Storm Framework

(Formerly known as Tosca)

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Soar 27: May 24th, 2007

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S O F T W A R E

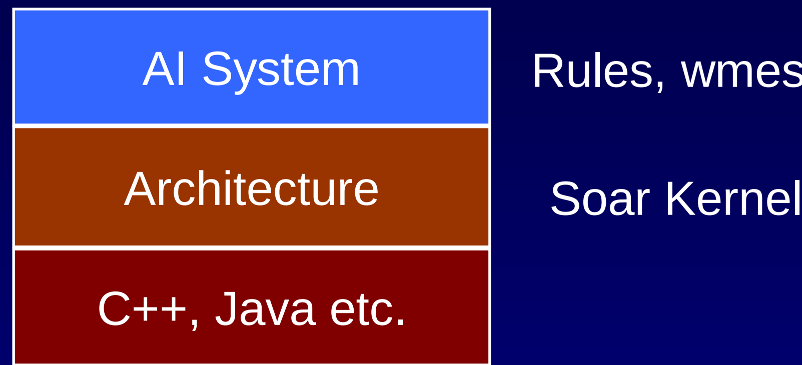
The Really Big Goal

- Research in Cognitive Architectures
  - Architecture: Cognitive systems built on top of a fixed set of capabilities
  - In some sense all Soar research contributes to this goal
  - Exploring the space of possible architectures
  - A major focus of John's career

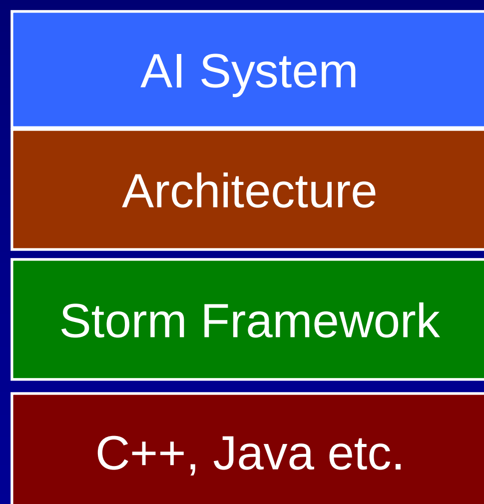
- But
  - Research at the architectural level is difficult
  - Theoretical concepts are easily muddled with implementation details
  - Architectural components are hard to replace or experiment with
    - E.g. Changing Soar's working memory implementation would be v. hard
  - Hard to evaluate the contribution of different architectural components
  - Biological constraints (brain mapping) is in the eye of the researcher

The Proposal: A Framework

- Current approach:



- Proposal:



Architectures make it easier to do research on AI systems

Hope is the Storm framework makes it easier to do research on architectures

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Major Goals for Storm Framework

1. Easy to experiment on architectural elements
   - Plug-in modules, quickly replaceable
   - Supports experimentation
   - Also supports distributed development well

2. Support heterogeneous collection of components
   - Allow researchers to work in a language they find convenient (C++, Java, R, Matlab etc.)
   - Each component executing in parallel on possibly different timescales
   - All integrated together into a single executing model by the framework

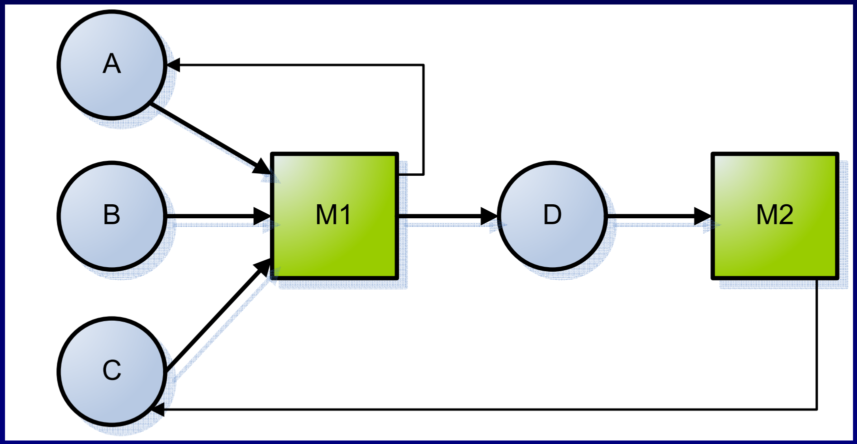
3. Ensure strong biological commitments made by architecture
   - Explicit representation of how processing maps to the brain
   - Explicit representation of which communication pathways are used in the brain

4. Flexible runtime configurations
   - Running on multiple operating systems
   - Running a simulation on a single machine
   - Running a simulation on a cluster of machines etc.

5. Flexible computational model
   - General focus is on flexibility
   - Architecture will likely be a more tightly defined and constrained model than the framework, which is more of a general purpose toolkit

Major Storm Elements

1. Function modules
   – Perform processing
2. State Variables
   – Hold all persistent data structures
   – Used for communication between modules
   – Examples:
     • Vector of floating point values (e.g. weights)
     • Frame buffer of image data
     • Control variables



Define brain mapping and brain connectivity based on these elements, through 3 graphs:

- Functional connectivity graph
- Brain mapping graph
- Brain connectivity graph

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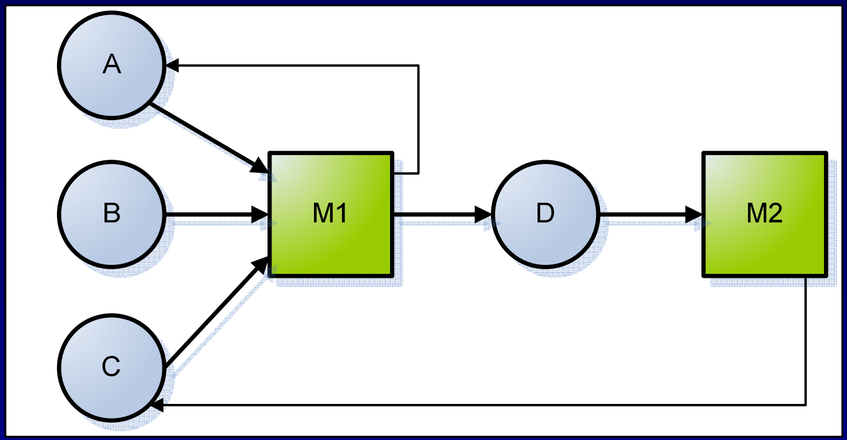
Functional Connectivity Graph

- Establishes a mapping of state variables to inputs and outputs of function modules:



- Implicitly defined by associations between modules and variables
  - E.g. M1 registers inputs A,B,C and output D
- State variables used for all persistent data

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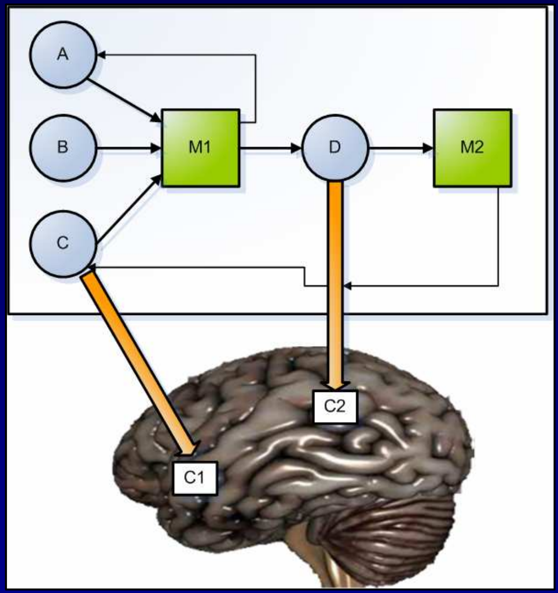
Brain Mapping Graph

- Mapping from state variable to brain regions



- Explicitly represented as a data structure in the framework
- Mapping will be complete
  - All state variables must map to a brain region
- May include unspecified regions
  - Makes gaps in the theory explicit

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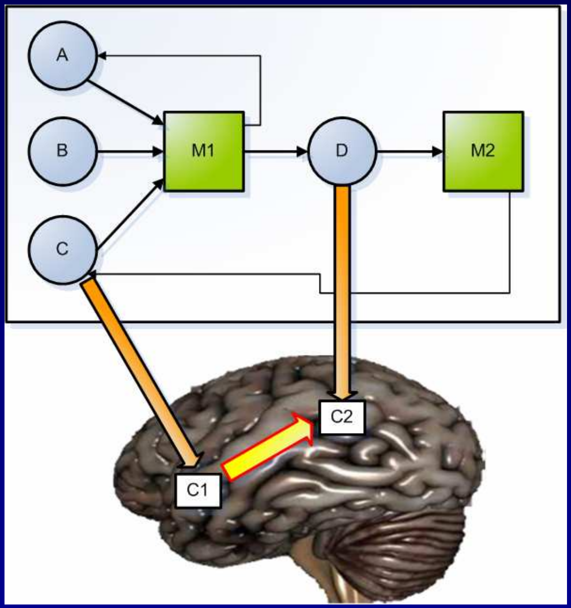
Brain Connectivity Graph

- Implied by function connectivity and brain mapping graphs



- Explicitly represent constraints on this mapping in the framework
- Automatic detection of constraint violations

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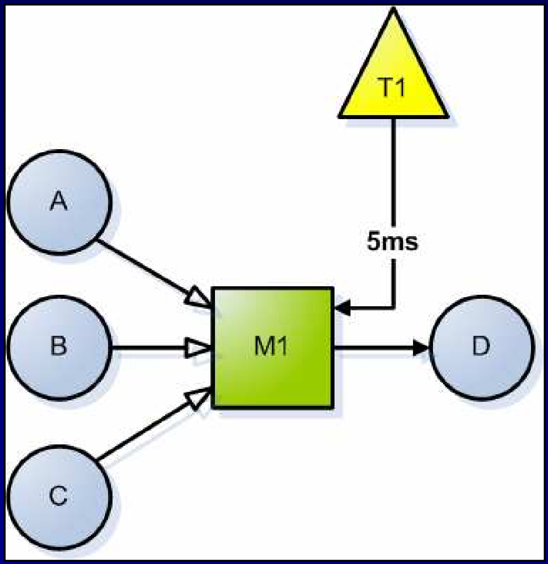
Sample Code

```
Value inputA = GetInput("A", time) ;
Value inputB = GetInput("B", time) ;
Value inputC = GetInput("C", time) ;

// Timescale need not be constant
ClockCannotAdvanceBeyond(time+5) ;

// Calculate the output

// Post the result
GetOuput("D")->SetValue(result, time+5) ;
```




```
GetInput("A")->NotifyWhenChanges(delay) ;
```

```
RegisterWakeup(time+10) ;
```

Event-driven : executes when input(s) change

Time-driven: executes at fixed rate

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Framework Design

- **Framework provides an abstraction**
  - Each module is defined in terms of its own temporal constraints and with its own communication requirements
  - The framework handles the details of synchronization and handling actual communication

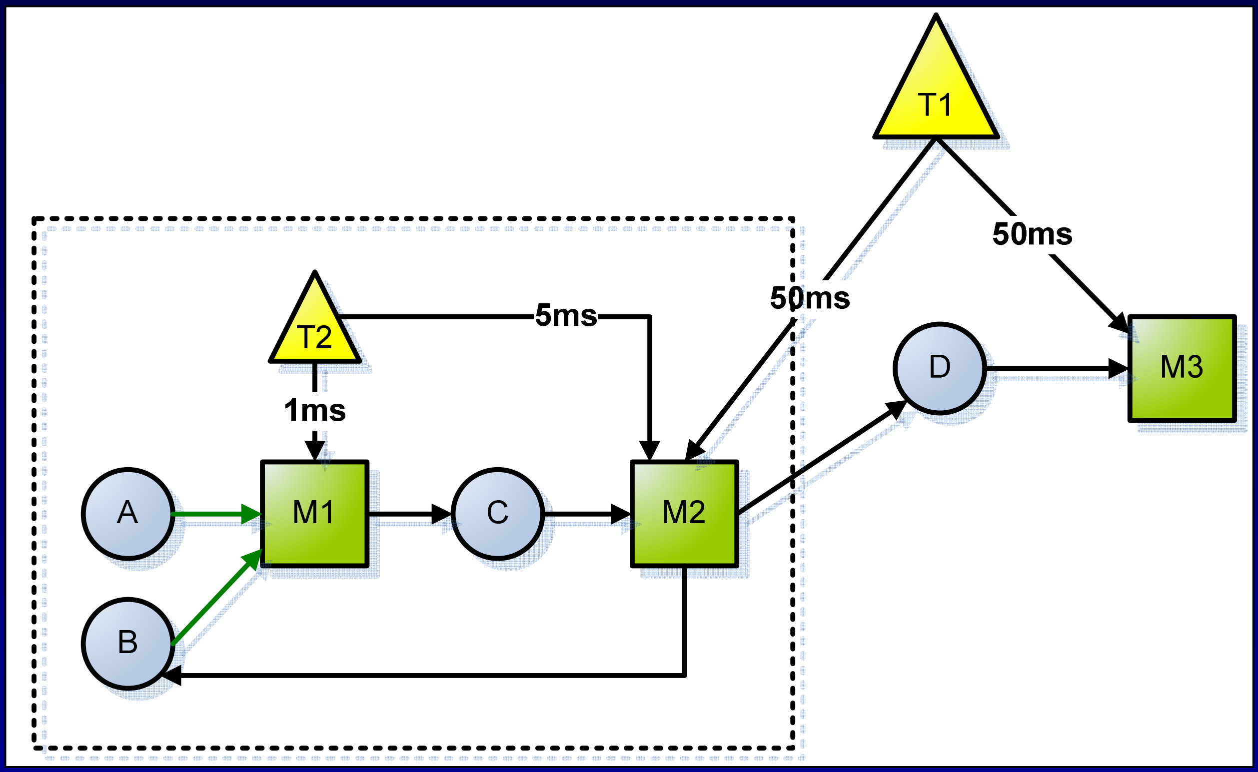
- Event triggers
  - *Clock-based* (after certain elapsed time) or
  - *Event-based* (after input changes)

  - *Delays :* inputs and outputs can include delays to model transmission time

- Flexible runtime configurations
  - Basing all comms on message passing between state variables, can generalize across:
    - Single process executing on one machine
    - Multiple processes using shared memory on one machine
    - Multiple machines communicating on a network
  - Current implementation executes each module in a separate thread
    - That base ensures separation between modules and explicit communication
    - Extends very well to multi-core revolution
    - Could support remote modules (machine clusters) in straightforward manner

- Language flexibility
  - Core implementation is in C++
  - Build interface modules to other languages using SWIG (same as used in SML).

Compose elements



Current implementation: Multiple communicating modules, different timescales.
No support yet for multiple clocks (should boost execution parallelism)

Summary

- Target is a flexible infrastructure layer that
  - Enhances experimentation
  - Forces brain commitments to be explicit
  - Scales flexibly to multiple machines, operating systems etc.
  - Supports a range of languages
  - Abstracts over communication details
  - Supports asynchronous execution
  - Supports a range of modeled time scales

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Nuggets and Coal

- Nuggets – implemented features
  - Function modules
  - State variables
  - Hierarchical state variables
  - Connectivity graph
  - Brain mapping graph
  - Brain connectivity graph
  - Multi-threaded, single machine
  - Cross language (C++ and Java)
  - Tracing tool based on output logs

- Coal – not yet implemented
  - Multiple clocks / hierarchical function modules
  - Constraints violation detection
  - Cross machine communication
  - Linux, R and Matlab support
  - Higher level constructs for building modules/state variables
  - Proof that really supports experimentation