SAND2023-12398C

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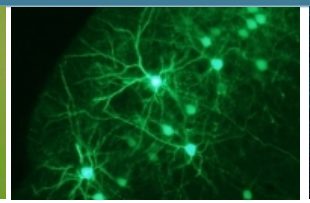
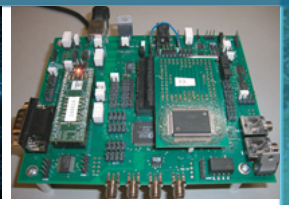
Sensorimotor Transformations in Neural and Neuromorphic Systems



Frances S. Chance

20th Annual World Congress of SBMT
Neuroscience Research at DOE National Labs
February 18, 2023

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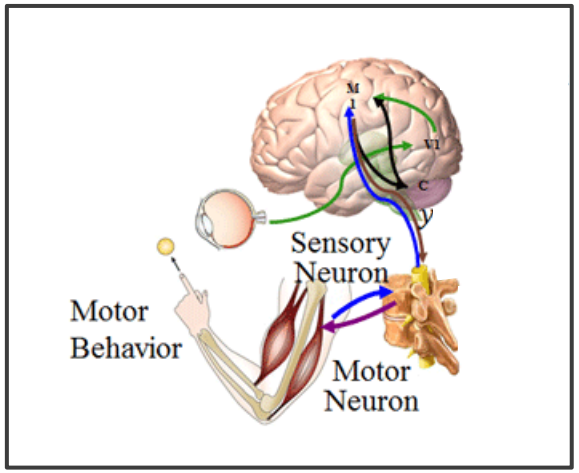
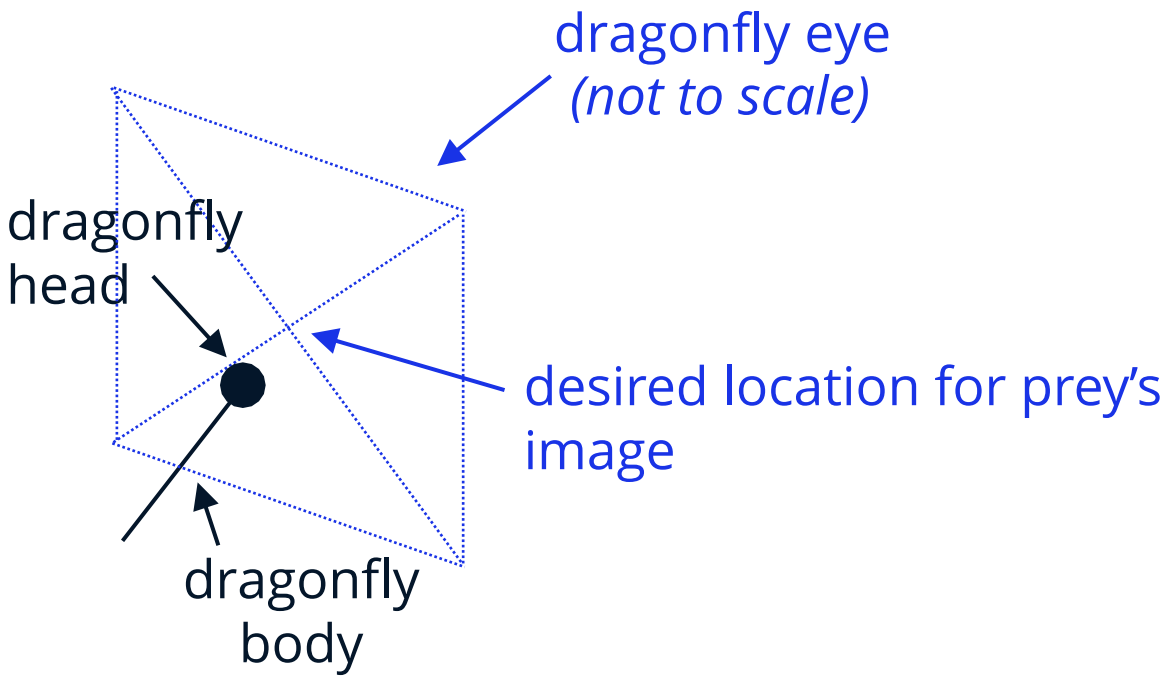
Sensorimotor transformations are essential for survival

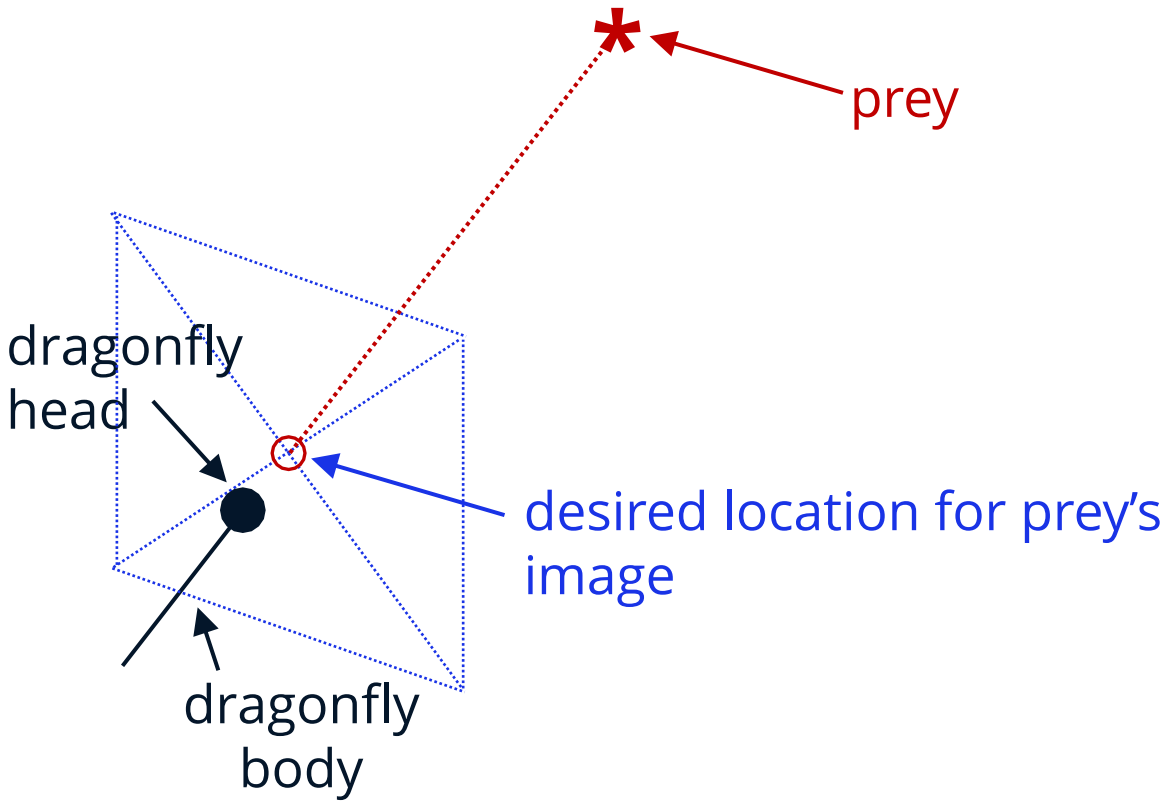
from Supple et al (2020)
Current Biology 30: 645



Building a model dragonfly



Model dragonfly turns to keep prey's image at eye's center



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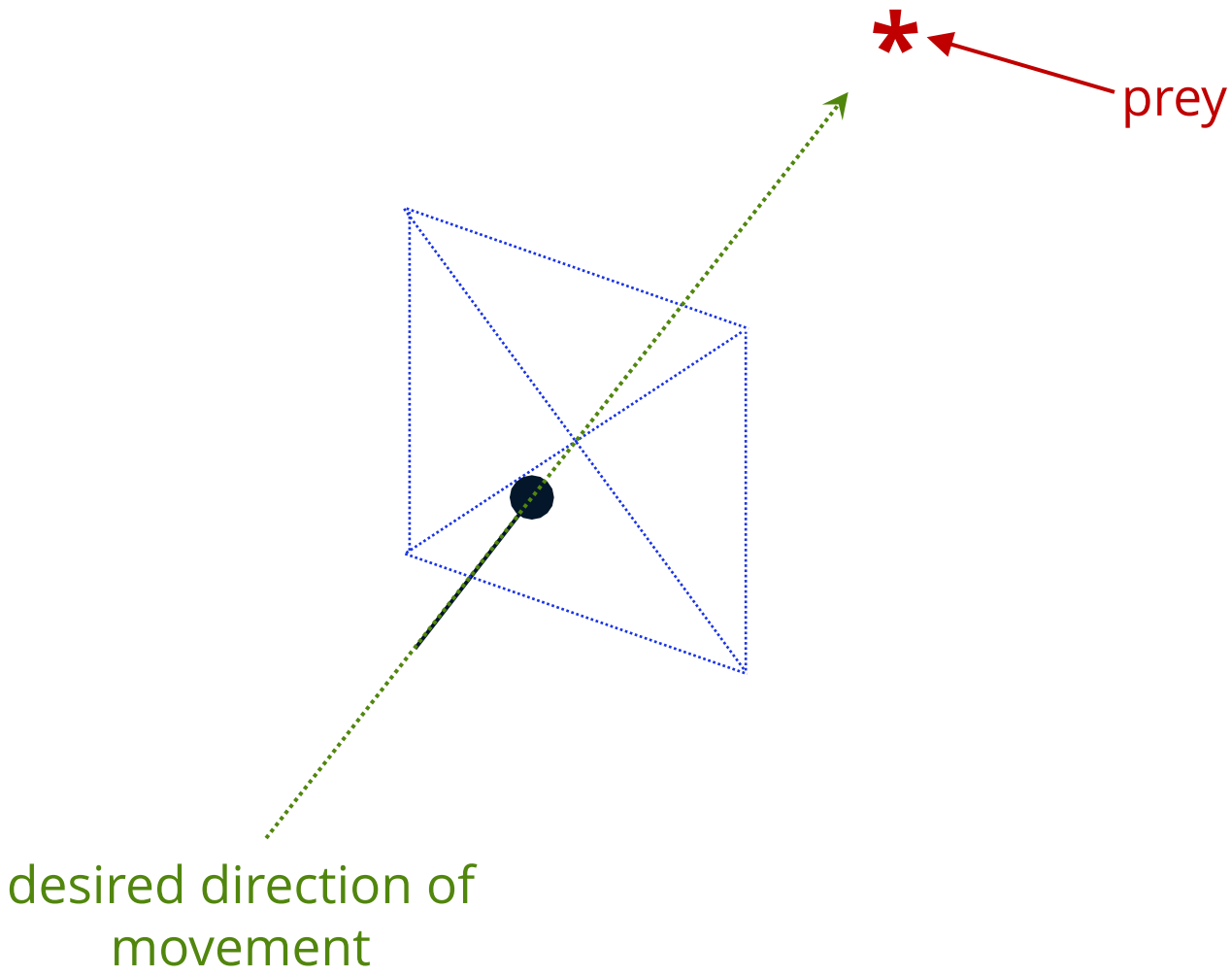
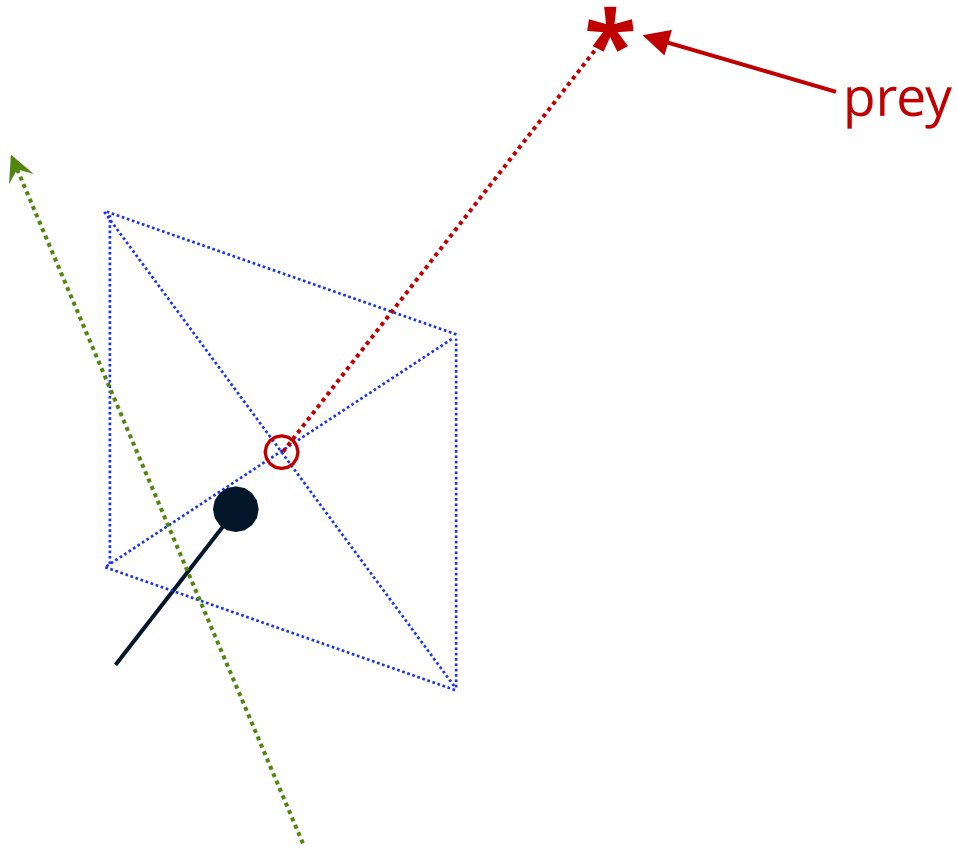


Coordinate transformations are needed if the dragonfly does not fly straight at the prey



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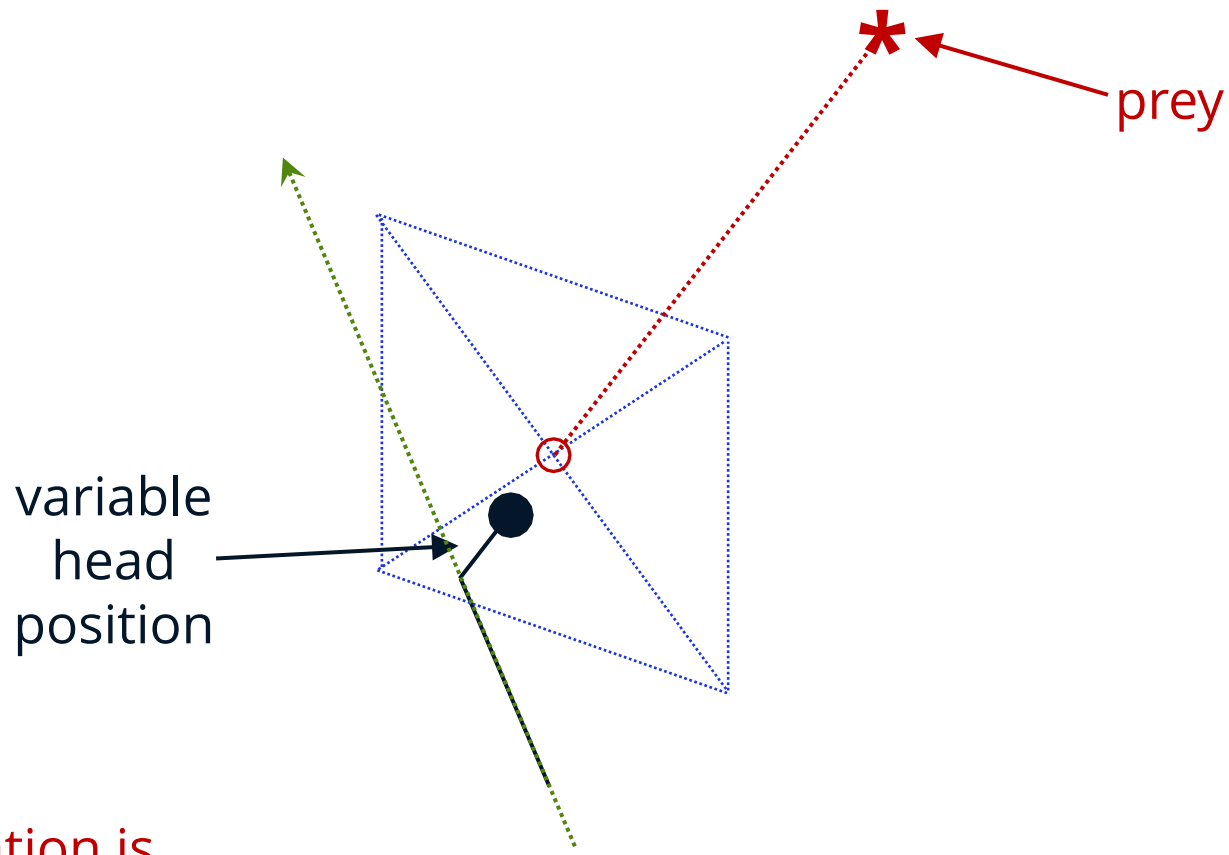
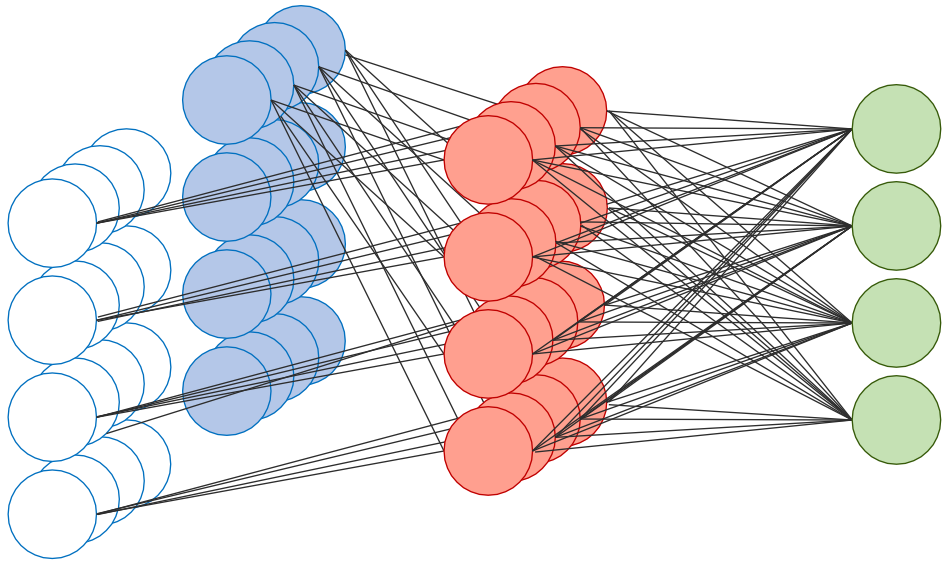


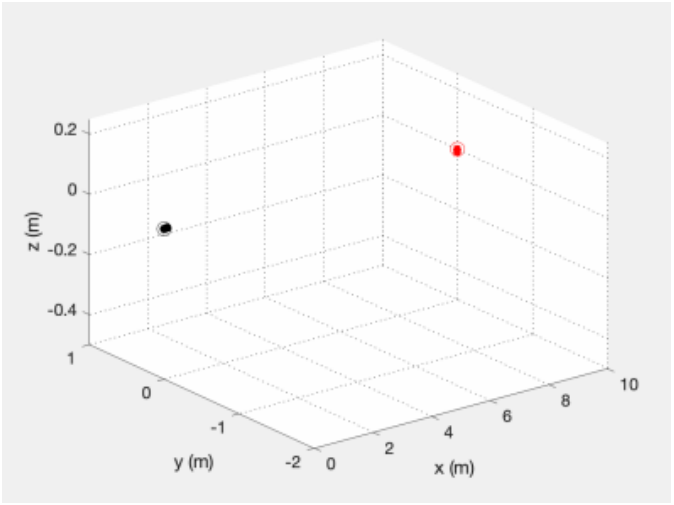
A sensorimotor transformation is required for calculating correct motor commands

Neural network model for dragonfly sensorimotor transformations

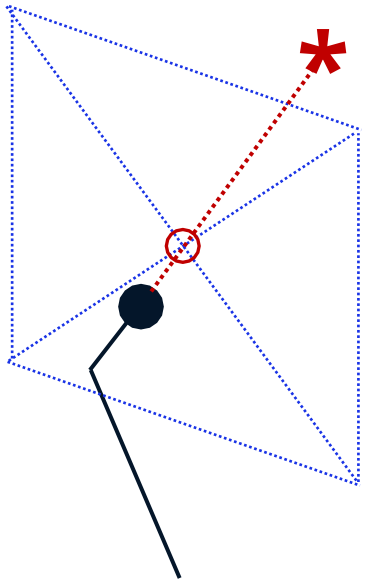
visual input from eye



motor commands

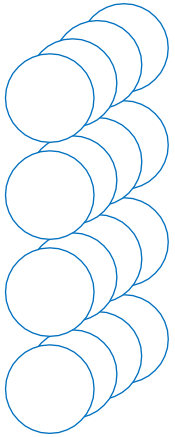


Neural network model receives visual input from eye



Model automatically adjusts head position to keep prey-image at eye center

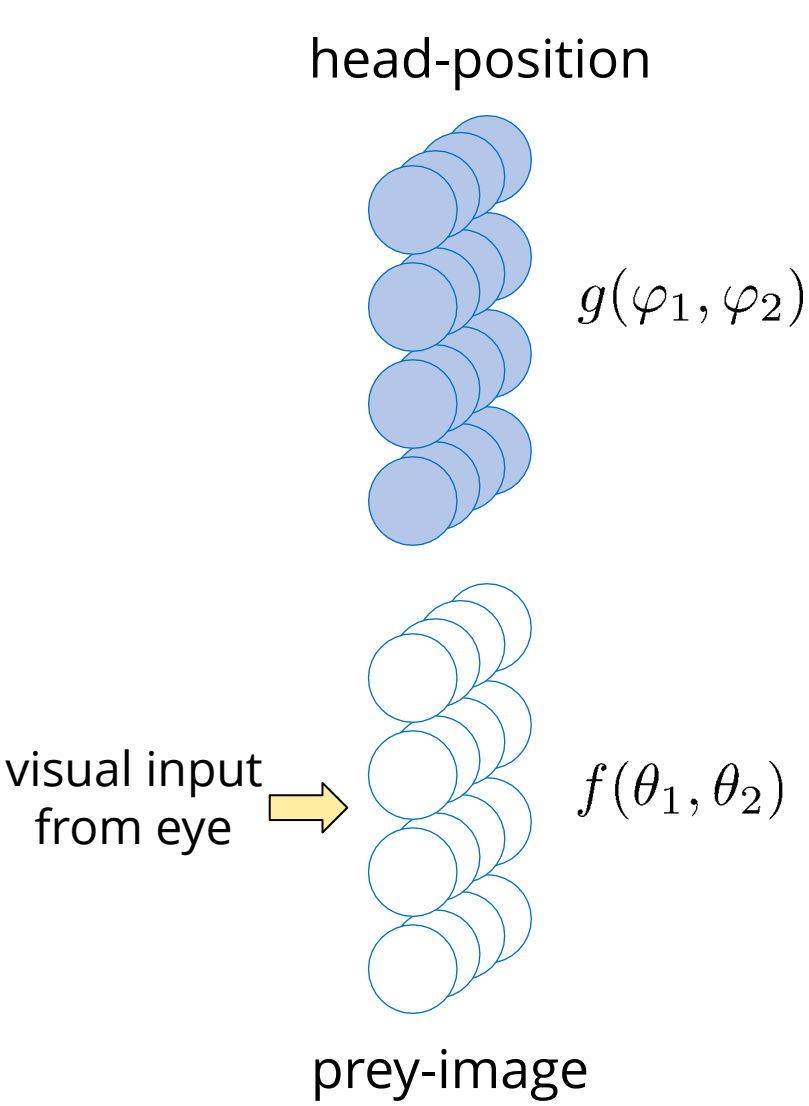
visual input from eye

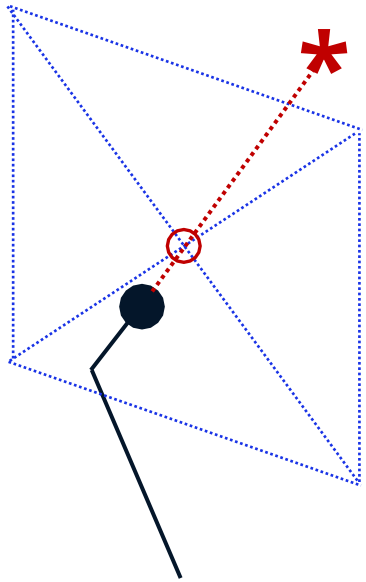


prey-image representation

$$f(\theta_1, \theta_2) = \frac{\exp(\kappa_f \left(\cos(\theta_1 - \mu_1) + \cos(\theta_2 - \mu_2)\right))}{4\pi^2 I_0(\kappa_f)^2}$$

Head-position neurons encode head angle

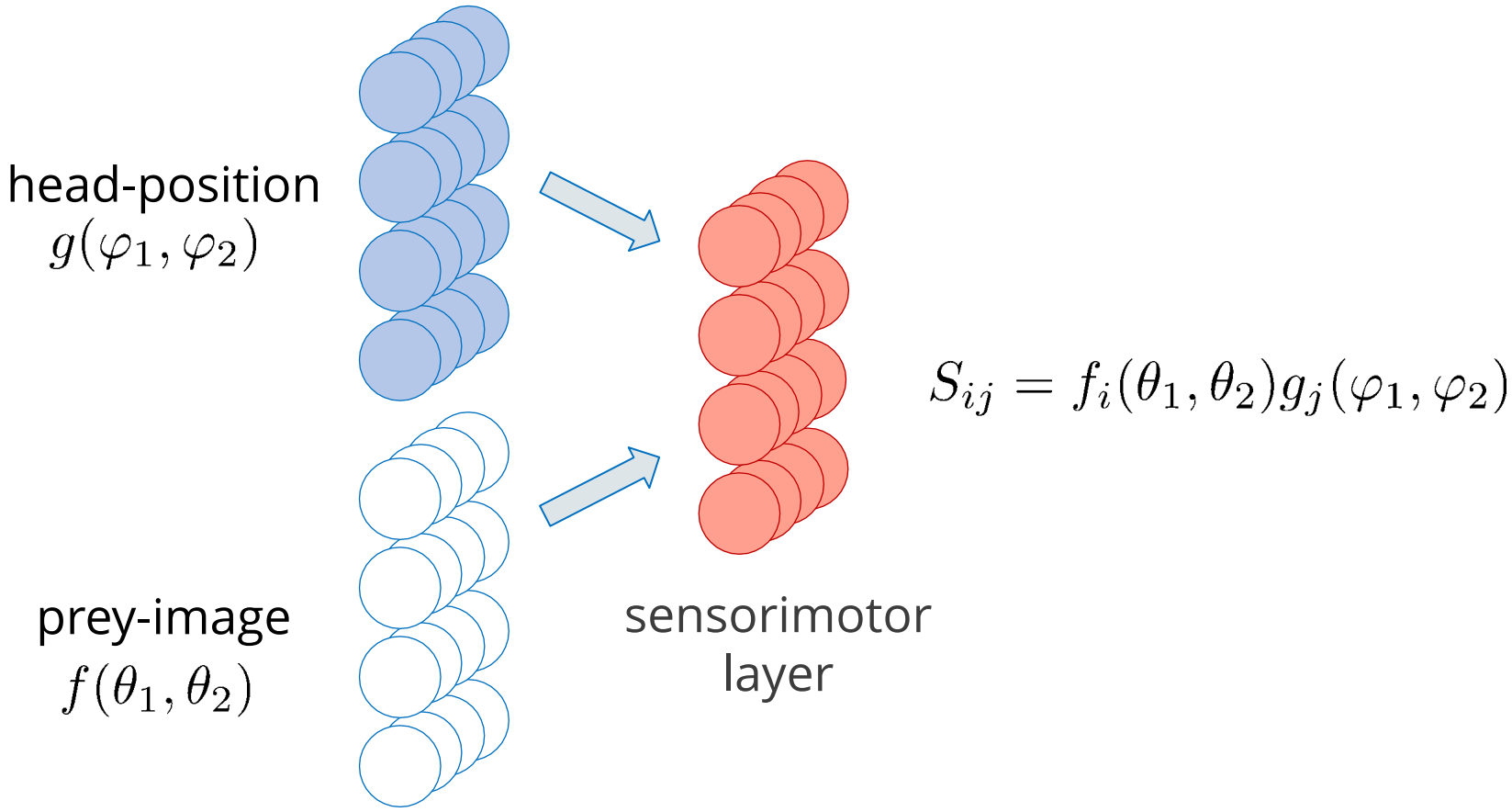




Model automatically adjusts head position to keep prey-image at eye center

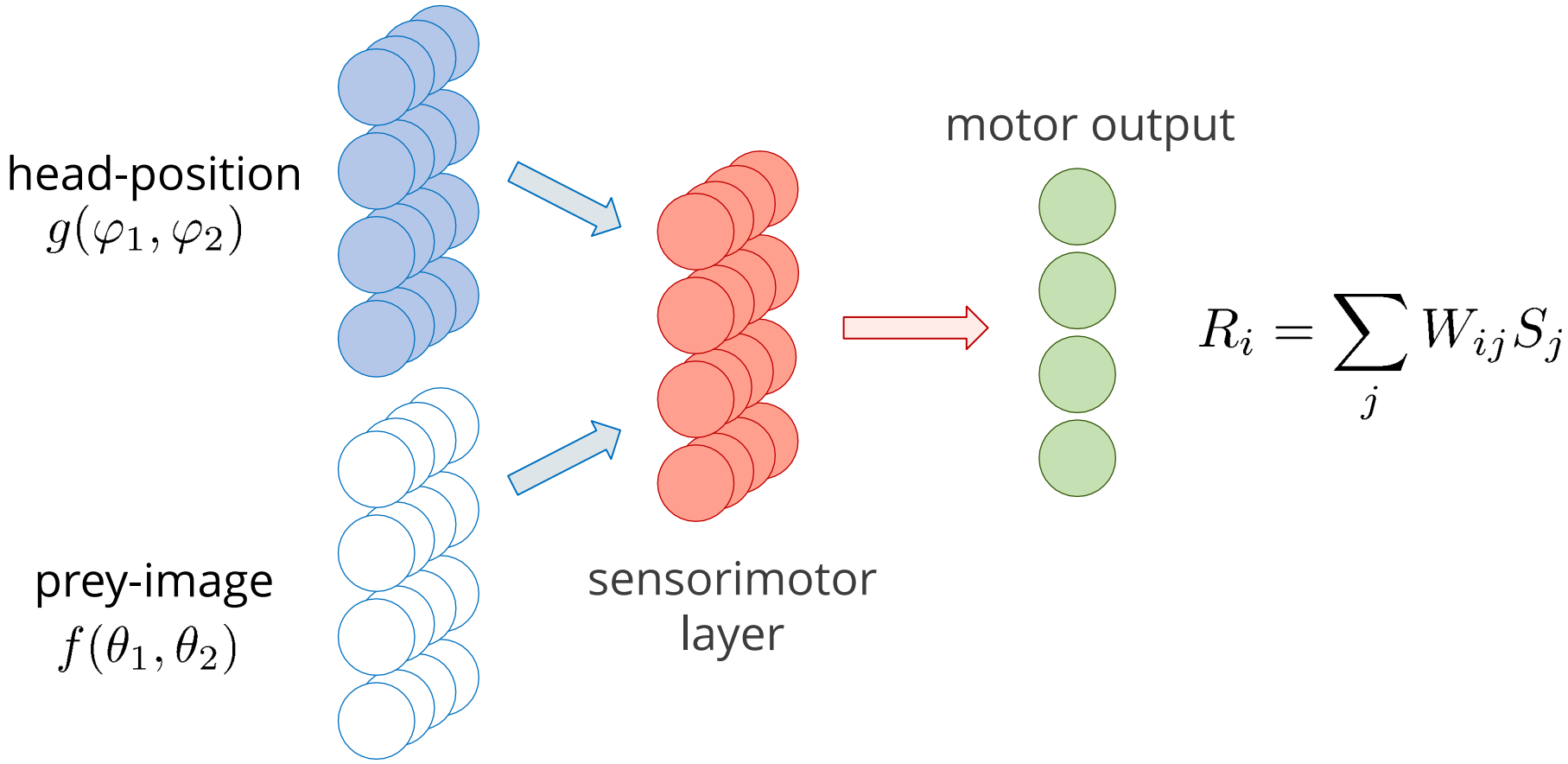
Head-position neurons encode desired head angle relative to body

Sensorimotor layer multiplicatively combines visual and head-position information



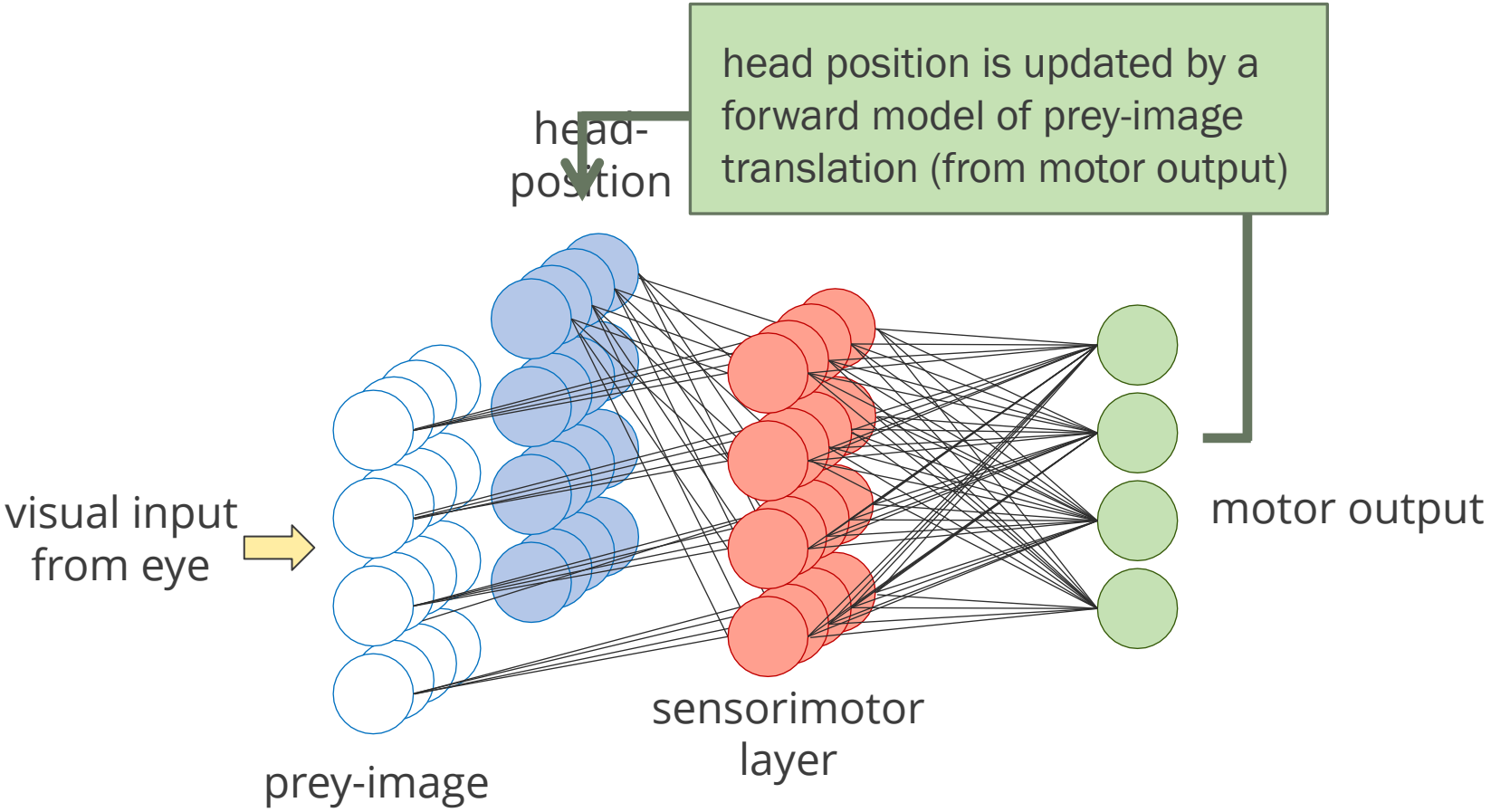
$$S_{ij} = f_i(\theta_1, \theta_2) g_j(\varphi_1, \varphi_2)$$

Motor output is a weighted sum of input from sensorimotor layer

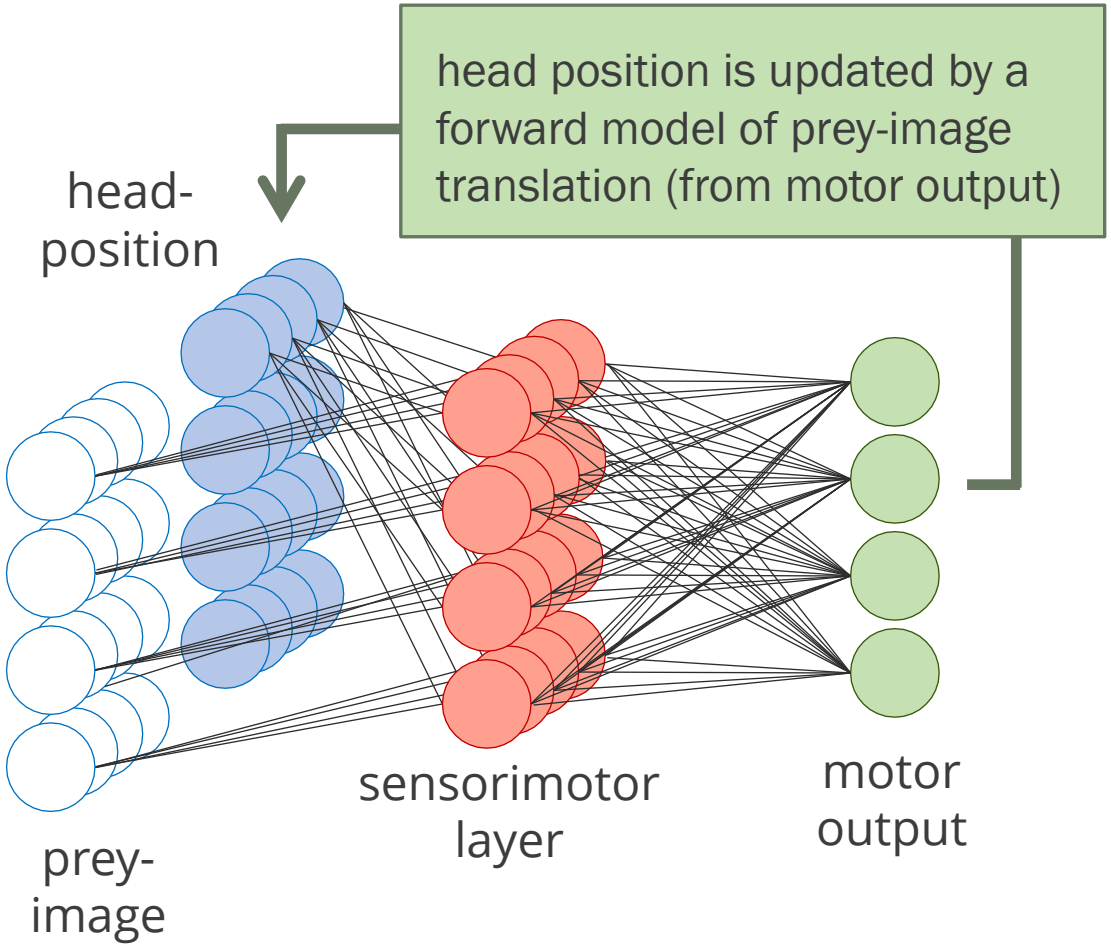


$$R_i = \sum_j W_{ij} S_j$$

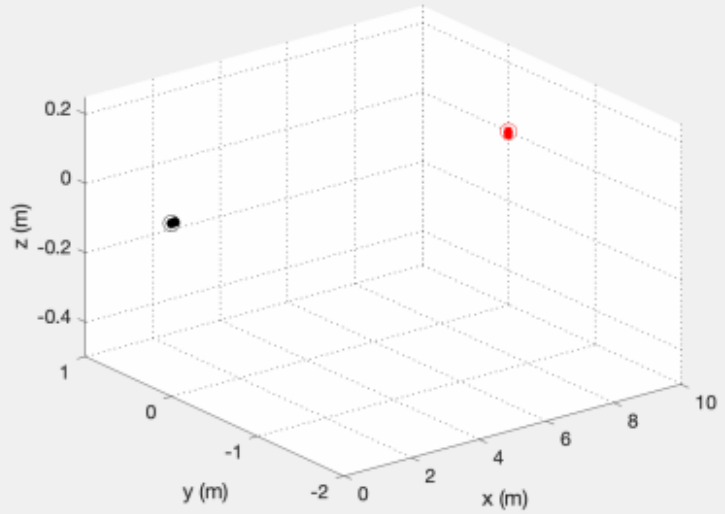
Forward model of prey-image drift updates head position

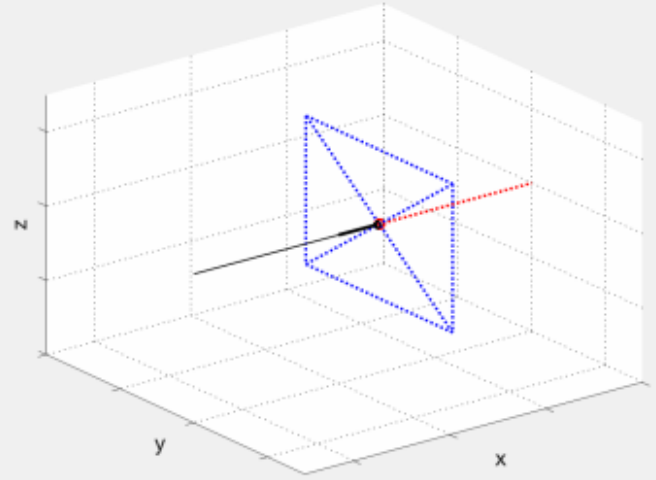


Prey-interception from dragonfly model



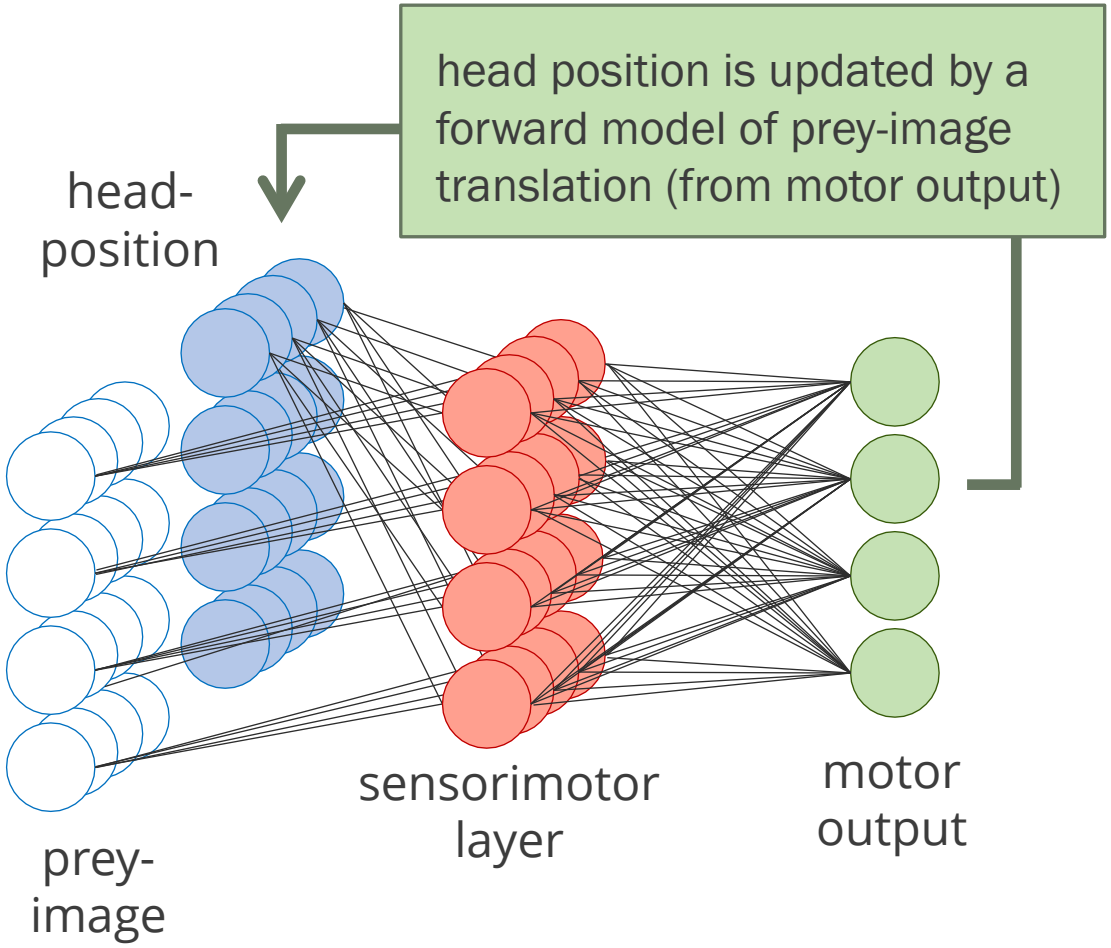
real-world reference frame



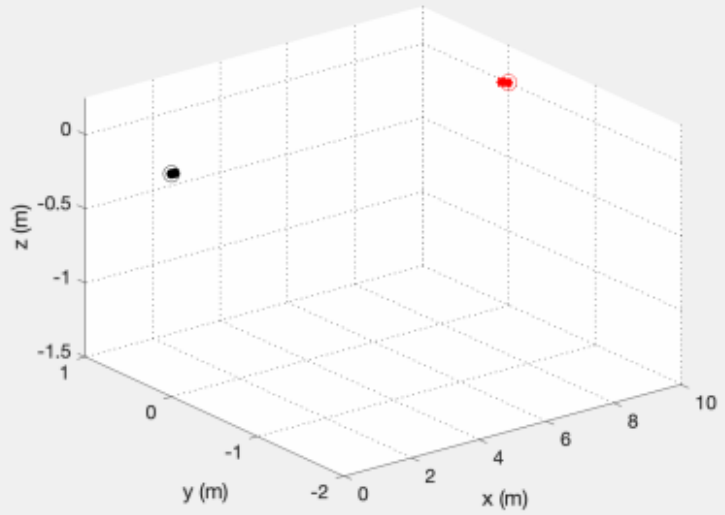


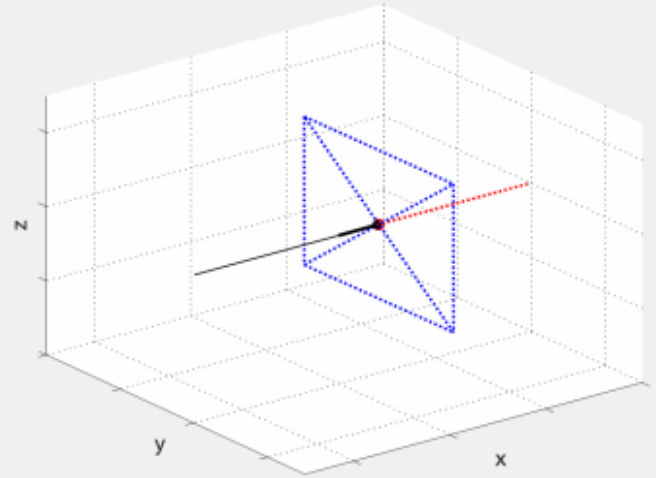
dragonfly-centered reference frame

Prey-interception from dragonfly model



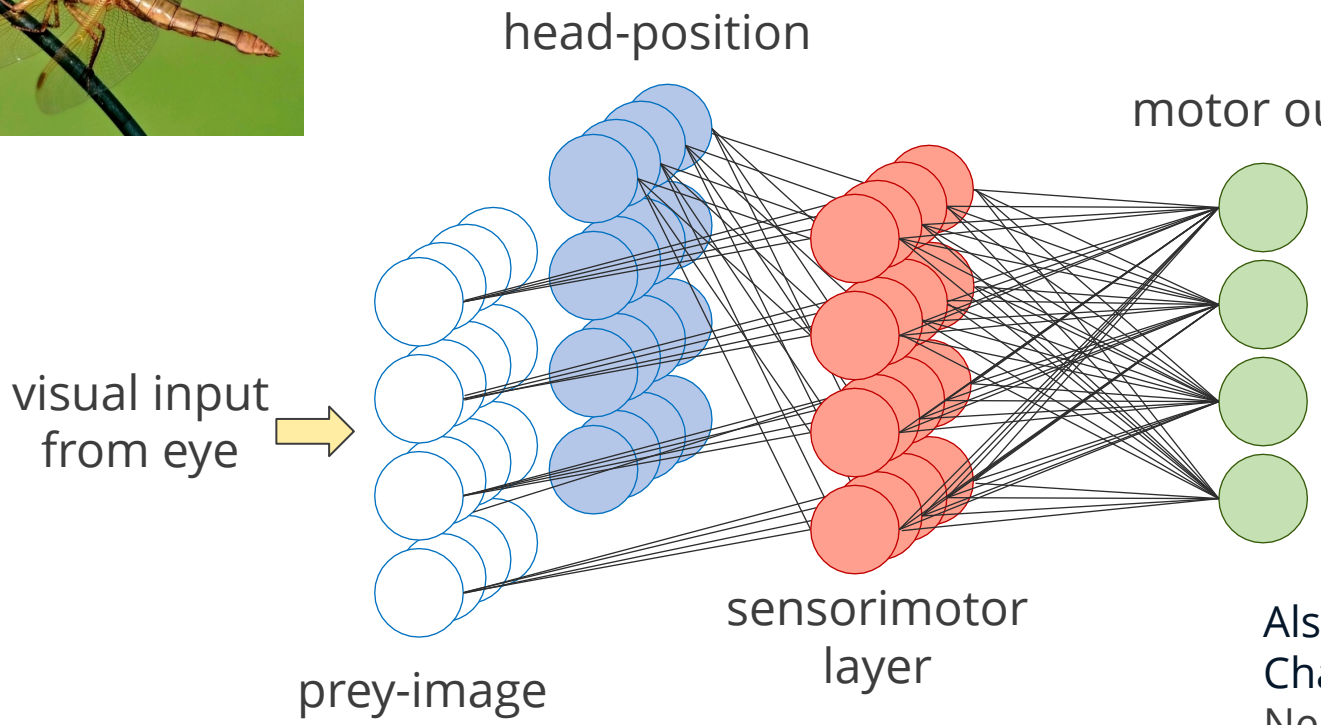
real-world reference frame





dragonfly-centered reference frame

All animal nervous systems rely upon sensorimotor transformations



Pre-calculated weights -- neural network is not trained

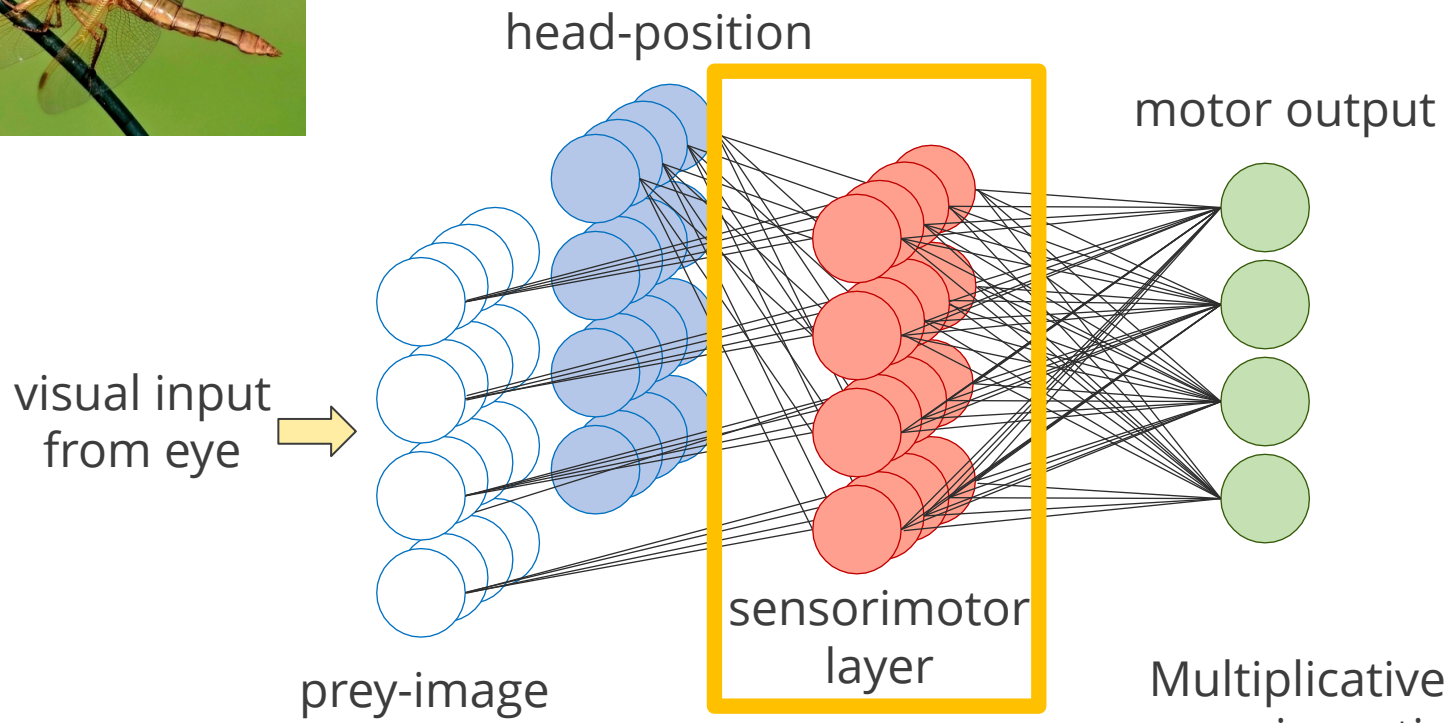
(see Zipser & Andersen, 1988; Salinas & Abbott, 1995)

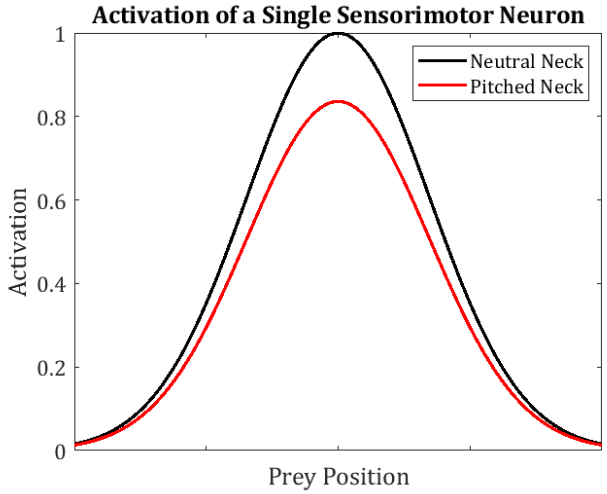
Also see:

Chance, International Conference on Neuromorphic Systems (ICONS) 2020 Proceedings

Plunkett & Chance, Neuro-Inspired Computing Elements (NICE) 2023 Proceedings

All animal nervous systems rely upon sensorimotor transformations

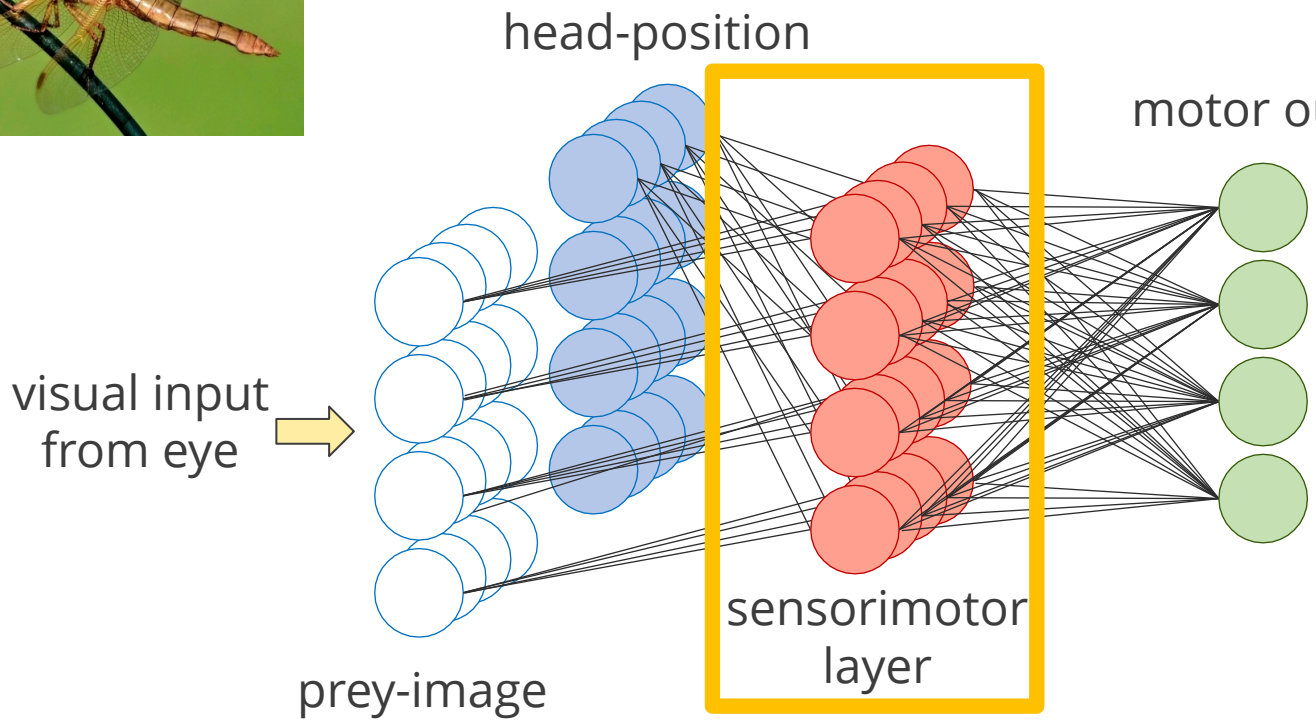


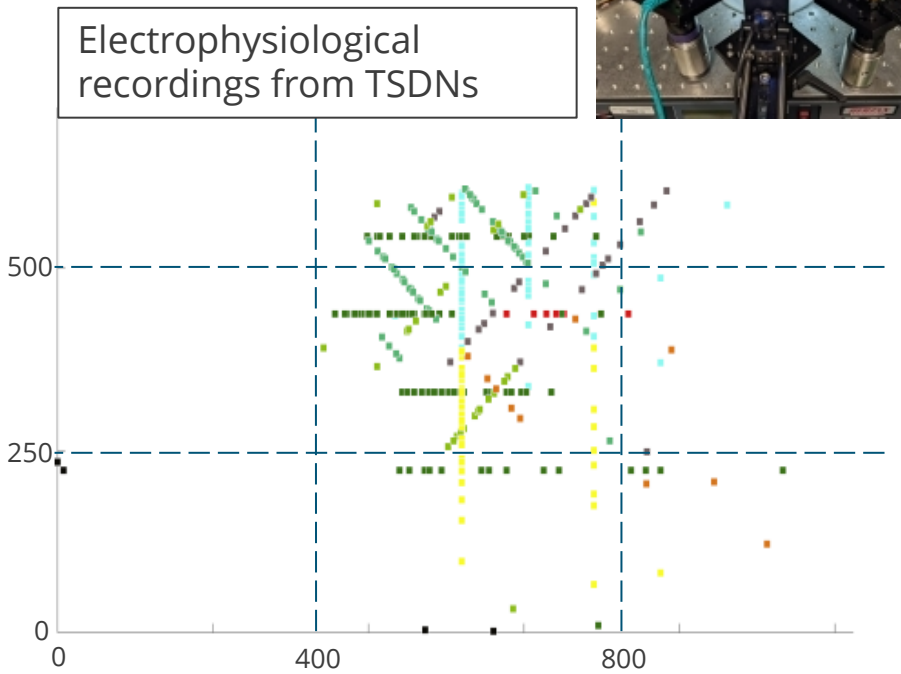


Multiplicative integration of visual and proprioceptive information

… reminiscent of gain fields observed in parietal cortex (Andersen and Mountcastle 1983)

Dragonfly mechanisms for sensorimotor integration are currently under investigation





Dr. Paloma Gonzalez-Bellido
David Munkvold
University of Minnesota

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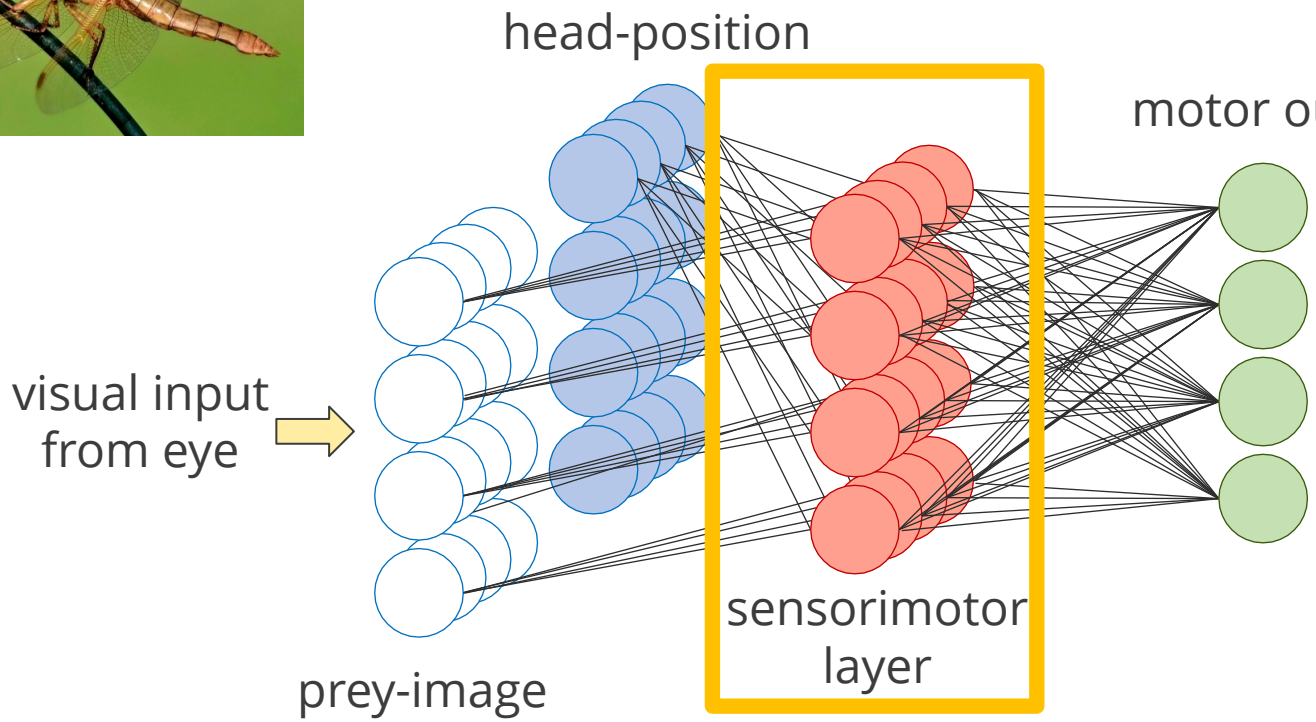
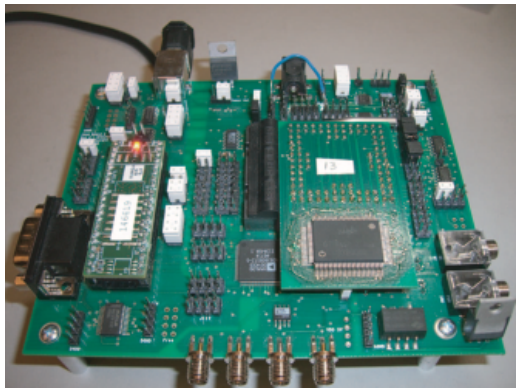
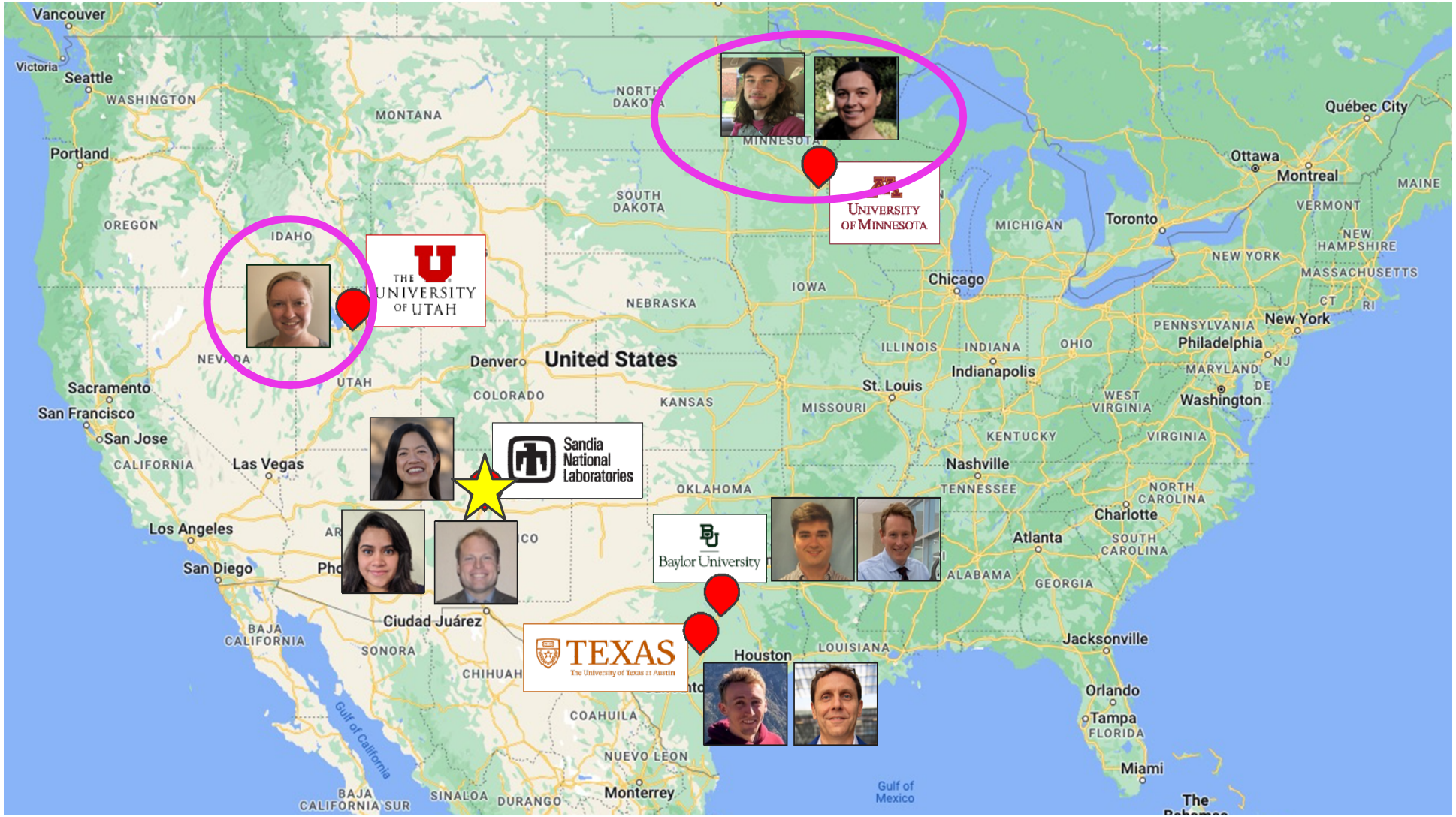


Can the dragonfly sensorimotor transformation mechanism be used to inspire novel neuromorphic architectures?



Thank you …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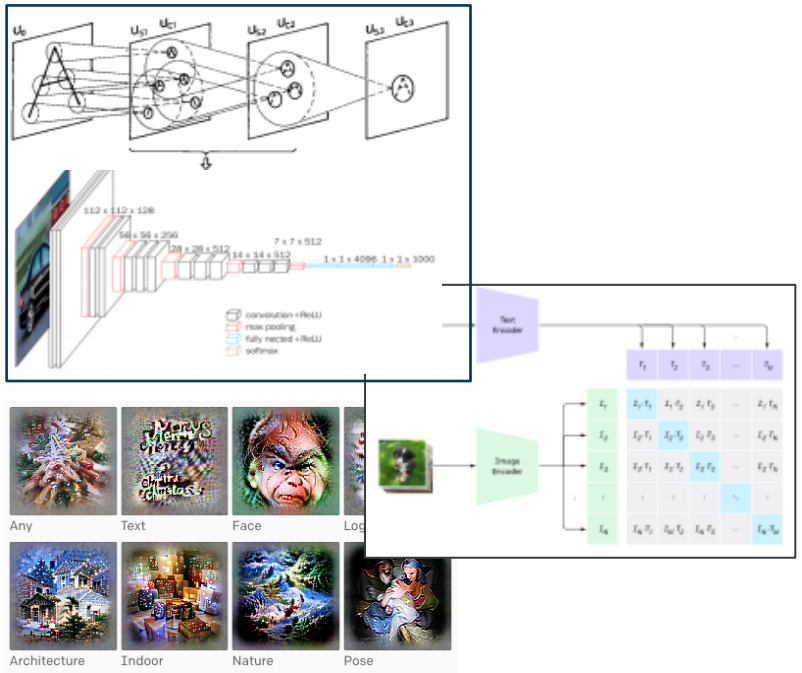
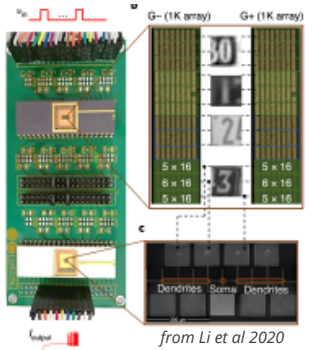
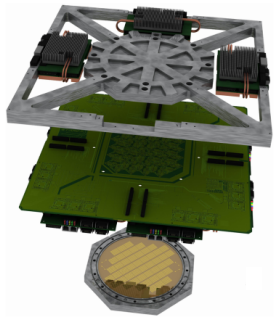
Neuroscience for next-generation computing



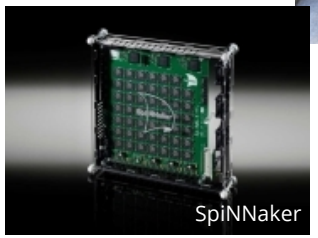
Neural-inspired algorithms

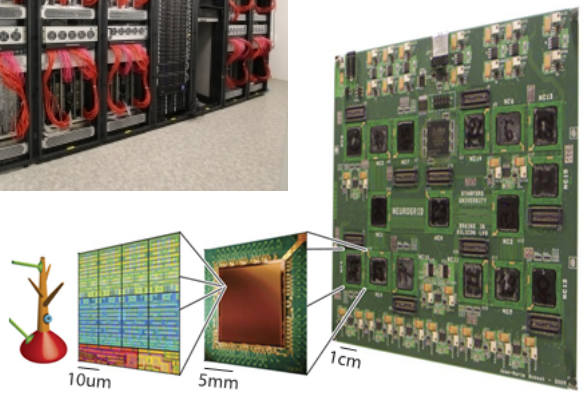


from Li et al 2020



from Petrovici et al 2014





from Benjamin et al 2021

Neuromorphic hardware

The End

Questions? Email fschanc@sandia.gov

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