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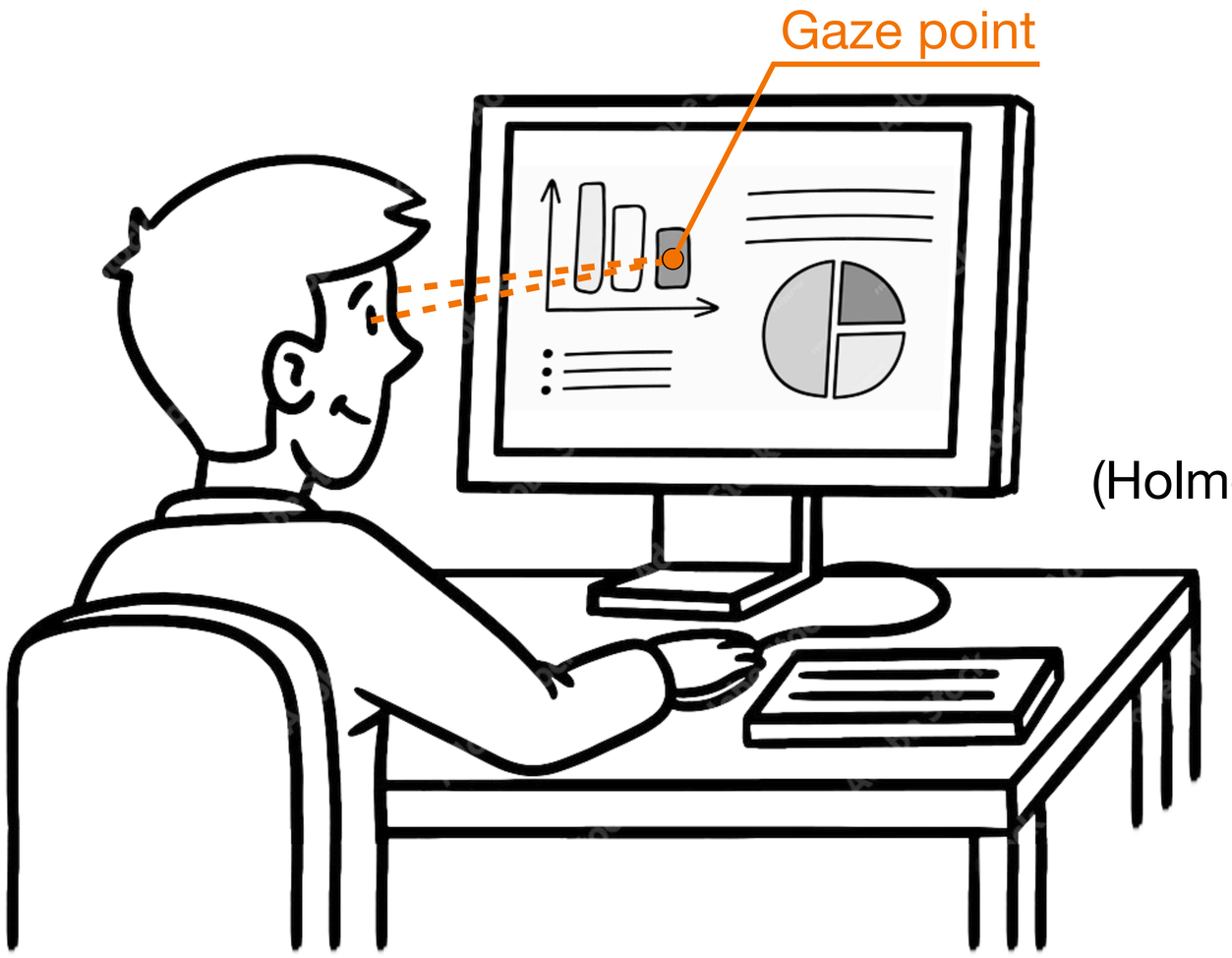
FSDM
4150

Eye Tracking Data Mining Based on Fuzzy Sets of Fixations

Presented by: Konstantin Ryabinin[1,2,3], Elena Erofeeva[2,3], Kira Guseva[3]

Affiliation: [1]Heidelberg University, Germany;
[2]Saint Petersburg State University, Saint Petersburg, Russia;
[3]Perm State University, Perm, Russia

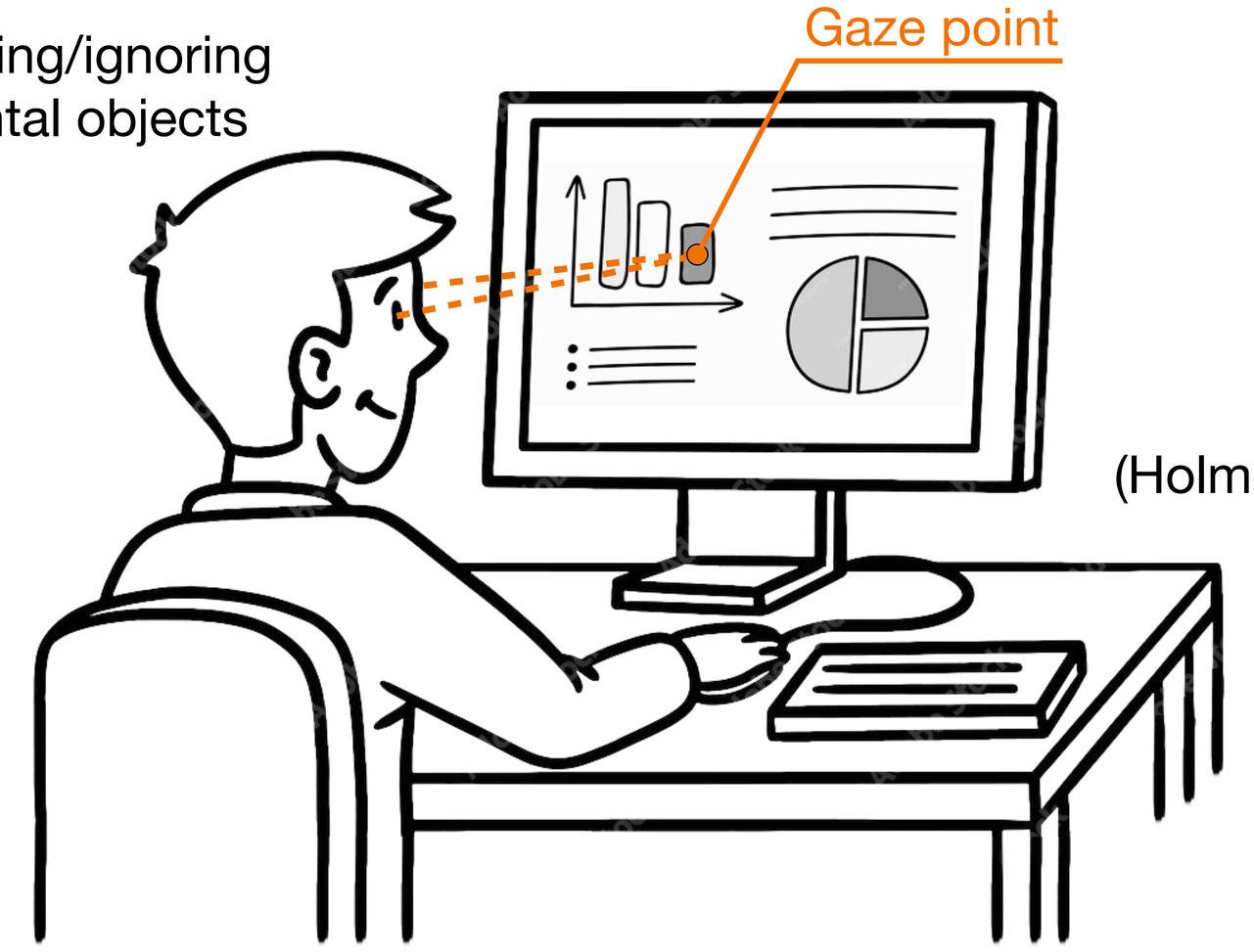
Perception Study via Visual Attention Estimation via Eye Tracking



(Holmqvist et al. 2017)

Perception Study via Visual Attention Estimation via Eye Tracking

Operations of selecting/ignoring distinct environmental objects



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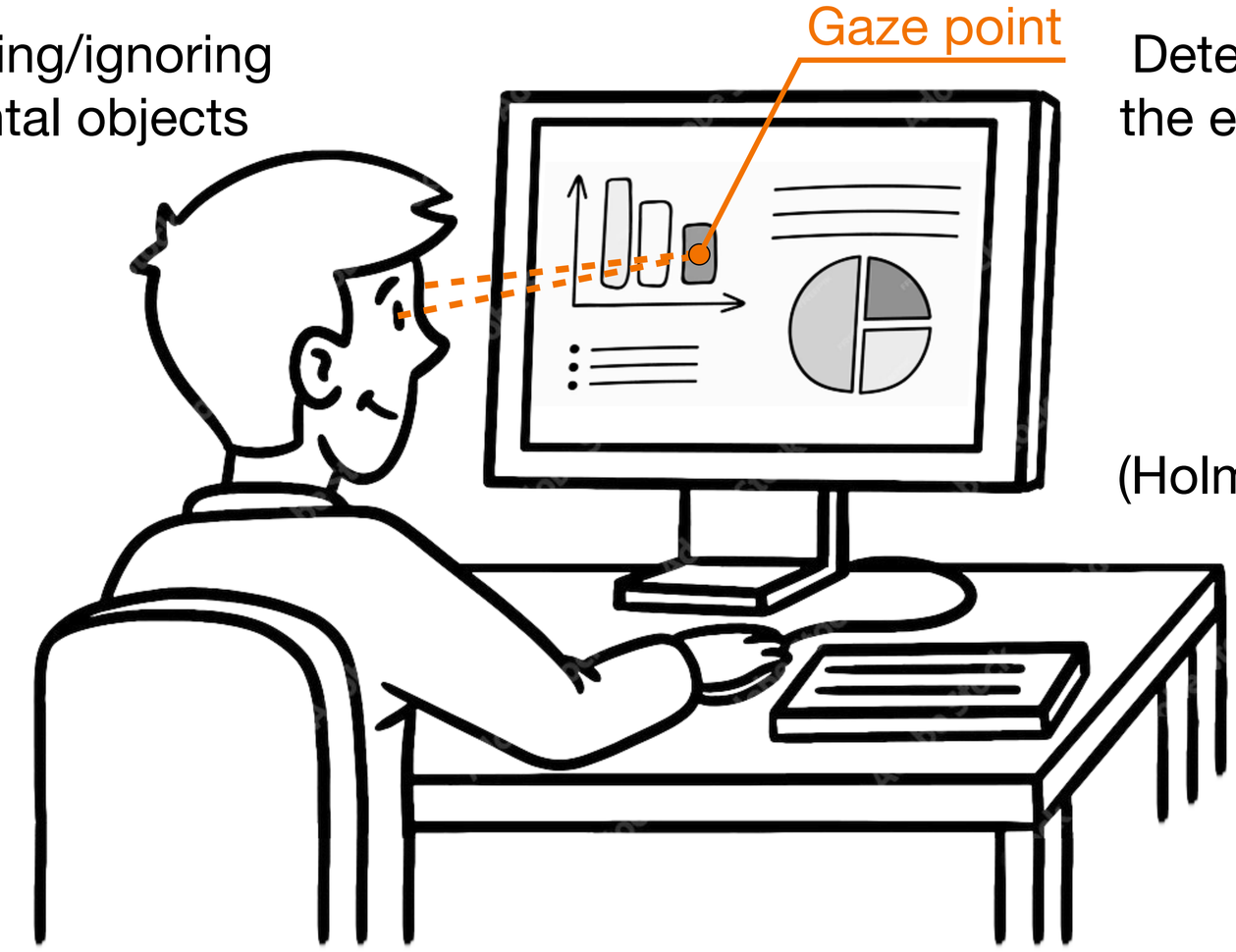
Perception Study via Visual Attention Estimation via Eye Tracking

Operations of selecting/ignoring distinct environmental objects

Detecting and analyzing the eye gaze movements

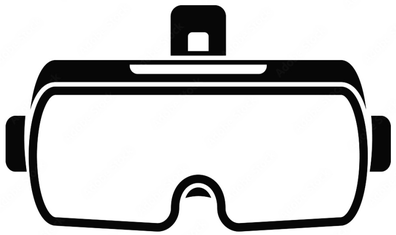


(Holmqvist et al. 2017)

Eye Tracking Study Workflow

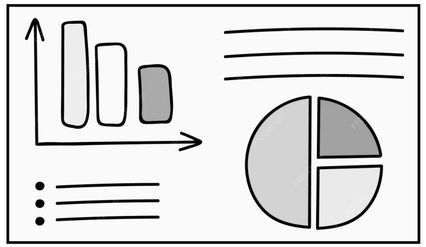
Informant

+



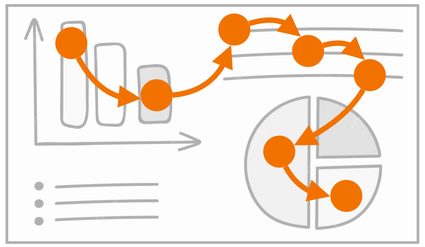
Eye Tracking Device

+



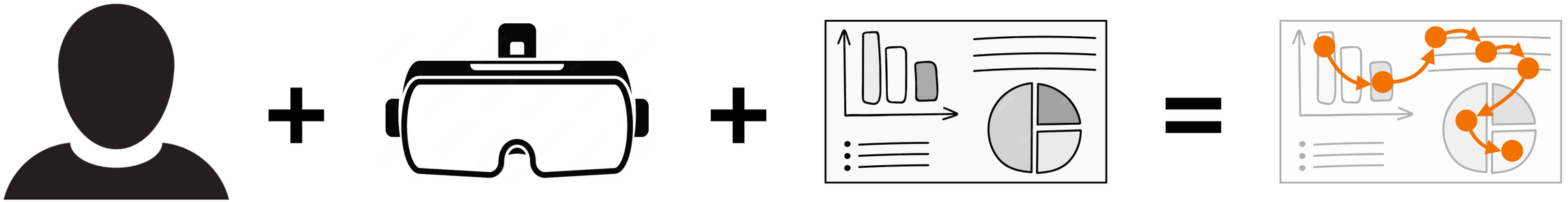
Stimulus

=

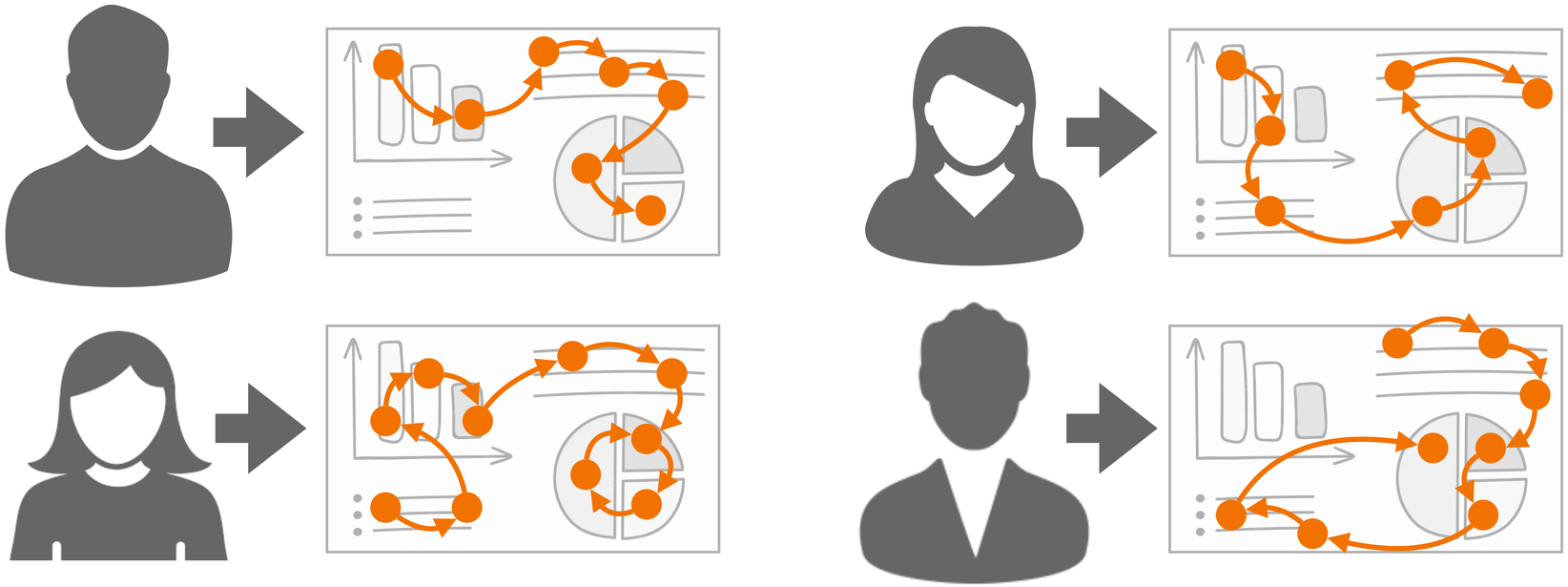


Scanpath: Set of Fixations and Saccades

Eye Tracking Study Workflow



Informant + Eye Tracking Device + Stimulus = Scanpath: Set of Fixations and Saccades



(Blascheck et al. 2015, 2017; Nava-Martnez et al. 2018)

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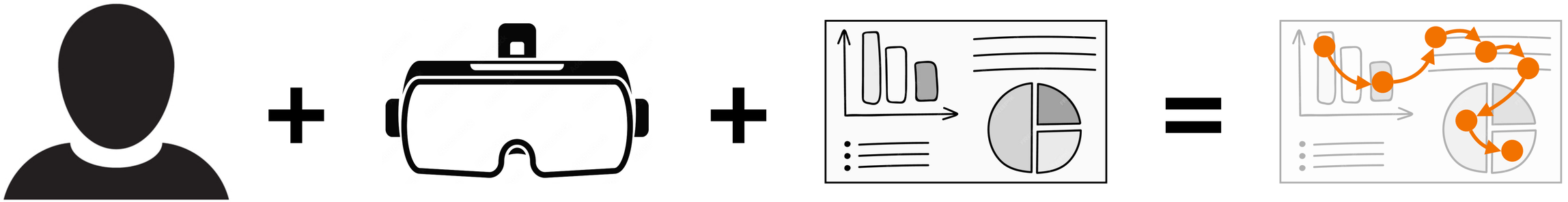

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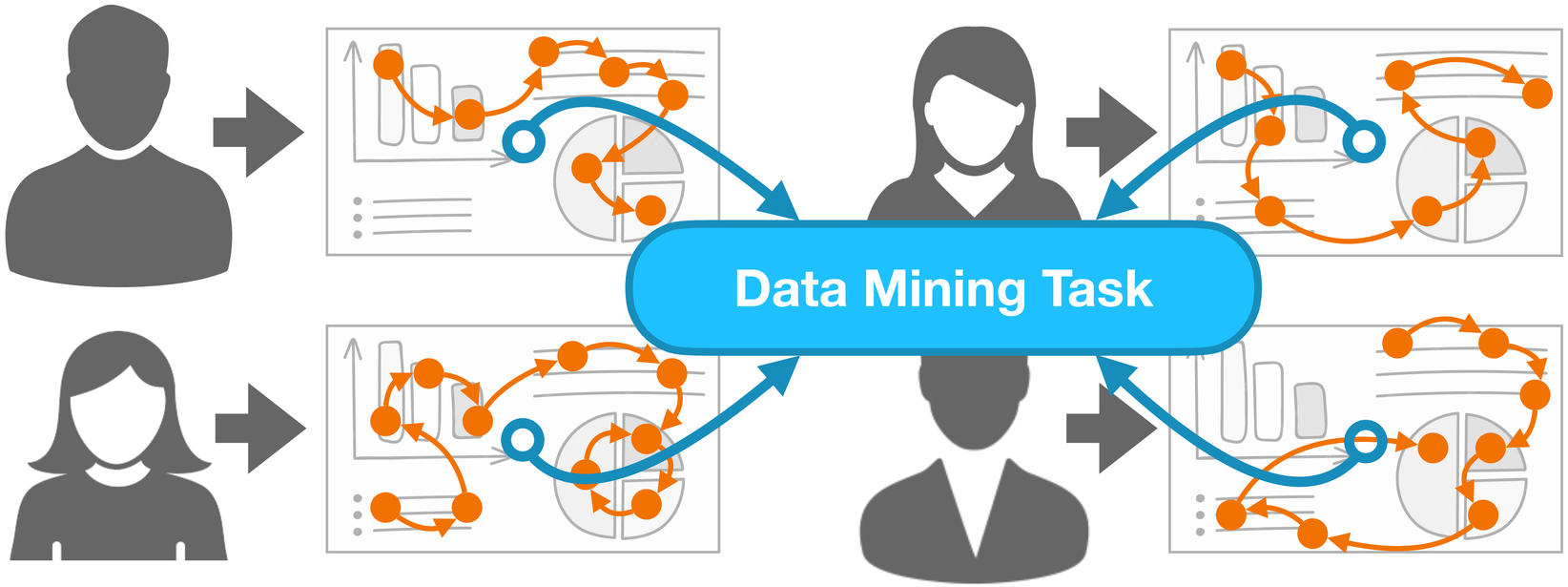
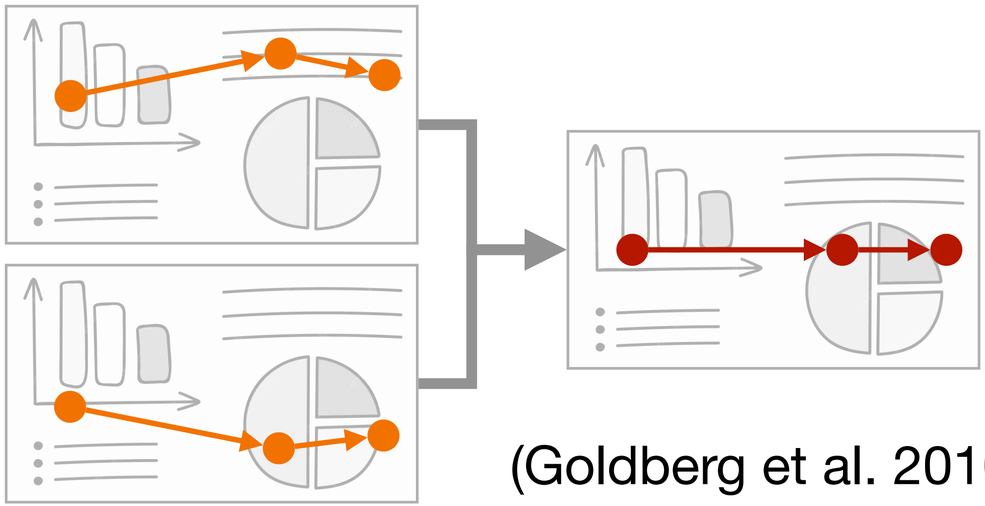


(Blascheck et al. 2015, 2017; Nava-Martnez et al. 2018)

Scanpath Aggregation

Traditional approaches are based on classical sets and averaging



(Goldberg et al. 2010; Peysakhovich et al. 2018)

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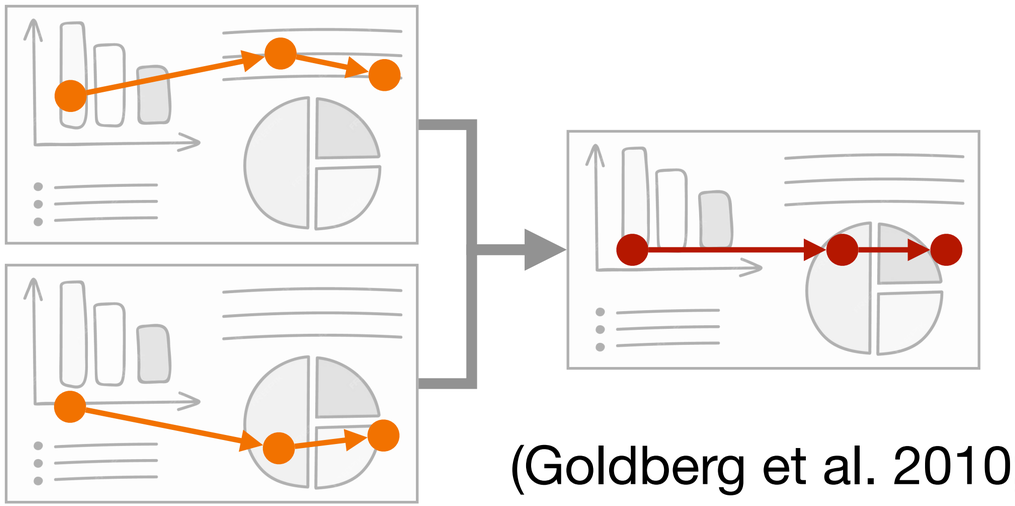

Fast & easy

(Goldberg et al. 2010; Peysakhovich et al. 2018)

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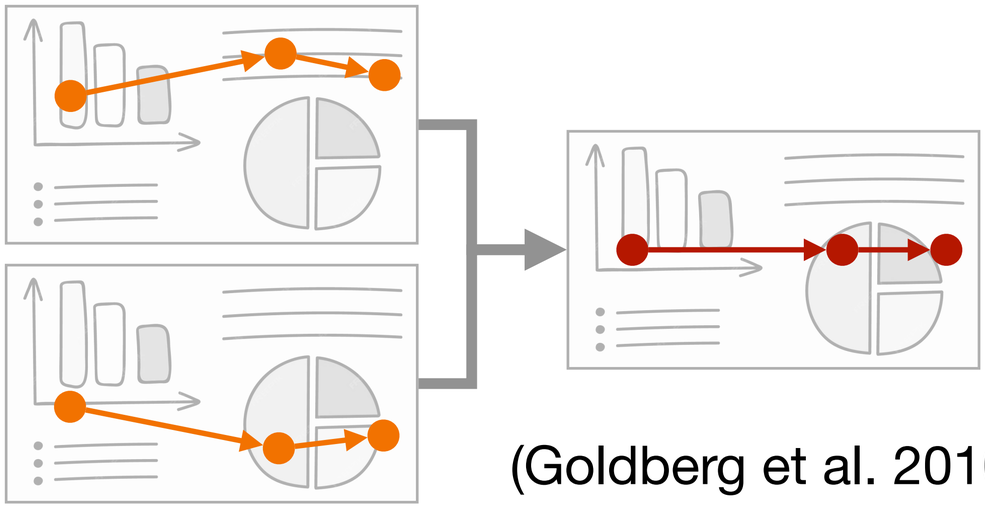

- Fast & easy
- Information gets lost

(Goldberg et al. 2010; Peysakhovich et al. 2018)

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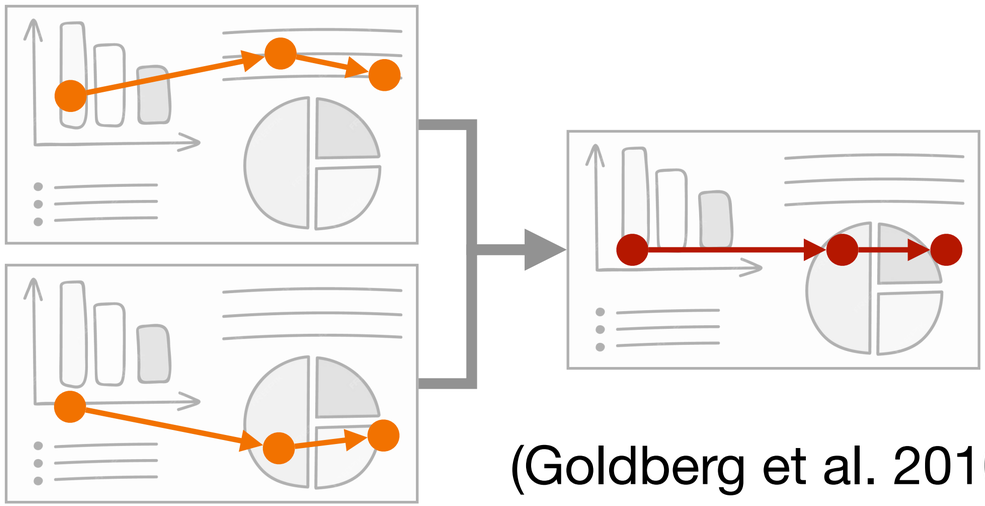


Fast & easy

Information gets lost

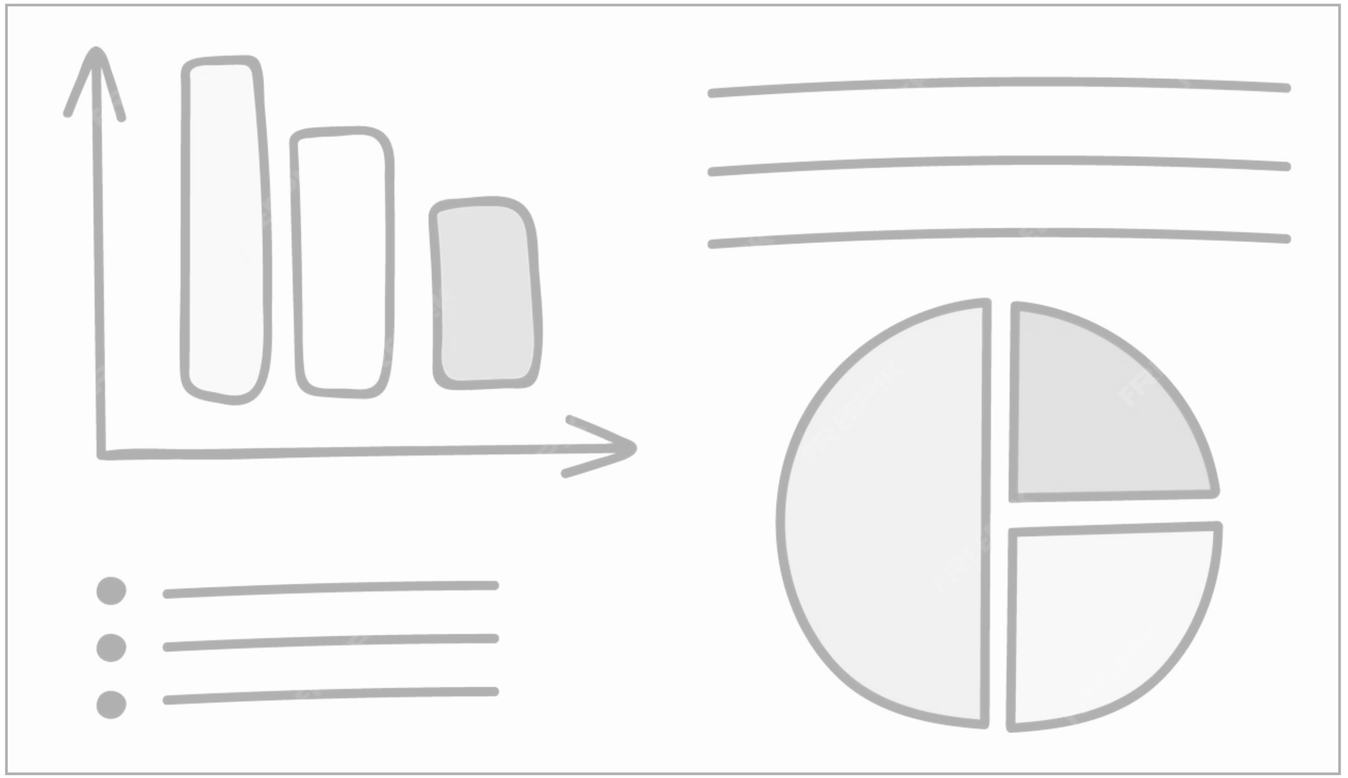
(Goldberg et al. 2010; Peysakhovich et al. 2018)

Why not to use fuzzy sets?

(Zhu et al. 2009;
Opach et al. 2011;
Naqvi et al. 2017)

Areas of Interest

Segmenting the stimulus into the areas of interest according to its structure



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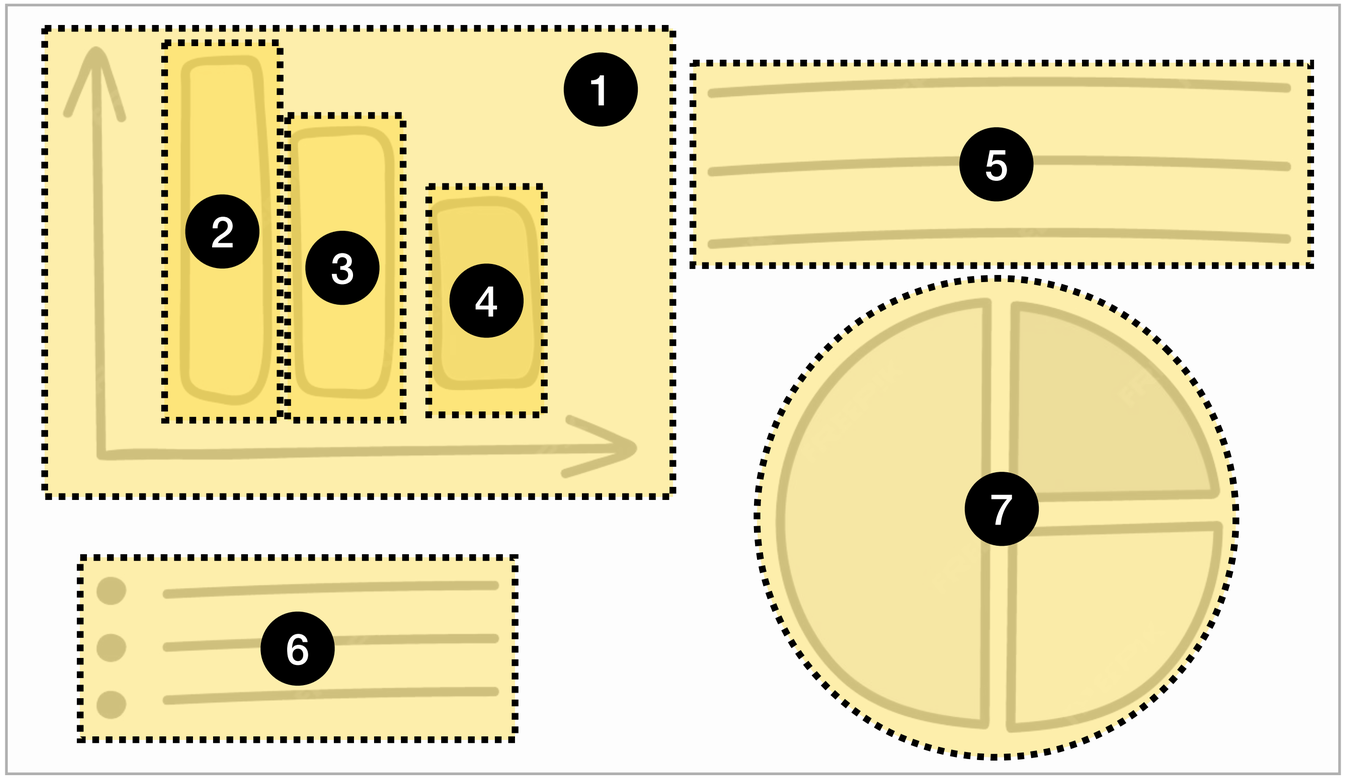

$$T = \bigcup_{i=1}^{n} \bigcup_{j=1}^{m} \left(\alpha_j, \omega_j^{(i)} \right)$$

Aggregated Scanpath Model Based on Fuzzy Sets

Aggregated scanpath

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Maximal number of fixations in all the scanpaths

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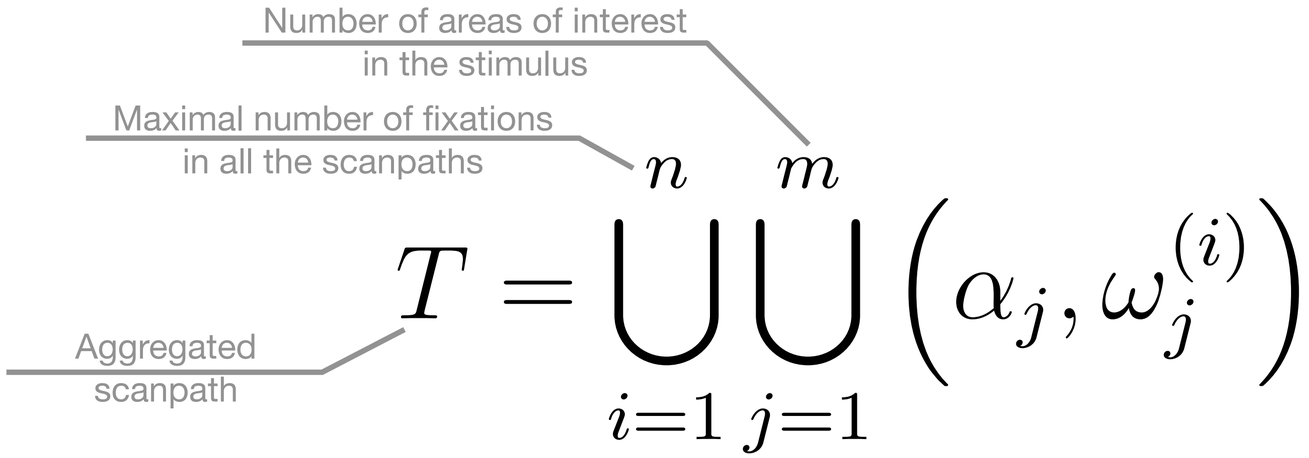

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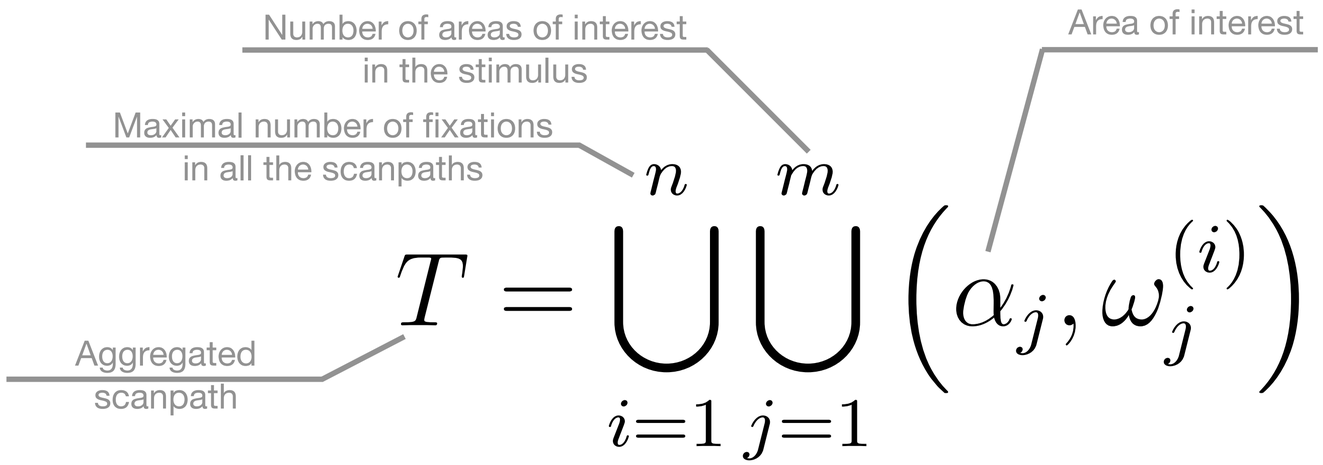

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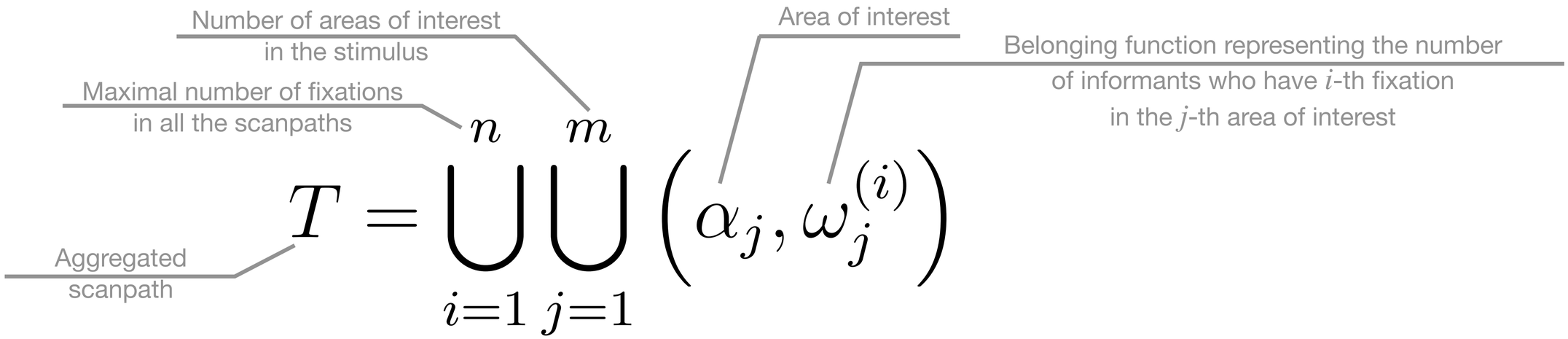

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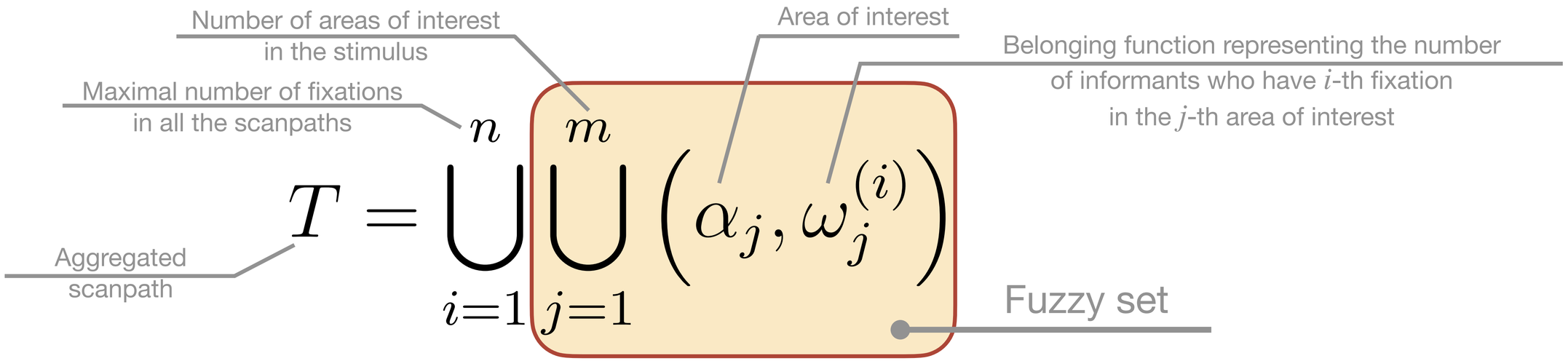

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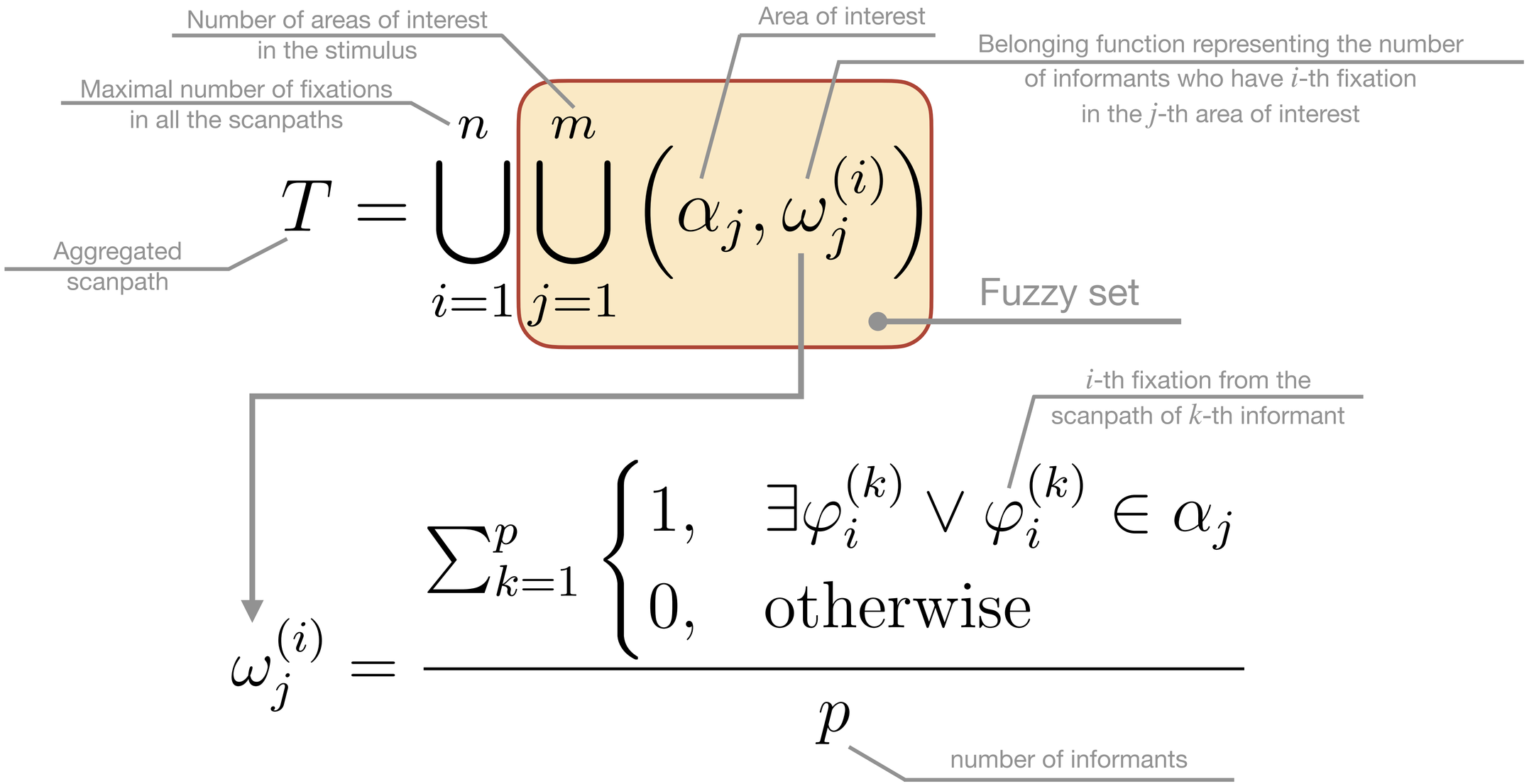

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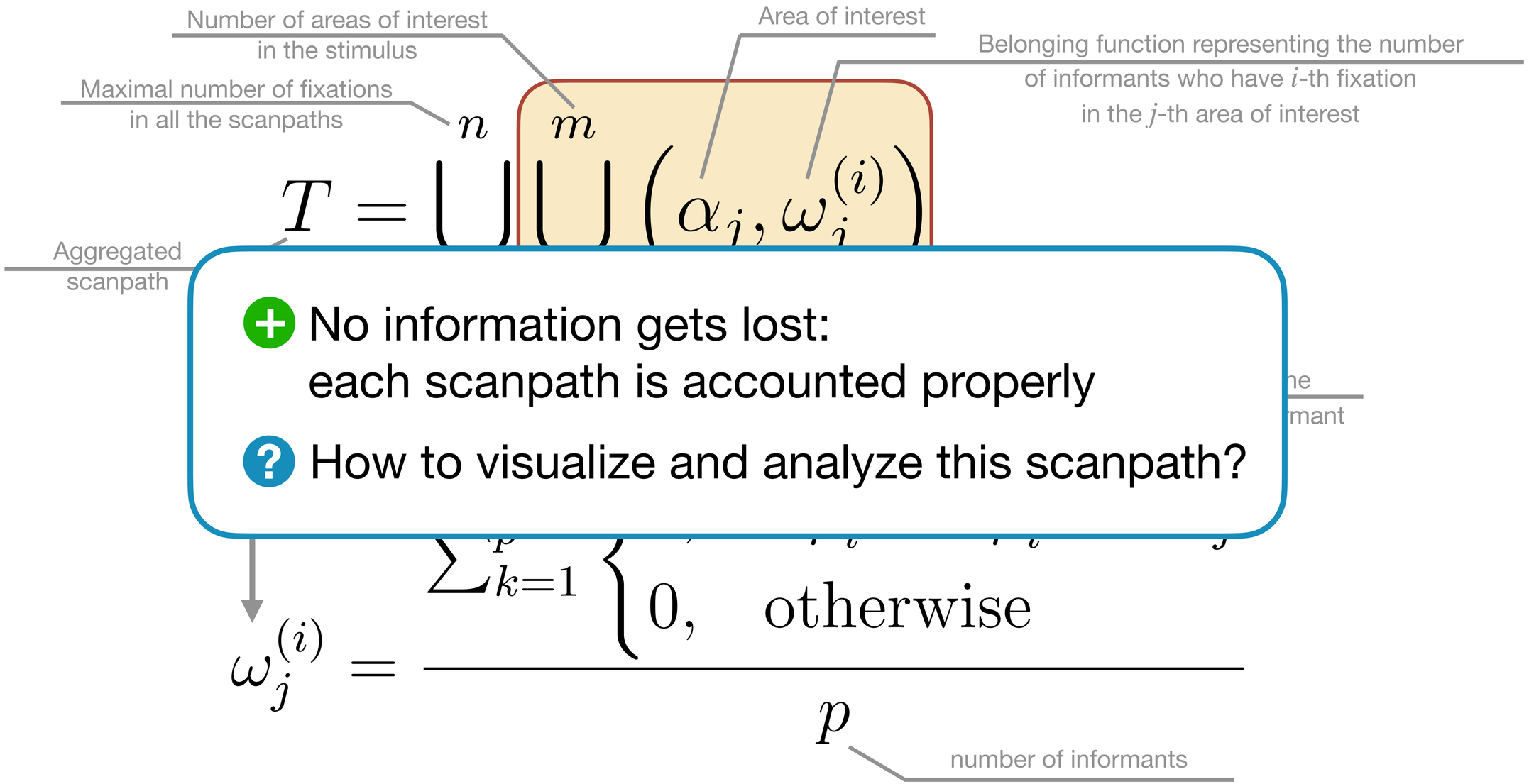
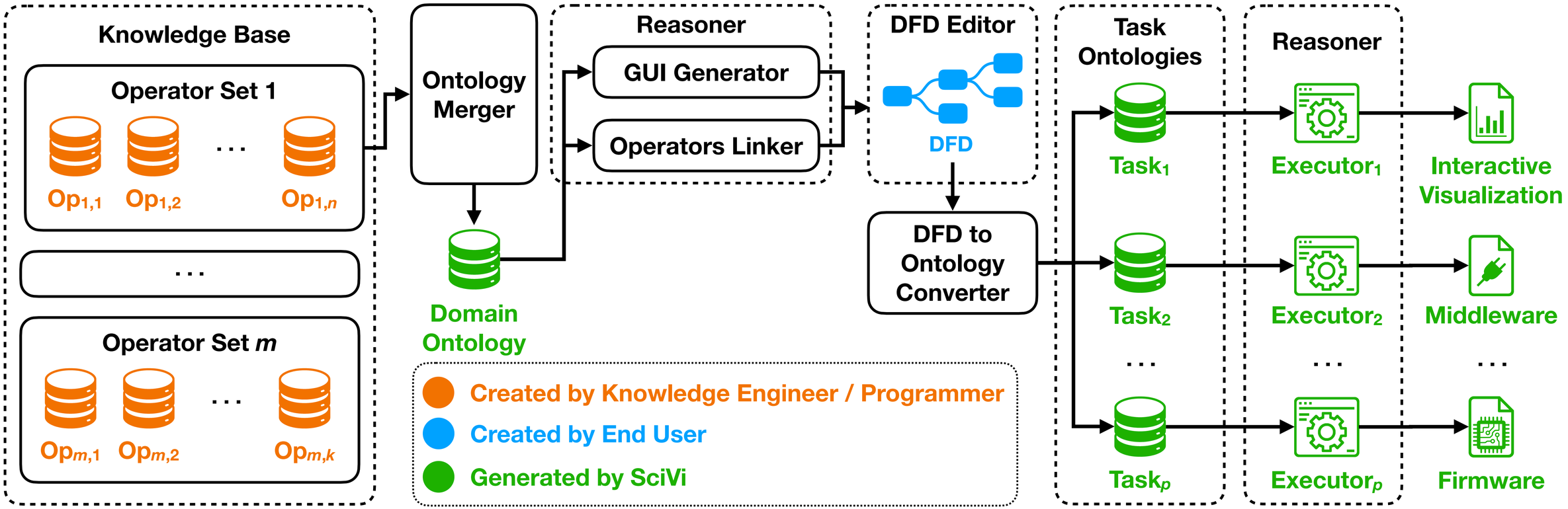


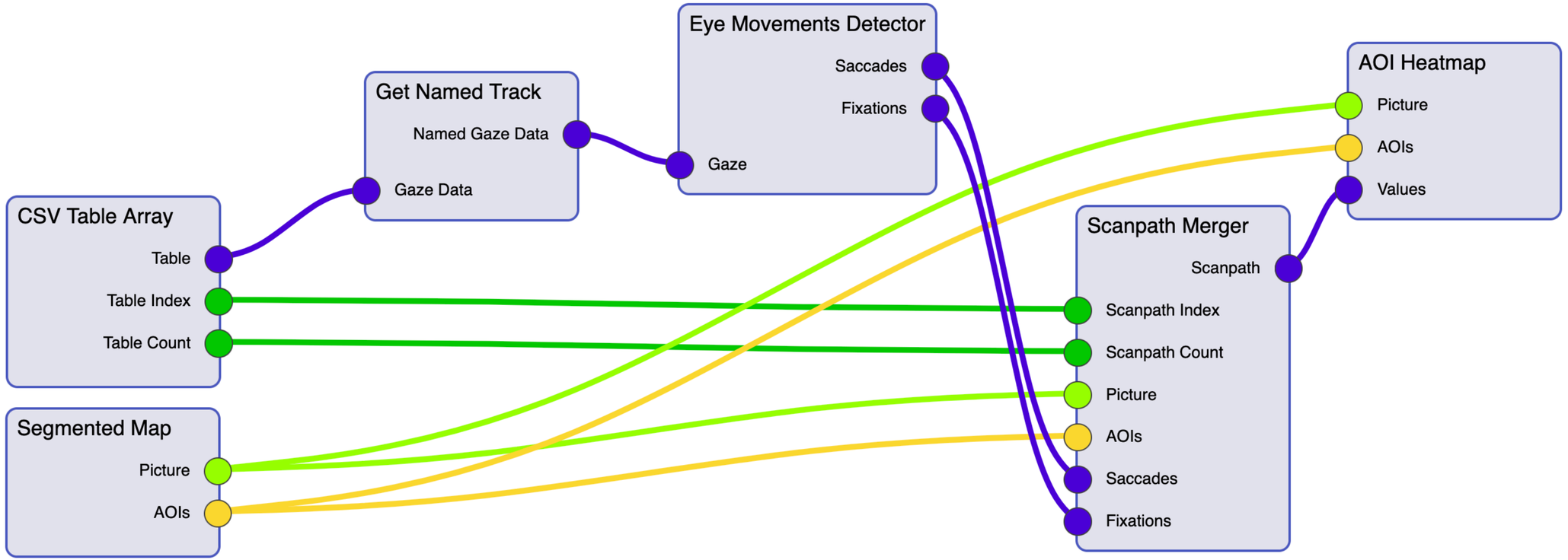
SciVi Semantic Data Mining Platform



https://scivi.tools

(Ryabinin et al. 2013–2023)

Calculating and Visualizing the Fuzzy Scanpath



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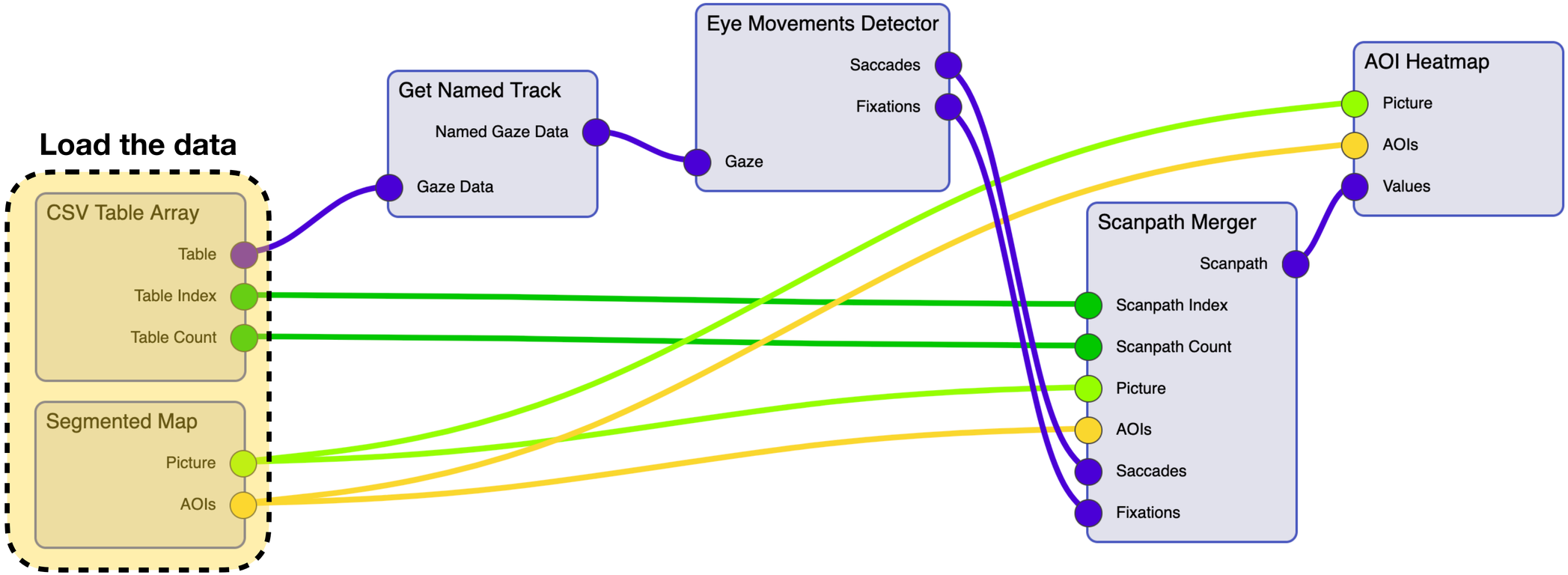

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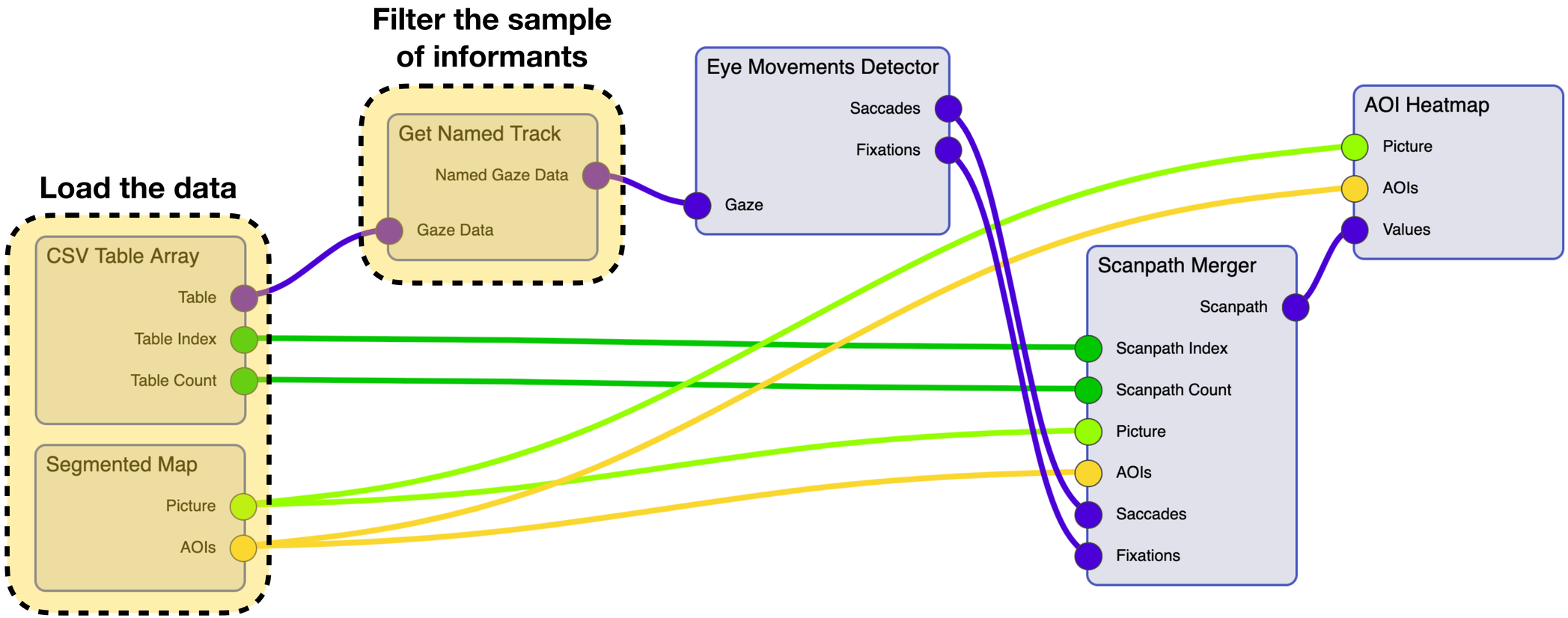

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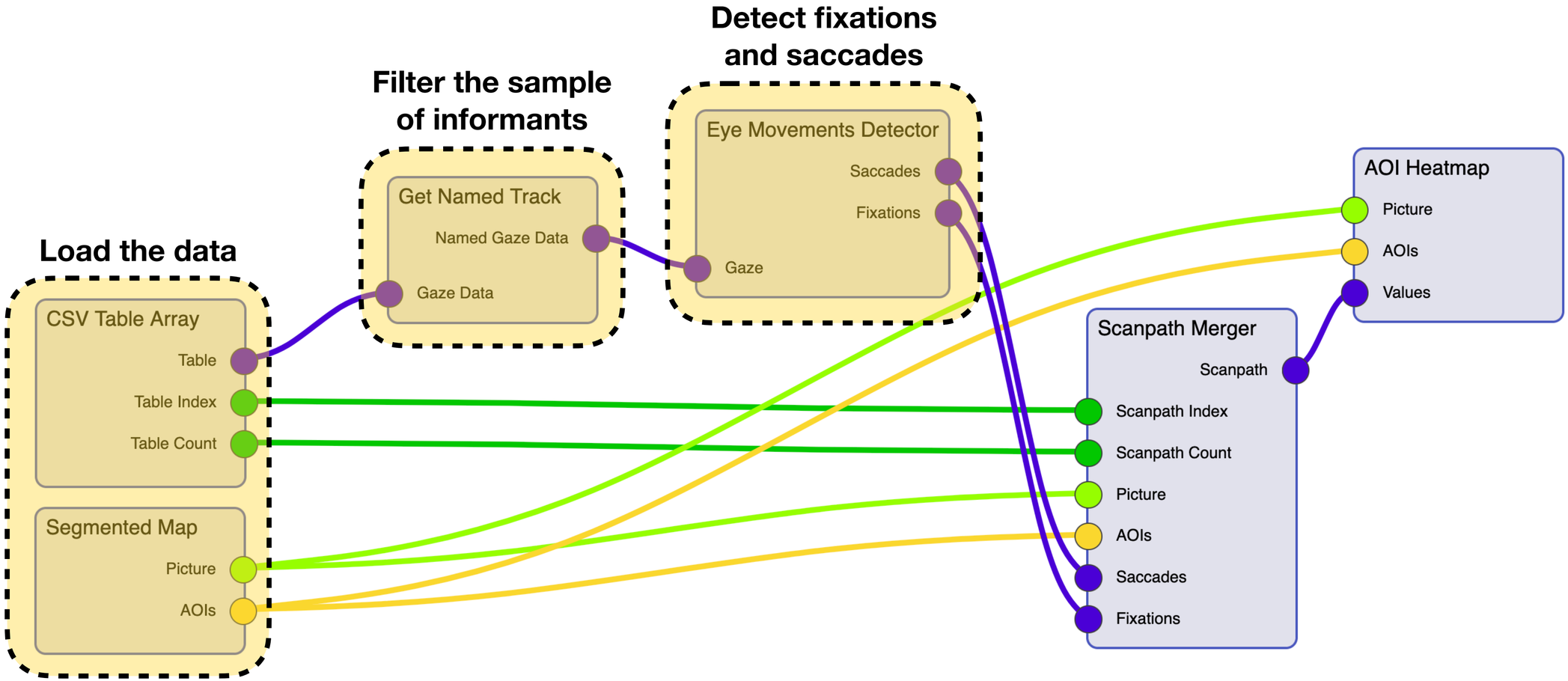

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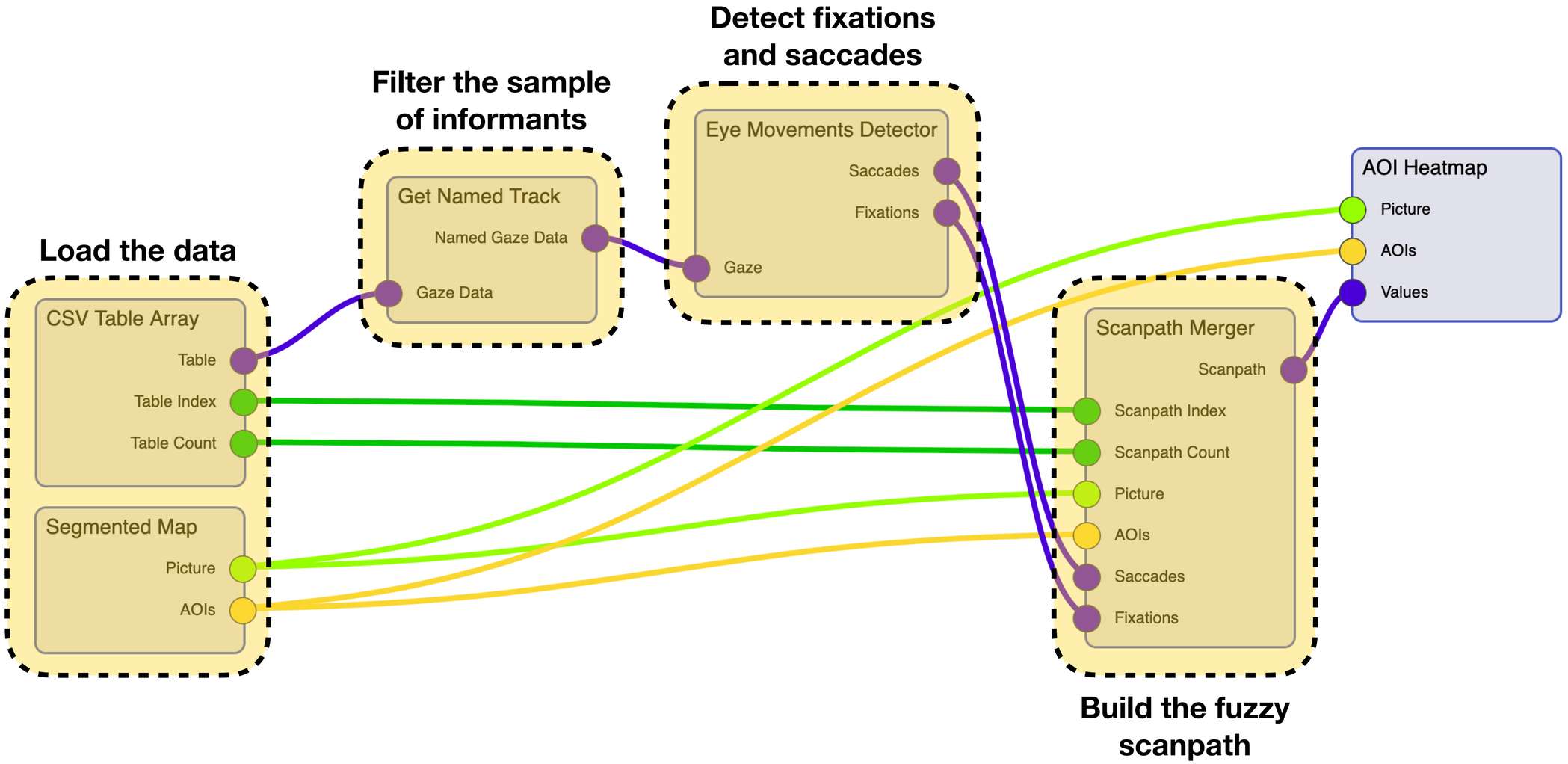

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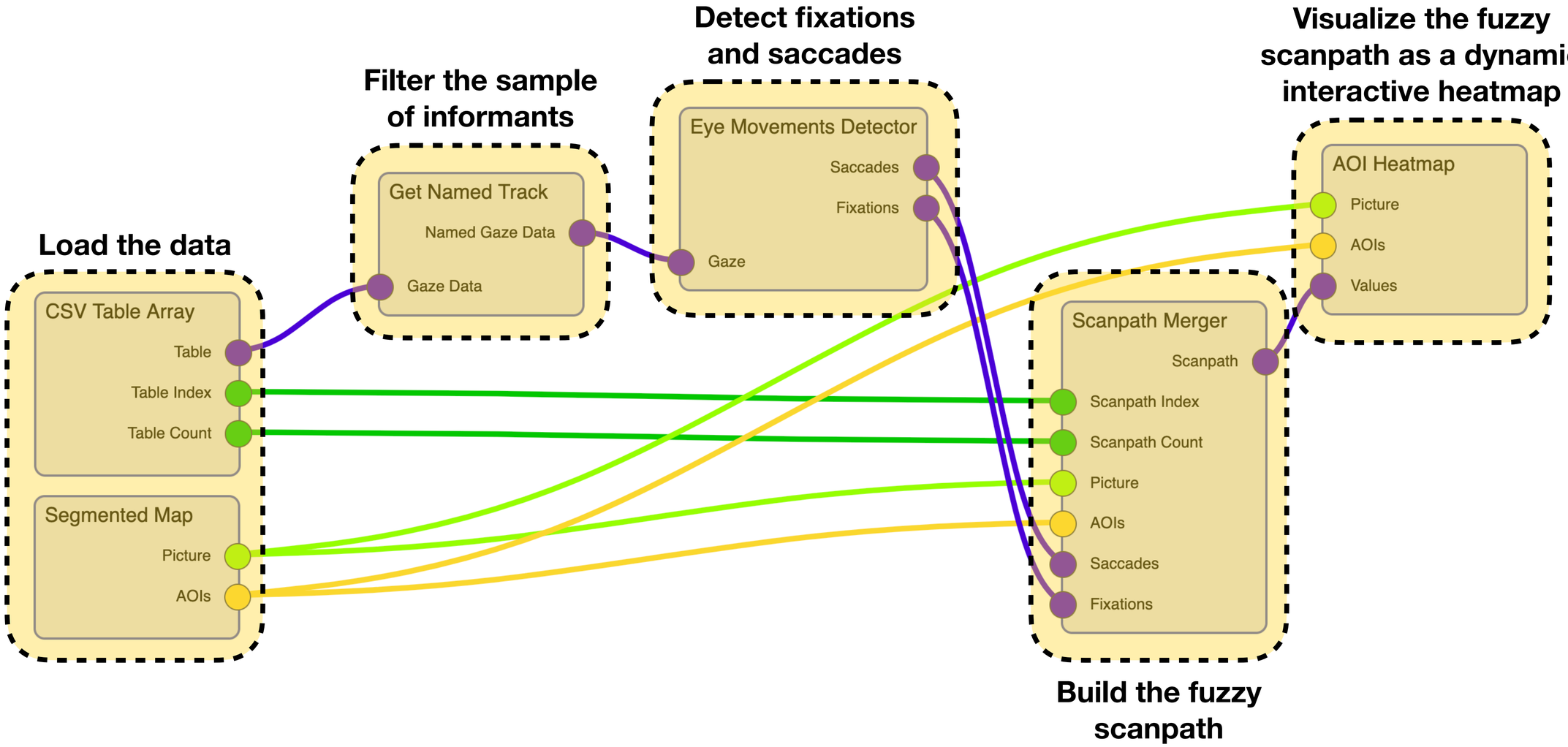
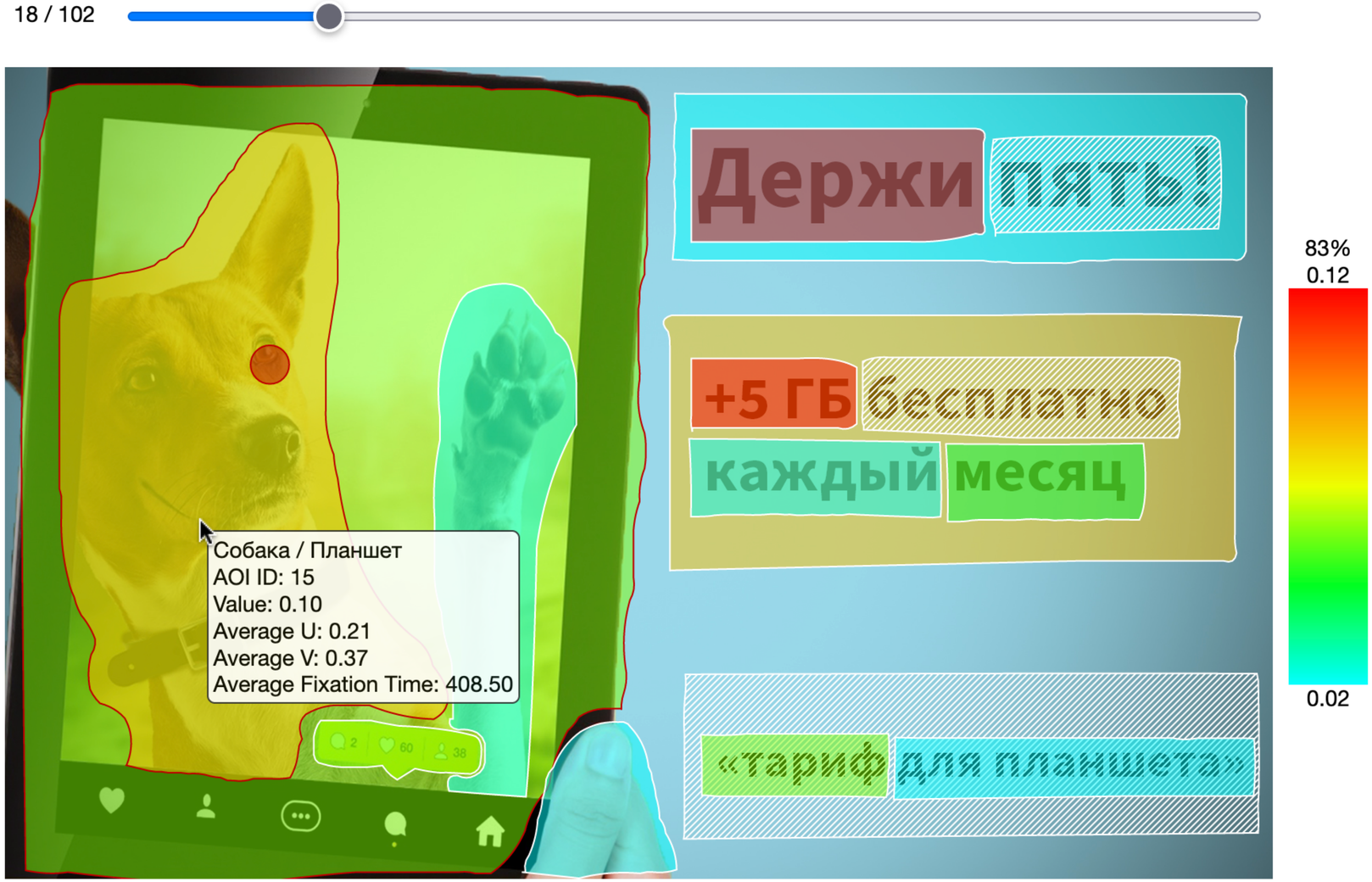


Dynamic Interactive Heatmap



https://scivi.tools/demo/fuzzyScanpath

Retrieval of Common Perception Structure

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✅ "... *saccades and fixations can be clustered, considering them related to a single cycle of cognitive processing*"

(Belardinelli et al. 2008)

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✅ Methods of network science can be used to study eye movements

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❓ Why not to use modularity of saccades graph?

Fuzzy Scanpath Filtering

$$\omega_j^{(i)} \geq \max\{\omega_j^{(i)}\} - \tau \vee \vartheta^{(i)} > \theta, j = \overline{1, m}$$

Belonging function representing the number of informants who have i-th fixation in the j-th area of interest

difference threshold (defaults to 0.03)

minimal ratio of informants having their scanpaths longer or equal to i fixations (defaults to 0.33)

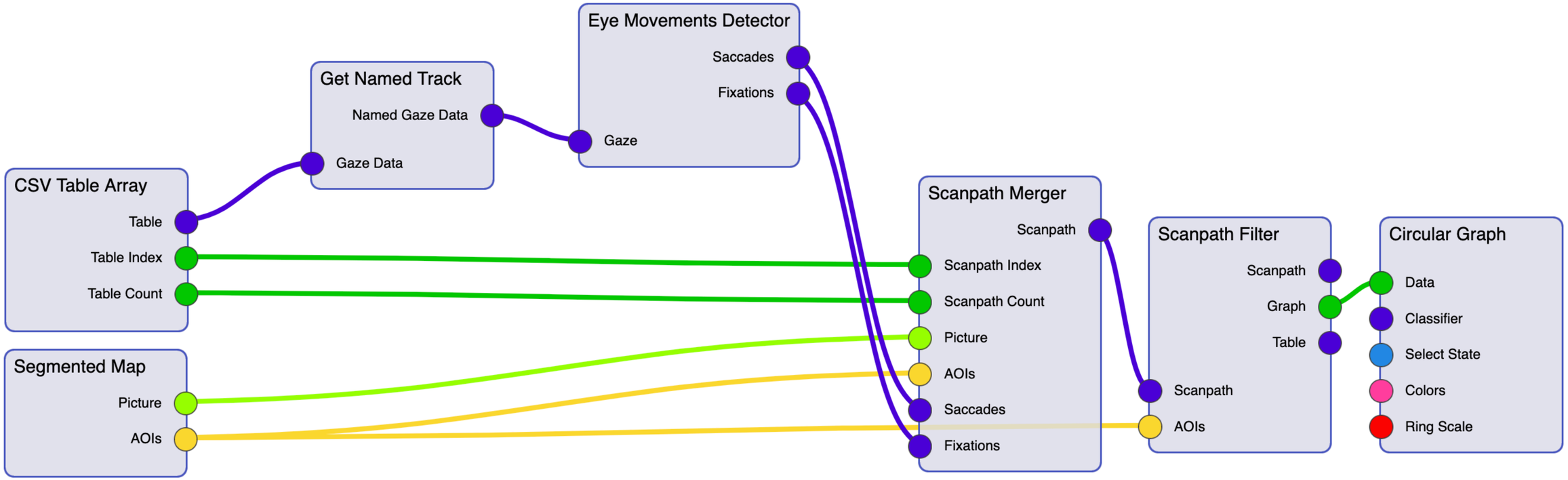
Number of areas of interest in the stimulus

$$\vartheta^{(i)} = \frac{\sum_{k=1}^{p} \begin{cases} 1, & \exists \varphi_i^{(k)} \\ 0, & \text{otherwise} \end{cases}}{p}$$

i-th fixation from the scanpath of k-th informant

number of informants

Calculating and Visualizing the Saccades Graph



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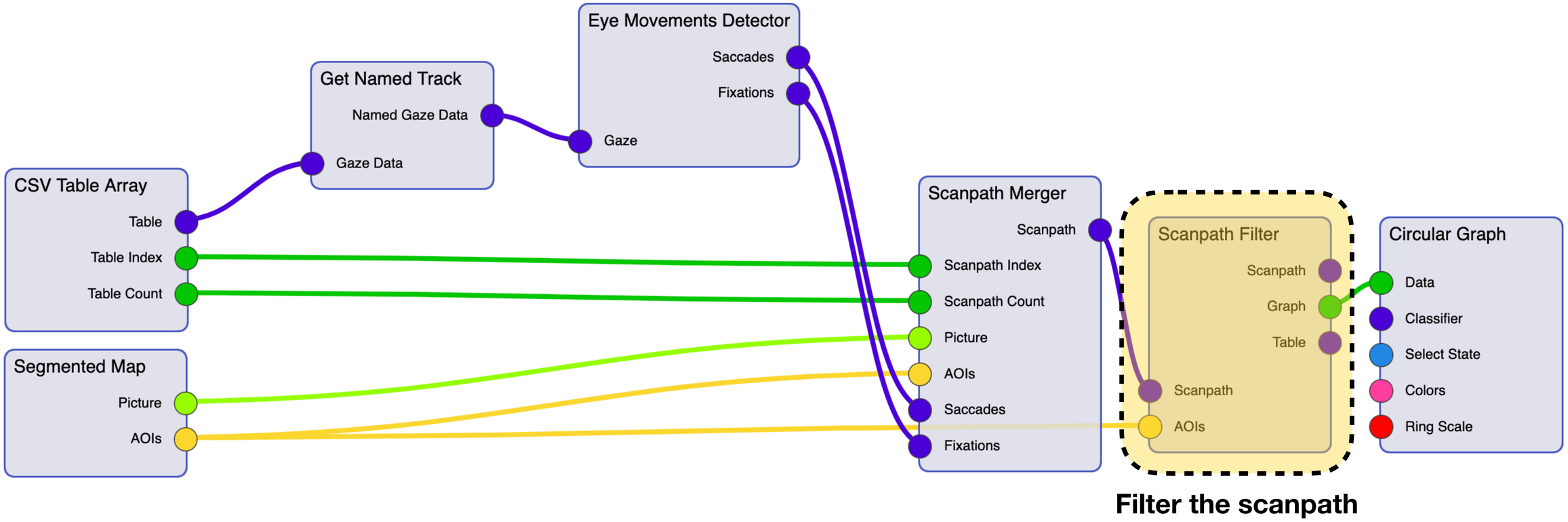
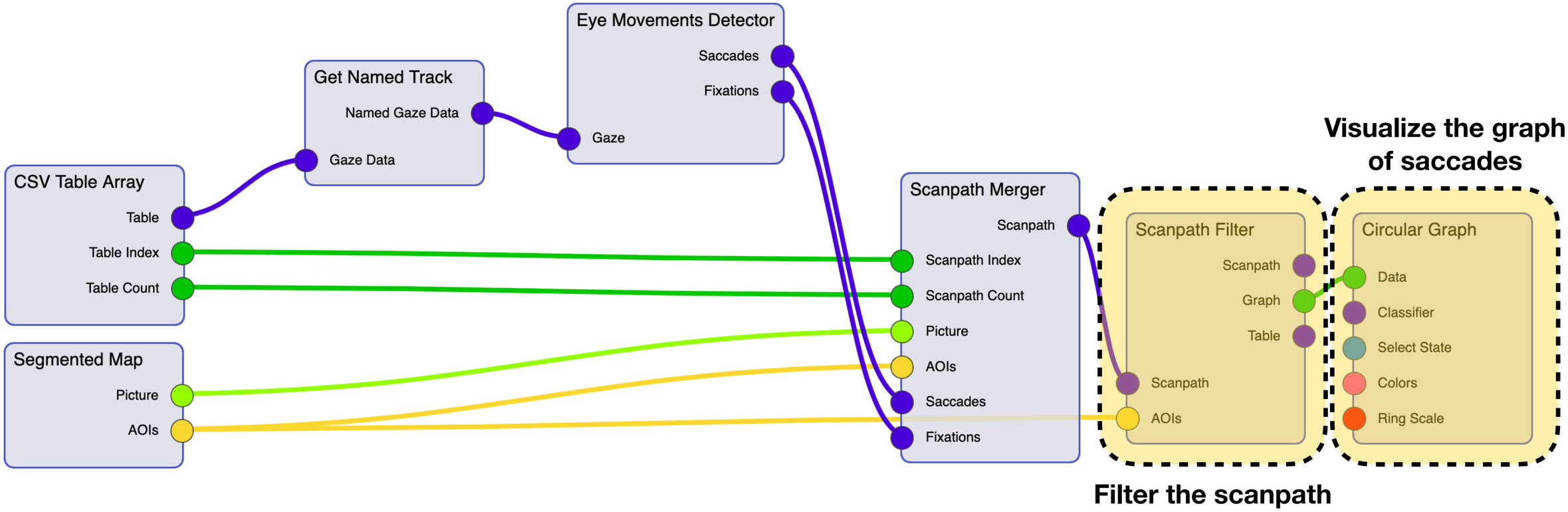
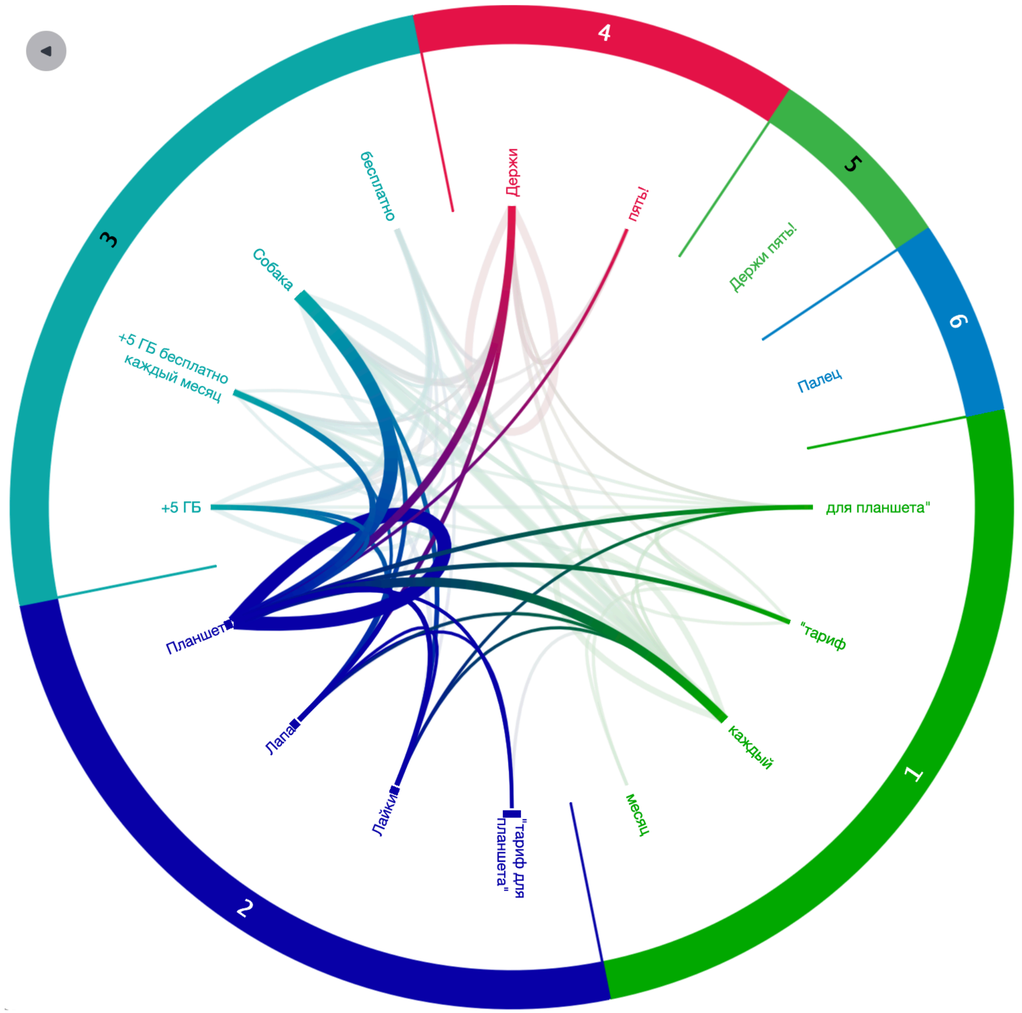


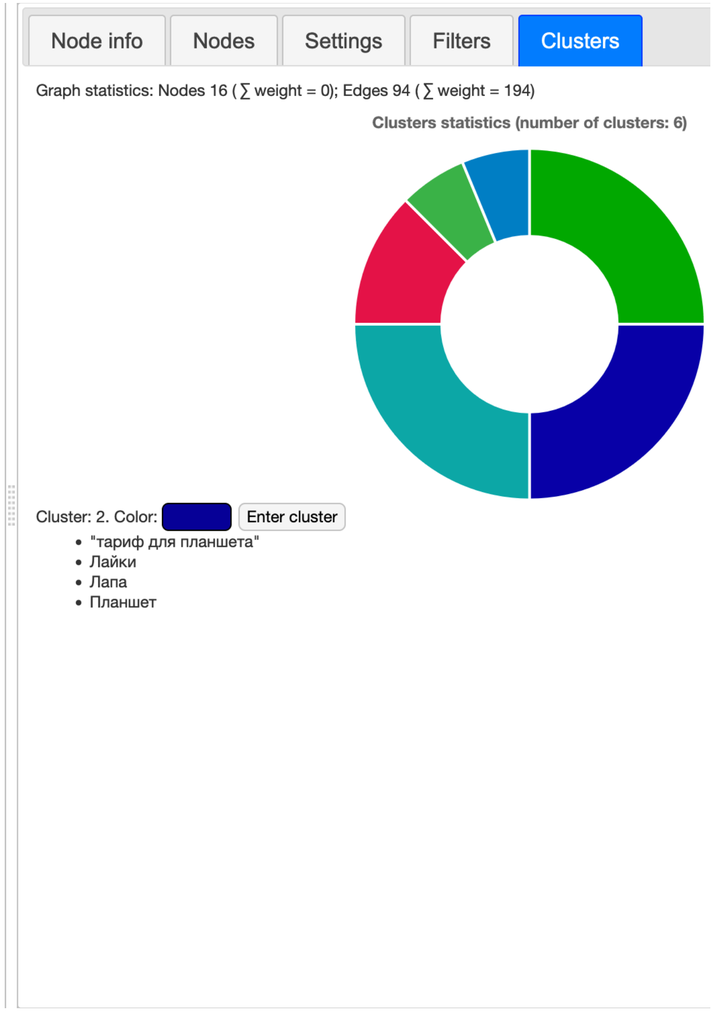
Filter the scanpath

Calculating and Visualizing the Saccades Graph



Dynamic Interactive Saccades Graph





https://scivi.tools/demo/saccadicCycles

Conclusion

Key Contributions:

1. Novel model of an aggregated scanpath of multiple informants based on fuzzy sets of fixations
2. Novel data mining algorithm for revealing the common perception structure of a visual stimulus based on saccades graph modularity within the fuzzy scanpath
3. Novel interactive visualization tools to display fuzzy scanpath and corresponding graph of saccades

Experimental Results:

1. Preliminary experiments conducted in VR using Vive Pro Eye headset with Tobii eye tracker
2. 196 different scanpaths analyzed (41 informant $\times$ 14 stimuli)
3. Proved that clustering of saccades based on fuzzy scanpath reveals perception patterns

Acknowledgments:

Supported by the research grant No. ID92566385 from Saint Petersburg State University

Thank you for your attention!

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