Envisioning a Robust, Scalable Metacognitive Architecture Built on Dimensionality Reduction
Scruffy Metacognition

Jason B. Alonso[1]   Kenneth C. Arnold[2,3]   Catherine Havasi[3,2]

[1]Personal Robots Group
MIT Media Laboratory

[2]MIT Mind Machine Project

[3]Software Agents Group
MIT Media Laboratory

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The Challenge

- Metacognitive architectures too expensive to explore iteratively
  - Programmers never count to 3.

What to do?

How do we build a scalable framework for metacognitive architectures?

- Hand-crafted metareasoners are out.
- Use many instances of a few types of simple but powerful reasoning units.
    - Difference between reasoner and metareasoner in the inputs
    - Communicate with simple symbols, generally opaque semantics
        - What kinds of symbols? More later.

What "reasoning units"?

What function should each component perform?

- Connectionist answer (switches, or "neurons") theoretically satisfying to some, practically less than enlightening
- Our answer: pattern discovery and matching
    - One basic process of an intelligent system is to identify useful patterns in its input and its output
    - One symbol $\iff$ one pattern
        - Summarizing many inputs and outputs with fewer symbols
        - ... in essence, dimensionality reduction

We claim...

- Planning can be a pattern completion problem that leverages dimensionality reduction
- Metacognitive functions, particularly metaplanning, can be built on these principles

We are "Scruffies"

- Imprecise and loosely statistical handling of symbolic representations

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- Imprecise and loosely statistical handling of symbolic representations

Current knowledge			
→ reading to your children is for educating them.	by ☺ kinchin	Score: 6	
→ teaching other people is for educating them.	by ☺ Jake512	Score: 4	
→ seeing art is for Education.	by ☺ MarkFarrar	Score: 4	
→ Education is acquisition of knowledge and understanding	by ☺ Bryan	Score: 4	
→ answering questions is for educating.	by ☺ LaserJoy	Score: 3	
→ watching television is for education.	by ☺ justJim	Score: 3	
→ The effect of going to school is education	by ☺ damien29	Score: 3	
→ education can further your career	by ☺ budo	Score: 3	

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Open Mind wants to know...

educate is similar to learn . [+] [-]
learn is similar to educate . [+] [-]
One of the things you do when you attend class is educate . [+] [-]

Open Mind Common Sense

We are "Scruffies"

- Imprecise and loosely statistical handling of symbolic representations

ConceptNet

We are "Scruffies"

- Imprecise and loosely statistical handling of symbolic representations

	cat	dog	airplane	toaster
...IsA pet	+6	+5		
...AtLocation home	+8	+2		+1
...CapableOf fly	−3	−5	+9	
...MadeOf metal			+1	+1
fur PartOf ...	+6	+5		

AnalogySpace, prepared

We are "Scruffies"

- Imprecise and loosely statistical handling of symbolic representations (dynamic representations)
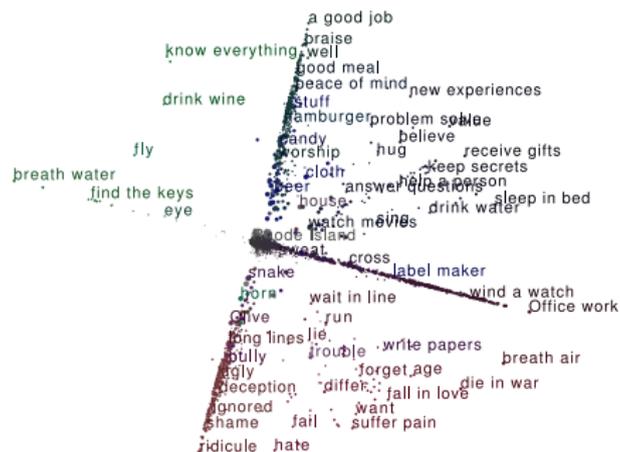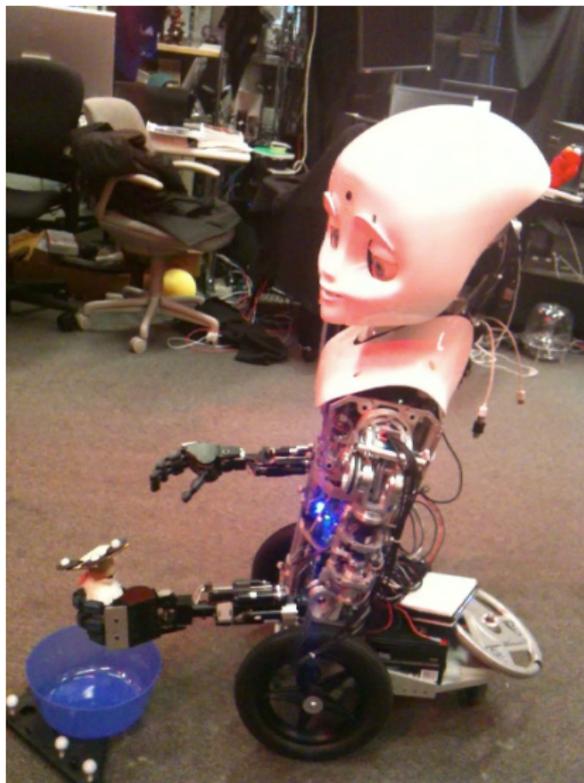

AnalogySpace, computed
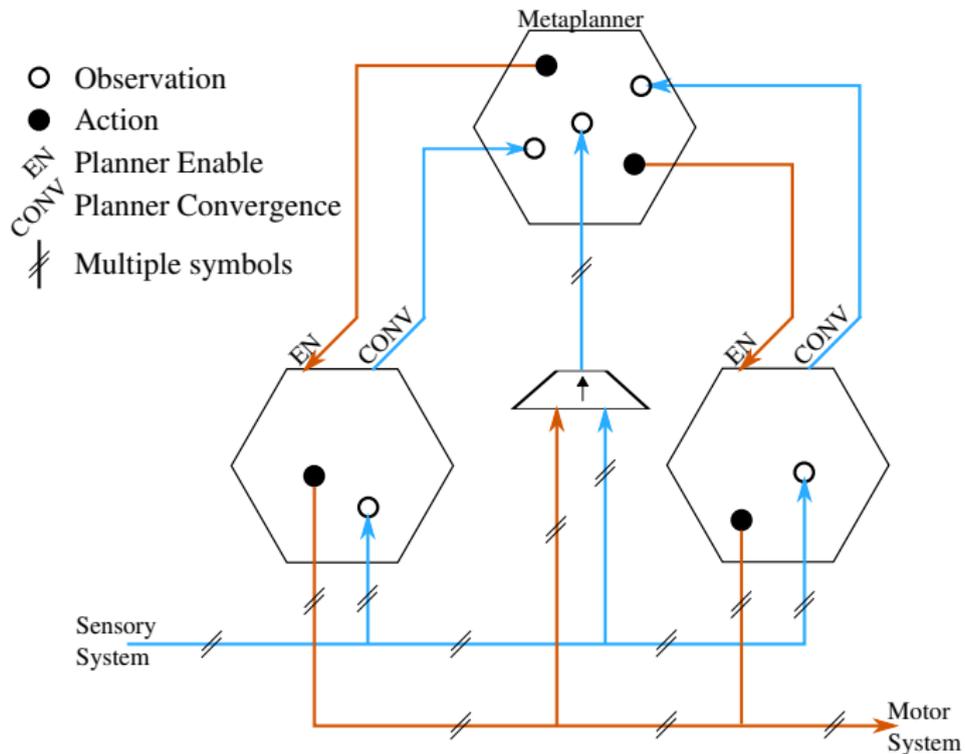
Sheep games
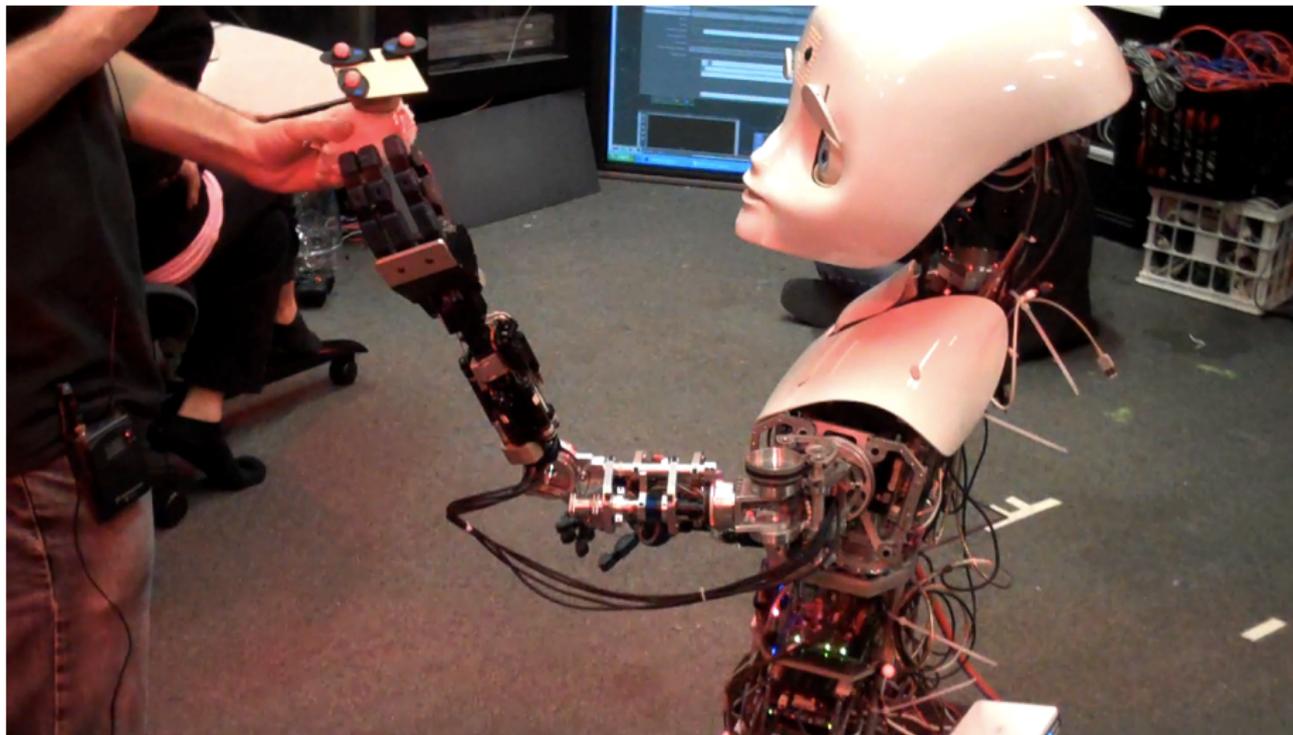
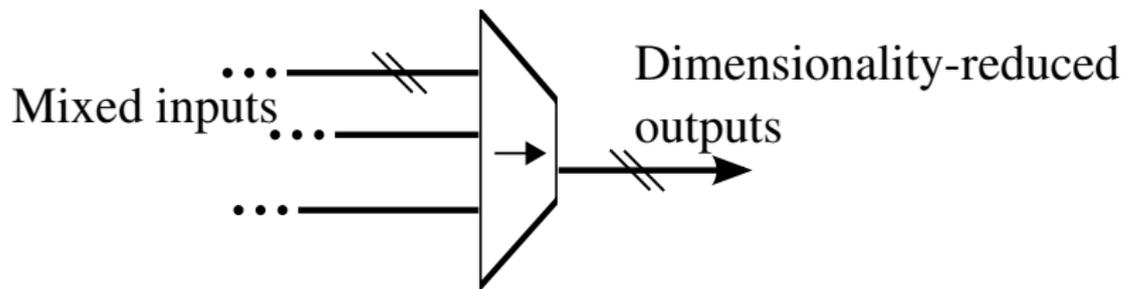"Nexi, come take the sheep."

Sheep games, continued

Now imagine two games...

- Both involve picking up toys and putting them somewhere
- How could Nexi know which game we're playing?

An architecture

- ○ Observation
- ● Action
- EN Planner Enable
- CONV Planner Convergence
- ⊬ Multiple symbols

Metaplanner

Sensory System

Motor System

The Reducer

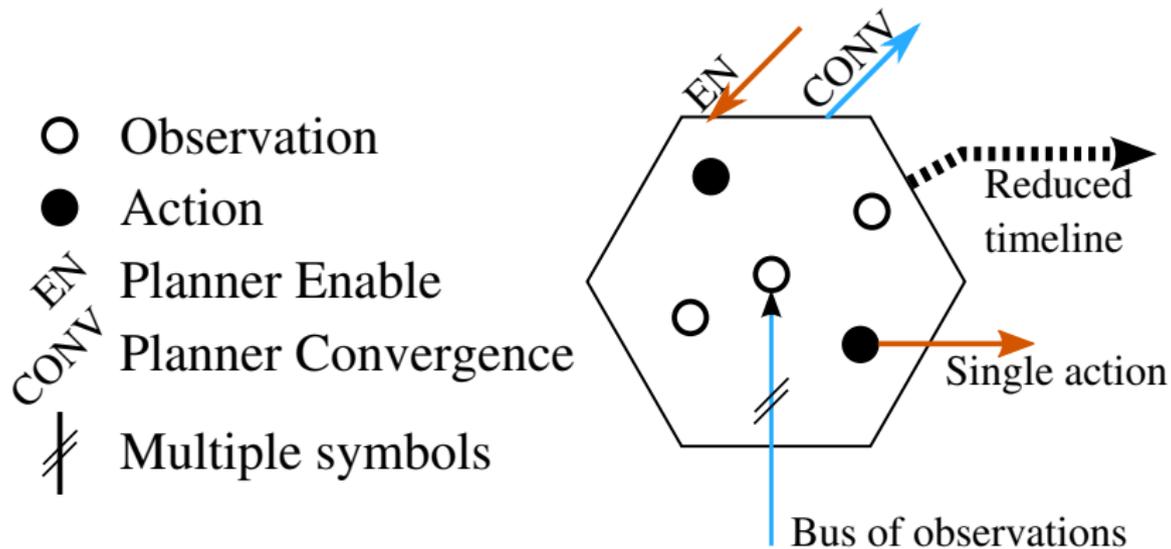Mixed inputs · · · ─── Dimensionality-reduced outputs

- Candid, Covariance-free Incremental Principal Component Analysis (CCIPCA) (Weng et al. 2003)
- Essentially AnalogySpace
  - Dynamically-generated representations
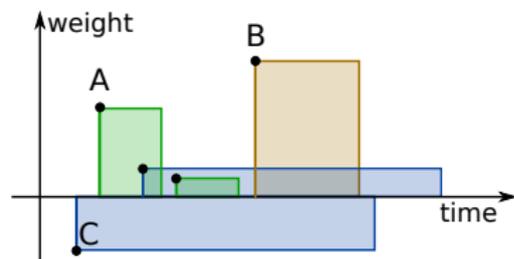 - Open domain
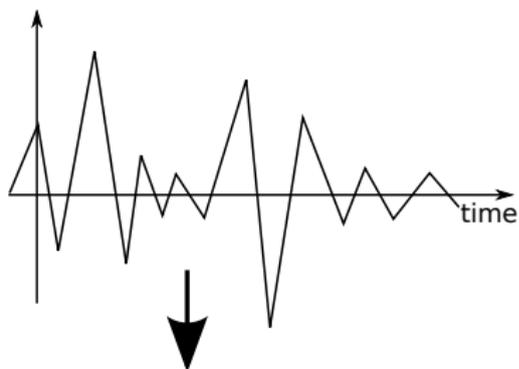
The Planner, part 1 of 2
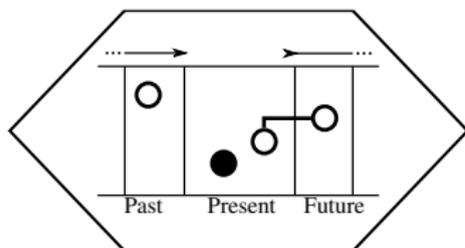
- Build a model of salient patterns in observable events and behaviors
- Generate plans that achieve goals given this model
- Incremental. Learn/refine models from experience in real time
- Scruffy. Statistical handling of symbolic representations of the real world to draw robust conclusions
- In practice, two approaches:
    - Replay of natural responses to environment and teammates
    - Goal-seeking

The Planner, part 2 of 2

○ Observation

● Action

EN Planner Enable

CONV Planner Convergence

⫽ Multiple symbols

EN

CONV

Reduced timeline

Single action

Bus of observations

Intuitive Introduction to MIDAWT

Given a multivariate waveform (timeline):

- Detect instances of previously-seen patterns
- Refine models for those patterns (or record new pattern)
- Describe timeline as a combination of understood patterns
- Complete timeline by interpolating gaps in timeline

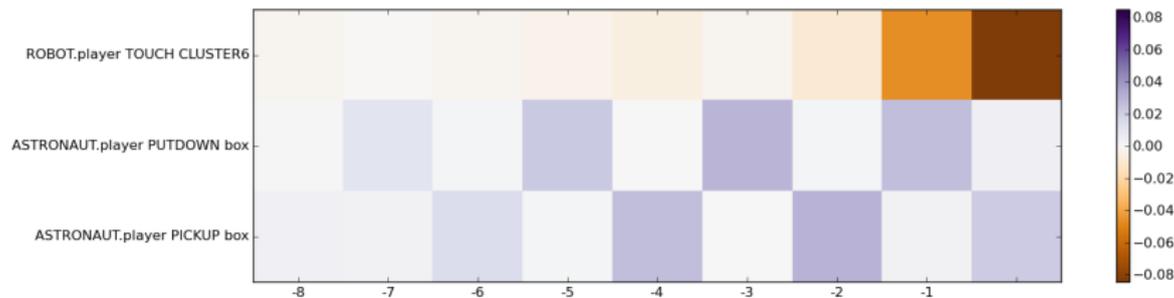$$\vec{f}[t] = (\sum_i a_i * \vec{g}_i)[t]$$
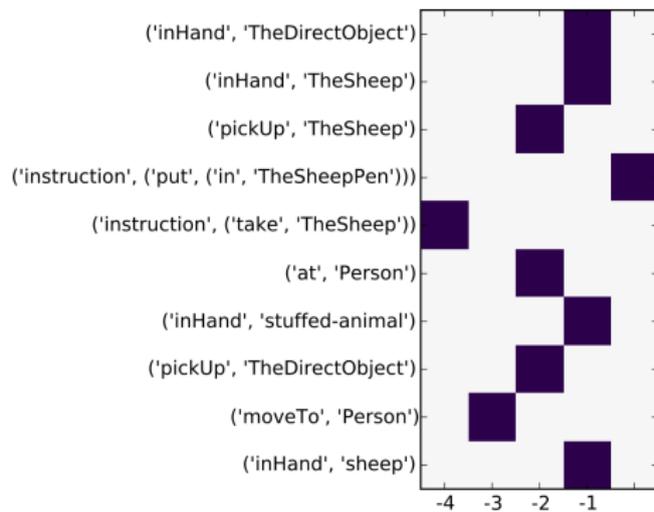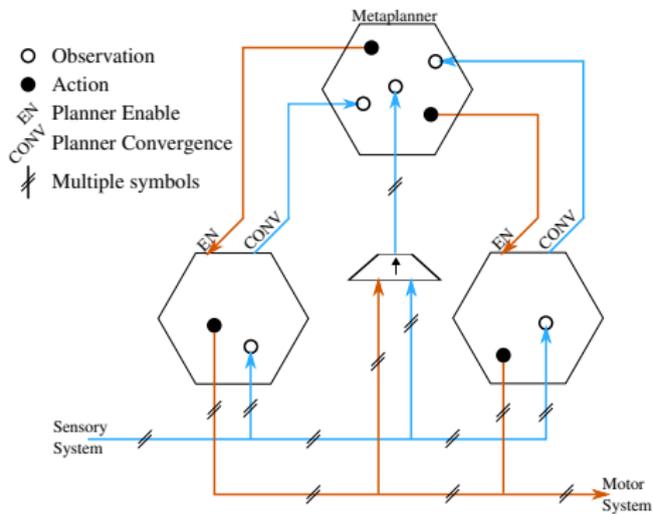
An architecture

Summary

- The difference between cognition and metacognition is in the wiring, permitting scalable architectures.
- Systems that build their own representations dynamically are more robust.

- Forthcoming experiments
  - Mars Escape
  - Restaurant Game
  - Explore/exploit

Here be dragons

A Unique MIDAWT/SP Insight

- When the astronaut player is engaged in a search activity with a bunch of boxes, the robot is not about to hit the elevator call button.
- Correlation not causal, but reflective of teaming behavior
- Anti-correlation not found in CBP or plan networks