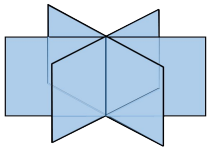
Developmental Embodied Agents as Meta-brain Models





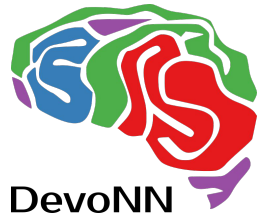

Bradly Alicea, Stefan Dvoretskii, Ziyi Gong, Ankit Gupta, Sam Felder, and Jesse Parent



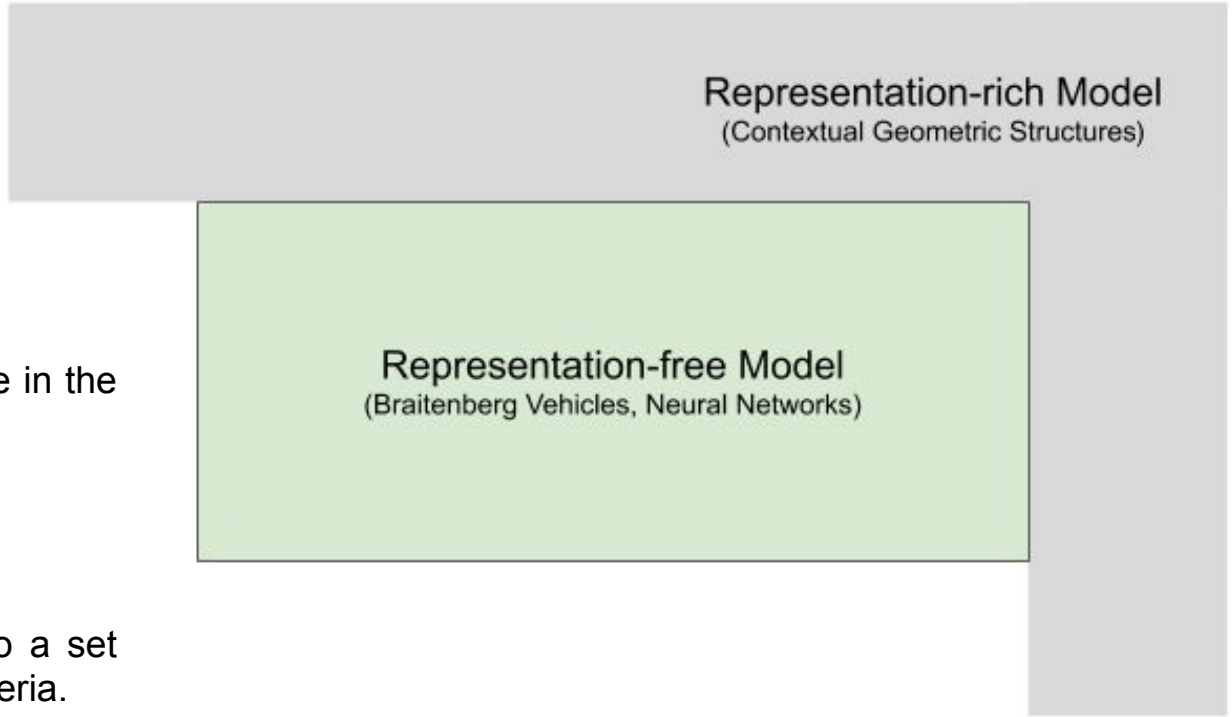
Orthogonal Research and Education Laboratory







Meta-brain Models



Representation-free:

- relies solely on structure in the empirical world.

Representation-rich:

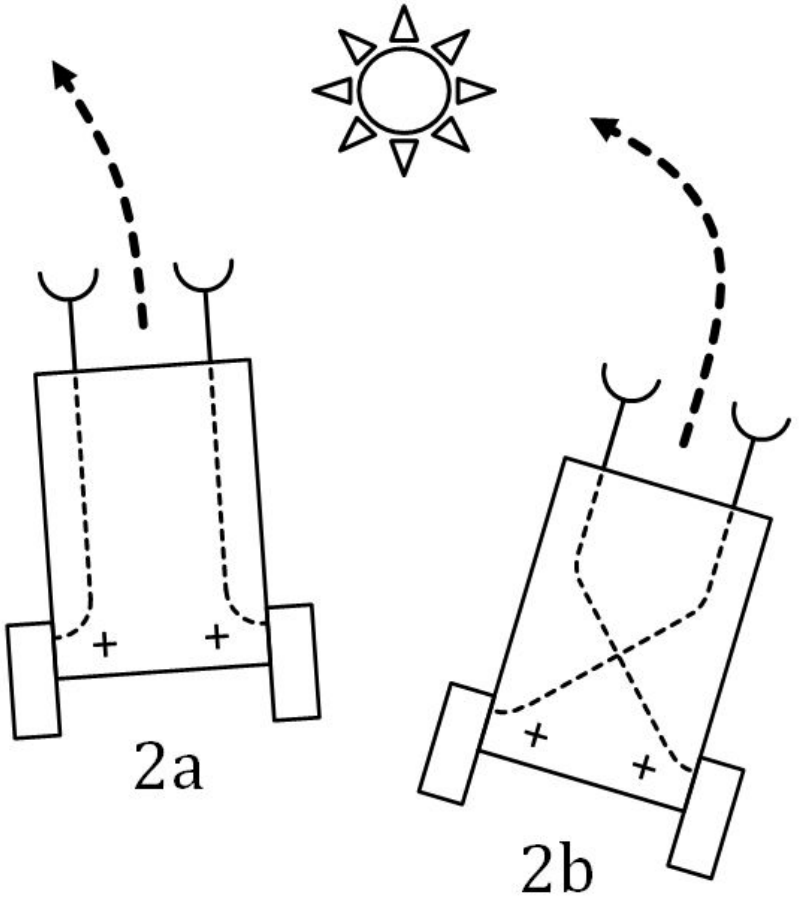
- maps empirical world to a set of signs, interpretive criteria.

Braitenberg Vehicles

First-order stimulus-response mapping:

- observe empirical world, hard-wired to elicit response.
- vehicle types yield taxis, or reflexive behavior.

Very simple neural networks that are embodied agents (effects of body are explicit).



dBV Brains and Connectivity Matrix

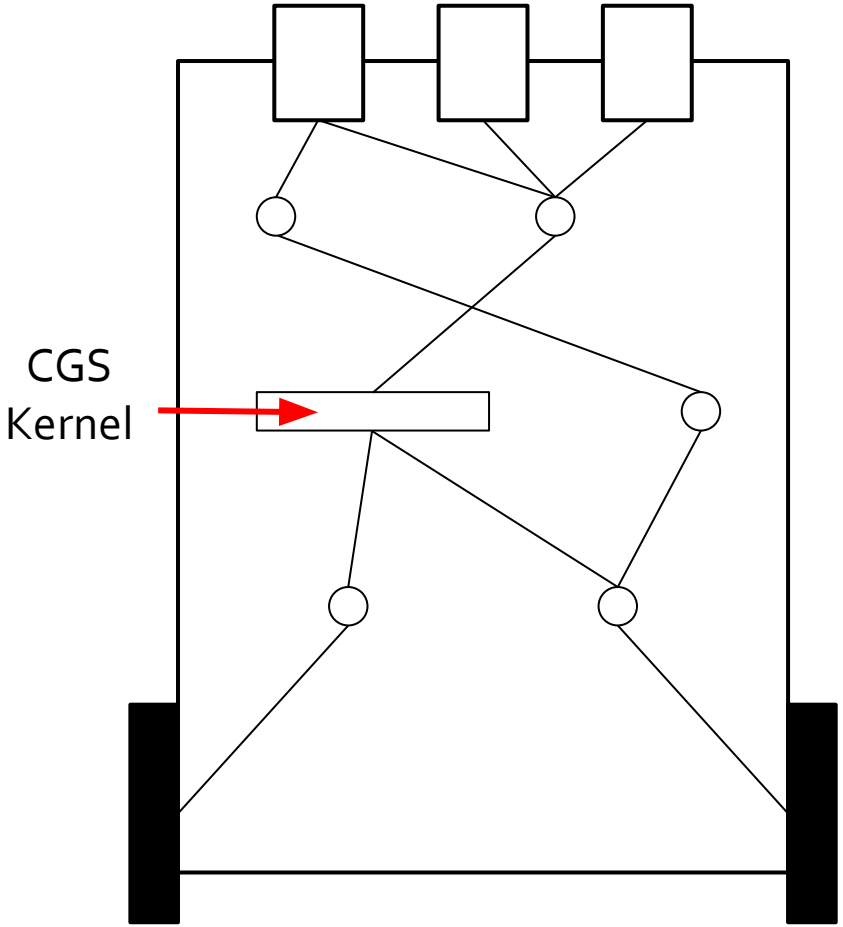
Developmental Braitenberg Vehicles (dBVs) can be achieved in a number of ways. Key component is *connectivity-activation encoding*.

W(i,j)

Expand or prune the number of connections (size of *i,j* or values in *i,j*)

- Hebbian Learning: modify matrix using a "wire together, fire together" rule to create viable spatially-explicit multimodal associations.

- Genetic Algorithms: create mass topological re-ordering and selection of viable matrices through mutation and recombination + fitness function.



Sensor Nodes

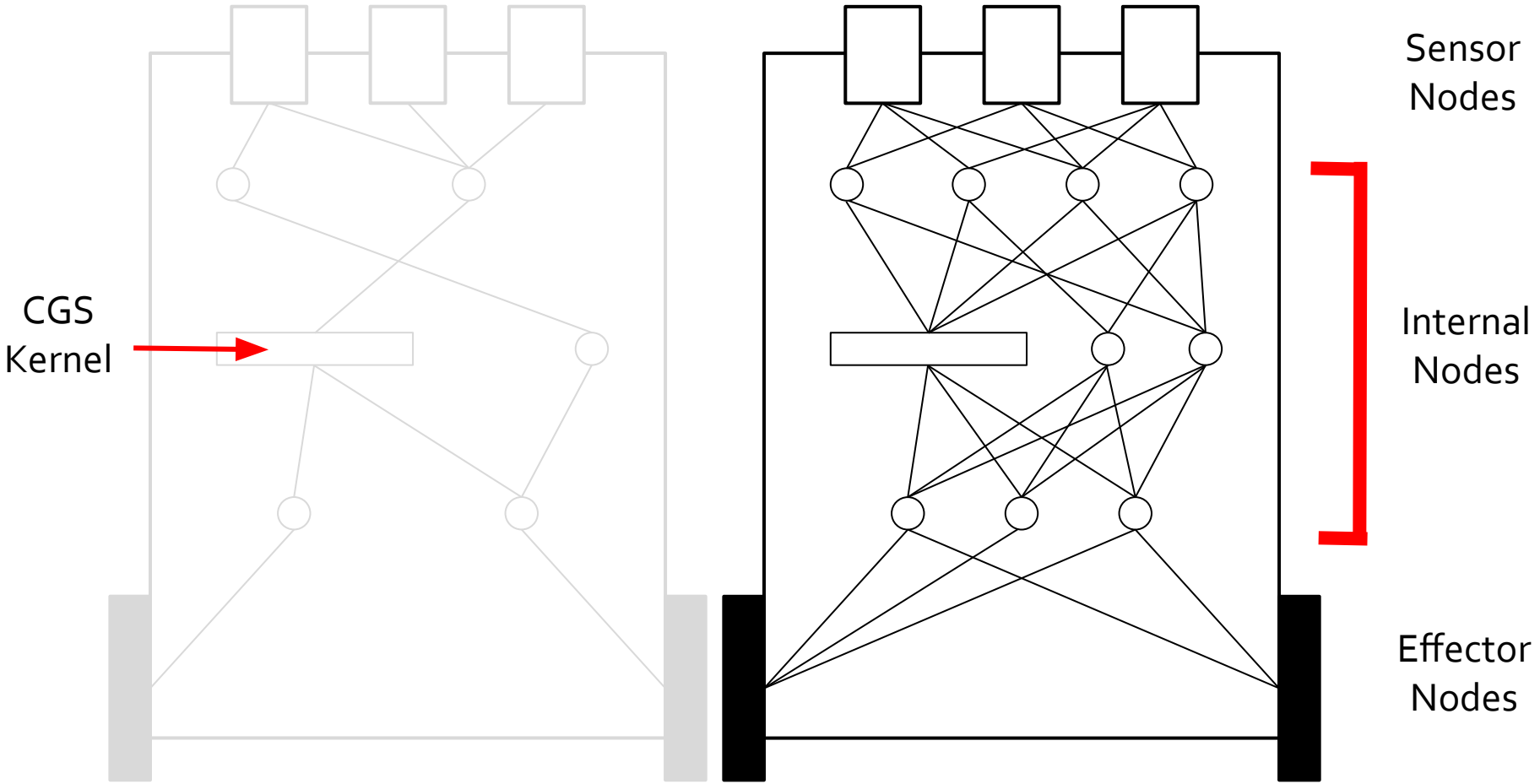
Internal Nodes

Effector Nodes

Simple mapping between sensors and effectors, limited connectivity to CGS (no redundant connections).

Internal node mediate between sensor and effector, combine sensory signals.

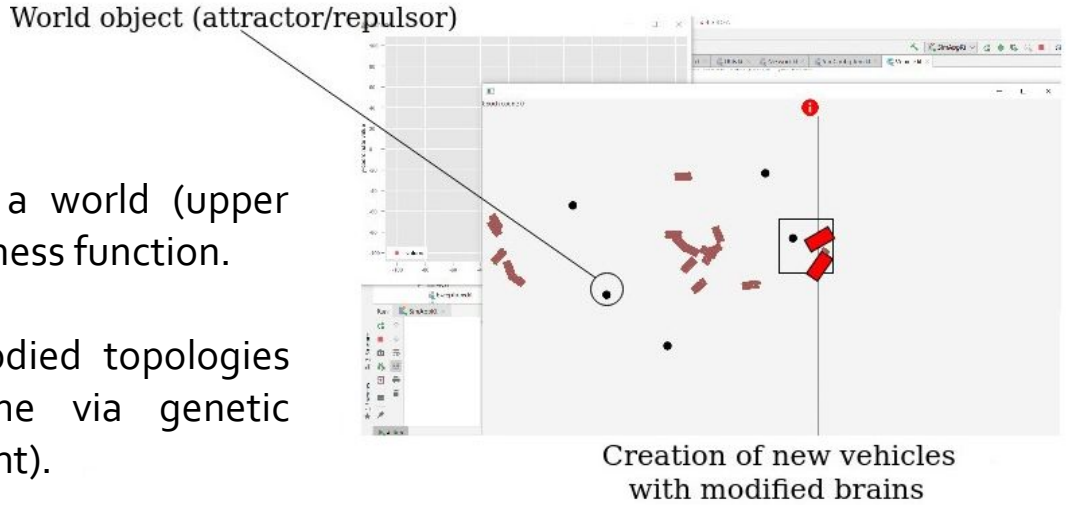
CGS kernel embedded among the internal nodes, transforms signals into fuzzy combinations (probabilistic signals).

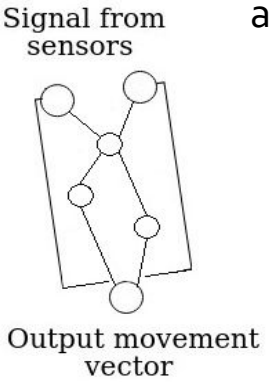

CGS
Kernel
Sensor
Nodes
Internal
Nodes
Effector
Nodes

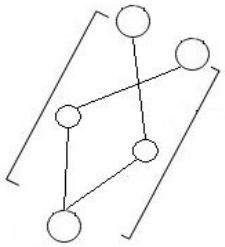
Growing dBV Brains

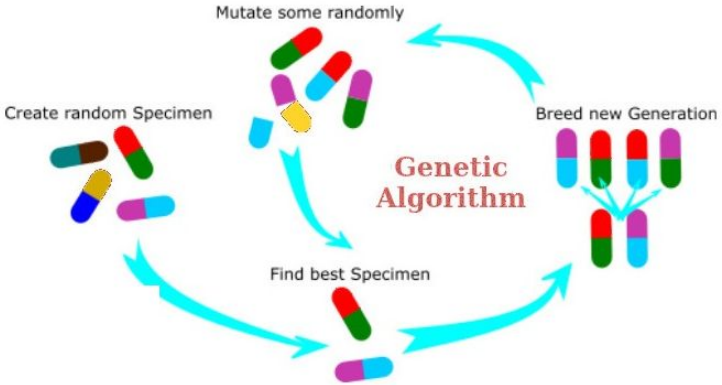
Vehicles interact in a world (upper right) that defines fitness function.

Generation of embodied topologies (lower left) is done via genetic algorithms (lower right).

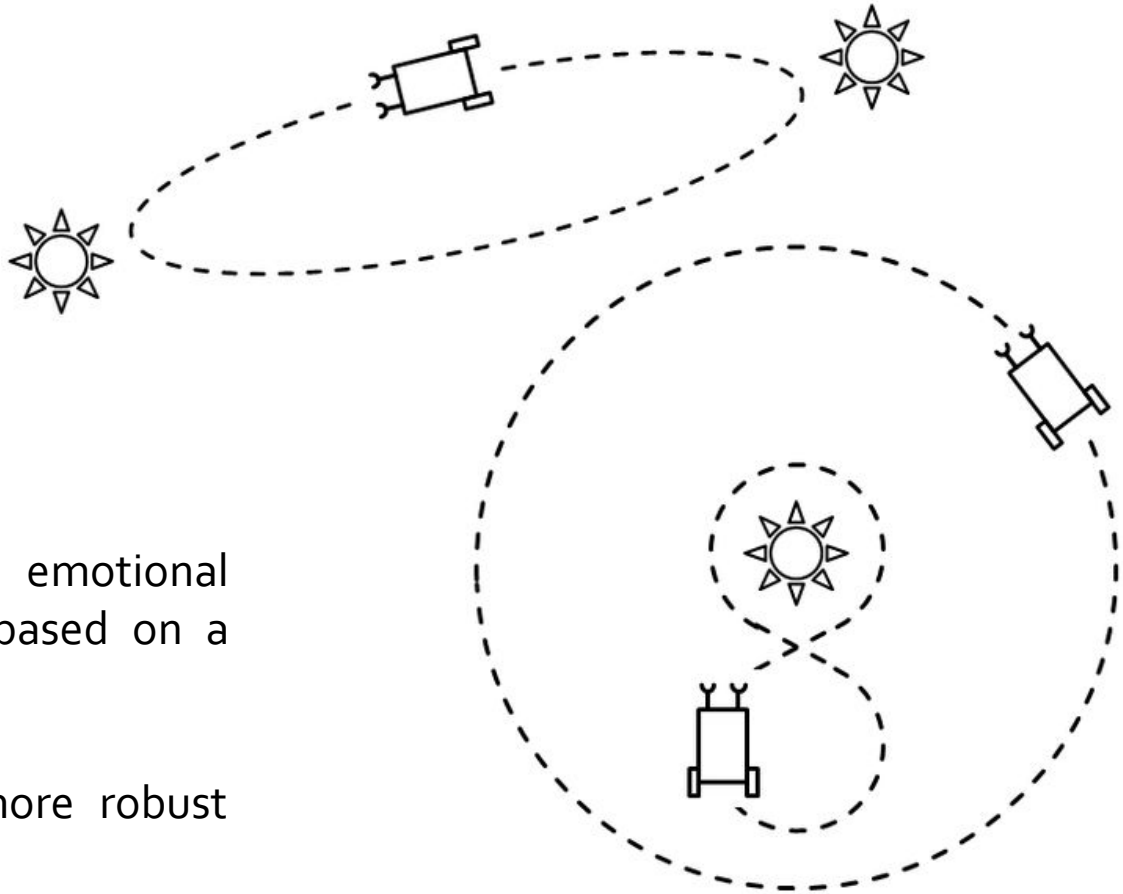








Other rudimentary behaviors (characterized as love, aggression, or happiness) are possible.



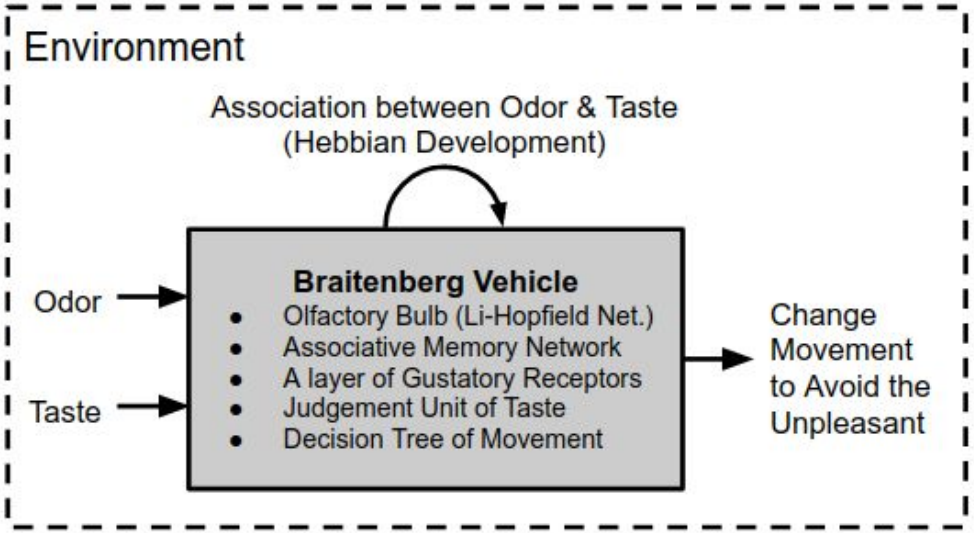
Behaviors "look like" these emotional affinities, ergo they are (not based on a formal representation).

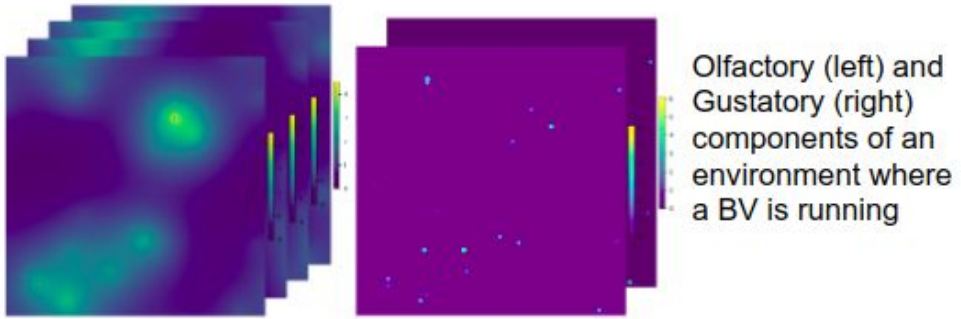
How do we achieve richer, more robust symbolic behaviors?

Contextual Integration

In the Hebbian learning example, two sensory modalities are used to establish associative learning

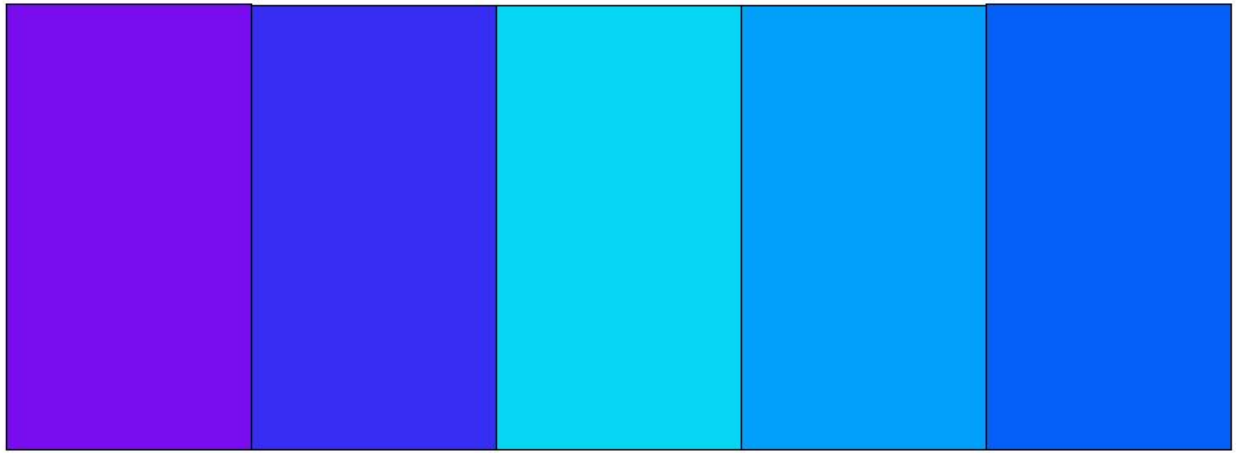
Associative learning is the basis for developmental plasticity, and enables connectivity-activation encoding.

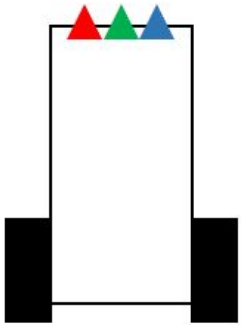




Olfactory (left) and Gustatory (right) components of an environment where a BV is running

Chromotaxis





Chromotaxis: attracted to a specific color.

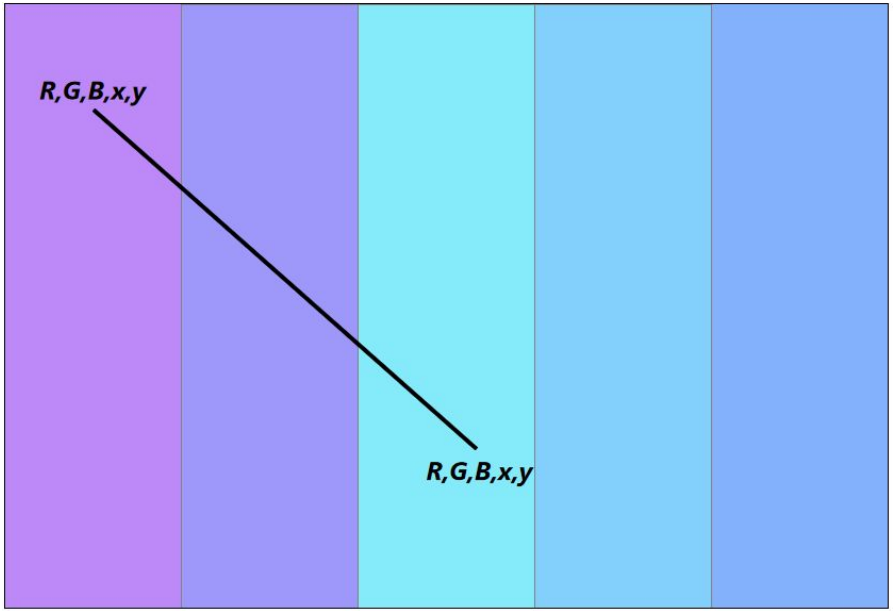
* as a phototaxis, simple attraction/repulsion.

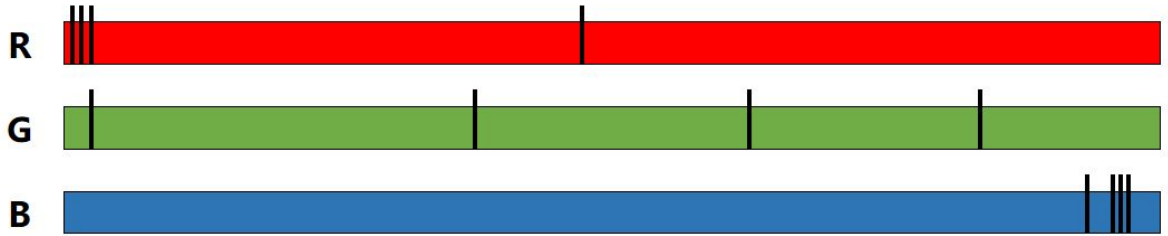
* as a preference, a seperate continuum of emotional valence.

Creating a cultural representation continuum

Agent will sample color space at different points (right).

Sampling density (below) determines how the physical continuum of a given color channel is included in the cultural representation.





CGS Model (kernel)

Contextual Geometric Structures: modeling the fundamental components of cultural behavior. ***Proceedings of Artificial Life*****, 13, 147-154.**

Soft classificatory kernel

- fuzzy logic classification (phenomenon = degree of membership).

- halfway between light and dark (50% light, 50% dark). Attributes of both.

Based on a Structuralist View

- cultural relationships are a series of overarching structures (understood as binary oppositions and dynamically changing symbols).

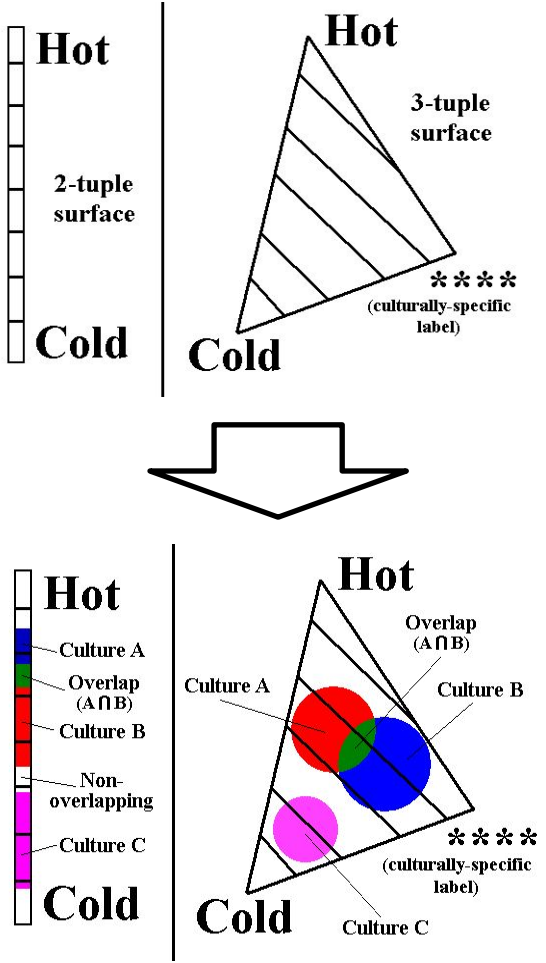
- structures are key to cultural representation (relationship with nature, kinship, and the ritual world).

Conceptual Automata

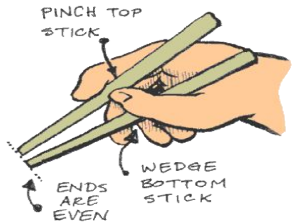
Inspired by the concept of **Habitus** (Pierre Bourdieu, "Logic of Practice")

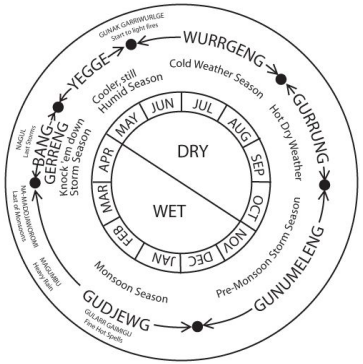
* definitions: "durable, transposable dispositions"…."generative"…."organizes practices and representations adaptively".

Computational objective: a scheme that transforms physical phenomena into operations that can be compared in an evolutionary context.



How do we "represent" sensory information to perform a cultural "operation"?





Representationally rich *n*-tuple surfaces with a soft classification scheme

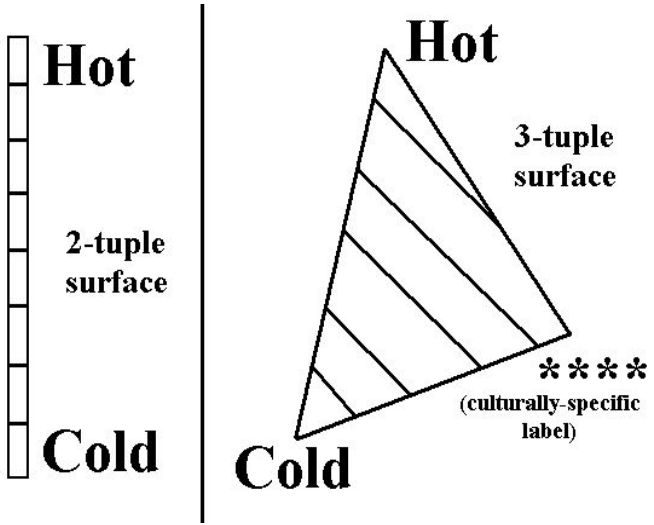
All possible combinations of representation for combination of action, objects, and environment.

Cultural phenomenon: symbol, practice, or artifact.

* What is the membership of cultural phenomenon *x* in this space?

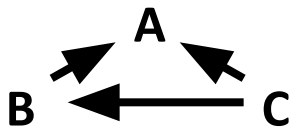
Soft (fuzzy) classification

Membership function on interval {0,1}. **NOT** a probability.



Does **NOT** require transitivity, distributivity, or symmetry.

TRANSITIVITY

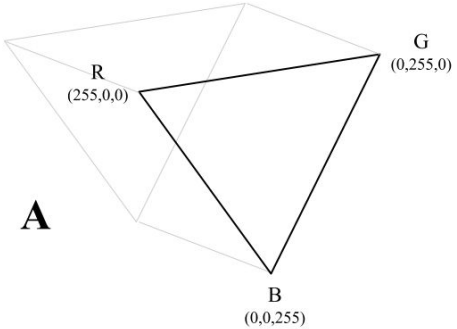


SYMMETRY

A = B B = A

DISTRIBUTIVITY

A * (B + C) = (A * B) + (A ∗ C)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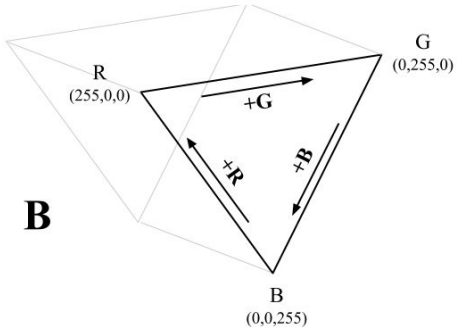
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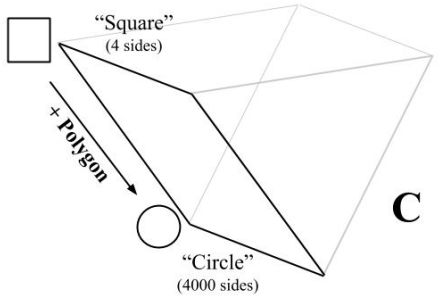
"Square"
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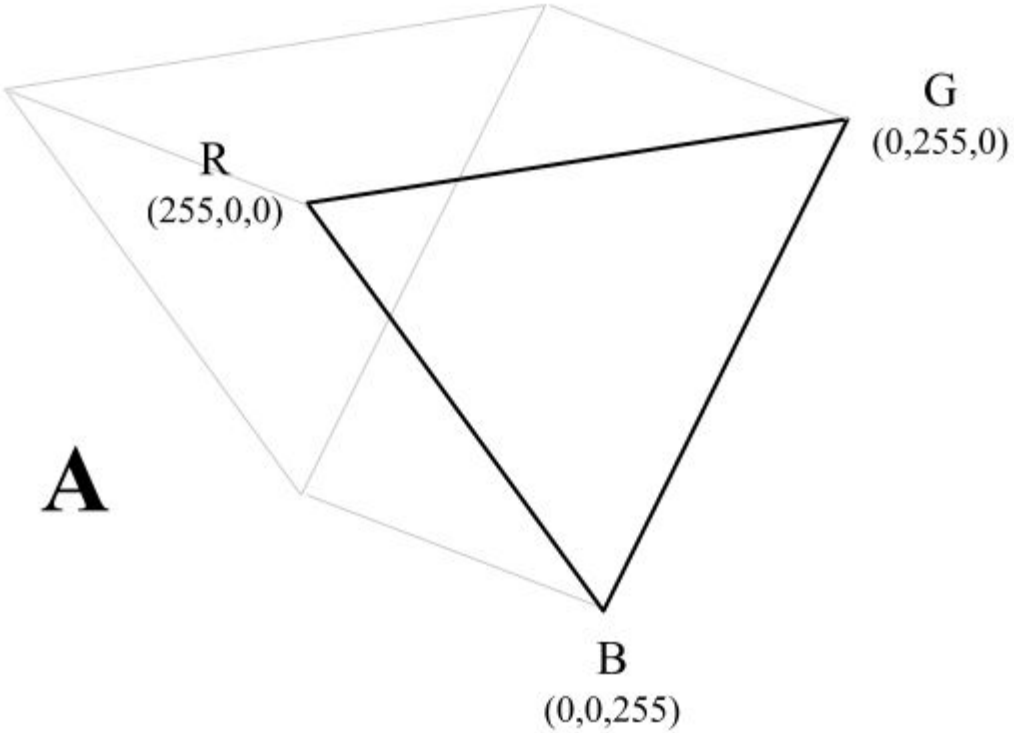
"Circle"
(4000 sides)
C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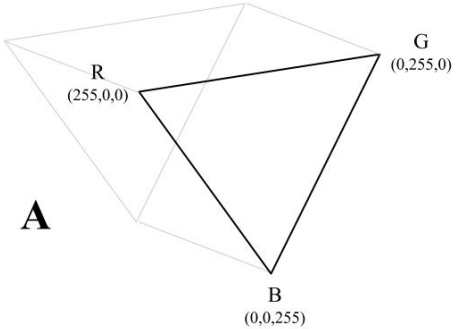
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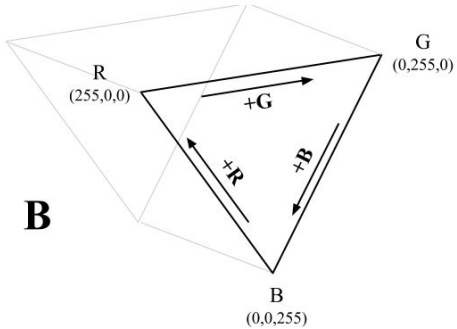
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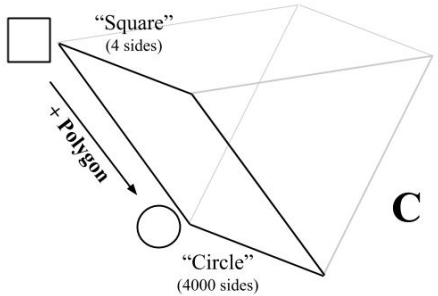
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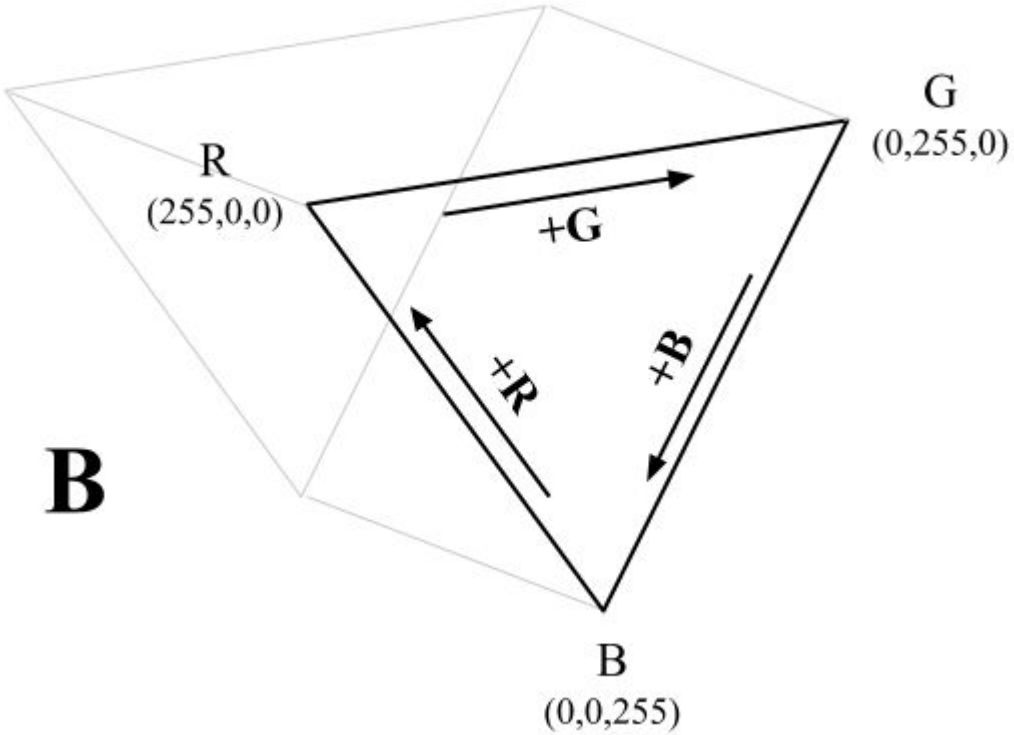
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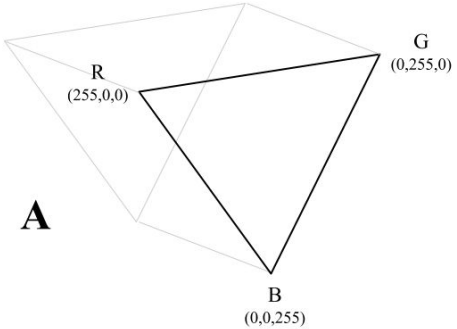
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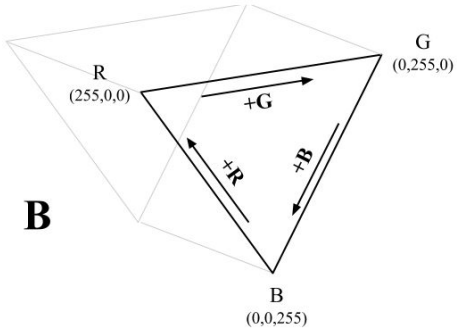
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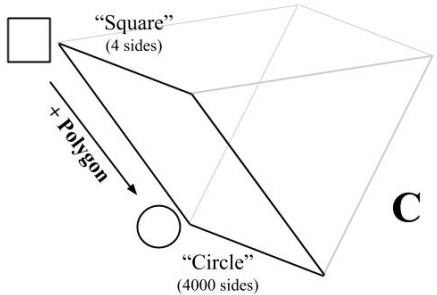
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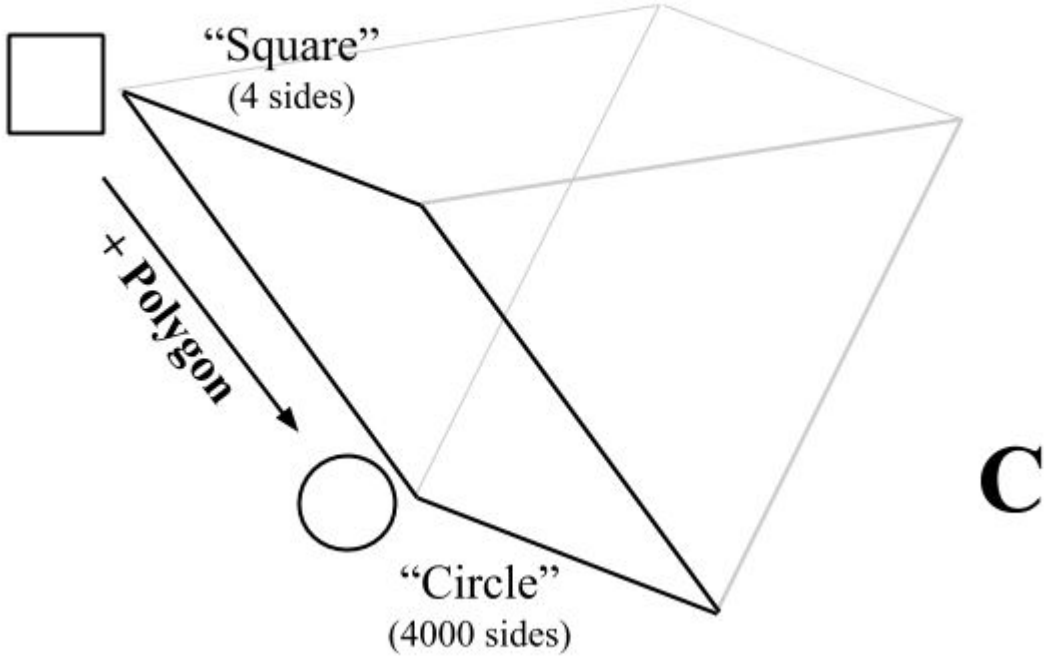
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Future Directions

Cumulative behavior exhibited in a population of Vehicle 2a (*Figshare*, doi:10.6084/m9.figshare.11906847)

Integration of model types (Hybrid Models)

How are dBVs and CGS models integrated? As "layers" or as parallel systems?

What about cumulative and collective behavior (exhibited in social groups)?

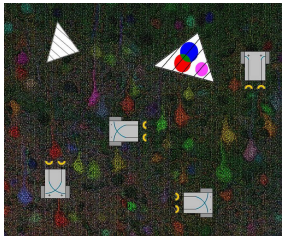
Alternative to dBVs, CGS (forming a general meta-brain)

dBV are representationally sparse, but embodied: could another model such as embodied deep learning or developmentally-inspired agent-based modeling substitute?

CGS are representationally rich but limited in scope: could another model such as ideological modeling or cultural algorithms work even better?

Thanks for Your Attention!

Who are they attending to now?



Attend Saturday Morning NeuroSim:
https://representational-brains-phenotypes.weebly.com/

Thanks to Google Summer of Code, 2018 and 2019

Contribute to our Github repo:
https://github.com/Orthogonal-Research-Lab/Meta-brain-Models