Adding Attentional Mechanisms to a Scan Path Model

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Eye Movement Models

Static Saliency

- Image features (empirical fixation density or model such as GBVS or Deepgaze)
Eye Movement Models

Dynamic Local Saliency

- Image features
- Gaussian approximates fovea
Eye Movement Models

SceneWalk Model (Engbert et al, 2015)

- Image features and Gaussian activation
- Inhibition of previous locations (neurophysiological basis in FEF (Mirpour et al, 2019))
Animation
## Assumptions

<table>
<thead>
<tr>
<th></th>
<th>Image</th>
<th>Foveation</th>
<th>Inhibition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static saliency</td>
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<td>SceneWalk model</td>
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</table>
From Macro-Dynamics to Micro-Dynamics

Perisaccadic Attention

1. Attention precedes the fixation to its target $^1$ $^2$ $^3$
2. Attention moves retinotopically leaving an activation trace $^3$ $^4$ $^5$
3. Return saccades indicate attention at the one-back fixation location $^6$

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$^1$Deubel & Schneider (1996)
$^2$Irwin & Gordon (1998)
$^3$Rolfs, Jonikaitis, Deubel & Cavanagh (2011)
$^4$Golomb, Chun & Mazer (2008)
$^5$Golomb, Marino, Chun & Mazer (2010)
$^6$Smith & Henderson (2009)
From Macro-Dynamics to Micro-Dynamics

Perisaccadic attention (Theory)

Attention
Fixation Location

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Extended SceneWalk Model

Fixation n:
- Phase Main

Fixation n:
- Pre-saccadic Shift
  - Pick next fixation
  - Make saccade

Fixation n+1:
- Post-saccadic Shift

Fixation n+1:
- Phase Main

- Current Inhibition Component
- Fixation-based Inhibition Stream $F(t)$
- Combined $u^*$
- Activation Stream $A(t)$
- Current Activation Component

Maps evolve around current fixation location
Next fixation location is decided
Evolve step with attention centered around pre-saccadic shift
Saccade
Evolve step with attention centered around post-saccadic shift
Evolve step with activation centered around current position

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Extended SceneWalk Model

Fixation $n$: Phase Main

Fixation $n$: Pre-saccadic Shift

Fixation $n+1$: Post-saccadic Shift

Fixation $n+1$: Phase Main

Current Inhibition Component

Fixation-based Inhibition Stream $F(t)$

Combined $u^*$

Activation Stream $A(t)$

Current Activation Component

Maps evolve around current fixation location

Next fixation location is decided

Evolve step with attention centered around pre-saccadic shift

Saccade

Evolve step with attention centered around post-saccadic shift

Evolve step with activation centered around current position

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General Likelihood

![Bar chart showing the comparison of different models in terms of log-likelihood. The x-axis represents the model types: density sampling, local saliency, baseline model, and extended model. The y-axis represents the log-likelihood in bits/fixation. The extended model shows the highest log-likelihood, followed by the baseline model, local saliency, and density sampling.]
Model Results

Saccade Amplitude Distribution
Systematic Tendencies

Serial Dependencies

Saccade

Saccade Turning Angle
Model Results

Saccade Turning Angle Distribution

![Graph showing saccade turning angle distribution with various models and an empirical data point.](image)
Systematic Tendencies

Turning Angle–Amplitude Relation

![Graph illustrating the turning angle-amplitude relation with axes labeled 'parallel to previous saccade' and 'orthogonal to previous saccade', marked with a point labeled 'Saccade n-1'.]
Systematic Tendencies

Turning Angle–Amplitude Relation

parallel to previous saccade vs. orthogonal to previous saccade
Systematic Tendencies

Turning Angle–Amplitude Relation

![Graph showing the turning angle-amplitude relation. The x-axis represents the parallel to previous saccade, and the y-axis represents orthogonal to previous saccade. The graph visualizes the distribution of saccades, with colors indicating the intensity of the relation.](image-url)
Systematic Tendencies

Turning Angle–Amplitude Relation

![Graph showing the turning angle-amplitude relation with a heatmap and labels for 'Return Saccades'.]
Systematic Tendencies

Turning Angle–Amplitude Relation

![Graph showing the turning angle-amplitude relation with categories for Return Saccades and Onward Saccades.]
Model Results

Turning Angle–Amplitude Relation

- Empirical data
- Extended model
- Baseline model

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Model Results

Turning Angle and Fixation Duration

![Graph showing turning angle and fixation duration](image)

- **Empirical Data**
- **Extended Model**
- **Baseline Model**

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Scan path models frequently assume attention = fixation position
Research on perisaccadic mechanisms suggests attentional shifts
Adding these shifts improves the model performance on saccade statistics
The model converges on these estimates with (despite?) very non-specific likelihood-based fitting procedure
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Research on perisaccadic mechanisms suggests attentional shifts
Adding these shifts improves the model performance on saccade statistics
The model converges on these estimates with (despite?) very non-specific likelihood-based fitting procedure
Thank you
Experiment

- Subset of Potsdam Sceneviewing Corpus (https://osf.io/n3byq/)
- 34 participants, viewed 30 images from each category without a task
- Categories (in that order):
  - 15 left biased
  - 15 right biased
  - 15 bottom biased
  - 15 top biased
  - 15 center biased
  - 15 Patterns
- Model-fitting on the training data set. Model comparisons on the test data.
### Assumptions

<table>
<thead>
<tr>
<th>Assumption</th>
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<th>IoR</th>
<th>FoR</th>
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Marginal Posterior Distributions of Parameters

- estimate 6 parameters
- estimation using general likelihood sampling - pyDREAM (DiffeRential Evolution Adaptive Metropolis)
- fit each subject individually
- test and training data sets
Results: Systematic Tendencies

Absolute saccade Angle Distribution

![Graph showing absolute saccade angle distribution with three lines representing empirical data, extended model, and baseline model. The x-axis represents angle relative to the horizontal in degrees, and the y-axis represents frequency.]
Results: Systematic Tendencies

RSA and Amplitude

![Graph showing saccade amplitude versus change in saccade direction.](image)

- **empirical data**
- **extended model**
- **baseline model**
Results: Systematic Tendencies

Distance to Center

![Graph showing distance to image center over fixation number]

- **Empirical data**
- **Extended model**
- **Baseline model**

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