

Gaze Tracking Enabled Automatic Robot Error Detection

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CIS II Project Proposal

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Introduction

In the field of human-robot interaction (HRI), researchers focus on how humans interact with robots and the different conclusions we can draw upon these interactions. HRI is a growing field with the potential for many applications in medicine or health care. Robots could assist with kitting in surgical settings, help patients in hospitals by providing bedside assistance, or even interact with COVID-19 patients in the ICU to help minimize the risk of exposure for healthcare workers. Nevertheless, robots are fallible and can make mistakes when executing their actions.

Relevance/Importance: As the potential for robotic applications in the real world begins to grow, it is crucial to study how humans react to robot errors to gain a better understanding of humans' interactions with robots. Studying a human's physical and social responses to robot errors can inform researchers and roboticists of how not only robot errors may affect the trust humans place in a robot's actions, but also of ways to make future predictions of robot errors. If a robotic system does not have a built-in error detection system in place, recognizing that an error has occurred from a human's reaction is critical information; the feedback from such a detection system can allow a robot to minimize the severity of an error, allow a robot to correct its error, or even implement early stopping if the error is detected with enough notice.

There already has been a robot error detection system created, by my mentors on this project, that detects a robot error in real time by analyzing facial action units (AUs). Initial studies from my mentors show that people react very differently to physical mistakes executed by robots. Furthermore, depending on the task at hand and the users present, there may be a variety of human reactions.

The overall workflow of this current system consists of using two cameras aimed at a human's face, determining the current AUs present, detecting if an error has occurred based on these AUs, and logging the result with the corresponding timestamps. The ML algorithm that detects the error has been trained on a set of data of 19 participants reacting to robotic errors. The data collected was manually coded frame by frame in Microsoft PSI by two independent coders.

Goals and Aims

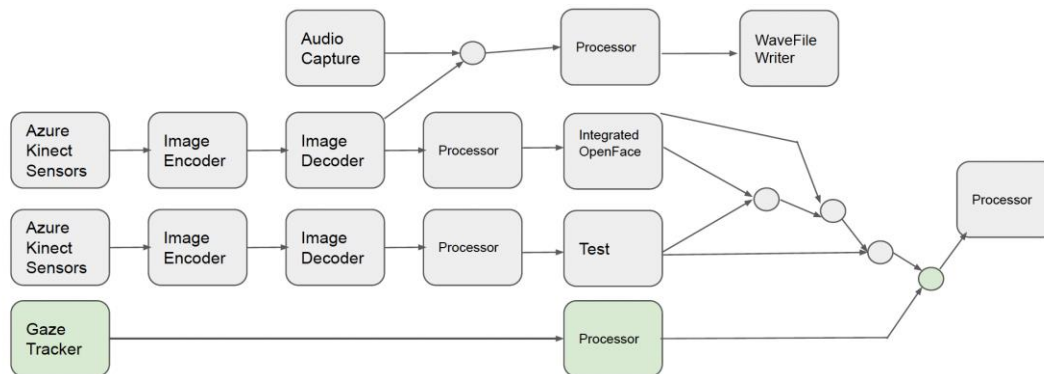
The goal of this project is to build upon this system by introducing human eye gaze as another potential metric of robot error detection. The current AU detection system will still function correctly if a user wears glasses. Pupil Labs has released a mobile gaze tracker in the form of a pair of eyeglasses for a human to wear. We intend to have users wear these glasses while interacting with a robot as a robot error occurs to gain a better understanding of their gaze

patterns. We hope to learn whether gaze can be an informative metric in robot error detection scenarios. Based on different types of errors, we want to investigate if human eye gaze is consistent; if there is a noticeable pattern that we could use down the line. Furthermore, we are interested in discovering if fixation points will appear that can inform us later in future scenarios explanations. Thus, the aims of this project consist of collecting data to understand human gaze reactions associated with physical robotic error, adding the gaze tracker data as an additional component to the Microsoft PSI system pipeline, and creating a ML algorithm with the data collected so that it will automatically detect the robot error as it occurs.

Technical Approach Summary

This project is divided into three major sections: Microsoft PSI, a user study, and the ML algorithm.

Microsoft PSI



We plan to integrate the gaze tracking component (shown in green) to the existing Microsoft PSI workflow. We hope to run this independently first to determine how informative the gaze fixations are without the influence of AUs. Some gaze fixation data from the following user study may need to be manually coded; if necessary, two independent coders will be used.

User Study

Hypothesis: We can understand robot errors based on humans' reactions through gaze analysis.

We hope to recruit at least 15-20 participants that will complete a task with the Kinova robot. There will be a planned robot error that the participant is not aware of, allowing for a scenario that can generate a genuine human reaction to an unexpected event. There may be different conditions that will have a different type of robot error in each condition. The data will be recorded via video cameras, the Kinect Azure, pupil labs invisible gaze tracker eyeglasses, and a questionnaire. The invisible gaze tracker is automatically calibrated. The questionnaire will include questions regarding basic demographic information, and if the participants witnessed an error and its corresponding severity.

ML Algorithm

As we begin our pilot study and view our collected data, we will research several approaches for a machine learning detection algorithm. Some ideas currently include implementing a binary classifier or conducting an independent component analysis with an SVM.

Deliverables

Minimum:	<ul style="list-style-type: none">• User Study Results and Analysis of Data• Integrate gaze tracker component into PSI for real-time error detection
Expected:	<ul style="list-style-type: none">• User Study Results and Analysis of Data• ML Algorithm that automatically detects errors using gaze data
Maximum:	<ul style="list-style-type: none">• User Study Results and Analysis of Data• ML algorithm that classifies error based on severity OR second study to validate data collection

Milestones

Description	Expected Date Done By	Status
Preliminary Papers Read	3/1/22	Completed
PSI Learned	3/10/22	In Progress
Gaze Tracker Component Written	3/19/22	Not Started
Gaze Tracker Component Tested	4/1/22	Not Started
User Study Prep Completed	4/1/22	In Progress
<ul style="list-style-type: none">• Questionnaire Created	3/19/22	Not Started
<ul style="list-style-type: none">• Tutorial Created	3/19/22	Not Started
<ul style="list-style-type: none">• IRB Approval	3/1/22	Completed
<ul style="list-style-type: none">• Pilot Study Conducted	4/1/22	Not started
<ul style="list-style-type: none">• Participant Recruitment Process Started	3/27/22	Not Started
User Study Conducted	4/9/22	Not Started

• Half of participants completed study	4/2/22	Not Started
ML Algorithms Tested	4/16/22	Not Started
• Tested Possible Algorithm #1	4/2/22	Not Started
• Tested Possible Algorithm #2	4/9/22	Not Started
Poster Presentation / Report	5/5/22	Not Started

Dependencies

Dependency	Contact	Solution	Alternative Plan	Completed
PSI Software	Maia Stiber	Online Github Instructions	N/A	Y
Computer (Windows)	Chien-Ming Huang	Lab Computer	Parallels on Personal Laptop	Y
Robot	Chien-Ming Huang	Use ICL Lab Kinova robot	N/A	Y
Cameras	N/A	Get cameras from lab	Personal Camera	Y
Room for User Study	Chien-Ming Huang	Malone 335	Talk to Chien-Ming Huang to find available room	Y
Participant Recruitment	Maia Stiber	Follow IRB protocol	N/A	N
Data/Code Backup		Github	External HD	N
IRB Approval	Chien-Ming Huang	Get added to IRB	N/A	Y
SD Card Reader	N/A	USB-C/HDMI/SD Card adapter	USB SD Card reader	Y

Management Plan

During the term, I will have weekly meetings with Chien-Ming Huang on Wednesdays from 2:00PM to 2:30PM and weekly meetings with Maia Stiber (time/date is flexible depending on the week). Otherwise, my mentors can be reached via Slack and email.

Reading List and 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>
- Stiber, M., & Huang, C.-M. (2020). Not All Errors Are Created Equal: Exploring Human Responses to Robot Errors with Varying Severity. Companion Publication of the 2020 International Conference on Multimodal Interaction, 97–101. <https://doi.org/10.1145/3395035.3425245>
- Kontogiorgos, D., Tran, M., Gustafson, J., & Soleymani, M. (2021). A Systematic Cross-Corpus Analysis of Human Reactions to Robot Conversational Failures. In Proceedings of the 2021 International Conference on Multimodal Interaction (pp. 112–120). Association for Computing Machinery. <https://doi.org/10.1145/3462244.3479887>
- Honig, S., & Oron-Gilad, T. (2018). Understanding and Resolving Failures in Human-Robot Interaction: Literature Review and Model Development. *Frontiers in Psychology*, 9. <https://www.frontiersin.org/article/10.3389/fpsyg.2018.00861>
- Aliasghari, P., Ghafurian, M., Nehaniv, C. L., & Dautenhahn, K. (2021). Effect of Domestic Trainee Robots' Errors on Human Teachers' Trust. 2021 30th IEEE International Conference on Robot Human Interactive Communication (RO-MAN), 81–88. <https://doi.org/10.1109/RO-MAN50785.2021.9515510>