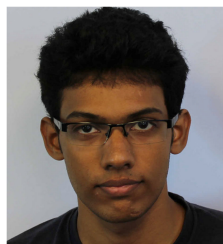


# Can a Fruit Fly Learn Word Embeddings?



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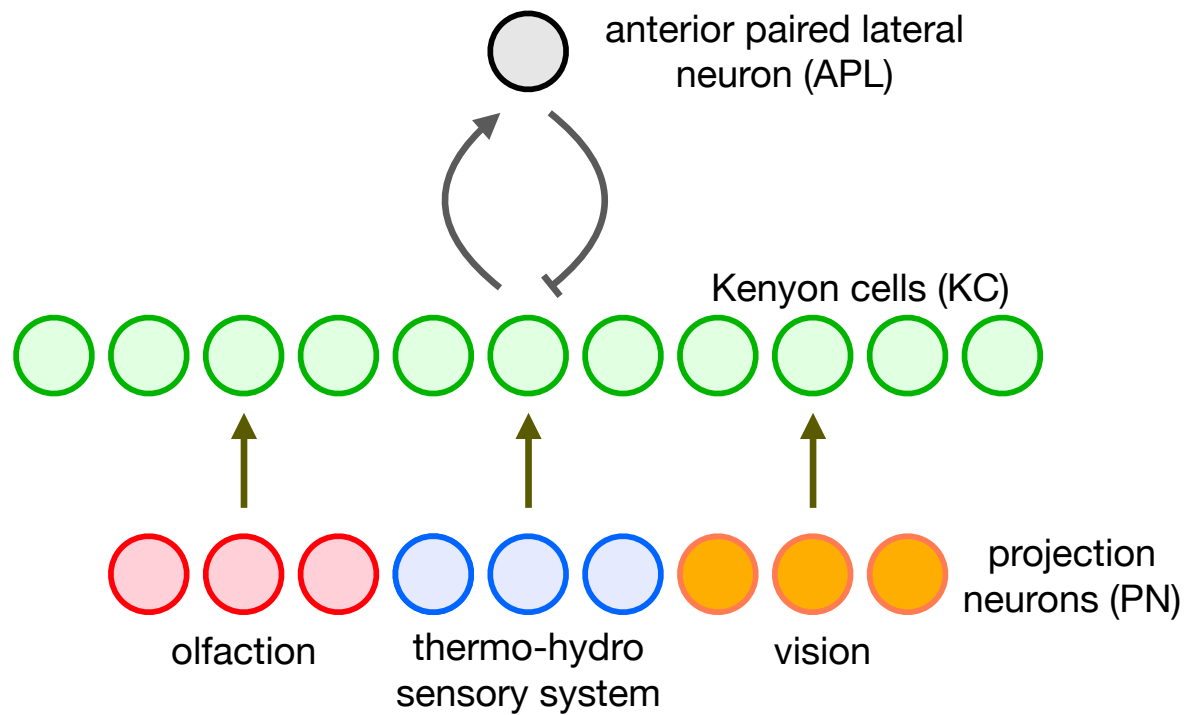


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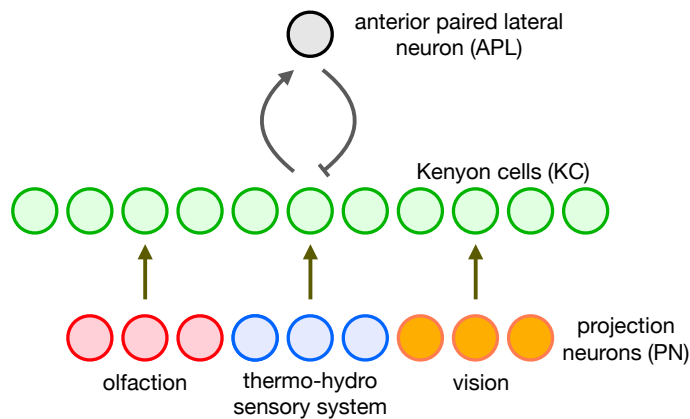
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# Mushroom Body Network



# Fruit fly network for word embeddings

“a word is characterized by the company it keeps” (Firth, 1957)



Apple stock rises on optimism for the new iPhone.

| context |       |       |       |       |       | target |       |       |       |       |       |
|---------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|
| 0       | 1     | 0     | 1     | 0     | 0     | 0      | 0     | 0     | 0     | 0     | 1     |
| rises   | Apple | stock | rises | Apple | stock | rises  | Apple | stock | rises | Apple | stock |

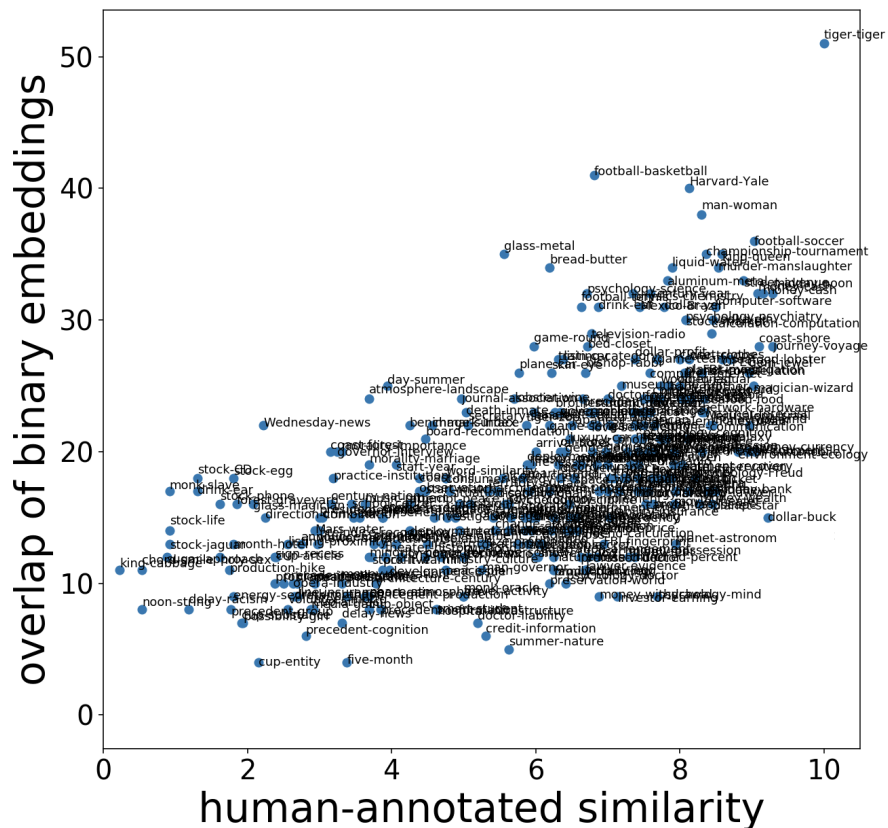
$$W_i = \varepsilon g \left[ \sum_j W_j v_j^A \right] \left[ \frac{v_i^A}{p_i} \right]$$

$$\sum_j W_j \frac{v_j^A}{p_j} \bigg) W_i$$

Hebbian-like local plasticity rule  
from Krotov & Hopfield, PNAS 2019

# How well does this work?

## Word similarity task



| Method  | Hash Length ( $k$ )       |             |             |             |             |             | Hash Length ( $k$ )      |             |             |             |             |             |
|---------|---------------------------|-------------|-------------|-------------|-------------|-------------|--------------------------|-------------|-------------|-------------|-------------|-------------|
|         | 4                         | 8           | 16          | 32          | 64          | 128         | 4                        | 8           | 16          | 32          | 64          | 128         |
|         | <b>MEN</b> (69.5/68.1)    |             |             |             |             |             | <b>WS353</b> (64.0/47.7) |             |             |             |             |             |
| Ours    | <b>34.0</b>               | <b>49.9</b> | <b>55.9</b> | <u>56.7</u> | <u>55.3</u> | 51.3        | <b>43.2</b>              | <b>52.1</b> | <b>55.3</b> | <b>57.4</b> | <b>60.3</b> | 51.7        |
| LSH     | 16.9                      | 23.7        | 35.6        | 42.6        | 53.6        | 63.4        | 8.2                      | 20.7        | 30.0        | 34.7        | 43.9        | 50.3        |
| RandExp | <u>27.5</u>               | <u>37.7</u> | <u>46.6</u> | <b>57.6</b> | <b>67.3</b> | <b>71.6</b> | <u>20.9</u>              | <u>32.9</u> | 41.9        | <u>48.4</u> | <u>57.6</u> | <u>61.7</u> |
| ITQ     | 0.1                       | 7.7         | 10.5        | 16.5        | 30.4        | 50.5        | -6.6                     | -6.1        | -2.4        | -4.4        | 6.1         | 24.8        |
| SH      | 9.4                       | 17.0        | 22.9        | 37.6        | 52.9        | 65.4        | 15.4                     | 14.1        | 19.5        | 32.3        | 43.1        | 58.4        |
| PC H    | 12.5                      | 21.8        | 27.6        | 39.6        | 53.4        | <u>68.1</u> | 6.4                      | 6.3         | 20.6        | 33.9        | 49.8        | <b>62.6</b> |
| NLB     | -                         | -           | -           | -           | 46.1        | 63.3        | -                        | -           | -           | -           | 30.1        | 44.9        |
|         | <b>SIMLEX</b> (31.5/29.8) |             |             |             |             |             | <b>RW</b> (46.8/31.4)    |             |             |             |             |             |
| Ours    | <b>13.4</b>               | <u>16.5</u> | <b>22.8</b> | <u>22.1</u> | 21.1        | 17.0        | 11.0                     | <b>22.6</b> | <u>25.8</u> | <u>36.9</u> | <u>38.6</u> | 35.2        |
| LSH     | 6.8                       | 11.9        | 17.0        | 21.2        | 26.8        | 30.9        | 10.8                     | 16.3        | 21.8        | 27.8        | 36.3        | 45.0        |
| RandExp | <u>10.4</u>               | <b>17.2</b> | <b>22.8</b> | <b>28.5</b> | <b>32.4</b> | <b>35.2</b> | <u>19.9</u>              | 21.3        | <b>30.9</b> | <b>40.5</b> | <b>47.6</b> | <b>53.3</b> |
| ITQ     | 7.0                       | 1.6         | 4.3         | 5.5         | 11.8        | 18.2        | 13.7                     | 5.3         | 6.6         | 6.9         | 12.5        | 26.5        |
| SH      | 9.3                       | 15.6        | 15.9        | 17.0        | 23.1        | 31.2        | <b>22.6</b>              | <u>21.5</u> | 24.3        | 28.8        | 36.1        | <u>45.8</u> |
| PC H    | 4.4                       | 10.3        | 11.0        | 17.3        | 24.1        | <u>31.6</u> | 12.4                     | 16.7        | 21.5        | 30.3        | 36.9        | 44.4        |
| NLB     | -                         | -           | -           | -           | 20.5        | 31.4        | -                        | -           | -           | -           | 25.1        | 34.3        |
|         | <b>RG</b> (74.2/67.6)     |             |             |             |             |             | <b>Mturk</b> (57.5/61.9) |             |             |             |             |             |
| Ours    | <u>24.0</u>               | <u>40.4</u> | <b>51.3</b> | <u>62.3</u> | <u>63.2</u> | 55.8        | <b>44.0</b>              | <b>49.0</b> | <b>52.2</b> | <b>60.1</b> | 57.7        | 55.2        |
| LSH     | 21.2                      | 35.4        | 44.6        | 55.1        | 63.1        | 70.1        | 16.0                     | 23.1        | 33.2        | 35.6        | 42.7        | 55.5        |
| RandExp | <b>36.6</b>               | <b>49.0</b> | <u>49.5</u> | <b>66.1</b> | <b>69.6</b> | <u>70.9</u> | <u>29.3</u>              | <u>35.8</u> | 41.4        | <u>50.4</u> | <b>59.0</b> | <b>61.6</b> |
| ITQ     | -17.5                     | -8.9        | 26.3        | 41.7        | 50.5        | 66.2        | 9.9                      | 7.8         | 10.1        | 17.7        | 32.8        | 47.3        |
| SH      | 4.5                       | 5.8         | 20.3        | 42.9        | 61.3        | <b>72.6</b> | 18.9                     | 17.6        | 27.5        | 35.45       | 48.1        | <u>57.9</u> |
| PC H    | 1.9                       | 9.6         | 19.8        | 40.9        | 53.3        | 68.2        | 15.5                     | 15.1        | 27.1        | 41.7        | 46.5        | 56.2        |

# How well does this work?

## Word in context

| word in context                       | 10 nearest neighbor words in the hash code space                                   |
|---------------------------------------|------------------------------------------------------------------------------------|
| design of <b>apple</b> latest iphone  | design, web, features, graphics, radeon, android, apps, ios, apple, nvidia         |
| filling sweet <b>apple</b> pie recipe | chocolate, sweet, crispy, noodles, syrup, coconut, cheese, sauce, butter, cinnamon |
| money in <b>bank</b> checking account | money, credit, loans, account, cash, funds, savings, paying, banks, pension        |
| boat on the <b>bank</b> of the river  | river, lake, near, island, creek, canyon, valley, mountains, area, shore           |

| Method                 | mean        | std   |
|------------------------|-------------|-------|
| BERT                   | <b>56.8</b> | 0.54  |
| word2vec ( $w = $ )    | 56.7        | 0.005 |
| GloVe ( $w = 3$ )      | 40.9        | 1.3   |
| GloVe ( $w = $ )       | 54.4        | 0.10  |
| Word2Sense ( $w = 3$ ) | 41.4        | 0.01  |
| Word2Sense ( $w = $ )  | 54.2        | 0.008 |
| Ours ( $w = $ )        | 49.1        | 0.36  |

Table 3: SCWS dataset: mean and std for Spearman rank correlation. The best window value is also shown.

| Method                 | mean        | std   |
|------------------------|-------------|-------|
| BERT                   | <b>61.2</b> | 0.22  |
| word2vec ( $w = 5$ )   | 51.3        | 0.004 |
| Word2vec ( $w = $ )    | 50.0        | 0.003 |
| GloVe ( $w = 7$ )      | 54.9        | 0.26  |
| GloVe ( $w = $ )       | 50.1        | 0.25  |
| Word2Sense ( $w = 7$ ) | 56.5        | 0.004 |
| Word2Sense ( $w = $ )  | 50.0        | 0.003 |
| Ours ( $w = 21$ )      | 57.7        | 0.27  |

Table 4: WiC dataset: mean and std for accuracy. The best window value is also shown.

FLYVEC Demo Blog Paper Code Authors + PyPI

## Fruit Fly Word Embeddings

Select a query phrase from the dropdown to search for most related concepts

This sentence corresponds to providing our fly-inspired model a **smell** or analogous sensory input. The displayed wordclouds represent the **receptive fields** of the top activated **Kenyon Cells** (KCs).

Click and hover over the grid to **explore every concept** learned by our model

Each circle on the grid represents a KC with its corresponding receptive field (optimal stimulus that leads to the KC's activation).

Senate majority leader discussed the issue with the members of the committee

**Neuron 159** 8.4%

vast leader majority  
**mitch**  
mcconnell  
senate  
g house rky

**Neuron 275** 4.9%

community  
made  
**family**  
congress  
staff party gang who

**Neuron 54** 0.5%

representatives  
committee  
**white**  
boehner  
speaker  
commons  
judiciary  
senate  
pelosi

**Neuron 101** 0.4%

leader  
republican  
conservative  
**party**  
democratic  
socialist  
communist  
labour

**Neuron 302**

able will <NUM>  
wait lasts periods take  
lasted shorter  
period takes  
stay afford term  
distances  
live  
exists  
bit  
little

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## flyvec 0.2.1

pip install flyvec

Latest version

Released: Feb 6, 2021

A biologically inspired method to create sparse, binary word vectors

**Navigation**

- Project description
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**Project description**

### FlyVec

Sparse Binary Word Embeddings Inspired by the Fruit Fly Brain

Code based on the ICLR 2021 paper [Can a Fruit Fly Learn Word Embeddings?](#).

https://flyvec.org