Using Model Tracing and Evolutionary Algorithms to Determine Parameter Settings for Cognitive Models From Time Series Data such as Visual Scanpaths

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Time-series data such as eye movements or mouse movements contain rich information about the dependencies between successive human actions. This poster demonstrates how model tracing, which simulates a task by tracking time-series data, along with the use of an evolutionary optimization algorithm, led to robust estimates for parameters of visual acuity functions needed by visual search models.

Model Tracing

Model tracing involves predicting an observable human action with the task context that the participant experienced before making that action. Model tracing is different from conventional cognitive modeling in the following two ways:
1. A tracing model continually reagents itself with the observed human actions.
2. A tracing model predicts the likelihood of the observed event rather than providing conventional summary statistics such as the number of fixations in a trial.

Visual Acuity Functions

Model tracing is applied in this study to estimate the parameters of visual acuity functions, which describe how the visibility of object features gradually diminishes as objects move further from the point of gaze. Figure 1 illustrates the effect.

The goal of this paper is to use model tracing to estimate the free parameters of the visual search model. Estimates of the parameters are obtained by fitting the model to a large amount of data, tracing improves the statistical power of parameter estimation, which helps to provide a sufficiently good fit to the scanpath data, though they are not guaranteed to be optimal.

Estimate Parameters Using Tracing

We developed a standalone computational model, a scanpath tracing model, to simulate a person doing this visual search task. The scanpath tracing model adopts the theoretical concepts of the visual acuity function and a visual perceptual store (VPS) adapted in part from the EPIC cognitive architecture (Kieras, 2010). If an object candidate to be perceived by the visual acuity function, it is deposited in the VPS for a short time period (e.g., 300 ms). Figure 1 illustrates what features might be perceived by the acuity functions while the eyes remain on the feature for the specified time.

The scanpath tracing model simulates the task by cycling through these three steps:
1. Move the gaze to the observed fixation location and set the simulation time to the fixation time.
2. Delete from VPS (visual perceptual store) the items that should have decayed before the next fixation. For this study, the search was set to terminate after 300 generations. The scanpath tracing model determines if the VPS contains an object feature.
3. Based on the contents of the VPS, calculate how likely it is that the following fixation, the model will set the next observation as the candidate.

In every cycle, the contents of VPS will contain some combination of the following:
- Visible-candidates - objects that have a feature in common with the target.
- Non-targets - objects that have a feature that is known and which makes it not possible the target (such as a red object when looking for a blue target).
- Unknown-objects - objects that are visible but have no known color, size, or shape features.

The estimated visual acuity function parameters were further validated by transferring them into Kieras’ EPIC-based visual search model to see whether the model can fit the summary statistics of the eye movement data. Figures 2 and 3 compare the models’ predictions with the observed data on two critical aspects of the visual search performance. The results show that the new parameters estimated by the tracing model explain the data much better, and in most cases, outperform the original EPIC parameters that were specifically adjusted to fit the summary eye movement statistics.

Conclusion

Model tracing is a novel and useful approach to explaining human data that may have great potential for developing and evaluating accurate computational cognitive models of human performance. By fitting the model to a large amount of data, it improves the statistical power of parameter estimation, which helps to address the challenge of parameter fitting discussed in Howes et al. (2009).

References

