Incorporating Eye Gaze Into Shared Autonomy for Assistive Robots

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Introduction

Robots are empowering people with disabilities in their activities of daily life, but:

Robots are **difficult** to control

Assistive systems designed to aid robotic control are **not optimal**

In this project, we use eye gaze as an additional trajectory input to predict the user's goals for a better usage experience with these assistive robotic arms.

Background

Shared Autonomy

Using shared autonomy, **robots mitigate the difficulty of control by adjusting the user's input based on its own planning.**[1]

These systems **rely on knowing about the user's goal** before attempting an action. They learn about the user's goal from information provided by the inputs and use that information to generate an action.[2]

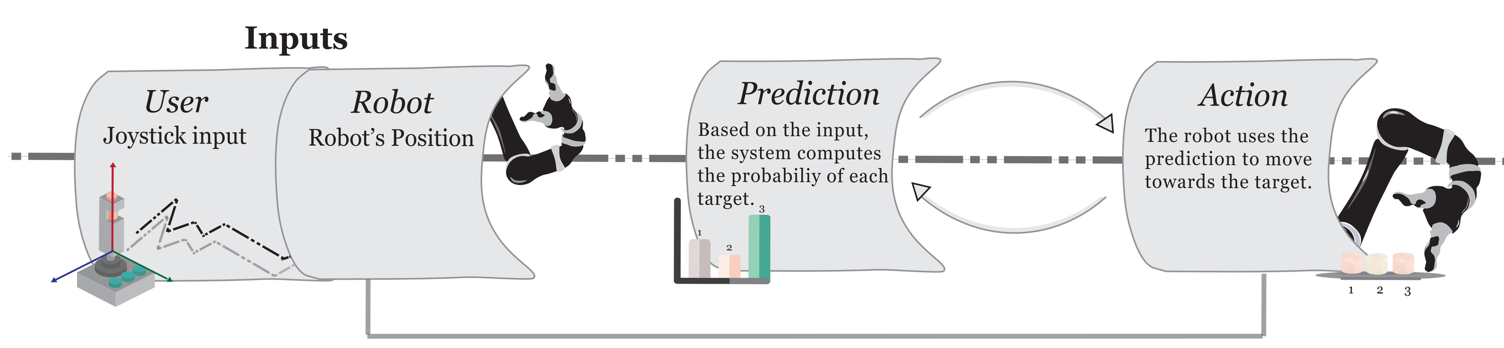

Figure 1. Shared Autonomy system

Current predictions methods **require substantial user input to infer their goals early in the task**.

Eye Gaze

Eye gaze reveals people's intentions during robot manipulation. [3]

Documented gaze patterns have shown that:

- People follow targets closely in a task[4]
- People's gaze can be used to dissect a task into different stages[5]

Natural eye gaze can be used as an implicit input for predicting a user's goal.

Approach

Model Development
Develop a model for predicting goal based on eye gaze

Model Validation
Test the model with the pre-existing HARMONIC dataset

User Study
Integrate the model into our current assistance system and evaluating it with users for efficiency, ease of use, and speed

Model Development

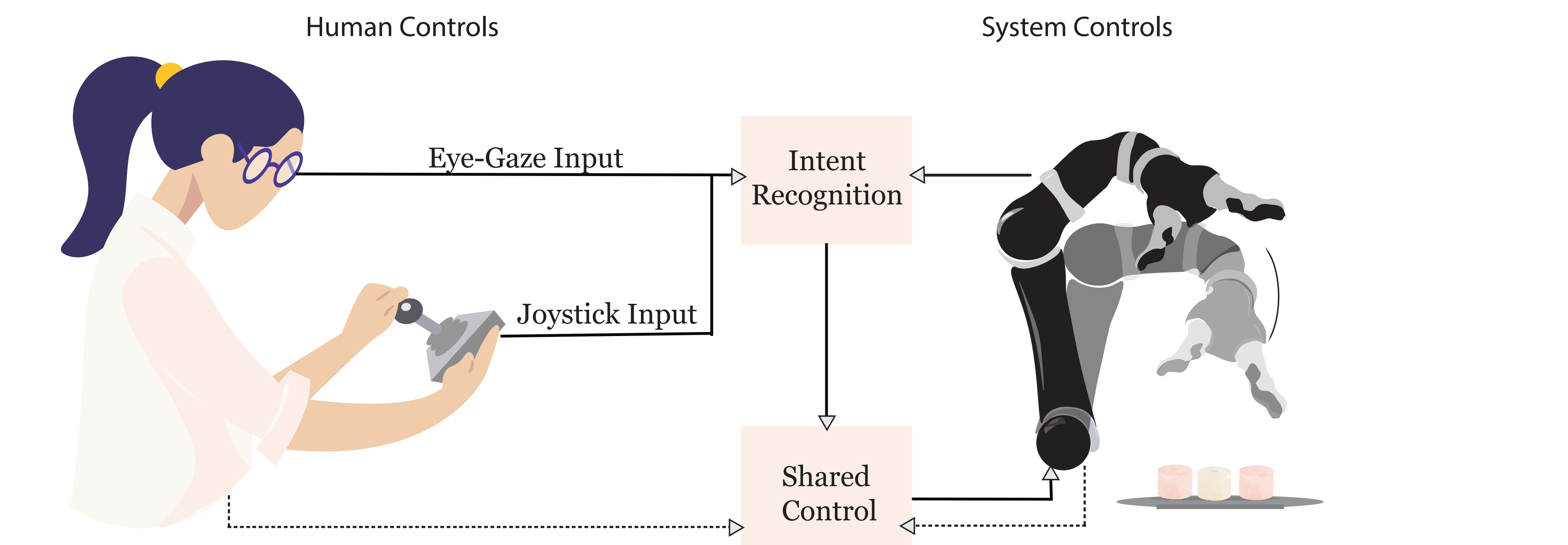

Figure 2. Our proposed Shared Autonomy system structure

We developed a number of score-based models to evaluate the confidence of different eye-gaze **prediction metrics:**

Fixation Durations | **Number of Fixations** | **Fixation patterns** | **Position of Fixation**

These metrics are incorporated into our model as part of the following **pipeline:**

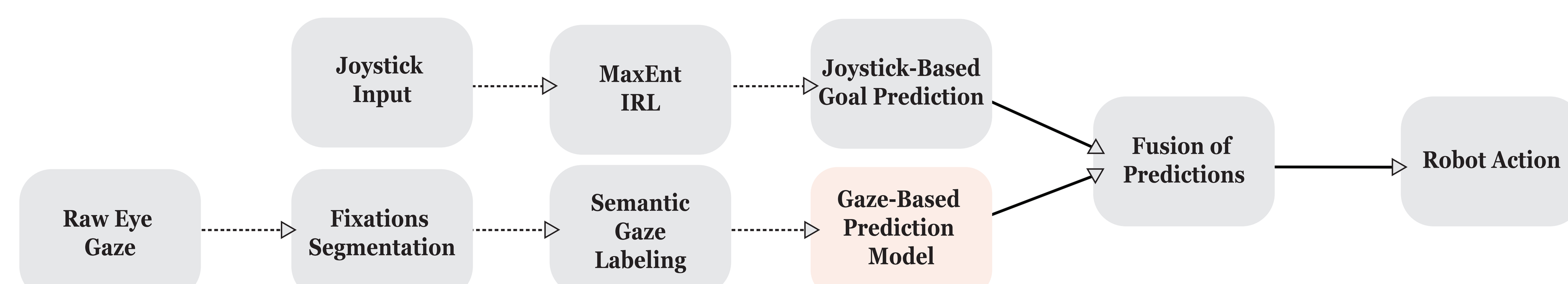

Figure 3. Our proposed model pipeline

Model Validation using HARMONIC dataset[6]

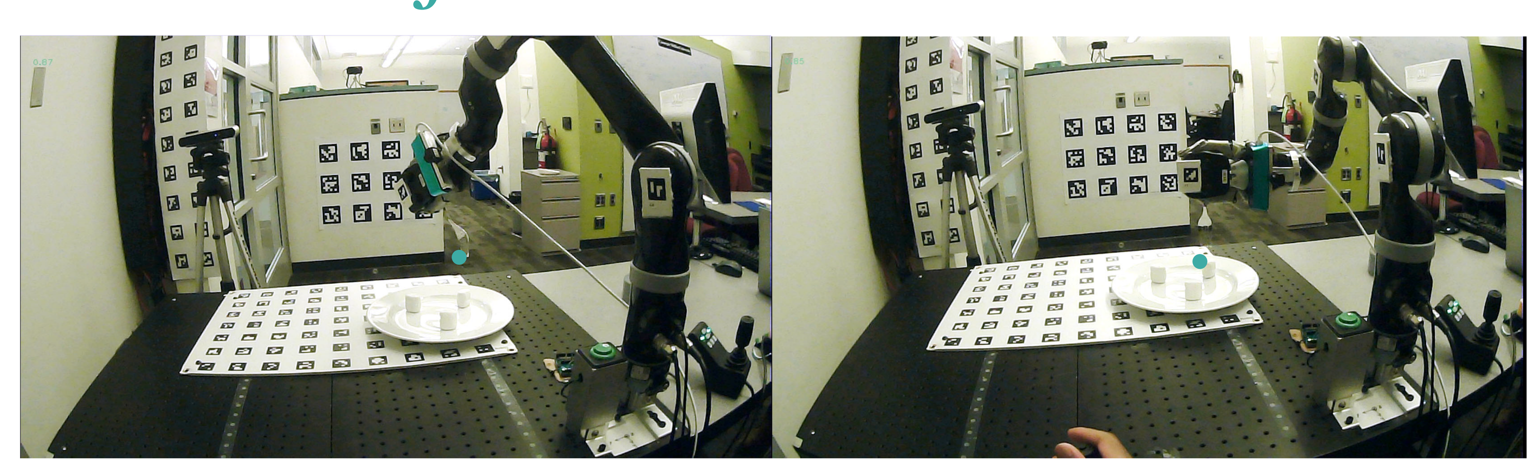

Figure 4. Screen recording of annotated videos from HARMONIC with gaze labeling

The HARMONIC dataset contains video and gaze data from users working with the Kinova robotic arm to spear a marshmellow.

Eye-gaze–based prediction perform better than random selection predictions

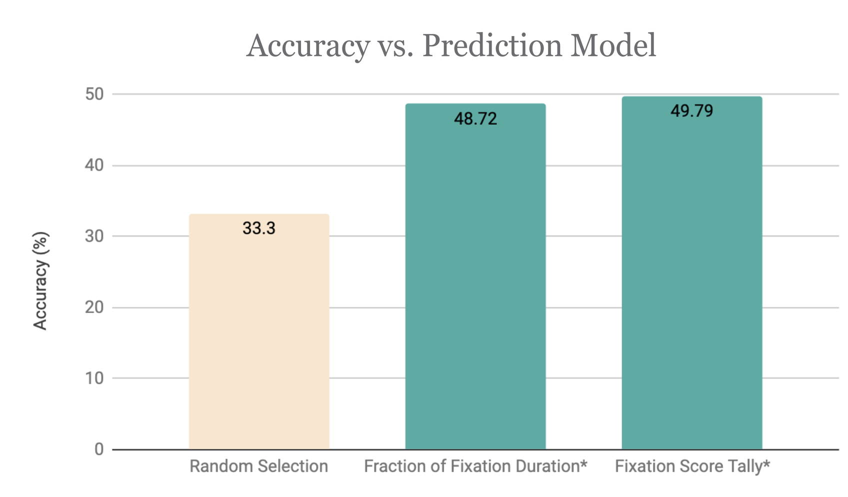

Figure 5. Comparative analysis of prediction model accuracy between the baseline of a random selection and the models developed in this project.

Users look at goals more frequently for shorter periods of time

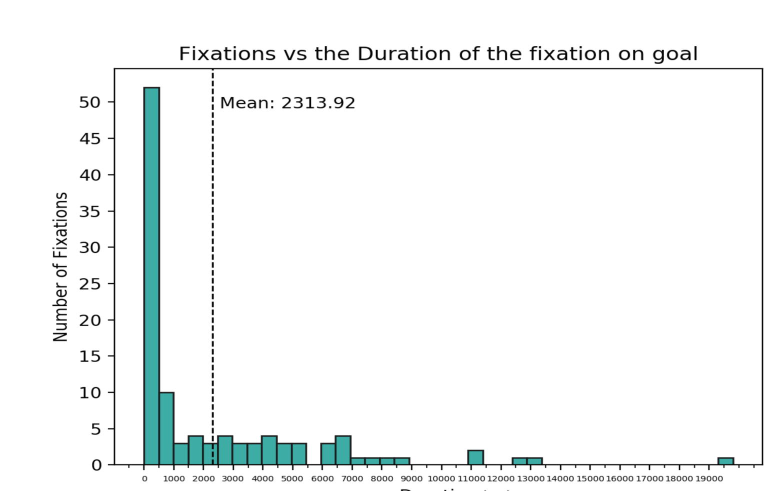

Figure 6. Duration distribution of gaze fixations on goal revealed that the average fixation time was around 2.3 seconds.

User Study and Future Work

We plan to continue this work by conducting a pilot study using the same spearing task from HARMONIC but with a different configuration of morsels.

Model Optimization
Continue testing gaze-based prediction models to determine the most efficient model

Model Evaluation
Evaluate the model with conditions :
(1) Gaze only **(2)** Joystick only **(3)** Both

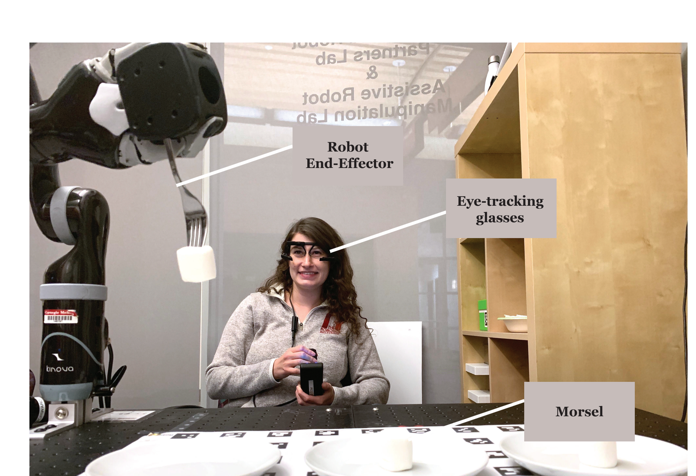

Figure 7. Suggested setup for user study

Acknowledgements

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References

[1] R. M. Aronson, T. Santini, T. C. Kubler, E. Kasneci, S. Srinivasa, and H. Admoni, "Eye-Hand Behavior in Human-Robot Shared Manipulation," in Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction (HRI '18). Chicago, IL, USA: ACM Press, 2018, pp. 4–13.
[2] H. Admoni and S. Srinivasa, "Predicting User Intent Through Eye Gaze for Shared Autonomy," AAAI Fall Symposium Series, North America, Sep. 2016. p. 6
[3] R. S. Johansson, G. Westling, A. Bäckström, and J. R. Flanagan, "Eye Hand Coordination in Object Manipulation," The Journal of Neuroscience, vol. 21, no. 17, pp. 6917–6932, Sep. 2001.
[4] C.-M. Huang and B. Mutlu, "Anticipatory robot control for efficient human-robot collaboration," in Proceedings of the 2016 ACM /IEEE International Conference on Human-Robot Interaction (HRI '16). Piscataway, NJ, USA: IEEE Press, 2016, pp. 83–90.
[5] M. F. Land and M. Hayhoe, "In what ways do eye movements contribute to everyday activities?" Vision Research, vol. 41, no. 25-26, pp. 3559–3565, Nov.2001
[6] B. A. Newman, R. M. Aronson, S. S. Srinivasa, K. Kitani, and H. Admoni, "HARMONIC: A Multimodal Dataset of Assistive Human-Robot Collaboration,"arXiv:1807.11154 [cs], Jul. 2018