Spiking Mushroom Body Model for the Investigation of Ant Navigation

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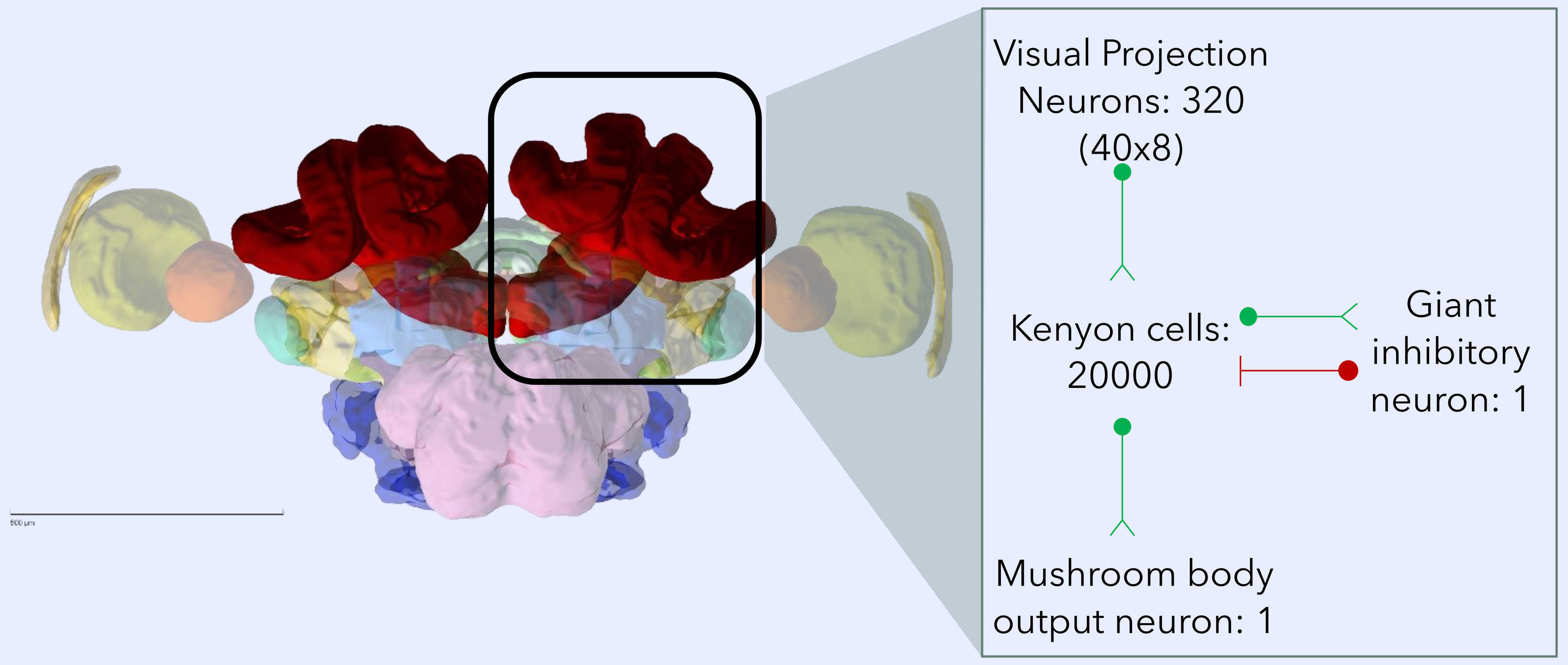
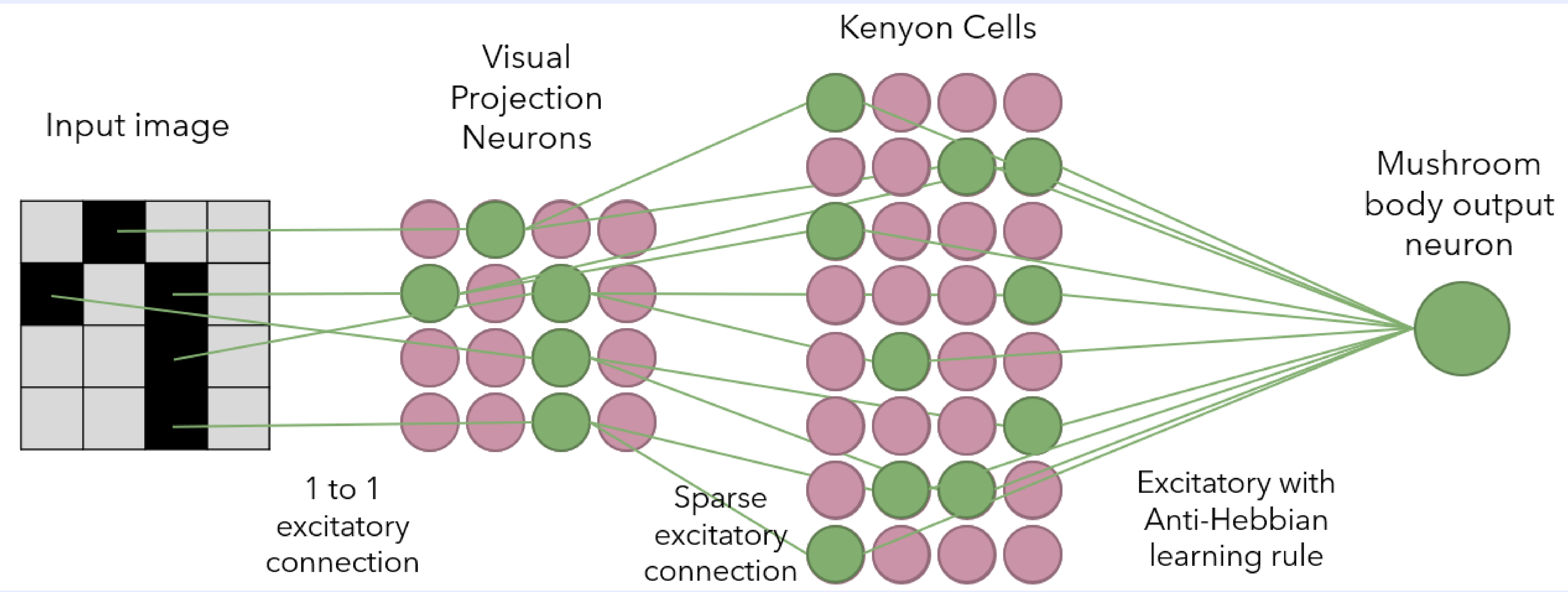
Overview

- Ants are efficient navigators; they have small brains but can forage over large distances.
- We have built a spiking neural network (SNN) model of the mushroom body (MB), a region of ant brains vital to spatial learning[1], using the GPU-accelerated SNN library PyGeNN[2].
- Our MB model could learn long routes with high accuracy for extended sections of a given route.
- In future changes to the image processing capabilities of our model may increase robustness and heading accuracy.

Model Architecture & learning rule



- Our model contains VPNs which take in visual input, KCs which represent the input sparsely in a high dimensional space and an MBON which signals whether the input is familiar or not. A GGN provides feedback inhibition on the KCs.
- All neurons are leaky integrate and fire neurons, except the GGN which is an integrate and fire neuron, and which helps to control KC firing.
- The connection between the VPN and KC populations is non-learning and random, with 10 random connections from a KC neurons and a VPN.
- Between the KCs and MBON is a plastic excitatory connection with an anti-Hebbian learning rule based on spike-timing dependent plasticity (STDP). When a KC and the MBON fire close in time together, the corresponding synapse weakens. As a result, a repeated pattern of activation makes the MBON less likely to fire.



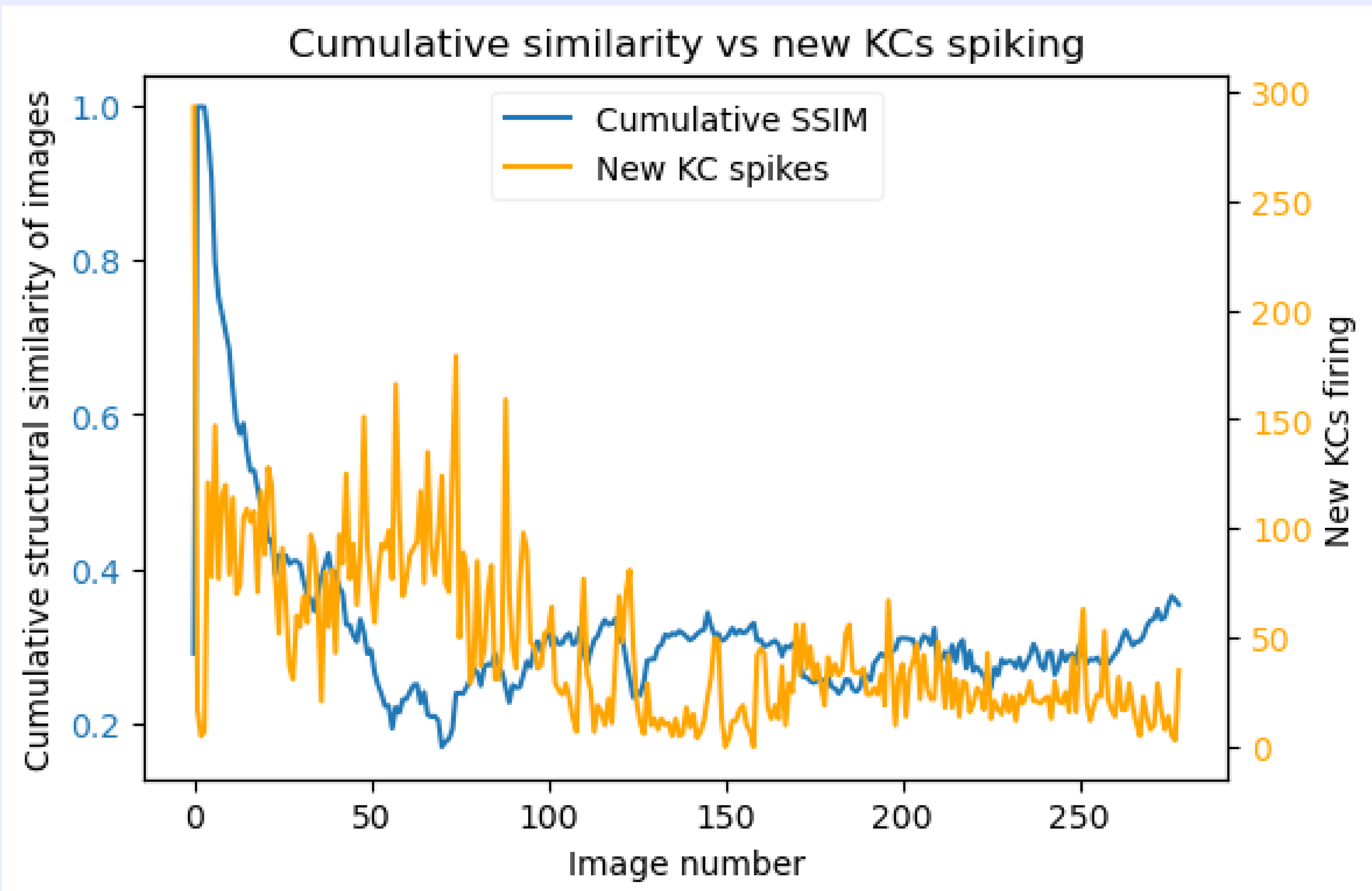
Dataset

- We used a robot in a real indoor arena to acquire panoramic route images for testing the navigation performance of our MB model.
- All input images were down-sampled to 40x8 resolution and converted to greyscale.
- Each image had an associated x-y coordinate and angular heading.

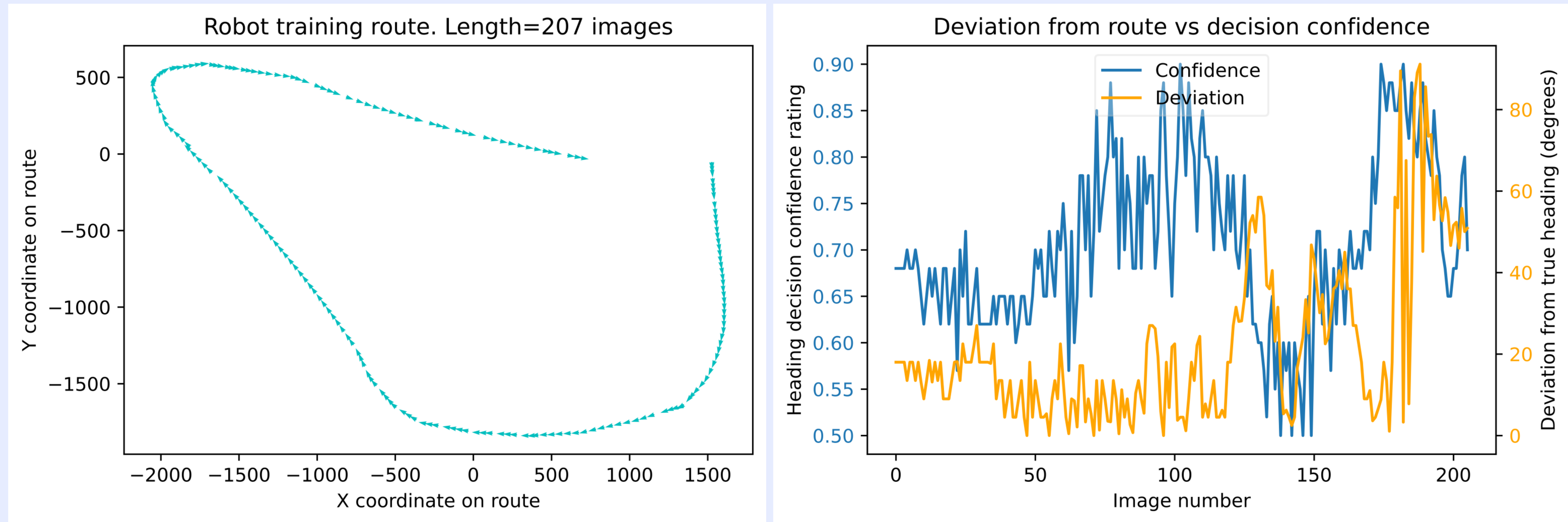
Abbreviations: ***MB*** *- mushroom body,* ***VPN*** *- Visual projection neuron, Kenyon cell,* ***MBON*** *- Mushroom body output neuron,* ***GGN*** *- Giant GABAergic inhibitory neuron,* ***STDP*** *– Spike time dependant plasticity,* ***SSIM*** *– Structural similarity index metric.*

KC activity during training

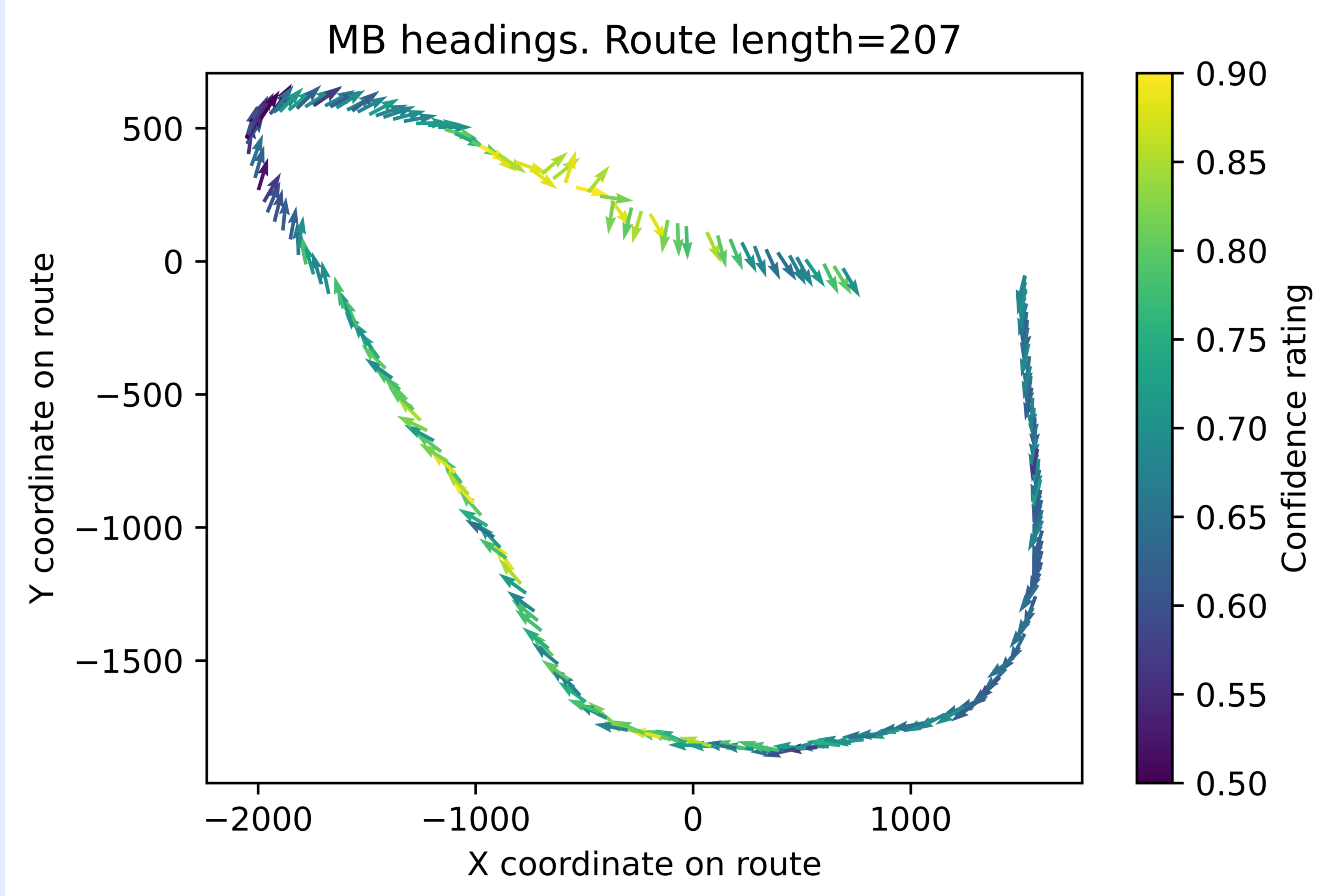
- To gain intuition on what the KCs are encoding during training, we recorded their activity during training on a route of images.
- We compared the number of new KCs firing in response to each training image to a cumulative structural similarity index measure(SSIM). This cumulative SSIM compared how similar any given training image was compared to all previously encountered images.



Route Navigating Performance



- We trained the model by presenting it with images taken in 10cm intervals from a navigation route.
- For the test phase we presented the model with each route image and rotations of the test image from 0 to 360 degrees in 9 degree intervals, while recording MBON activity.
- We then averaged all the angles the MBON classified as familiar (by having a spike response), to give the heading direction, and compared this to the original heading.
- Confidence was defined as the ratio of angles (out of a max of 40) classified as familiar. High confidence means a low number of angles were classified as familiar.



Conclusion & Future Work

We have demonstrated that a realistic spiking MB model can learn from real world data, with the presence of real world noise. We have also shown that the MB model can be trained on long routes and still produce accurate headings for extended sections of navigation routes. We predict that heading accuracy can be greatly increased by adding image regularisation to cope with non-uniform lighting conditions throughout the dataset. In future we are interested in embodying the model with free-movement behaviour within a 3D environment, to investigate how familiarity in the MB relates to observed ant behaviour.

References

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Funded by the EPSRC (grants EP/P006094/1 and EP/S030964/1) and The Leverhulme Trust