

Planning, Execution & Learning: Temporal Planning

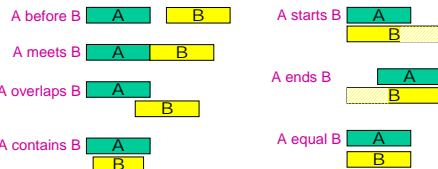
Reid Simmons

Representing Time

- Qualitative (Relational)
 - Points
 - Intervals
- Quantitative (Metric)
 - Discrete
 - Continuous

Interval Logic (Allen, 1983)

- Intervals are Atomic Units
 - “Points” are intervals with zero duration
- Intervals Can Meet with No Overlap
 - Solves a logical paradox regarding state of the world



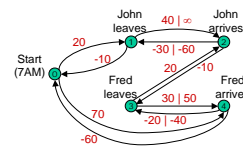
Temporal Constraint Networks (Dechter 1991)

- Metric Constraints Between Time Points
 - Binary $X_j - X_i \in [t_0, t_1]$ $t_0 \leq X_j - X_i \leq t_1$
 - Unary $X_i \in [t_2, t_3]$ $t_2 \leq X_i - X_0 \leq t_3$

- Represent Using Directed, Disjunctive **Distance Graph**

- John goes to work either by car (30-40 minutes), or by bus (at least 60 minutes).
- Fred goes to work either by car (20-30 minutes), or in a carpool (40-50 minutes).
- John left home between 7:10 and 7:20
- Fred arrived at work between 8:00 and 8:10
- Fred left home about 10-20 minutes before John arrived at work.

Q: What are the possible times that Fred left home?
Q: Could John have taken the bus and Fred used the carpool?



Simple Temporal Networks

- Temporal Constraint Network **Without** Disjunction
 - At most one interval constraint between pairs of time points
- Represent Using **D-Graph**
 - Completely connected distance graph
 - Solvable in polynomial time (Floyd-Warshall all-pairs-shortest-path)
 - Inconsistent if negative cycles ($d_{ii} < 0$)

John car; Fred carpool

0	20	50	30	70
-10	0	60	40	60
-40	-20	0	-10	20
-30	-10	20	0	30
-60	-40	0	-20	0

John bus; Fred carpool

-20	-10	50	30	50
-30	-20	40	20	40
-90	-80	-20	-40	-20
-70	-60	0	-20	0
-110	-100	-40	-60	-40

Representing Temporal Actions

- Actions Have Duration
 - $a_e - a_s \in [t_0, t_1]$
- Timed Conditions and Effects
 - Associate conditions and effects with either endpoint
 - Associate with *any* endpoint
- Invariant Conditions
 - Hold throughout the action

ZENO (cont.)

- Handling Metric Constraints
 - Posted to a constraint-reasoning system
 - Linear equalities: *Gaussian elimination*
 - Linear inequalities: *Simplex*
 - Non-linear constraints: *Delay until other solutions make them linear*
 - Check for inconsistencies after each step
- Handling Constraints Over Time Intervals
 - Non-deterministic split into subintervals
 - Enables one to deal with piece-wise linear changes
 - Takes advantage of linearity to post only at endpoints of intervals
- Handling Continuous Change
 - Convert to linear equation:
 $\partial/\partial t \text{ fuel}(t, \text{plane}) = \delta \Rightarrow \text{fuel}(t, \text{plane}) = \text{fuel}(t_0, \text{plane}) + \delta(t - t_0)$