Development of an Autonomous Robot Arm System for Playing Ping Pong

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This project deals with the development and construction of an autonomous robot arm with a camera system. Catching a ball using a hoop and volleying a ping pong ball were chosen as example applications. The self-developed autonomous system consists of three components: (1) Robot arm with ping pong paddle, (2) Camera system for dynamic image capture, and (3) Software for ball detection and localization in three-dimensional space as well as trajectory prediction and robot arm control. Design and construction of the robot arm were carried out using CAD design software and a 3D printer. The system's components were optimized for the planned dynamic applications, focusing on speed, weight, and robustness. My paper details the selection of corresponding components, such as high-torque motors and high-frequency cameras. Additional solutions were developed and implemented for both system applications: Methods are shown for how the cameras can automatically determine their position in space using AprilTags, how the ball is detected against its background, how camera measurement errors are minimized, and how temporal deviations in recordings can be mitigated. Furthermore, it describes how the ball's trajectory can be predicted using the captured position data, and shows a method for calculating the optimal point where the ball should be caught or returned by the robot arm. The project also deals with calculating an optimal paddle position and movement sequence to return the ball with a ping pong paddle mounted on the arm. Appropriate test series demonstrate the successful application of the robot arm system both in catching a ball with an average catch rate of over 87%, and in ping pong play with a return rate of 90% and a play sequence of up to 20 hits.

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