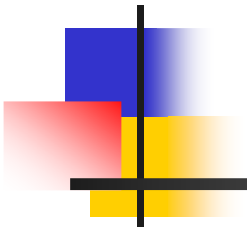


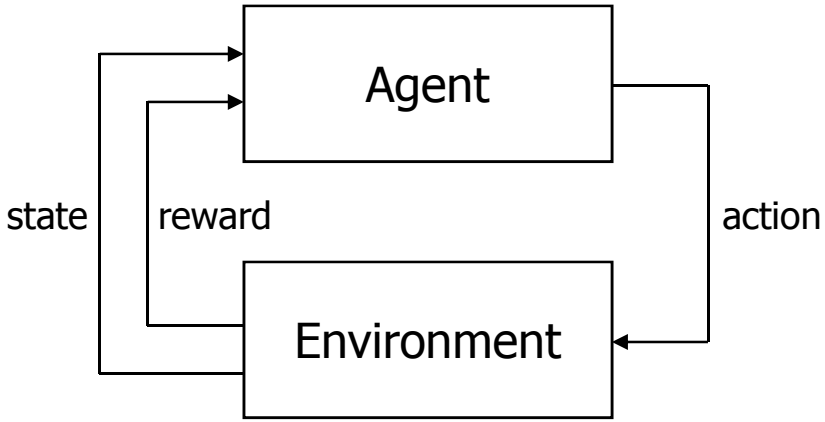
Learning to Control Internal Memory

Nicholas Gorski

28th Soar Worskhop
May 6, 2008

Learning Control in AI

- Central problem in reinforcement learning: selecting actions in environment so as to maximize reward



- No internal state under agent's deliberate control

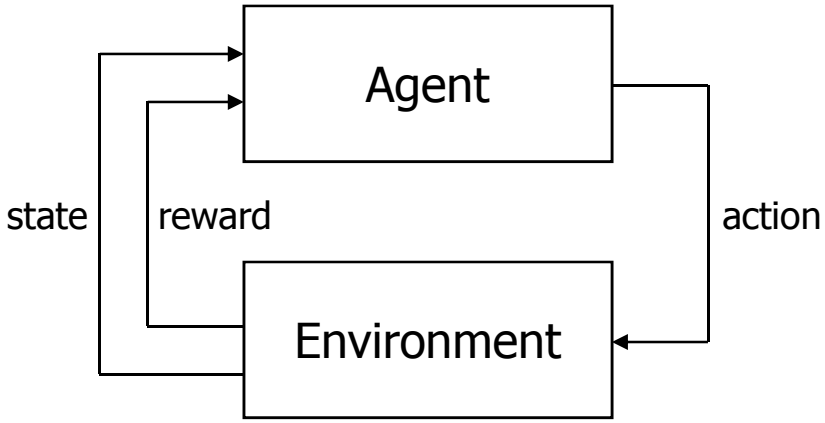
Memory & Learning in Cognitive Architectures

- Cognitive architectures do have additional internal memory mechanisms
  - Procedural, semantic, and episodic memories
- Learning in cognitive architectures
  - Adjusts control knowledge over actions in environment
  - Implicitly learns control over internal mechanisms
  - Focus: external behavior, not control of internal memory

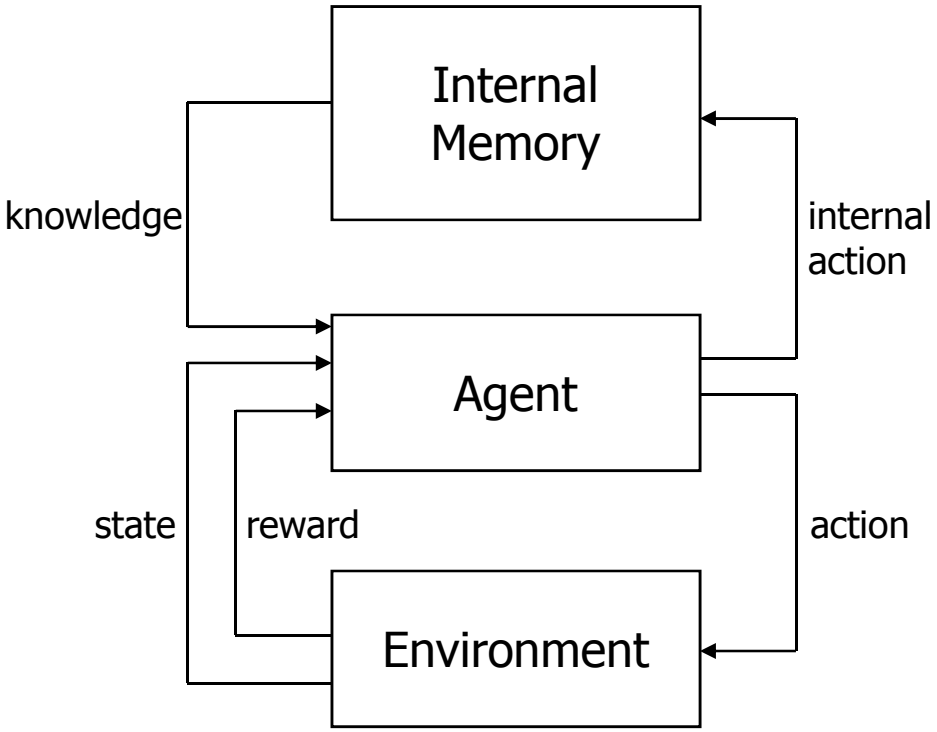
Learning to Control Internal Memories

- What happens when a simple agent can learn control over an internal memory?
  - Relatively unexplored
    - Peshkin, Meuleau, Kaelbling ICML '99
    - Lanzi SAB '00
  - Factorization gives functional benefit?
    - Memory treated as part of state
    - Simplifies learning action selection in environment
- Might inform our knowledge of likely memory mechanisms

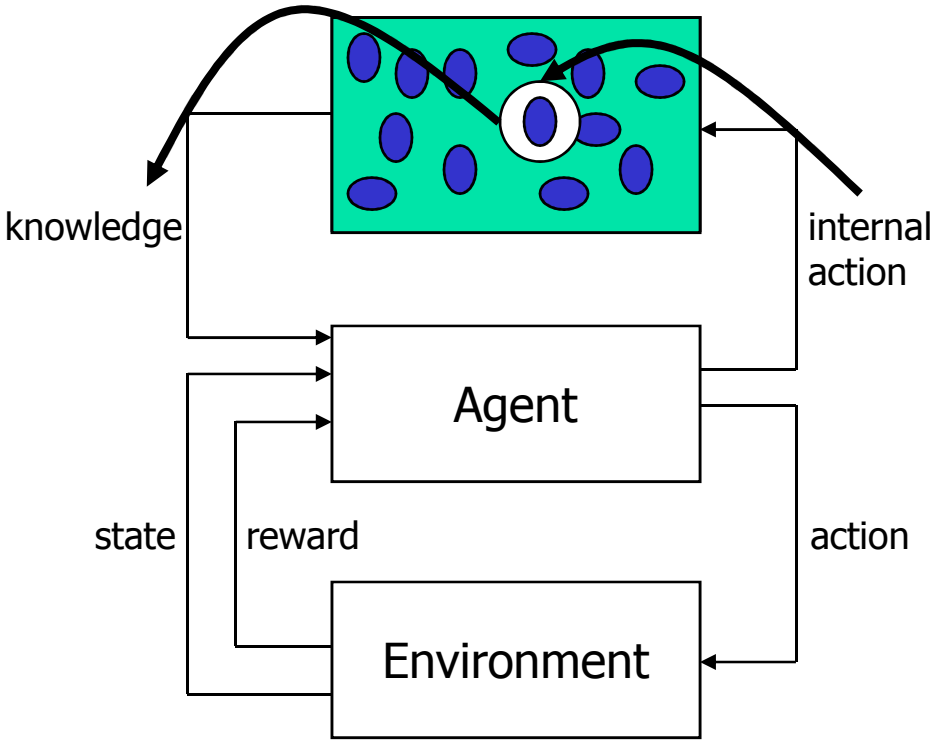
A Framework to Learn to Control Memory



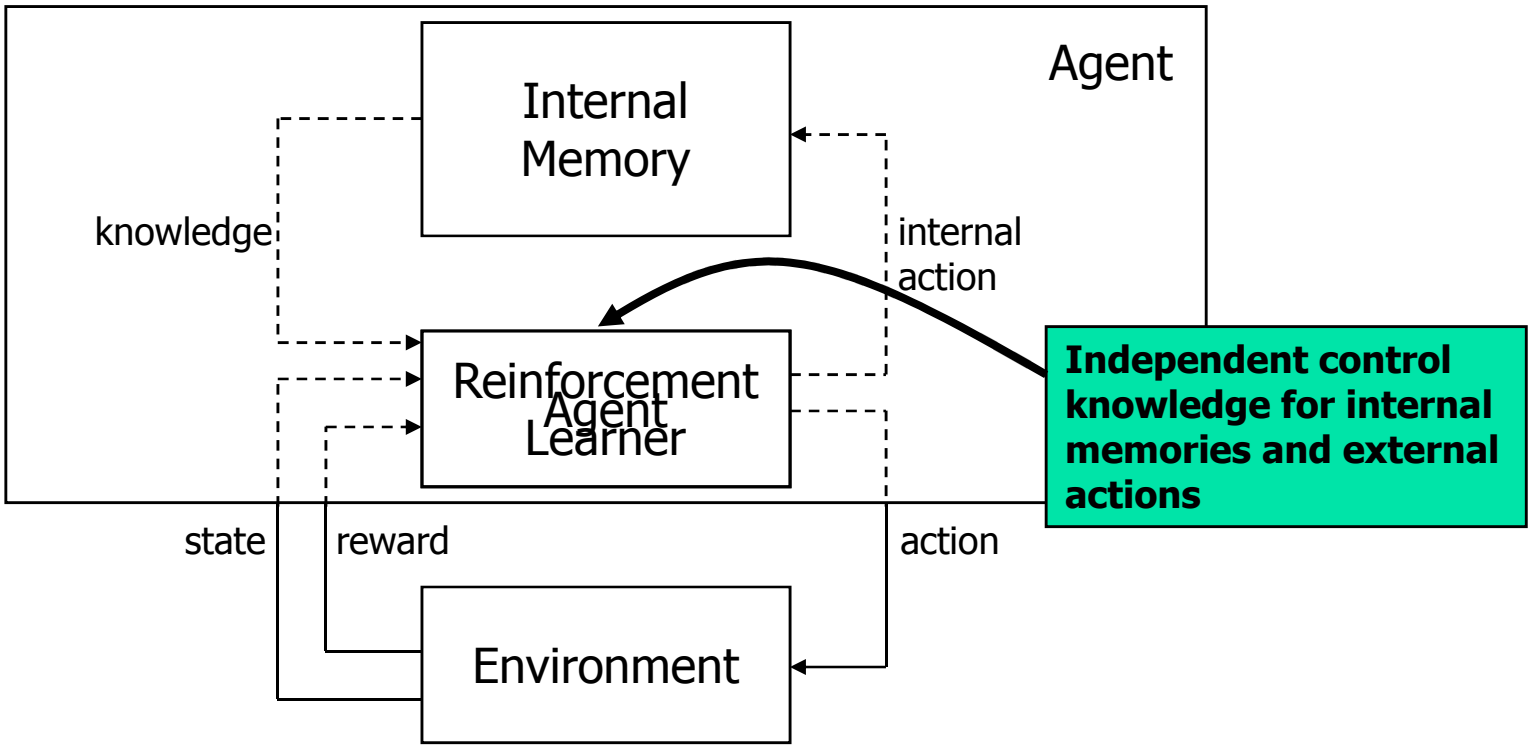
A Framework to Learn to Control Memory

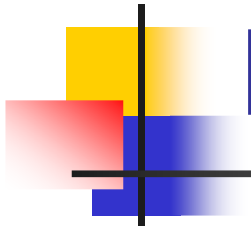


A Framework to Learn to Control Memory



A Framework to Learn to Control Memory



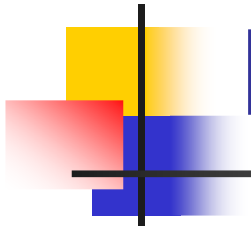


Research Directions

1. Enumerate dimensions of design space for memory mechanisms
   - Informed by cognitive psychology
2. Empirically evaluate design spaces
   - Using parameterized domains that allow for cross-comparisons between designs
3. Determine how domain characteristics impact performances of different designs
   - Identify classes of problems on which certain implementations apply / don't apply

Dimensions of Design Space

- Size
  - Of memory mechanism
    - Finite
    - Infinite
  - Of memory elements
    - Single symbol
    - Tuple
    - Chunk
- Internal representation
  - Slot-based
    - General-purpose
    - Special-purpose
  - Combinatorial working memory
- Amodal / Multimodal
- Decay & Persistence
- Interference
  - Proactive
  - Retroactive

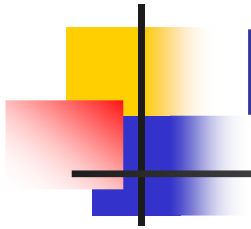


Exploratory Empirical Work

- Preliminary work with
  - very simple tasks
  - very simple memory mechanisms
- Goal: determine if learning to control memory is deserves further investigation
- Two tasks
  - long-term memory in a grid world
  - episodic memory with paired associate recall

Long-term Memory Task

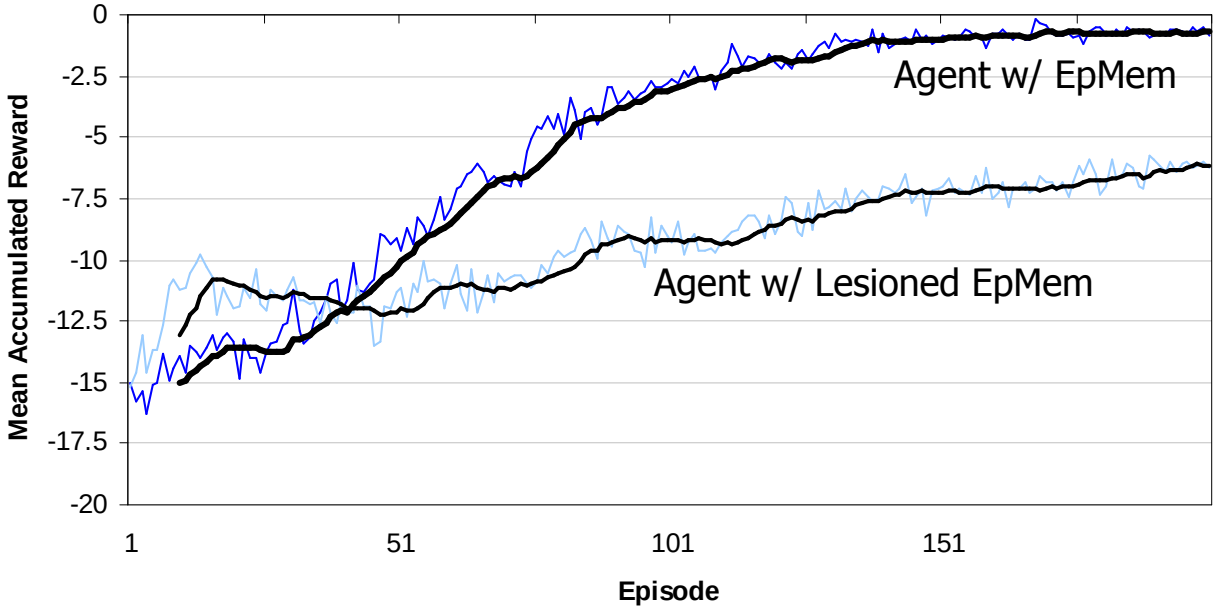
- Mechanism
  - Automatic storage of salient symbols to memory
  - Available actions: retrieve <x>, maintain, noop
- Grid world task where optimal performance required
  - Navigating to a special location and observing an event
  - Retrieving and maintaining memory while navigating to corresponding goal location
- Results
  - Agent learned to control memory
  - Learned to selectively retrieve task-relevant knowledge
  - Learned to control memory over delayed retrievals



Episodic Memory Task

- Motivation: initial exploration of learning to control an episodic-like (associative) memory mechanism
- Inspiration: paired associate recall
  - I say "X", you ask "what is paired with X?"
  - I say "X is paired with 2", you do action correlated with "2"
  - Later, I say "X", you think "2" and do act correlated with "2"
  - Pairings randomized every episode
  - 2 presentations of each pair every episodie
- Goal
  - when agent doesn't know paired symbol, it asks for it
  - when agent knows paired symbol, retrieves it from memory

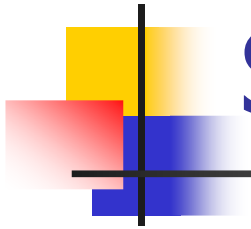
Episodic Memory Task Results



- Results:
  - + learned paired associative recall task
  - - failed to learn more difficult, temporally extended task

Other Research Questions

- What 2nd order phenomena occur in agents' behaviors as a result of learning?
  - Rehearsal → limited persistence
  - Attention → interference
  - Or do they require additional mechanisms?
- Is Intrinsic Reward necessary to learn well?
  - Partial observability can lead to rewarding loops that prevent agent from fully exploring domain
- Can agent learn over simultaneous actions?
  - Or are composite actions necessary?



Summary

- Exploring effects of learning over internal memory mechanisms
- May inform work in cognitive modeling & architecture design
- Early work… no nuggets or coal yet.