Robot Navigation: Two Inplimantations of State of the Arts

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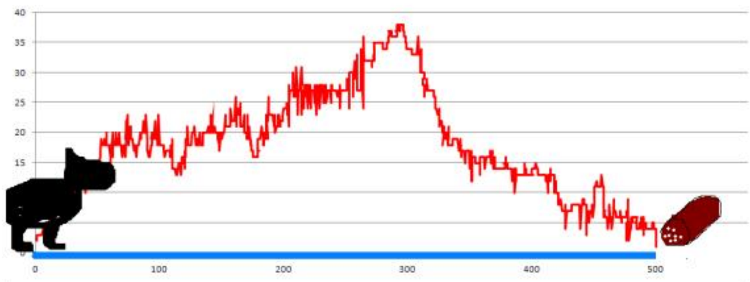
I. Navigation by Neural Network (NN)

(1) NN with fixed weight

A lucky dog reached a sausage avoiding cliff.

But is he intelligent?



(2) With weights modified during a run

(McCullough-Pitts Neurons with Hebb rule)

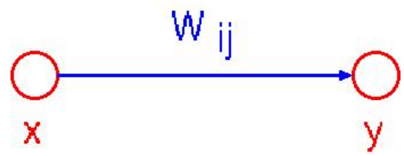
Floreano & Urzelai (2000) ⇒ light seeking robot

Hebb rule

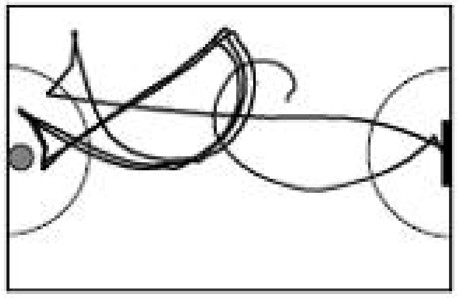
start with random weight values ⇒ then renewed every 100ms

$$w_{ij}(t) = w_{ij}(t-1) + \eta \Delta W \qquad (0.0 < \eta < 1.0)$$

where $\Delta W = (1 - W)xy$.



An example path with Hebb rule



(3) With spiking neurons
Rate Coding

Floreano & Matiussi (2001) ⇒ also light seeking task

Spiking neuron model

Incoming spikes can increase or decrease the membrane potential

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The neuron emits a spike when its membrane potential exceed threshold

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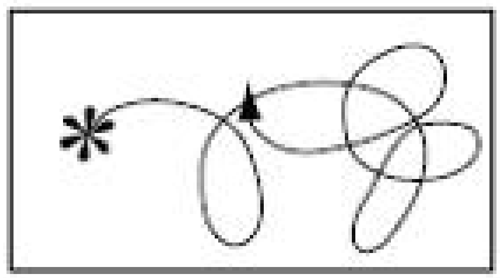
After firing, the membrane potential resets to a low negative voltage

An example path with rate-coding



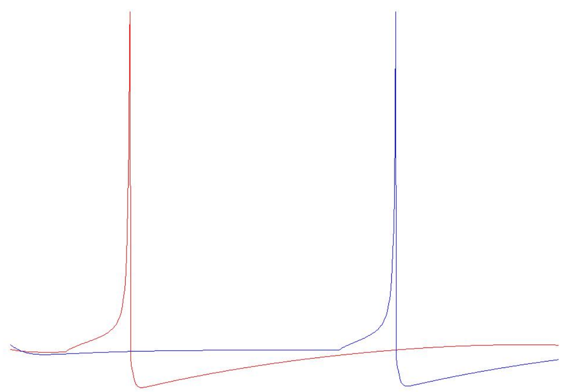
(4) With spiking neurons Spike Timing Dependent Plasticity (STDP)

di Paolo (2001) $\Rightarrow$ also light seeking task

STDP

Spiking neuron's vergion of Hebb rule

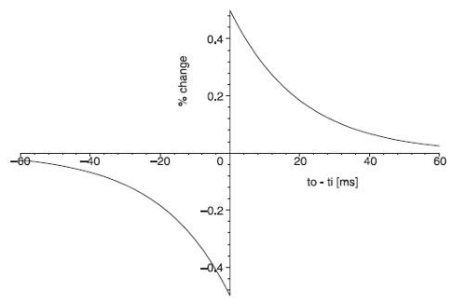
$$\Delta t = t_{post} - t_{pre}$$



How does STDP change weights?

$$W(\Delta t) = \begin{cases} A_+ \exp(-\Delta t/\tau_+) & \text{if} \quad \Delta t \geq 0 \\ -A_- \exp(-\Delta t/\tau_-) & \text{if} \quad \Delta t < 0 \end{cases}$$

where $\quad \Delta t = t_{post} - t_{pre}$



HodgkinHuxley model

$$C_M \frac{dv}{dt} = -g_{Cl}(v - E_{Cl}) - g_K(v - E_K) - g_{Na}(v - E_{Na}) + I(t)/A$$

Computationary very expensive $\Rightarrow$ possible only with a few neurons

Spiking Responce model

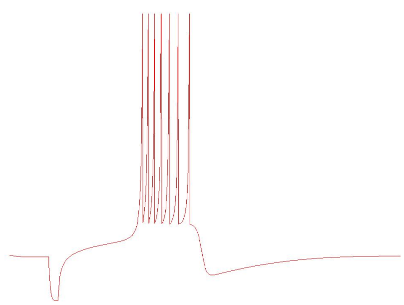
$$v_i(t) = \sum_j w_{ji} \sum_f \epsilon_j(t - t_j^f) + \sum_f \eta_i(t - t_i^f)$$

Integrate Fire model

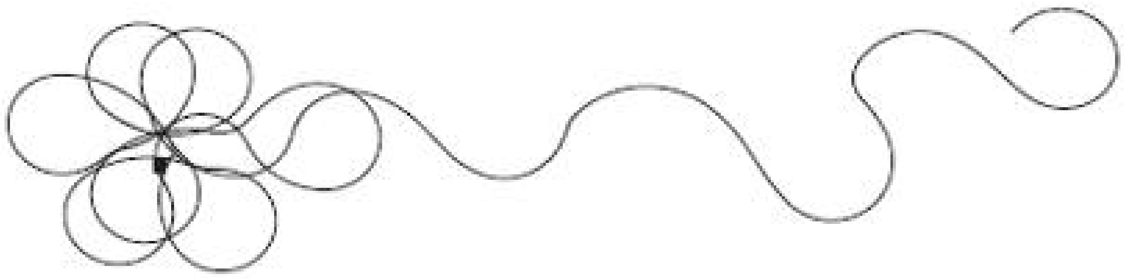
$$v_i(t) = v_r + (v_i(t - \Delta t) - v_r) \exp(-\Delta t/\tau) + \sum_j w_{ij} f_j(t - \Delta t)$$

Ihzkevich model

$$v' = 0.04v^2 + 5v + 140 - u + I$$
$$u' = a(bv - u)$$



An example path with STDP



II. Brain Machine Interface

Obama's proposal on brain science (2013)

$3 billion investment
to map

85 to 100 billion neurons in the human brain.

H. Markram et al. in Lausanne

Let's create a "virtual copy of the human brain."

Neuroscience: rich in data & poor in theory?

Analyzing the brain data without a theory

⇓

A person who does not understand how a computer works got the wiring diagram of a computer and all snapshots of voltages at all the spots of the wires. Then he said "now we have data, and we need to analyze it!"

(J. Weng in Connectionists Digest, Vol 335 (4) 12 March 2013)

Neural Dust

- A concept of human-machine interface by D. Seo et al. (U.C.Berkley).
- Thousands of tiny sensors, 100 micrometers, in a human brain ⇒ dust
  - Each dust, powered by ultrasound transmissions, picks up electrical signals from nearby neurons
    - They return data from the brain via ultrasound to a transceiver implanted under the skull.

Neural Dust works like MRI and PET

- It would easily monitor neurological activity for research and medical monitoring.
- We could also see this technology as a brain-machine interfaces .

Navigation by Electroencephalogram (EEG)

EEG what for?

- The most direct way to record brain activity is to cut open the skull and place electrodes directly onto your grey matter, which presents other problems.

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Most of the research on human brain uses EEG

Use your brain to control the world!

(A promise of the brain-machine interface)

- It enables cursor control, brain-to-brain communication etc.

$\Downarrow$

Farewell to smart-phone!

(J. Bleecker and N. Nova at the South by Southwest Interactive conference)

It might sound like a Science-Fiction but actually not! It's a reality.

Now let's go back to a reality!

Robot navigation with EEG

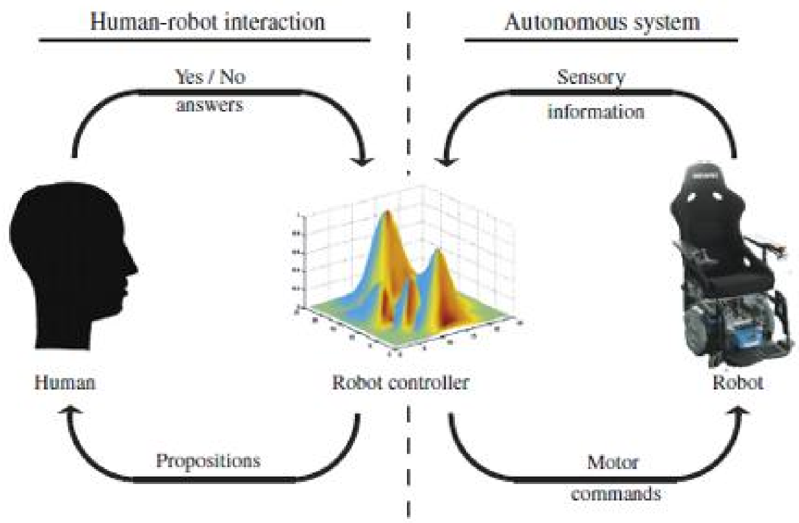
- Brain-coupled interaction for semi-autonomous navigation of an assistive robot

  X. Perrin (2010)

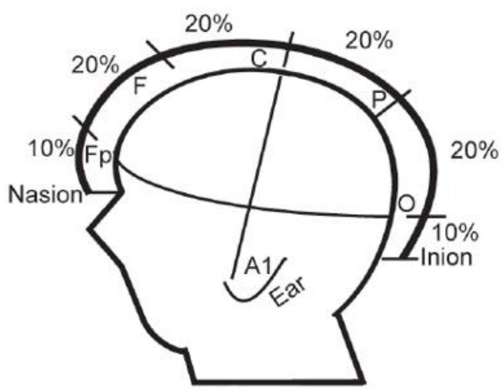
- EEG Based Brain-Machine Interfacing: Navigation of Mobile Robotic Device

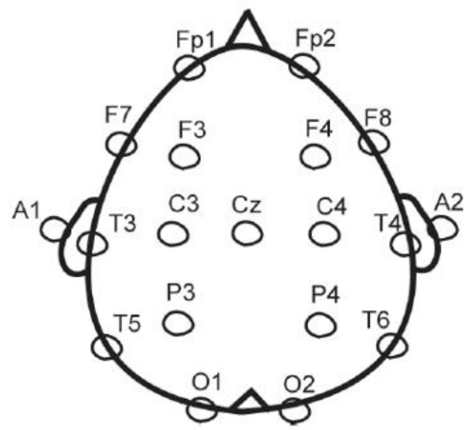
  M. Mahmud et al. (2011)

A brain machine interface

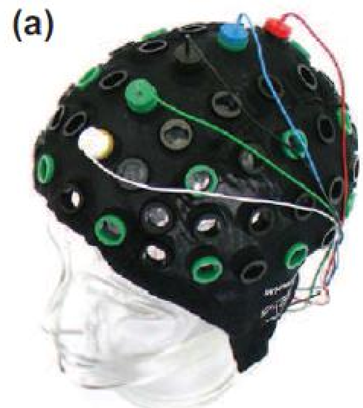


Spots to detect EEG signal



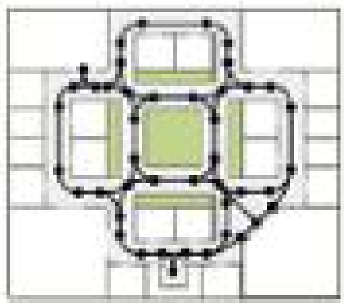


A cap to detect those EEG signals



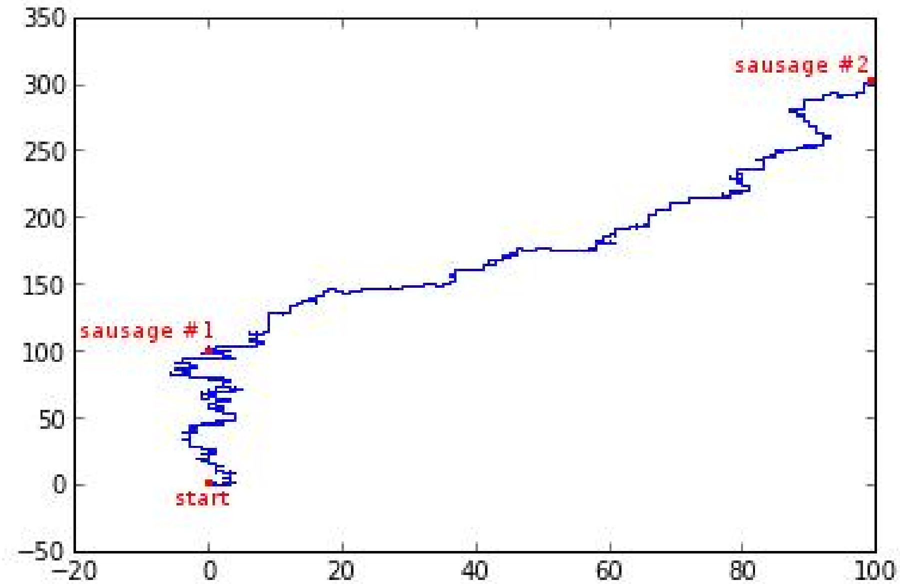
EEG can make a robot navigate just by thinking

An example path with EEG



III. Let me propose a Benchmark

A lucky dog who survived



The Jeep Problem

The 52nd problem

in the

"Propositiones ad acuendos inventes" (in Latin)

attributed to

Alcuin of York (732–804)

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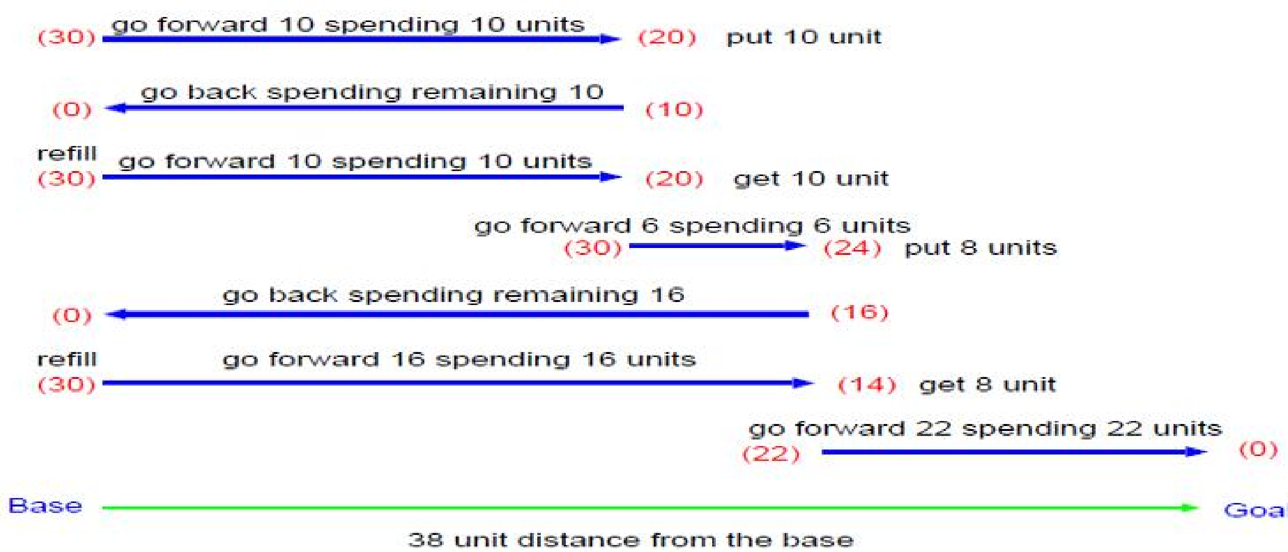
Camel carrying grain in a desert.

The task in the modern version

Maximize the distance a Jeep can penetrate into 1-D desert.

- Jeep can move a unit distance with a unit fuel.
- Jeep can unload its fuels anywhere in the desert.
- Fuels can be filled only at the base.
- Jeep can go back to the base n times to re-fill its tank.

An example of a success



An extension to 2-D Desert

Goal is to "maximize the total distance of exploration"

with n reserve tanks to put fuels on its path for a future usage

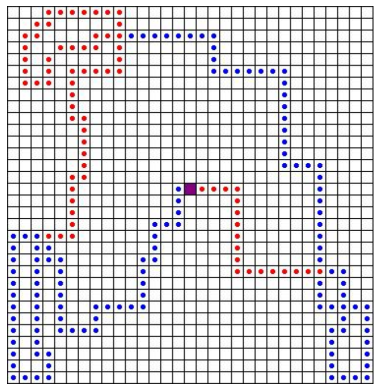
(1) Start the base

(2) Navigate the desert

(3) Put fuels somewhere, or find the fuels to get

(4) Return to the base

Possible route of such a exploration



Let's apply Turing Test!

to 2D Jeep in Desert Problem

- Set the situation, like, "Explore region X
  with being allowed 3 times return to the base"
- The Jeep A is navigated by an artificial agent
- The Jeep B is navigated by a human via EEG
- Can we tell current one is by A or B?

Tank you for attention!