VIBRAINT: A Visual-Brain Tool
Visualizing High-Level Cognitive Functions in a Brain Architecture

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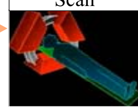
Abstract

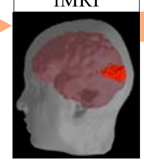
The Visual Brain Tool (VIBRAINT) research program is attempting to bridge the gap between higher-level cognitive functions and system-level brain-structures. The methodology used is one of defining and cataloging primitive cognitive functions (brain-processes) and mapping these to corresponding brain structures. VIBRAINT's approach involves a multi-tiered distributed-event simulation capability that allows simultaneous simulation of cognitive functions and mappings of these functions to both brain-processes and brain-structures. This capability potentially offers free computing-power (P-to-P on the Internet), enabling large-scale simulations.
In a typical simulation, a functional model is mapped to elementary brain-process instructions of which it is assumed that these implement the functional model. These instructions are then mapped to brain-structures. Interactive visualization and analysis enables both viewing and debugging the simulation at run-time and in replay, as well as comparing real fMRI with 'virtual-fMRI' based on the simulated activity of these brain-structures. 'Device driver' nodes in a simulation open up the possibility to interface with real physical devices (e.g. artificial retina, robotic limb).
Although there are still many open questions, we think this approach will allow brain researchers and cognitive scientists to systematically integrate models and theories, predict fMRI output, and subsequently check their hypotheses by comparing predicted output with real experimental fMRI data.

Cognitive task

Scan

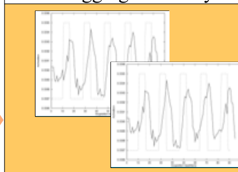


fMRI



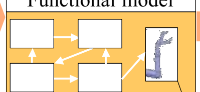
Interactive visualization and analysis enables both viewing and debugging the simulation at run-time and in replay, as well as comparing real fMRI with 'virtual-fMRI' based on the simulated activity of these brain-structures.

Interactive visualization, debugging and analysis



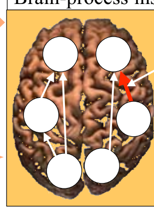
Cognitive theory

Functional model

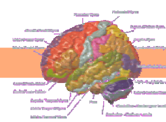


Compile

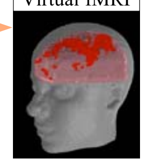
Brain-process instructions



Virtual Lesion



Virtual fMRI



Virtual fMRI enables researchers to directly compare computational models with biological brains. BPIs send activation signals to brain-structures. Activation is translated to a BOLD signal. Virtual fMRI is generated from this simulated BOLD signal. The result is visualized as a 3D structural model of a simulated brain.

Neurobiological theory

Device driver nodes allow embedding of robotic limbs, artificial retina, etc., for interaction with the real world.

Simulate

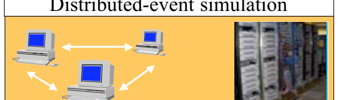
A BPI set consists of elementary operations executable by the brain. It is used to compile cognitive models to brain-processes. These processes are then mapped to brain-structures. This approach enables simulated lesion studies and virtual fMRI.

Effective distribution of neuronal structures over nodes enables the simulation of large-scale models over a peer-to-peer network like the Internet, but also on cluster machines. This approach facilitates the use of VIBRAINT since it does not require specific hardware investments.

Simulate

Lesion studies are a common tool in neuroscience. Detailed BPI's enable simulated lesion studies and, in combination with Virtual fMRI, give direct feedback about cognitive neuroscientific hypotheses.

Distributed-event simulation



Simulating a model at real-time (or hyper time) enables embedding of time-critical devices in a simulation allowing real-time interaction.

"The Holy Grail"

1. Use virtual fMRI and virtual lesions to validate and advance integration of system-level cognitive-neuroscientifc models and theories (e.g. computational models of consciousness).
2. Debug and test higher-level cognitive functions that, once implemented, will control robotic devices.
3. Simulate drug effects on cognitive functions.
4. Debug and test neuroprostheses in a safe, easy to parametrise setting.

Open Questions

1. How does simulated activity of brain-structures relate to BOLD signals?
2. How to effectively distribute neuronal structures over nodes?
3. How to 'compile' higher-level cognitive models into brain-processes.
4. What is a meaningful abstraction for a brain-process instruction-set?
5. What kind of instructions would be needed (parallel, serial, non-deterministic)?
6. How to integrate time-critical devices in a distributed-event simulation?

Related work

Large-scale high-performance modeling: SpikeNet (A. Delorme and S. Thorpe 2001), SPLIT (P.Hammarlund and O. Ekerberg, 199

System oriented simulators: Catacomb2 (R. C. Cannon et al, 2002), NEOSIM (N. Goddard et al, 2001), NeuroML

Other: The Whole Brain Atlas (K. A. Johnson and J. A. Becker), Human Brain Project, XtremWeb