Causal Reflective Programming

Bo Morgan, Ph. D. Candidate

Responsive Environments — Research Brief

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Media Laboratory, MIT

Causal Reflection

Funk2: A programming language providing process failure recognition and response opportunities.

Three fundamental types of causal tracing Events:

1. memory read event
2. memory write event
3. memory creation event

Execution contexts provide a Cause object that is associated with Events as they occur.

A few types of Causes are:

1. function calls with arguments
2. goals
3. perceptions
4. recognized reflective patterns

In general, a Cause is data that is useful for later reflective processes.

A few types of reflective processes are:

1. interference summarizers
2. imaginative memory with function calls

Run-Time Reflection

Run-Time Reflective Programming allows...

1. ...more adaptive goal-oriented control algorithms,
2. ...simpler description of real-time adaptive planning algorithms,
3. ...transferable learning for multiple context problem solving, and
4. ...more manageable complex heterogeneous control systems!

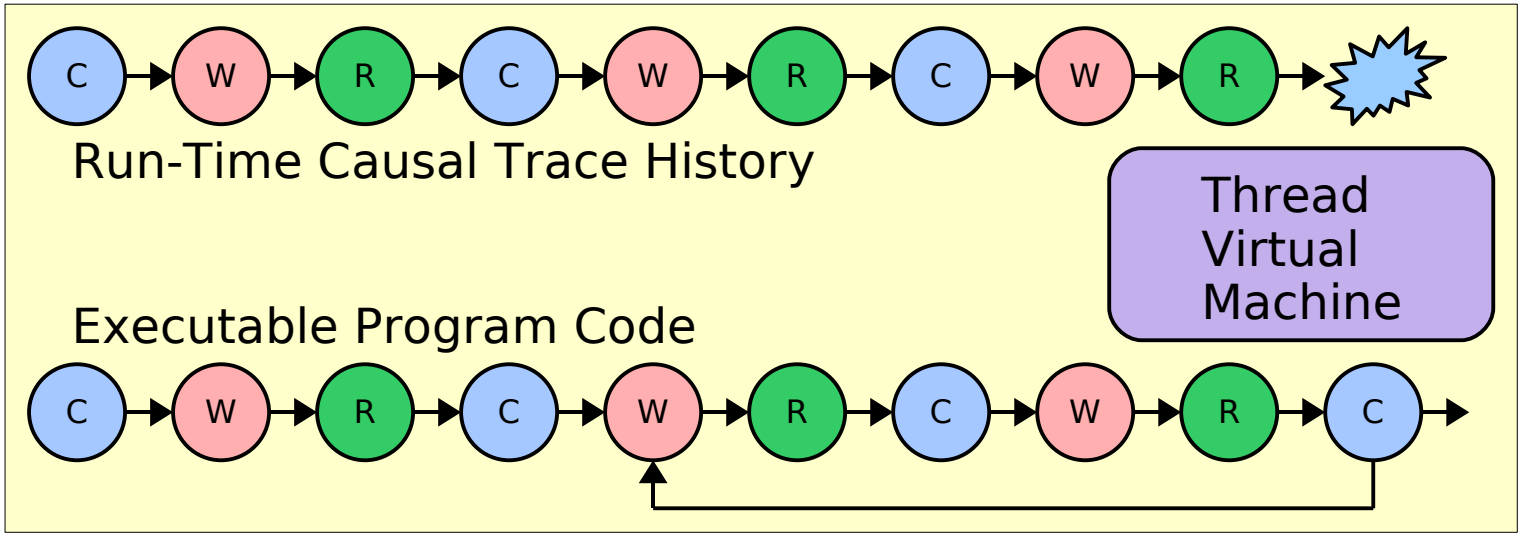
The Funk2 programming language allows a process to be efficiently monitored, which allows processes of reflection to be written.

Learning to Plan by Credit Assignment

Threads of execution create causal traces that can be inspected by other threads. This allows critical reflection in order to recognize how to debug specific types of execution failures, or bugs.

In a complex goal-oriented planning system, often plans are imagined and compiled long before they are executed unsuccessfully, at which point specific steps must be debugged and learning must occur by credit assignment to responsible plan compiling functionality.

Because the planning functions are causally traced, these forms of learning by credit-assignment can be performed long after the point of compiling a plan.



Learning by Reflective Induction

As a goal is pursued or a function is called, a causal history from the beginning of the function call to the end of the function call can be stored with the function to be used for later imagining the effects of the function being called or goal being pursued.

Previous function execution traces allow imagining plans toward goals.

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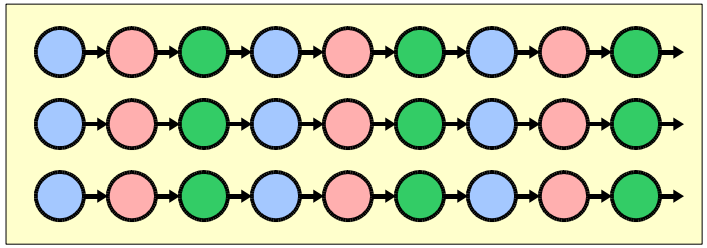

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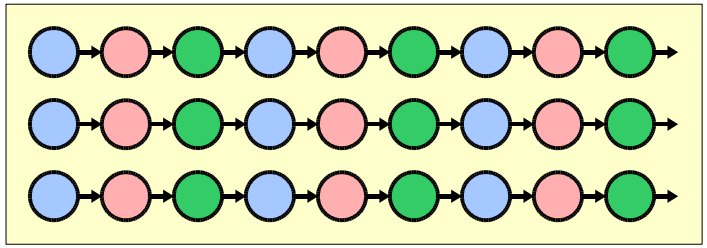

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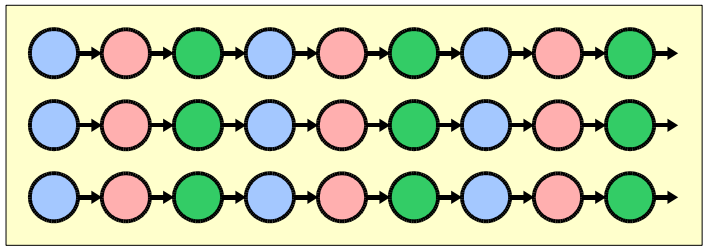
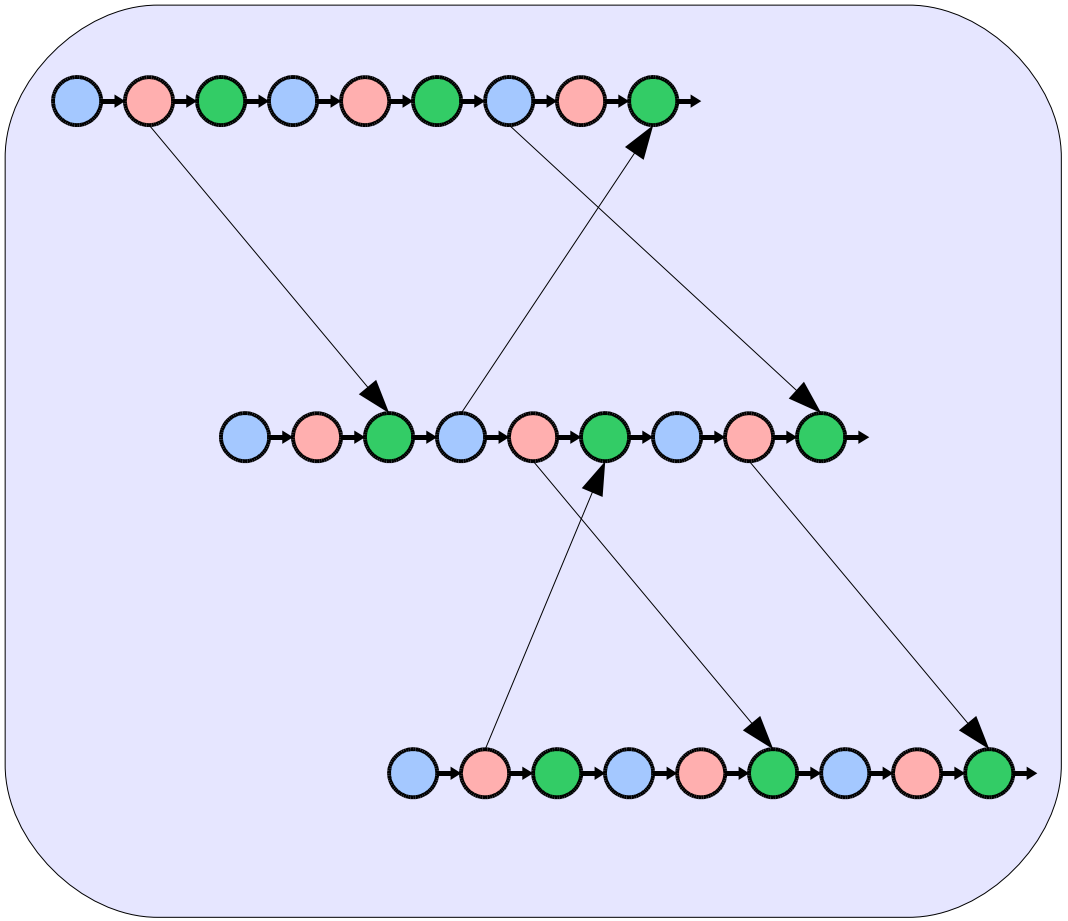




Funk2: Processing System Overview

We are creating debugging tools for programming large heterogeneous parallel processors. Reflective causal traces inherent in the Funk2 language allow this new method of debugging complex systems.

Lightweight Threads

Virtual threads are meant as very lightweight descriptions of parallel processes.

Multiple Core Processing:

Each core owns an independently MutEx'ed swap memory pool, allowing for full speed execution of memory independent threads.

Hardware:

Funk2 runs on 32- and 64-bit x86 processors. Local and remote file-system memory (e.g. 10GB) can be cached for large-scale process monitoring.

Grid Processor:

Experimenting with a simple networked memory system.
Reflective trace monitoring can be used for optimizing processor-process assignments.

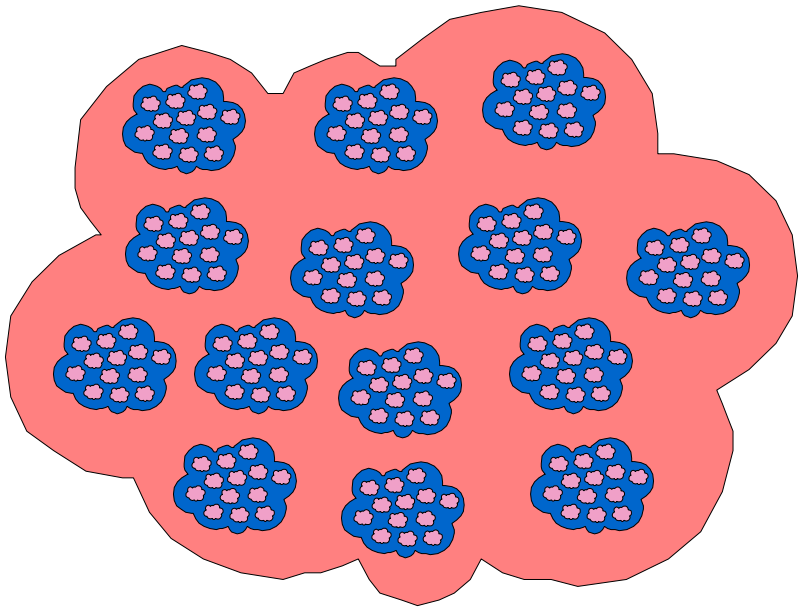
Resource Model (review)

Abundant mental resources can work in parallel to solve simple problems.

Limited mental resources are serially reconfigured into different "ways to think" when solving problems.

A few of the basic processing resources for problem solving:

- Procedural Memory
  - Frame
    - Transframe
    - Deduction
    - Induction
    - Analogy
  - Sensory Recognition
  - Locomotion
    - Dextrous Manipulation
    - Spatial
  - Imagination
    - Memory Consolidation
- Declarative Memory
  - Short-term Trace Memory
  - Language Parsing
  - Language Compiling
  - Language Generation



A "Cloud" of Processing Resources

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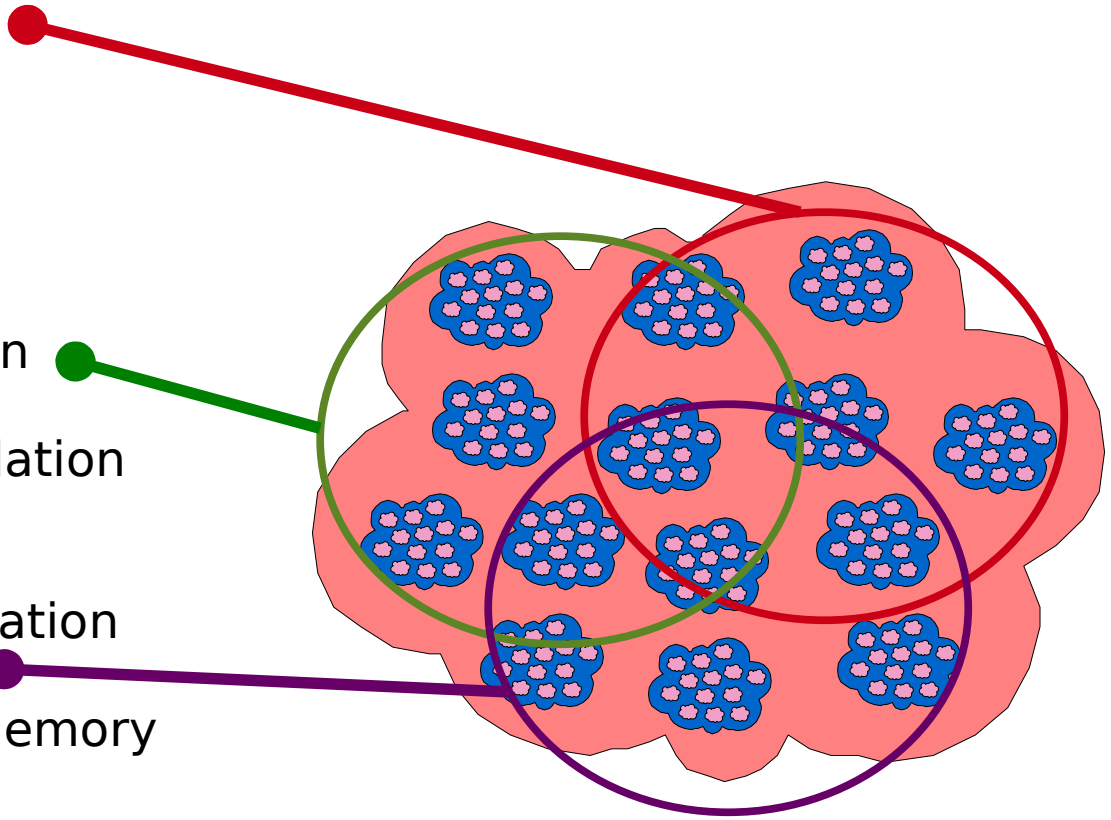


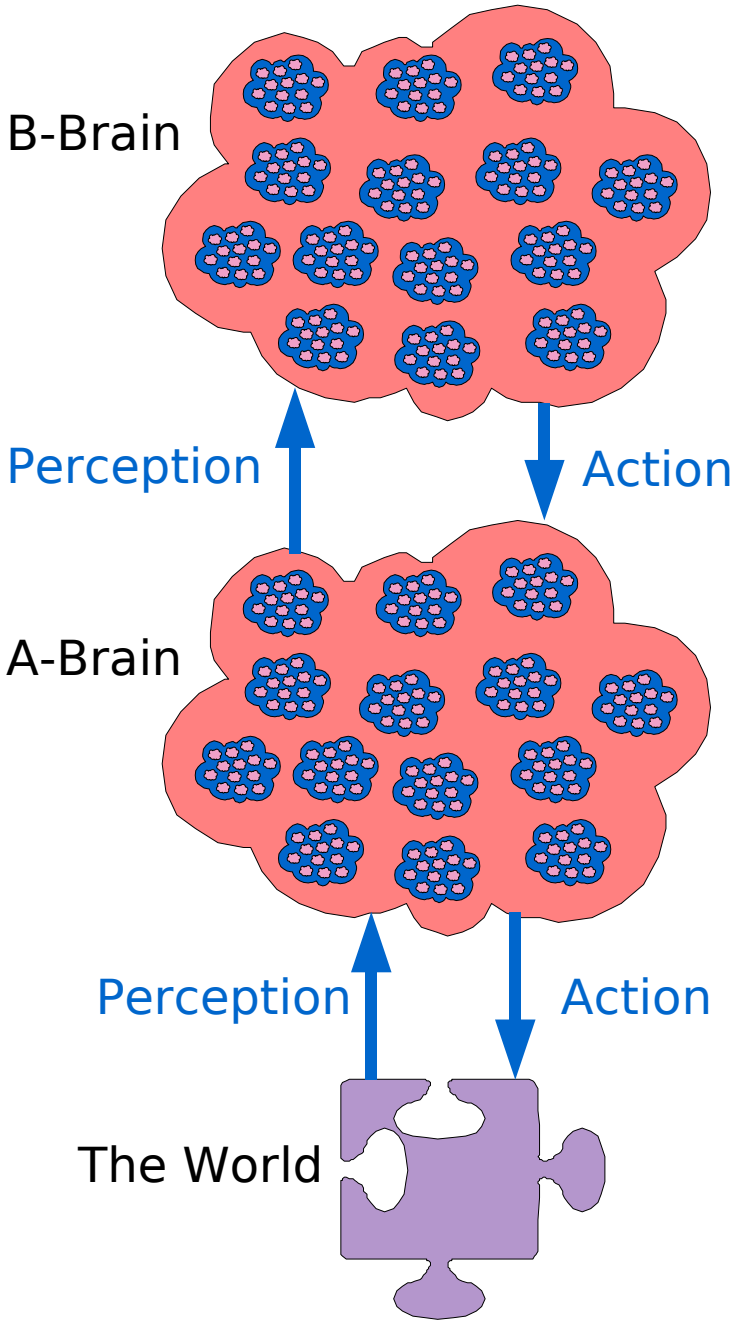
A "Cloud" of Processing Resources

Reflective Model (review)

The reflective model emphasizes that sometimes humans solve problems in their minds in addition to the physical world.

A few different types of critical reflection:

- faults in plans
- faults in planning processes
- faults in knowledge
- conflicts in goals
- credit assignment for success
- credit assignment for failure



Critic-Selector Model (review)

Critics recognize problems, monitor anti-goals
inhibit problematic critics and selectors

Selectors recognize solutions, promote goals,
activate critics and selectors

Critics and Selectors work together to debug layered, goal-directed, and pitfall-avoidance thought processes.