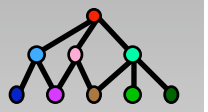
Extended Example



Hospital Knowledge Base

Definitions and Queries

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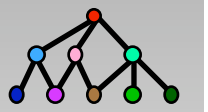
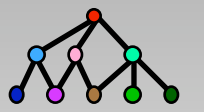
Extended Query Example: Hospital Knowledge Base



```
(defconcept facility)
(defconcept hospital :is
  (:and facility
        (:at-least 1 ward-capacity)))

(defrelation ward-capacity
     :domain hospital)

(tell (:about h-1
            (ward-capacity 120)
            (ward-capacity 120)
            (ward-capacity 100)))

(tell (:about h-2
            (ward-capacity 110)
            (ward-capacity 90)))
```

Is H-1 a Hospital?

```
(tell (:about h-1
            (ward-capacity 120)
            (ward-capacity 120)
            (ward-capacity 100)))
```



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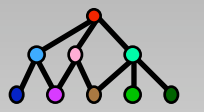
Is H-1 a Hospital?

```
(tell (:about h-1
            (ward-capacity 120)
            (ward-capacity 120)
            (ward-capacity 100)))
```



Yes, *for classified instances,*
because of the :domain entry in

```
(defrelation ward-capacity
      :domain hospital
      :range ...)
```

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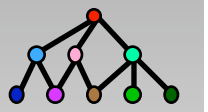
How Many Wards for H-1?

```
(tell (:about h-1
            (ward-capacity 120)
            (ward-capacity 120)
            (ward-capacity 100)))
```



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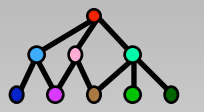
How Many Wards for H-1?



```
(tell (:about h-1
            (ward-capacity 120)
            (ward-capacity 120)
            (ward-capacity 100)))

(pi h-1)  ==>

    (:ABOUT H-1...
            (WARD-CAPACITY 120)
            (WARD-CAPACITY 100))
```

ONLY 2!

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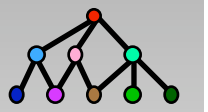
What Does This Query Ask?

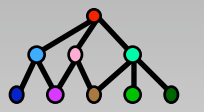
```
(retrieve (?x ?y)
     (> (ward-capacity ?x)
        (ward-capacity ?y)))
```



USC ISI

What Does This Query Ask?

```
(retrieve (?x ?y)
     (> (ward-capacity ?x)
        (ward-capacity ?y)))
```



Implicit :for-some wrapped around query, therefore returns:

```
((|I|H-1 |I|H-1) (|I|H-1 |I|H-2)
  (|I|H-2 |I|H-1) (|I|H-2 |I|H-2))
```

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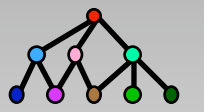
What Is Wrong with This?

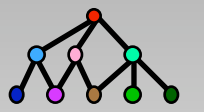
```
(defrelation ward-capacity) ; no :domain

(retrieve (?x ?y)
    (> (ward-capacity ?x)
       (ward-capacity ?y))
```



USC ISI

What Is Wrong with This?

```
(retrieve (?x ?y)
    (> (ward-capacity ?x)
       (ward-capacity ?y)))
```

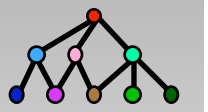


Performance Warning: Query scans the entire knowledge base to generate bindings for the variables ?X and ?Y.

Query time solution:

```
(retrieve (?x ?y)
    (:and (hospital ?x)
          (hospital ?y)
          (> (ward-capacity ?x)
             (ward-capacity ?y)))
```

Find Hospitals Ordered by Their Largest Wards



```
(defrelation ward-capacity
        :domain hospital)

(retrieve (?x ?y)
  (:and (> (max (ward-capacity ?x))
           (max (ward-capacity ?y)))))


==> ((|I|H-1 |I|H-2))
```

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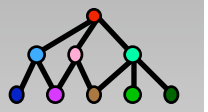
What About All Wards Larger?



```
(retrieve (?x ?y)
  (:and (> (min (ward-capacity ?x))
           (max (ward-capacity ?y)))))

 ==>  NIL
```

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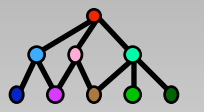
Hospital with a Ward Larger Than 100 beds?

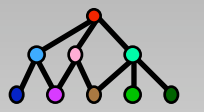


```
(retrieve (?x)
      (:for-some (?len)
            (:and (ward-capacity ?x ?len)
                  (>= ?len 100))))
```

Note the explicit :for-some designation!

USC ISI

Hospital with All Wards Larger Than 100?



```
(retrieve (?x)
    (:for-all (?len)
        (:implies
            (ward-capacity ?x ?len)
            (>= ?len 100))))
```

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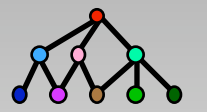
Special Syntax in :for-all

```
(retrieve (?x)
    (:for-all (?len)
        (:implies
            (ward-capacity ?x ?len)
            (>= ?len 100)))))
```

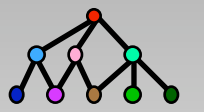


Implication used in :for-all to restrict the domain of the quantified variable (?len)

Alternate possibility:

```
(…(:for-all (?len)
      (:or
        (not (ward-capacity ?x ?len))
        (>= ?len 100)))))
```

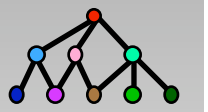
Implication Equivalence



(:implies A B)

(:or (:not A) B)

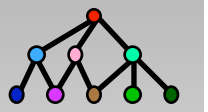
Hospital with All Wards Larger Than 100?



```
(retrieve (?x)
   (:for-all (?len)
         (:implies
              (ward-capacity ?x ?len)
              (>= ?len 100))))
```

Problem: Couldn't find a closed set of fillers for the role ward-capacity.

Three Possible Solutions



At the individual level:

```
(tell (:about h-1
        (:exactly 2 ward-capacity)))
```

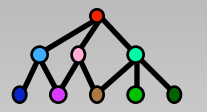
At the relation level:

```
(defrelation ward-capacity ...
   :characteristics :closed-world)
```

At the context level:

```
(setf (open-closed-mode
            (current-context))
      :closed)
```

Hospital with All Wards Larger Than 100?



```
(retrieve (?x)
     (:and (hospital ?x)
           (:for-all (?len)
              (:implies
                   (ward-capacity ?x ?len)
                   (>= ?len 100)))))

==> (|I|H-1)
```

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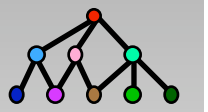
Nested Queries Are OK



```
(retrieve (?x ?y)
  (:and (hospital ?x) (hospital ?y)
        (:for-all (?a)
          (:implies
            (ward-capacity ?x ?a)
            (:for-some (?b)
              (:and (ward-capacity ?y ?b)
                    (> ?a ?b)))))))

==> ((|I|H-1 |I|H-2))
```

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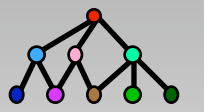
How To Get Multiple Wards of the Same Size for H-1?

```
(tell (:about h-1
              (ward-capacity 120)
              (ward-capacity 120)
              (ward-capacity 100)))
```



Need to make wards individuals, so they can be differentiated.

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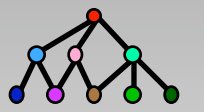
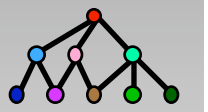
New Domain Model



```
(defconcept facility)
(defconcept hospital :is
  (:and facility
        (:at-least 1 hospital-ward)))

(defconcept ward :is
  (:and facility
        (:exactly 1 ward-capacity)))

(defrelation hospital-ward
   :domain hospital :range ward
   :characteristics :closed-world)

(defrelation ward-capacity
   :domain ward
   :characteristics :closed-world)
```

Auxiliary Relation

```
(defrelation hospital-ward-capacity
   :is (:compose hospital-ward
                 ward-capacity))
```



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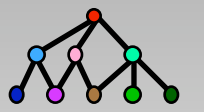
Domain Facts



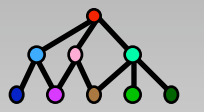
```
(tell (:about h-1
            (hospital-ward w1)
            (hospital-ward w2)
            (hospital-ward w3)))

(tell (ward-capacity w1 120)
      (ward-capacity w2 120)
      (ward-capacity w3 100))

(tell (:about h-2
            (hospital-ward w4)
            (hospital-ward w5)))

(tell (ward-capacity w4 110)
      (ward-capacity w5  90))
```

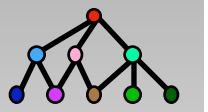
Retrieve Multiple Wards for H-1



```
(retrieve (?w ?l)
   (:and (hospital-ward h-1 ?w)
         (ward-capacity ?w ?l)))

==> ((|I|W1 120) (|I|W2 120) (|I|W3 100))
```

Retrieve Multiple Wards for H-1



```
(retrieve (?w ?l)
   (:and (hospital-ward h-1 ?w)
         (ward-capacity ?w ?l)))
```

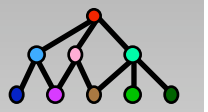
```
==> ((|I|W1 120) (|I|W2 120) (|I|W3 100))
```

What about a short-hand notation?

```
(retrieve ?l
   (hospital-ward-capacity h-1 ?l))

==> (120 100)
```

Lessons from the Example



Modeling Advice:

- **Determine Detail Level**
- **Use Specialized Operators**
- **Be Explicit in Queries**