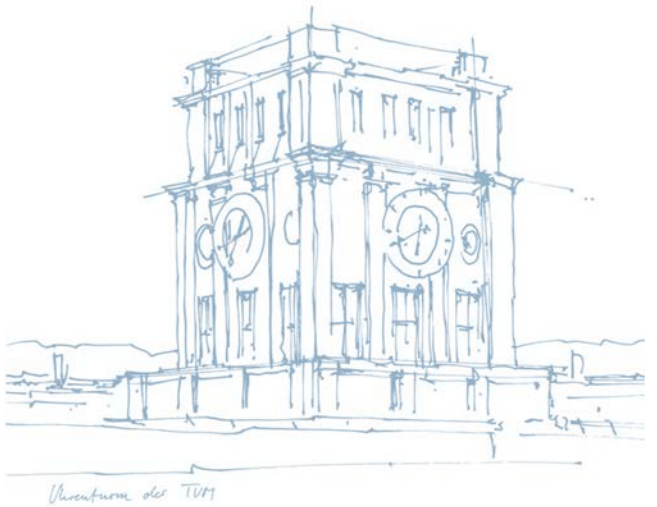
Human Brain Project

Robotics, Artificial Intelligence
and Real-Time Systems

The Neurorobotics Platform

Embodiment: Connecting neural models to function



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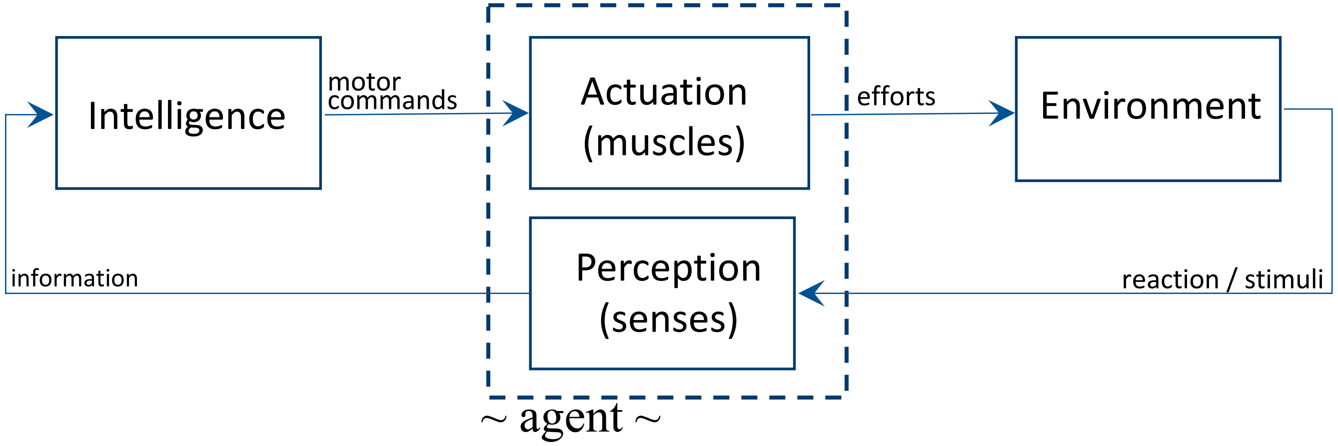
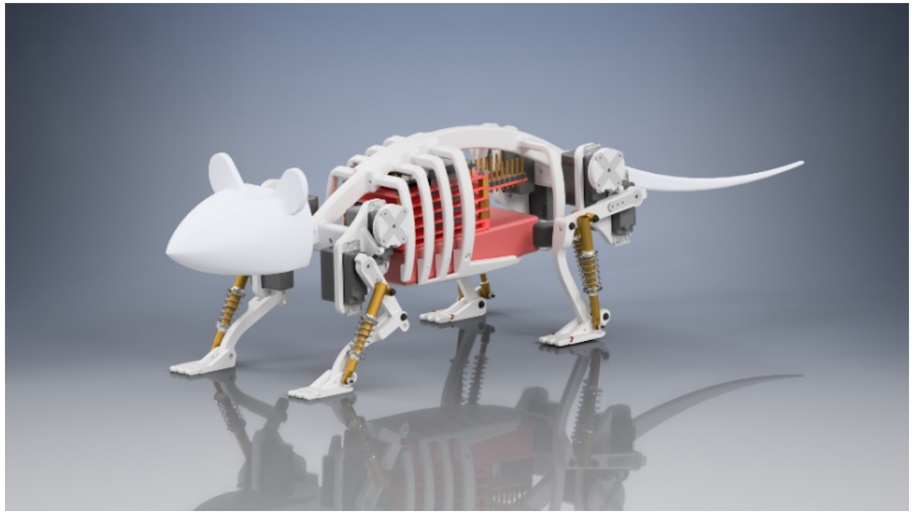
Embodiment

“**A brain is built to be about other things**.” That is: It takes in information about the world, and it moves human and animal bodies, which then influence that world. How much would we really learn from a disembodied brain in a virtual jar, which isn’t connected to eyes, ears, or limbs? “You could take a chunk of tissue and do all the physics, but it wouldn’t get at what it’s all for,” Fairhall says. “Biology is matter that has meaning. Simulating the tissue is doable, but meaningless.”

Prof. Adrienne Fairhall, The Atlantic, July 2019





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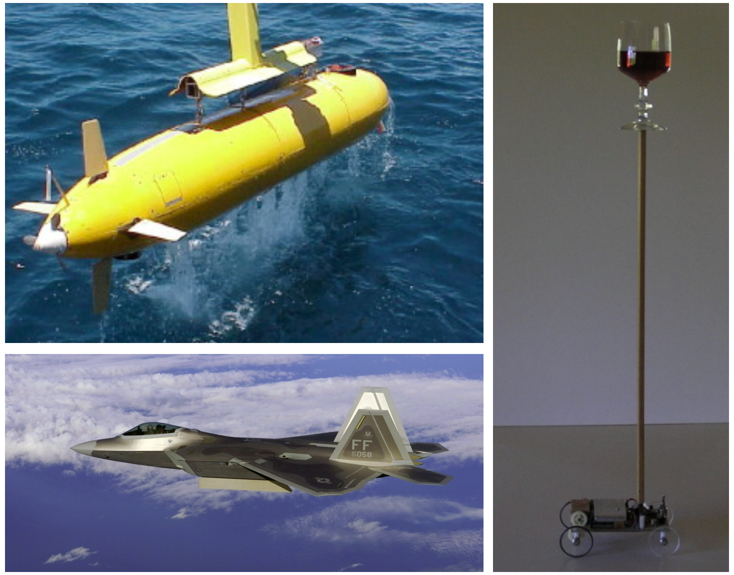
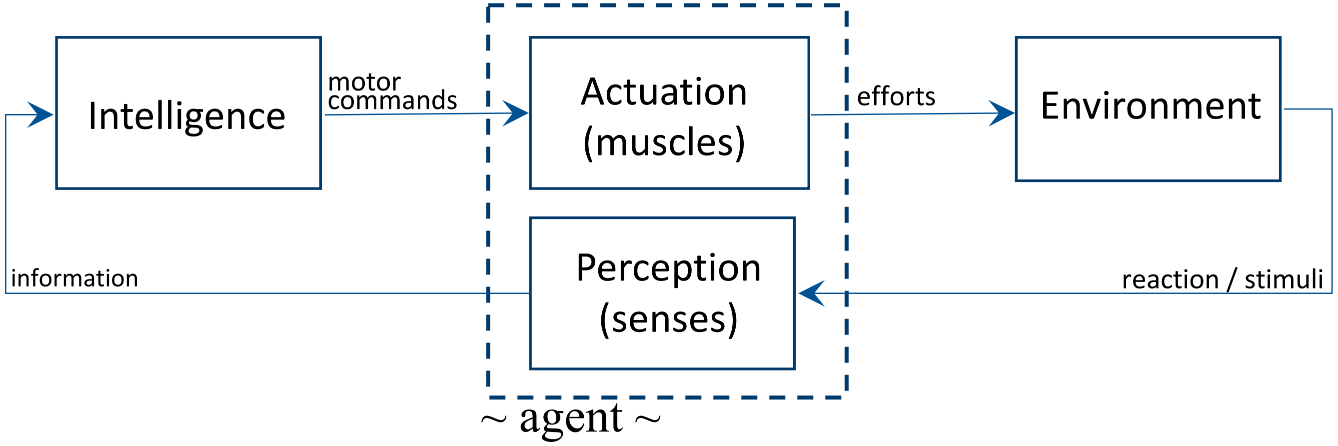
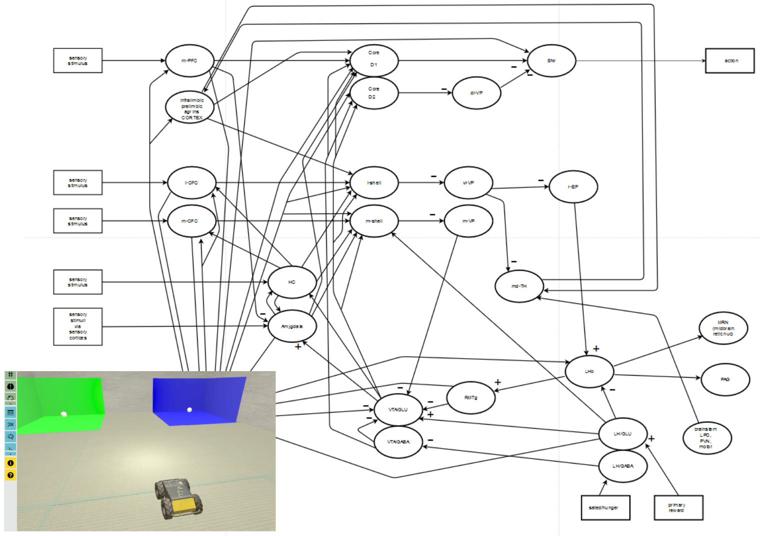
Closed-loop

- **Why**: Needed for delicate, dextrous, accurate, robust action.
- **Where**: From HDDs, to aeronautics, to biology; things that moves, anything that does something on its own (robots).
- <u>**Key notion**</u>: Closed-loop behaviour (usually) completely foreign to open-loop behaviour.







Limbic wiki map / Bernd Porr

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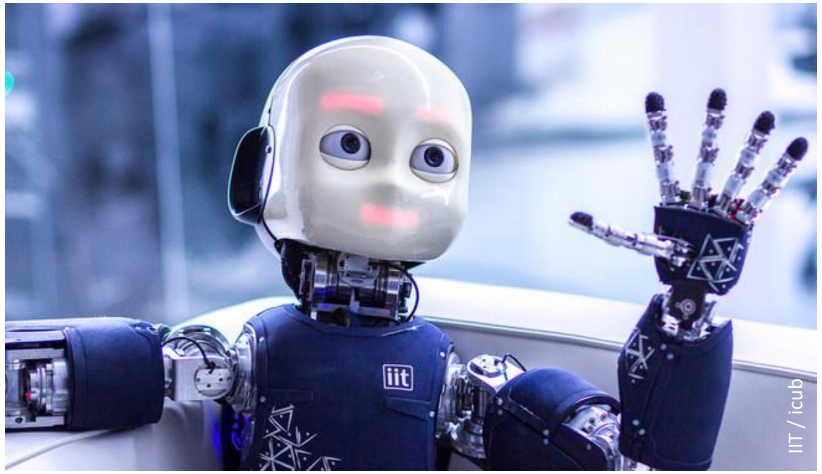
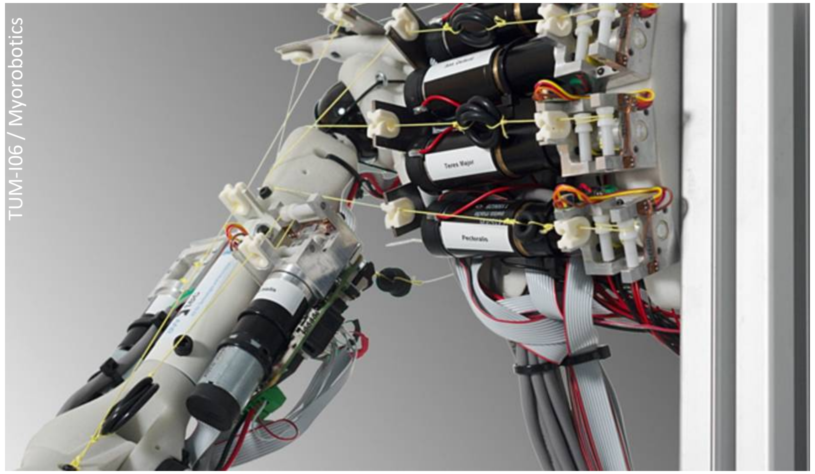
Connection to physical robotics

- **Immediate approach**: connection to real-world system, including robotic platforms,
- Systems supporting expression of function of interest, e.g. mobi-le platform for navigation, arm & gripper for grasping,
- **Downside**: Expansive, complicated, lots of downtime, high over-head.



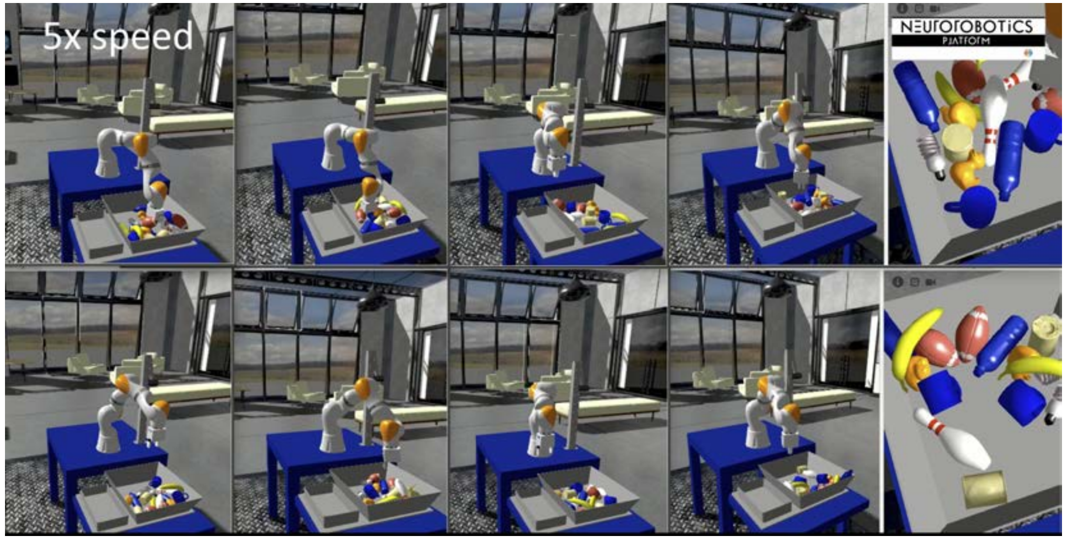


Embodiment in simulation

- **Addresses real-world systems limitations**: no hardware costs, no maintenance, no downtime, scale-up with compute resources,

- **Additional benefits**: no real-time constraint (computations), no absolute physics constraint, accelerate time, parallelize execution (data generation), digital twin functionality (visibility on all internal variables).

- **Limitations**: faking physics, how accurate is accurate enough?



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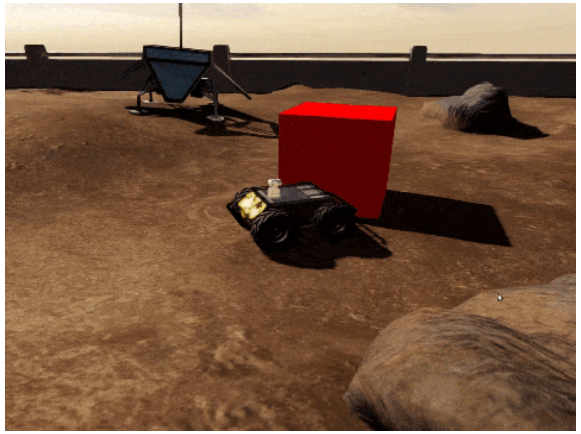
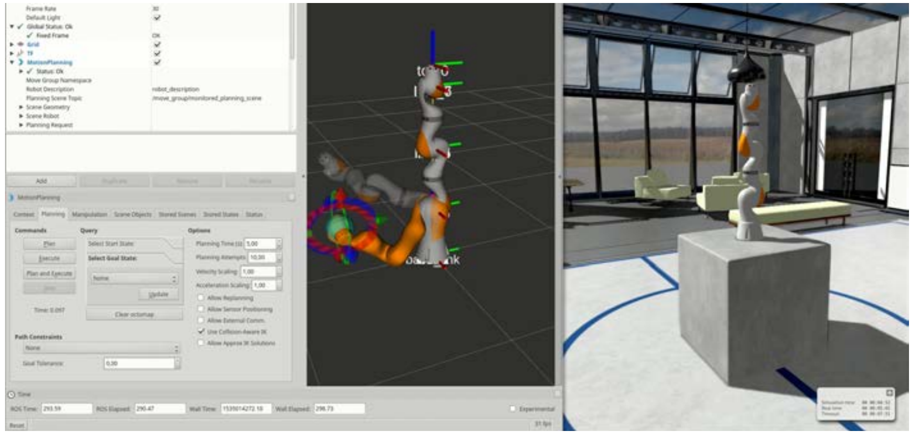
Why is simulation difficult?

- **Core challenge**: Providing faithful reflection of physical interactions with environment,
- **Problem**: Some things easy to model, other not so much, e.g. friction,
- **Computational cost**: Some things easy to model analytically, expansive/difficult to compute; e.g. high DoFs systems, MB systems, closed kinetic chains, grasping,
- **Bottom line**: Some things better in simulation, others better in the real-world.

(a) Bullet Constraint-based Simulation

(b) Penalty-based Simulation



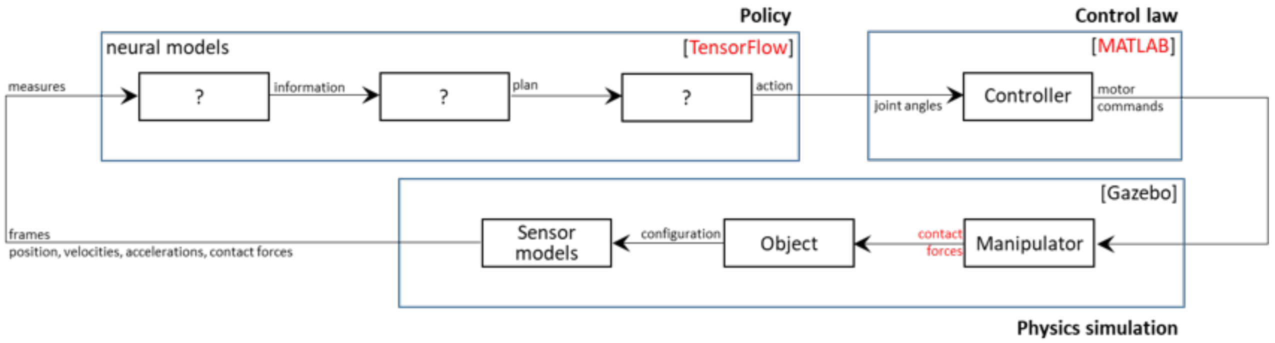


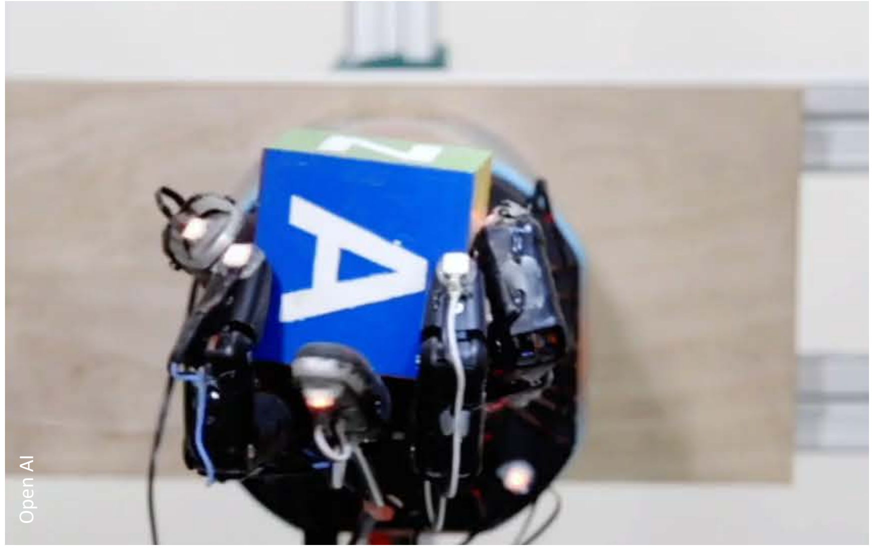
Applications

- **Grasping**: Deep learning for robotic grasping,
- **Virtualisation** of approach implemented a few years back,
- **Why**? No HW cost, acceleration of data generation, illustrating faithfulness of physics simulation (PoC for learning virtualisation of grasping),
- **NRP**: Pilot study, motivates implementation of necessary workflows for learning (scripting, data generation, distribution on HPC VMs, scalable compute).

Applications

- **Dexterous grasping**: Fine motor control, precise interaction with object/environment,
- SGA2 Voucher (Zechmair-Morin/TUM), SGA3 Demonstrator (Senden/UM),
- **Industrial interest**: Implementation of Shadow motivated by request from industrial partner, Shadow Robotics,
- **Practical use**: Delicate object manipulation (short terms), and humanoid robotics (longer term).





Applications

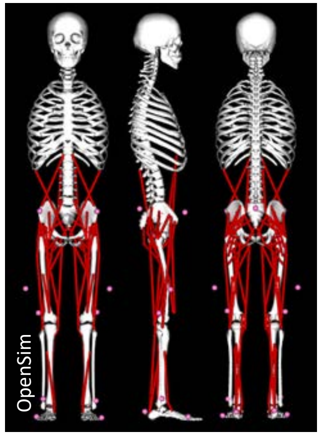
- **Modern robotics terrible** at higher-level of abstraction problems,
- **Robust solutions to**: Scene decomposition, relational reasoning, planning and navigation, decomposition of complex tasks in simpler problems; open substantial **application perspectives**.

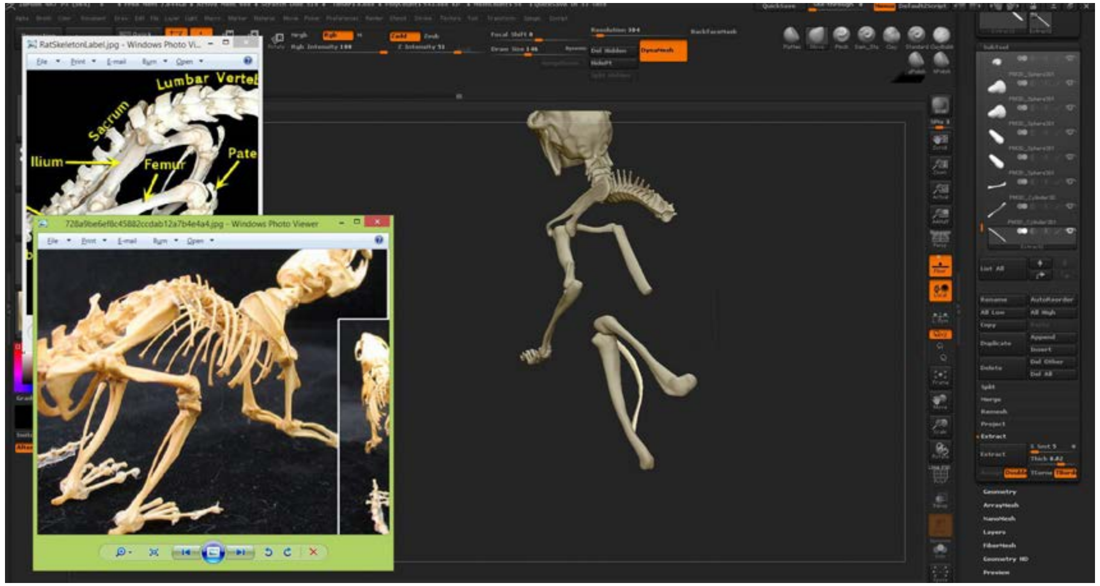
1. **Intelligent warehouse**: Mobile shelves, space occupancy reduction, faster order assembly,
2. **Collaborative assembly**: multiple robotic arms, human in the loop.

The NRP: closed-loop embodiment

What's it good at?

- **Physics**: Expanded capacities compared to Gazebo, integration of OpenSim, specialized work on collision/interactions for grasping.
- **Design tools**: Robot-designer for musculoskeletal systems, environment designer,
- **Ready-made examples**: Agents (mobile systems, robotic arms, etc.), closed-loop simulation examples,
- **NMC**: SpiNNaker backend (UMAN),
- **HPC**: VMs, scalable compute resources (CSCS).





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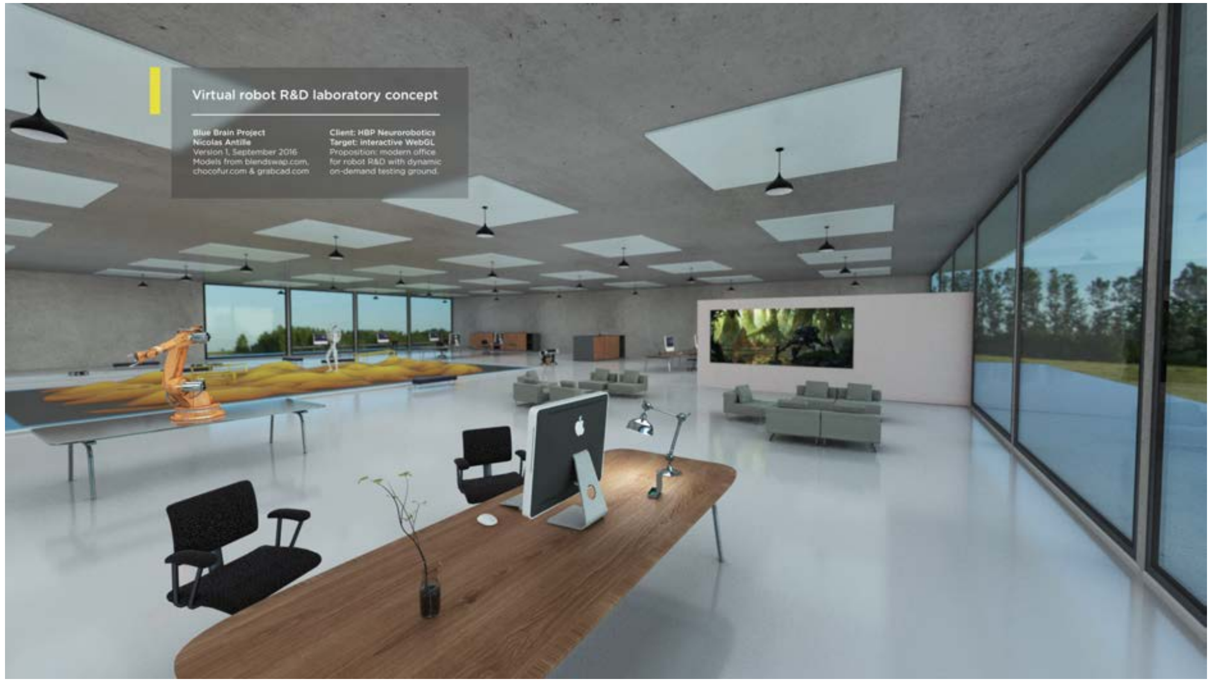
The NRP: closed-loop embodiment

Working on?

- **Usability**: Ambitious, overhead in implementing simulation scenario,
- **Flexibility**: Architecture rooted in NEST and Gazebo, need to code way to flexibility (e.g. MATLAB, TensorFlow).

What next?

- **CSCS/UNIPV Use-Case**: 100K spiking neuron cerebellar model (now),
- **X-Platform WFs**: Across SIMFLOW, KG (now),
- **Modularity**: Composition of functional algorithmic modules (end 2020),
- **NRP lite™**: Streamlined, immediate usability (end 2020).



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