Semantic-Memory Tutorial

Soar Workshop 32 – Nate Derbinsky

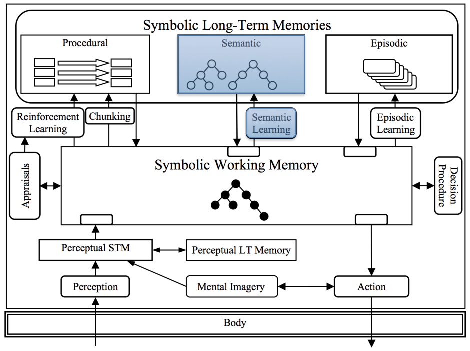
While waiting…

1. Make sure you have internet access
2. Download Soar Tutorial package v9.3.2
   `code.google.com/p/soar/wiki/SoarTutorial`
3. Download Graphviz
   `www.graphviz.org`
4. Download Eclipse (with at least Java)
   `www.eclipse.org`
5. Download tutorial support files
   `web.eecs.umich.edu/~nlderbin/workshop32`

Agenda

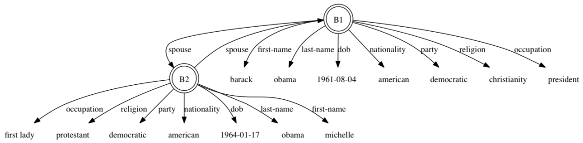
- Big picture
- Basic usage
- WordNet demo
- Additional resources

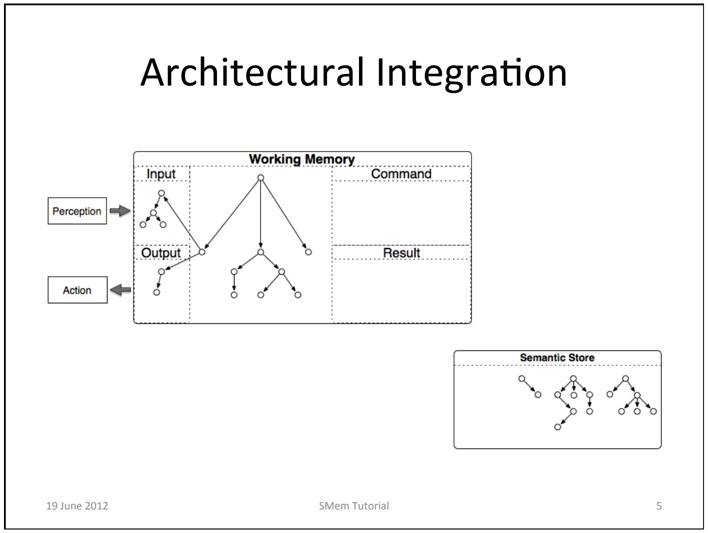
Soar 9



Semantic Memory: Big Picture

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





Architectural Integration

Working Memory

Input

Command

Output

Result

Perception

Action

Semantic Store

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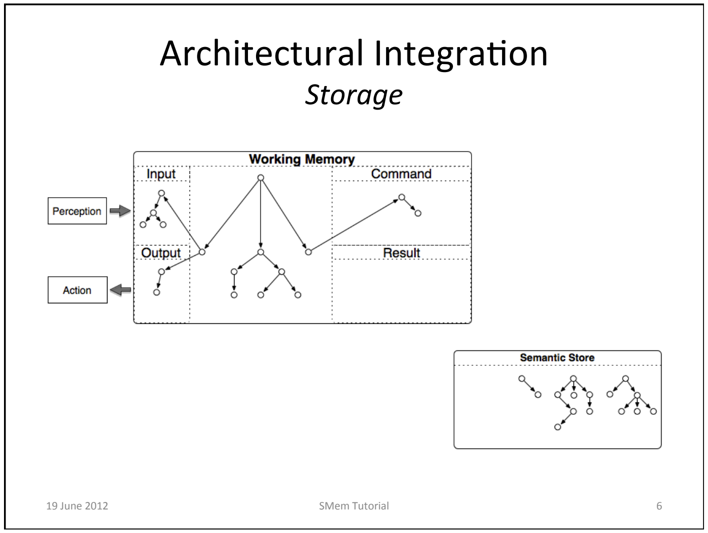

Architectural Integration

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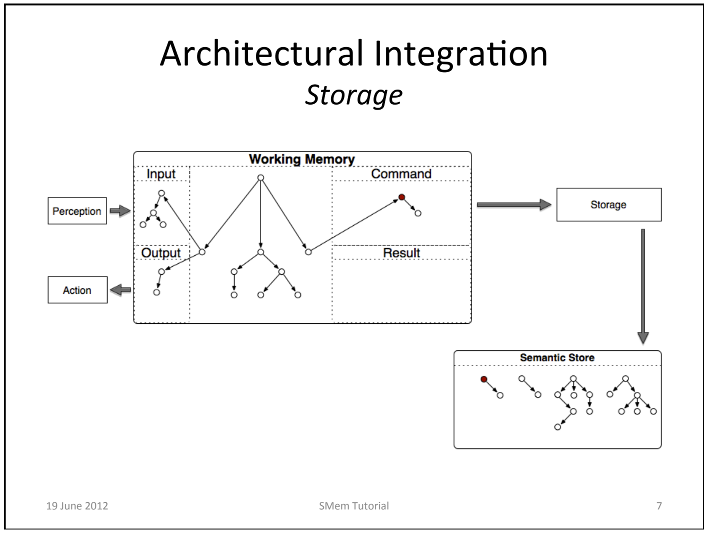

Architectural Integration

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Semantic Store

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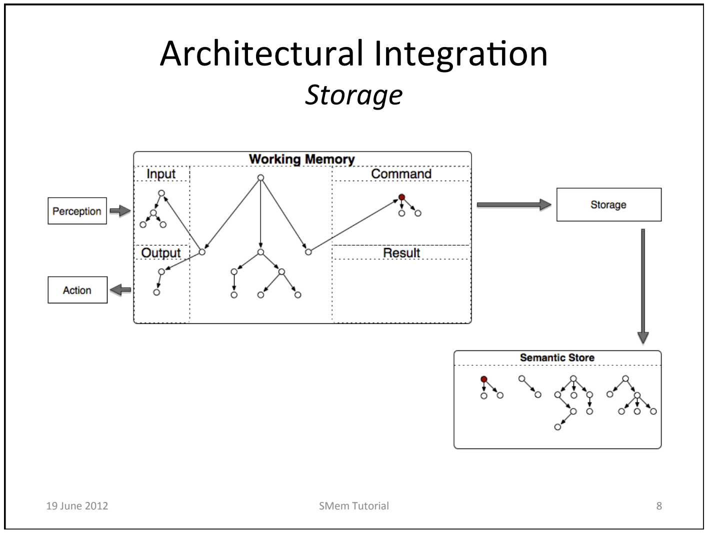

Architectural Integration

Storage

Working Memory

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Storage

Semantic Store

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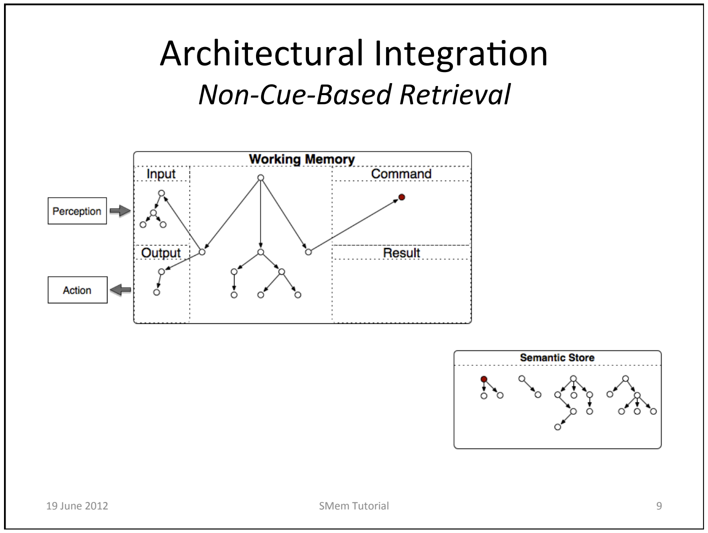


Architectural Integration

Non-Cue-Based Retrieval

Working Memory

Input

Command

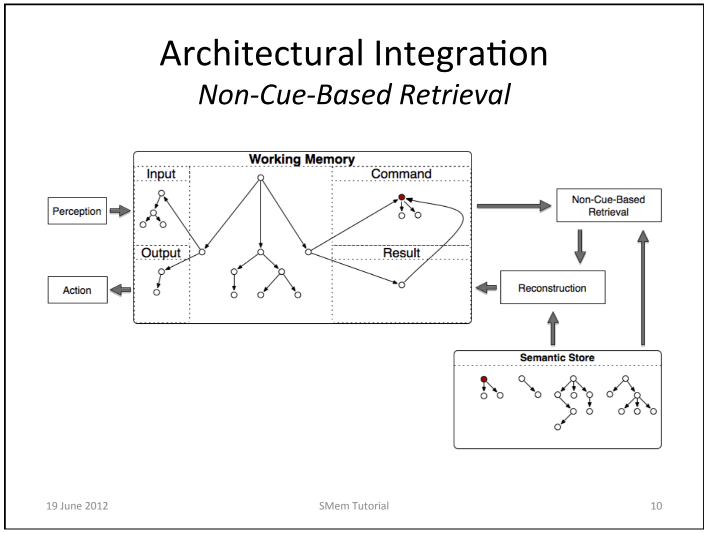
Output

Result

Perception

Action

Semantic Store



Architectural Integration

Non-Cue-Based Retrieval

Working Memory

Input

Command

Output

Result

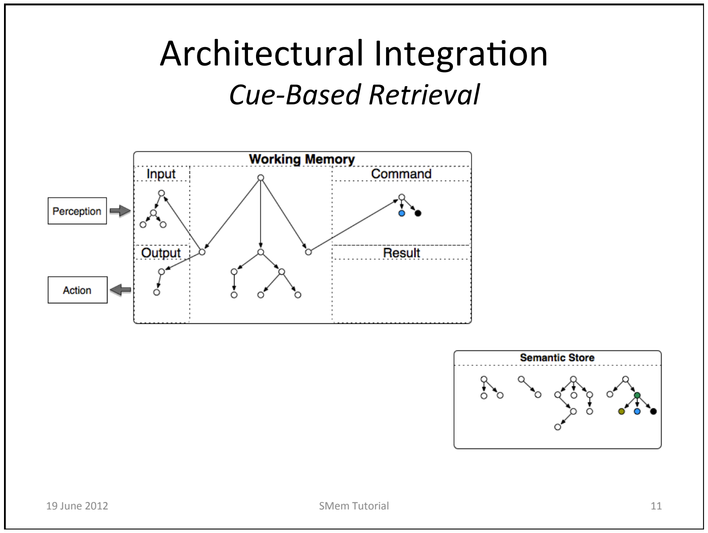
Perception

Action

Non-Cue-Based Retrieval

Reconstruction

Semantic Store



Architectural Integration

Cue-Based Retrieval

Working Memory

Input

Command

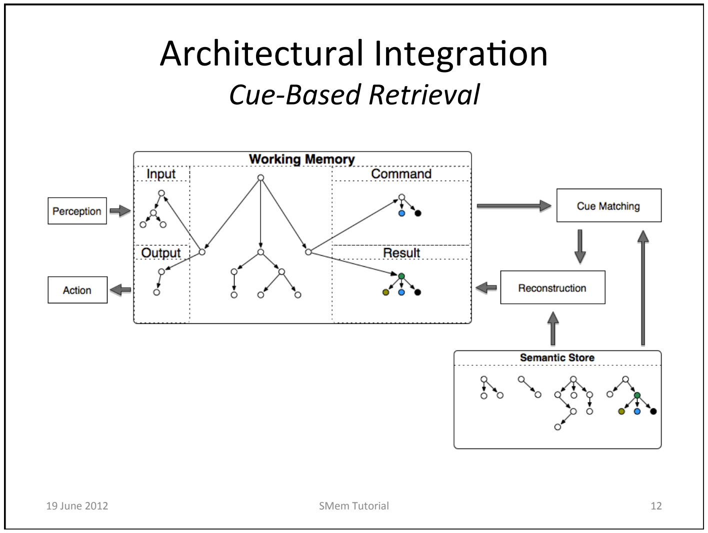
Output

Result

Perception

Action

Semantic Store



Architectural Integration

Cue-Based Retrieval

Working Memory

Input

Command

Output

Result

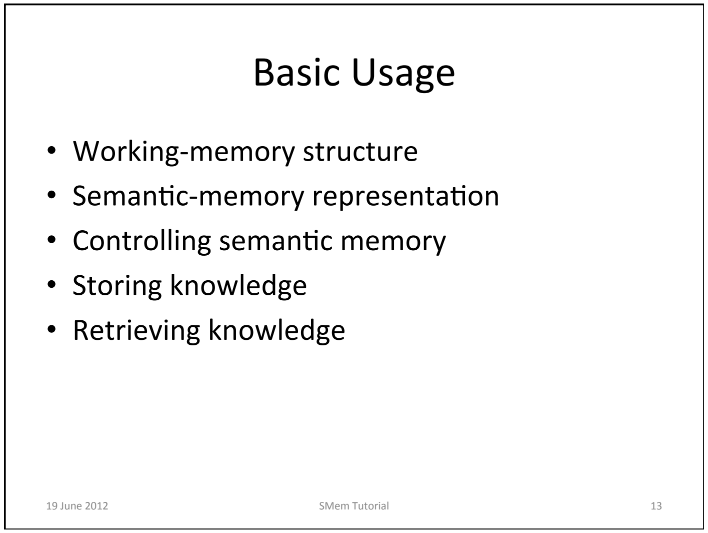
Perception

Action

Cue Matching

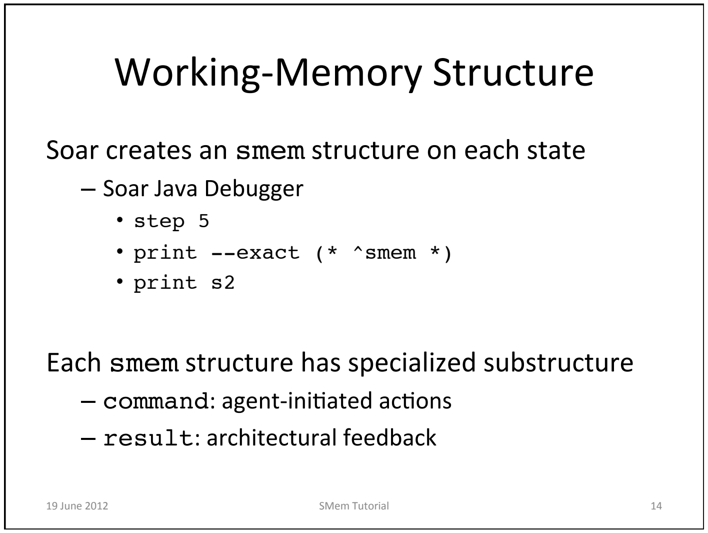
Reconstruction

Semantic Store



Basic Usage

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



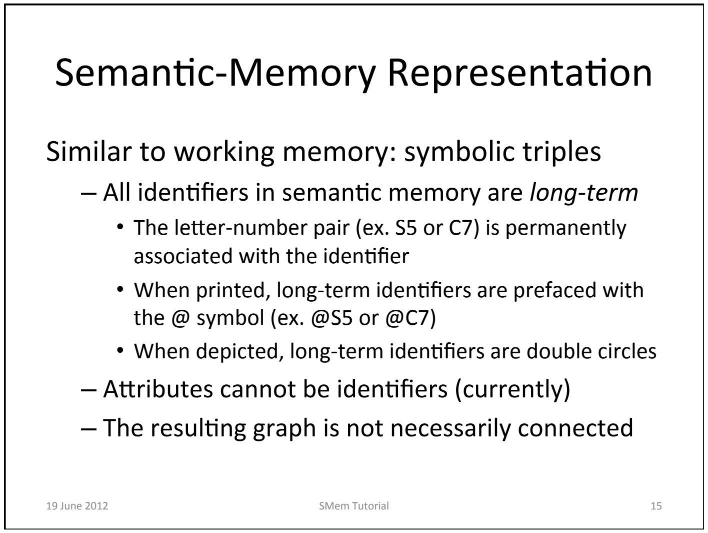
Working-Memory Structure

Soar creates an `smem` structure on each state

- Soar Java Debugger
  - `step 5`
  - `print --exact (* ^smem *)`
  - `print s2`

Each `smem` structure has specialized substructure

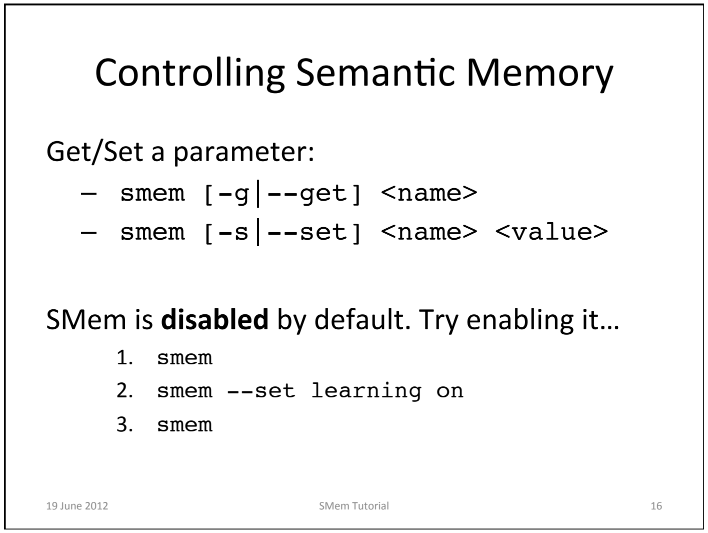
- `command`: agent-initiated actions
- `result`: architectural feedback



Semantic-Memory Representation

Similar to working memory: symbolic triples

- All identifiers in semantic memory are *long-term*
  - The letter-number pair (ex. S5 or C7) is permanently associated with the identifier
  - When printed, long-term identifiers are prefaced with the @ symbol (ex. @S5 or @C7)
  - When depicted, long-term identifiers are double circles
- 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. Try enabling 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

Manual Storage

Syntax: similar to production RHS

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

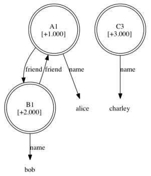
Manual Storage: Example

friends-manual.soar

Soar Java Debugger

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

2. `smem --print`
3. `ctf temp.gv smem --viz`



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

friends-agent.soar

- Soar Java Debugger
  1. `smem --set learning on`
  2. `watch 5`
  3. `source`
  4. `run 4 -p`
  5. `print --depth 10 s2`
  6. `smem --print`

```
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> ^name charley)
}
```

Examining the Trace

```
=>WM: (25: C3 ^name charley)
=>WM: (24: B1 ^friend A1)
=>WM: (23: B1 ^name bob)
=>WM: (22: A1 ^friend B1)
=>WM: (21: A1 ^name alice)
=>WM: (20: C2 ^store A1)
=>WM: (19: C2 ^store B1)
=>WM: (18: C2 ^store C3)
=>WM: (17: S1 ^name friends)
--- Change Working Memory (PE) ---
=>WM: (28: R3 ^success @A1)
=>WM: (27: R3 ^success @B1)
=>WM: (26: R3 ^success @C3)
```

Agent Storage: Modification

friends-agent-mod.soar

Rules

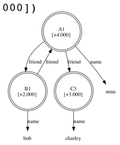
```
sp {propose*mod
   (state <s> ^name friends)
-->
   (<s> ^operator <op> +)
   (<op> ^name mod)
}

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

Result

```
1. smem --set learning on
2. source
3. run -p 4
4. run -p 5
5. smem --print
```

```
(@A1 ^friend @B1 @C3 ^name anna [+4.000])
(@B1 ^friend @A1 ^name bob [+2.000])
(@C3 ^name charley [+3.000])
```



Semantic-Store Statistics

- Soar Java Debugger
  1. Source `friends-manual.soar`
  2. `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

ncb-retrieval.soar

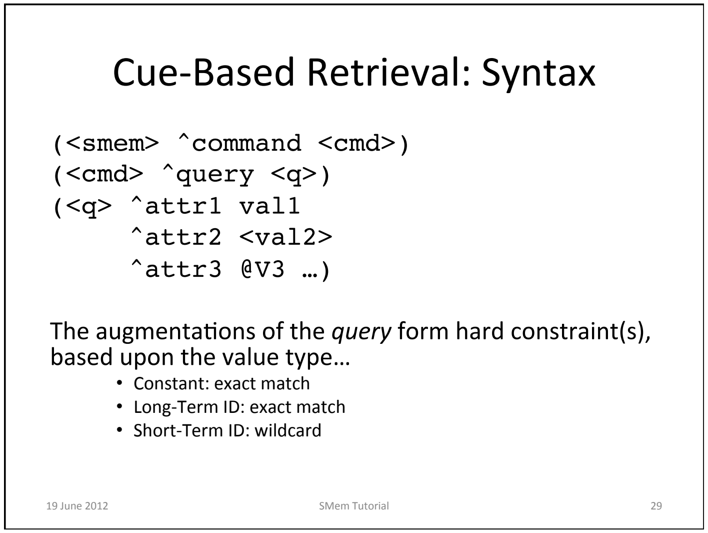
- Soar Java Debugger

```
1. smem --set learning on
2. smem --add {
     (@A1 ^name alice ^friend @B1 @C3)
     (@B1 ^name bob ^friend @A1)
     (@C3 ^name charley)}
3. sp {ncb
     (state <s> ^superstate nil
                ^smem.command <cmd>)
   -->
     (<cmd> ^retrieve @A1)}
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 @A1 added to WM
  - Features/relations of @B1, @C3 would require additional `retrieve` commands
- Statistics kept about number of `retrieve` commands processed
  - `smem --stats`
    - (“Retrieves”)
- Meta-data maintained during *output* phase

```
1. excise ncb
2. run 2 -p
3. print --depth 10 s2
4. run 3 -p
5. print --depth 10 s2
```

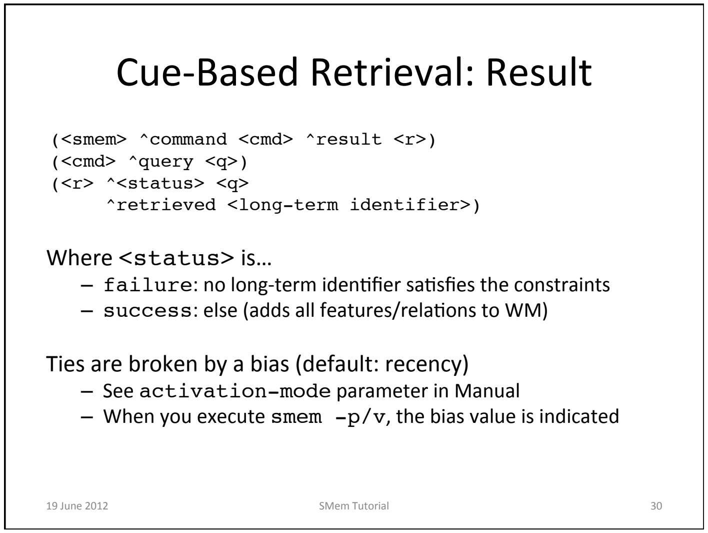


Cue-Based Retrieval: Syntax

```
(<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

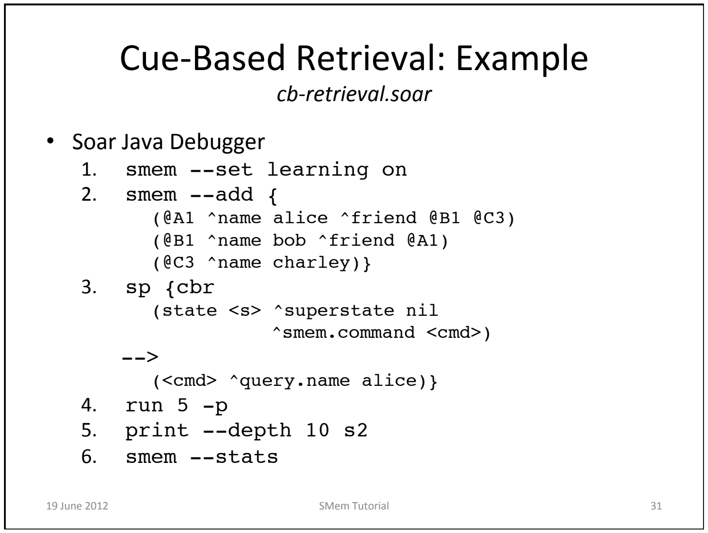
```
(<smem> ^command <cmd> ^result <r>)
(<cmd> ^query <q>)
(<r> ^<status> <q>
     ^retrieved <long-term identifier>)
```

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/v`, the bias value is indicated

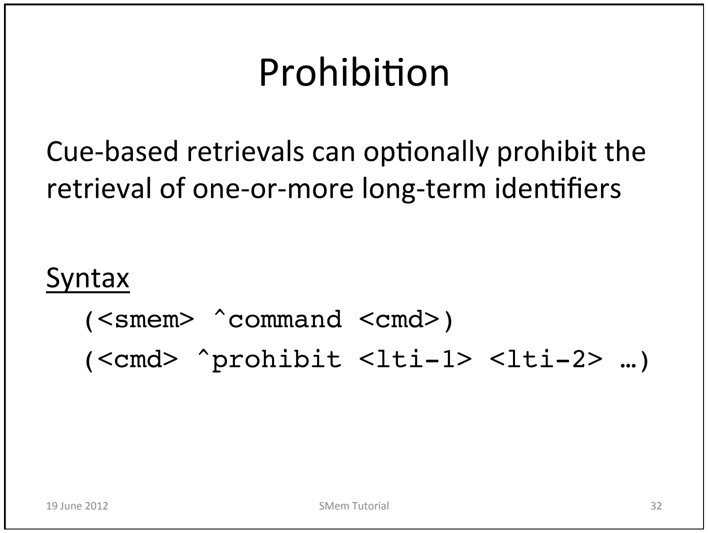


Cue-Based Retrieval: Example

cb-retrieval.soar

- Soar Java Debugger

```
1.  smem --set learning on
2.  smem --add {
      (@A1 ^name alice ^friend @B1 @C3)
      (@B1 ^name bob ^friend @A1)
      (@C3 ^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
```

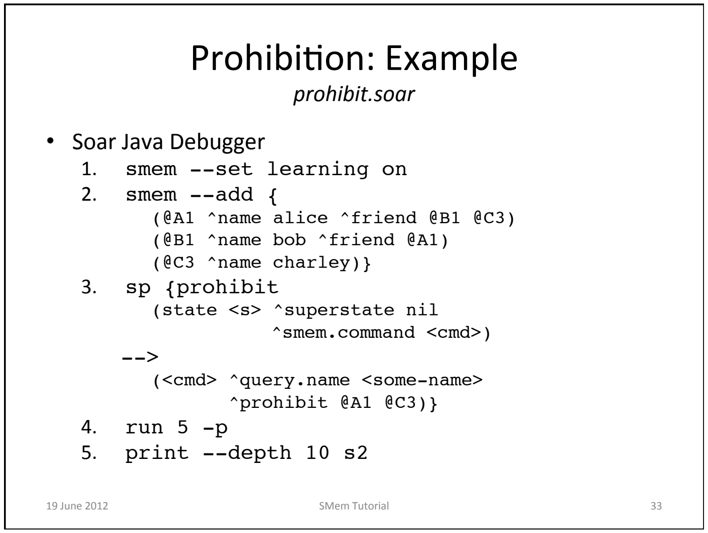


Prohibition

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

Syntax

```
(<smem> ^command <cmd>)
(<cmd> ^prohibit <lti-1> <lti-2> …)
```

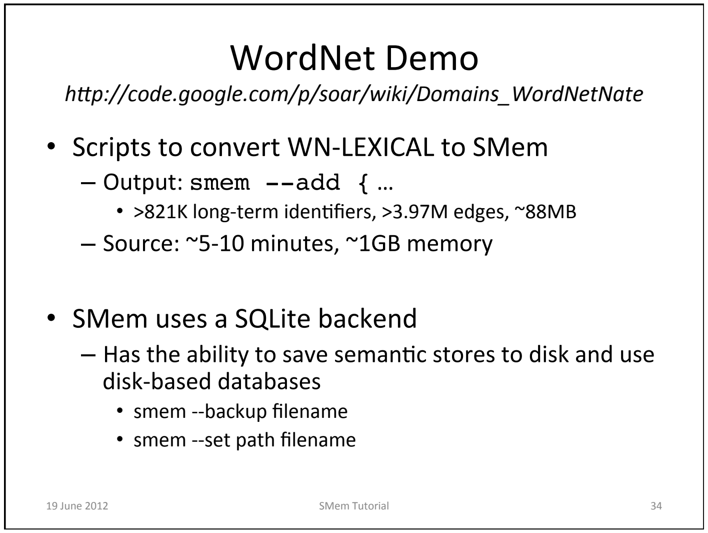


Prohibition: Example

prohibit.soar

- Soar Java Debugger

```
1.  smem --set learning on
2.  smem --add {
       (@A1 ^name alice ^friend @B1 @C3)
       (@B1 ^name bob ^friend @A1)
       (@C3 ^name charley)}
3.  sp {prohibit
       (state <s> ^superstate nil
                  ^smem.command <cmd>)
    -->
       (<cmd> ^query.name <some-name>
              ^prohibit @A1 @C3)}
4.  run 5 -p
5.  print --depth 10 s2
```

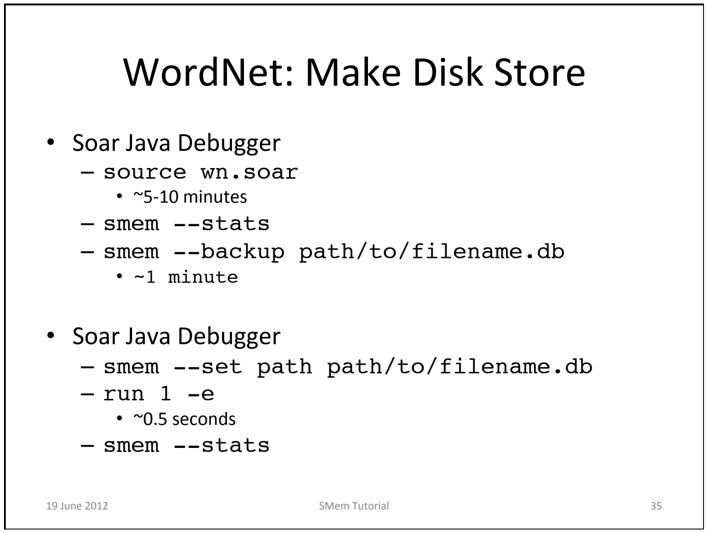


WordNet Demo

http://code.google.com/p/soar/wiki/Domains_WordNetNate

- Scripts to convert WN-LEXICAL to SMem
  - Output: `smem --add {` …
    - >821K long-term identifiers, >3.97M edges, ~88MB
  - Source: ~5-10 minutes, ~1GB memory

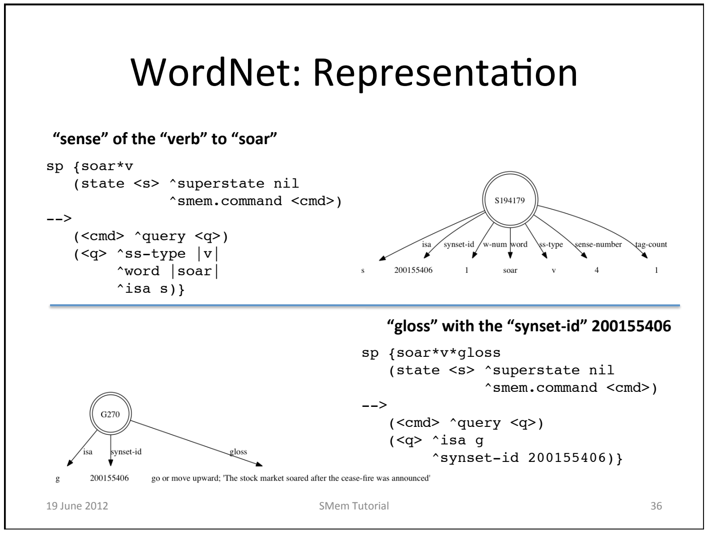
- SMem uses a SQLite backend
  - Has the ability to save semantic stores to disk and use disk-based databases
    - smem --backup filename
    - smem --set path filename



WordNet: Make Disk Store

- Soar Java Debugger
  - `source wn.soar`
    - ~5-10 minutes
  - `smem --stats`
  - `smem --backup path/to/filename.db`
    - `~1 minute`

- Soar Java Debugger
  - `smem --set path path/to/filename.db`
  - `run 1 -e`
    - ~0.5 seconds
  - `smem --stats`



WordNet: Representation

“sense” of the “verb” to “soar”

```
sp {soar*v
   (state <s> ^superstate nil
              ^smem.command <cmd>)
-->
   (<cmd> ^query <q>)
   (<q> ^ss-type |v|
        ^word |soar|
        ^isa s)}
```

“gloss” with the “synset-id” 200155406

```
sp {soar*v*gloss
   (state <s> ^superstate nil
              ^smem.command <cmd>)
-->
   (<cmd> ^query <q>)
   (<q> ^isa g
        ^synset-id 200155406)}
```

G270
isa
synset-id
gloss
g
200155406
go or move upward; 'The stock market soared after the cease-fire was announced'

WordNet: Task

wn-senses.soar

Find all definitions, given lexical word/POS

- Use `wn-senses-start.soar` as a baseline
- 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)
```

Additional Resources

- Documentation
- Demo agents
- Readings

Documentation

Manual & Tutorial

`Documentation/`

Additional Topics

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

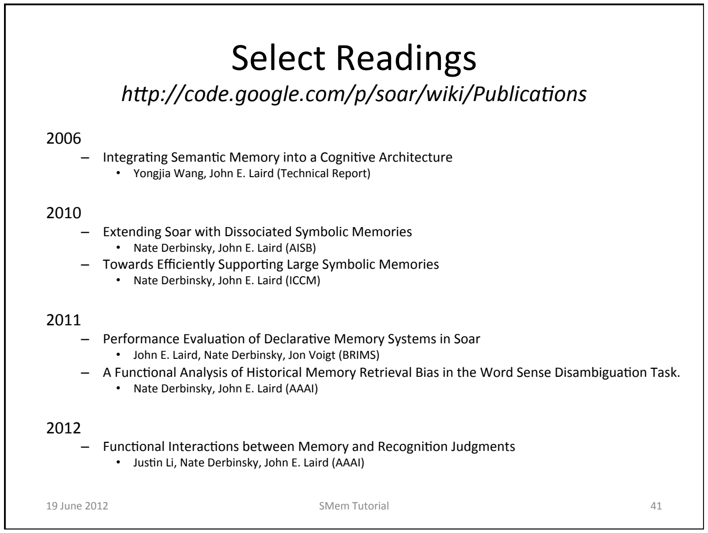
…

Demo Agents

`Agents/`

- Arithmetic

  Performs rule-based addition/subtraction using either working memory or semantic memory as a store of facts



Select Readings

http://code.google.com/p/soar/wiki/Publications

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)