Intelligent Control and Cognitive Systems

brings you...

Cognitive Architectures

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From Last Week

- Combinatorics is the problem, search is the only solution.
- The task of intelligence is to focus search.
  - Called bias (learning) or constraint (planning).
  - Most `intelligent' behavior has no or little real-time search (non-cognitive) (c.f. Brooks IJCAI91).
- For artificial intelligence, most focus from design.

Architectures

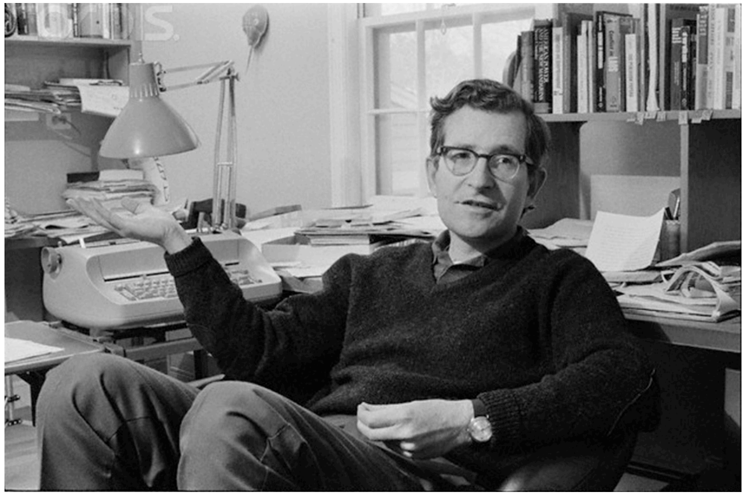
- What kinds of parts does the system need?
  - Ontology
- How should those parts be put together?
  - Development methodology
- How exactly is the whole thing arranged?
  - Architecture

“Architectures?”

- Like *reactive planning*, the term *cognitive architecture* doesn’t quite mean what its component words do.
- People have been looking for a generic plan for building “real” (human-like) AI.
- This used to be a popular area of research, now gets fewer publications.
- Nevertheless, evolutionary history tells us something about what worked & didn’t.

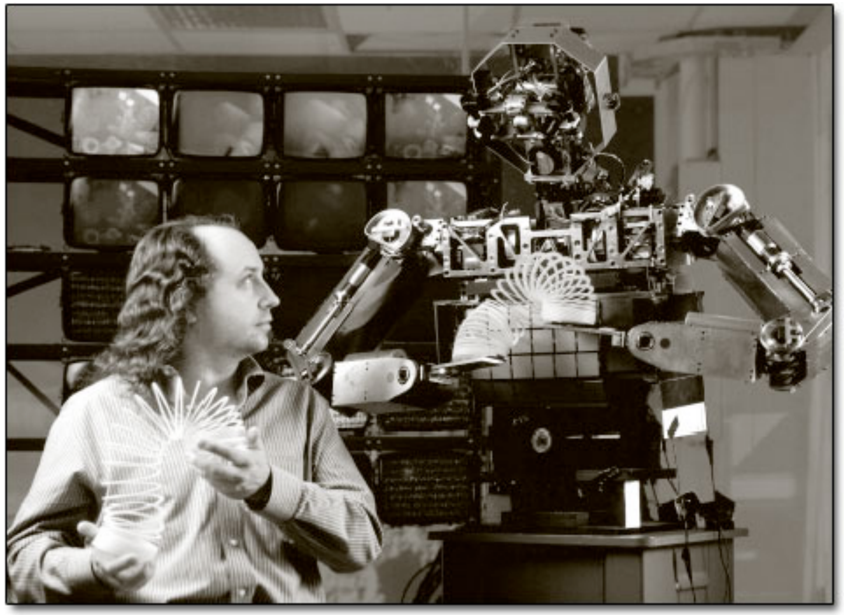
What Worked

- The past does not necessarily predict the future, particularly in AI.
- Changes in hardware and other tech change what is possible.



Cognitive Architecture

- Where do you put the cognition?
- Really: How do you bias / constrain / focus cognition (learning, search) so it works?



Basic Unit– Production

- From sensing to action (c.f. Skinner; conditioning; Witkowski 2007.)
- These work -- basic component of intelligence.
- The problem is choice (search).
  - Require an arbitration mechanism.

Production-Based Architectures

*arbitration mechanisms

- Expert Systems: allow choice of policies, e.g. recency, utility, random.
- SOAR: problem spaces (from GPS), impasses, chunk learning.
- ACT-R: (Bayesian) utility, problem spaces (reluctantly, from SOAR/GPS.)

Expert Systems

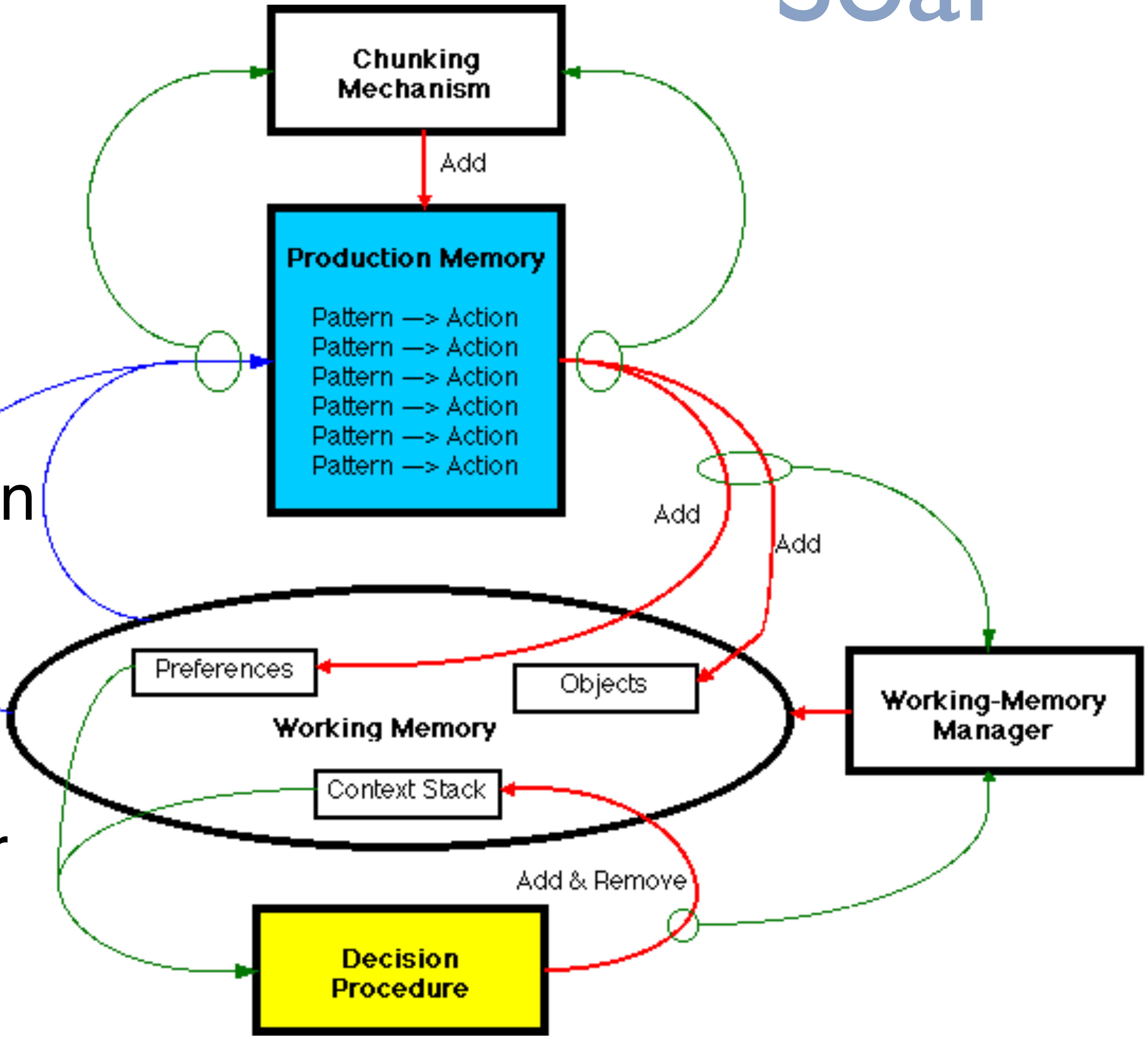
- Idea: Encode the knowledge of a domain expert as productions, replace them with AI.
- Big hype in 1980s, do still exist e.g. for checking circuit boards, credit / fraud detection, device driver code.
- Problem: Experts don't know why they do what they do, tend to report novice knowledge (last explicit rules learned.)

General Problem Solver

- GPS, written by Newell, Shaw & Simon (1959, CMU), first program that separated specific problem (coded as productions) from reasoning system.
- Cool early AI, but suffered from both combinatorial explosion and the Markov assumption.
- Soar was Newell's next try.

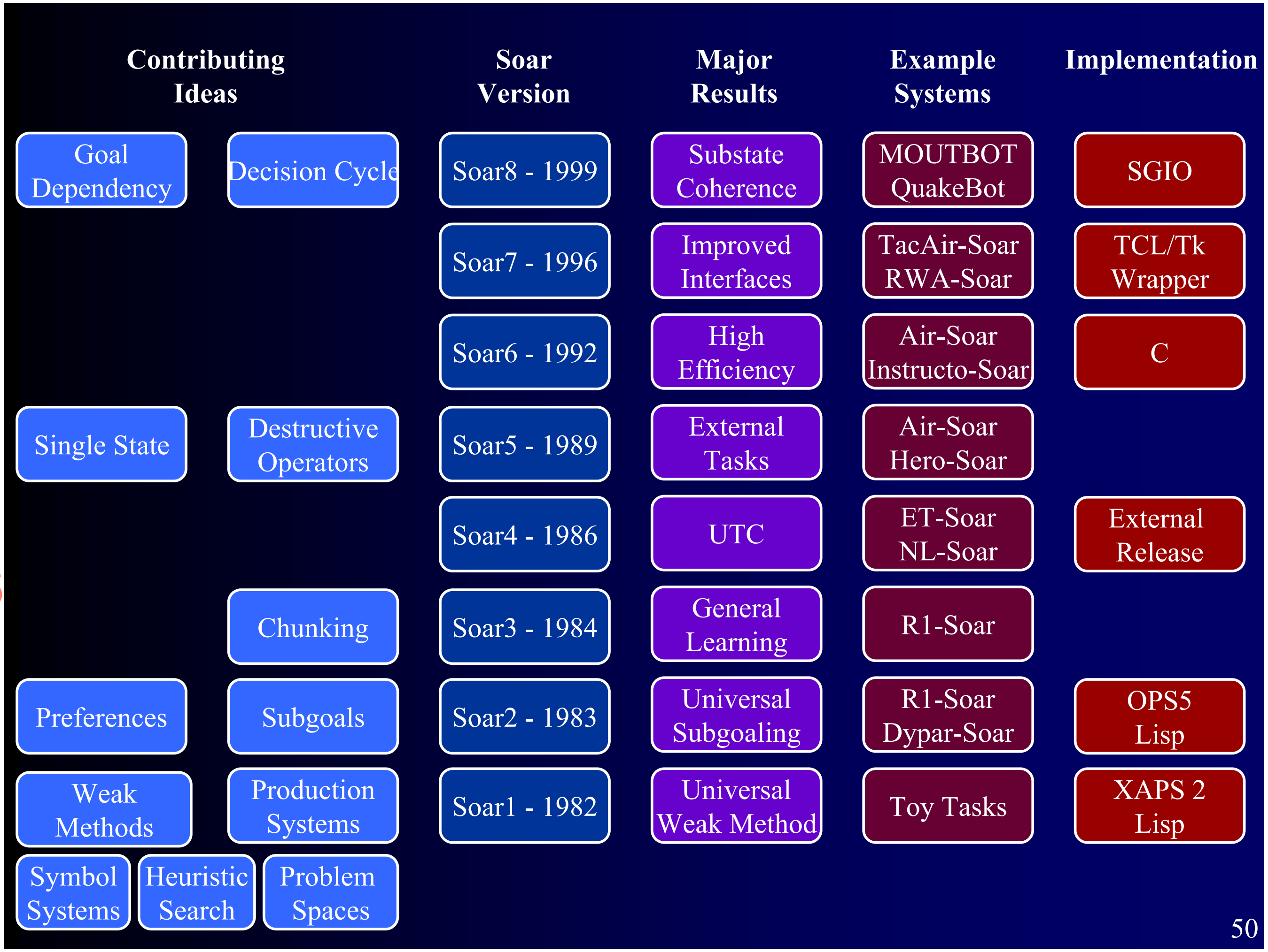
Soar

- Productions operate on a predicate database.
- If conflict, declare impasse, then reason (search harder).
  - Remember resolution: chunk



Soar

- Soar has serious engineering.
- "Evolution of Soar" is a favourite AI paper (Laird & Rosenbloom 1996) – admits problems & mistakes!
  - Not enough applications for human-like AI



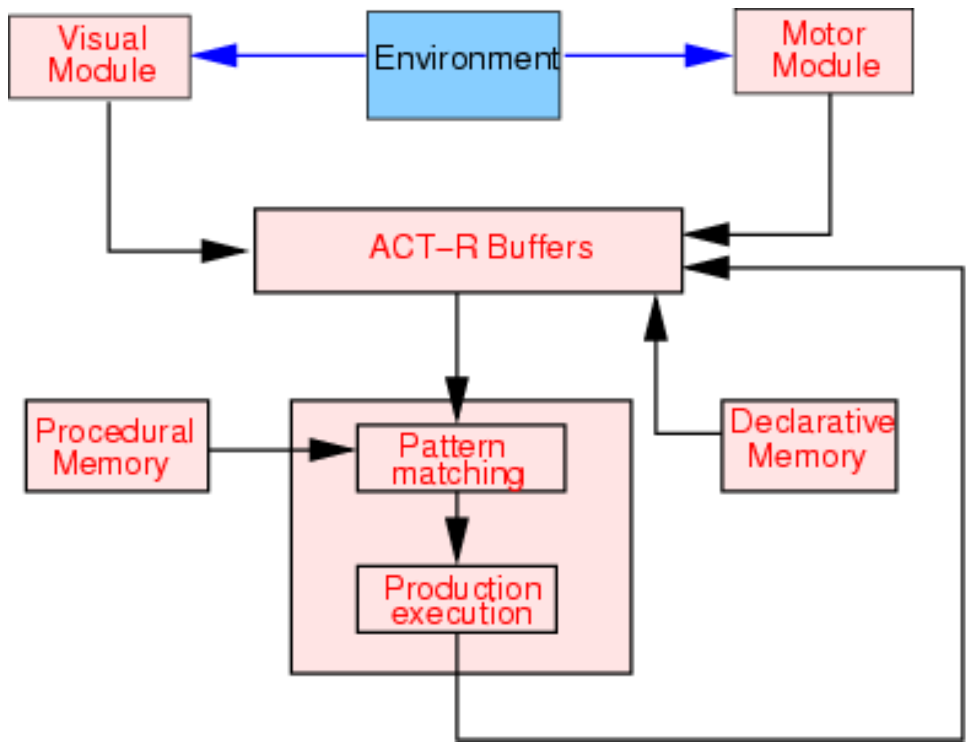
← One problem: main ap / funding is war games for US military.

Architecture Lessons (from CMU➢Michigan)

- An architecture needs:
  - action from perception, **and**
  - further structure to combat combinatorics.
- Dealing with time is hard (Soar 5).

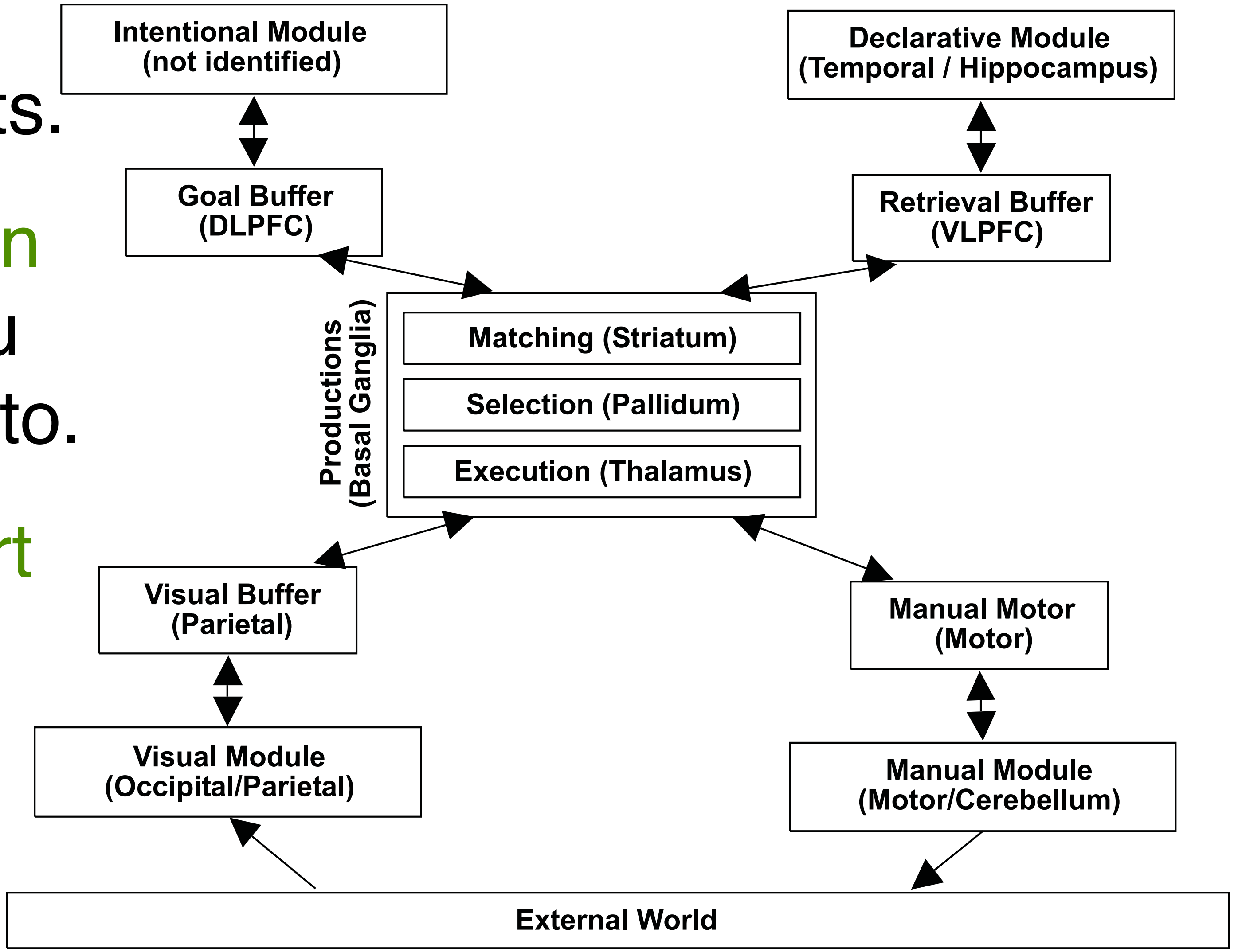
ACT-R

- Learns (& executes) productions.
- For arbitration, relies on (Bayesian probabilistic) utility.
  - Call utility "implicit knowledge".



ACT-R Research Programme

- Replicate lots of Cognitive Science results.
- See if the brain does what you think it needs to.
- Win Rumelhart Prize (John Anderson, 2000).

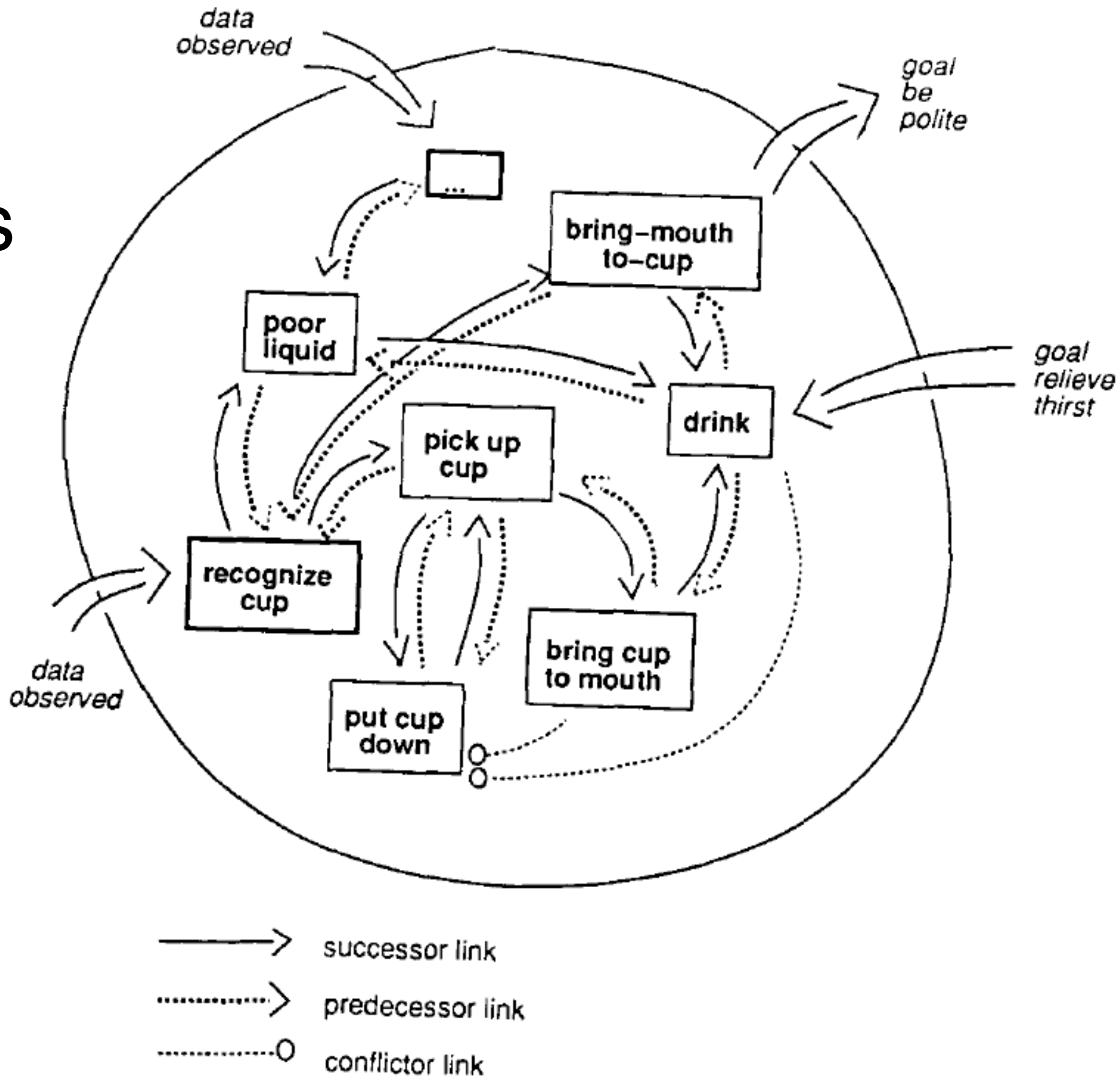


Architecture Lessons (from CMU Ψ)

- Architectures need productions and problem spaces.
- Real-time is hard.
- Grounding in biology is good PR, may be good science too.
- Being easy to use can be a win.

Spreading Activation Networks

- "Maes Nets" (Adaptive Neural Arch.; Maes 1989, VUB)
- Activation spreads from senses and from goals through net of actions.
- Highest activated action acts.



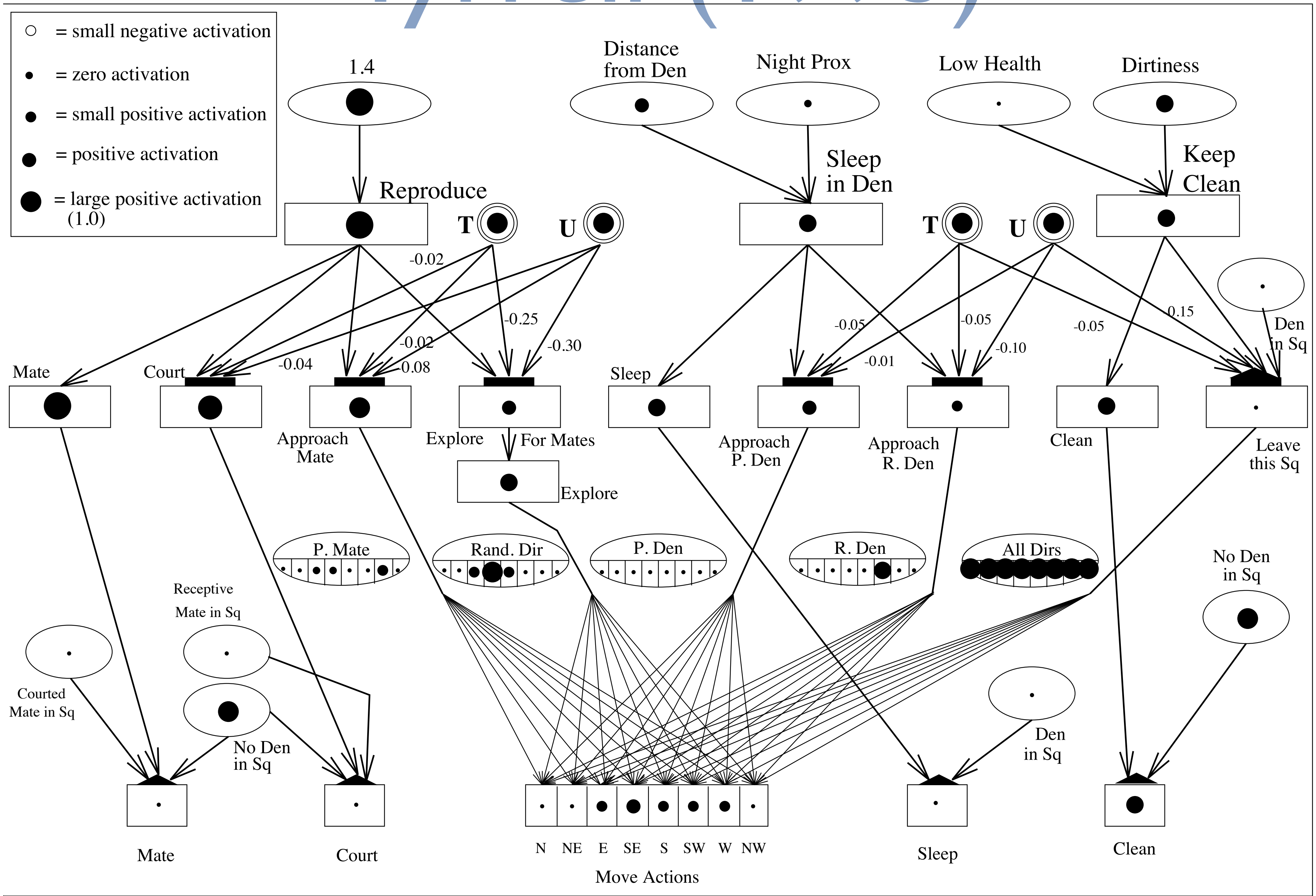
Spreading Activation Networks

- Sound good:
  - easy
  - brain-like (priming, action potential).
  - Still influential (Franklin & Baars 2010, Shanahan 2010).
- Can't do full action selection:
  - Don't scale; don't converge on comsumatory acts (Tyrrell 1993).

Tyrrell's Extended Rosenblatt & Payton Networks

- Consider all information & all possible actions at all times.
- Favour consumatory actions by system of weighting.
- Also weight uncertainty (e.g. of memory, temporal discounting).

Tyrrell (1993)



Extended Rosenblatt and Payton Free-Flow Hierarchy

Tyrrell's Analysis

- Compared all leading architectures.
- Discovered many weren't practical.
- Hoped to be "fair" by having parameters learned with a GA.
- Discovered this wasn't tractable.
- Went into oceonagraphy after PhD.

National Oceanography Centre, Southampton
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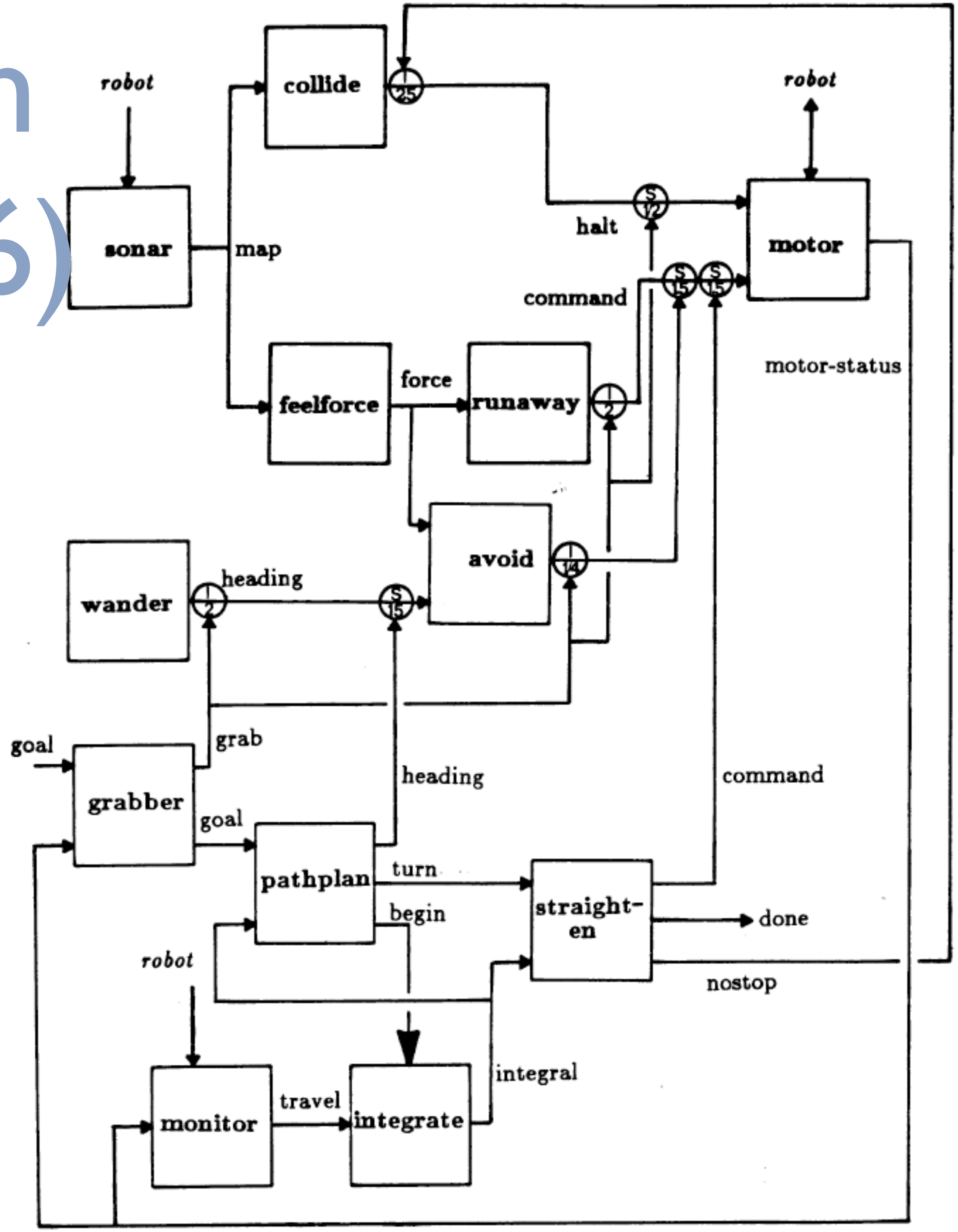
Research Interests

How organisms interact with their environments. Ecology of phytoplankton, coccolithophores in particular. Ocean acidification. Ocean biogeochemistry, including during extreme events in Earth' ancient past such as the E/O and K/T boundaries. Ocean carbon cycle and its effect on future atmospheric CO2 levels. Marine cycles of N, P, C, Si. The control of biogenic element concentrations in the sea as a function of ecological competition between different functional groups of phytoplankton. Modelling of all of the above.

Subsumption (Brooks 1986)

- Emphasis on sensing to action (via Augmented FSM).
- Very complicated, distributed arbitration.
- No learning.
- Worked.

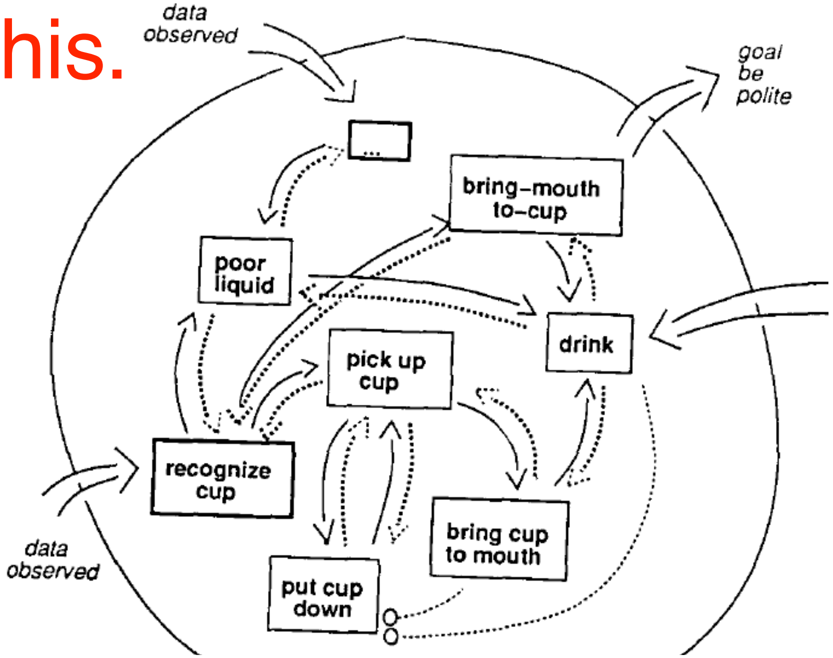


Architecture Lessons (Subsumption)

- Action from perception can provide the further structure – modules (behaviors).
  - Modules also support iterative development / continuous integration.
- Real time should be a core organising principle – start in the real world.
- Good ideas can carry bad ideas a long way (no learning, hard action selection).

Architecture Lesson?

- Goals ordering needs to be flexible.
- Maybe spreading activation is good for this.



A Robust Layered Control System for a Mobile Robot

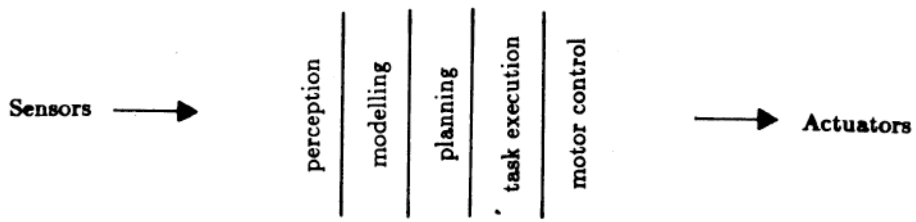
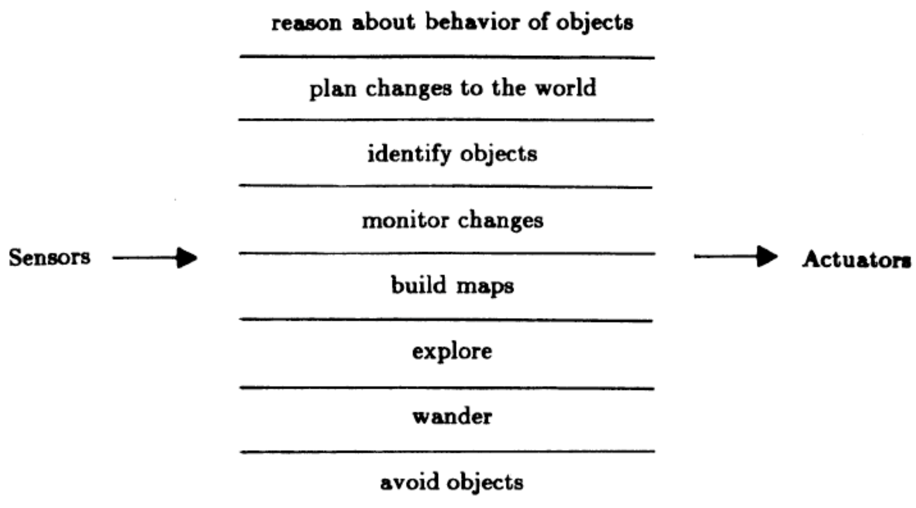
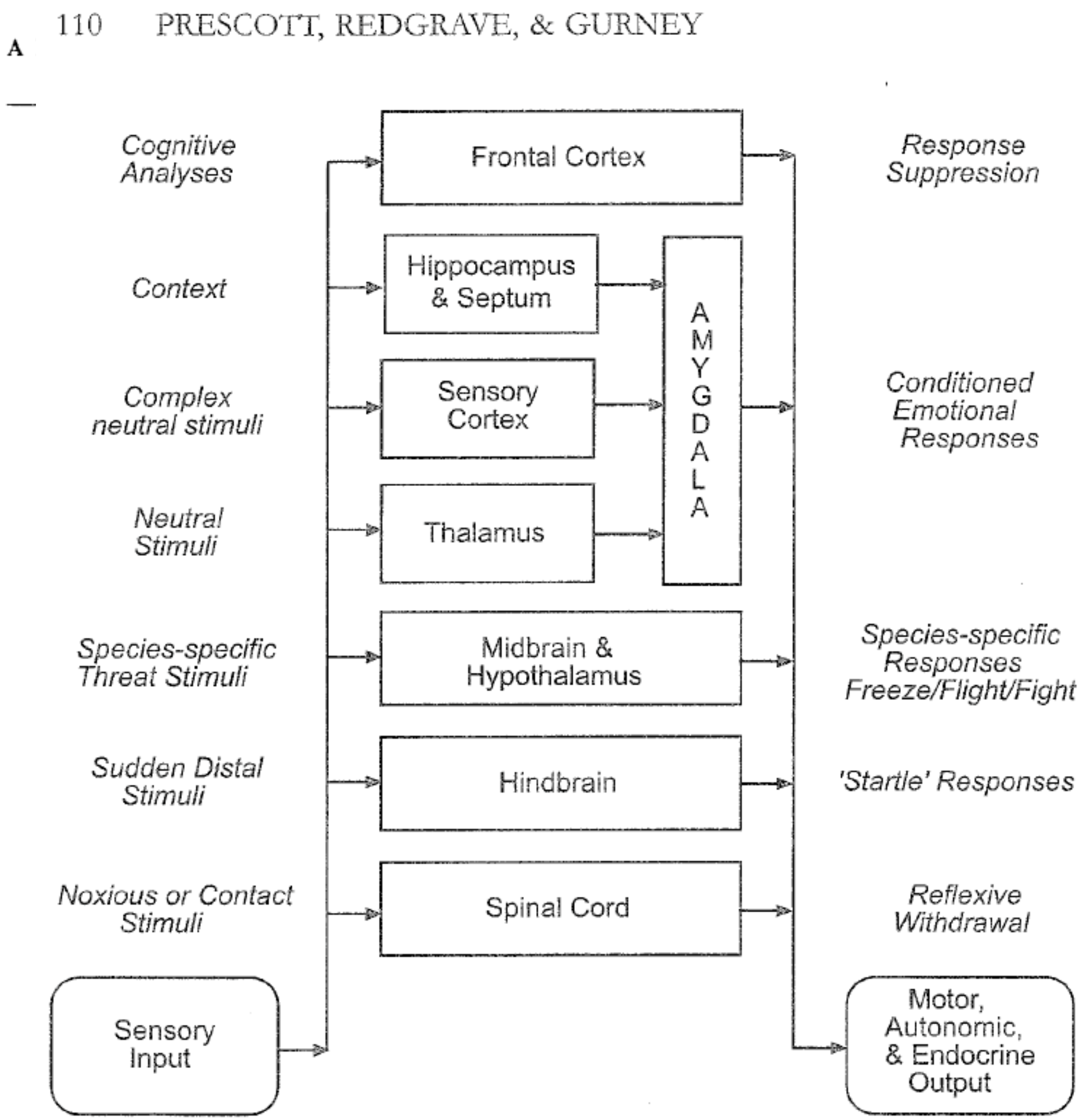
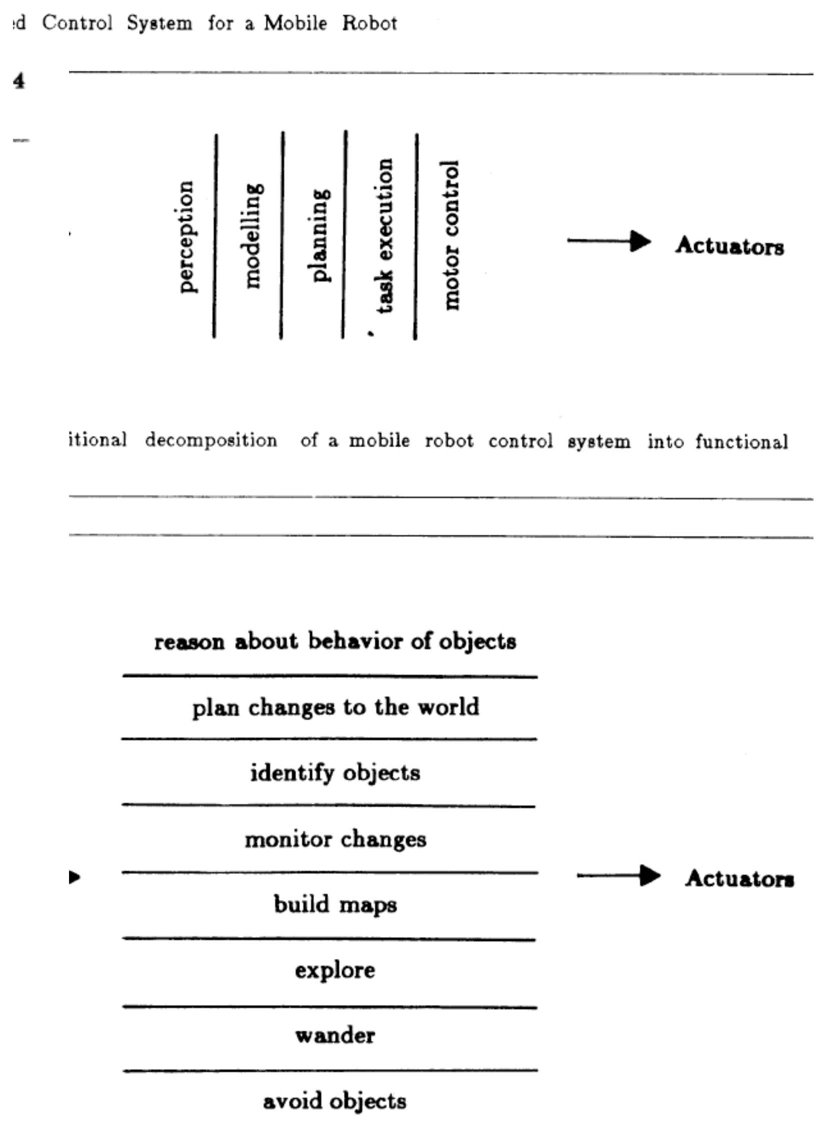


Figure 1. A traditional decomposition of a mobile robot control system into functional modules.



SA: Layers vs. Behaviours





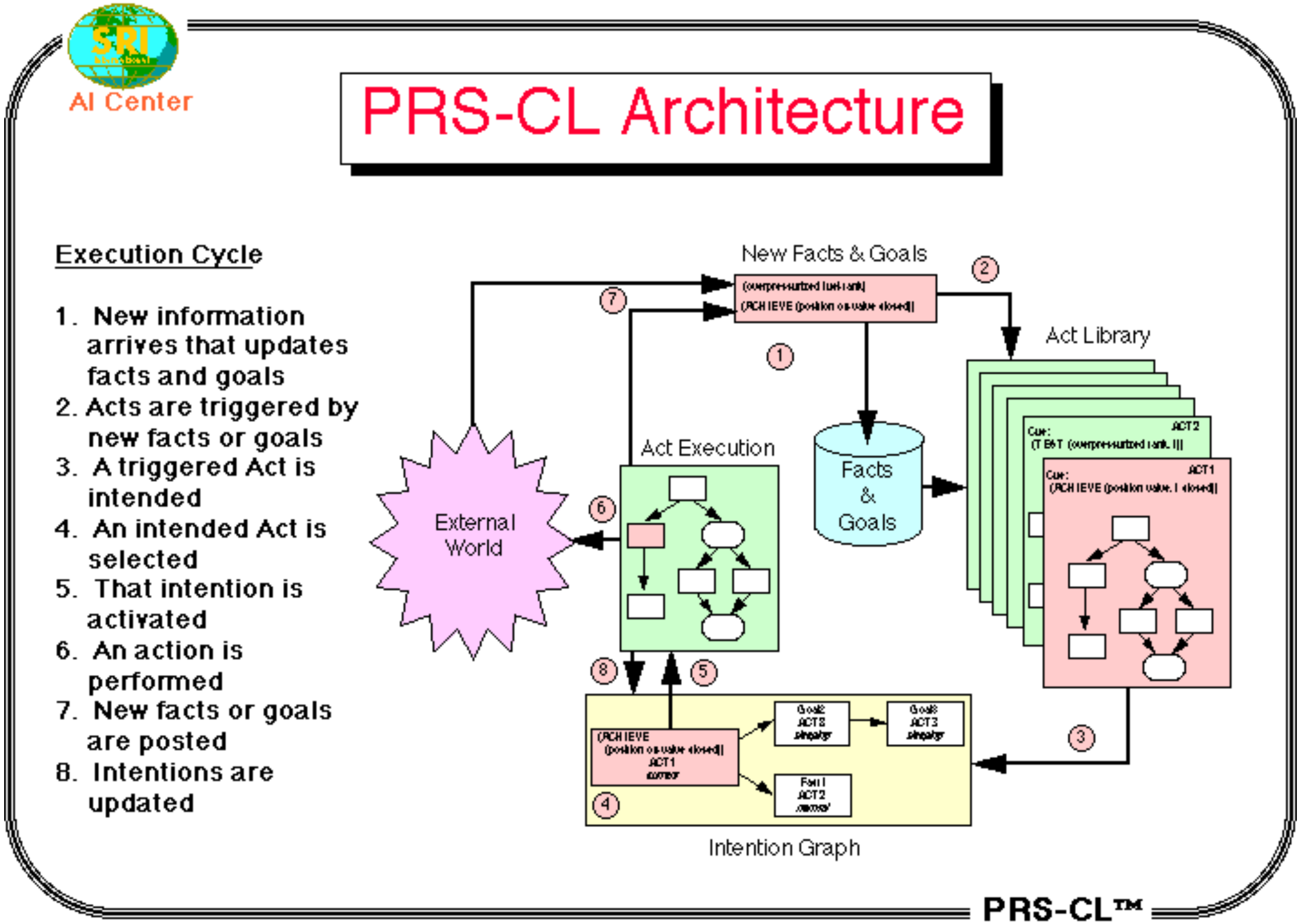
Layered *or* Hybrid Architectures

1. Incorporate behaviors/modules (action from sensing) as “smart” primitives.
2. Use hierarchical dynamic plans for behavior sequencing.
3. (Allegedly) some have automated planner to make plans for layer 2.

- Examples: Firby/RAPS/3T (‘97); PRS (1992-2000); Hexmoore ‘95; Gat ‘91-98

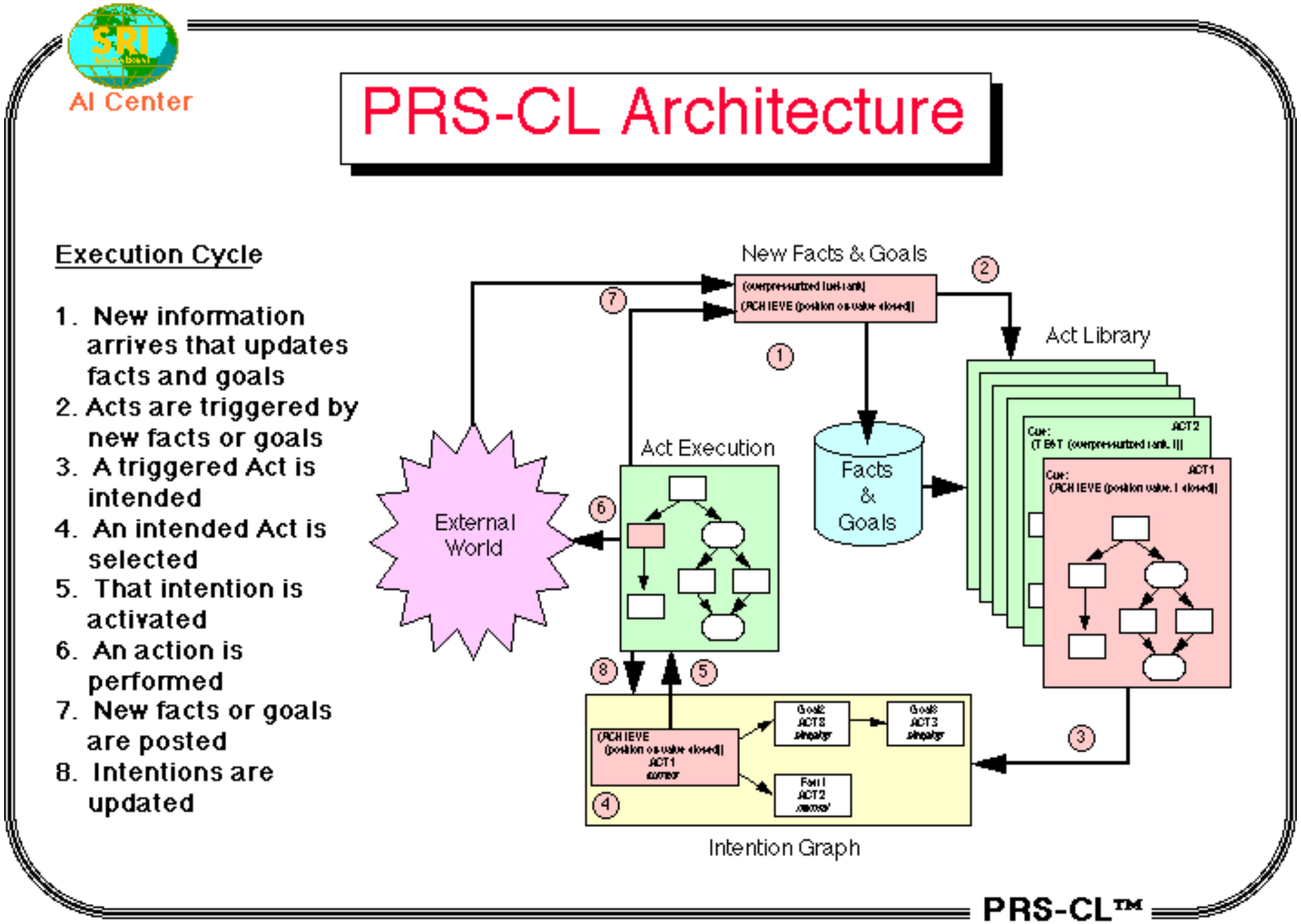
Belief, Desires, Intentions (BDI)

- *Beliefs*: Predicates
- *Desires*: goals & related dynamic plans
- *Intentions*: current goal



Procedural Reasoning System

- BDI
- And reactive (responds to emergencies by changing intentions.)
- Er... once or twice (Bryson ATAL 2000).



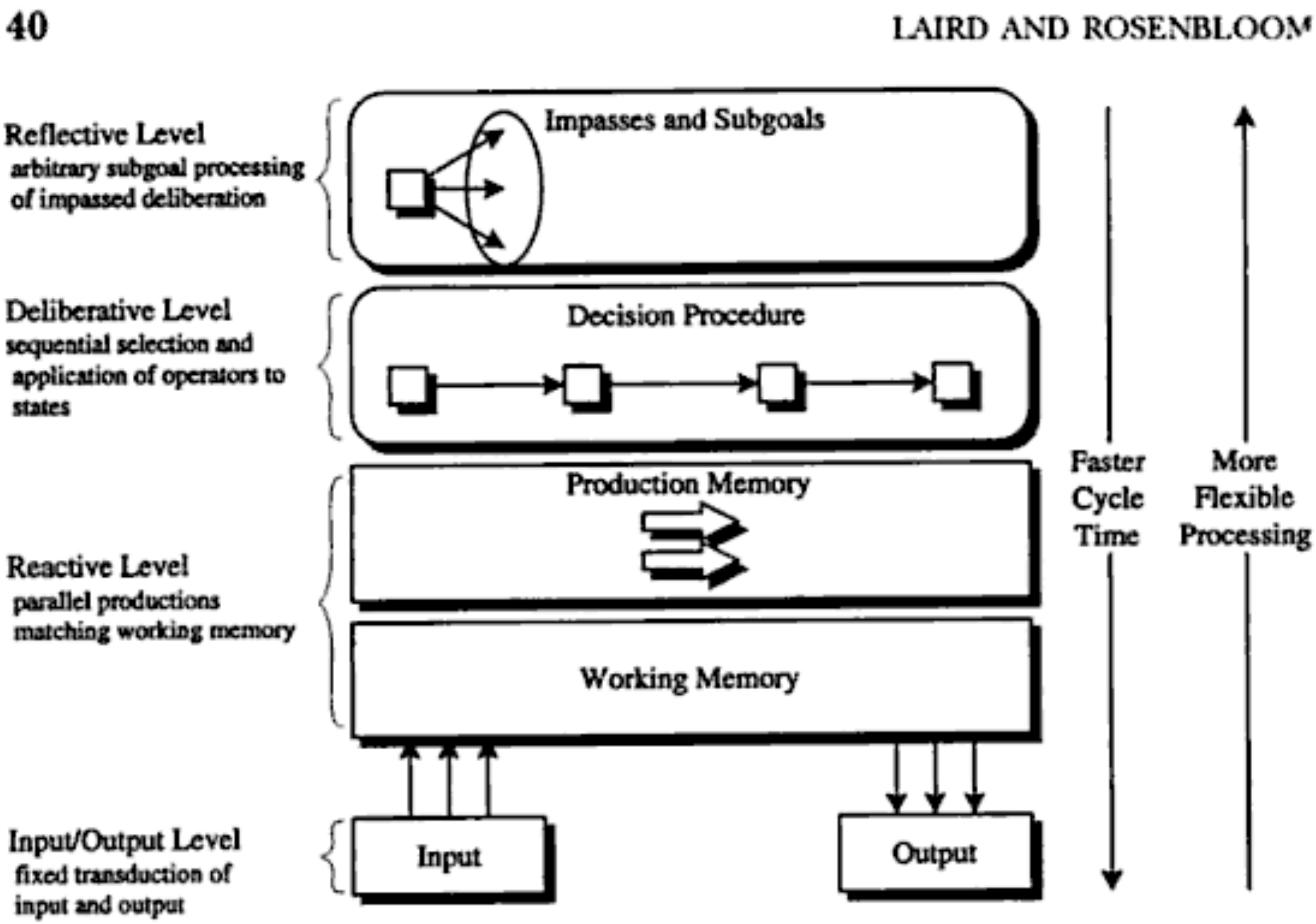
Architecture Lessons

- Structured dynamic plans make it easier to get your robot to do complicated stuff.
- Automated planning (or for Soar, chunking/learning) is seldom actually used.
- To facilitate that automated planning, modularity is often compromised.

(Bryson JETAI 2000)

Soar as a 3LA

J. Laird & P. Rosenbloom, “The Evolution of the Soar Cognitive Architecture”, *Mind Matters*, D. Steier and T. Mitchell eds., 1996.



Architecture Lessons

- Structured dynamic plans make it easier to get your robot to do complicated stuff.
- Automated planning (or for Soar, chunking/learning) is seldom actually used.
- Military turns chunking off because more productions slow down the system.
- “Teaching by brain surgery” / programming, not learning in real, installed systems.

CogAff

- Reflection on Top.
- Sense & Action separated!
- (Davis & Sloman 1995)

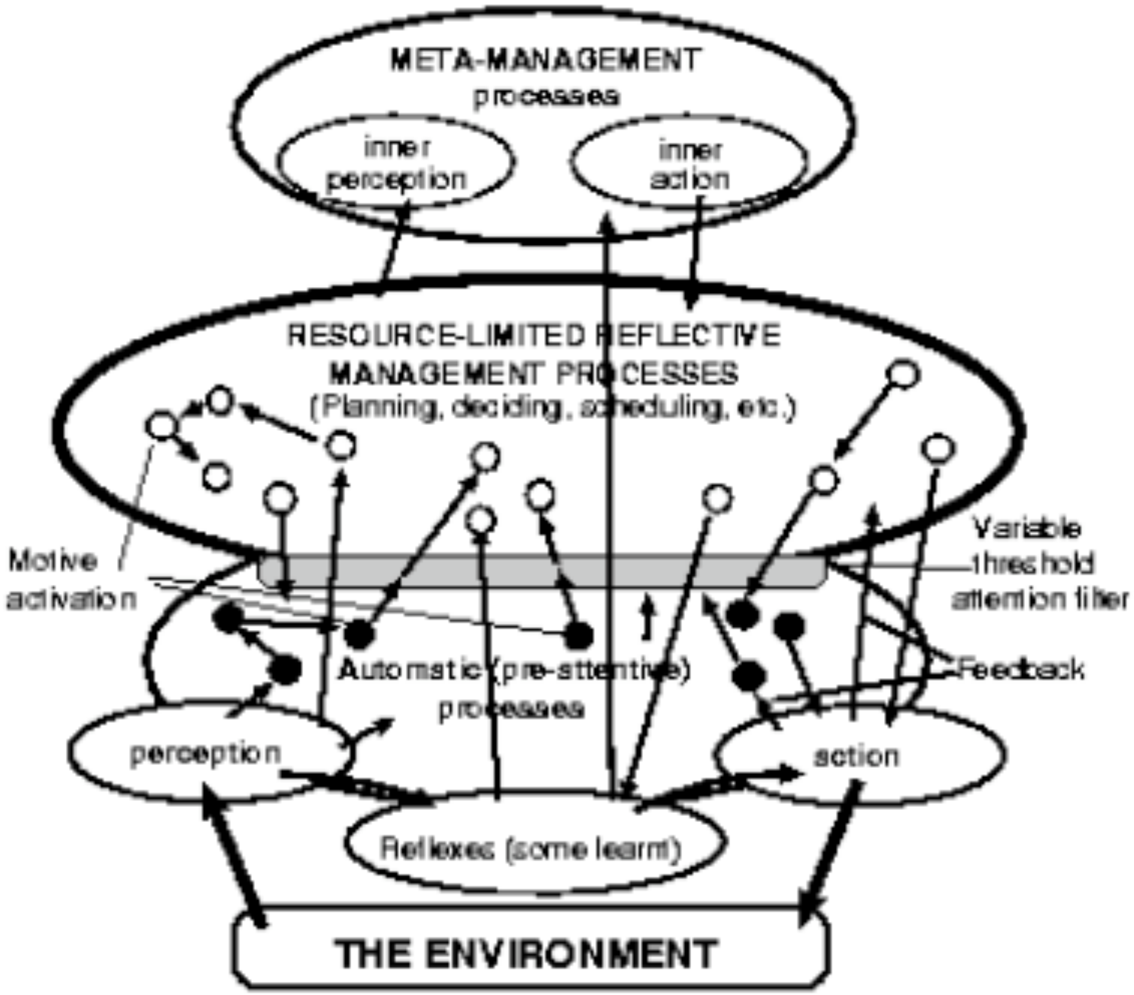
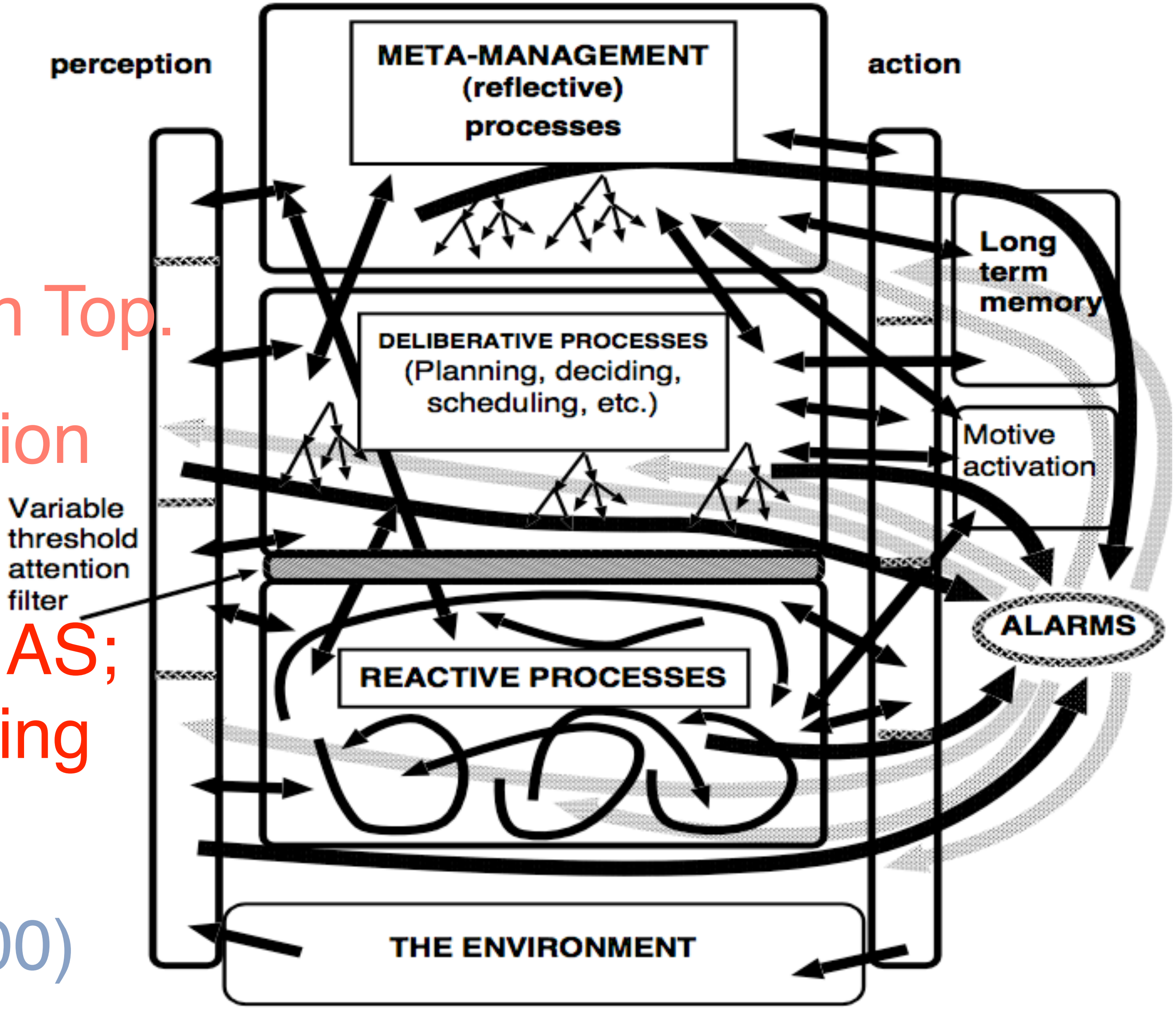


Figure 1 Towards an Intelligent Agent Architecture

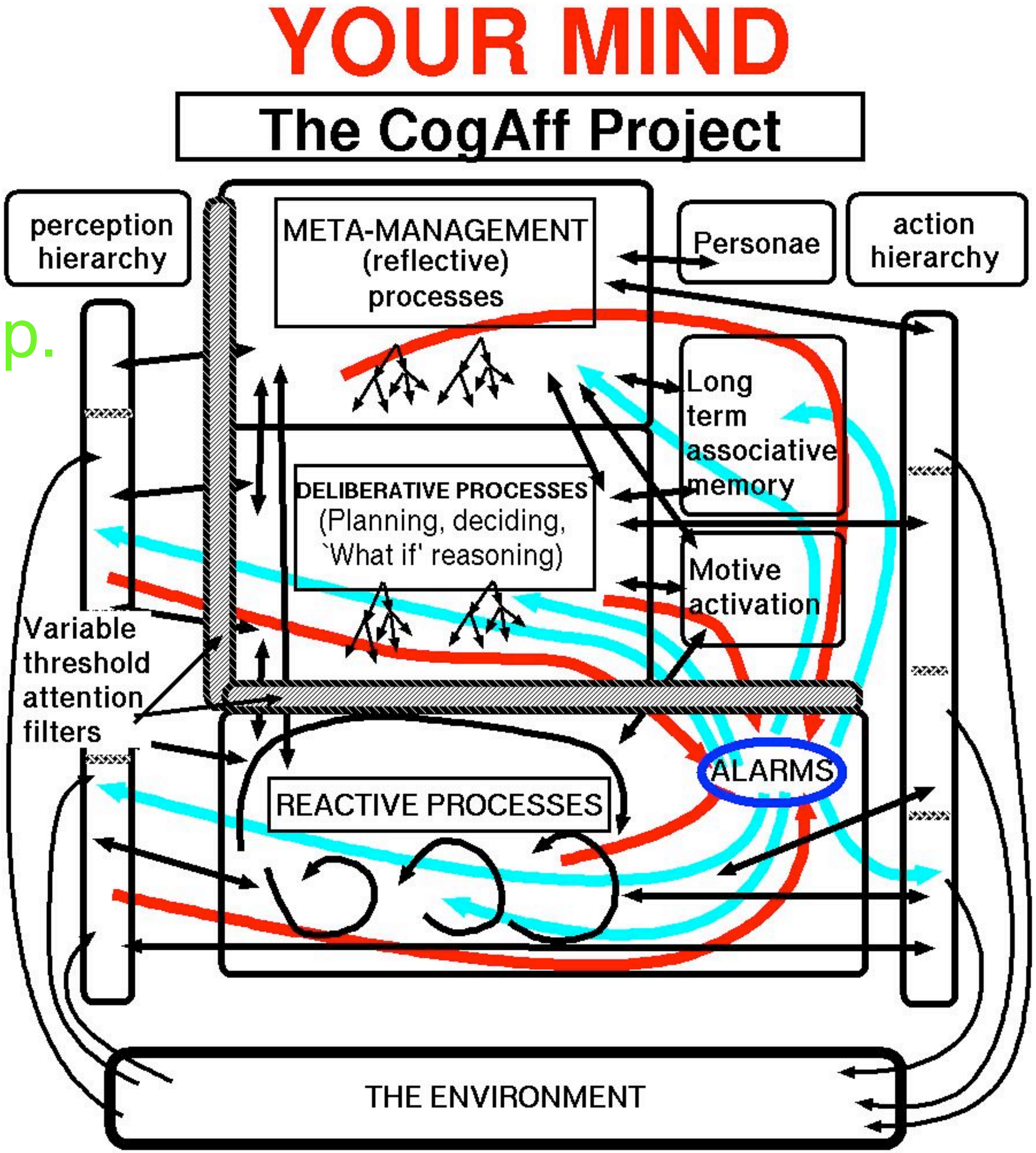
CogAff

- Reflection on Top.
- Sense & Action separated!
- Hierarchy in AS; Goal Swapping (Alarms).
- (Sloman 2000)

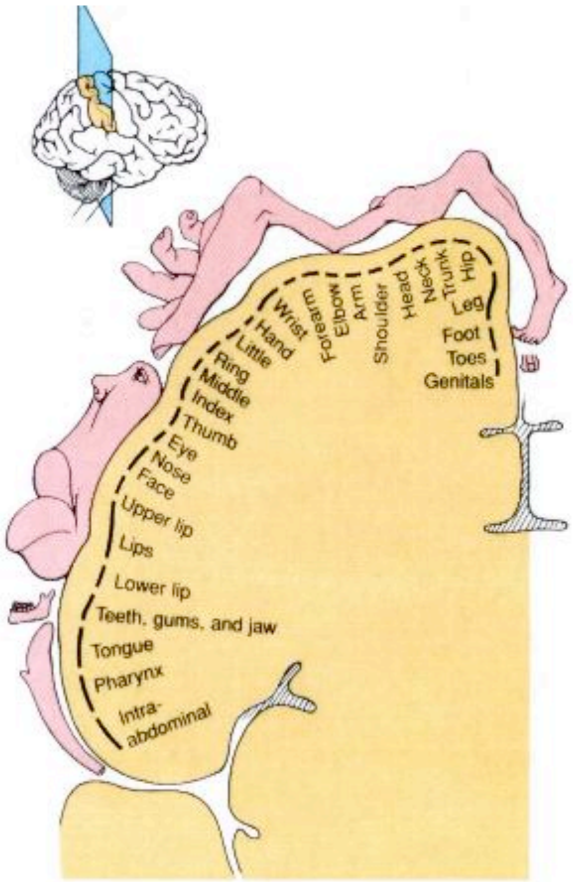


CogAff

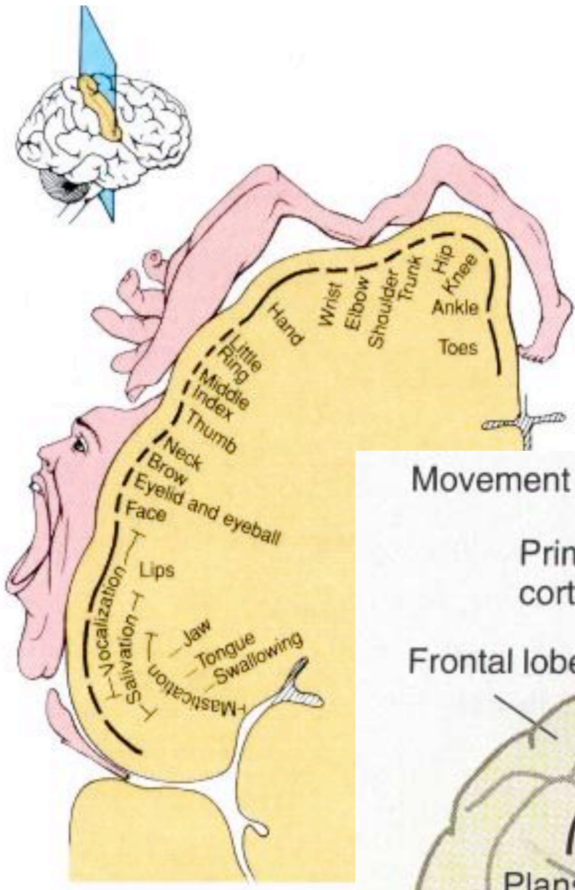
- Reflection on Top.
- Sense & Action separated!
- Hierarchy in AS, Goal Swapping (now reactive).
- Current Web



Separate Sense & Action

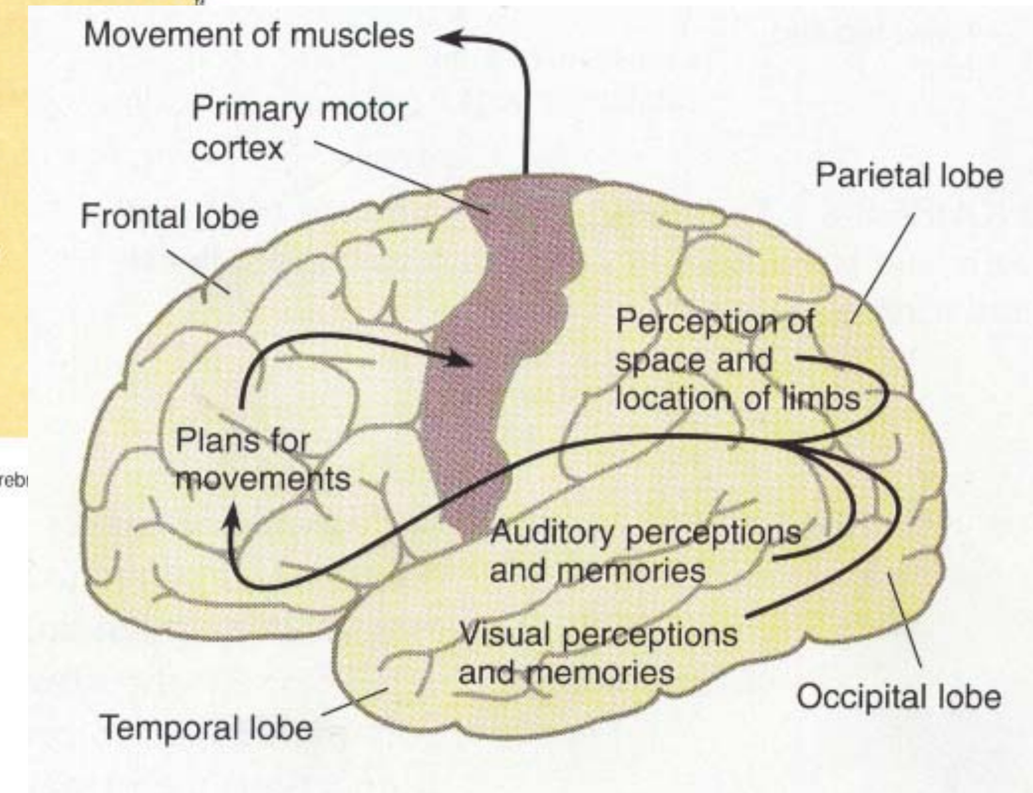


(a) Somatosensory cortex in right cerebral hemisphere



(b) Motor cortex in right cerebr

- Something we higher mammals do.
- Central Sulcus



Chance for Cognition?

(pictures from Carlson)

Architecture Lessons (CogAff)

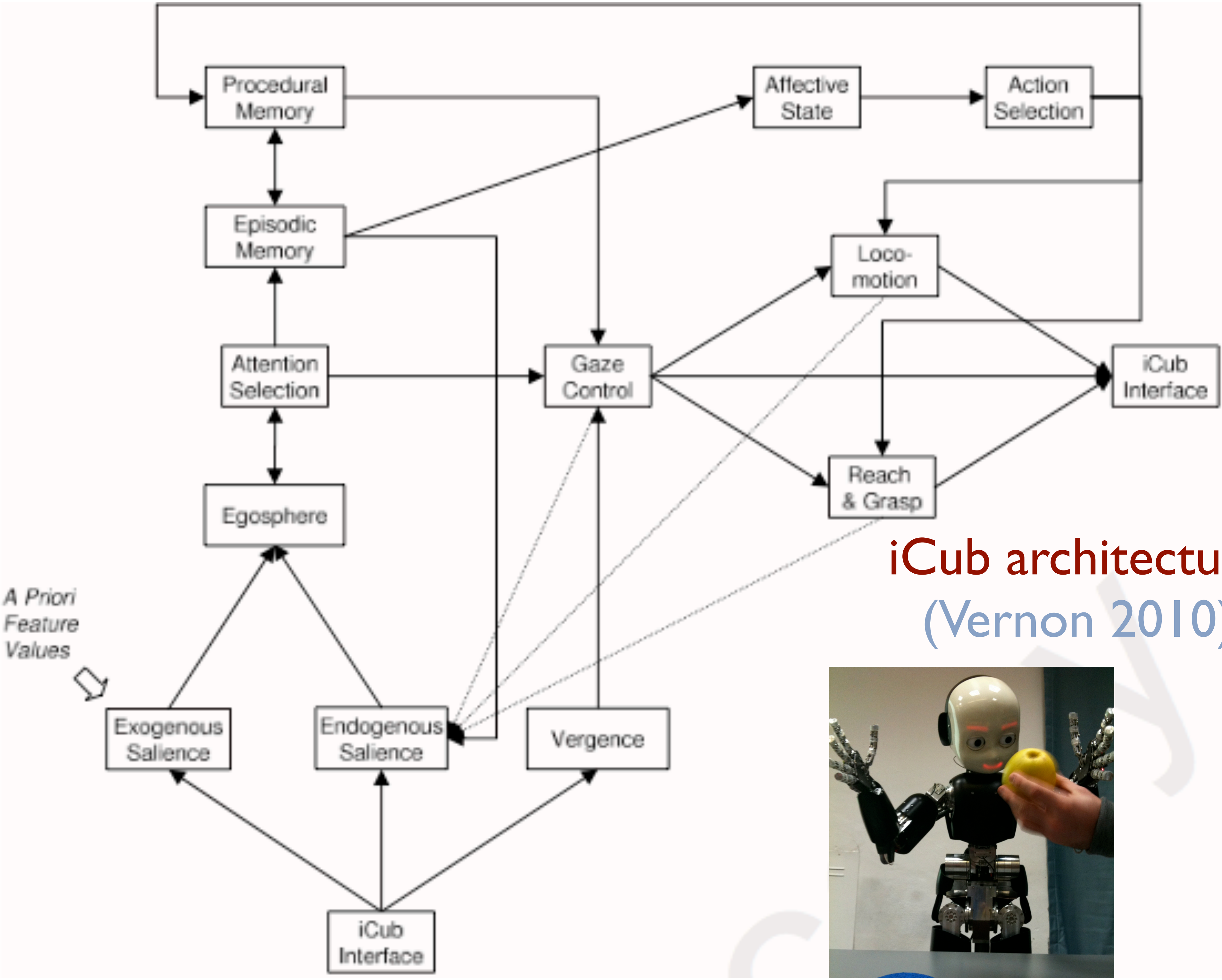
- Maybe you don't really want productions as your basic representation – you may want to come between a sense and an act sometimes.
- Your architecture looks very different if you really worry about adult human linguistic / literature-level behaviour rather than just making something work.

Contemporary Architectures?

- Currently people talk more about an architecture for a system, not an "architecture" meaning a generic development methodology + ontology.
- But the topic may come back again.
- And the ontologies and histories are still useful.

iCub architecture

(Vernon 2010)



Contemporary Architectures?

- Currently people talk more about an architecture for a system, not an "architecture" meaning a generic development methodology + ontology.
- But the topic may come back again.
- And the ontologies and histories are still useful.

Summary

- Architectures assume an ontology of what intelligence needs, and a development methodology.
- Architectures describe how the necessary parts should be connected.
- Cognitive architectures are often identified with working code – action selection systems.