# TOWARDS GENERATION OF VISUAL ATTENTION MAP FOR SOURCE CODE

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## INTRODUCTION

### Attention in Program Comprehension

**Human programmers** focus their gaze on important components in the presented source code [1]. **Gaze focuses get sparser with higher expertise.** Such attentional gaze behavior might help expert programmers to **capture context and composition in source code** much efficiently.

Towards modeling the mechanism of human programmers' attention, we focus on testing biological plausibility of ML attention mechanisms.

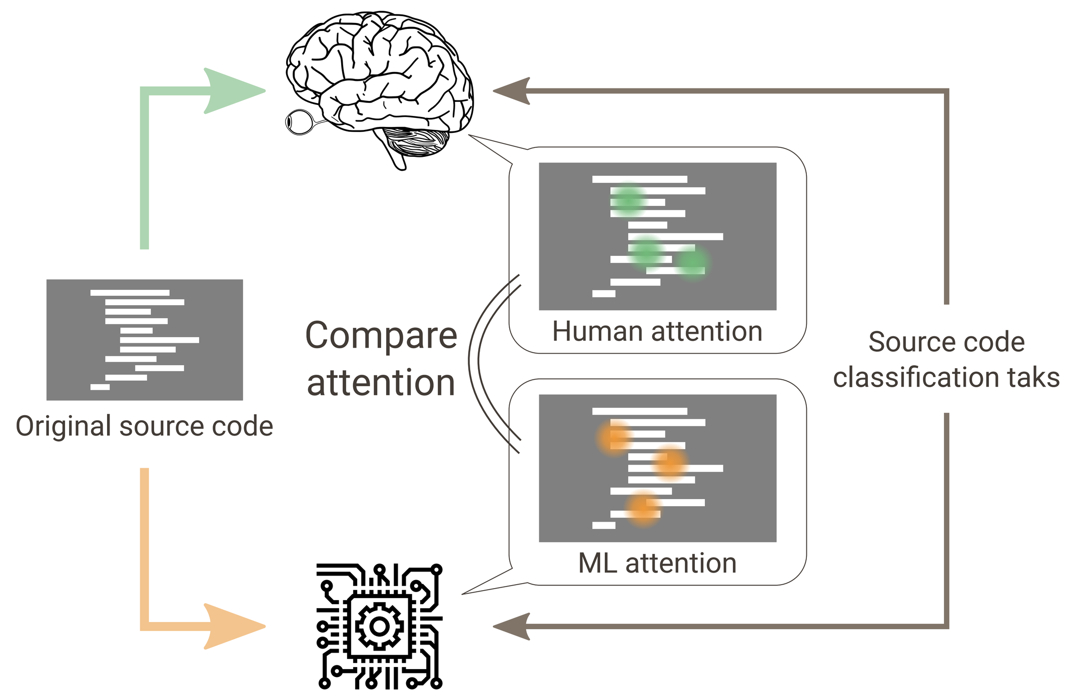
### Objective

Our objective is to develop a gaze analysis framework to **compare programmers' gaze attention to ML attention mechanism**.

### Expected Results

**a)** If human gaze and ML attention are **consistent**:
→ **ML model might explain human attention**.

**b)** If they are **inconsistent**:
If humans outperform ML, programmers' attention strategy can be used to **improve ML attention** [3].
If ML outperforms humans, ML attention can be used to **guide programmers' gaze** [4].

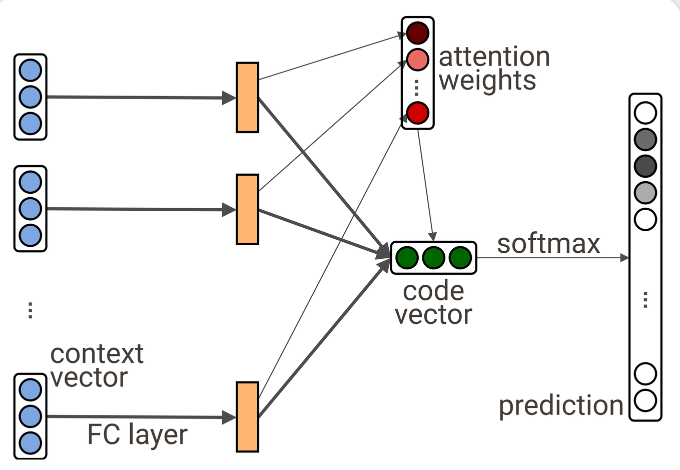



Comparing biological attention to artificial attention

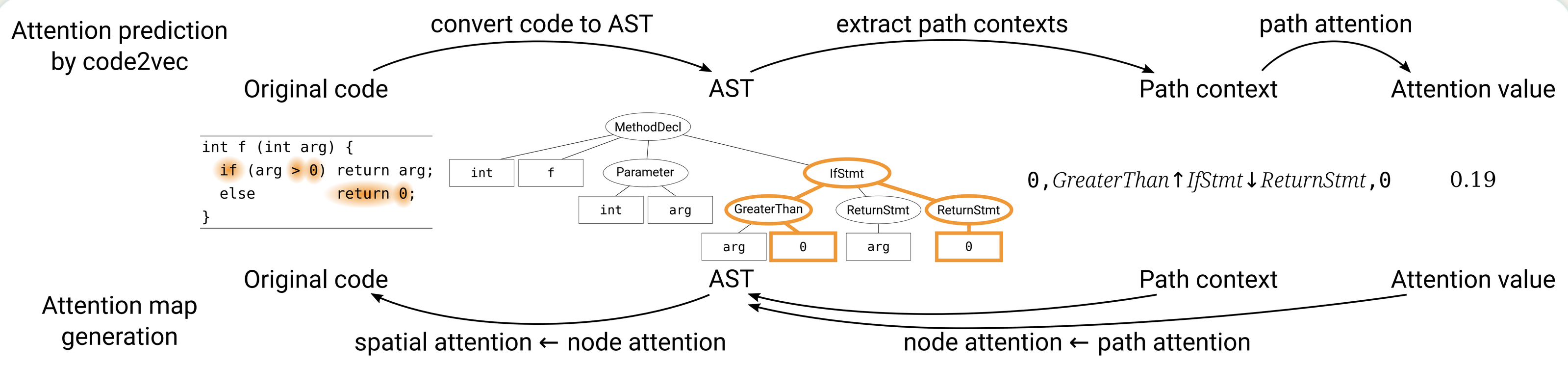
## METHODS

### Visual Attention Map

Code2vec [3] learns a distributed representation of program functions to discriminate their names.
Attention mechanism quantifies components' importance for discrimination.
The visual attention map is computed by **mapping code2vec's path attention into the original source code image**.



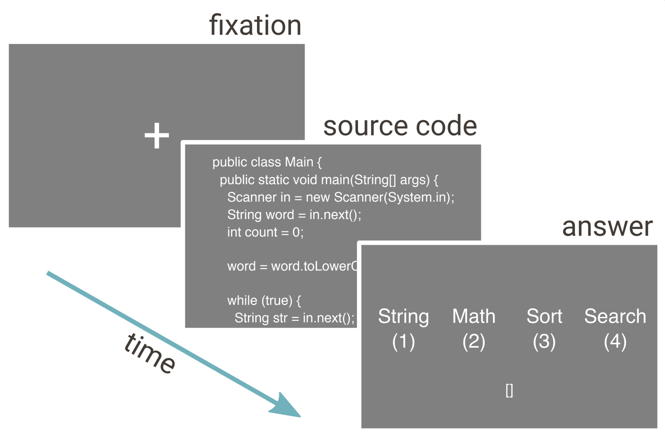

code2vec architecture (from [3]; modified)




Procedure for generating visual attention map

### Preliminary Gaze Experiment

Subjects (1 expert + 1 novice) engaged an algorithm classification task.
Gaze behavior was recorded with Tobii Pro TX 300.
Recorded gaze distribution was compared to the visual attention map to evaluate consistency.

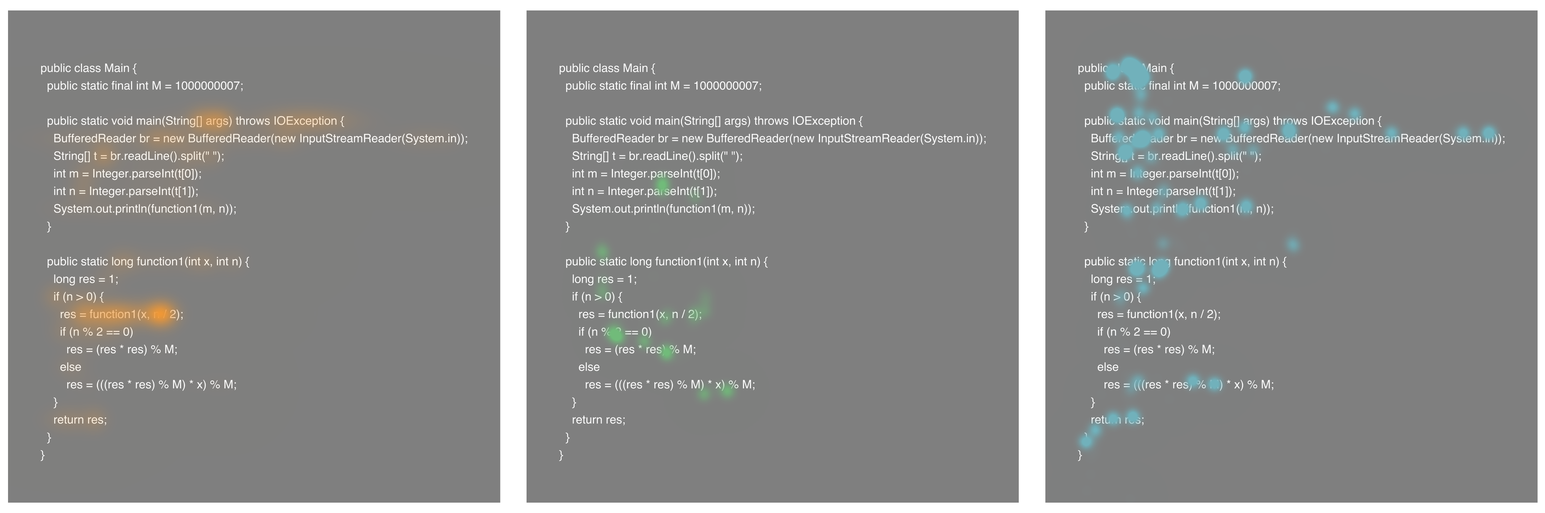



Experimental procedure

## PRELIMINARY RESULTS & DISCUSSION

### Preliminary Results

We conducted ROC analysis between the gaze distributions and the VAM.
**The expert showed a higher AUC value than the novice.**



Visual attention map (code2vec) | Expert gaze distribution (AUC = 0.87) | Novice gaze distribution (AUC = 0.77)

### Discussion

The expert's gaze was more consistent with the VAM than the novice.
The VAM and the expert showed much sparser attention than the novice.
There might be a **common importance metric, shared among attentional ML models and expert human programmers**.

We will continue experimenting to quantify the relationship between programmers' attention and ML attention mechanisms, with more human subjects, varying source code snippets, and performance evaluation.

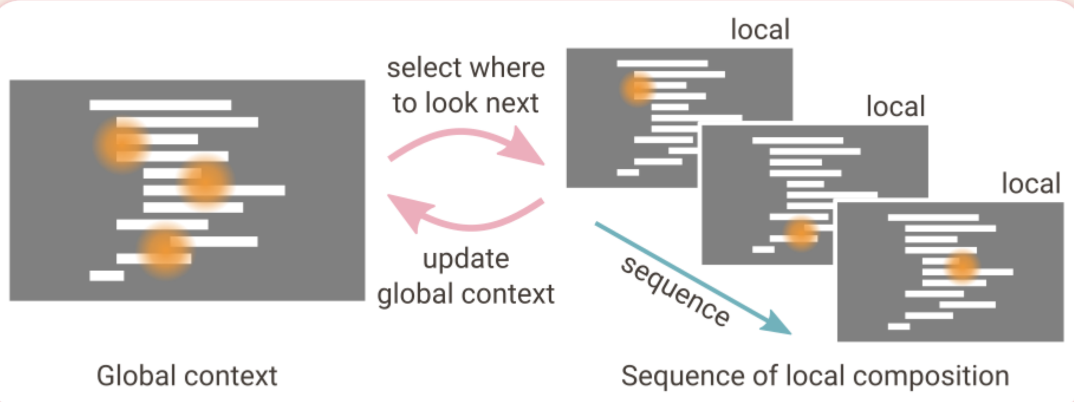
The current result also supported that our VAM method is feasible.
We will test the biological plausibility of other ML models and **seek for common attention representation** for program comprehension.

## PROSPECTS: PROGRAM COMPREHENSION IN BIOLOGICAL & ARTIFICIAL SYSTEMS

### Context and Compositionality in Gaze

Gaze focuses, or fixation points, move sequentially on presented source code.

**[Hypothesis]**
Each fixation grabs local spatial composition.
A sequence of fixations forms a global context.
Experts can form an accurate global context with fewer fixation points, and can determine where to look at in the next fixation.




### Composition-Aware ML Model

Code2vec decomposes programs into a set of "paths," and possibly **it cannot capture the composition** in source code.

We are now developing a new ML algorithm for program comprehension, that is designed with **considering the hierarchical compositionality** in source code.
By considering compositionality, we expect that...

**a)** Model performance on program comprehension task will be improved.
**b)** The VAM will be much consistent with human experts' gaze behavior.
**c)** The model can be used in a model-based fMRI decoding study to explain neural representations in the programmers' brain.

### Neural Representation of Expertise

Our fMRI study (*in prep.*) confirmed that **semantic categories of source code could be decoded from programmers' brain**.
Several brain regions contribute to the better categorization performance of expert programmers.
These brain regions might process context and composition of source code.

FIGURE NOT AVAILABLE

[1] Uwano *et al.*, *ACM Symposium on Eye Tracking Research & Applications*, 2006.
[2] Crosby *et al.*, *14th Workshop of the Psychology of Programming Interest Group*, 2002.
[3] Alon *et al.*, *ACM on Programming Languages*, 2019.
[4] Ikutani *et al.*, *6th International Workshop on Eye Movements in Programming*, 2019.

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