A Hybrid Robotic Control System using Neuroblastoma Cultures

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Departamento de Inteligencia Artificial, UNED, Spain

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Objectives of this research

- To analyze the computing capabilities of human neuroblastoma cultured cells.
- To define connection schemes for controlling a robot behavior.

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- Long-term potentiation (LTP) is an enhancement in signal transmission between two neurons stimulated synchronously (Hebb).
  - Calcium concentration has to be over a threshold in postsynaptic neuron.
  - It is related to synaptic plasticity.
- Tetanization consists on a high-frequency sequence of individual stimulations of a neuron.
- Tetanization induces NMDA receptor-dependant long-term potentiation (LTP).
  - Increase transmitter release (post-tetanic potentiation).
  - Produce a change in vesicle exocytosis.

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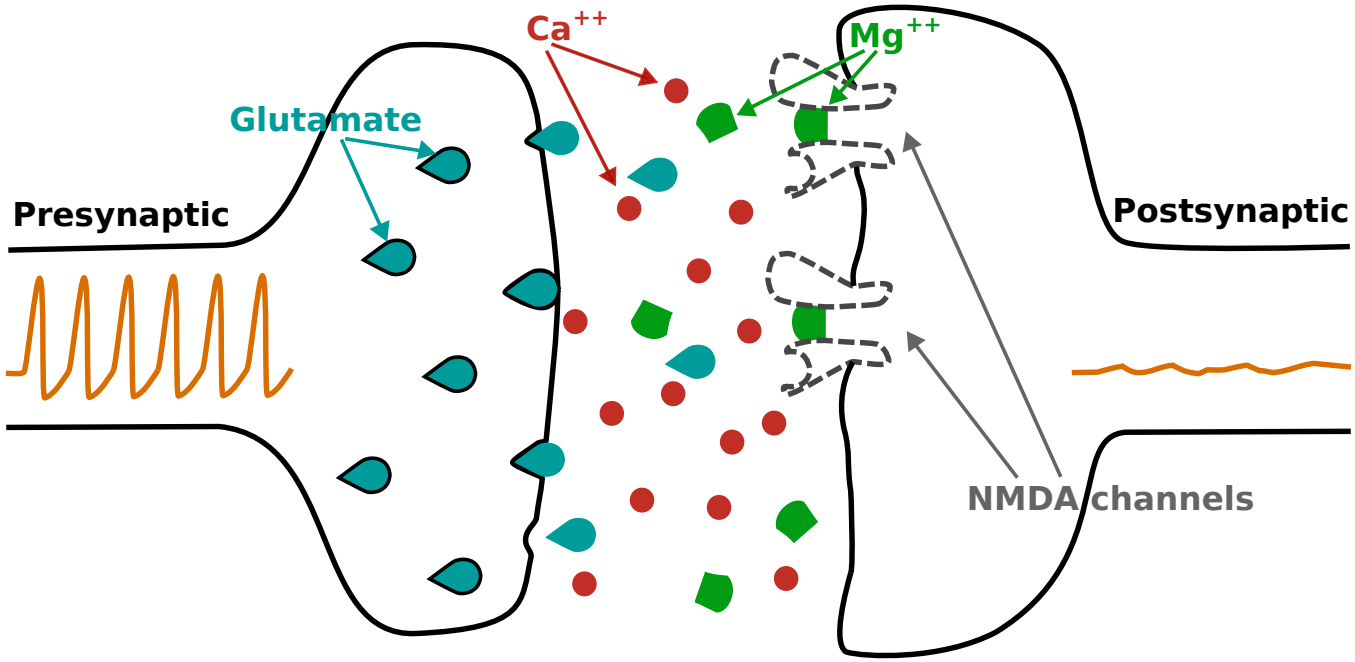
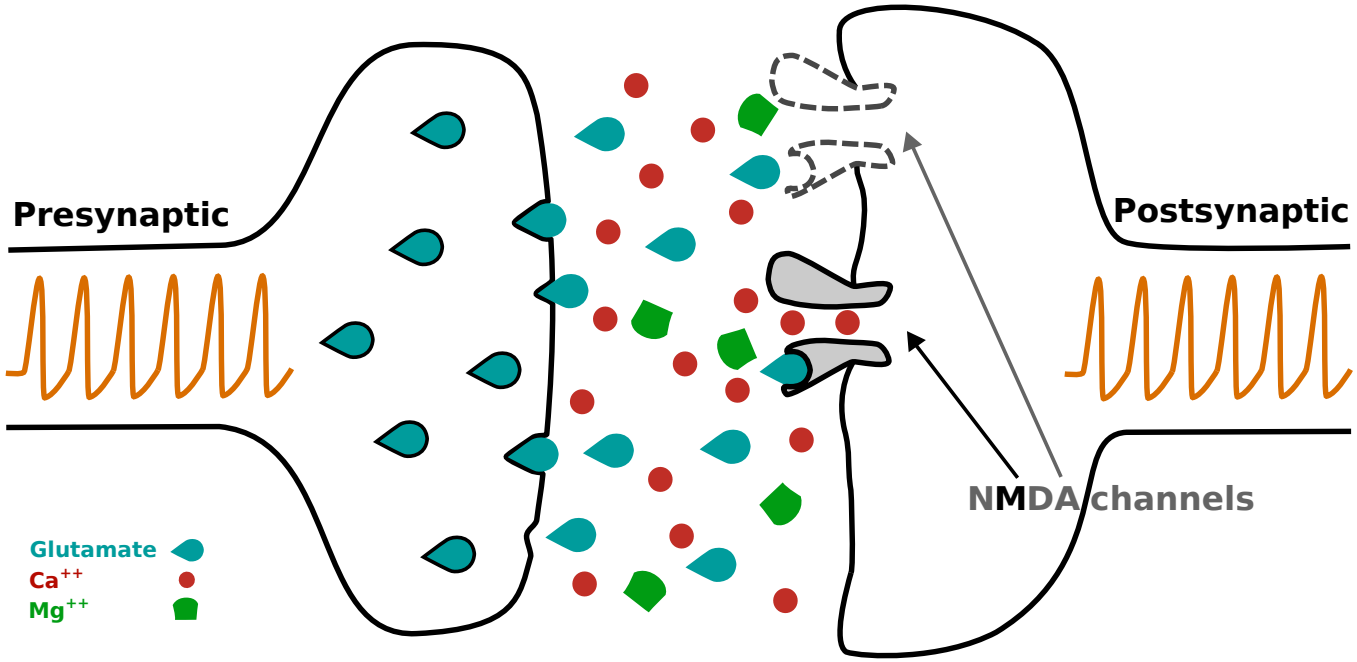


Tetanization physiology 2.



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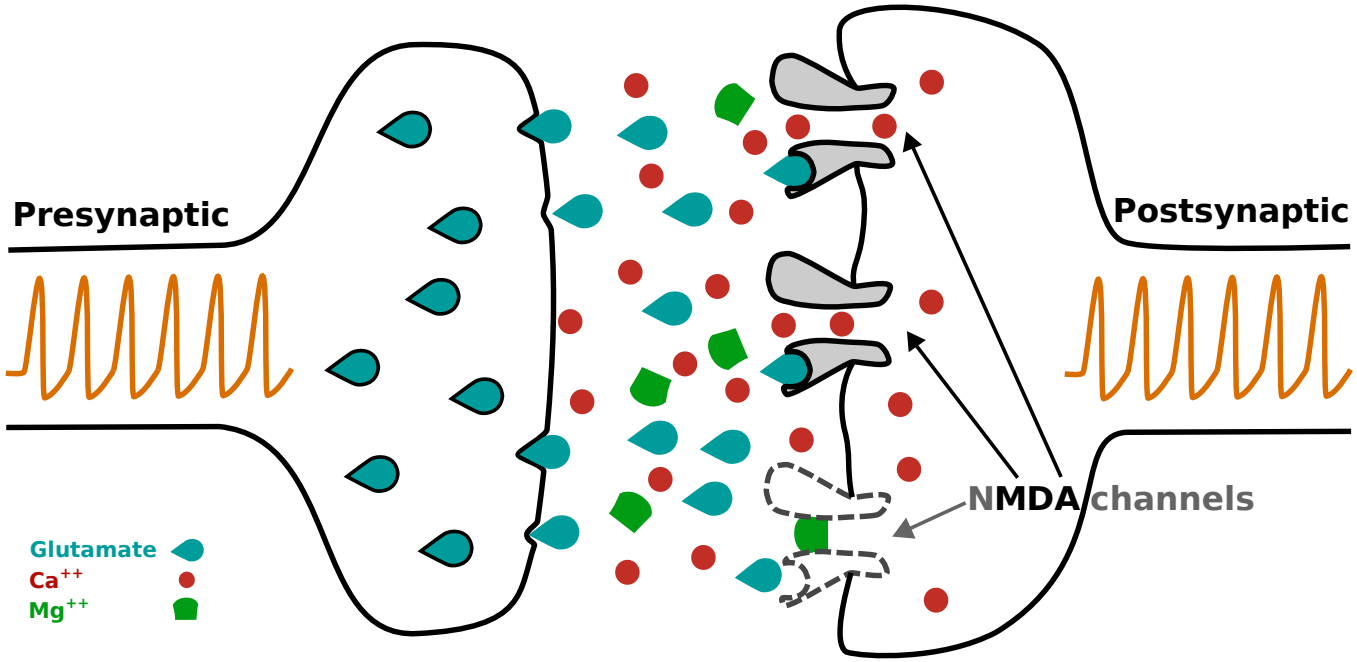

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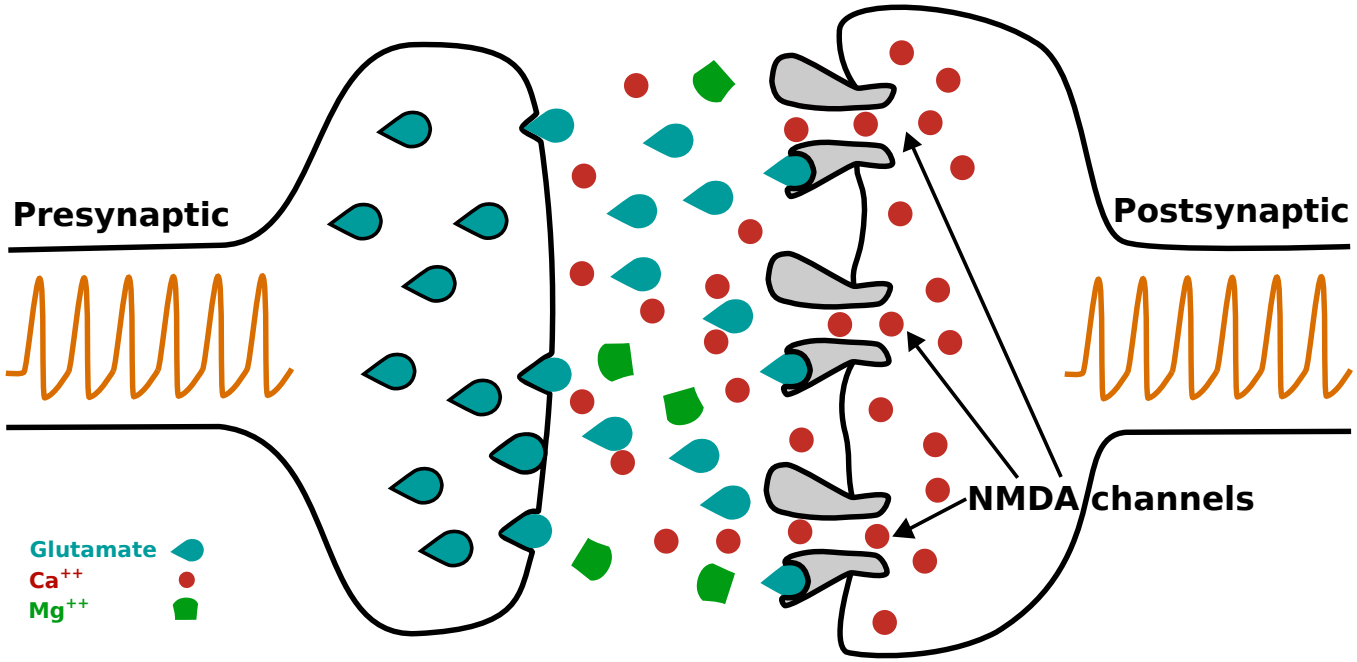

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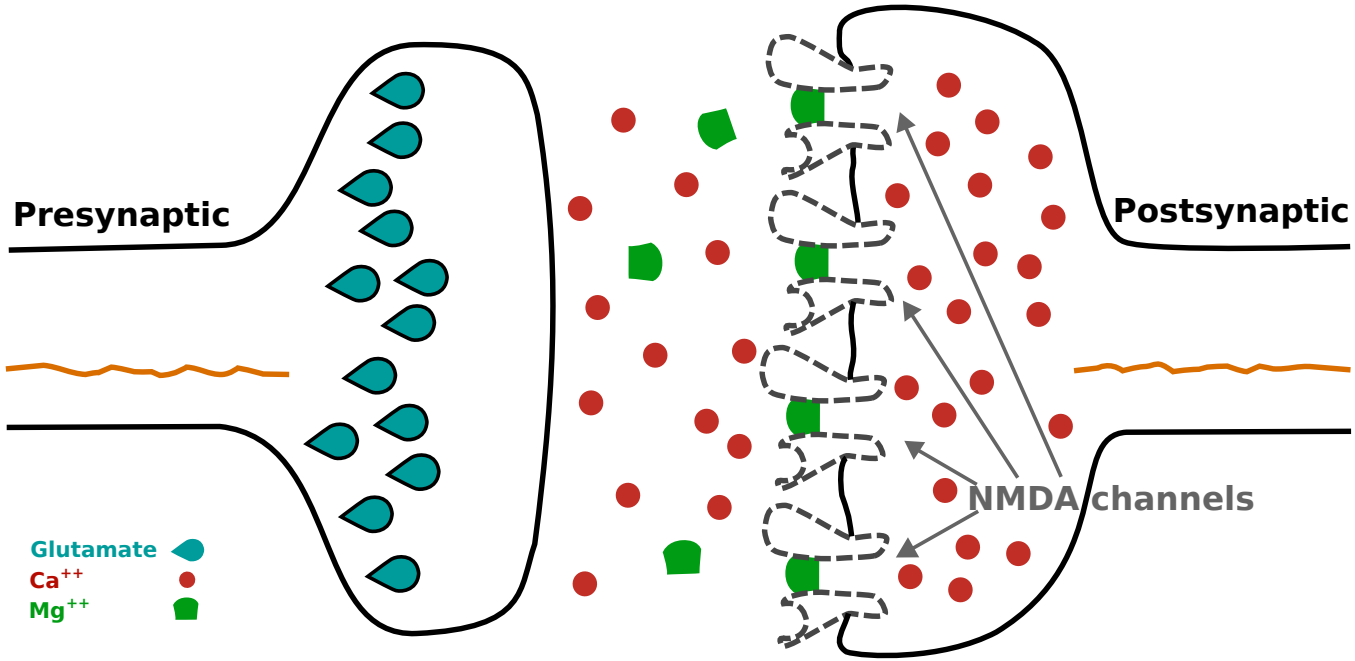

Outline

Human neuroblastoma cultures.

- Tumor neuroblasts, embryonic nervous tissue cells.
  - SH-SY5Y cell line expresses clonal especific human dopamine and NMDA receptors.
  - They respond to different neurotransmitters.
  - They tend to cluster.
- Culture conditions
  - Chemicals to avoid clustering, during 15 days (div), and to induce neuritic growth.
  - 37 degrees humidified incubator.
  - 5% CO_2 and 95% O_2.
  - Serum-free Neurobasal medium.
- Other cells may be used
  - Cortical, hipocampal and retinal tissues.

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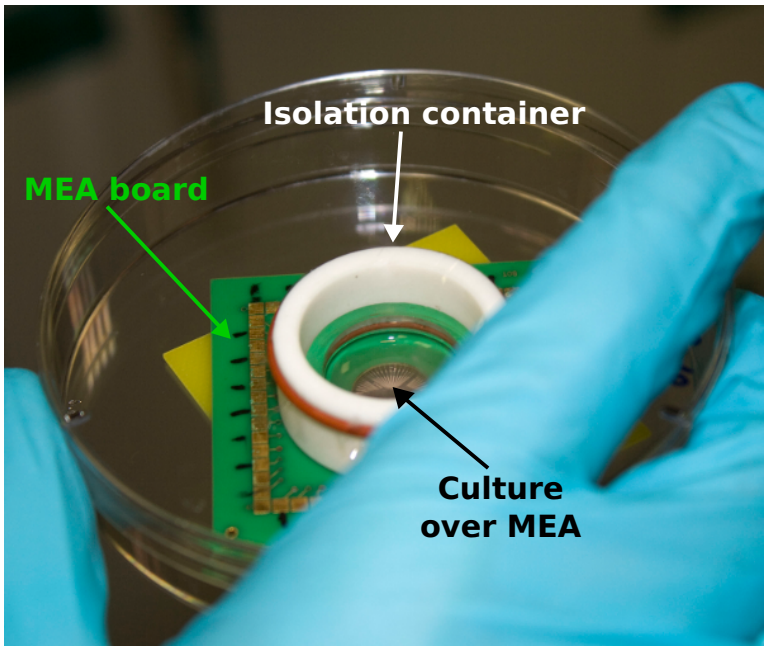
Culture conditions

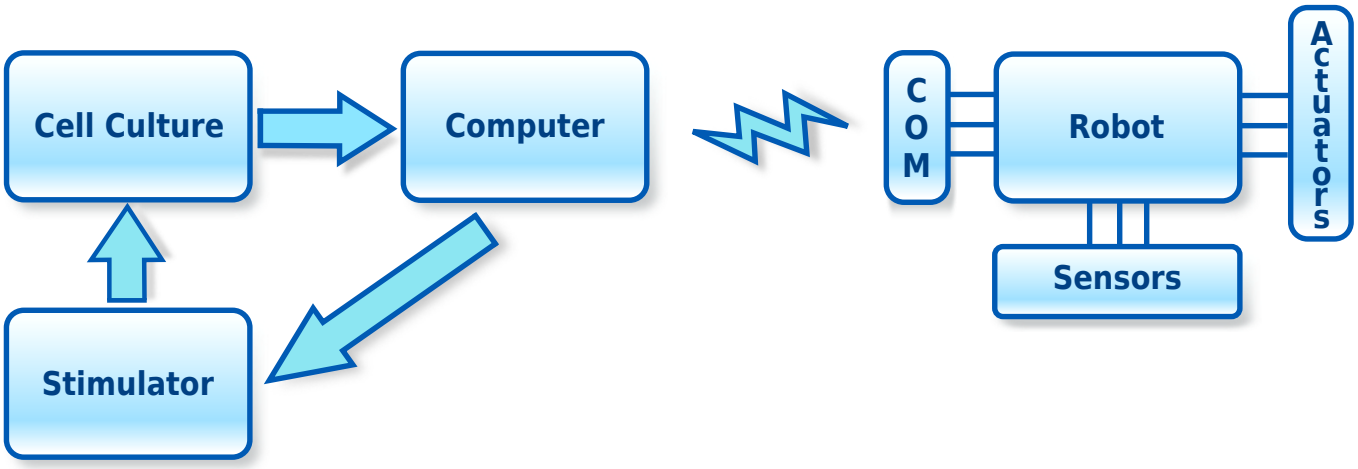
Incubator



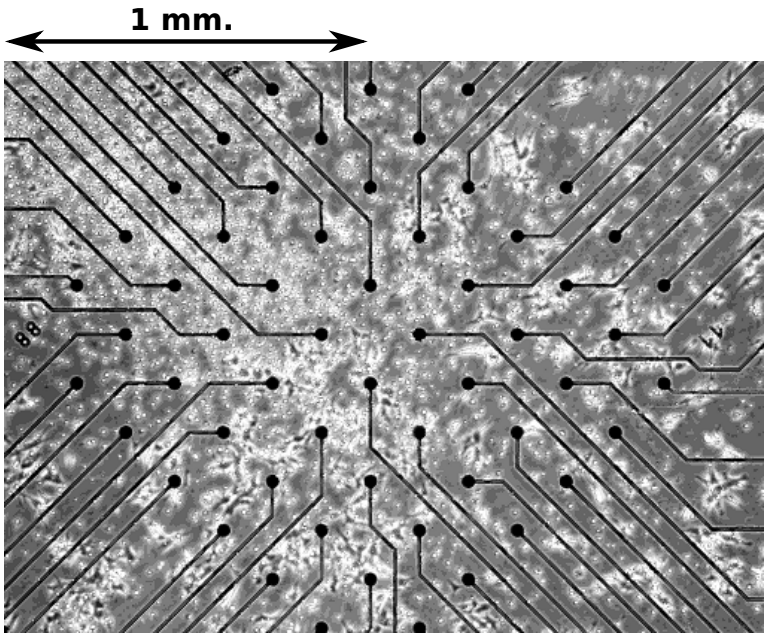
Petri dish containing a cultured MEA

Outline

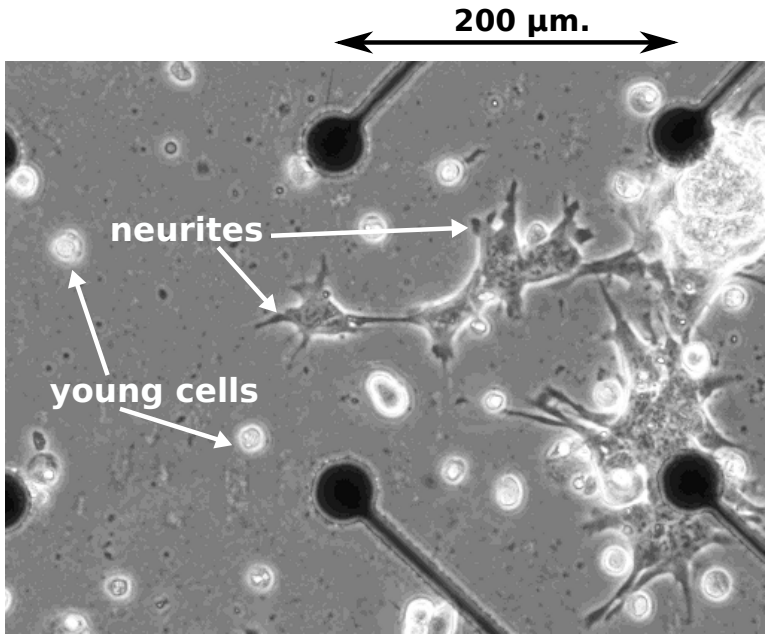
Basic components



Multi electrode array (MEA)



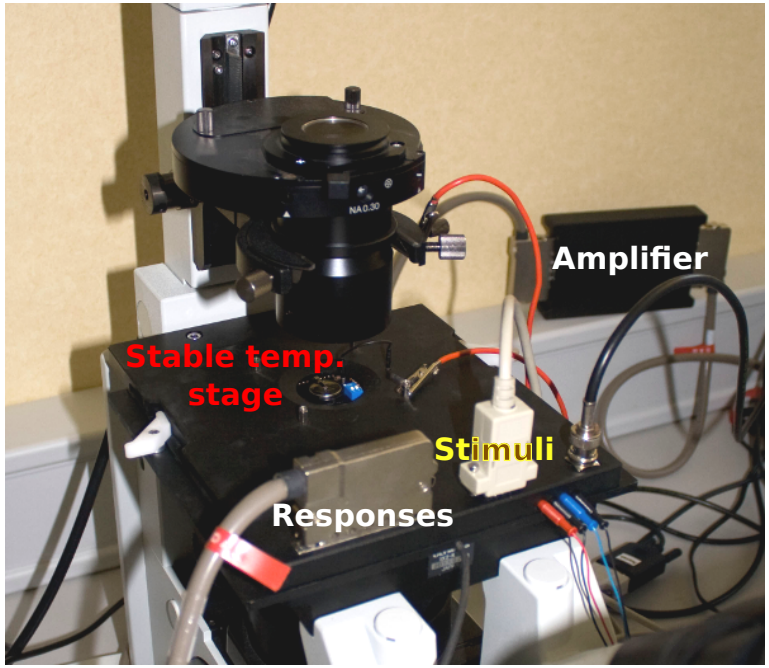
Multi electrode array, 60 electrodes and about 100.000 neurons



MEA detail showing neurons at 2 div with different growth stages

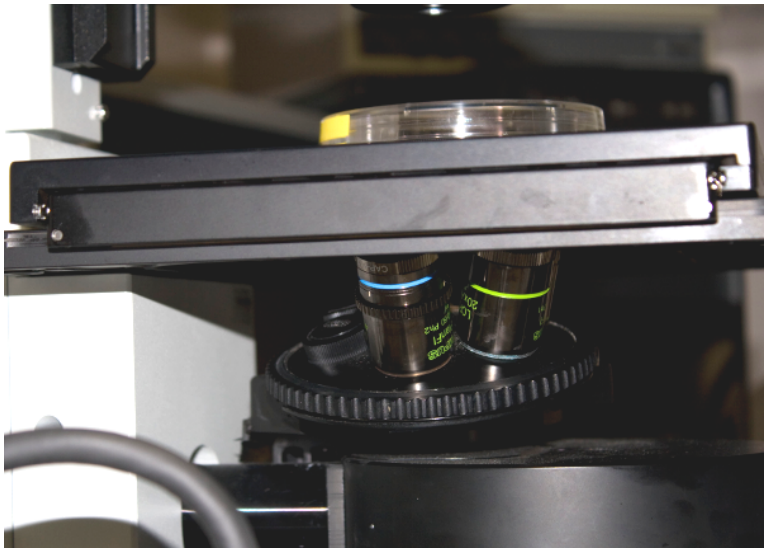
Inverted microscope and hardware 1

Inverted microscope with special stage for MEA applications and MEA stimulator

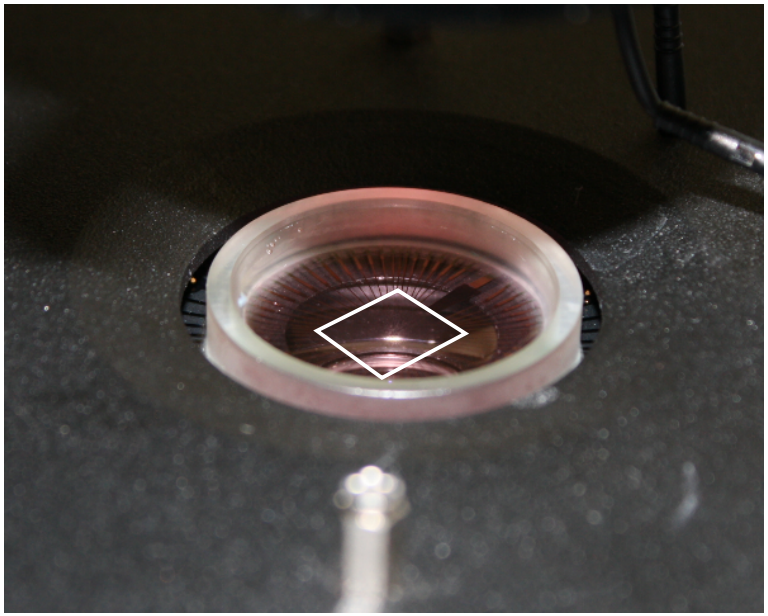


Microscope stage detail

Inverted microscope and hardware 2



Detail of inverted turret and objectives under the stage



MEA board inside the stage, only isolation container is left outside, MEA is marked out

Outline

Counting spikes

- Counting spikes embedded in noisy signals on-line.
  - Sampling period 25Khz.
  - Compute standard deviation (std. dev.) over 500 ms.
  - Set threshold as a multiple, from -1 to -4, of std. dev.
  - Activity below threshold is considered as spike.
- Later off-line analisys may be done.

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Electro physiological properties

- Network spontaneous activity was recorded for 15 days in two cultures.
- Bursting and spiking activity has been observed.
  - Firing rates varie highly across recordings.
- Synchronized activity between electrodes has been observed.
  - Bursts with large number of spikes at many channels.
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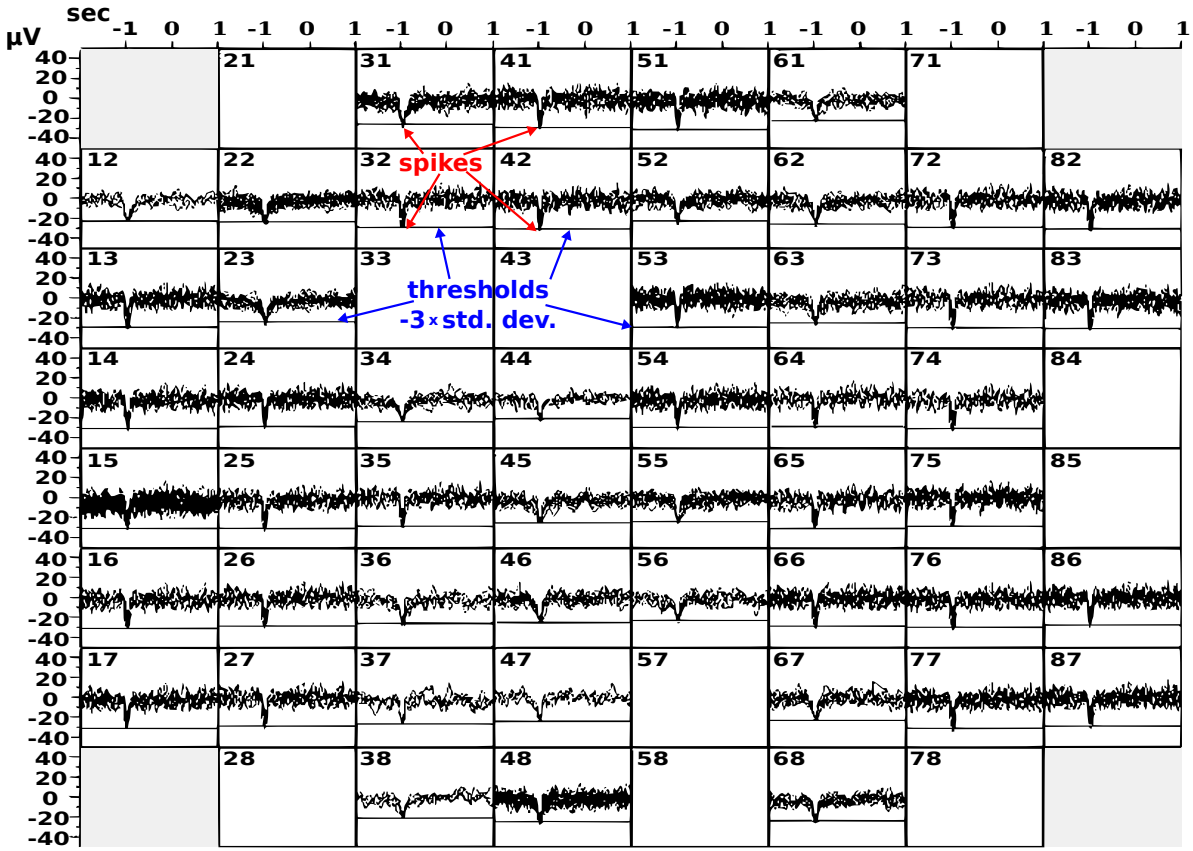
Culture spontaneous activity



Network spontaneous activity. Neurons age from 1 to 7 div.

Tetanization results

- Stimuli
  - 10 trains of a 100 anodic-first waveform, amplitude 1 Volt.
  - Targeting every MEA electrode.
- Responses
  - 3 minutes record before stimulation .
  - 3 minutes record after stimulation.
- Results
  - New connections are created, increment of spikes number.
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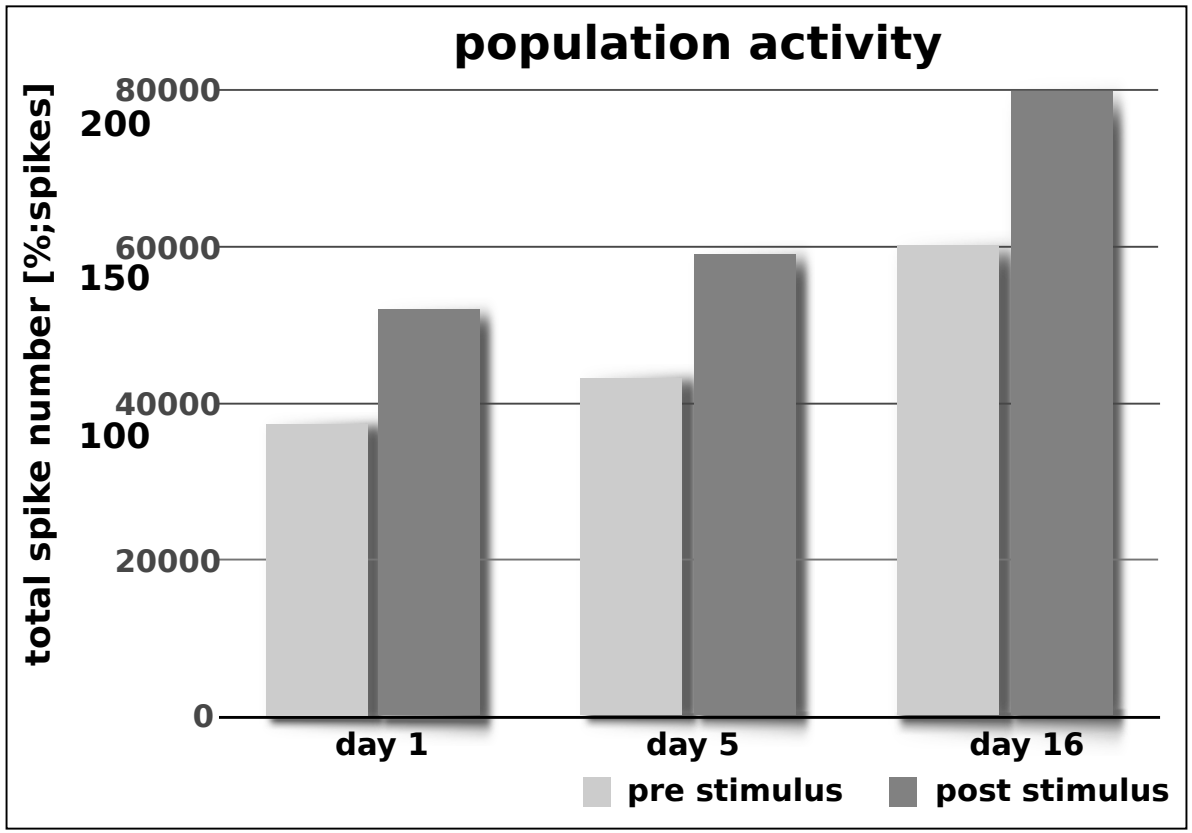
Statistics about tetanization



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Robotic control for obstacle avoidance

- Sensors information used to selective tetanization.
  - If an obstacle is detected, electrodes corresponding to obstacle position are stimulated.
  - Electrodes selection depends on connections scheme between sensors and actuators.
- Robot direction vector is obtained from network response.
- Preliminary experiments with a robot has been done.

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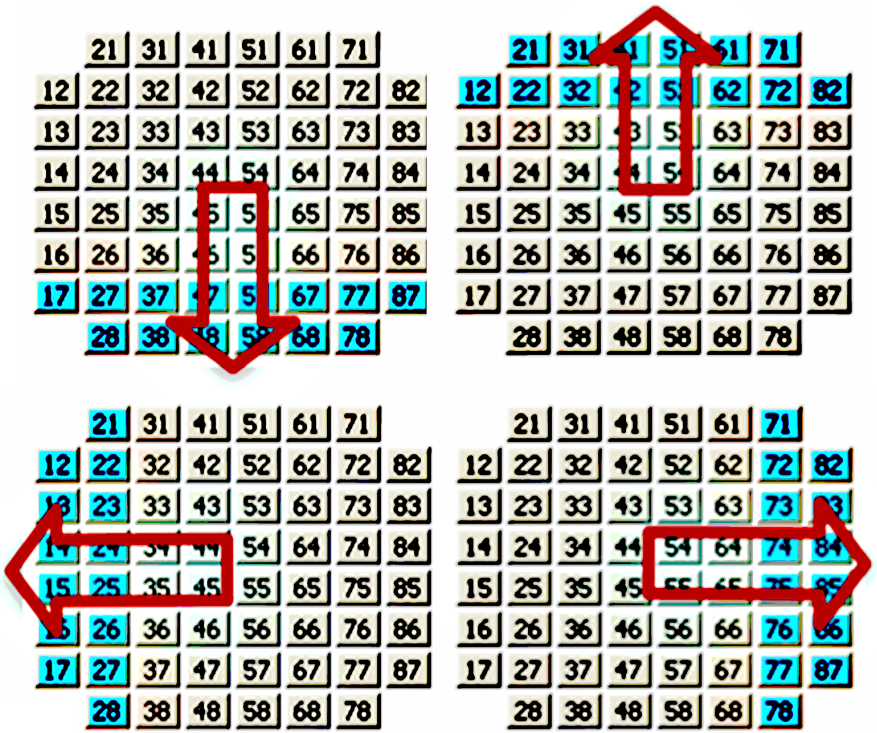
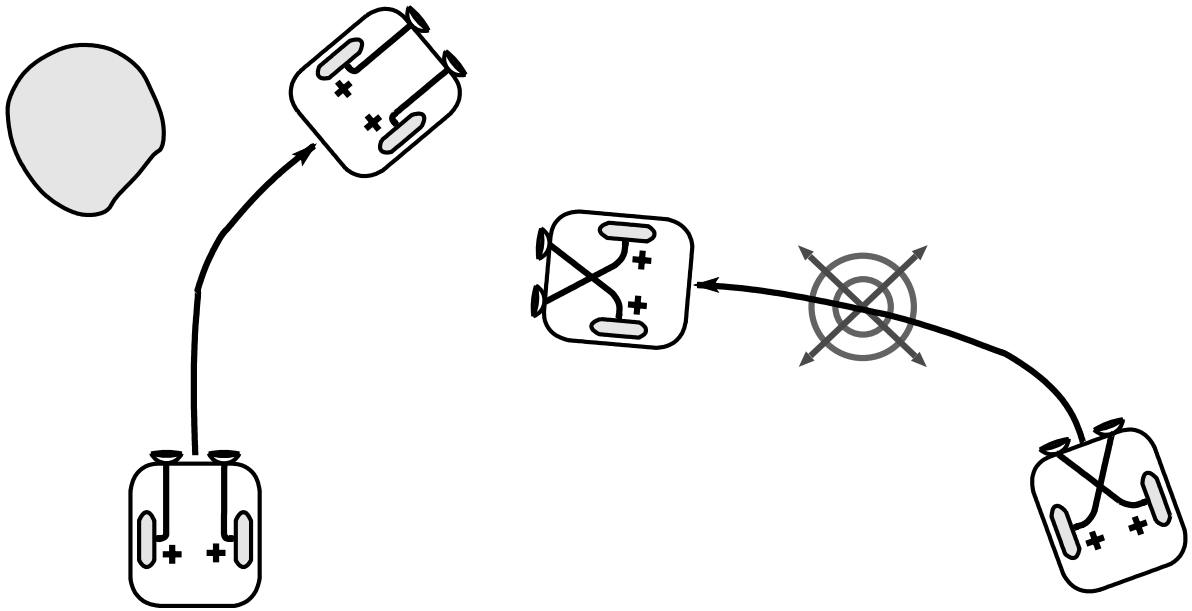
Selective stimulation

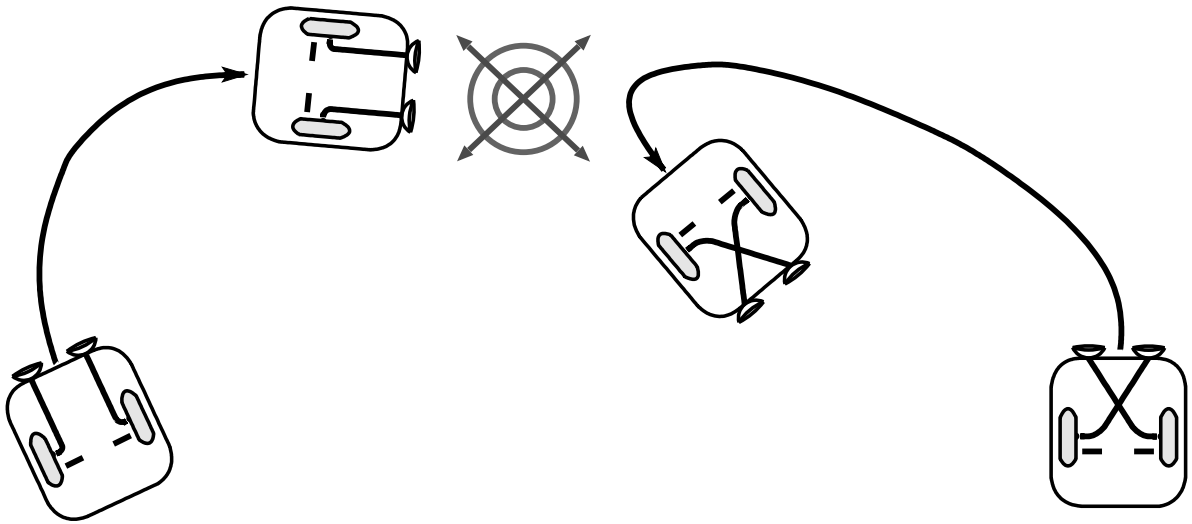


Selective electrode stimulation for collision avoidance, using direct excitatory connections from sensors to actuators.

Excitatory connections schemes



Inhibitory connections schemes



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Summary

- Growth and learning tests have been done.
  - Cultured human neuroblastoma cells can dendrify over a MEA.
  - LPT can be induced via tetanization.
- Cultured neuroblastoma cells may be used for very simple robot control.
  - Cells may be stimulated selectively to roughly represent sensors information.
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Future work

- Other simple robotic control implementations, e. g. Braitenberg's vehicles.
- Mixing two or more sensorial systems for more complex taxes, e. g. goal reaching.
  - Using several MEAs, very expensive.
  - Training subpopulations over one MEA, accuracy loss.
  - One sensorial system for cells and the others for conventional hardware.
  - Large spatial resolution through optical stimulation and reading.

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