Weight Agnostic Neural Networks

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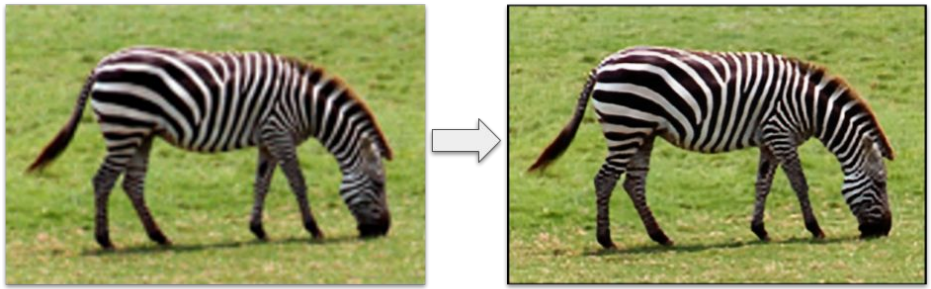
Innate abilities in animals

Innate abilities in machines

Super-resolution



Corrupted

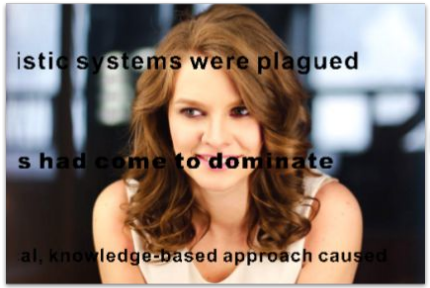
Deep image prior

Denoising

Corrupted

Deep image prior

Inpainting



Corrupted

Deep image prior

Inpainting

Corrupted

Deep image prior

Ulyanov, D., Vedaldi, A., & Lempitsky, V. (2018). Deep image prior. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*

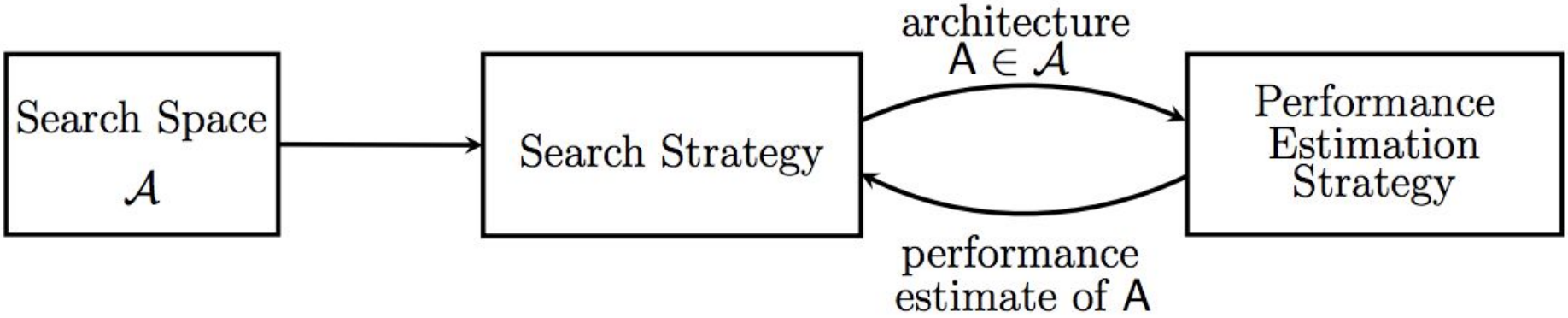
To what extent can neural net architectures *alone* encode solutions to tasks?

Neural Architecture Search

Searching for trainable networks

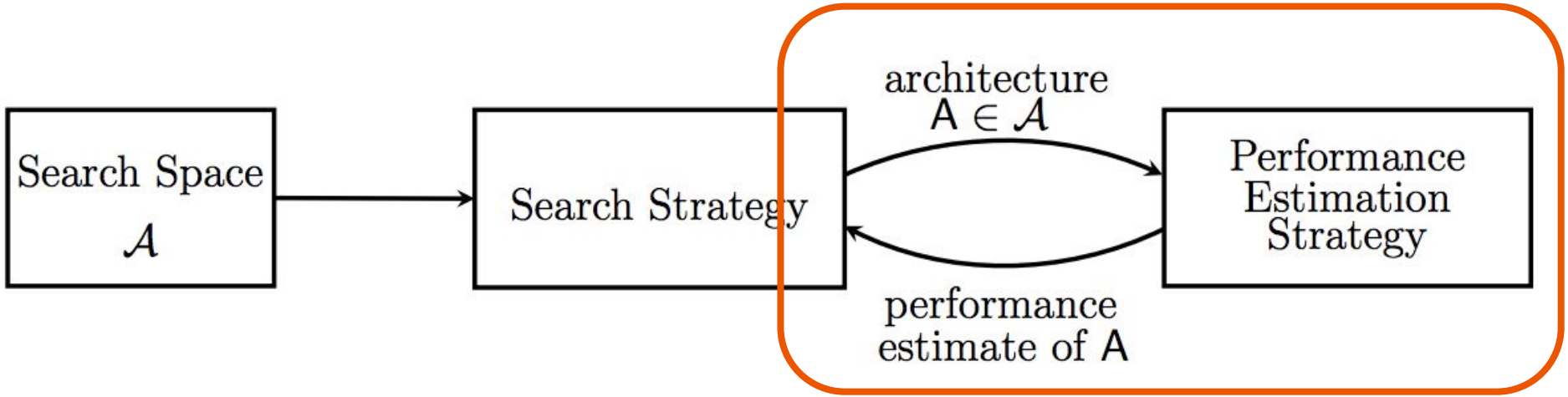
- Architectures, once trained, outperform hand designed networks
- Expensive -- training of network required to judge performance
- Solution is still encoded in weights of network, not in architecture

Searching for Architectures



Elsken, T., Metzen, J. H., & Hutter, F. (2018). Neural architecture search: A survey. *arXiv preprint arXiv:1808.05377*

Searching for Architectures



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How can we search for architectures...*not* weights?

Search without Training

Assume weights are drawn from a particular distribution

- Search for architecture to perform given weights from this distribution

Replace inner loop training with sampling

- Draw new weights from distribution at each rollout
- Judge network on zero-shot performance

Weight Sharing

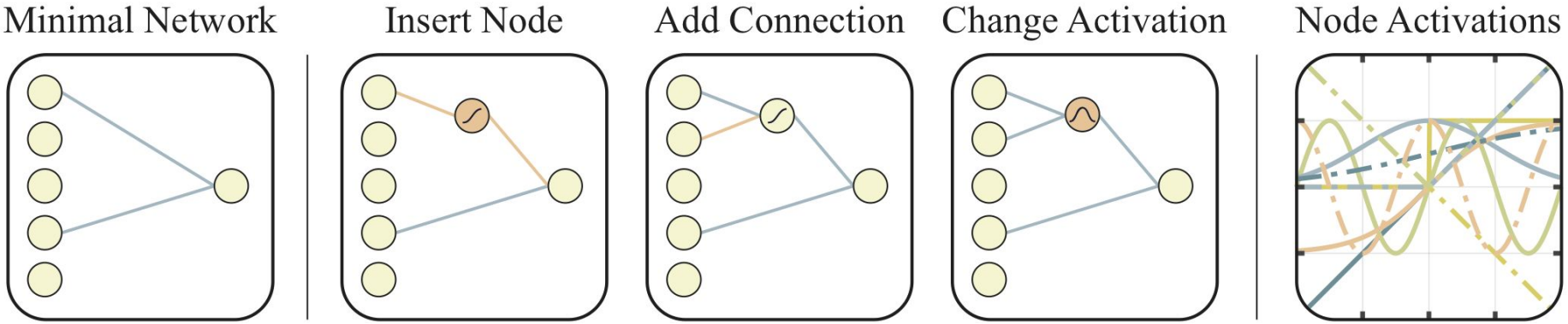
Single shared weight value used for all connections

- Weight value selected from distribution at each rollout
- Reduces number of parameters of network to 1
    - Reliable expected reward of topology

Architecture search

- Explore space of network topologies
- Judge network architecture based on performance over a series of rollouts

Topology Search

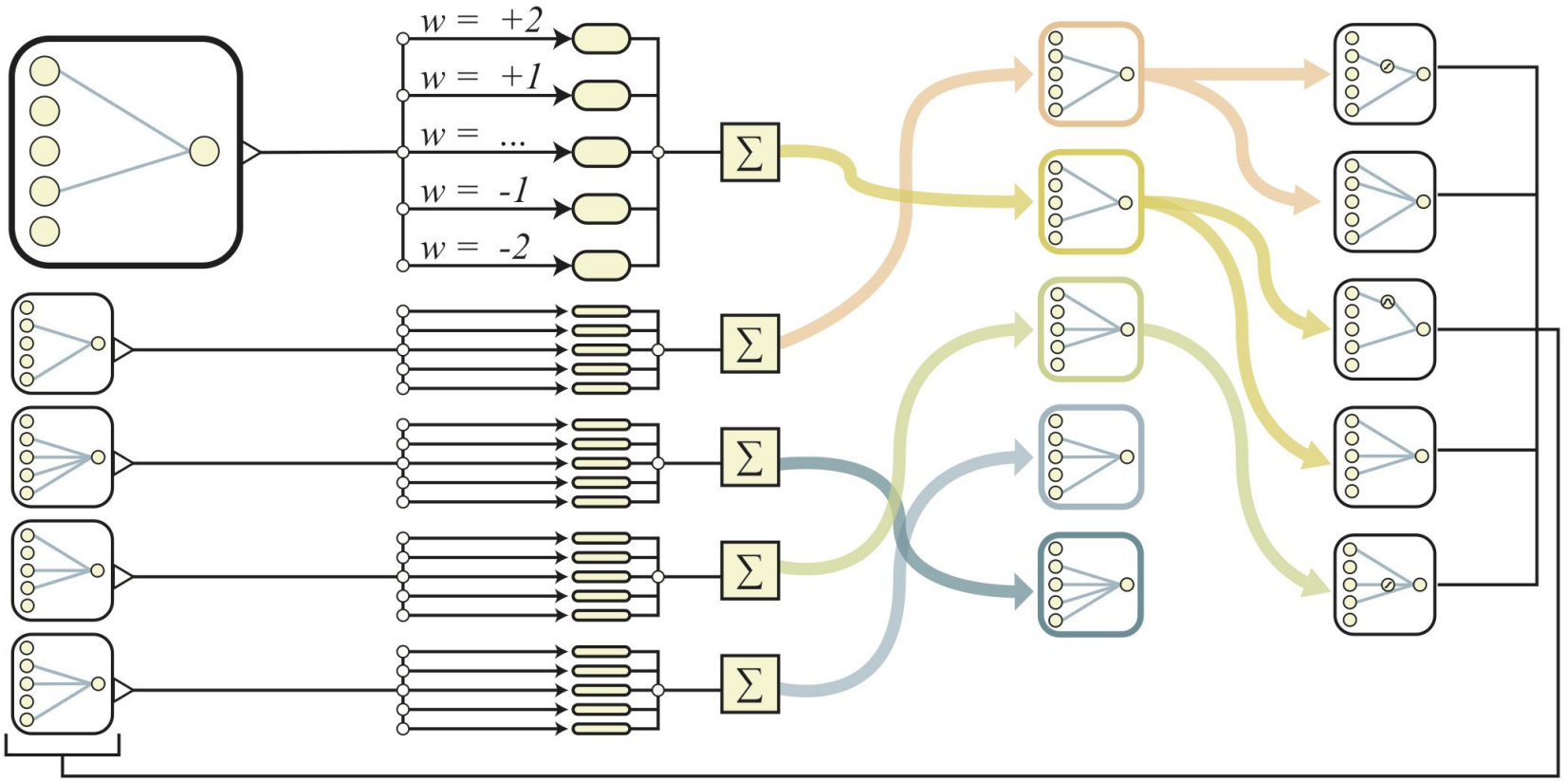


1.) Initialize
Create population of minimal networks.

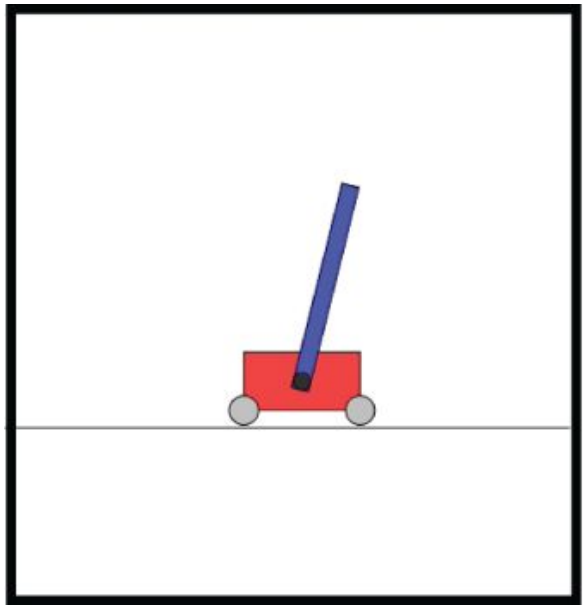
2.) Evaluate
Test with range of shared weight values.

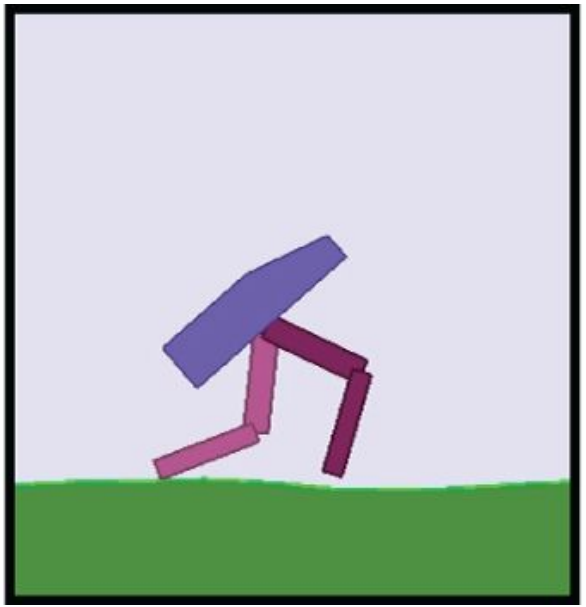
3.) Rank
Rank by performance and complexity

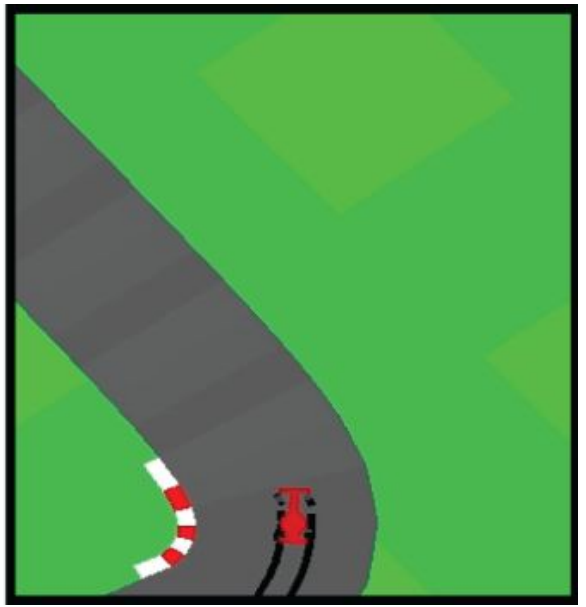
4.) Vary
Create new population by varying best networks.



WANNs find solutions in variety of RL tasks







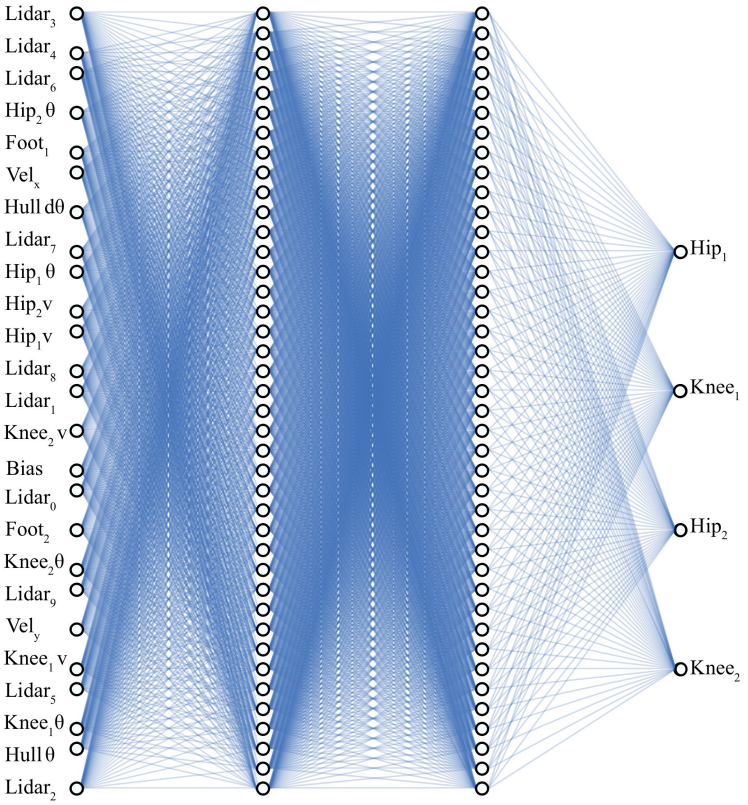
WANNs perform with and without training

Swing Up	Random Weights	Random Shared Weight	Tuned Shared Weight	Tuned Weights
WANN	**57 ± 121**	**515 ± 58**	**723 ± 16**	**932 ± 6**
Fixed Topology	21 ± 43	7 ± 2	8 ± 1	918 ± 7

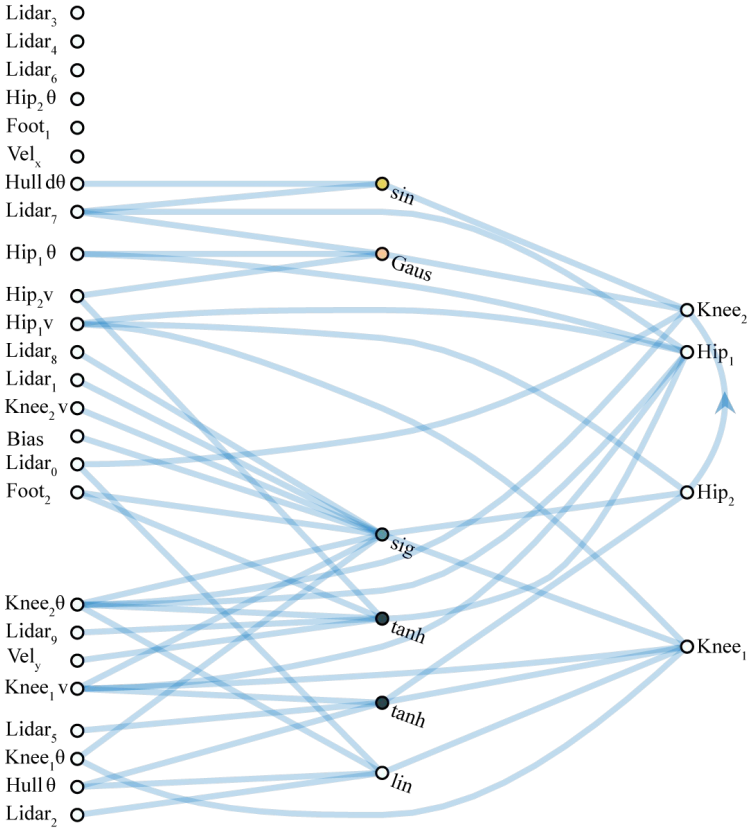
Biped	Random Weights	Random Shared Weight	Tuned Shared Weight	Tuned Weights
WANN	**-46 ± 54**	**51 ± 108**	**261 ± 58**	332 ± 1
Fixed Topology	-129 ± 28	-107 ± 12	-35 ± 23	**347 ± 1**

CarRacing	Random Weights	Random Shared Weight	Tuned Shared Weight	Tuned Weights
WANN	**-69 ± 31**	**375 ± 177**	**608 ± 161**	893 ± 74
Fixed Topology	-82 ± 13	-85 ± 27	-37 ± 36	**906 ± 21**

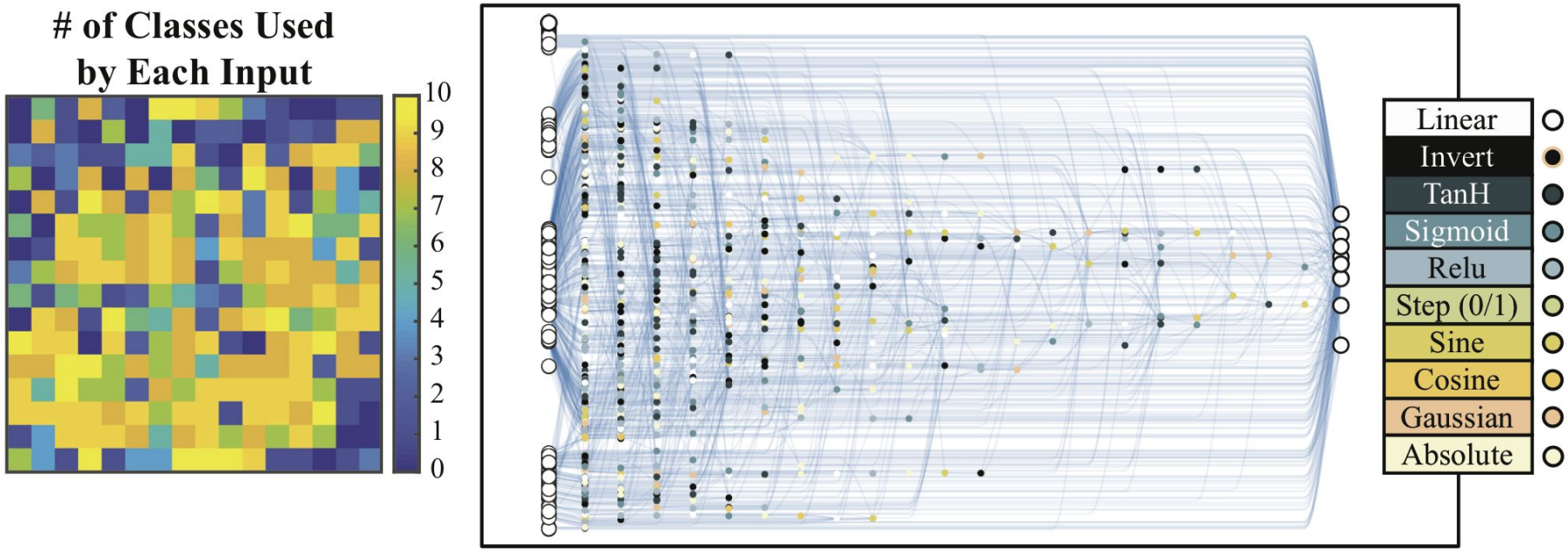
ANN Bipedal Walker (2760 connections, weights)



WANN Bipedal Walker (*44 connections, 1 weight*)

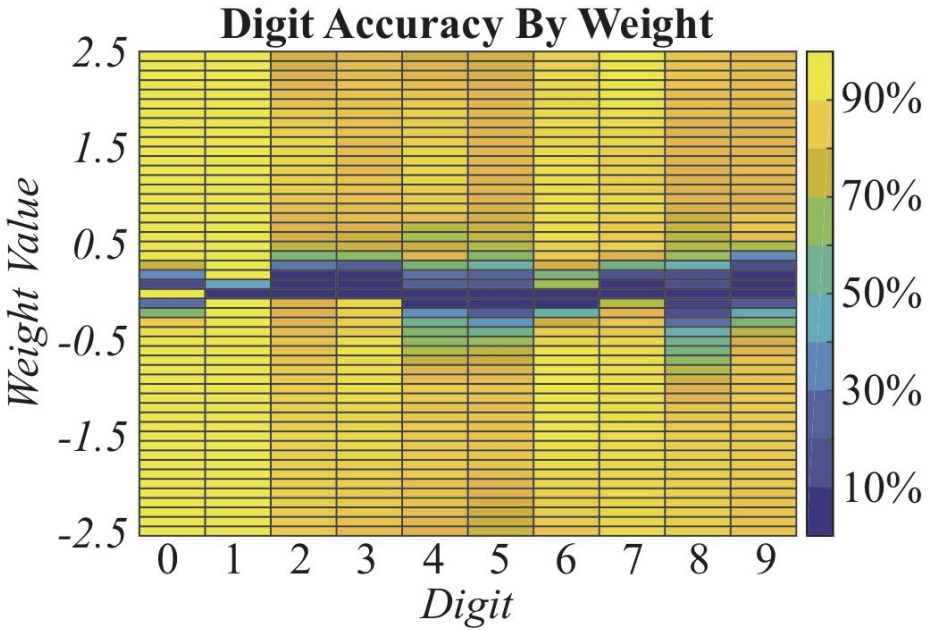


Can we find WANNs outside of reinforcement learning domains?


# of Classes Used
by Each Input
10
9
8
7
6
5
4
3
2
1
0
Linear
Invert
TanH
Sigmoid
Relu
Step (0/1)
Sine
Cosine
Gaussian
Absolute

WANN	Test Accuracy
Random Weight	*82.0% ± 18.7%*
Ensemble Weights	*91.6%*
Tuned Weight	*91.9%*
Trained Weights	*94.2%*

ANN	Test Accuracy
Linear Regression	*91.6%* [50]
Two-Layer CNN	*99.3%* [12]



Searching for Building Blocks

First steps toward a different kind of architecture search

- Network architectures with innate biases can perform a variety of tasks
- ...and these biases can be found through search

Weight tolerance as a heuristic for new building blocks

- ConvNets and LSTMs can work even untrained
- Finding novel building blocks at least as important as new arrangements of those which already exist

interactive article @:

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wednesday 10:45