Less is More: Examining Robot Ping Pong Enables the Design of Multi-Purpose Systems

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1 Research Context and Problem Statement

Robotic table tennis has been studied for years since it is an excellent test bed for real-time computation, sensing, and motion planning. This data is increasingly crucial in fields that require low latency and sub-one-second response times, such as aeronautics, robotics, and autonomous systems [3]. Our research intends to examine robotic ping pong as a means of determining computer architecture requirements for high-performance platforms. This is a breadth-wise approach that will enable the design of more efficient, effective, and versatile computer systems.

Current, state-of-the-art robots require specialized platforms to perform computationally expensive tasks quickly and efficiently. Falanga [2] considers the role of perception latency in high-speed robot navigation by comparing frame-based cameras against event cameras for quadrotor flight. It is concluded that event cameras are significantly more useful when dealing with agile robots, as computational power is reduced. This work demonstrates the relationship between perception latency and actuation limitations.

Our study compares perception, motion planning, and robotic hardware, and its relation to overall latency. Yu[1] discussed the design of a humanoid ping-pong robot, alongside its arm mechanisms, vision system, and motion planning methods. While they found some success with a trade-off between joint velocity and manipulability, we hope to investigate more trade-offs and if there are some changes from 2013 to now.

Our approach consists of the characterizations of ping pong players and obtaining quantitative measurements from different skill levels, beginners, intermediate, and advanced. In each match, we record the reaction time of the player (strike to bounce), their consistency (their streaks in hitting the ball before they lose that point), and speed. From this investigation, we will analyze the timing and physics constraints a robotic player must follow to play alongside a human player. The goal is to optimize the robotic player by analyzing at which stage of the computation in the system (robotic hardware, computing hardware) resources should be allocated for optimization and investigate the optimal trade-offs between perception, motion, planning time, and resources.

The goal is to determine a computer architecture that can be generally purposed such that it is programmable and establish a quantitative basis that can improve the system and help generalize it to other areas of the tasks. This allows for the establishment of a threshold, for platforms with low latency requirements. The problem in robotics is that it is very centralized to do one specific task. Our solution is that we will look at the statistics of real ping pong players and replicate those movements in the robot arm to make it flexible and have a fast reaction time.

2 Proposed Solution

We will evaluate the trade-offs with the data that we will gather from ping pong players. For this process, we will watch ping pong videos from beginner to advanced level. The classification of players is based according to the level of the match they participate in (local, national, and international levels). From these videos, we will calculate the reaction times: bounce to bounce and strike to strike. We also take the angle at which the video is recorded into account, in order to accurately measure the geometric motion of the ball. Once we gather preliminary parameters, we will begin a physics computer simulation of a ping-pong match with a robotic player. The goal is to simulate how a ping-pong match against a robotic arm will play out when we control a specific parameter, such as sensing performance and actuation. For the simulation, we will use a combination of Mujoco Physics Simulation and the Robosuite API to create a virtual simulation of the tennis table and ball. With the simulation, we will gather data on the motion, curvature, and speed of the ball. Using the data, we will analyze the reaction time constraints of the robot player such that we can inspect the trade-offs, and the optimal allocation of resources to either perception, motion, or planning time, in order for the robot to be the most efficient.

3 Evaluation and Implementation Plan

Evaluation Plan: We know our research is successful when we obtain simulated numbers that can be compared with the preliminary metrics obtained from videos of human players. Ultimately our goal is to gain a larger understanding of the required computational power for perception and actuation, and determine at a glance whether or not more complex computer architectures are necessary for robotic platforms.

Timeline: Below is a proposed timeline for the rest of the academic year:

Dates	Task
October 17	Gather preliminary ping pong data on human players
October 18	Met with MIT Robotics Team via Kendrick
November 22	Edit Robosuite code to build our custom environment and objects
November 29	Render a ball object in MuJoCo
December 7	Complete the research proposal
Late January	Meet with team to discuss next steps
Late February	Share simulation progress with team
Late April	Share findings with team

References

[1] Design of a humanoid ping-pong player robot with redundant joints, 2013.

[2] How fast is too fast? the role of perception latency in high-speed sense and avoid, 2019.

[3] Deterministic iteratively built kd-tree with knn search for exact applications, 2020.