A Comparison of Smooth Pursuit- and Dwell-based Selection at Multiple Levels of Spatial Accuracy

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Abstract

We compared pursuit- and dwell-based selection methods at multiple levels of spatial accuracy. Participants performed both selection methods while we artificially reduced the spatial accuracy of our eye tracker.

Introduction

Eye tracking is increasing in popularity, but it still has some usability concerns:

- An initial calibration phase is required before each session.
- Most eye trackers suffer from poor spatial accuracy.
- A chin rest is usually needed to minimize head movements.

Most eye-guided interfaces use dwell-based selection, which requires a user to stare at a target for some amount of time. However, poor spatial accuracy and head movements hinder the effectiveness of dwell-based selection, especially for smaller targets.

In contrast, smooth pursuit-based selection needs only the relative movement of the eye rather than its exact position. Spatial accuracy is therefore virtually meaningless when performing pursuit-based selection, and calibration is unnecessary.

Mobile and wearable devices, along with self-made eye trackers, typically have worse spatial accuracy than professional-grade eye trackers. These types of devices would benefit most from pursuit-based selection.

Pursuit-based Selection

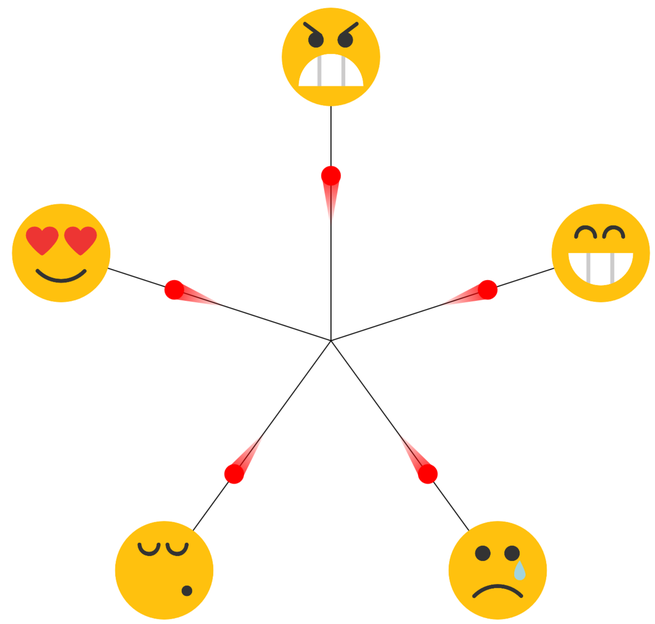
The key of smooth pursuit selection is having a moving stimulus and comparing its movement with the movement of the eye. We maintained a window of gaze (g) and stimulus (s) positions and found the correlation between the sets using the Pearson product-moment test:

$$r = \frac{\sum_{i=1}^{n}(g_i - \bar{g})(s_i - \bar{s})}{\sqrt{\sum_{i=1}^{n}(g_i - \bar{g})^2}\sqrt{\sum_{i=1}^{n}(s_i - \bar{s})^2}}$$

Methods and Materials

Eye tracker: Tobii EyeX Controller (60 Hz)
Participants: 8 college-aged students (6 male/2 female)
Base spatial accuracy: 0.55° ± 0.31°

Participants were instructed to select one of five circular emoji ("nodes") arranged in a layout designed to mimic a radial menu. Each node had a diameter of about 2°. For *dwell-based selection*, each node simply checked whether its circular bounds contained the newest gaze in the window of gaze positions. For *pursuit-based selection*, each node was connected to a line along which a small, red stimulus traveled back and forth:



These emoji were designed by Roundicons from Flaticon.

Each stimulus had a diameter of 0.55° and traveled at a speed of about 5.3°/s. We used a correlation threshold of 0.6, chosen empirically, to determine whether a pursuit-based node should progress toward selection.

For both selection methods, participants had 10 seconds for each selection attempt. 10 selection attempts were made for each method, after which the accuracy of the eye tracker was artificially reduced by offsetting the gaze position captured by the tracker.

Results

- We used a Mixed Model ANOVA to determine significance.
- At baseline accuracy, dwell-based outperformed pursuit-based selection, but this was not significant (t = -0.76, p = .4456).
- At all other accuracies, pursuit-based was significantly better.
- Dwell-based selection attempts: 50.6% C / 3.1% I / 46.3% F*
- Pursuit-based selection attempts: 80.6% C / 16.3% I / 3.1% F*

**(C = correct selection, I = incorrect selection, F = failed selection)*

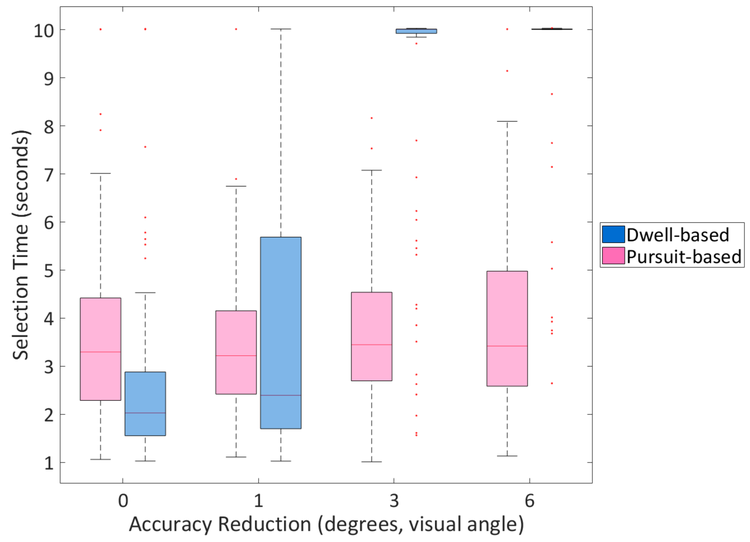


Chart 1. Effect of accuracy reduction on selection time for either selection method

Discussion

- On average, **pursuit-based selection** was **significantly faster** than dwell-based selection.
- **Pursuit-based selection** resulted in **more unwanted/incorrect selections** (16.3% of attempts) than dwell-based (3.1%).
- We acknowledge that **artificially reducing accuracy** does **not accurately reflect** real-world performance, so these results should be viewed as rough estimates.
- Some **emoji appeared ambiguous** for a few participants which may have affected the incorrect rates of both methods.
- Our pursuit-based method resulted in **selection times of over 3.5 seconds** on average; this is **not practical** for real use cases and would **need to be improved** by refining the gradual selection process we used.

Conclusions

We compared pursuit- and dwell-based selection methods at multiple levels of spatial accuracy. We found that the time to perform a pursuit-based selection remains consistent even as spatial accuracy degrades, while dwell-based selection takes considerably longer to perform the worse accuracy becomes.

Future Work & Acknowledgements

We are interested in investigating how spatial precision might affect both dwell- and pursuit-based selection. We would also like to test pursuit-based selection on a mobile/wearable device.

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