. Although a larger frame rate and higher resolution will lead to more dense or accurate observations for the trajectories, it will also slow down the output of the estimation results of the trajectory due to the limitations of the computation

[1] The video of our Ping-Pong robot working with onboard vision system is attached in the submission system.
[2] There is a rigid constraint among these two cameras when mounting, the constraint can be calibrated offline.