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State of AI and ML - Summer 2019

Cognitive Architecture in Models for Natural and Artificial Intelligence

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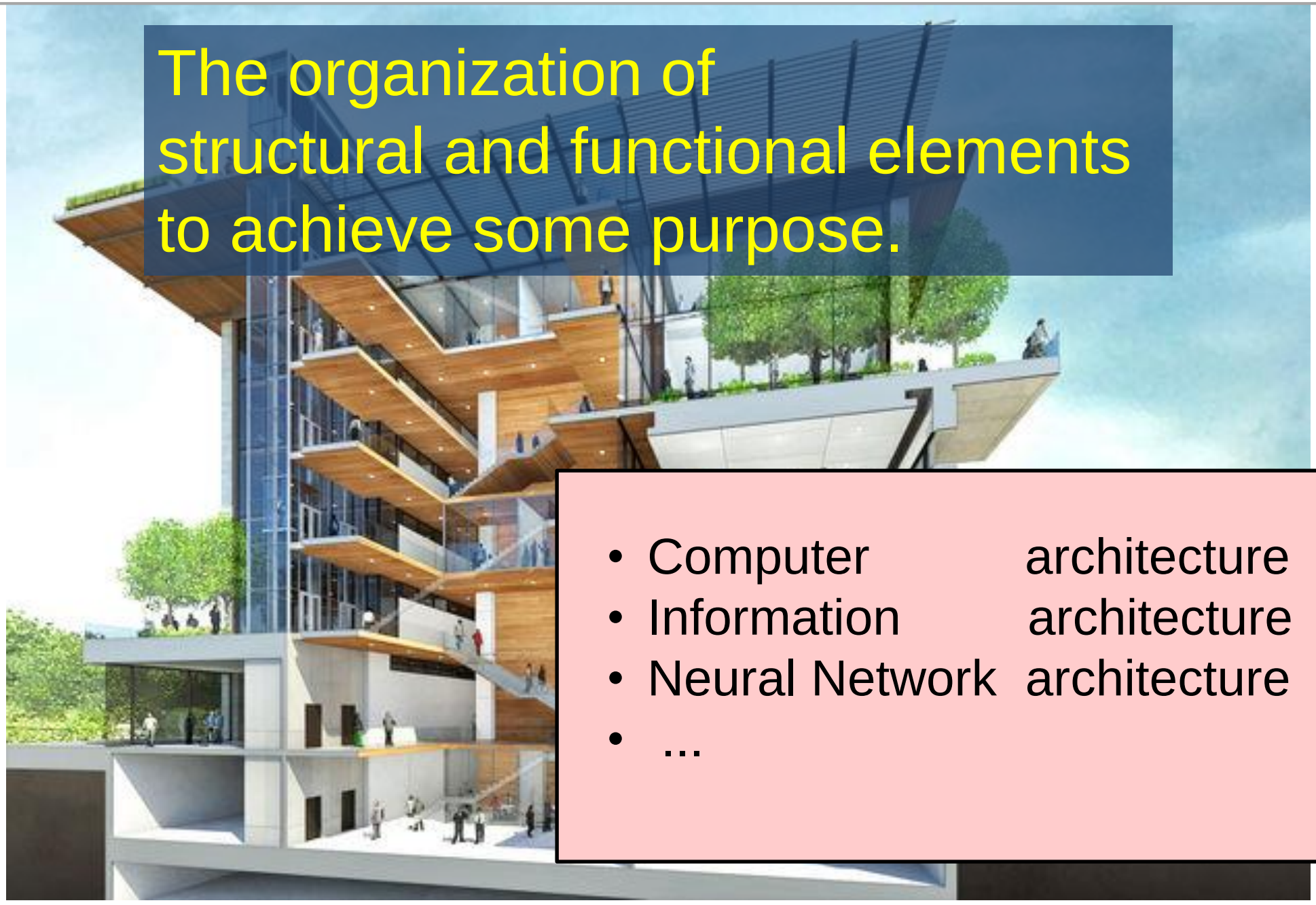
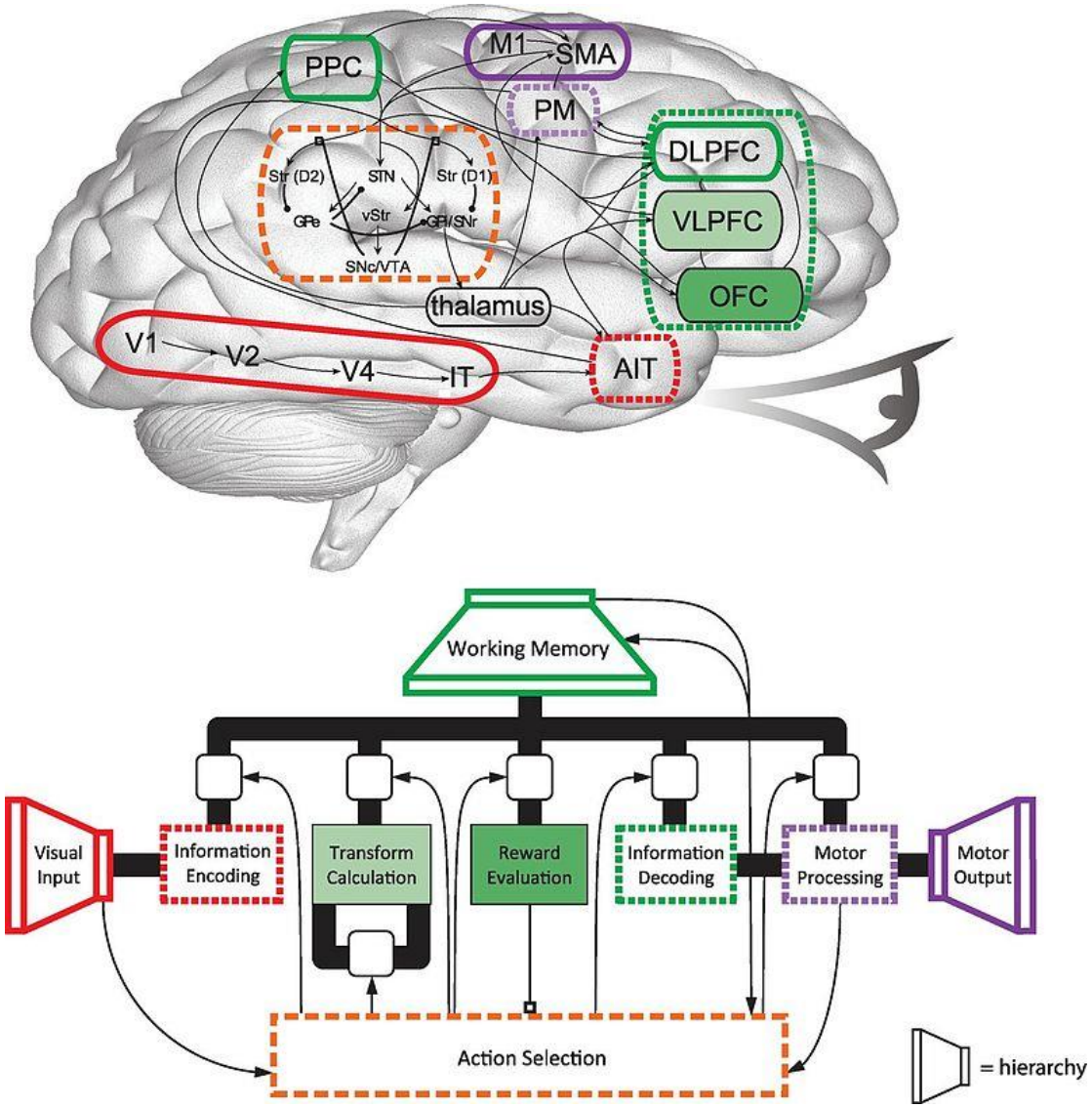
www.saund.org



The organization of
structural and functional elements
to achieve some purpose.

- Computer architecture
- Information architecture
- Neural Network architecture
- ...

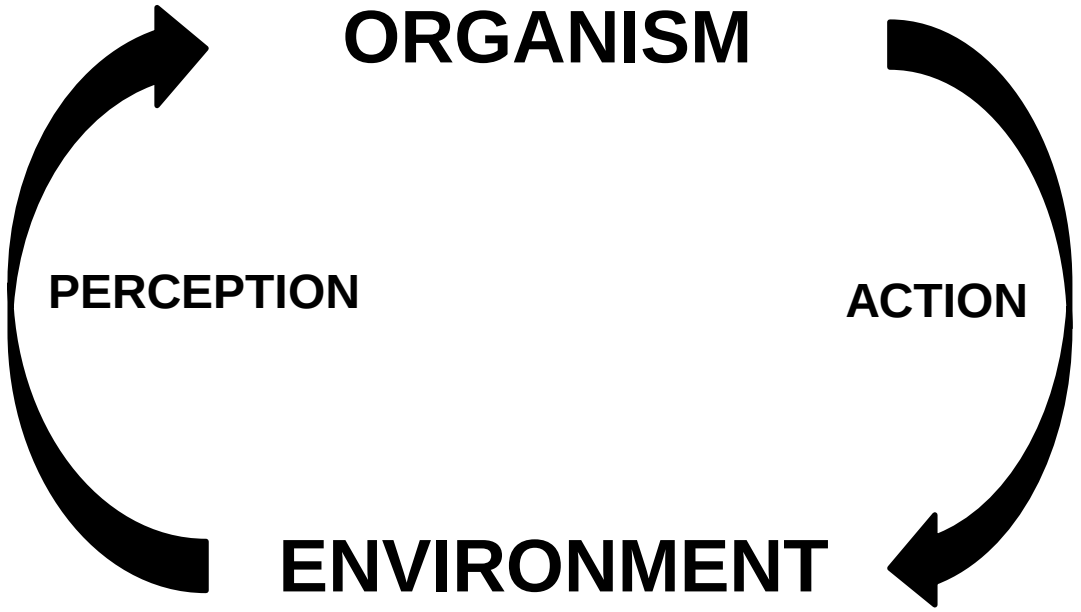
Brains and Minds



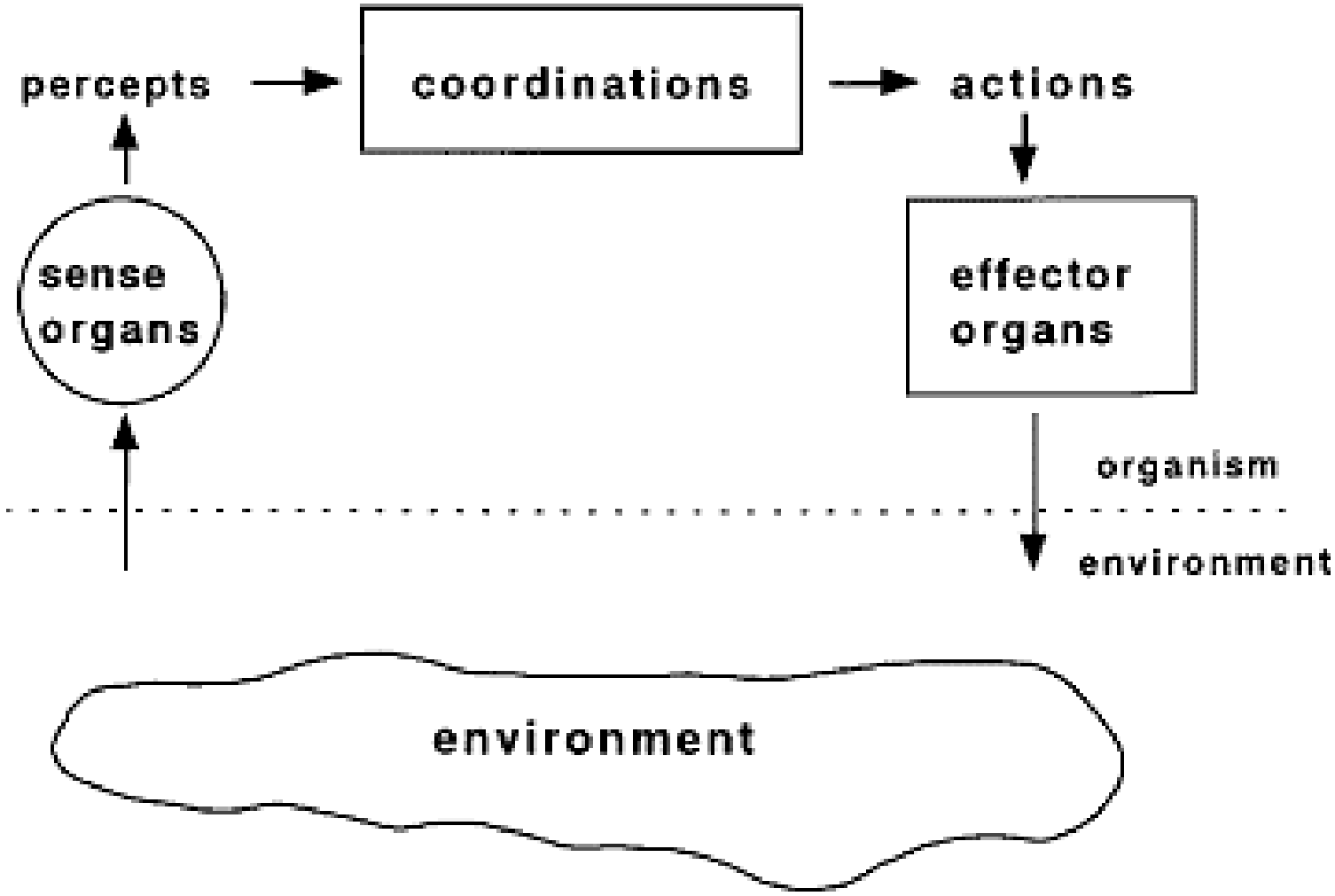
Outline

- The Standard Model for Cognitive Architecture
- Example: Soar
- Important Concepts:
  - Marr's Three Levels
  - Reactive vs Deliberative
- Architecture in NN / Deep Learning Networks
- AI Application: Conversational Agents

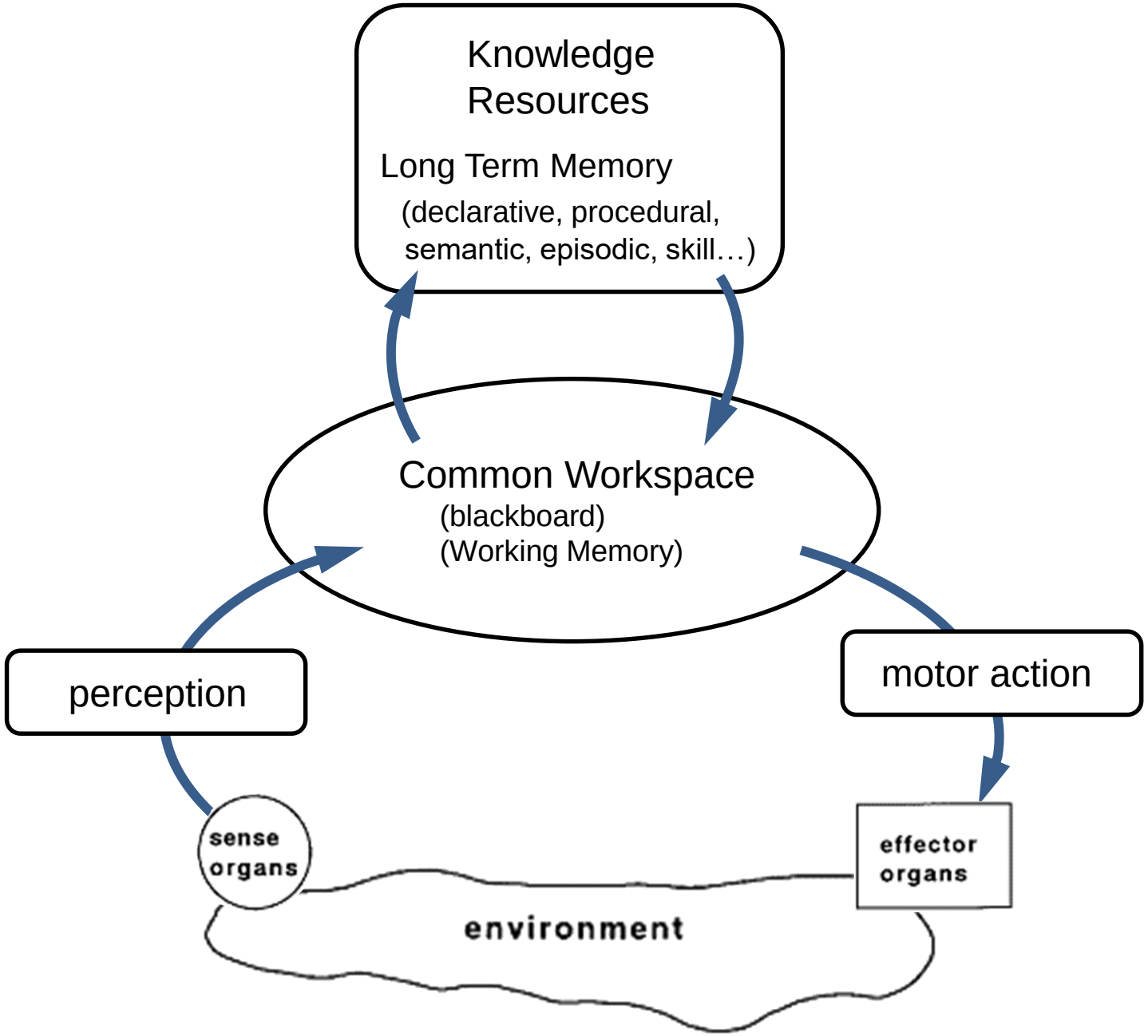
Cognitive Architecture: Basic Agent



Cognitive Architecture: Basic Agent



Cognitive Architecture: Standard Model



Cognitive Architecture: Big Questions

- What are the *types of content* held in the workspace?
  - percepts
  - beliefs
  - memories
  - goals
  - intentions
  - action plans
  - emotions
- What are the *representations* for state and knowledge?
  - activation patterns over fixed vectors
  - graphs of objects and relations
- How is processing *controlled*?
  - automatic processes
  - conscious deliberation
  - selection of operators

Soar

(Newell, Laird,
1983 -> present)

- Definition of intelligence:
  - problem states and transitions
  - solutions found through *search* in state space
- Representation:
  - graphs of objects and relations
- Control: production system
  - Working Memory blackboard
  - procedural knowledge
  - declarative knowledge

} Long-Term Memory

Soar: Water Jug Problem Example

Definition of intelligence:

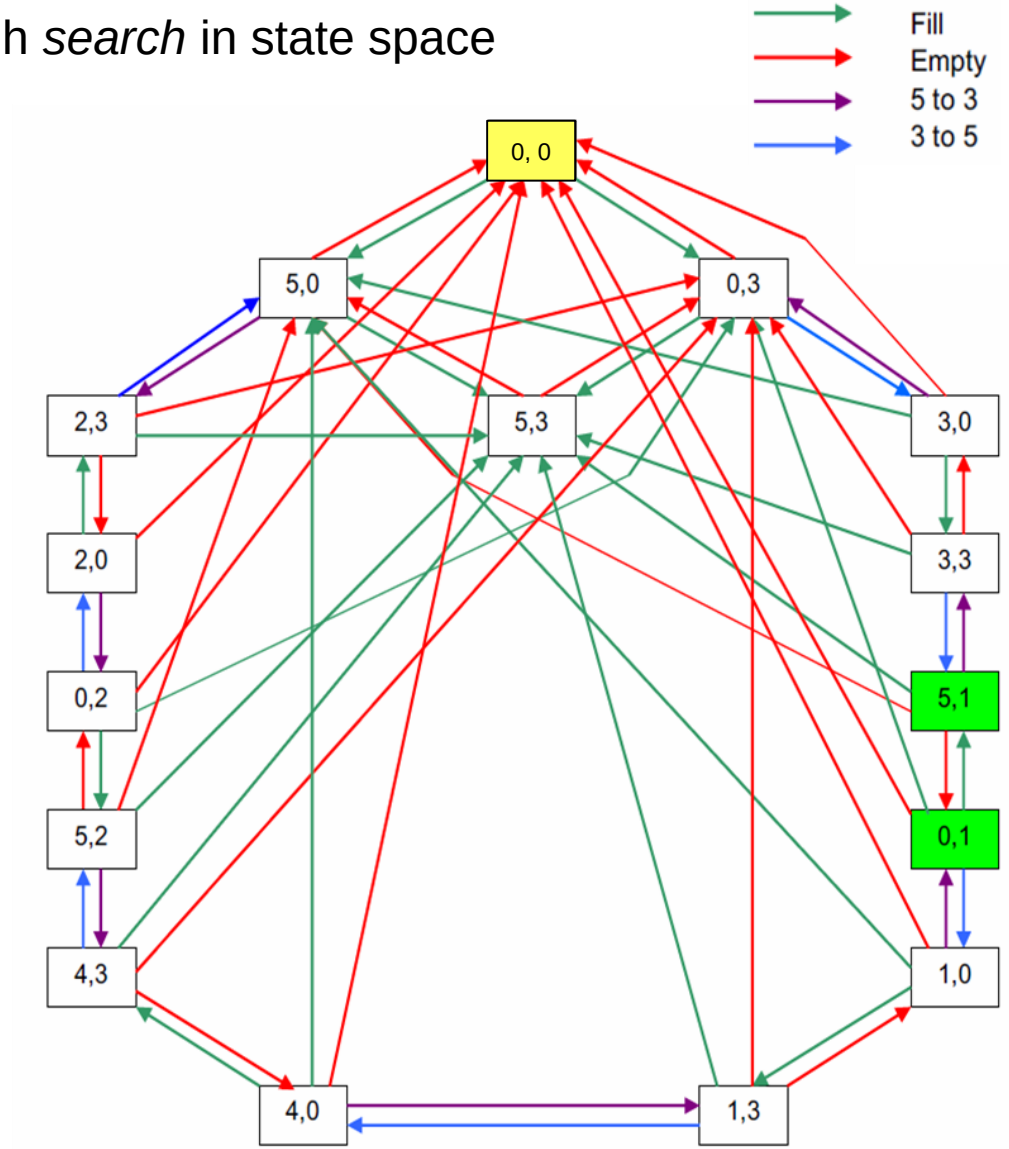
- problem states and transitions
- solutions found through *search* in state space

5 gal.

3 gal.

Start state: both jugs empty.

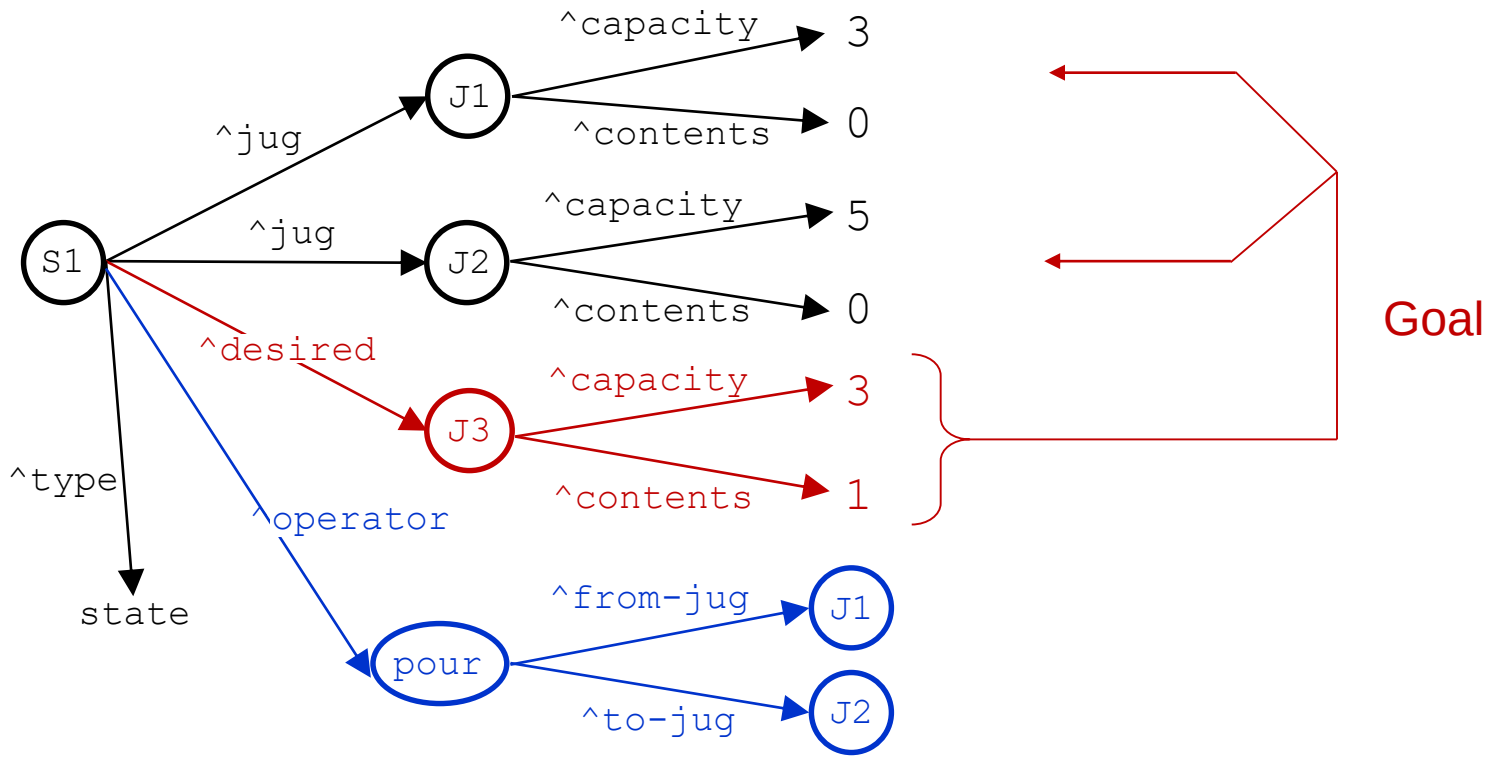
Goal state: 3-gallon jug contains 1 gallon of water.



Representation in Soar

Graph

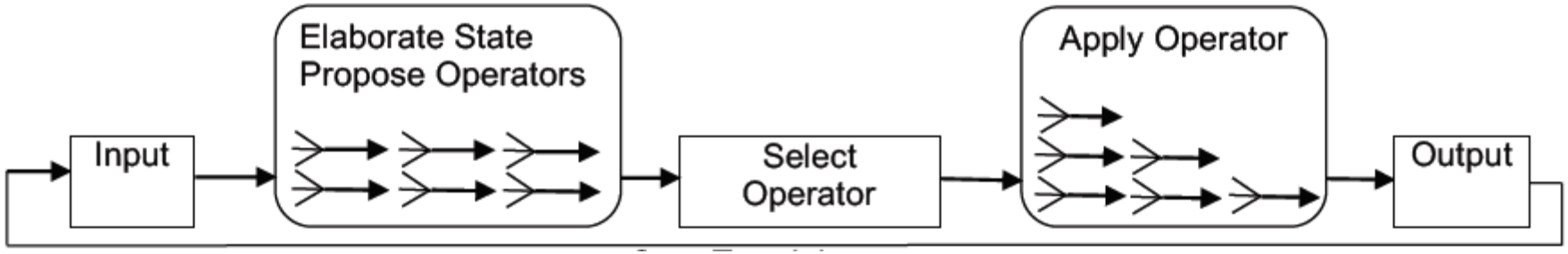
- data objects
- attributes & relations
- operators
- Working Memory (state)
- Long-Term Memory (knowledge)



Control in Soar

Production System

- Working Memory blackboard
- declarative knowledge - what
- procedural knowledge – how
  - rules
  - operators
- subgoal states



Processing Cycle

Executive Function (Psychology, Cognitive Neuroscience):

- update Working Memory from sensory and Long-Term Memory resources
- focus attention, inhibit distractors
- shift task context

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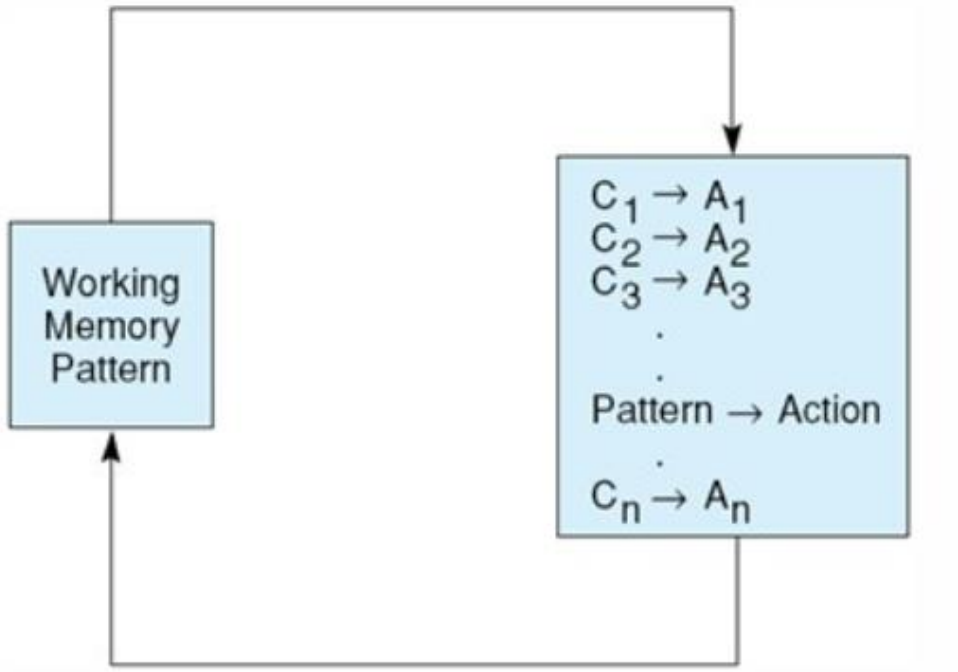
Production Rules vs. Neurons



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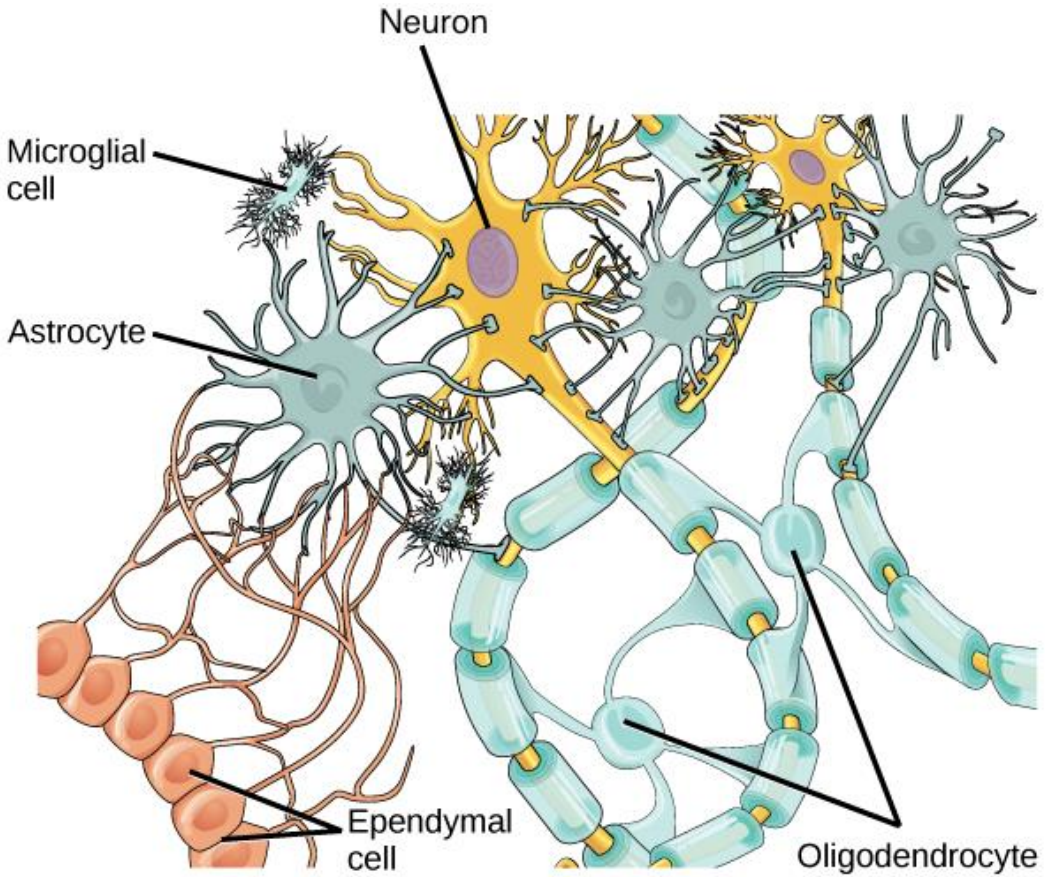
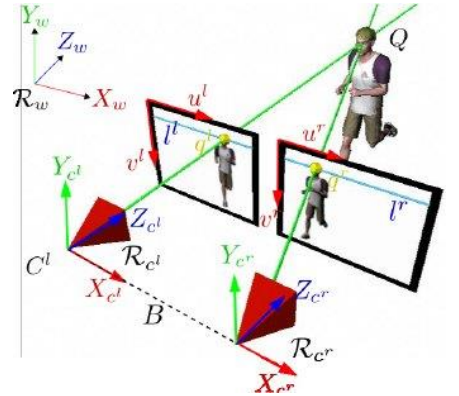


Marr's Three Levels of Abstraction

David Marr: *Theoretical Neuroscience* → *Computational Intelligence*

what? why?

Example: Stereo Vision



- **Computational Theory**

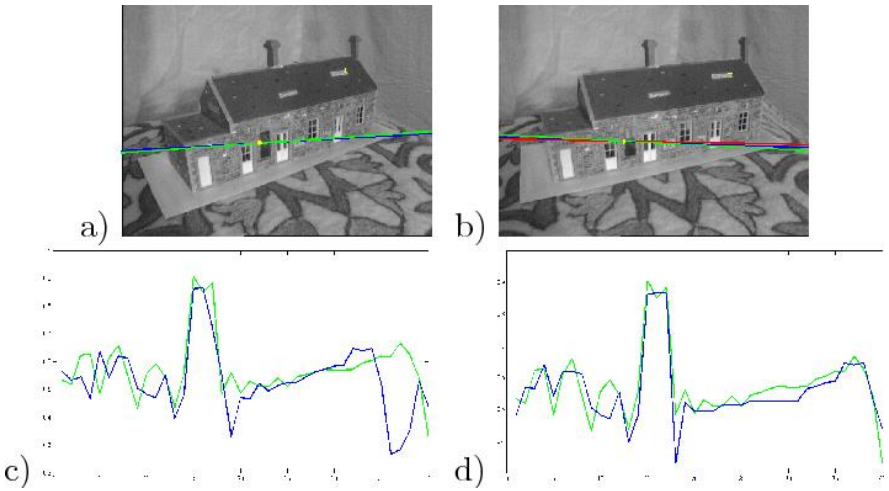
  What is the computation and by what principles is it accomplished?

- **Algorithm**

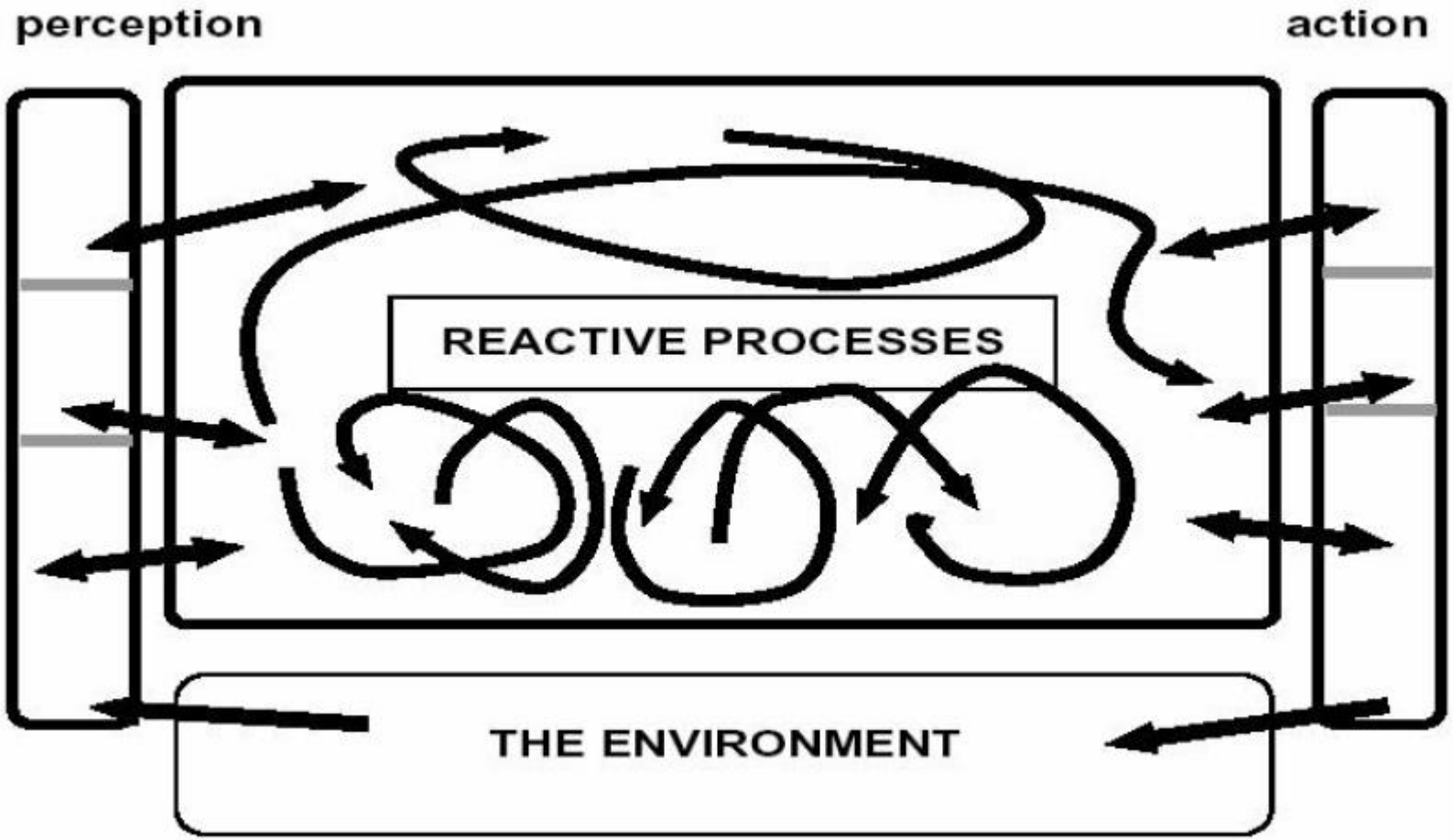
  What representations and algorithms are used to carry forth computation?

- **Implementation**

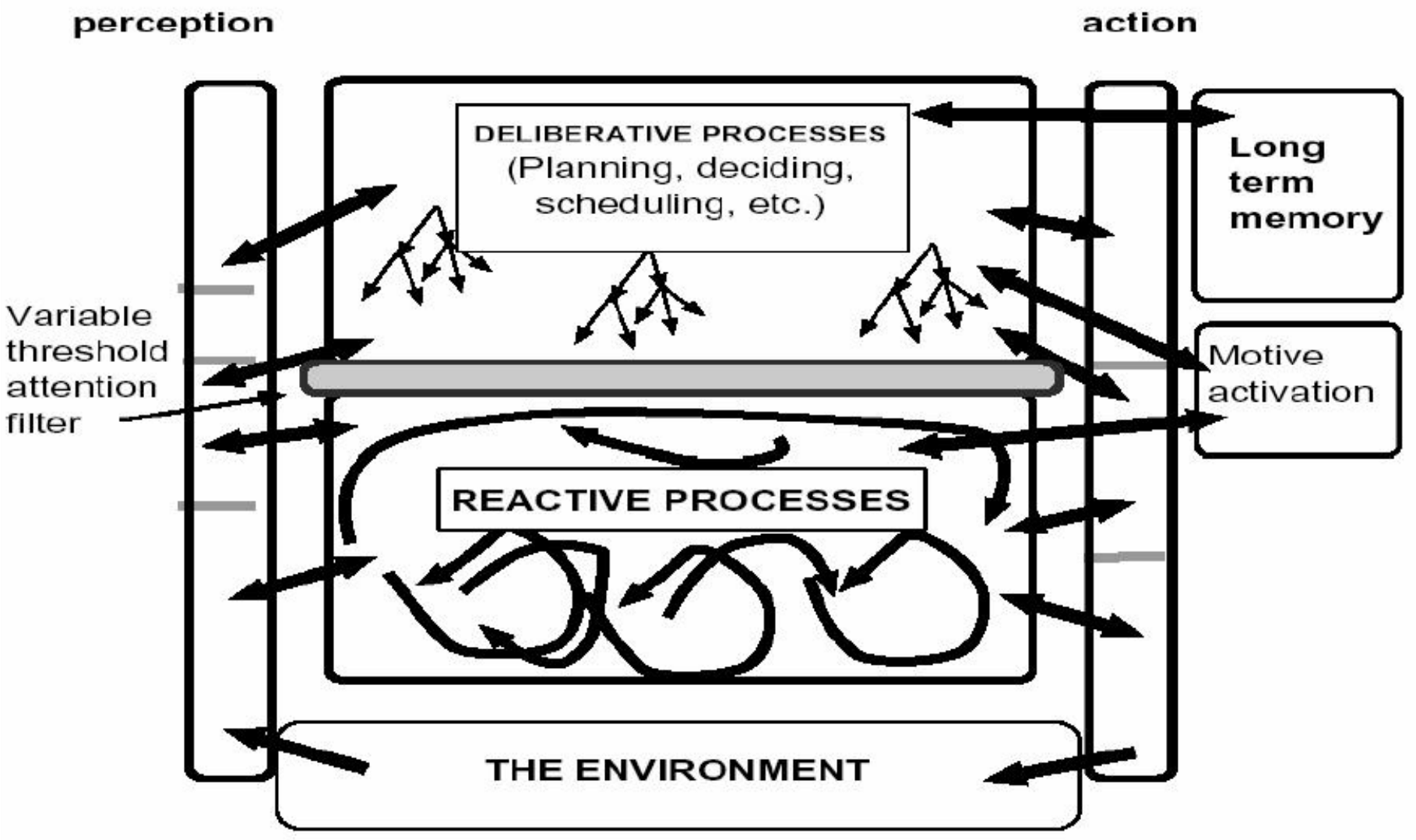
  On what physical hardware and firmware is the algorithm run?



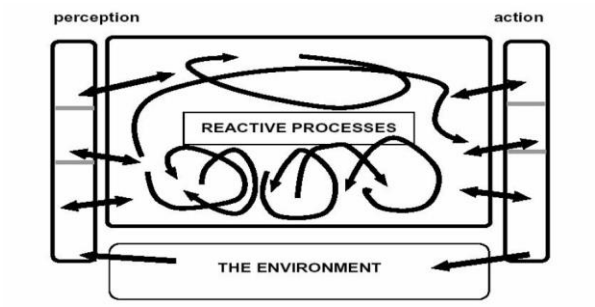
Cognitive Architecture: Reactive Agent

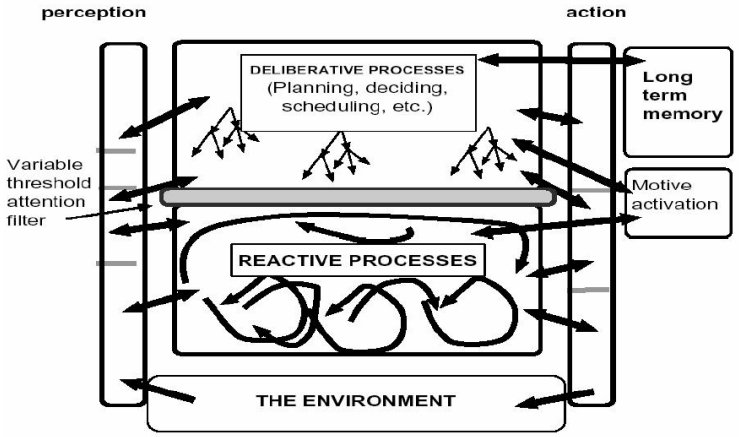


Cognitive Architecture: Deliberative Agent



Reactive vs. Deliberative





Reactive

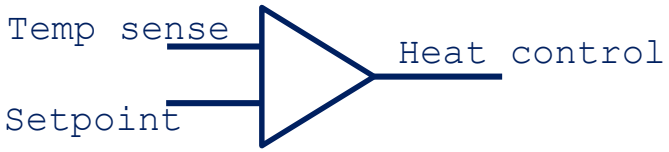
automatic & strictly determined

modest internal state

implicit representations

Kahneman System 1

Example: thermostat



Deliberative

makes choices

rich internal state

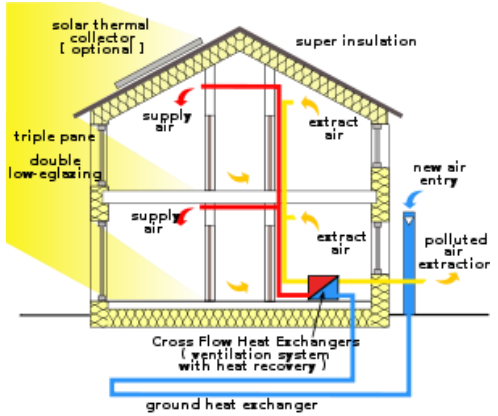
explicit world models

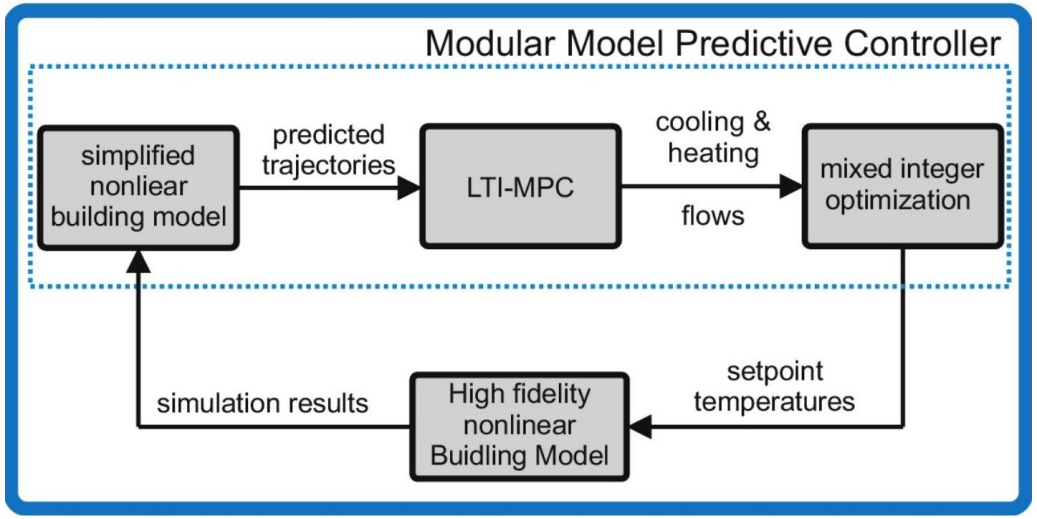
Kahenman System 2

Example: building temperature management system

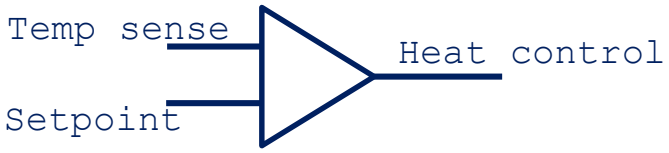
Reactive vs. Deliberative Building Temperature Controller

Building Thermal Model



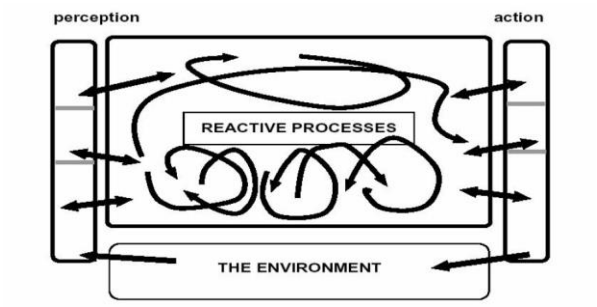


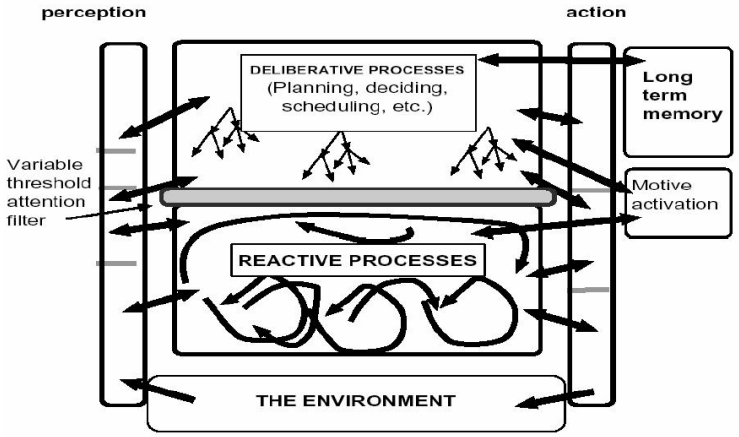
Example: thermostat



Example: building temperature management system

Reactive vs. Deliberative





Reactive

modest internal state

implicit representations

automatic & strictly determined

Deliberative

rich internal state

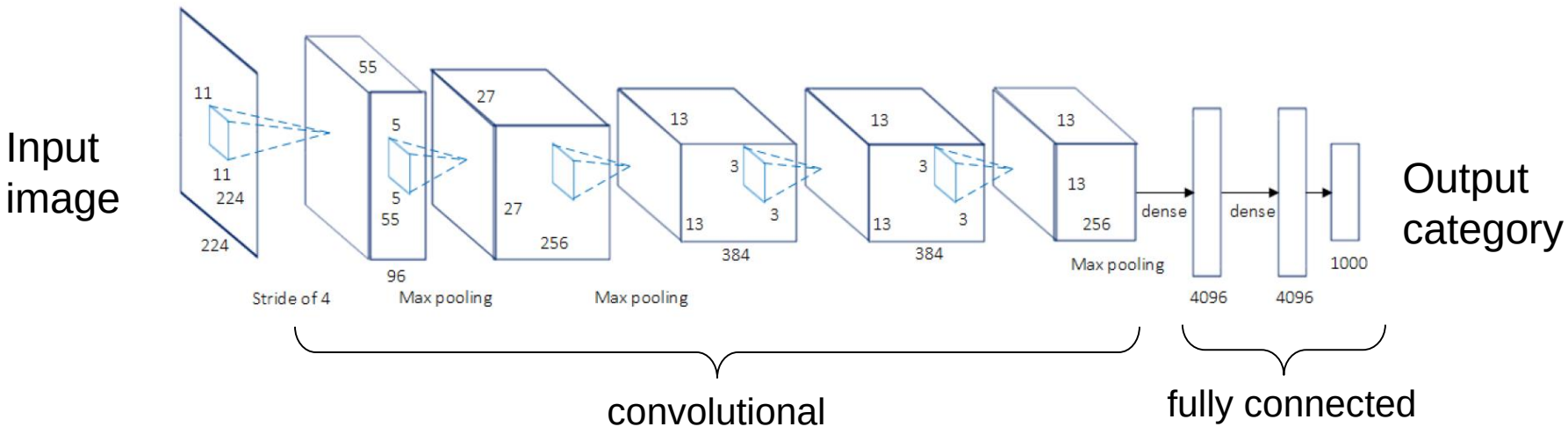
explicit world models

makes choices

?

Soar

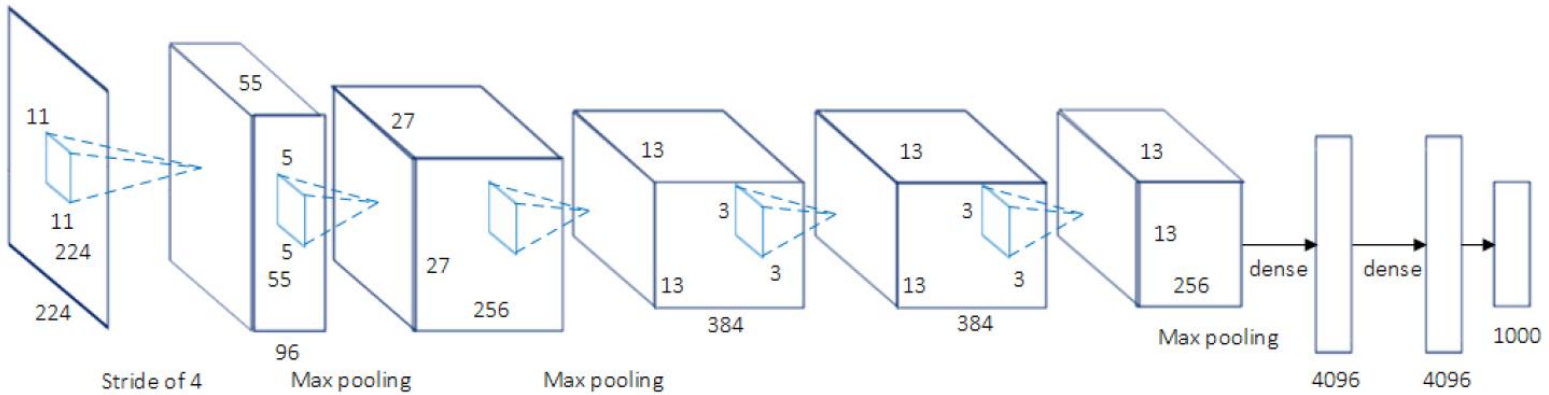
Neural Network Architectures



Alexnet

- Architectural Elements — Layer dimensions, weights, nonlinearities
- Organization — Layer connectivity
- Purpose — Function approximation

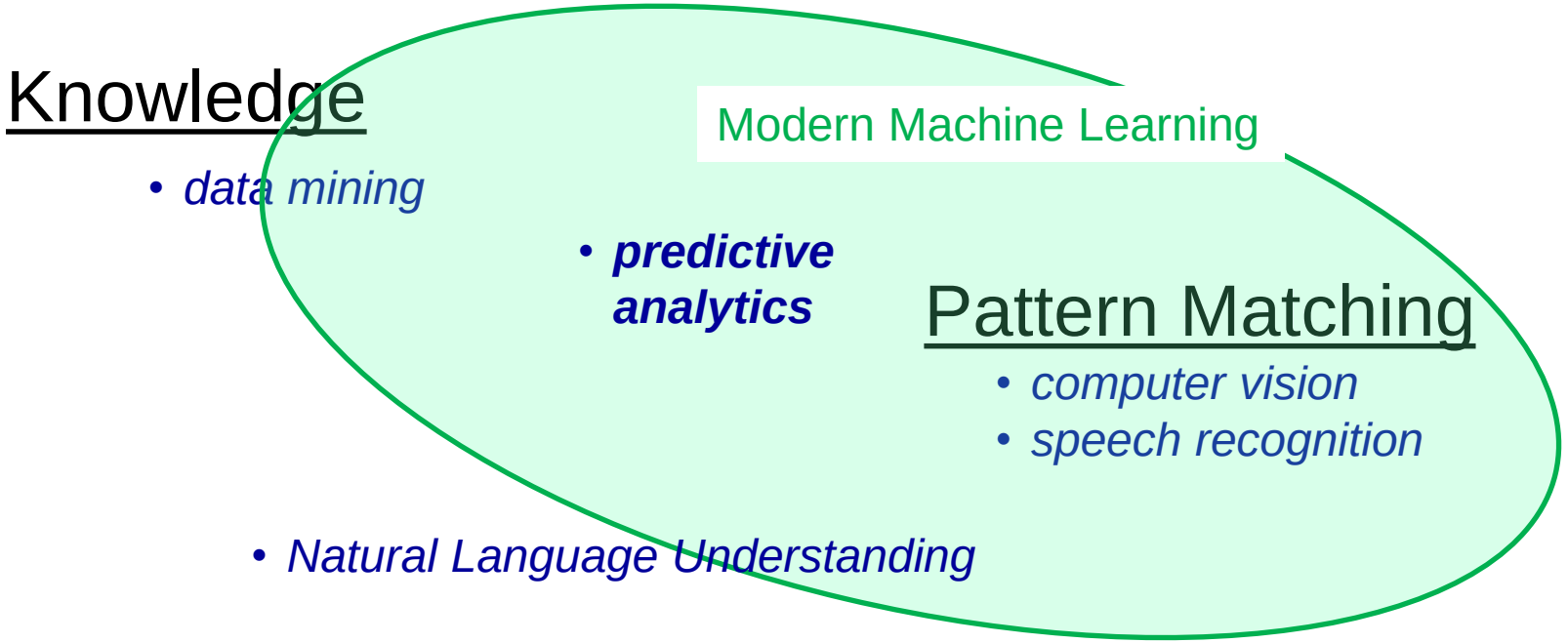
Neural Network Architectures



Reactive or Deliberative?

choices?
state?
implicit/explicit

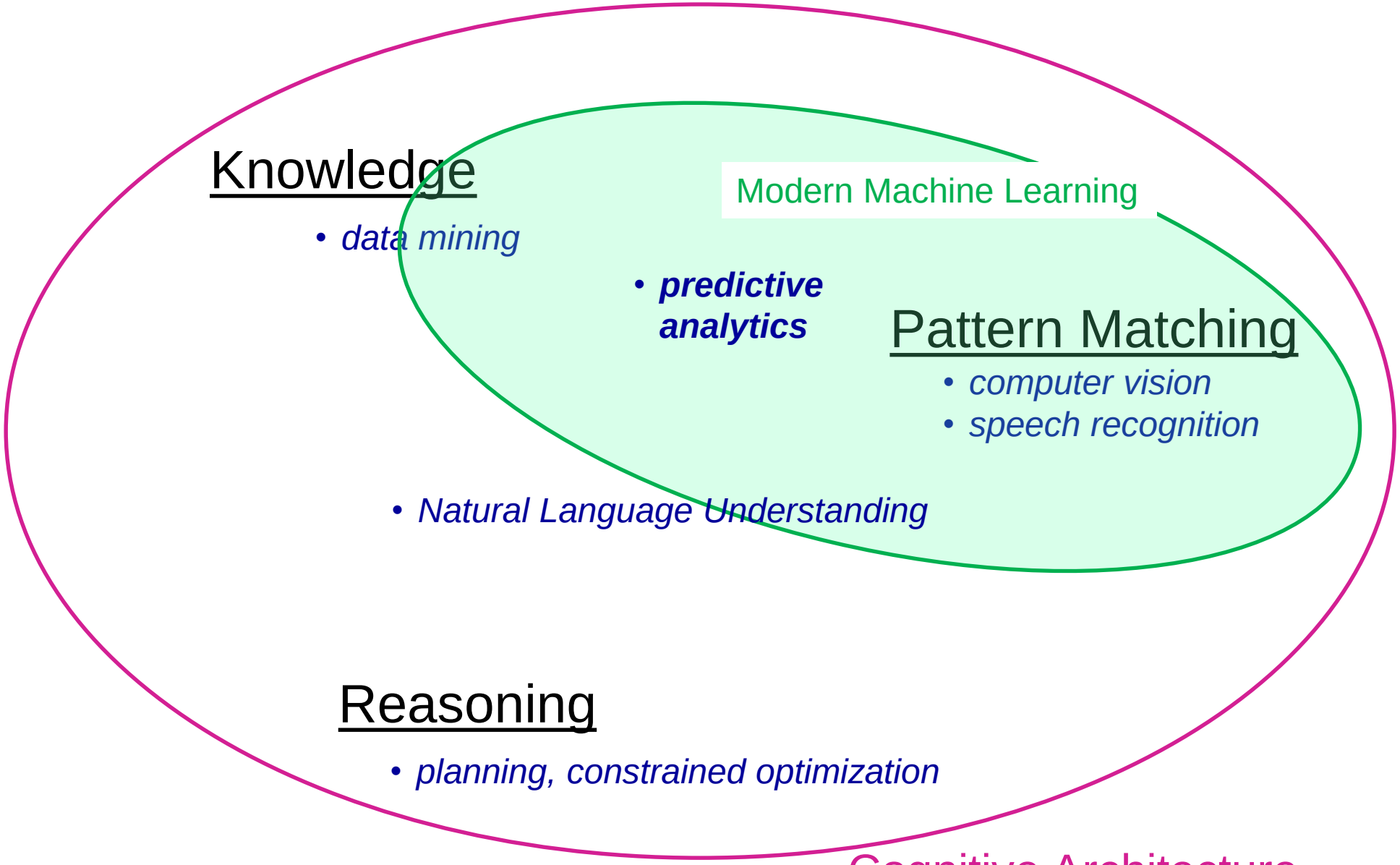
The Ingredients of Intelligence



Reasoning

- *planning, constrained optimization*

The Ingredients of Intelligence



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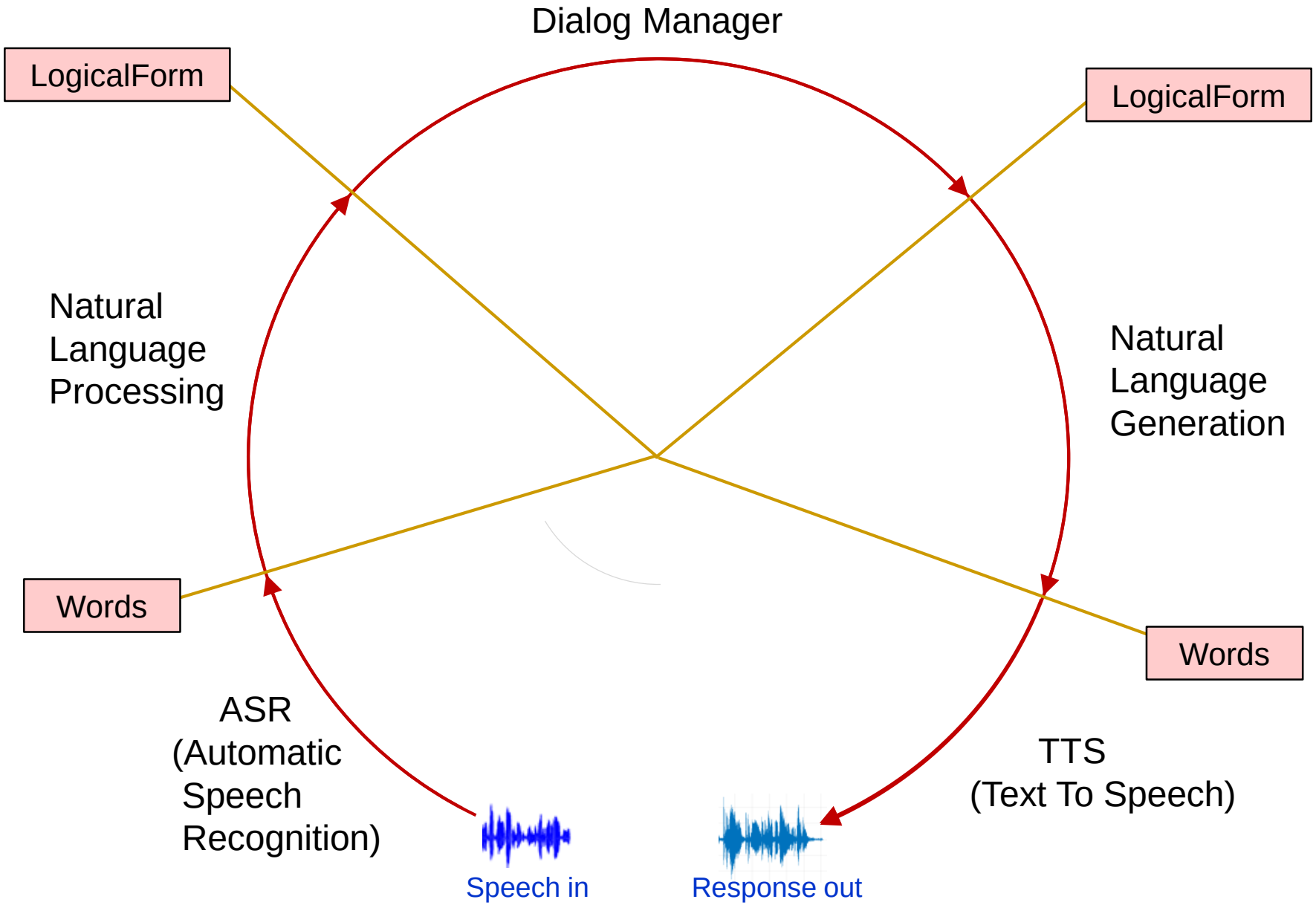
Conversational Agent

Question answering task

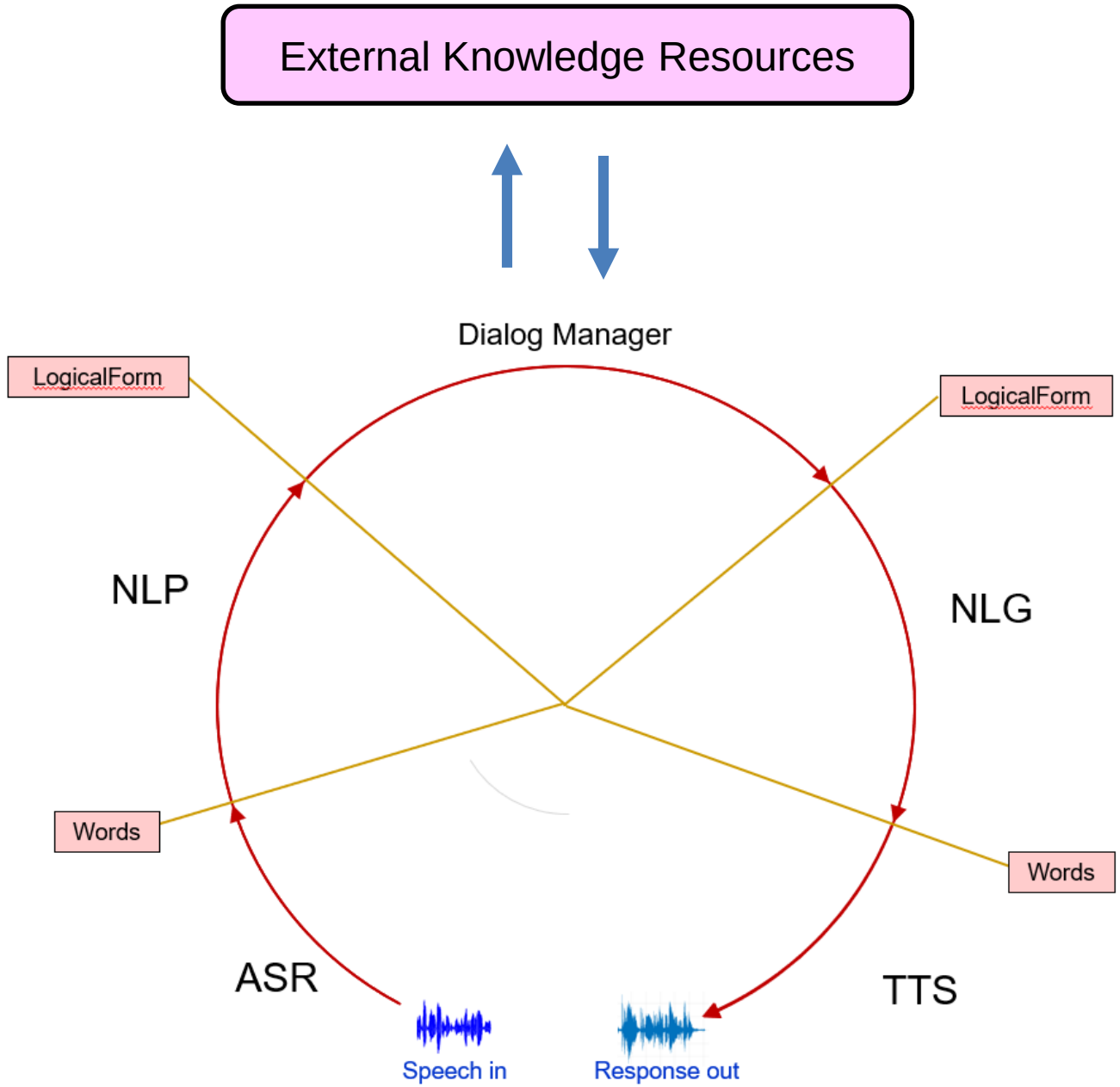
"Alexa, who won the 1934 world series?

"The Saint Louis Cardinals beat the Detroit Tigers 4-3 in the 1934 World Series."

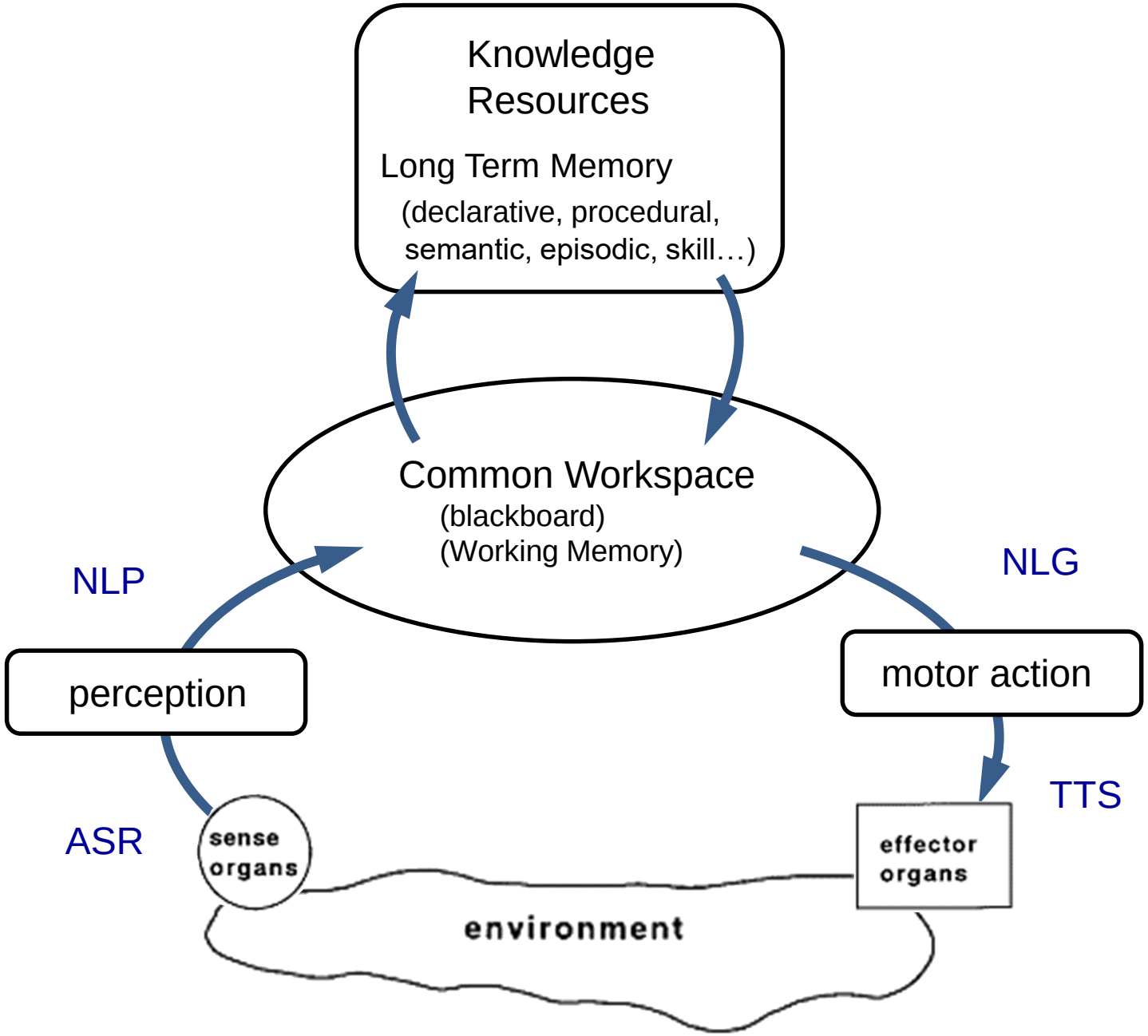
Architecture of a Conversational Agent



Architecture of a Conversational Agent



Cognitive Architecture: Standard Model



Why Are Conversational Agents So Dumb?

"Alexa, who won the 1934 world series?

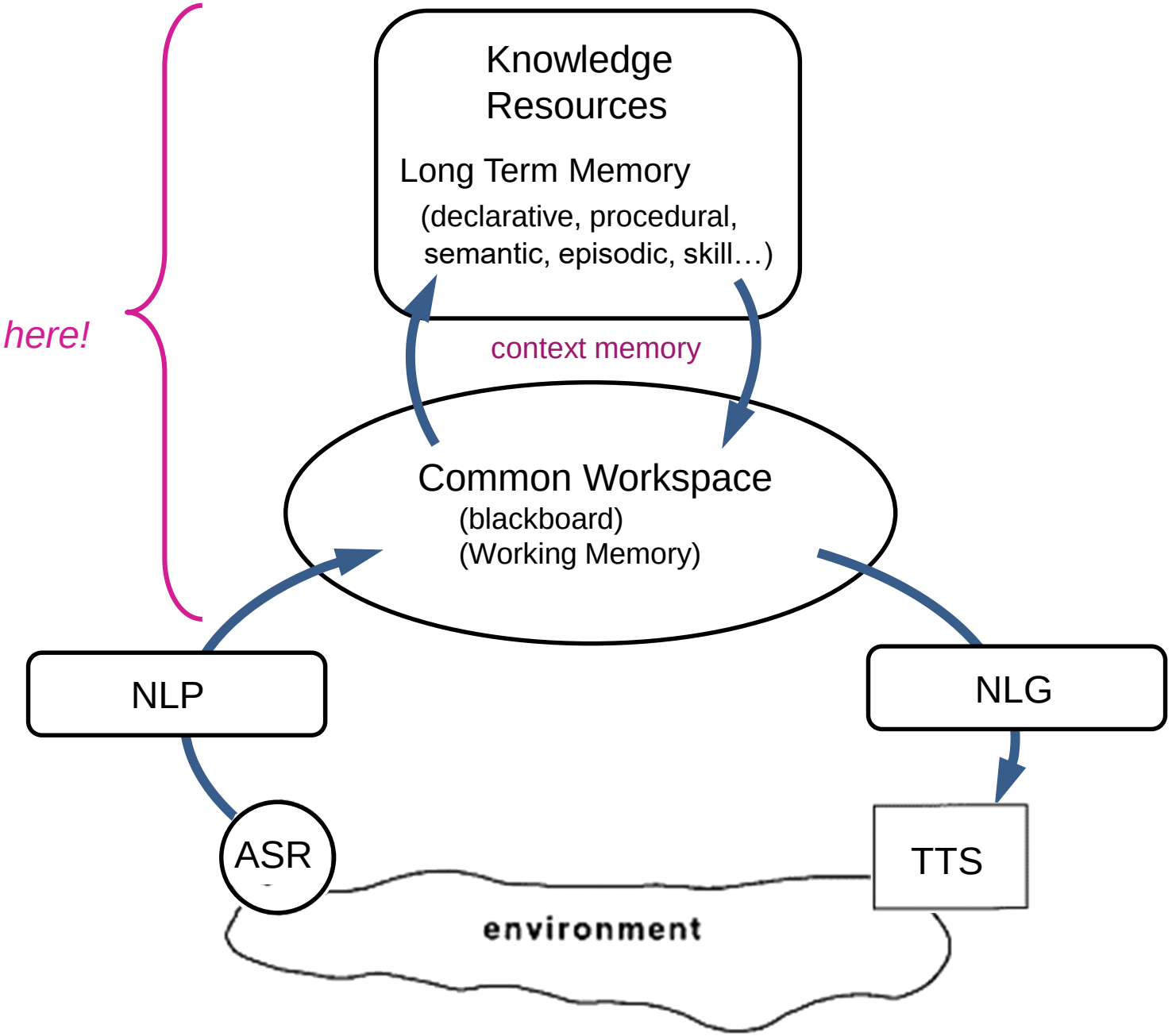
"The Saint Louis Cardinals beat the Detroit Tigers 4-3 in the 1934 World Series."

"Alexa, who was the president then?"

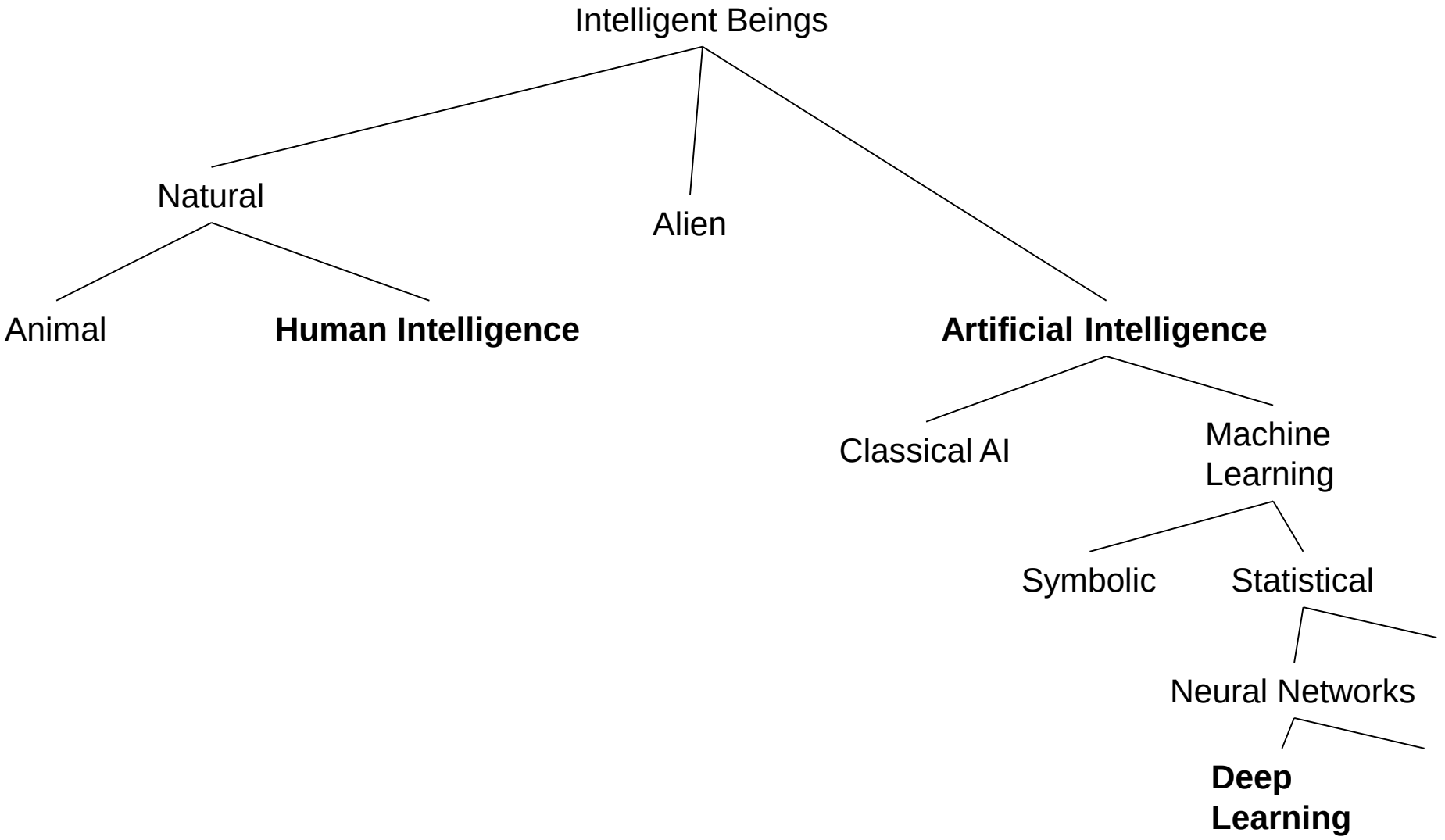
"This might answer your question. The president of the United States is Donald Trump."

Cognitive Architecture for a Conversational Agent

Dialog Manager
Much work to do here!



Summary: Taxonomy



Cognitive Architecture

NN Architecture

Eric Saund

- *Research scientist in Cognitive Science and AI.*
- *Conversational Agents, Visual Perception, Cognitive Architectures.*
- *I build stuff.*

Projects

Papers

Curiosities

Links

Contact

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Conversation