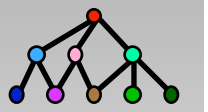
Modeling in a Medical Domain



Basic Concepts

Using Recognition

More Sophisticated Relations

Methods, Actions and Production Rules

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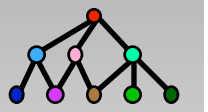
Basic Concepts—Personnel



Primitive Concepts

```
(defconcept person)
(defconcept official-responder
    :is-primitive person)
```

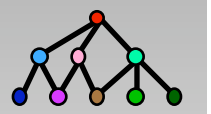
Closed World Concepts

```
(defconcept medical-person
    :is-primitive person
    :characteristics :closed-world)
```

Defined Concepts

```
(defconcept medic
        :is (:and official-responder
                  medical-person))
```

Basic Concepts—Personnel (alternate)



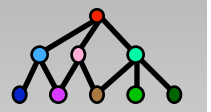
Primitive Concepts and Relations

```
(defconcept person)
(defrelation training)
```

Defined Concepts

```
(defconcept medical-person
   :is (:and person
            (:some training medical)))
(defconcept emergency-responder
   :is (:and person
            (:some training emergency)))
(defconcept medic
         :is (:and emergency-responder
                   medical-person)))
```

Basic Concepts—Injury



Full set

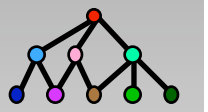
```
(defconcept injury
     :is (:one-of 'airway 'breathing
          'circulation 'neurologic-disability
          'exposure 'head 'neck 'chest 'other))
```

Subsets (subsumption calculated automatically)

```
(defconcept primary-injury
    :is (:one-of 'airway 'breathing
         'circulation 'neurologic-disability
         'exposure))

(defconcept secondary-injury
    :is (:one-of 'head 'neck 'chest 'other))
```

Basic Concepts—Injury (alternate)



Subsets

```
(defconcept primary-injury
     :is (:one-of 'airway 'breathing
          'circulation 'neurologic-disability
          'exposure))

(defconcept secondary-injury
     :is (:one-of 'head 'neck 'chest 'other))
```

Union specified by "or"

```
(defconcept injury
     :is (:or primary-injury
              secondary-injury))
```

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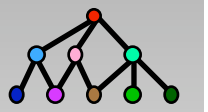
Basic Relations—Injuries



Primitive

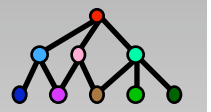
```
(defrelation injuries
     :characteristics :closed-world)
```

Defined (range restricted)

```
(defrelation primary-injuries
     :is (:and injuries
                (:range primary-injury)))
(defrelation secondary-injuries
     :is (:and injuries
                (:range secondary-injury)))
```

Closed world by inheritance

Basic Concepts—Casualties



Defined by number restrictions

```
(defconcept casualty
   :is (:and person
             (:at-least 1 injuries)))

(defconcept critical-casualty
   :is (:and person
             (:at-least 1
                  primary-injuries)))
```

Negated concepts can also be formed

```
(defconcept non-critical-casualty
   :is (:and casualty
             (:at-most 0
                  primary-injuries)))
```

Implies ≥ 1 injuries

Needs closed world!

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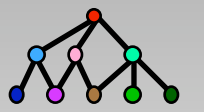
Basic Concepts—Negations



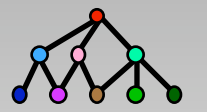
Negated concepts can also be expressed

```
(defconcept helper
    :is (:and person
              (:at-most 0 injuries)
              (:not medical-person)))
```

Recall that "medical-person" was declared to be closed world

- ***This is crucial to reasoning with ":not"***
- ***Without the closed world assumption, any individual not explicitly asserted to not be a medical-person could conceivably be one.***
- ***This uncertainty would inhibit recognition.***

Using Recognition



- Loom can recognize when assertions about individuals causes them to fulfill definitions
- This allows information to be added as it becomes available
- The logical consequences of the existing information is always maintained
- Example:

```
(tell (:about p2 Person
              (injuries 'airway)
              (injuries 'other)))
```

p2 is no longer a "Helper"

p2 is now a "Casualty" and a "Critical Casualty"

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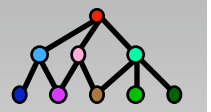
Sophisticated Relations



- *Some relations can involve sophisticated calculations*
- *Loom provides a method for defining a relation that is the result of a calculation rather than an assertion*
  - `:predicate indicates a test for the relation`
  - `:function indicates a generator for the relation`
  - `Such relations are assumed to be single-valued.`

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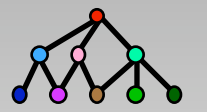
Sophisticated Relations—Geography



We need to associate a location with individuals

```
(defrelation location
    :characteristics :single-valued)
```

We want to calculate distance between locations

```
(defrelation distance-from-locations
    :arity 3
    :function grid-distance)
```

The auxiliary function does the calculation

```
(defun grid-distance (loc1 loc2)
   (sqrt (* (- (loc-x loc2)
               (loc-x loc1)))
            ...)))
```

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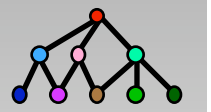
Sophisticated Relations—Geography



We also want to find the distance between individuals

```
(defrelation distance :arity 3
     :is (:satisfies (?x ?y ?d)
          (distance-from-location
               (location ?x)
               (location ?y)
               ?d)))
```

Direction can be handled analogously

Loom uses computed relations in backward chaining mode only—Information is not propagated forward.

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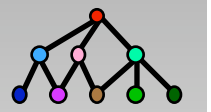
Sophisticated Relations— Inference Direction



Concepts and relations can be defined in terms of computed relations:

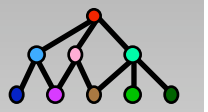
```
(defrelation in-range
    :is (:satisfies (?x ?y)
                    (< (distance ?x ?y)
                       (range ?x))))
```

This relation can be queried, but it will not propagate information forward.

```
(ask (in-range helo-1 Hospital))

(retrieve ?c
   (:and (casualty ?c)
         (in-range helo-1 ?c)))
```

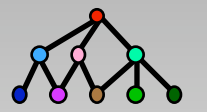
Sophisticated Relations—Alternate Inheritance



Problem: How can we automatically update the locations of individuals being transported by a vehicle?

- ***Each time the vehicle moves, update all passenger locations***
- ***Determine the passenger location based on the vehicle location***

Sophisticated Relations—Transitive Closures



Base relation "contained-in" is single-valued

```
(defrelation contained-in
     :characteristics :single-valued)
```

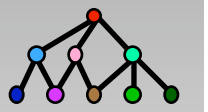
Transitive Closures

```
(defrelation contained-in* :is
    (:satisfies (?x ?y)
      (:exists (?z)
          (:and (contained-in ?x ?z)
                (contained-in* ?z ?y))))))
```

Note the recursive definition

Transitive Relation Idiom

Standard Definition of a Transitive Relation R* Based on the Relation R:



```
(defrelation R*  :is
    (:satisfies (?x ?y)
          (:exists (?z)
           (:and (R ?x ?z)
                 (R* ?z ?y ))))))
```

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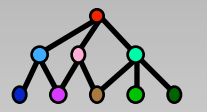
Sophisticated Relations—Following a Transitive Link



Base relation "position" is single-valued

```
(defrelation position
     :characteristics :single-valued)
```

Transitive Closures

```
(defrelation position*  :is
   (:satisfies (?x ?y)
        (:exists (?z)
             (:and (contained-in* ?x ?z)
                   (position ?z ?y))))))
```

The transitive link is followed in this relation to find a ?z with a position. Note that this will find ALL such ?z's!

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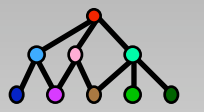
Sophisticated Relations—Alternate Inheritance Path



Base relation requires inverse

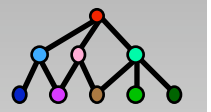
```
(defrelation contained-in)
(defrelation contains
      :is (:inverse contained-in))
```

"position" inherits via "contained-in"

```
(defrelation position
     :inheritance-link contained-in)
```

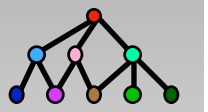
This allows the creation of meaningful "part-of" hierarchies, with inheritance of appropriate properties.

Methods, Actions and Production Rules



- ***Methods specify procedures that are specialized by Loom queries***
- ***Loom methods have a richer vocabulary than CLOS methods***
- ***Actions specify properties of methods such as selection rules***
- ***Production rules trigger on changes in the state of the knowledge base***
- ***Production rules allow a reactive or event-driven style of programming***

Example Method



```
(defmethod assess-casualty (?medic ?casualty)
    :situation
      (:and (Medic ?medic)(casualty ?casualty))
    :response
      ((format t "~%Medic ~8A examines ~8A"
                ?medic ?casualty)
        (tell (examined ?casualty 'yes)))
   )
```

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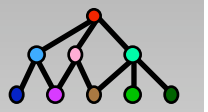
Example Method



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    :situation
      (:and (Medic ?medic)(casualty ?casualty))
    :response
      ((format t "~%Medic ~8A examines ~8A"
                ?medic ?casualty)
        (tell (examined ?casualty 'yes)))
  )
```

Query determines applicability

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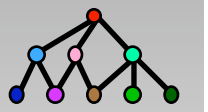
Example Method



```
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    :situation
      (:and (Medic ?medic)(casualty ?casualty))
    :response
      ((format t "~%Medic ~8A examines ~8A"
                ?medic ?casualty)
        (tell (examined ?casualty 'yes)))
  )
```

Query determines applicability

Lisp code in the response

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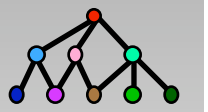
Example Method



```
(defmethod assess-casualty (?medic ?casualty)
    :situation
      (:and (Medic ?medic)(casualty ?casualty))
    :response
      ((format t "~%Medic ~8A examines ~8A"
                ?medic ?casualty)
        (tell (examined ?casualty 'yes)))
  )
```

Query determines applicability

Lisp code in the response

Loom assertions in the response

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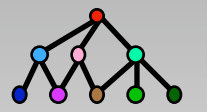
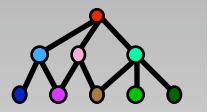
Methods Can Be Performed Immediately or Scheduled



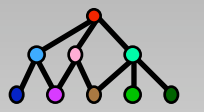
- *To call a method immediately use the "perform" function*
- *To schedule a method for execution use the "schedule" function*
  - *Scheduled methods can be given a priority (the built-in priorities are :high and :low)*
  - *Methods are performed the next time there is a knowledge base update (ie, "tellm")*
  - *Methods are executed in accordance with the priority*
  - *Within a priority methods are executed in the ordered they were scheduled*

The :situation Determines Method Applicability



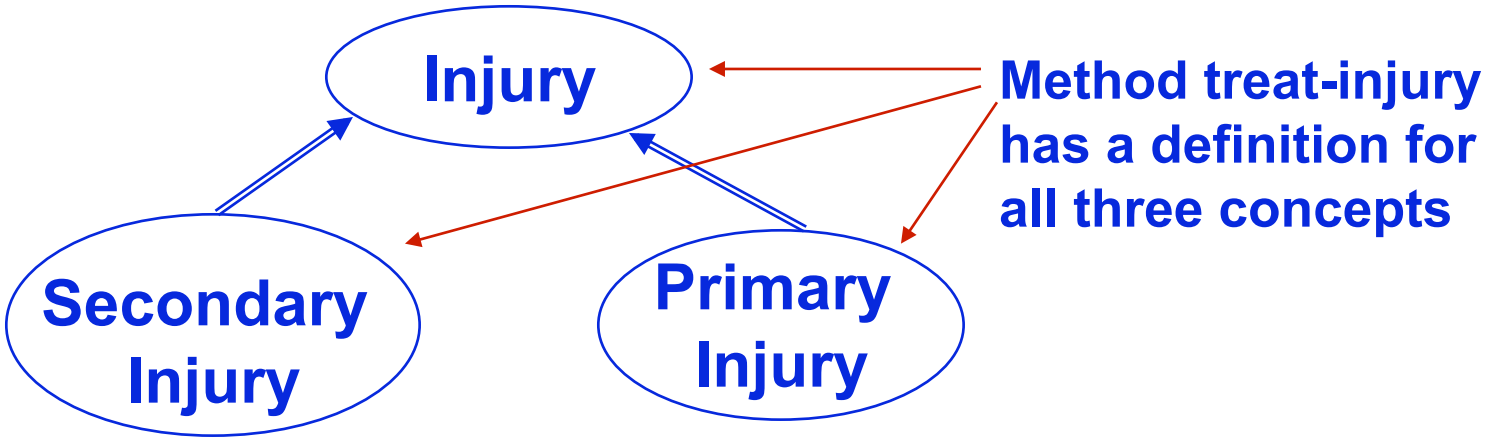
```
(defmethod treat-patient (?medic ?patient)
   :situation (:and (medic ?medic)
                    (critical-casualty ?patient)
                    (examined ?patient 'no))
   :response
   ((schedule (goto ?medic ?patient)
              :priority :high)
    (schedule (assess-casualty ?medic ?patient)
              :priority :high)))
(defmethod treat-patient (?medic ?patient)
   :situation (:and (medic ?medic)
                    (non-critical-casualty ?patient)
                    (examined ?patient 'no))
   :response
   ((schedule (goto ?medic ?patient)
              :priority :low)
    (schedule (assess-casualty ?medic ?patient)
              :priority :low)))
```

More on Choosing a Method



- Often several methods are applicable to a particular situation. "defaction" forms can specify how to resolve ambiguities
  - Choose all applicable methods
  - Choose the most specific method
  - Choose the last method defined
  - Choose a method at random
  - Issue a warning
  - Cause an error
- These resolution methods can be combined and are used in order

Example of Combined Resolution



If both secondary and primary injuries exist, :most-specific does not give a single result

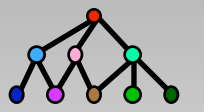
Multiple selection criteria resolves the problem

```
(defaction treat-injury (?medic ?patient)
    :filters (:most-specific :select-all))
```

The criteria are prioritized

Avoids the need to define methods for all combinations of concepts

Methods Can Also Have Query-Based Iteration



Finding all casualties reported on Medic's clipboard

```
(defmethod locate-casualties (?medic)
      :situation (medic ?medic)
      :with (casualties
                  (clipboard ?medic) ?c)
      :response (...))
```

The response is executed once for each `?c` ***that the query in the :with clause finds.***

In the response `?medic` ***is bound to the method argument and*** `?c` ***to a particular casualty reported on the medic's clipboard.***

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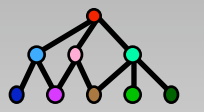
Production Rules Trigger on Changes in the Knowledge Base



- ***The changes can be additions to the KB (:detects)***
  - ***This applies to relation additions and concept additions***
- ***The changes can be deletions from the KB ((:undetects)***
  - ***This applies to relation deletions and concept deletions***
- ***The change can be in a relation value (:changes)***

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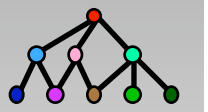
Noticing a New Injury



```
(defproduction notice-injury
     :when ((:and (:detects (injury ?self ?i))
                  (phone ?i ?phone)))
     :do ((perform (report-injury ?phone ?i)))
```

The :detects clause triggers the production

The additional query (phone ?i ?phone) *is a guard clause and also provides an additional variable binding*

The variables from the :when clause are bound for the execution of the production body. In this example, the injury is reported using a phone by calling the method "report-injury".
A different method could be used if a radio were available.