

Soar Workshop

Semantic Memory Tutorial

Nate Derbinsky

While waiting... download WordNet

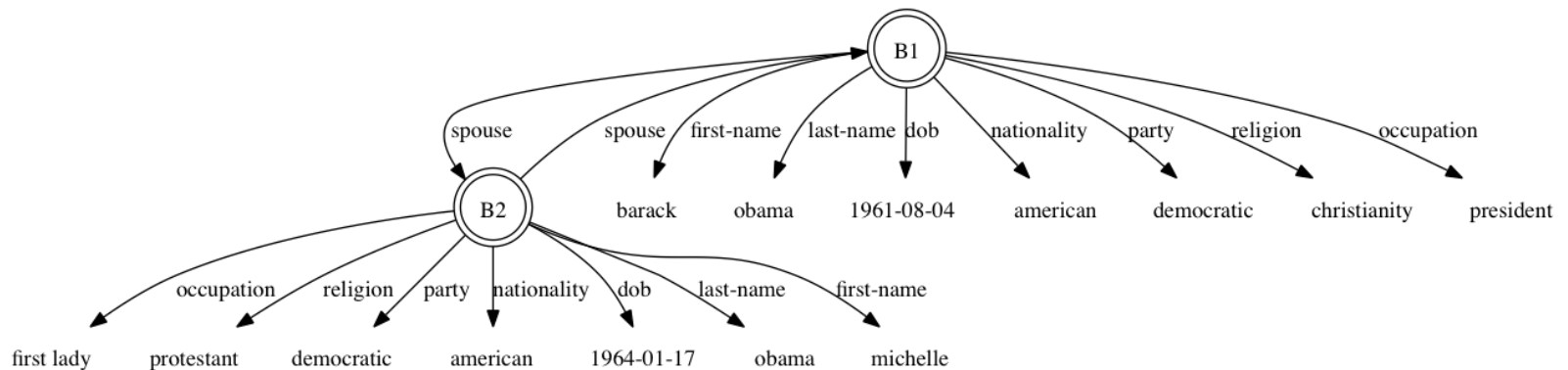
<https://soar.eecs.umich.edu/tutorial/>

Agenda

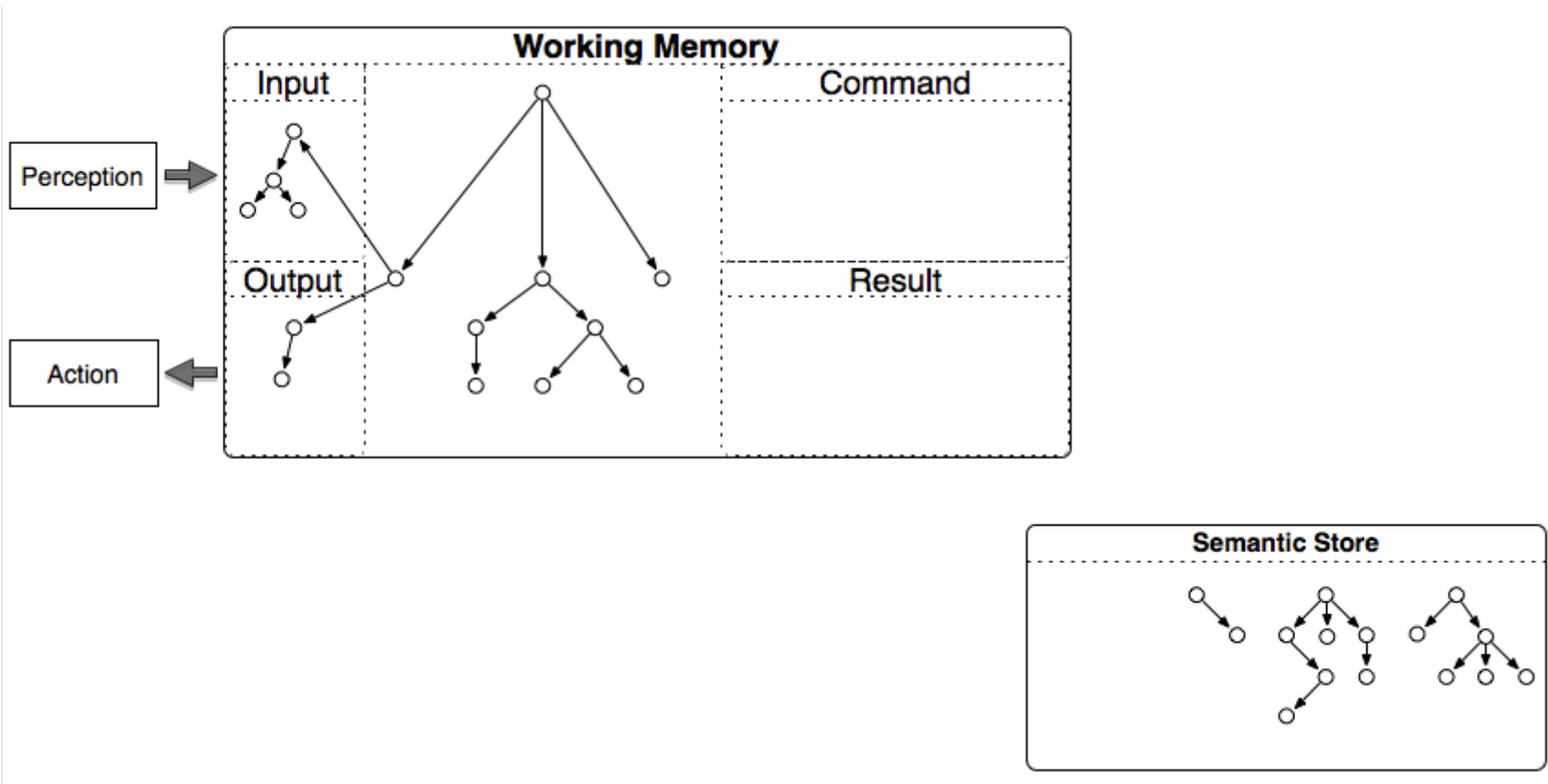
- Big picture
- Basic usage
- WordNet demo
- Additional resources

Semantic Memory: Big Picture

Supports deliberate storage and retrieval of long-term “objects,” features, and relations

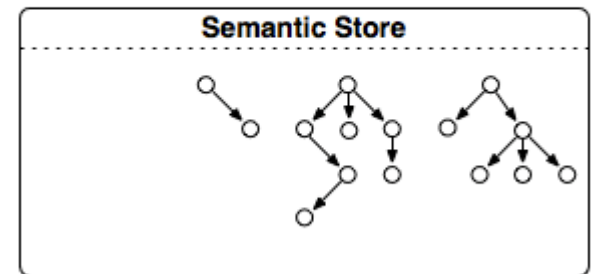
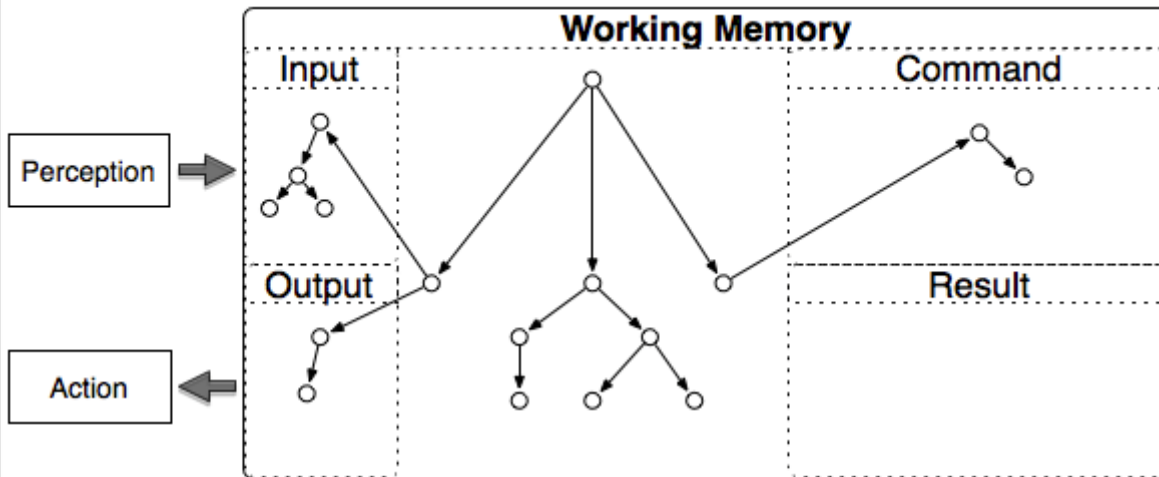


Architectural Integration



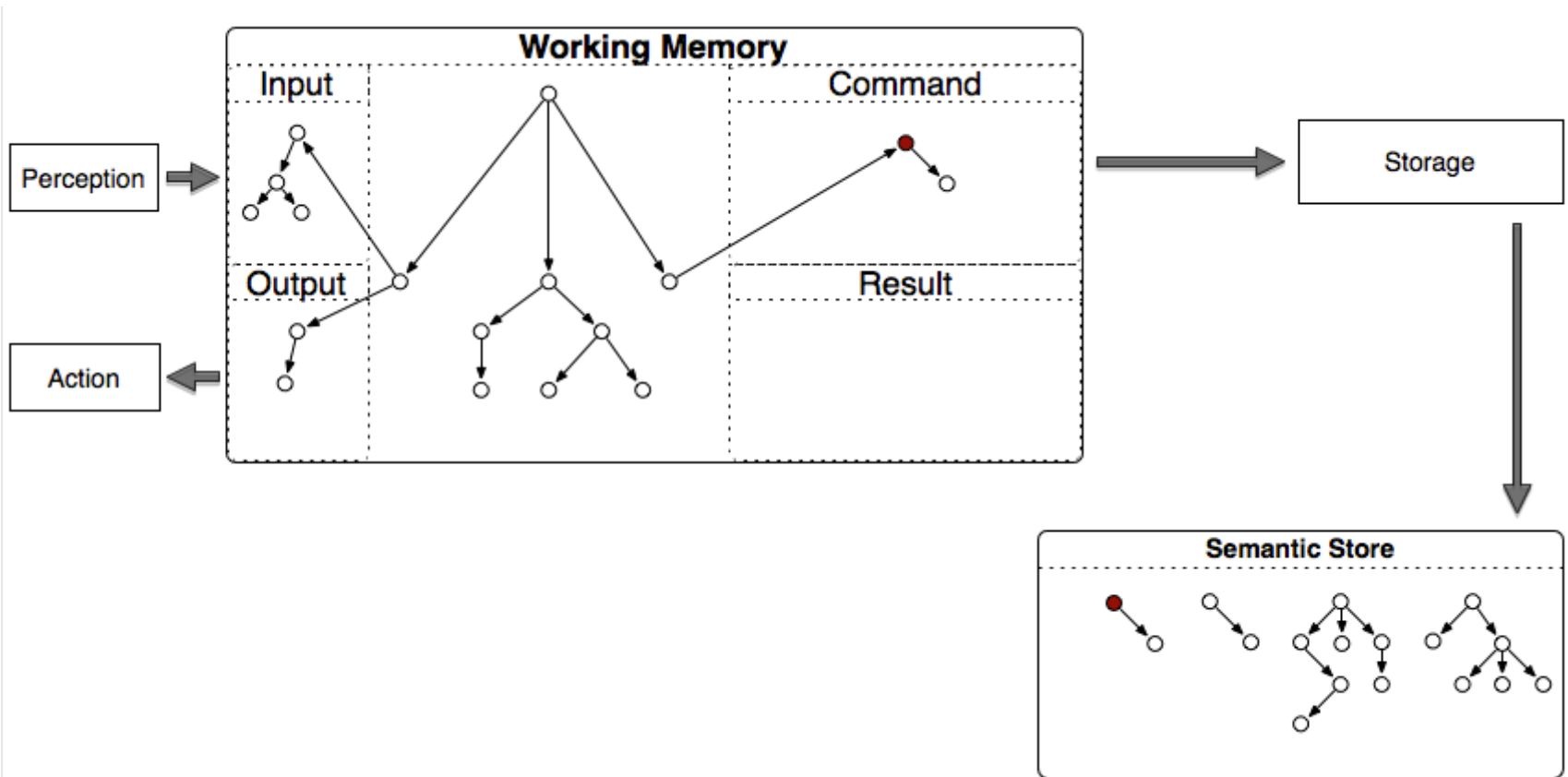
Architectural Integration

Storage



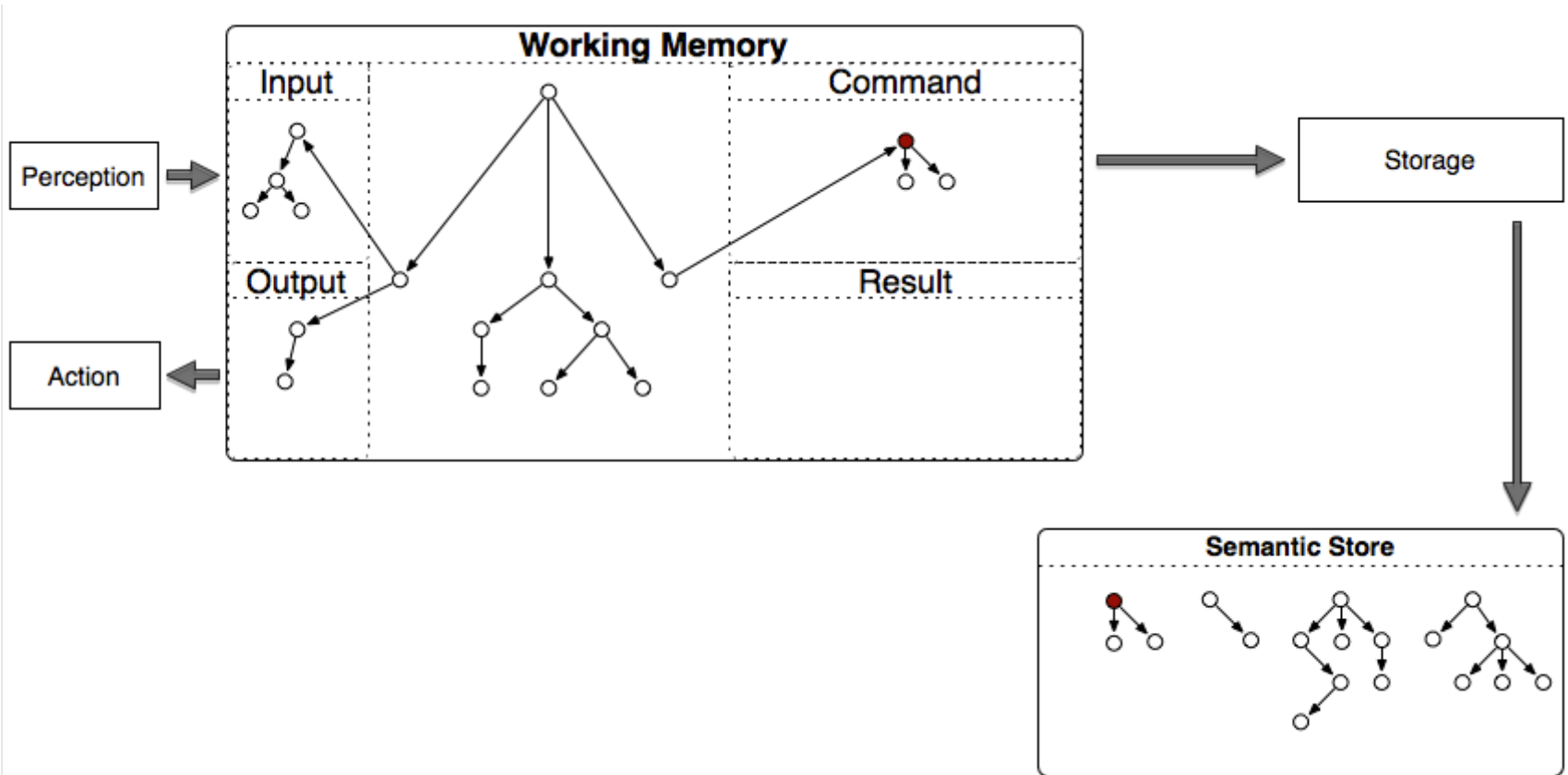
Architectural Integration

Storage



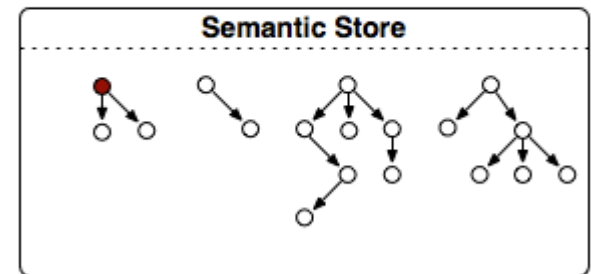
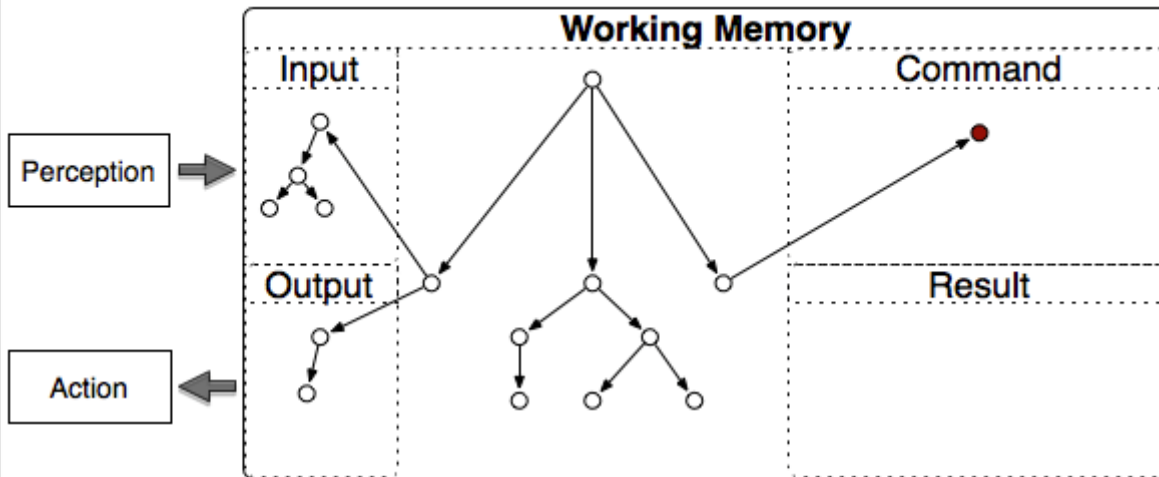
Architectural Integration

Storage



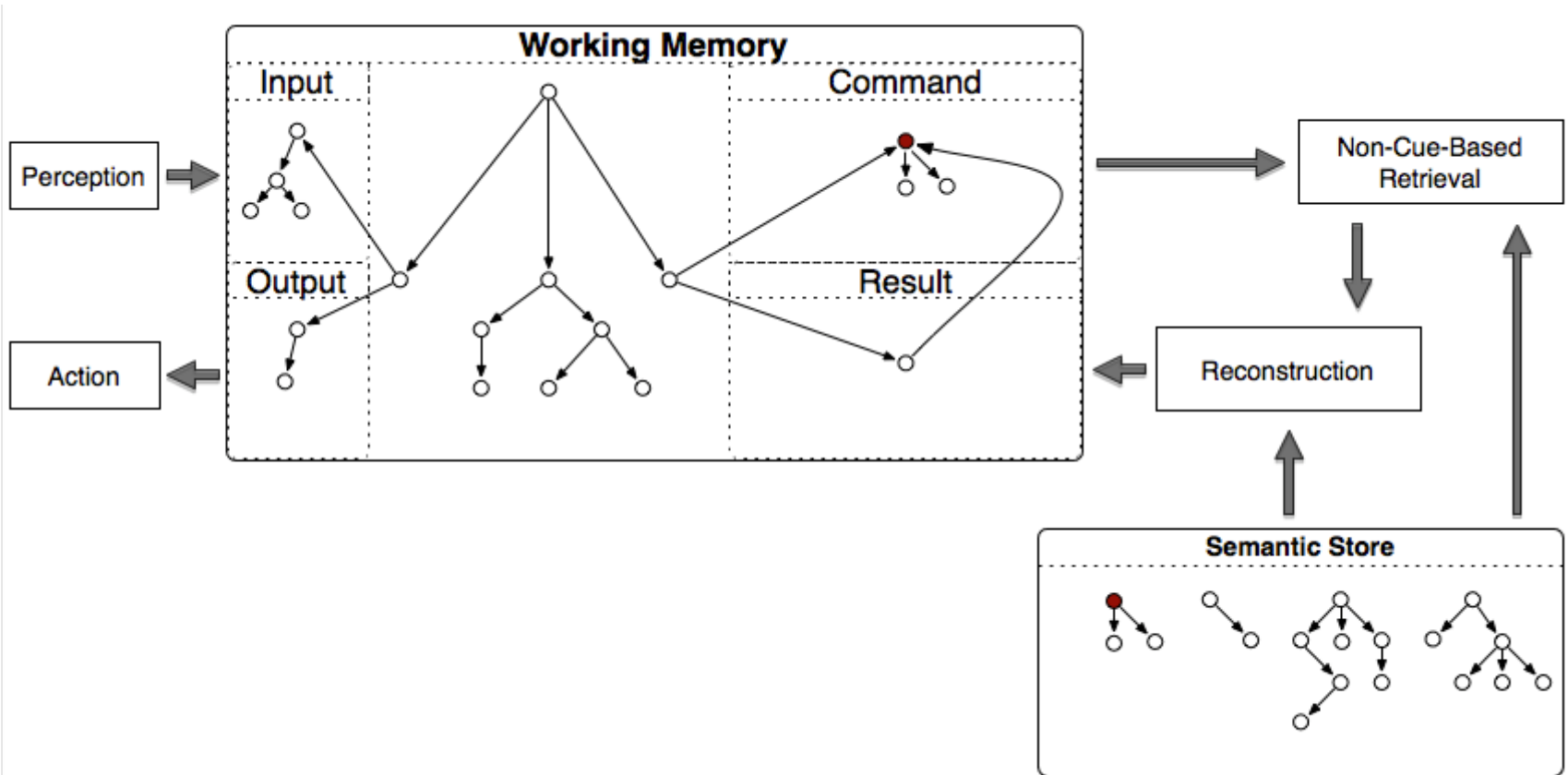
Architectural Integration

Non-Cue-Based Retrieval



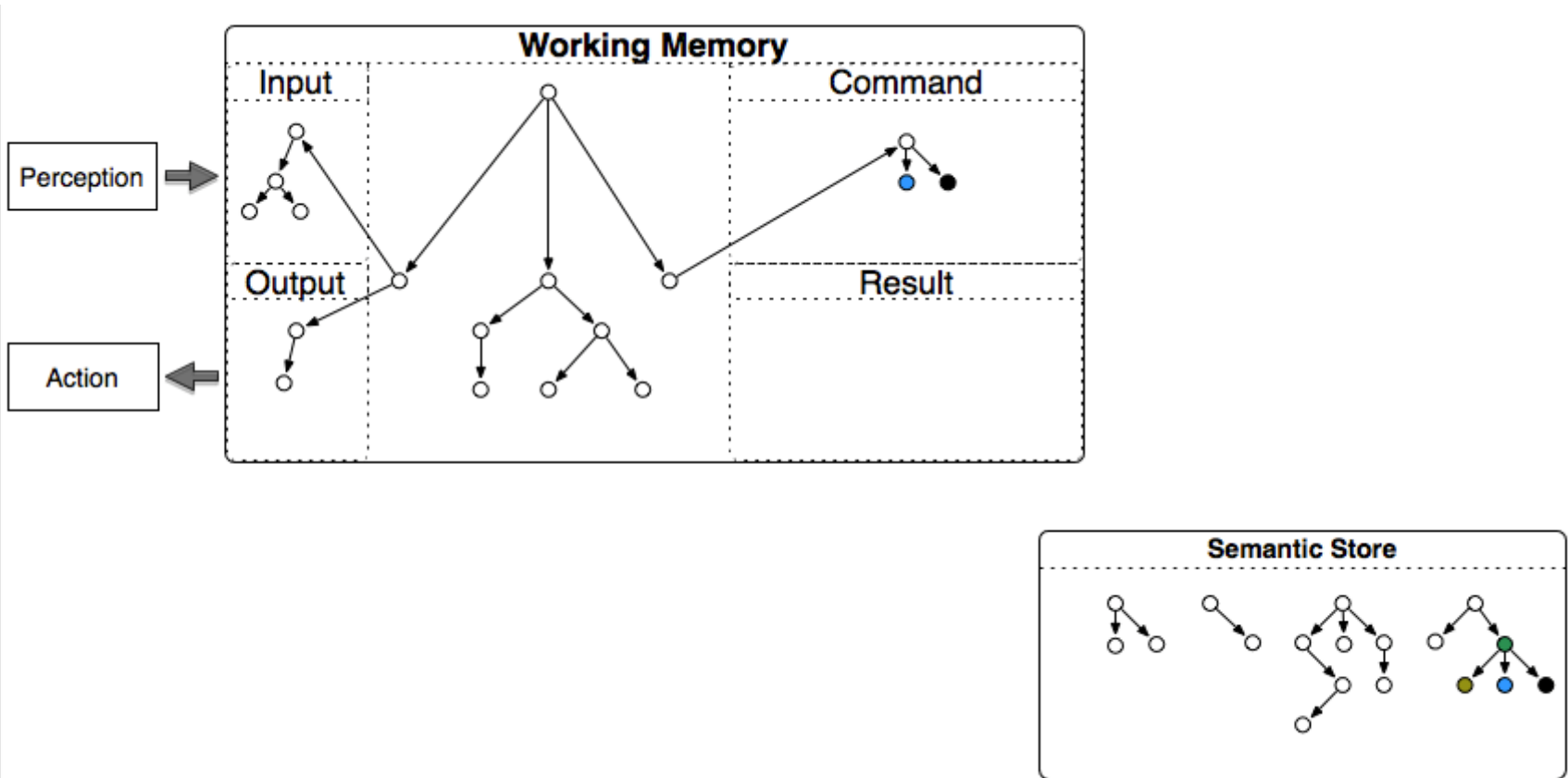
Architectural Integration

Non-Cue-Based Retrieval



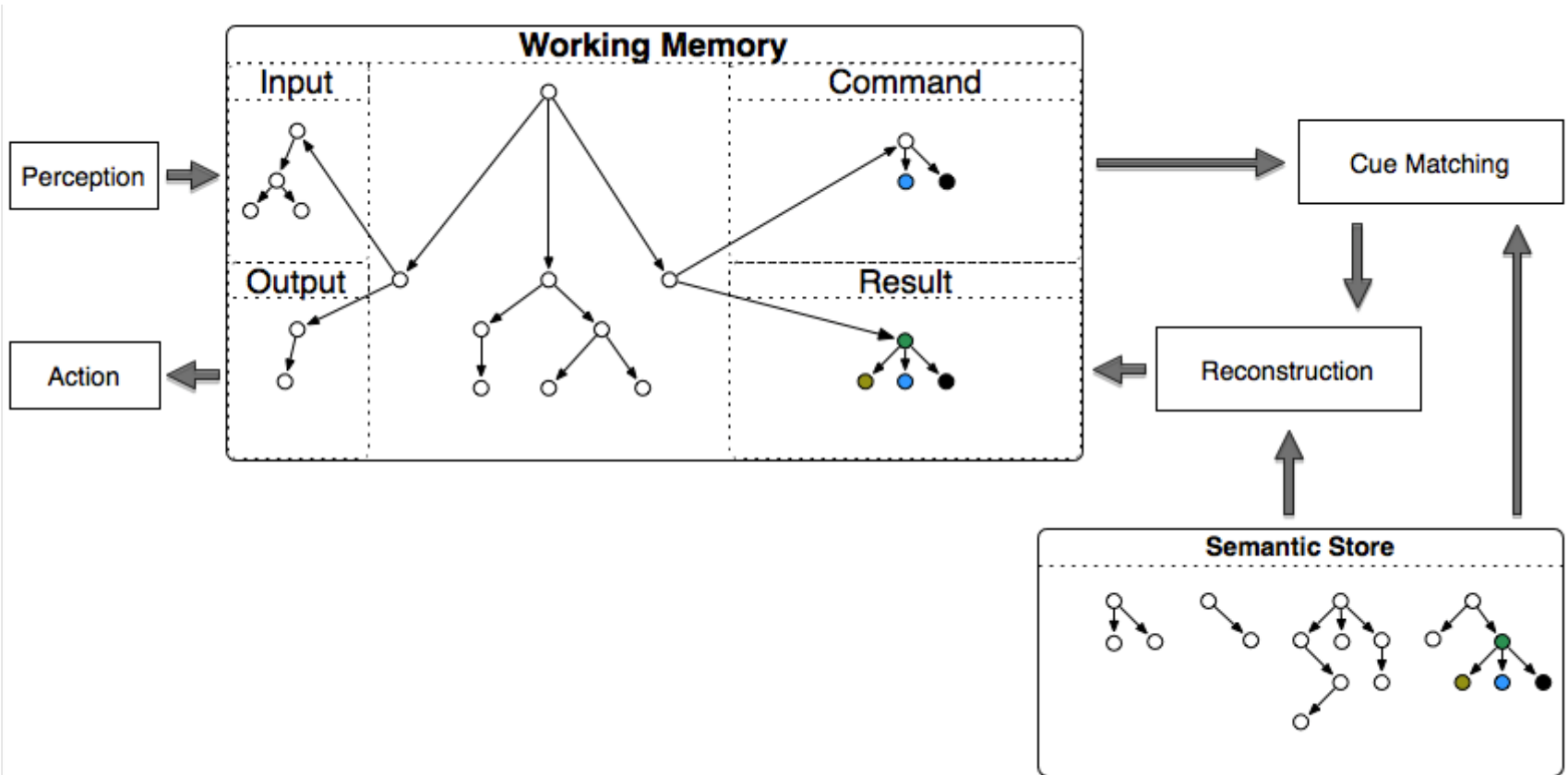
Architectural Integration

Cue-Based Retrieval

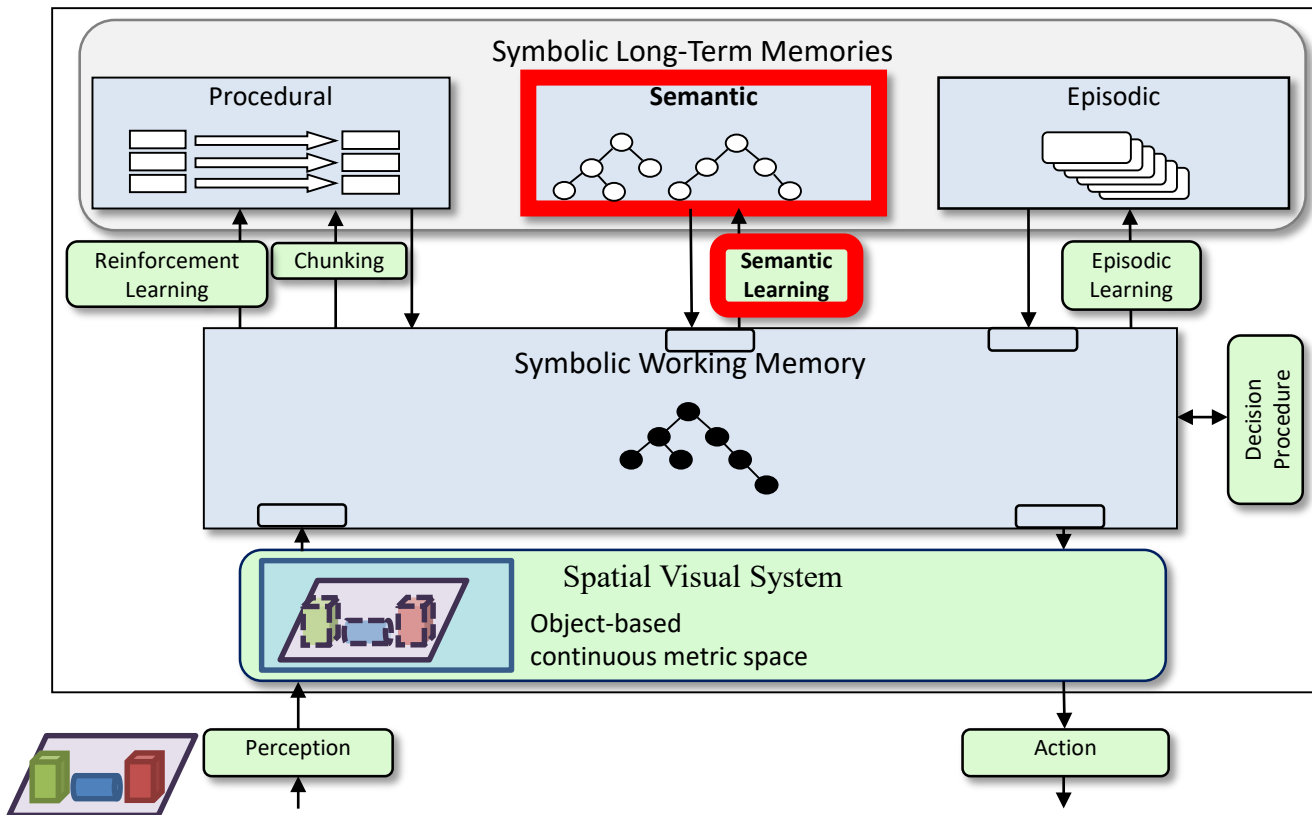


Architectural Integration

Cue-Based Retrieval

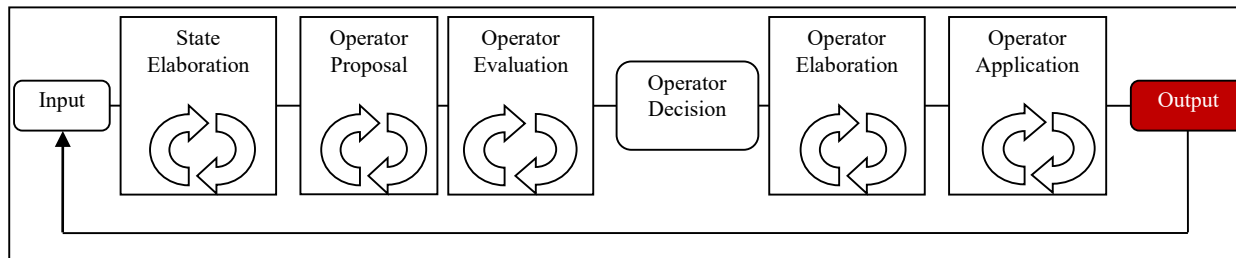


Soar 9



Soar Basic Functions

1. Input from environment
2. Elaborate current situation: *parallel rules*
3. Propose operators via acceptable preferences
4. Evaluate operators via *preferences: Numeric indifferent preference*
5. Select operator
6. Apply operator: Modify internal data structures: *parallel rules*
7. Output to motor system [and access to long-term memories]



Basic Usage

- Working-memory structure
- Semantic-memory representation
- Controlling semantic memory
- Storing knowledge
- Retrieving knowledge

Working-Memory Structure

Soar creates an `smem` structure on each state

– Soar Java Debugger

- `step`
- `print <s> --depth 2`
- `print s2`

Each `smem` structure has specialized substructure

- `command`: agent-initiated actions
- `result`: architectural feedback

Semantic-Memory Representation

Similar to working memory: symbolic triples

- Attributes cannot be identifiers (currently)
- The resulting graph is not necessarily connected

Controlling Semantic Memory

Get/Set a parameter:

- `smem [-g|--get] <name>`
- `smem [-s|--set] <name> <value>`

SMem is **disabled** by default. To enable it...

1. `smem`
2. `smem --set learning on`
3. `smem`

Storing Knowledge

Manual

Method of appending via command line (especially useful for loading external KBs)

Agent

Deliberate (via rules) addition/modification

Note: both methods can change existing and/or add new knowledge in semantic memory.

Manual Storage

Syntax: similar to production RHS

```
smem --add {  
    (<id1> ^attr1 val1 val2 ^attr2 val1 ... )  
    (<id2> ^attr3 <id1> val5 ... )  
    (<id3> ^attr4.attr5 <id3>)  
    ...  
}
```

Manual Storage: Example

Soar Java Debugger

```
1. smem --add {  
    (<a> ^name alice ^friend <b>)  
    (<b> ^name bob ^friend <a> <c>)  
    (<c> ^name charley)}
```

```
2. smem --print
```

```
(@A1 ^friend @B1 ^name alice [+1.000])  
(@B1 ^friend @A1 @C4 ^name bob [+2.000])  
(@C4 ^name charley [+3.000])
```

Agent Storage

Syntax

```
(<smem> ^command <cmd>)  
(<cmd> ^store <id1> <id2> ...)
```

- Requires that SMem is enabled (slide 16)
- Processed at end of phase in which rule fires
- Multiple identifiers may be stored at once
- Storage is **not** recursive

Result

```
(<smem> ^command <cmd> ^result <r>)  
(<cmd> ^store <id1> <id2> ...)  
(<r> ^success <id1> <id2> ...)
```

Agent Storage: Example

- Soar Java Debugger

1. smem --set learning on
2. watch 5
3. source
4. run 4 -p
5. print --depth 10 s2

```
sp {propose*init
    (state <s> ^superstate nil
        -^name)
-->
    (<s> ^operator <op> +)
    (<op> ^name init)
}
```

```
sp {apply*init
    (state <s> ^operator.name init
        ^smem.command <cmd>)
-->
    (<s> ^name friends)
    (<cmd> ^store <a> <b> <c>)
    (<a> ^name alice ^friend <b>)
    (<b> ^name bob ^friend <a> <c>)
    (<c> ^name charley)
}
```

Examining the Trace

```
=>WM: (30: C4 ^name charley)
=>WM: (29: B1 ^friend A1)
=>WM: (28: B1 ^friend C4)
=>WM: (27: B1 ^name bob)
=>WM: (26: A1 ^friend B1)
=>WM: (25: A1 ^name alice)
=>WM: (24: C2 ^store A1)
=>WM: (23: C2 ^store B1)
=>WM: (22: C2 ^store C4)
=>WM: (21: S1 ^name friends)
--- Change Working Memory (PE) ---
=>WM: (33: R3 ^success @A1)
=>WM: (32: R3 ^success @B1)
=>WM: (31: R3 ^success @C4)
```

Semantic-Store Statistics

```
smem --stats
```

- Nodes: number of long-term identifiers
- Edges: number of features/relations
- Stores: number of agent stores

Retrieving Knowledge

Non-Cue-Based

Add the features/relations of a known long-term identifier to working memory

Cue-Based

Find a long-term identifier that has a set of features/relations and add it to working memory with its full feature/relation set

Common Constraints:

- Requires that SMem is enabled (slide 16)
- Only one per state per decision
- Processed during *output* phase
- Only re-processed if WM changes to commands
 - Meta-data (status, etc) automatically cleaned by the architecture

Non-Cue-Based Retrieval

Syntax

```
(<smem> ^command <cmd>
<cmd> ^retrieve <long-term identifier>)
```

Result

```
(<smem> ^command <cmd> ^result <r>
<cmd> ^retrieve <long-term identifier>)
<r> ^<status> <long-term identifier>
    ^retrieved <long-term identifier>)
```

Where <status> is...

- failure: <long-term identifier> is not long-term
- success: else (adds all features/relations to WM)

Non-Cue-Based Retrieval: Example

- Soar Java Debugger

1. `smem --set learning on`
2. `smem --add {`
 `(@A1 ^name alice ^friend @B1)`
 `(@B1 ^name bob ^friend @A1 @C4)`
 `(@C4 ^name charley) }`
3. `sp {ncb`
 `(state <s> ^superstate nil`
 `^smem.command <cmd>)`

 `-->`
 `(<cmd> ^retrieve @B1) }`
4. `run 5 -p`
5. `print --depth 10 s2`
6. `smem --stats`

Non-Cue-Based Retrieval: Debrief

- Be cautious of long-term identifiers in rules
 - Only legal if already in semantic store
 - Will occur via chunking
- Only features/relations of @B1 added to WM
 - Features/relations of @A1, @C4 would require additional `retrieve` commands
- Statistics kept about number of `retrieve` commands processed
 - `smem --stats`
 - (“Retrieves”)
- Meta-data cleaned up during *output* phase

Cue-Based Retrieval: Syntax

(<smem> ^command <cmd>)

(<cmd> ^query <q>)

(<q> ^attr1 val1
 ^attr2 <val2>
 ^attr3 @V3 ...)

The augmentations of the *query* form hard constraint(s), based upon the value type...

- Constant: exact match
- Long-Term ID: exact match
- Short-Term ID: wildcard

Cue-Based Retrieval: Result

```
(<smem> ^command <cmd> ^result <r>)  
(<cmd> ^query <q>)  
(<r> ^<status> <q>  
    ^retrieved <long-term identifier>)
```

Where <status> is...

- failure: no long-term identifier satisfies the constraints
- success: else (adds all features/relations to WM)

Ties are broken by a bias (default: recency)

- See `activation-mode` parameter in Manual
- When you execute `smem -p`, the bias value is indicated

Cue-Based Retrieval: Example

- Soar Java Debugger

1. `smem --set learning on`
2. `smem --add {
 (@A1 ^name alice ^friend @B1)
 (@B1 ^name bob ^friend @A1 @C4)
 (@C4 ^name charley)}`
3. `sp {cbr
 (state <s> ^superstate nil
 ^smem.command <cmd>)
-->
 (<cmd> ^query.name alice)}`
4. `run 5 -p`
5. `print --depth 10 s2`
6. `smem --stats`

Prohibition

Cue-based retrievals can optionally prohibit the retrieval of one-or-more long-term identifiers

Syntax

(<smem> ^command <cmd>)

(<cmd> ^prohibit <l*ti*-1> <l*ti*-2> ...)

Prohibition: Example

- Soar Java Debugger

1. `smem --set learning on`
2. `smem --add {
 (@A1 ^name alice ^friend @B1)
 (@B1 ^name bob ^friend @A1 @C4)
 (@C4 ^name charley)}`
3. `sp {prohibit
 (state <s> ^superstate nil
 ^smem.command <cmd>)
-->
 (<cmd> ^query.name <some-name>
 ^prohibit @A1 @C4)}`
4. `run 5 -p`
5. `print --depth 10 s2`

Also Useful: Manual Query

```
smem -q { (<cue> ^name charley) }
```

WordNet Demo

<https://github.com/SoarGroup/Domains-WordNet>

- Scripts to convert WN-LEXICAL to SMem
 - Output: `smem --add { ...`
 - >821K long-term identifiers, >3.97M edges, ~88MB
 - Source: ~5-10 minutes, ~1GB memory
- SMem uses a SQLite backend
 - Has the ability to save semantic stores to disk and use disk-based databases
 - `smem --backup <filename>`

WordNet: Make Disk Store

- Soar Java Debugger
 - `source wn.soar`
 - ~5-10 minutes
 - `smem --stats`
 - `smem --backup path/to/filename.db`
 - ~10 seconds
- Soar Java Debugger
 - `smem --set path path/to/filename.db`
 - `smem --set database file`
 - `smem --init`
 - `smem --stats`

WordNet: Representation

“sense” of the “verb” to “soar”

```
smem -q {( <c> ^isa s ^ss-type v ^word soar)}
```

```
(@S194181 ^isa s ^sense-number 4  
  ^ss-type v ^synset-id 200155406  
  ^tag-count 1 ^w-num 1  
  ^word soar ^word-lower soar [+194177.000])
```

“gloss” with the “synset-id” 200155406

```
smem -q {( <c> ^isa g ^synset-id 200155406)}
```

```
(@G270  
  ^gloss |go or move upward; 'The stock market soared after the  
  cease-fire was announced'|  
  ^isa g ^synset-id 200155406 [+425386.000])
```

WordNet Task

wn-senses.soar

Find all definitions, given lexical word/POS

– High-level algorithm

1. query: ^isa s ^word lex ^ss-type pos
2. If successful
 - a) query: ^isa g ^synset-id <sense ^synset-id>
 - b) If successful
 - » write <gloss ^gloss>
 - c) prohibit: <sense>
 - d) Loop
3. Else
 - a) (halt)

Eaters!

Interactive Task Learning (Rosie)

- Storage, retrieval, and reasoning about word definitions and meanings

Additional Resources

- Documentation
- Readings

Documentation

See the Soar Manual and Tutorial

Additional Topics

- Details of integration with other mechanisms
- Retrieval biases
- Performance
- Usage: commands, parameters, statistics, etc.
- ...

Select Readings

<http://soar.eecs.umich.edu/Soar-RelatedResearch>

2006

- Integrating Semantic Memory into a Cognitive Architecture
 - Yongjia Wang, John E. Laird (Technical Report)

2010

- Extending Soar with Dissociated Symbolic Memories
 - Nate Derbinsky, John E. Laird (AISB)
- Towards Efficiently Supporting Large Symbolic Memories
 - Nate Derbinsky, John E. Laird (ICCM)

2011

- Performance Evaluation of Declarative Memory Systems in Soar
 - John E. Laird, Nate Derbinsky, Jon Voigt (BRIMS)
- A Functional Analysis of Historical Memory Retrieval Bias in the Word Sense Disambiguation Task.
 - Nate Derbinsky, John E. Laird (AAAI)

2012

- Functional Interactions between Memory and Recognition Judgments
 - Justin Li, Nate Derbinsky, John E. Laird (AAAI)

2014

- A Case Study of Knowledge Integration Across Multiple Memories in Soar
 - John E. Laird, Shiwali Mohan (BICA)