Using Time in Loom

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Outline

- Time Representation
- Basic Assertions
- Basic Queries
- Persistence
- Time and the Classifier
- Advanced Examples
Agent and World Time

- World Time Records Domain Facts

- Agent Time Records Knowledge Base Changes
Time Representation

- **Definite Times**
  - Integers
  - Time Strings “10/28/94 11:33”

- Anchored to Calendar
  - Common Lisp universal time

- Points Are Basic Units

- Intervals Are Derived

- “Property” Interpretation of Intervals
Properties and Events

- **Properties**
  - True over all subintervals
  - “The house is red”

- **Events**
  - True only over the entire interval
  - “John ran completely around the track.”
Basic Assertions

- **Transitions Only**
  - (:begins-at time-point assertion)
  - (:ends-at time-point assertion)

- **Strong Temporal Assertion**
  - Before :begins-at, assertion is false.
  - After :begins-at, assertion is true.
Basic Assertions

\[ \text{not} (P \ x) \quad P \ x \quad \text{Time1} \]

\[ \text{tell} (:\text{begins-at Time1} \ (P \ x)) \]

\[ \text{not} (P \ x) \quad P \ x \quad \text{not} (P \ x) \quad \text{Time1} \quad \text{Time2} \]

\[ \text{tell} (:\text{ends-at Time2} \ (P \ x)) \]
Basic Queries—Transitions

Transitions:

\[(\text{ask} (:\text{ends-at} \ t1 \ (P \ x)))\]
Basic Queries—States

- **Transitions:**
  - \((\text{ask (:ends-at } t1 \ (P \ x)))\)

- **States:**
  - \((\text{ask (:holds-at } t1 \ (P \ x)))\)
Basic Queries—States

Problem

- **Transitions:**
  - \((\text{ask (:ends-at } t1 \ (P \ x)))\)

- **States:**
  - \((\text{ask (:holds-at } t1 \ (P \ x)))\)
  - *But this can be ill-defined*
Basic Queries—States

Solution

- **Introduce Directional Operators**
  - \((\text{ask (:holds-before } t1 \ (P x))\))
  - \((\text{ask (:holds-after } t1 \ (P x))\))
- **Yields well-defined results:**

\[
\begin{align*}
:\text{holds-before} & \implies t \\
:\text{holds-after} & \implies \text{nil}
\end{align*}
\]
Non-Transitional Assertions

- **Persistence Only**
  - (:holds-after time-point assertion)
  - (:holds-before time-point assertion)

- **Weak Temporal Assertion**
  - Before :holds-after, assertion can be true or false.
  - After :holds-before, assertion can be true or false.

- :holds-at is the combination of :holds-before and :holds-after
  - The assertion is true both before and after a :holds-at
Persistence Assertions

(P x) Time1
(tell (:holds-after Time1 (P x)))

(P x) Time1 Time2
(tell (:holds-after Time2 (P x)))

(P x) Time1 Time2 Time3
(tell (:holds-before Time3 (P x)))
# Temporal Operator Truth Table

<table>
<thead>
<tr>
<th>Temporal Operator</th>
<th>t1</th>
<th>t2</th>
<th>t3</th>
</tr>
</thead>
<tbody>
<tr>
<td>:begins-at</td>
<td>t</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>:holds-after</td>
<td>t</td>
<td>t</td>
<td>nil</td>
</tr>
<tr>
<td>:holds-at</td>
<td>nil</td>
<td>t</td>
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</tr>
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<td>:holds-before</td>
<td>nil</td>
<td>t</td>
<td>t</td>
</tr>
<tr>
<td>:ends-at</td>
<td>nil</td>
<td>nil</td>
<td>t</td>
</tr>
</tbody>
</table>
Changes to Classifier

- Classifier Is Time Sensitive
  - Temporal information in the ABox affects classification

- Definitions Are Time Invariant
  - TBox definitions hold over the entire time line
(defconcept Married
  :characteristics :temporal)

(defconcept Bachelor :is
  (:and Male (:not Married)))

(tell (Male p1)
  (:begins-at t1(Married p1)))
Widow Example

(defun dead
  (:characteristics :temporal)

(defun husband
  (:is (:and spouse (:range Male))
   :characteristics :temporal)

(defun widow
  (:is (:and Female
       (:some husband Dead))))
Widow Assertions

(tellm (Female Mary) (Male John))

(tellm (:begins-at "1/1/90"
    (spouse Mary John))
    (:begins-at "1/1/94"
    (Dead John)))
Widow Derivation

\[
\begin{align*}
&(\text{tellm} \ (\text{Female} \ Mary) \ (\text{Male} \ John)) \\
&(\text{tellm} \ (:\text{begins-at} \ "1/1/90") \\
&(\text{spouse} \ Mary \ John)) \\
&(\text{:begins-at} \ "1/1/94") \\
&(\text{Dead} \ John))
\end{align*}
\]
Widow Queries

(spuase Mary John)
1/1/90

(Dead John)
1/1/94

(Widow Mary)
1/1/94

(retrieve ?x (:holds-at "10/28/94"
  (widow ?x)))
=> (|i|Mary)

(retrieve ?x (:begins-at ?x
  (Widow Mary)))
=> (2966400000)
; = "1/1/94 00:00:00"
Former Hockey Player

(definition concept former-hockey-player :is
  (:and person
    (:satisfies (?p)
      (:for-some (?t)
        (:and (past ?t)
          (:ends-at ?t
            (hockey-player ?p)))))))
Temporal concept “past” constrains matches for \(?t\) to occur before the time this definition is satisfied.

A former hockey player is “someone who ceased to be a hockey player sometime in the past.”
Former Hockey Player
Temporal Clause

(defconcept former-hockey-player :is
  (:and person
    (:satisfies (?p)
      (:for-some (?t)
        (:and (past ?t)
          (:ends-at ?t
            (hockey-player ?p ))))))

Temporal relation to the concept “hockey-player” established.
(tellm (Person Fred))
(tellm (:ends-at "1/1/90"
  (hockey-player Fred)))

(ask (:holds-at "1/1/88"
  (hockey-player Fred))) => T
(ask (:holds-at "1/1/88"
  (former-hockey-player Fred))) => NIL

(ask (:holds-at "1/1/94"
  (hockey-player Fred))) => NIL
(ask (:holds-at "1/1/94"
  (former-hockey-player Fred))) => T
Summary

- World and Agent Time Supported
- Definite, Calendar-Anchored Time
- ABox Supports Temporal Assertions
- Inference Is Time Sensitive