Categories and Objects

Events

- **Event calculus**, models how the truth value of relations changes because of events occurring at **certain times**.
- Event *E* occurring at time *T* is written as *event(E,T)*.
- It is designed to allow reasoning over intervals of time.

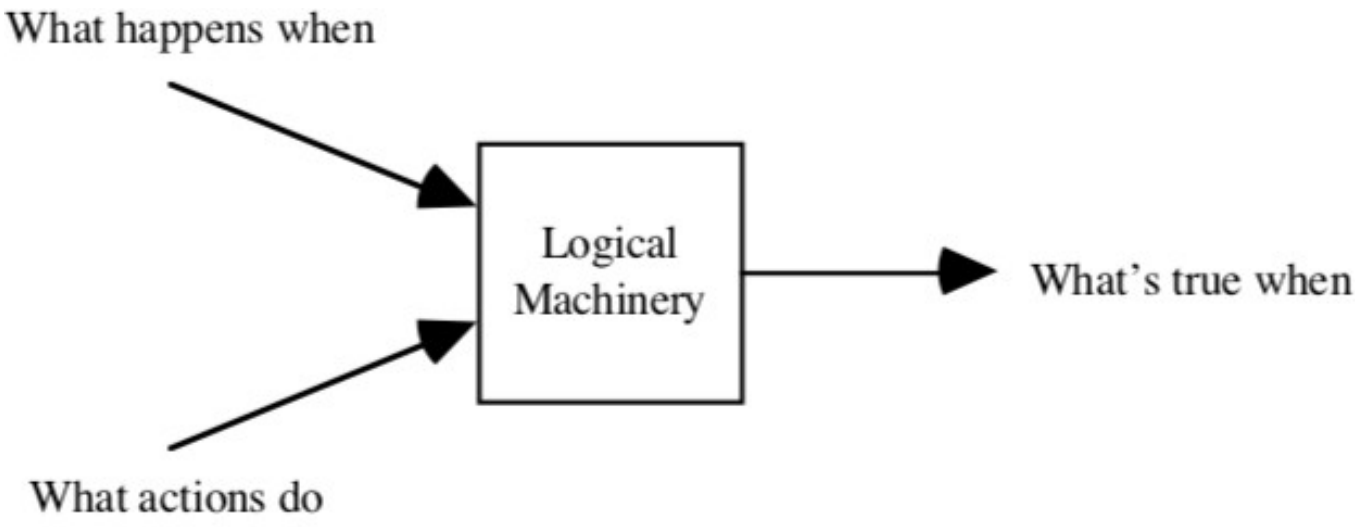


Figure 1: How the Event Calculus Functions

Reified Fluents in Event calculus

Fluents: Is a condition that can change over time.

- In logical approach, fluent is a predicate or function that vary from one situation to the next.
  - "the box is on the table" - **On(box, table)**
  - if it can change over time - **On(box, table, t)**
  - Here "On" is a predicate.
- Fluents can also be represented by functions are said to be reification
- When using reified fluents, a separate predicate is necessary to tell when a fluent is actually true or not.
- For example, **HoldsAt(on(box,table), t)** means that the box is actually on the table at time t, where the predicate **HoldsAt** is the one that tells when fluents are true.
- This representation of reified fluents is used in the event calculus.

Complete set of predicates for one version of the event calculus

- **HoldsAt(f,t)** - Fluent f is true at time t
- **Happens(e, i)** - Event e happens at time i
- **Initiates (e, f , t)** - Event e causes fluent f to be true after time t
- **Terminates (e, f , t)** - Event e causes fluent f to cease after time t
- **Clipped(t, f, t_2)** - Fluent f ceases to be true at some point during time interval between t and t_2
- **Restored(t, f, t_2)** - Fluent f becomes true sometime during time interval between t and t_2

The Axioms of the Simple Event Calculus

- Collection of axioms relating the various predicates together to represent an action

$$HoldsAt(f,t) \leftarrow [Happens(e,t_1) \wedge Initiates(e,f,t_1) \wedge (t_1 < t) \wedge \neg Clipped(t_1,f,t)]$$

This formula means that the fluent represented by the term f is true at time t if:

1. an event e has taken place: $Happens(e,t_1)$;
2. this took place in the past: $t_1 < t$;
3. this event has the fluent f as an effect: $Initiates(e,f,t_1)$;
4. the fluent has not been made false in the meantime: $Clipped(t_1,f,t)$

- A fluent is true at time *t* if and only if it has been made true in the past and has not been made false in the meantime.

Contd..

- The *Clipped* predicate, stating that a fluent has been made false during an interval, can be axiomatized as follows:

Clipped(t1, f, t2) $\Leftrightarrow \exists$e, t[Happens(e, t)$\wedge$t1 $\leq$t<t2$\wedge$Terminates(e, f,t)]

- The *Restored* predicate, stating that a fluent has been made true during an interval, can be axiomatized as follows:

Restored(t1, f, t2) $\Leftrightarrow \exists$e, t[Happens(e, t)$\wedge$t1 $\leq$t<t2$\wedge$Initiates(e, f, t)]

Example

Happens(Turnoff(LightSwitch$_1$),1:00) – Lightswitch was turned off at exactly 1:00

Processes

- Any subinterval of a process is also a member of same process category called process category or liquid category
- Any process e that happens over an interval also happens over any subinterval:

$(e \in \text{Processes}) \wedge \text{Happens}(e, (t1, t4)) \wedge (t1 < t2 < t3 < t4) \Rightarrow \text{Happens}(e, (t2, t3))$

Example:

In(Shankar, New Delhi) – Shankar being in New Delhi

T(In(Shankar, New Delhi), Today) – He was in New Delhi all day

Time Interval

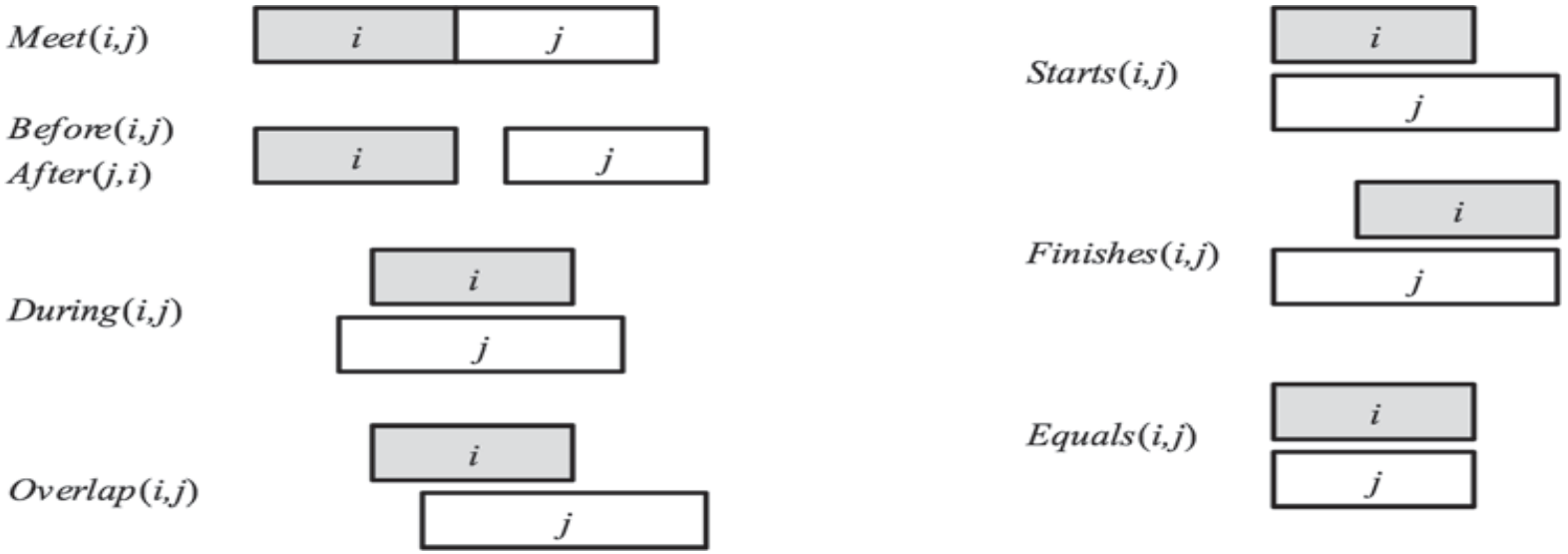
- Time is important to any agent that takes action
- 2 kinds of time intervals:
  1. moments
  2. extended intervals
- The distinction is that only moments have zero duration
  - **Partition ({Moments , ExtendedIntervals }, Intervals)**
  - **$i \in$ Moments $\Leftrightarrow$ Duration(i)=Seconds(0)**

Time scale

The moment at midnight (GMT) on Jan 1, 1900 has time 0

- Interval(i) ‹ Duration(i)=(Time(End(i))−Time(Begin(i))).
- Time (Begin (AD 1900)) = Seconds (0).
- Time(Begin(AD2001)) = Seconds(3187324800)
- Time(End(AD2001))=Seconds(3218860800)
- Duration(AD2001)= Seconds(31536000)

Predicate of time intervals

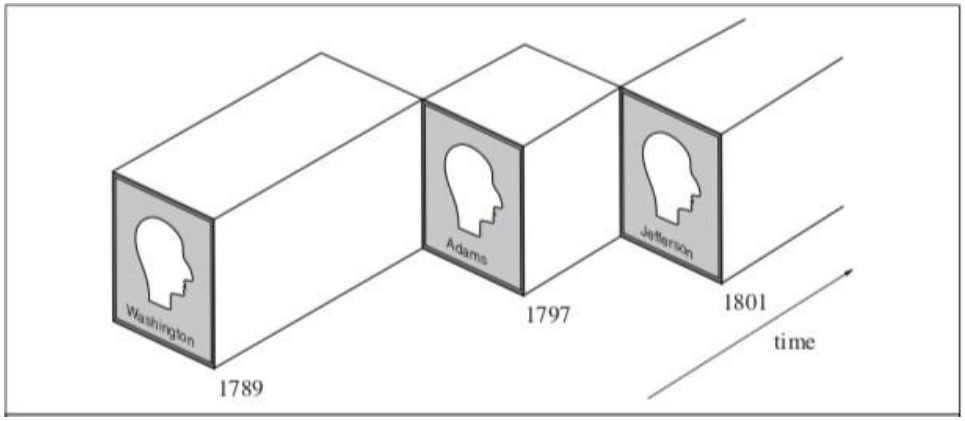


$$
\begin{aligned}
Meet(i,j) &\Leftrightarrow End(i) = Begin(j)\\
Before(i,j) &\Leftrightarrow End(i) < Begin(j)\\
After(j,i) &\Leftrightarrow Before(i,j)\\
During(i,j) &\Leftrightarrow Begin(j) < Begin(i) < End(i) < End(j)\\
Overlap(i,j) &\Leftrightarrow Begin(i) < Begin(j) < End(i) < End(j)\\
Begins(i,j) &\Leftrightarrow Begin(i) = Begin(j)\\
Finishes(i,j) &\Leftrightarrow End(i) = End(j)\\
Equals(i,j) &\Leftrightarrow Begin(i) = Begin(j) \wedge End(i) = End(j)
\end{aligned}
$$

Fluents and objects

- Physical objects can be viewed as generalized events, in the sense that a physical object is a chunk of space–time.
- President(USA, t) is a logical term that denotes a different object at different times.
- To say that George Washington was president throughout 1790, we can write

T (Equals (President (USA), GeorgeWashington), AD 1790)



object President(USA) for the first 15 years of its existence

Source of Information

- Textbook
- https://en.wikipedia.org/wiki/Fluent_(artificial_intelligence)
- https://en.wikipedia.org/wiki/Event_calculus
- https://artint.info/html/ArtInt_336.html
- https://www.doc.ic.ac.uk/~mpsha/ECExplained.pdf


THANK YOU