Usage of Neural Networks in Robotics

By Philipp Krug / 13.01.2014

Outline

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  - Neural Networks
  - Evolution
- Neural Networks in Robotics
  - Collision-free Navigation
  - Knot tying in surgery
  - Sound-Source Localisation
- Summary

Inspiration for Neural Networks

- Human brain consists of 86 billion neurons
- Used for pattern recognition

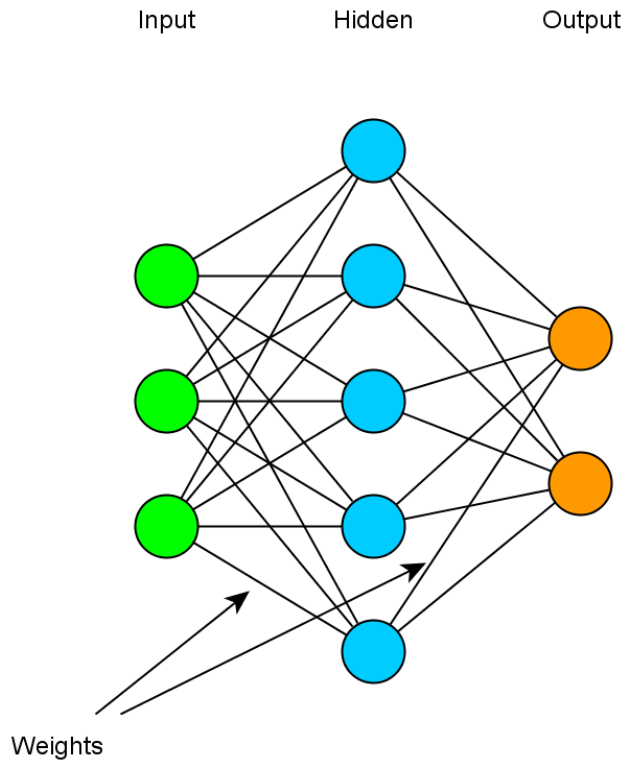
- McCulloch & Pitts proposed the first idea of computational neurons in 1943

Source: http://scientopia.org/blogs/scicurious/2011/05/04/science-101-the-neuron/

Neural Networks (1)

- Different layers of neurons
- Weighted connections
- Possible internal states

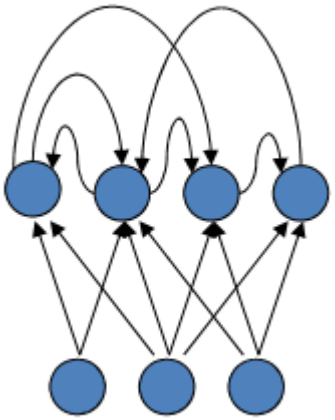
- Different types
  - Feed-forward networks
  - Recurrent networks



Neural Networks (2)

Continuous Time Recurrent Neural Network (CTRNN)

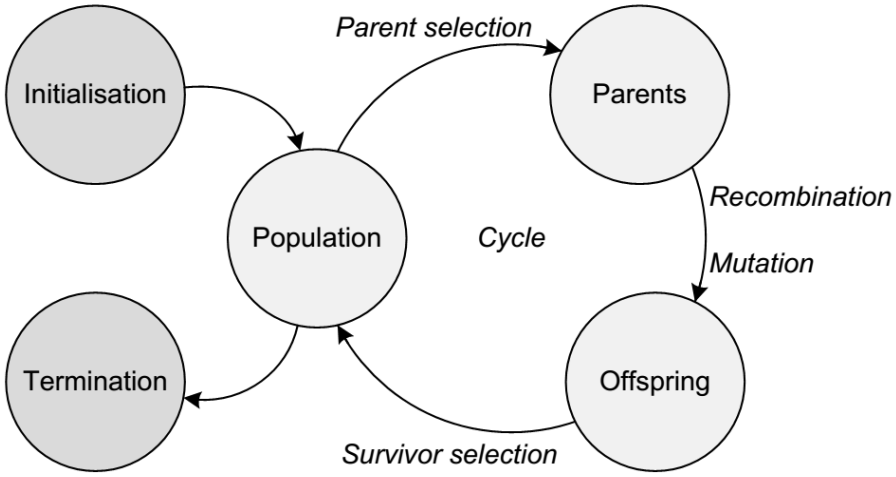
- Dynamical neural network
- Can approximate dynamical systems
- Often used for robot controllers

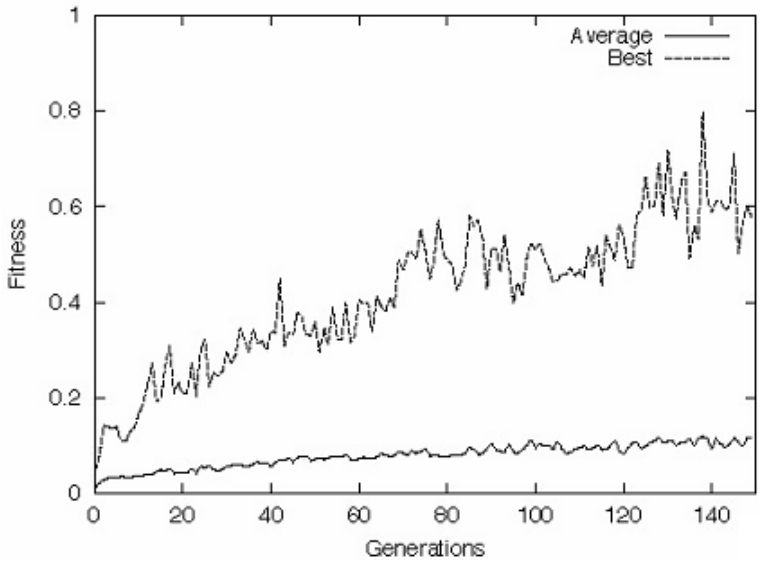


$$y_i^{t+1} = y_i^t + \frac{\Delta t}{\tau_i}\left[-y_i^t + \sum_{j=1}^{N} \omega_{ji}\sigma\left(y_j^t + \Theta_j\right) + I_i^t\right]$$

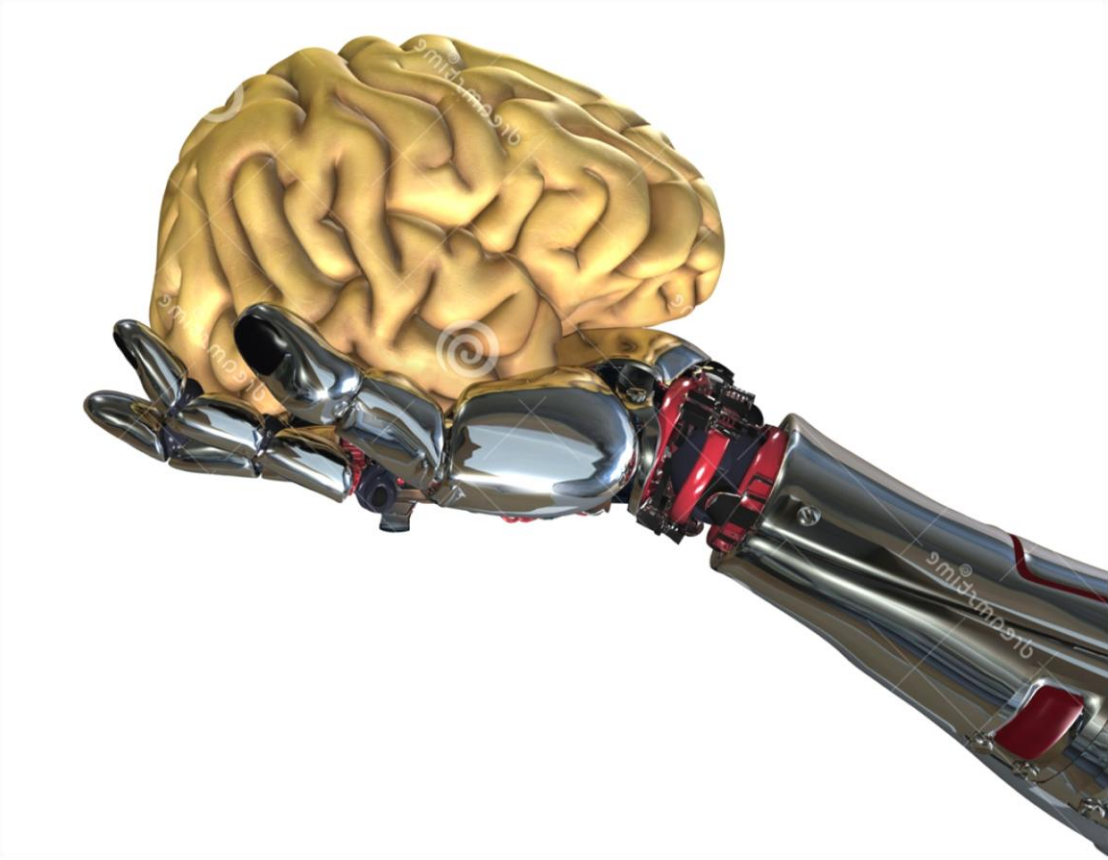
Evolution

- Trial-and-error problem solving method
- Multi-dimensional problem
- „Survival of the fittest“





Neural Networks in Robotics



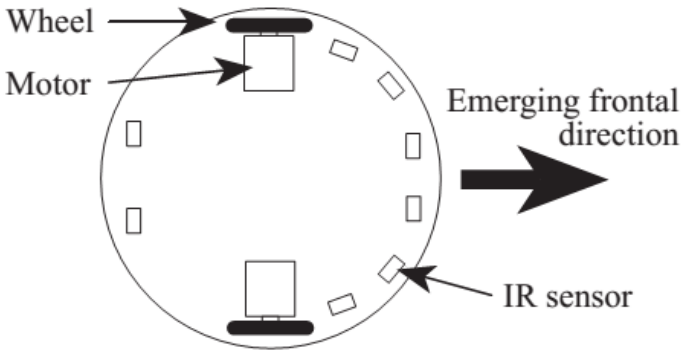
Source: Linda Bucklin, Dreamstime.com

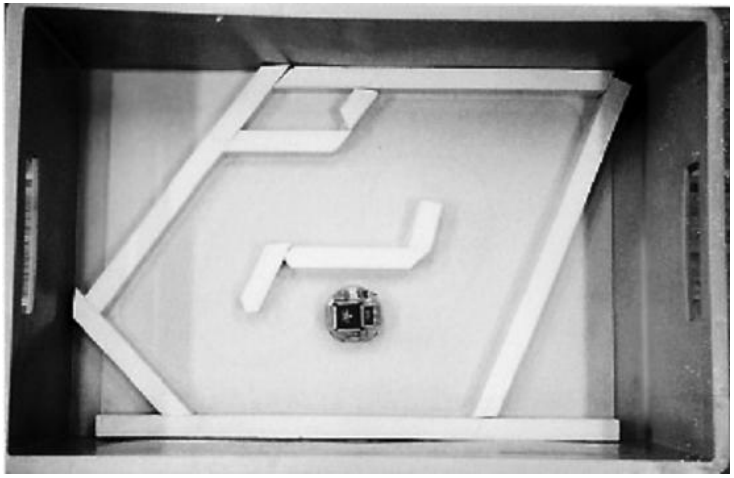
Collision-free Navigation

Genetic Evolution of a Neural-Network Driven Robot [2]

- Neural Network for controlling the movement of a robot
- Avoid collisions with obstacles or walls
- No pre-designed behavior
- No intervention during evolution

- Results
  - Approx. 50 generations for smooth and correct movement around the track





Knot tying in surgery

A System for Robotic Heart Surgery that Learns to Tie Knots Using Recurrent Neural Networks [4]

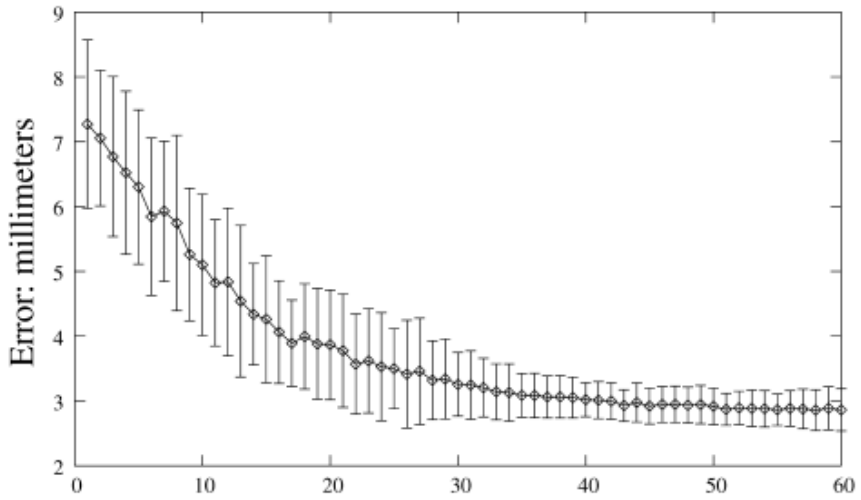
- Time-consuming task of knot tying in MIS done by robot
- Hybrid supervised/evolutionary learning framework
- Direct programming of the procedure is time consuming
- Usage of recurrent neural networks (RNN)

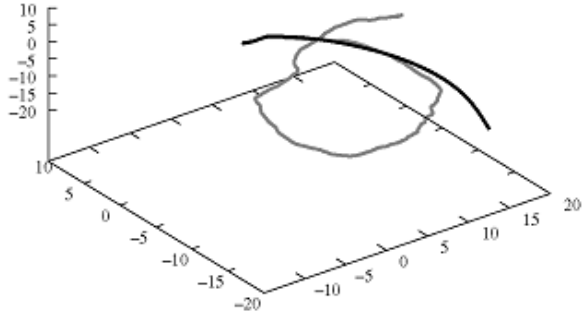
Source: http://www.geomagic.com

Knot tying in surgery

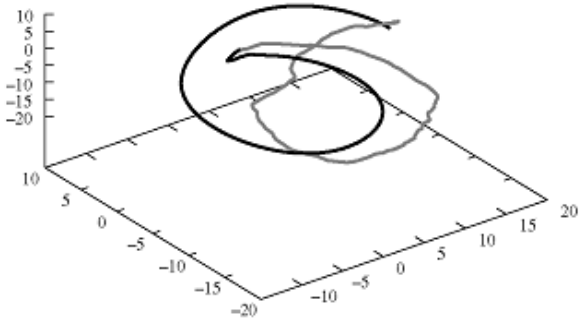
A System for Robotic Heart Surgery that Learns to Tie Knots Using Recurrent Neural Networks [4]

- Results
  - Approx. 60 generations
  - Time for a knot: 25.8s

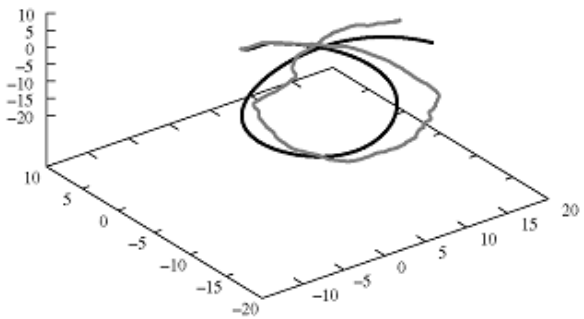




Generation 1



Generation 10



Generation 60

Summary

Wide variety of possible application

Generic solutions

Dynamic adaption to problems

Fault tolerance

Thank you!

Literature

[1] Dario Floreano, Franesco Mondada: Automatic Creation of an Autonomous Agent: Genetic Evolution of a Neural Network Driven Robot, Proceedings of the third international conference on Simulation of adaptive behavior: From Animals to Animats 3, p. 421-430 Cambridge, MA, USA: MIT Press, 1994

[2] Video: Evolution of Collision-free Navigation (http://www.youtube.com/watch?v=2LFzuBferew)

[3] John C. Murray, Harry R. Erwin, Stefan Wermter: Robotic sound-source localisation architecture using cross-correlation and recurrent neural networks, Neural Networks, Volume 22, Issue 2, p. 173-189, 2009.

[4] Hermann Mayer, Faustino Gomez, Daan Wierstra, Istvan Nagy, Alois Knoll & Jürgen Schmidhuber: A System for Robotic Heart Surgery that Learns to Tie Knots Using Recurrent Neural Networks, Advanced Robotics, Volume 22, Issue 13-14, 2008.