

CIS II Background Reading / Paper Critical Review

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Background

As humans interact with robots, studying individuals' nonverbal behaviors can lead to additional insights about their state of mind. Eye gaze is one metric that has the potential to inform researchers about a human's thoughts and intentions, especially when dealing with specific tasks in human-robot collaboration scenarios. Former studies show that gaze behavior is often task-driven, meaning that gaze rarely should deviate from the task at hand. Thus, it is interesting to analyze gaze behaviors and how they stray from the norm or what is expected.

Paper Purpose

Selected Paper: *"Gaze for Error Detection During Human-Robot Shared Manipulation"*

Authors: *Reuben M. Aronson and Henny Admoni*

The aim of this paper was to monitor human mental states by analyzing anomalies in their behavior. The authors wanted to track humans' gaze behaviors as they complete a food-spearing task with the robot and create a dataset from these behaviors. They hoped to use this dataset to gain additional insights of gaze behaviors and increase the robustness of future human-robot collaborative teleoperate systems to help the system handle failures. However, during their data collection processes, they noticed a subset of errors that occurred during the interactions and how gaze deviated as a result. Thus, they acknowledge the potential for using gaze to identify errors, as underlying patterns began to emerge.

System Summary

A joystick is used as a robotic manipulator to teleoperate the robot. The joystick has the capability to control the end-effector of a robot in x/y, z/yaw, or pitch/roll. A button on the joystick allows users to cycle through the modes. A Pupil Labs Pupil eye tracker (core) is used to gather the participant's gaze focal point information and video from the participant.

Study Summary

24 able-bodied individuals participated in a food-spearing task with the robot. The robot had a fork attached to its end effector. The participants used the robotic manipulator to attempt to spear a marshmallow. Three marshmallows were present on a plate in front of the robot. The paper did not specify how many marshmallows the participant was required to spear, nor if they were told to spear a specific marshmallow on the plate. Four different assistive conditions were examined in this study. One condition allowed the participant to fully teleoperate the robot, another was an autonomous condition where the joystick was used only for goal selection, and the other two maintained intermediate levels of assistance.

Results Summary

The researchers recognized two errors that occurred throughout their dataset and decided to identify them as case studies of anomalous behavior due to errors. Both examples each occurred at least five times in the dataset collected.

Case Study #1: *Goal occlusion by robot*

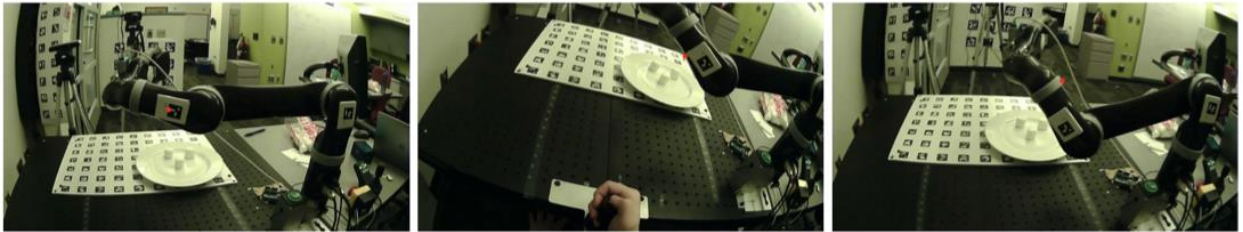


Fig. 3: When the robot occludes the robot end-effector, the user must move their head to get a better view. This behavior can be detected from the egocentric video data, shown here in a three-frame sequence.

At times, the participant moved the robot in a way such that the robot itself was blocking the participant's view of the end-effector. Thus, if they wanted to get a better view, they needed to move their head either to the left or right. In the interactions where the robot did not occlude the goal, the participant kept a steady head motion. This occlusion was thus perceived as an error because the participant did not intend to put the robot's end-effector in a location where they could not see it based on their current location, and their typical head motion created an anomalous behavior.

Case Study #2: *Poor robot kinematic configuration*

Another observed error was when the participant placed the robot in a poor configuration. In the case of the image in Figure 4, the participant wanted to drive the robot down towards the plate, but the current joint configuration of the robot elbow prevented the robot from following this action all the way. This caused the participant to fixate on the robot joint that was related to the bad configuration, an anomalous behavior. In other interactions, the participant almost never looked at the robot body apart from the end-effector.

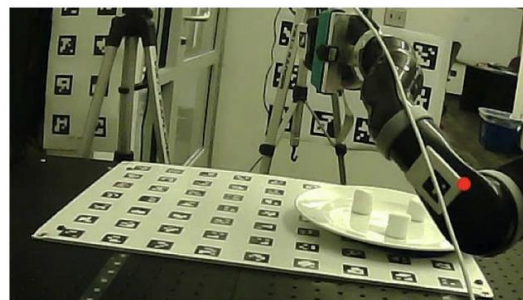


Fig. 4: The participant's gaze location, as indicated by the red circle, covers the robot joint as they maneuver through a bad kinematic configuration.

Assessment

Strengths. This paper clearly demonstrated how when studying human gaze data as participants complete a task with a robot and an error occurs, there is some clear indication that an error has occurred based on changes in gaze patterns. This is important because it signifies how there is a potential for gaze to be a clear metric at detecting if, and when, an error has occurred.

Weakness. This paper unfortunately used a small dataset, with only 24 participants and at least 10 instances total of the two errors mentioned. Furthermore, these errors were unintentional; this was not studying an intentional error scenario (i.e. a scenario where the experimenters planned for the robot to make a mistake). The errors were caused by the participant and the experimenters were not expecting these errors to occur until the pattern began to emerge. The authors also only focused on two types of errors. Although they mentioned that only surprising conditions occurred, albeit only a single time, they did not discuss them in their paper.

Possible Future Work. The authors acknowledge that errors can often be unpredictable, and that an anomaly detector can still recognize that an unexpected situation has occurred. They hope for future work where machine learning techniques incorporate gaze models to automatically detect anomalous behavior in human-robot collaboration scenarios and improve upon robot recovery strategies. Another potential future work that could be interesting is to repeat their same task but with more participants and to intentionally have the robot make a mistake during the interaction in a moment that is unexpected for the participants.

Relevance & Conclusion

This paper is extremely relevant, as I am considering adding gaze as a metric to Stiber's current robot error detection system and running a user study to collect data, and this paper focuses on how certain gaze patterns emerge during robot errors. Also, their gaze tracking instrument is from the same company as our intended gaze tracker, just a different model (core vs. invisible). The benefit with ours, the invisible, is that it does not need to be calibrated before use. Thus, their results indicate that live gaze-tracking has the potential to be insightful during robot error scenarios.

References

- Aronson, R. M., & Admoni, H. (2010). Gaze for Error Detection During Human-Robot Shared Manipulation. <https://www.semanticscholar.org/paper/Gaze-for-Error-Detection-During-Human-Robot-Shared-Aronson/390e9ac2e0a4162339a9a7e8bdb9c372bdcea659>