Learning from various sensory modalities

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Sensory modalities in robotics

Modality is an aspect of stimulus or what is perceived after stimulus

- Proprioceptive (touch, gyro, accelerations, temperature, energy consumption...)
- Exteroceptive (vision, range sensing, sound...)

Sensory modalities in robotics

Modalities

- Energy consumption
- Traversability
- Planning / obstacle avoidance
- Grasping

Challenges

- Classification
- Regression
- Control

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Used principles

- Evolutionary algorithms
- Classifiers - SVM, Boosting, etc.
- Neural networks

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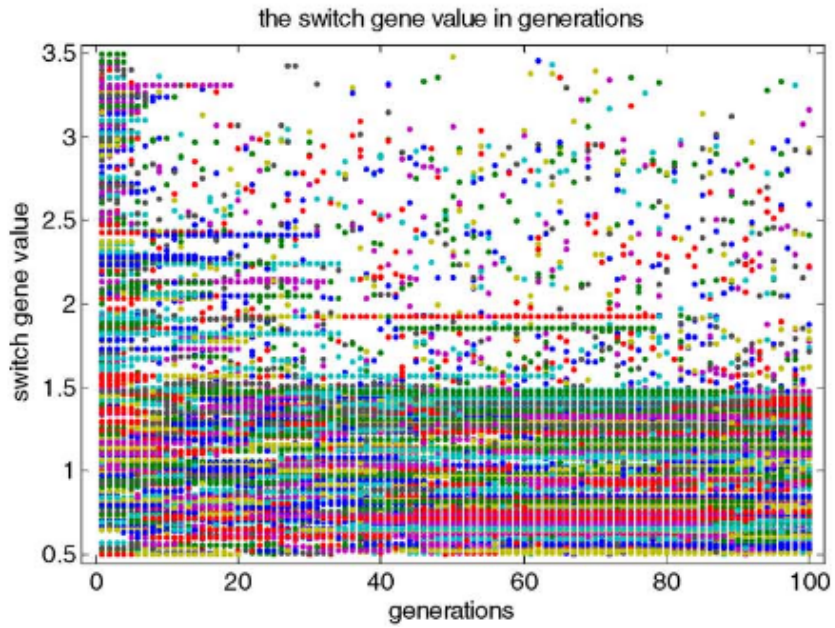
Evolutionary algorithms

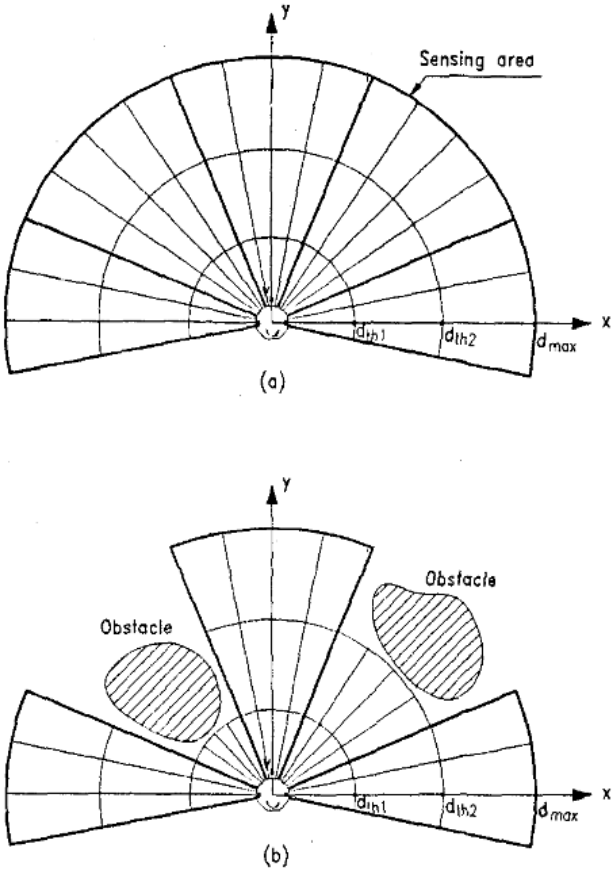
What is necessary:

- Genome
- Fitness function
- Crosover and mutation operations
- Simulation environment
- Computational power
- Time

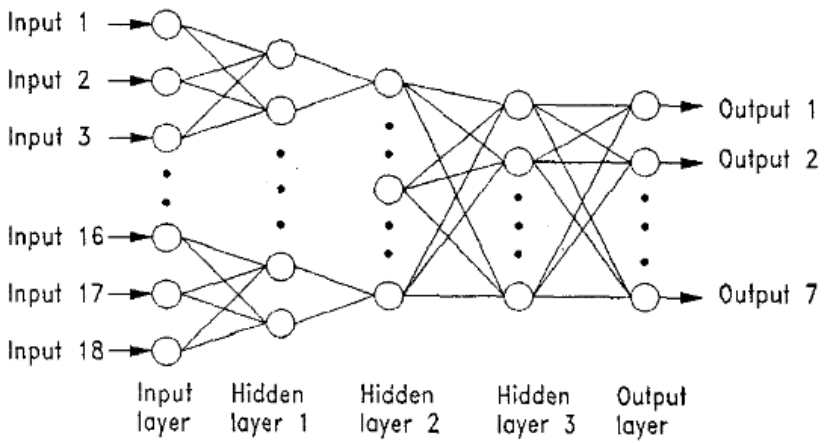


Neural networks - obstacle avoidance

[1] *Beom, Hee Rak, and H. Cho. "A sensor-based obstacle avoidance controller for a mobile robot using fuzzy logic and neural network." (1992).*



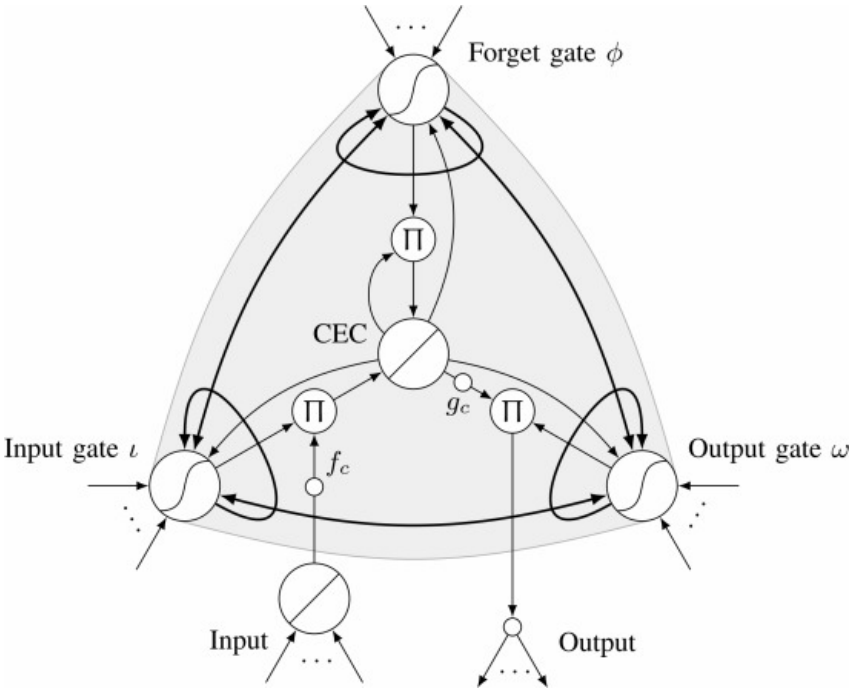
Courtesy of [1]



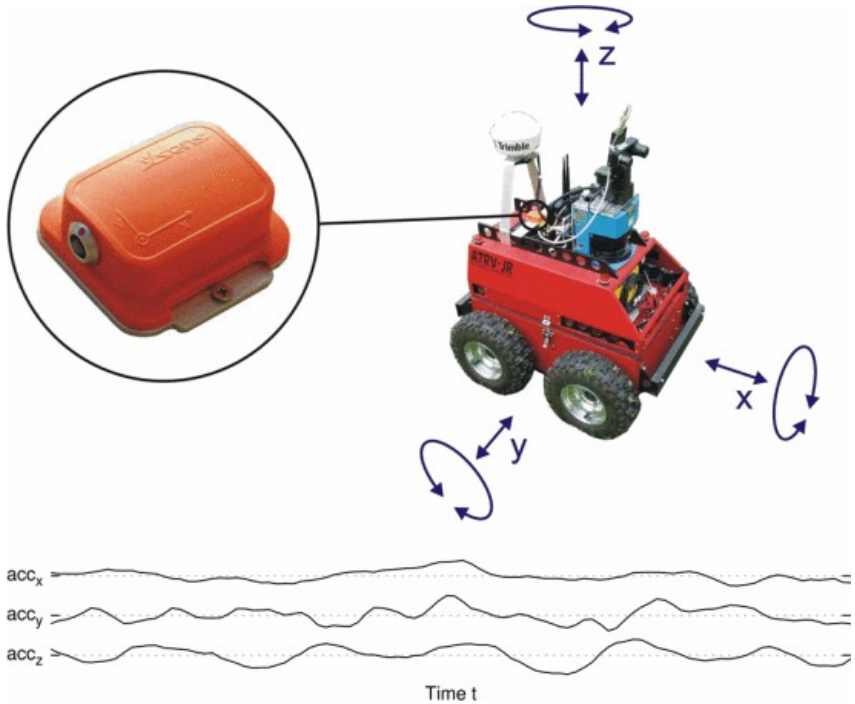
Courtesy of [1]

Neural networks - terrain classification

[2] *S. Otte, C. Weiss, T. Scherer and A. Zell, "Recurrent Neural Networks for fast and robust vibration-based ground classification on mobile robots," IEEE International Conference on Robotics and Automation, (2016)*



Courtesy of [2]



Courtesy of [2]

Neural networks - terrain classification

Input gate:

$$net_\iota^t = \sum_{i \in I} w_{i\iota} x_i^t + \sum_{h \in H} w_{h\iota} x_h^{t-1} + \sum_{c \in D} w_{c\iota} s_c^{t-1} + w_{\iota\iota} x_\iota^{t-1} + w_{\phi\iota} x_\phi^{t-1} + w_{\omega\iota} x_\omega^{t-1}$$

$$x_\iota^t = \varphi_\iota(net_\iota^t)$$

Forget gate:

$$net_\phi^t = \sum_{i \in I} w_{i\phi} x_i^t + \sum_{h \in H} w_{h\phi} x_h^{t-1} + \sum_{c \in D} w_{c\phi} s_c^{t-1} + w_{\iota\phi} x_\iota^t + w_{\phi\phi} x_\phi^{t-1} + w_{\omega\phi} x_\omega^{t-1}$$

$$x_\phi^t = \varphi_\phi(net_\phi^t)$$

Output gate:

$$net_\omega^t = \sum_{i \in I} w_{i\omega} x_i^t + \sum_{h \in H} w_{h\omega} x_h^{t-1} + \sum_{c \in D} w_{c\omega} s_c^{t-1} + w_{\iota\omega} x_\iota^t + w_{\phi\omega} x_\phi^t + w_{\omega\omega} x_\omega^{t-1}$$

$$x_\omega^t = \varphi_\omega(net_\omega^t)$$

where I is input layer, H is hidden recurrent layer, D is Dynamic Cortex Memory

Neural networks - terrain classification

85% accuracy on test data

Courtesy of [2]

Going deeper - Google grasping challenge

[3] *S. Levin, P. Pastor, A. Krizhevsky and D. Quillen, "Learning Hand-Eye Coordination for Robotic Grasping with Deep Learning and Large-Scale Data Collection,"(2016)*

`https://research.googleblog.com/2016/03/deep-learning-for-robots-learning-from.html`

- 14 robots
- 800000 grasps
- 2 months
- 82% success rate

Learning classifiers

[4] *S. Bose and M.Huber, "Incremental Learning of Neural Network Classifiers Using Reinforcement Learning," IEEE International Conference on Systems, Man, and Cybernetics (SMC), (2016)*

The idea - self adapting stream classifier composed of Neural networks.

- Ensemble learning MDP
- Type selection MDP
- Network creation MDP

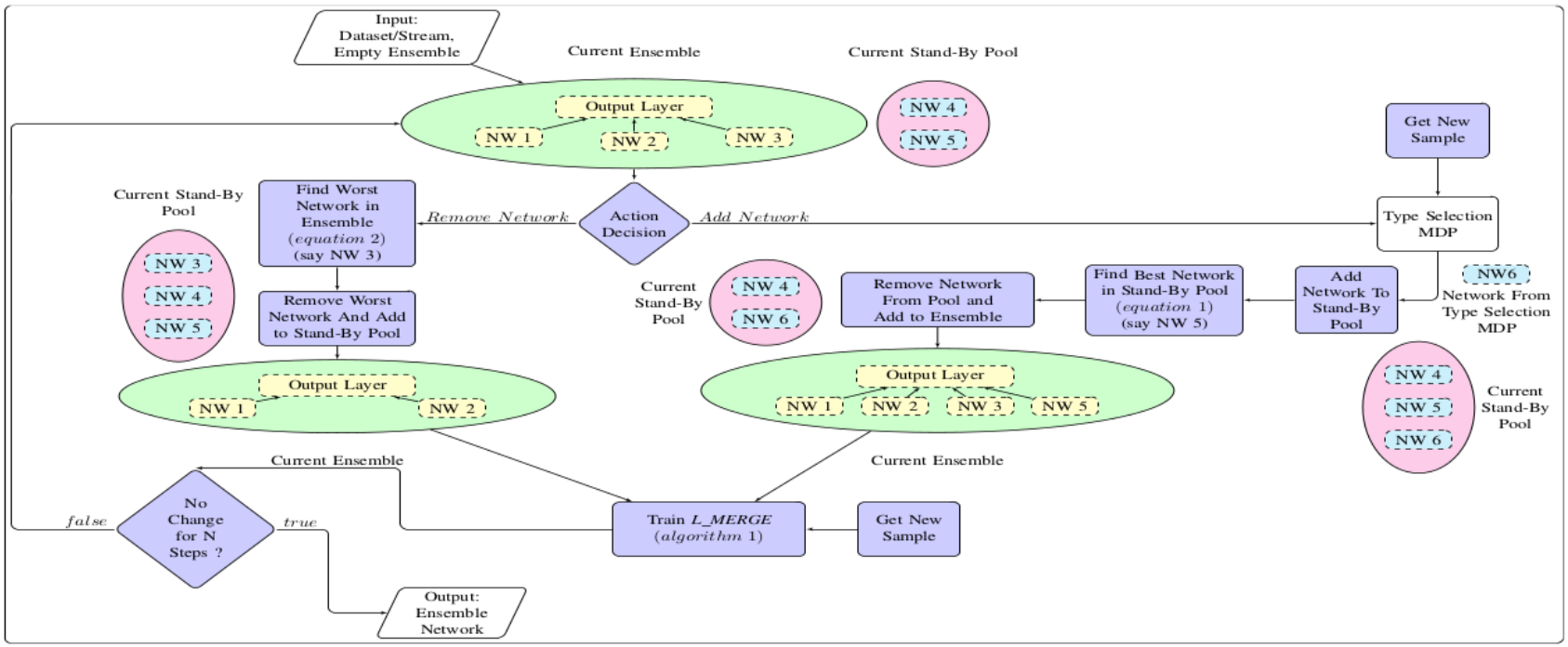
Learning classifiers

Ensemble learning MDP

Quality of ensemble: $Q = \frac{\min_{nn_i}(weight_{nn_i})}{\max_{nn_i}(weight_{nn_i})}$

Eligibility of i-th network: $E_{nn_i} = Acc_{nn_i} \frac{\#correctly\ classified\ in\ S'}{\#samples\ in\ S'}$, where S' are misclassified samples from S

Reward function: Accuracy of the ensemble



Courtesy of [4]

Learning classifiers

Type selection MDP

To establish new NN

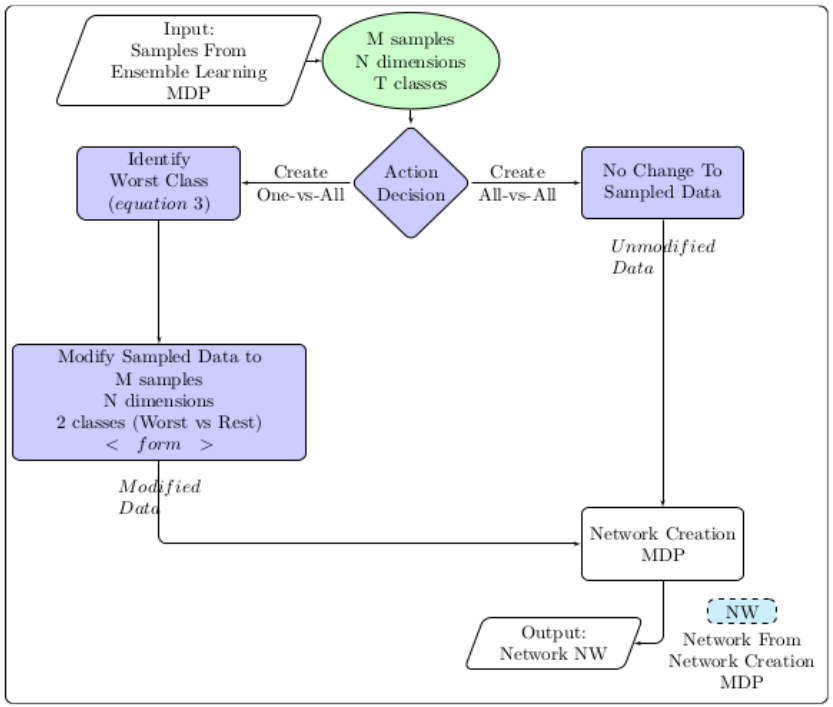
One-vs-all $\times$ all-vs-all

2-armed bandit problem

Class bias: $C_j = \frac{acc_j}{\max_j(acc_j)}$

Least accurate class: $minC = argmin_i(C_i)$

Reward function: Propagated accuracy of the whole ensemble



Courtesy of [4]

Learning classifiers

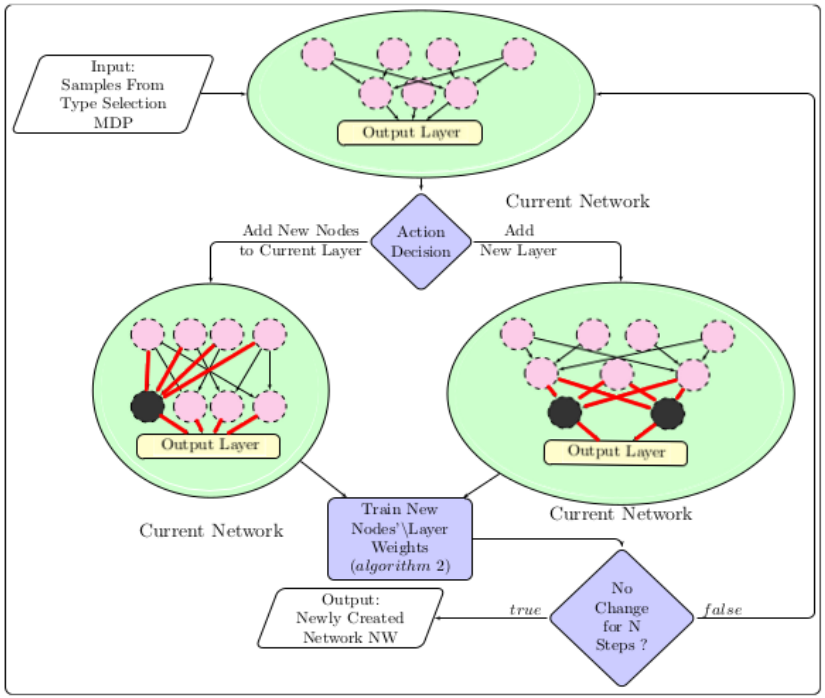
Network creation MDP

Adding nodes or layers to the NN

Error of NN:

$$Err = \frac{\#samples\ incorrectly\ classified}{\#total\ samples}$$

Reward function: change in *Err* after each action



Courtesy of [4]

Thank you for your attention!