Value Function Representation: Rete for Reinforcement Learning

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Reinforcement Learning

- Primary objective is to learn how to act,
  or to derive an optimal policy
- Prefer actions that lead to positive (or large) rewards
  to actions that lead to negative (or small) rewards
- Outcomes are are characterized as a discounted return, $\sum_{t=0}^{\infty} \gamma^t r_t$
- Deriving good estimates of these returns for different actions is essential for many RL algorithms

See Sutton and Barto (1998) for an excellent primer.

Temporal Difference Method: Q-Learning

Given

- a discount rate, γ
- a Q-function, $Q(s, a)$, to represent value estimates for state-action pairs, and
- an immediate reward, r,

the update rule is expressed:

$$Q(s, a) \overset{\alpha}{\leftarrow} r + \gamma \max_{a^*} Q(s', a^*)$$

- Conditions on RL-rules encode which features to test and how to discretize continuous state, defining the mapping $\mathcal{S} \times \mathcal{A} \Rightarrow \mathcal{Q}$
- The presence of multiple RL-rules/weights for an operator results in linear function approximation

Research Goal

Efficient feature selection for relational reinforcement learning domains

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- Given a description of the environment, which descriptors are most essential?

	Descriptors:
Blocks World:	`^in-place {<block> false}`
Puddle World:	`^x {<x> 0.23235}`
Tetris:	`^type {<type> line}`

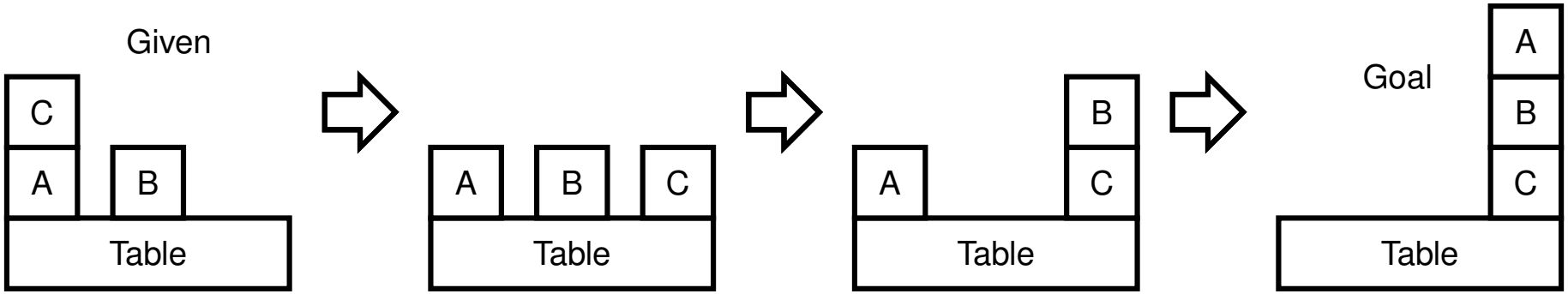
Research Goal

Efficient feature selection for relational reinforcement learning domains

- Given a description of the environment, which descriptors are most essential?
- Relational RL: ~~(<s> ^block @B)~~

```
(<b1> ^in-place false)
(<b1> ^on-top <b2>)
```

Blocks World:



Infinite Mario

http://julian.togelius.com/mariocompetition2009/

Features:

- ^button-dpad [released/down/left/right]
- ^button-jump [up/down]
- ^button-speed [up/down]
- ^distance-to-right-pit <d>
- ^is-above-pit [true/false]
- ^is-in-pit [true/false]
- ^obstacle-right [true/false]

⋮

Carli $\neq$ Soar – https://github.com/bazald/carli

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Meaning:

1. `^io.input-link`
2. ~~elaboration cycle~~
3. numeric preferences (and implicit operator proposal)
4. decide
   - ~~impasses~~
5. act

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What's offered:

- A Soar-like execution cycle
- Soar-RL-like reinforcement learning support
- Architectural support for efficiently creating more specific RL-rules over time – a generative model for a value function

What's missing or different:

- Manipulating WMEs from the RHS has not been tested yet
- Operators (as you know them) and impasses do not exist
- SMem, EpMem, and SVS do not exist

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Fringe RL-Rules (A Possible Syntax)

```
sp {rl-rule-1
 "A general RL-rule"
 # No flags
 (<s> ^operator <o> +)
 (<o> ...)
 # No other conditions
 # This is 100% general
-->
 (<s> ^operator <o> = 0)
}
```

```
gp {rl-rule-1f1
 "A fringe RL-rule"
 :fringe
 (<s> ^operator <o> +)
 (<o> ...
      ^attr-a [value-a1
               value-a2])
-->
 (<s> ^operator <o> = 0)
}
```

Next we'll refine the value function

Assume `rl-rule-1f2`, `rl-rule-1f3`, ⋮

:fringe

What does :fringe accomplish?

- Informs the system that it suggests a new condition
- Indicates that it should not contribute to value function
- Allows gathering of metrics about the new condition
  - Q-value
  - Update count
  - Firing count

⋮

Creating More Specific RL-Rules Over Time

Assume a refinement procedure just ran, choosing rl-rule-1f1**

```
gp {rl-rule-2
 "A bit more specific"
 # No flags
 (<s> ^operator <o> +)
 (<o> ...
      ^attr-a [value-a1
               value-a2])
 # One new condition
 # But only one
-->
 (<s> ^operator <o> = 0)
}
```

```
gp {rl-rule-2f1
 "New fringe RL-rule"
 :fringe
 (<s> ^operator <o> +)
 (<o> ...
      ^attr-a [value-a1
               value-a2])
      ^attr-b [value-b1
               value-b2])
-->
 (<s> ^operator <o> = 0)
}
```

Enumerable and Ranged Conditions

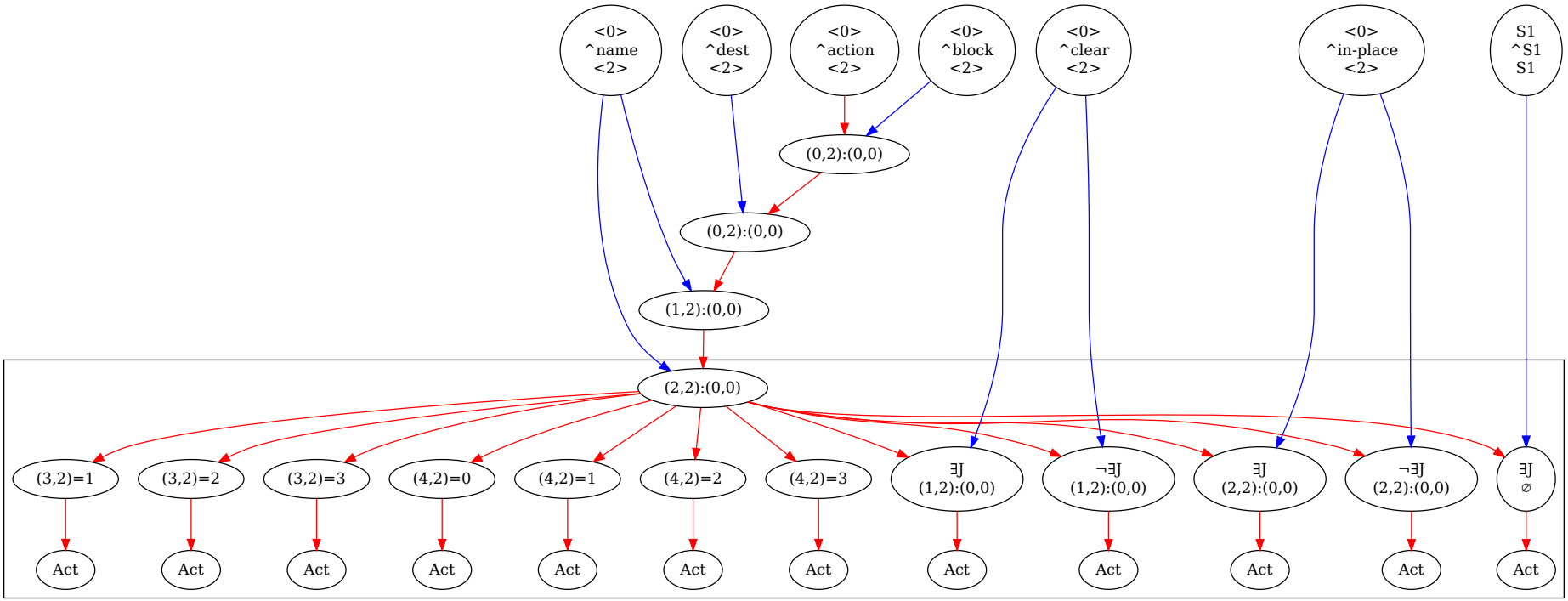
We are not restricted to enumerable conditions

```
gp {rl-rule-2f1
 "For Blocks World"
 :fringe
 (<s> ^operator <o> +)
 (<o> ^block <b>
      ^dest <d>)
 (<b> ^in-place [true
                 false])
-->
 (<s> ^operator <o> = 0)
}
```

```
gp {rl-rule-2f1
 "For Puddle World"
 :fringe
 (<s> ^operator <o> +)
 (<o> ^x <x>
      ^y <y>)
 (<o> ^x <x>
      {[< >=] 0.5})
-->
 (<s> ^operator <o> = 0)
}
```

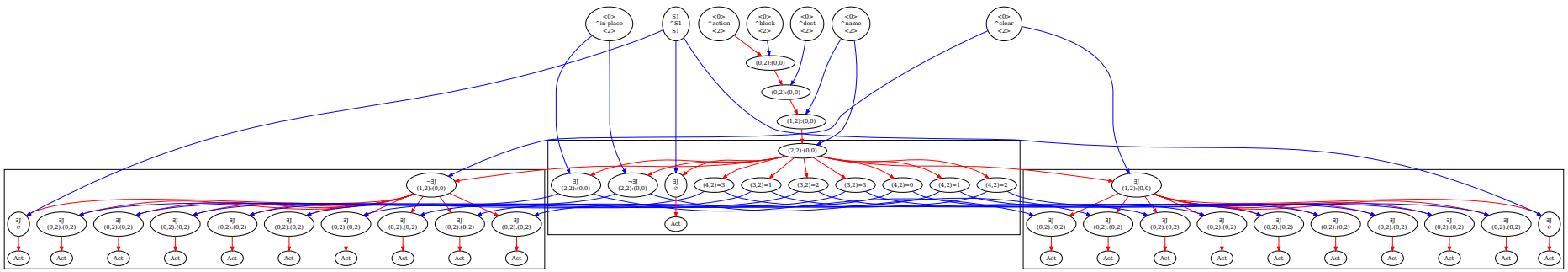
Note the deliberate ordering

Initial Rete for Blocks World

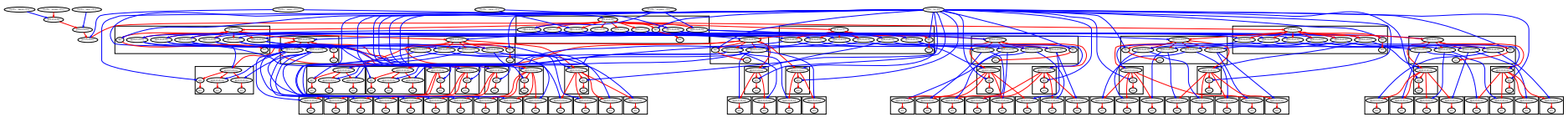


- Nodes in the first row (the α network) match on WMEs
- Lower nodes (the β network) join tokens and/or perform tests
- Actions simply add Q-values/weights to operators and decide whether to modify the value function representation
- Within any box, all weights but one represent a fringe

Later Retes for Blocks World



- Fringe weights/actions are removed
- Predicate tests move lower in the rete
- Other tests are joined from one layer to the next
- The number of fringe nodes is generally reduced over time
  - Numeric predicates may or may not be “infinitely” divisible
  - Not sure how, syntactically, to describe this to the architecture



Architectural Support? – The Bigger Picture

What does an architecture need to support efficiently creating more specific RL-rules over time?

- A fringe of possible more-specific RL-rules, each adding one condition
- A method for determining, with some confidence, which fringe RL-rules to promote to actual RL-rules
- Reverse methods to allow for corrections

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This is my current research

Refinement Criteria

When and how to best refine the value function?

- Cumulative absolute temporal difference error
  - Focus on regions of high activity and error
  - Seems to work better for Blocks World than the value criterion
- Value criterion (Whiteson, 2007)
  - Focus on improving value estimates
  - Early implementation
  - Already works better for Infinite Mario
- Policy criterion (Whiteson, 2007)
  - Focus on modifying policy
  - Coming soon

Nuggets and Coal

Nuggets:

- Another rete implementation taking advantage of C++11 features
- Progress on the development of a generative model for a value function
- It appears to be implementable as an extension to Soar-RL

Coal:

- As part of Soar-RL, it would involve excising rules over time, which does not appear to be common practice
- Some syntax details to work out before implementing in Soar-RL
- Good, general criteria for deciding when to refine/collapse/... the value function are not yet settled