How Minds Work
Brains, Ontologies & Virtual Machines

Stan Franklin
Computer Science Division &
Institute for Intelligent Systems
The University of Memphis
Question: How do minds work? What would an answer be like? That depends on the level of granularity.
Granularity in Science

<table>
<thead>
<tr>
<th>Field</th>
<th>Subfield</th>
<th>Example Entities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuroscience</td>
<td>Neuroanatomy</td>
<td>Hippocampus, amygdale, neocortex</td>
</tr>
<tr>
<td>Neuroscience</td>
<td>Neural tissue</td>
<td>Neuropil, cortex, layer, cluster</td>
</tr>
<tr>
<td>Neuroscience</td>
<td>Neurons</td>
<td>Cell body, dendrites, axon, membrane</td>
</tr>
<tr>
<td>Biology</td>
<td>Cell biology</td>
<td>Membrane, nucleus, mitochondria, organelle</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Organic chemistry</td>
<td>Alcohol, acid, amine, phosphate, amino acid</td>
</tr>
<tr>
<td>Chemistry</td>
<td></td>
<td>Elements, molecules</td>
</tr>
<tr>
<td>Physics</td>
<td>Nuclear physics</td>
<td>Atoms, protons, electrons, neutrons</td>
</tr>
<tr>
<td>Physics</td>
<td>Sub-atomic physics</td>
<td>Quarks, bosons, hadrons, leptrons</td>
</tr>
</tbody>
</table>
Levels of Granularity

Each level has its own

- Entities
- Relations
- Processes
- Theories

Each level

- Supports the level above it
- Needs its own theories to explain it
- Theories are in terms of its own ontology
Ontology?

• Philosophy—the study of the nature and relations of being
• Computer Science—a specification of the objects in a system and their relations
• How Minds Work—a particular collection of entities, relations, processes
A Simple Ontology
Types of Machines

• Matter manipulating machines — *diggers, drills, cranes, cookers*, …
• Energy manipulating machines — *drill, cookers, transformers, steam engines*, …
• Information manipulating machines — *thermostats, controllers, most organisms, operating systems, compilers, organizations, governments*, …
# Computational Virtual Machines

<table>
<thead>
<tr>
<th>Type</th>
<th>Virtual Machine Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application program</td>
<td>Microsoft Word, Internet Explorer, computer games, IDA</td>
</tr>
<tr>
<td>Developmental environment</td>
<td>JDK, JRE, Java Gnome, IntelliJ IDEA, etc.</td>
</tr>
<tr>
<td>Operating system</td>
<td>Berkeley Unix, Windows XP, Mac OS X, Red Hat Linux</td>
</tr>
<tr>
<td>Microcode</td>
<td>Specific to each machine</td>
</tr>
<tr>
<td>Hardware</td>
<td>Mainframe, PDP-11, IBM-PC, Mac Powerbook, Dell, etc.</td>
</tr>
</tbody>
</table>
Virtual Machines

• Can be implemented on
  – Physical machines
  – Other virtual machines

• Composed of abstract entities — words, sentences, numbers, bit-patterns, trees, procedures, rules, etc.

• Have causal powers

• Obey internal laws, but not physical laws
Things vs Agents

• Things (*molecules, rocks, planets, etc.*) react to physical forces acting on them

• Autonomous agents (*animals, mobile robots, software agent, etc.*) initiate (goal constrained) actions

• Autonomous agents have control structures, that is, *minds*
Mind and Information

• Minds are control systems
• Control systems must *produce, process* and *use* information
• What’s out there? (*perception*)
• What do I do about it? (*action selection*)
• How do I do it? (*procedural control*)
Minds as Virtual Machines

- Not every mind is a virtual machine — a thermostat’s is purely causal
- The mind of any mobile robot or software agent is a virtual machine implemented on another virtual machine
- The minds of humans or animals are virtual machines implemented on brains
Virtual Machine on a Brain

• Entities include *qualia, objects, categories, feelings, intentions, internal images, internal speech, etc.*

• Relations include *cause, before, on top of, isa, is not, can drink from, etc.*

• Processes include *perception, memory, action selection, learning, etc.*

• Note the partial ontology just created
**The Major Structures of the Neuron**

The neuron receives nerve impulses through its dendrites. It then sends the nerve impulses through its axon to the terminal buttons where neurotransmitters are released to stimulate other neurons.
Synapses

- Pulse - chemical - wave
- Excitatory or inhibitory
- Neurotransmitter reuptake
- Signal vs modulator
- Learning via strengthening
- Decay with disuse
Brains, Ontologies & Virtual Machines

Neurons in Action

• Neurotransmitters cross synaptic clefs changing the voltage of the neuron
• Internal voltage exceeds threshold
• Triggers pulse down the axon
• Releases neurotransmitter at each synaptic clef
About Neurons

• Little used neurons tend to die
• Learning by
  – Strengthening synapses
  – Adding new synapses
  – adding new neurons
• Interneurons vs projection neurons
The Triune Brain

- **Reptilian brain**
  *snakes, lizards – hunger, temperature control*

- **Limbic system**
  *cats, rats – mood, memory*

- **Neocortex**
  *primates – social, planning*
Lobes of the Human Neo-cortex

- Parietal Lobe
- Occipital Lobe
- Cerebellum
- Frontal Lobe
- Temporal Lobe

Brain Stem
A Cognitive “Theory of Everything”

- Sensation
- Perception
- Feeling & Emotion
- Working memory
- Episodic memory
- Consciousness
- Learning

- Deliberation
- Volition
- Automization
- Action Selection
- Problem solving
- Self
- Metacognition
Assigned Readings


Your "3-Brains-in-One" Brain
http://www.psycheducation.org/emotion/triune%20brain.htm (take the tour)
Email and Web Addresses

• Stan Franklin
  – franklin@memphis.edu
  – www.cs.memphis.edu/~franklin

• “Conscious” Software Research Group
  – www.csrg.memphis.edu/