Human Brain Project

15.12.2016, ShanghAI Lecture

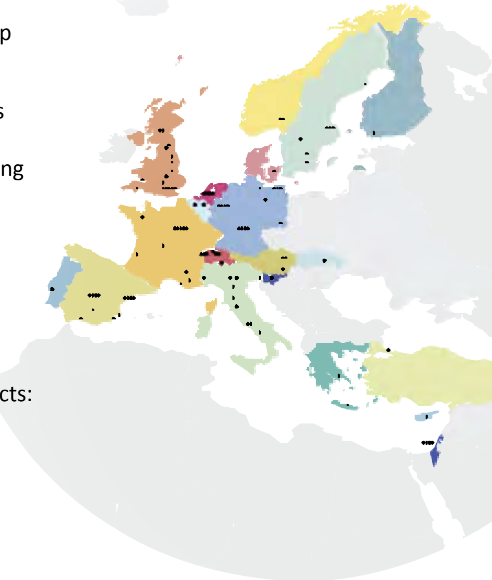
Tools for Virtual Neurorobotics

Florian Röhrbein

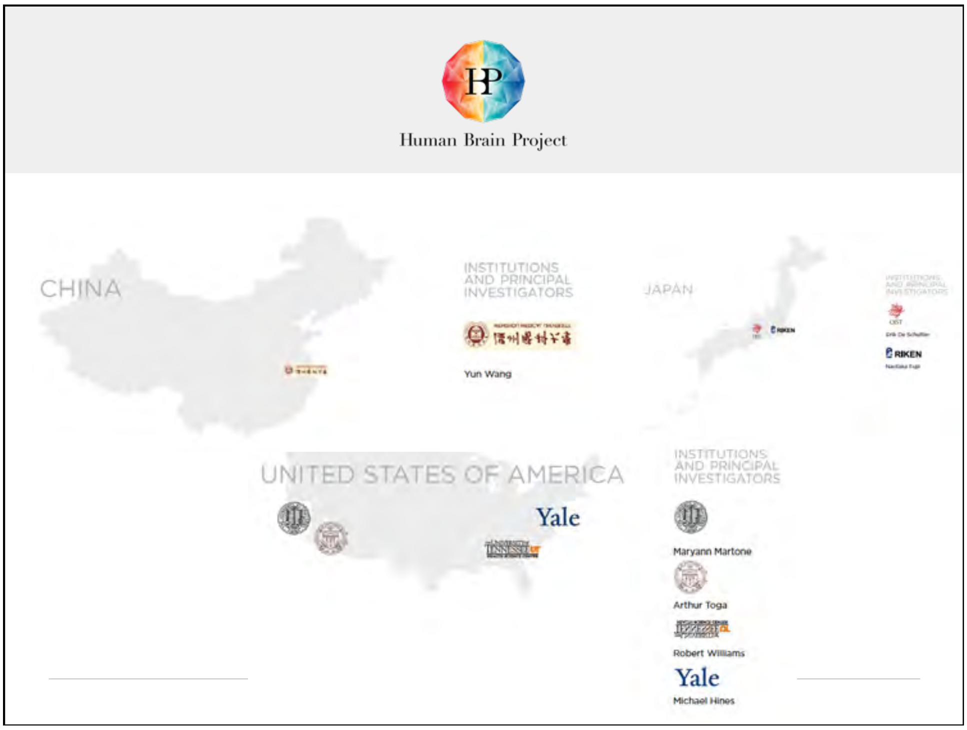
http://neurorobotics.net/

Robotics and Embedded Systems

The Human Brain Project at a glance



- Future Emerging Technology (FET) Flagship
- 10-year, **EUR 1 billion** Research Roadmap
  50% Core Project, 50% Partnering Projects
- Biggest EU ICT project: HBP uses ICT funding
- Ramp-up Phase (2 ½ years)
  - FP7 (54 million EUR)
  - 750+ scientists,
  - 114 institutions,
  - 24 countries, mainly Europe & Americas/Asia
- Builds on pre-existing EU & national projects:
  Blue Brain, BrainScaleS, JSC, SpiNNaker, Myorobotics
- Interfaces with EU & international efforts
  PRACE, US BRAIN initiative, …

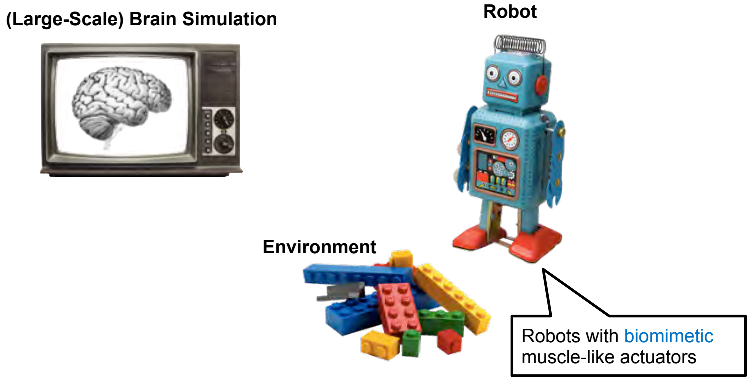


Neurorobotics in a Nutshell

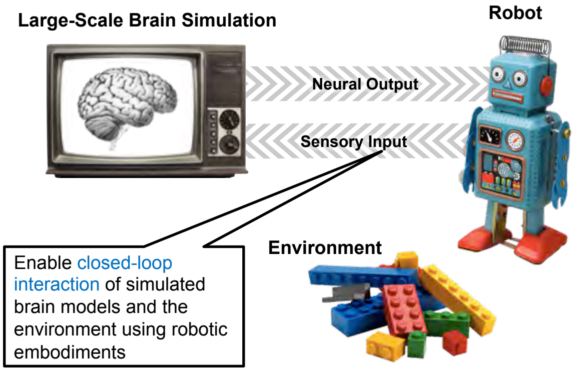
(Large-Scale) Brain Simulation

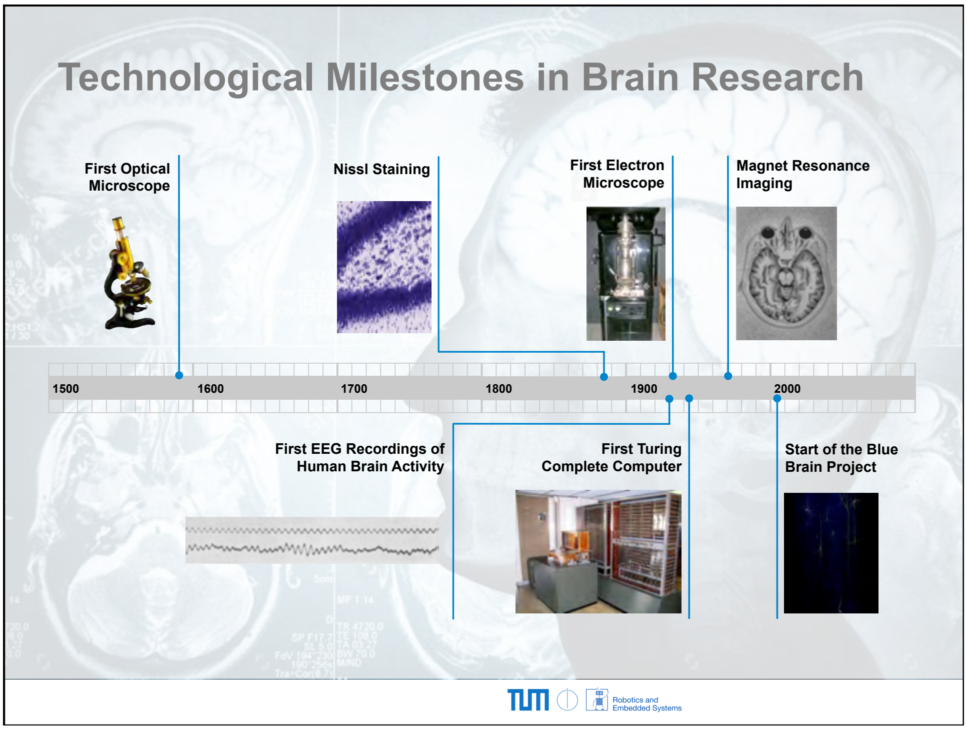
Biologically realistic large-scale models with millions of neurons

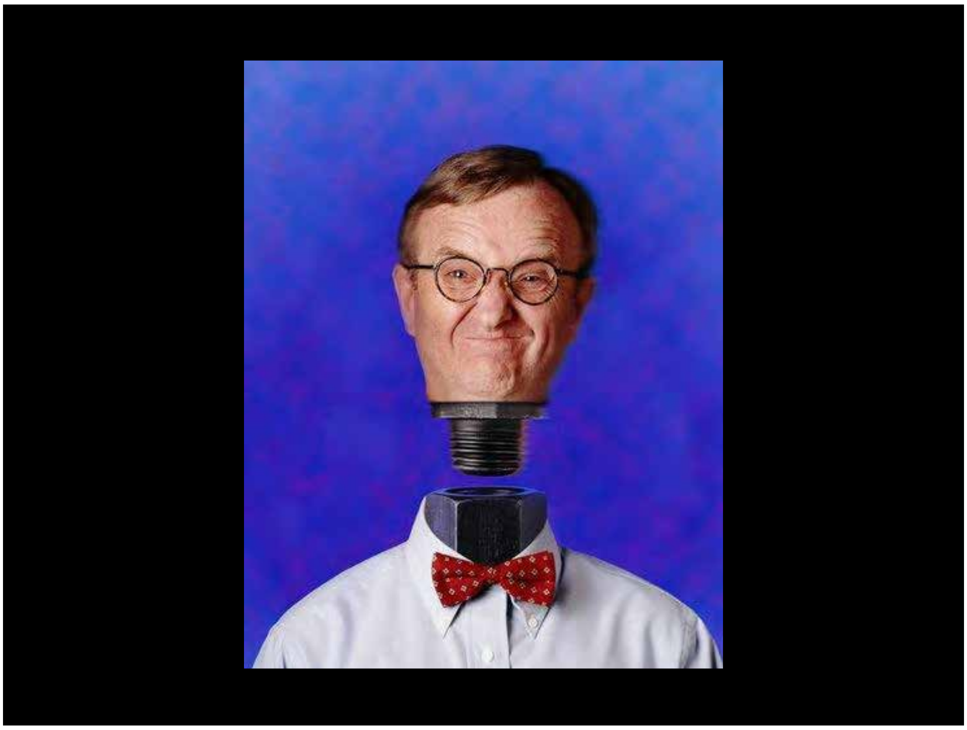
Neurorobotics in a Nutshell



Neurorobotics in a Nutshell



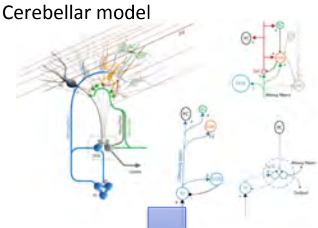

Technological Milestones in Brain Research
First Optical Microscope
Nissl Staining
First Electron Microscope
Magnet Resonance Imaging
1500
1600
1700
1800
1900
2000
First EEG Recordings of Human Brain Activity
First Turing Complete Computer
Start of the Blue Brain Project
Robotics and Embedded Systems



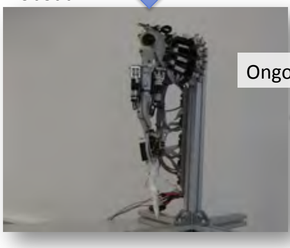
Towards physical robotics

Simulated robot arm

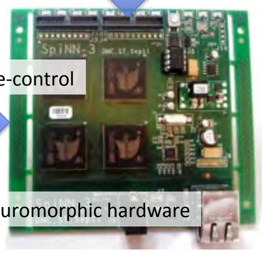
Cerebellar model



Physical robot arm



Ongoing: Realtime-control



Neuromorphic hardware

Definitions: What is a Robotics Simulator?

A **robotics simulator** is a simulation software used to create and test embedded applications for a robot (robot controller) without depending on the physical constraints of the real world.

I.e. the parameters of physical laws can be altered, simulations can – for instance – be slower or faster than realtime.

"**Simulation** is the imitation of the operation of a real-world process or system over time."*

Features of a Modern Robotics Simulator

- **Physics engine** in order to provide realistic movements
- **Realistic 3D rendering** of the robot and its environment
- May contain libraries of virtual entities
- May have an editor or designer for the entities
- May provide APIs or scripting interfaces

* J. Banks, J. Carson, B. Nelson, D. Nicol (2001). Discrete-Event System Simulation, p. 3.

Why Do We Want to Use a Robotics Simulator?

- **Reproducibility of experiments**
  - Rerun an experiment multiple times (deterministically)
  - Leads to higher observability
- **Influence on physical constraints**
  - Simple to influence surrounding conditions (simulation time, laws of physics)
  - Simulations make it possible to compute expensive algorithms that would need ages to run on real robot microcontrollers (e.g. genetic algorithms)
  - Test algorithms which may not yet run in realtime
- **Reduced time efforts and costs**
  - Quick and efficient testing of new concepts, strategies and algorithms (prevents costly errors)
  - Parallelization of work: Software can be developed while hardware is still constructed
  - Easier to setup, faster and more convenient to use (e.g. for sharing a showcase)
  - Building new robot models, setting up experiments takes way less time
  - Also results are (often) transferable to real robots (no extra costs for transfer)

Robotics Simulators – an Overview

Software	Developers	License	Physics Engine	3D Rendering Engine	Platforms
GAZEBO	**O**pen **S**ource **R**obotics **F**oundation	Apache 2.0	- ODE - Bullet - Simbody - DART	OGRE	Linux MacOS X (Windows)
MORSE	Academic community	BSD	Bullet	**B**lender **G**ame **E**ngine	Linux MacOS X BSD
Webots robot simulation	Cyberbotics	Proprietary	Custom version of ODE	OGRE	Linux MacOS X Windows
v-rep	Coppelia Robotics	Proprietary / GNU GPL	- ODE - Bullet - Vortex	Internal	Linux MacOS X Windows

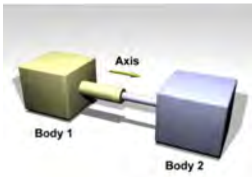
Information partly taken from http://en.wikipedia.org/wiki/Robotics_simulator

Robotics Simulators – an Overview

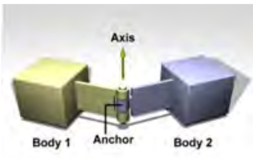
Software	Main Programming Language	Extensibility	External APIs	Formats	Robotics Middleware
GAZEBO	C++/Python	Plugins (C++)	C++	SDF/URDF	ROS, sockets (protobuf messages)
MORSE	Python	Python	Python	Own format, .blend	ROS, Sockets, YARP, Pocolibs, MOOS
Webots robot simulation	C++	Plugins (C++), API	C/C++, Python, Java, Matlab	WBT, VRML'97	ROS, URBI, NaoQI
v-rep	LUA	API, Add-ons, Plugins	C/C++, Python, Java, Urbi, Matlab, Octave	URDF	ROS, Sockets

Information partly taken from http://en.wikipedia.org/wiki/Robotics_simulator

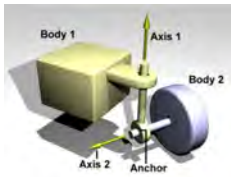
Gazebo Robotics Simulator | Element Types | Joint Types



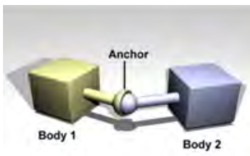
Prismatic: 1 DoF (Degree of Freedom) translational



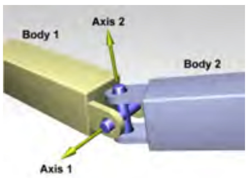
Revolute: 1 DoF rotational



Revolute: Two revolute joints in series



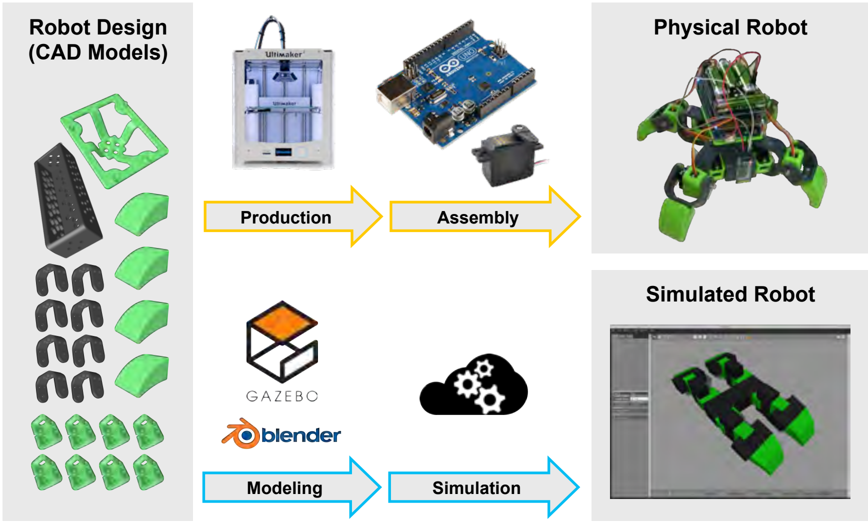
Ball: 3 DoF rotational



Universal: 2 DoF rotational

Source: http://gazebosim.org/assets/drc_kickoff_oct25_2012-43ef8c94bb51918fbd4912148cd20722.pdf

Translational Neurorobotics – A Case Study



Robotics and Embedded Systems

Goal of the project

Robotics and Embedded Systems

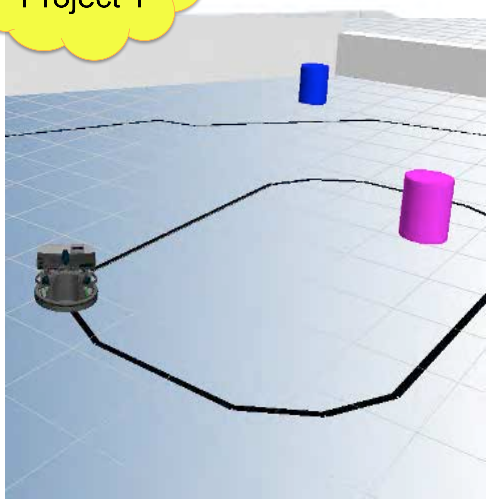
Student Project 1

Implementing a spiking neural network based lane following for the Robotino.

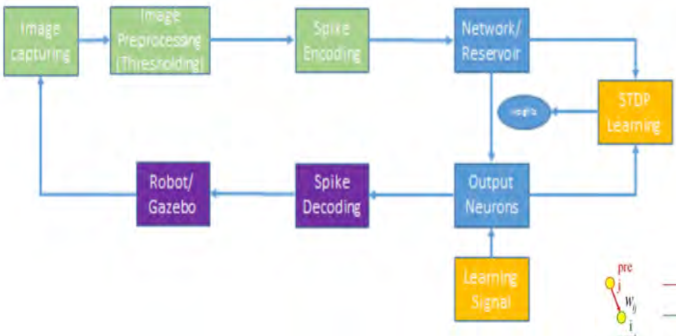
- In simulation (nest, gazebo)
- Real robot + SpiNNaker

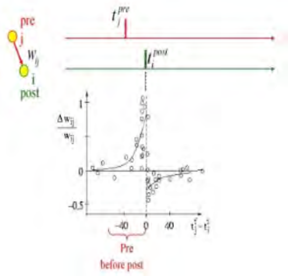
Additional objectives:

- Obstacles and robustness
- Use a dynamic vision sensor



System Structure



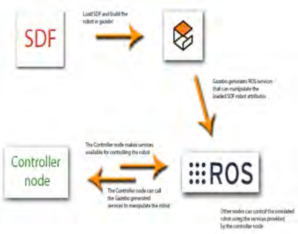


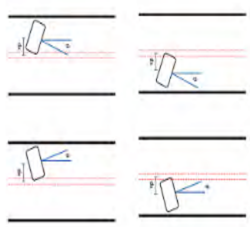
Input - Preprocessed image from camera

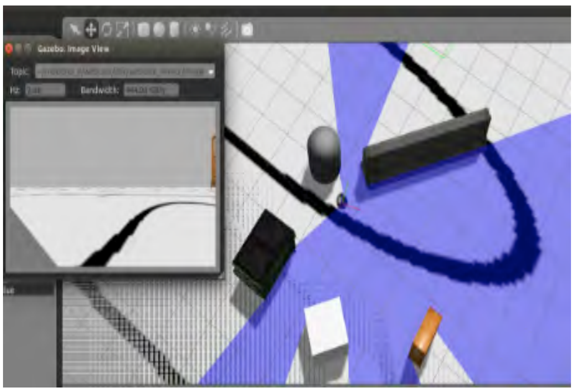
Output - Steering direction

Robotics and Embedded Systems

Gazebo Simulation







Toolchain for Rapid Deployment of **Machine Learning** Models for **Autonomous Driving**

Student Project 2

Daniel Plop

Rupam Bhattacharya

Nir Leibushor

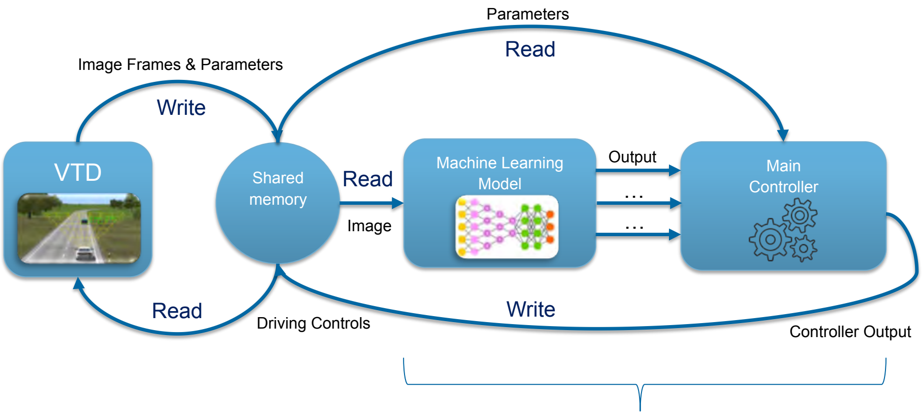
Technische Universität München

Informatik

Robotics and Embedded Systems

Garching, Datum 15. December 2016

System Architecture



Remote (e.g. TCP)
or
Local (RDB protocol)

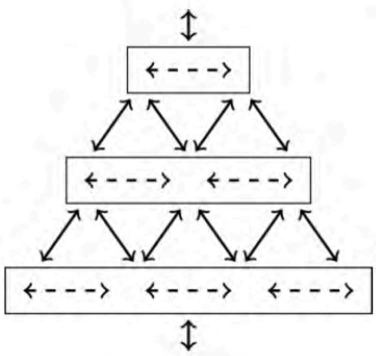
Multilayer Hierarchical Temporal Memory

Student Project 3

Goals

- Implementation of a general HTM network
- Testing with generated input data rooted in robotics
- Evaluation of an HTM network and their core idea

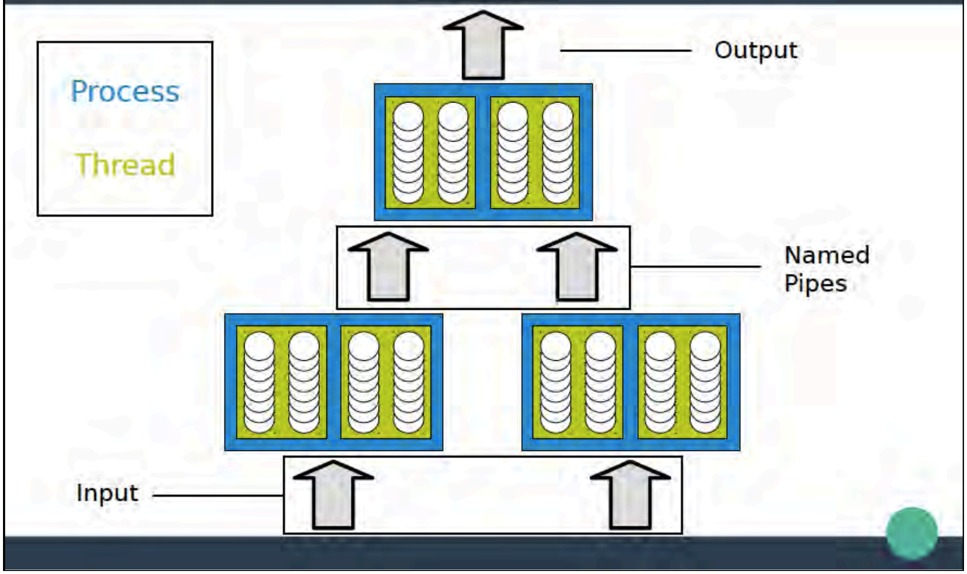
Multilayer Hierarchical Temporal Memory



Multilayer HTMs

- **Higher level predictions based on multiple other lower level predictions**
- **Simple ideas → complex ideas i.e. letters → words**
- **Unpredicted input = Anomaly**

Architecture



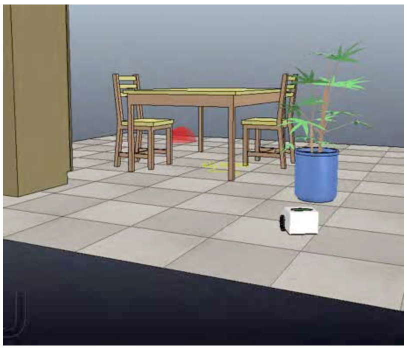
Student Project 4

1. Project Review

Goal:
- Navigation problem solved by:
  - Spinnaker
  - Neuroevolution with NEAT

Setup:
- 3D environment: V-Rep
- Two-wheel differential drive
- Short range distance sensors
- Relative goal position as input

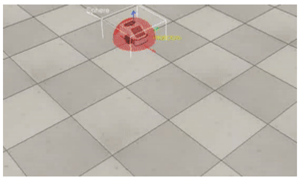
Challenges:
- Navigation
- Obstacle Avoidance
- SNN / SpiNNaker integration

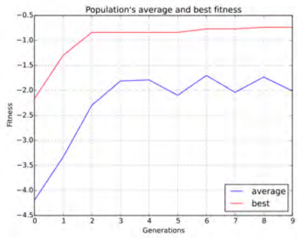


2. Approaches

4. Approach - ‘Working One’

- **Simulation**: V-Rep – one command, multiple samples
- **Inputs**: 2 – relative position of goal (x, y)
- **Outputs**: 2 – velocity command (v_L, v_R)
- **Goal**: Multiple fixed goals
- **Fitness**: Distance to goal
- **Result**:

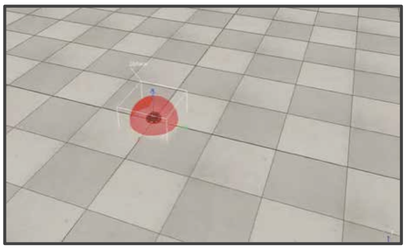


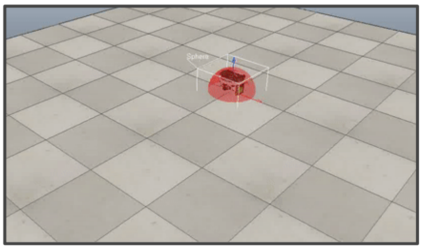


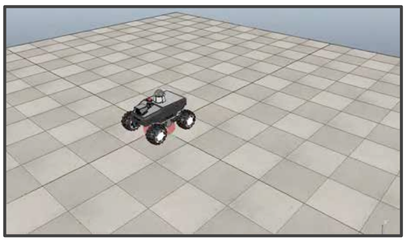
Problem:

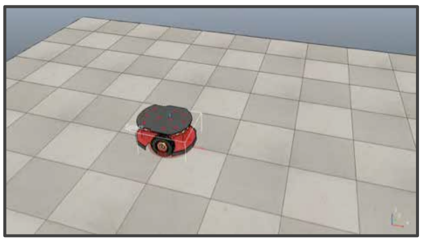
- Very slow – for 1 generation: 5 min (Population: 20, Samples: 20)

3. Various Robots









Objectives of the Neurorobotics Platform

SP10

With the Neurorobotics Platform, researchers can collaboratively design and run virtual experiments in cognitive neuroscience using brain models developed within and outside the Human Brain Project.

The Neurorobotics platform provides software and hardware tools for researchers to demonstrate how brain models can control robots in complex environments.

HBP Platforms

- **Collaborative research tools** for brain research and brain-inspired computing technologies.
- Prototype hardware, software, databases, brain atlases, and programming interfaces
- Embody the key objectives of the HBP
- **Continuous refinement** in close collaboration with end users
- Access as of today via the HBP Collaboratory

Photo: © John L Downes

Main Building Blocks (Server side)

The NRP is built on top of Gazebo

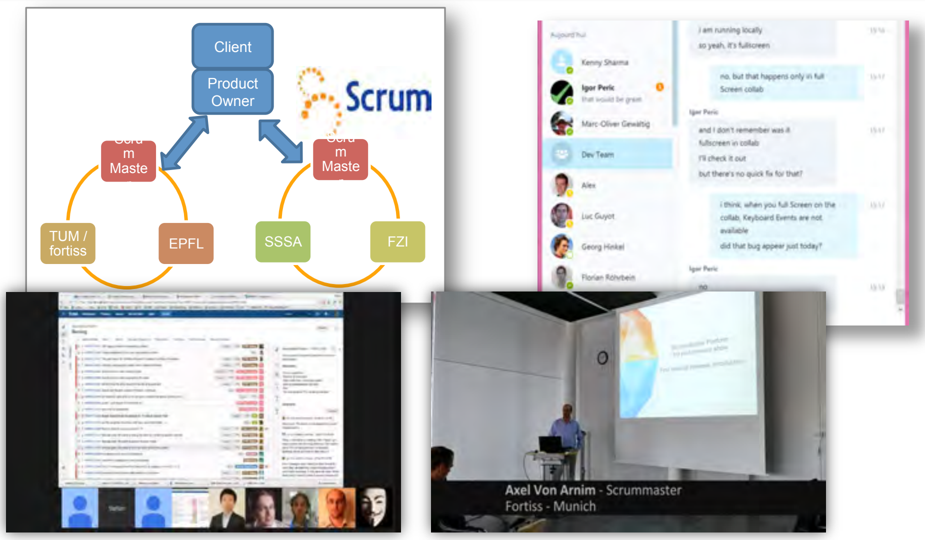
ROS is used as a middleware

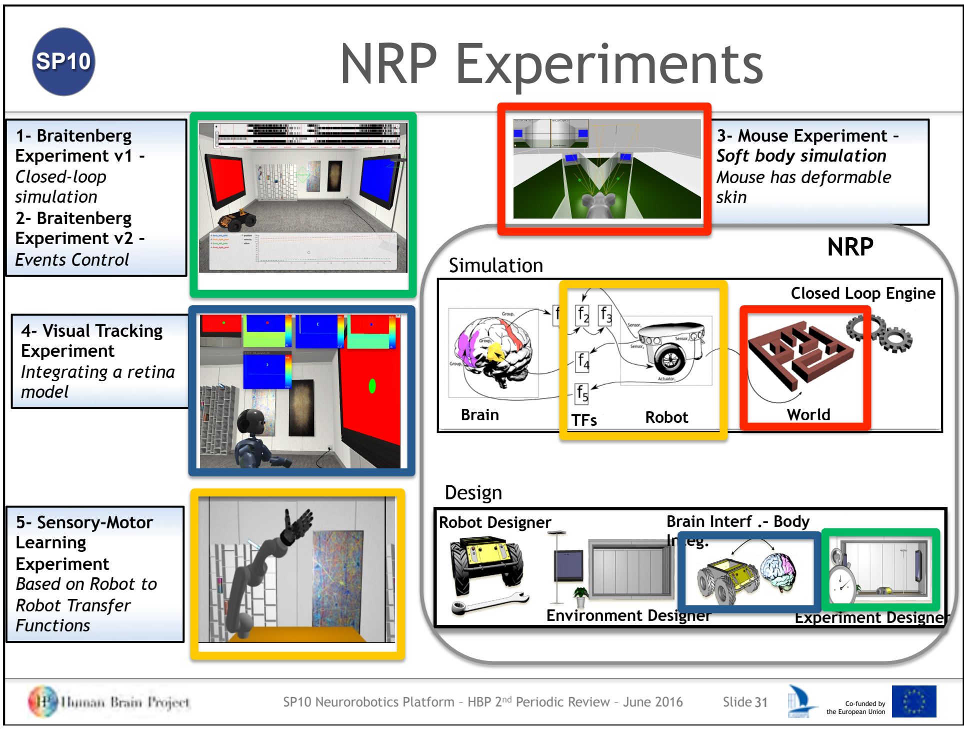
Python for the CLE and backend code

NEST is used as neuron simulator

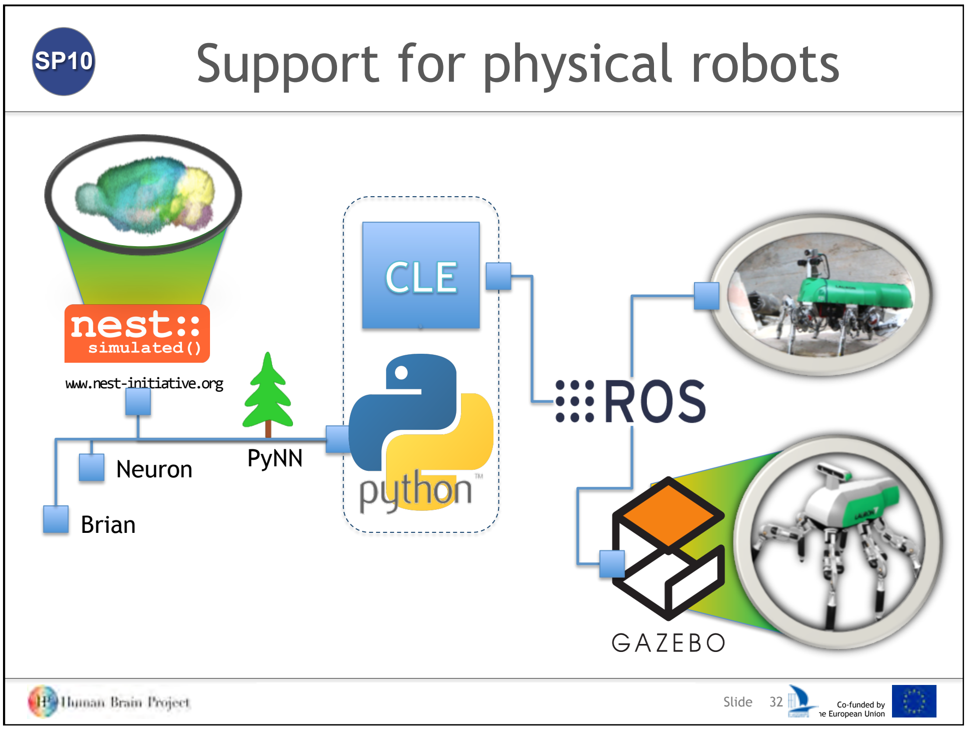
- Focuses on the dynamics, size and structure of neural systems rather than on the exact morphology of individual neurons

SP10 Methodology and communication





SP10
NRP Experiments
1- Braitenberg Experiment v1 - Closed-loop simulation
2- Braitenberg Experiment v2 - Events Control
3- Mouse Experiment - Soft body simulation
Mouse has deformable skin
4- Visual Tracking Experiment
Integrating a retina model
5- Sensory-Motor Learning Experiment
Based on Robot to Robot Transfer Functions
NRP
Simulation
Closed Loop Engine
Brain
TFs
Robot
World
Design
Robot Designer
Brain Interf .- Body Integ.
Environment Designer
Experiment Designer
Human Brain Project
SP10 Neurorobotics Platform - HBP 2nd Periodic Review - June 2016
Slide 31
Co-funded by the European Union



SP10
Support for physical robots
nest::
simulated()
www.nest-initiative.org
Neuron
Brian
PyNN
CLE
python
ROS
GAZEBO
Human Brain Project
Slide 32
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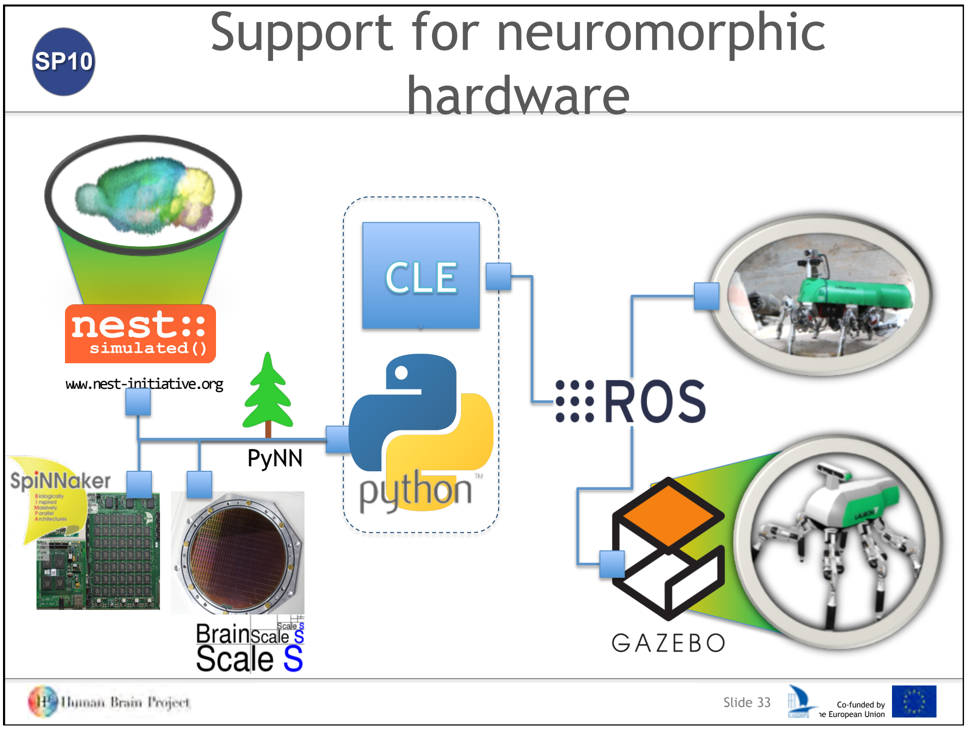
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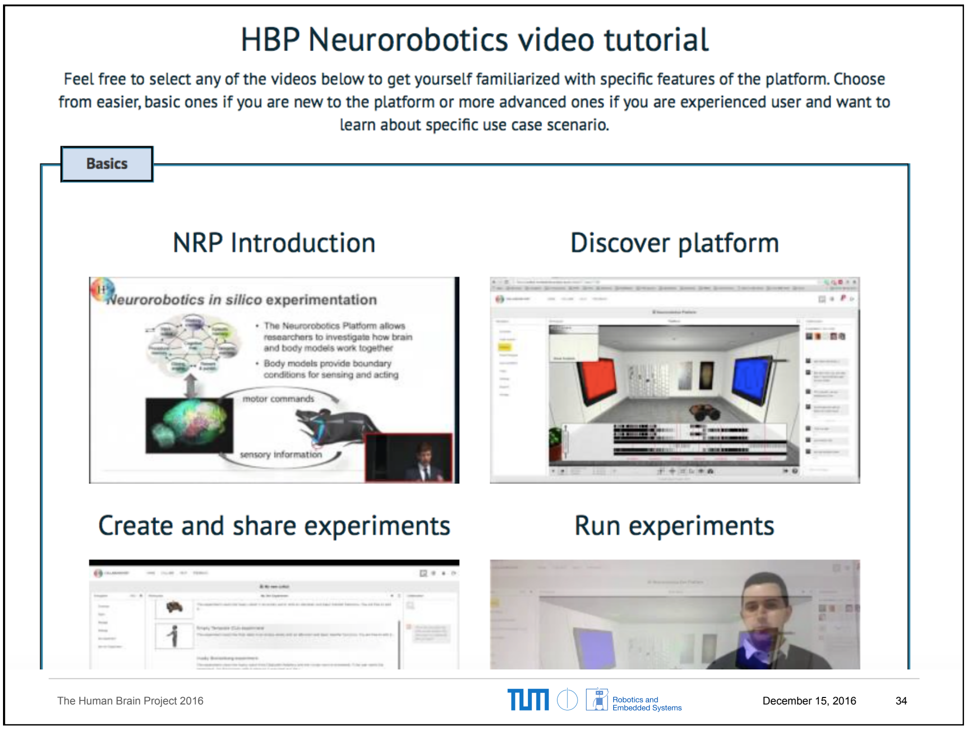
HBP Neurorobotics video tutorial
Feel free to select any of the videos below to get yourself familiarized with specific features of the platform. Choose from easier, basic ones if you are new to the platform or more advanced ones if you are experienced user and want to learn about specific use case scenario.
Basics
NRP Introduction
Discover platform
Neurorobotics in silico experimentation
The Neurorobotics Platform allows researchers to investigate how brain and body models work together
Body models provide boundary conditions for sensing and acting
motor commands
sensory information
Create and share experiments
Run experiments
The Human Brain Project 2016
Robotics and Embedded Systems
December 15, 2016
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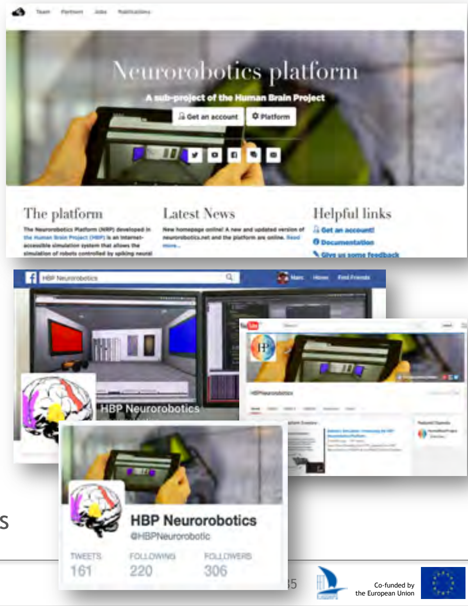
User community building

SP10

- Performance shows with open days
- Workshops and symposia
- Talks and demonstrations
- Platform homepage
  - www.neurorobotics.net
- Tutorial and demo videos
- Social Media
  - facebook.com/neurorobotics
  - twitter.com/HBPNeurorobotics
  - youtube.com/c/HBPNeurorobotics



Robotics and Embedded Systems

Thank your for your attention!

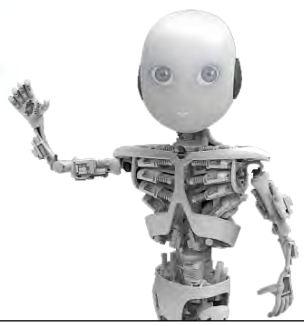
For more information visit us on

www.neurorobotics.net

and follow us on Twitter!

You Tube /HBPNeurorobotics

@HBPNeurorobotic



Human Brain Project