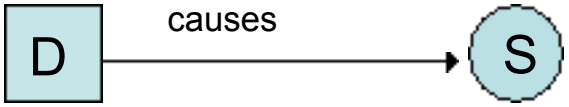
More Expert Systems

- Causality?
- What's in a Link?
- Temporal reasoning
- Quantitative reasoning
- Model-based reasoning
- Workflow

Meaning of Representation?



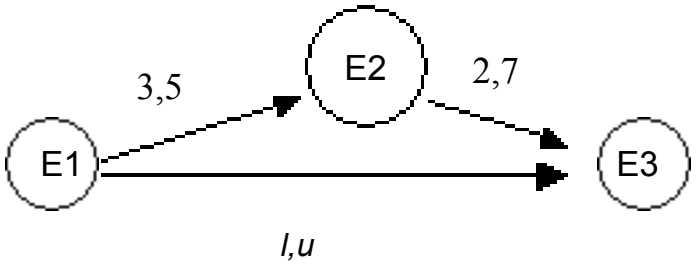
- Always? →probability
- Magnitude? →severity; bad cold → worse fever?
- Delay? →temporality
- Where? →spatial dependency
- Under what conditions? →context
- Interaction of multiple causes →physical laws
- Cross-terms →high-dimensional descriptions

Temporal Reasoning

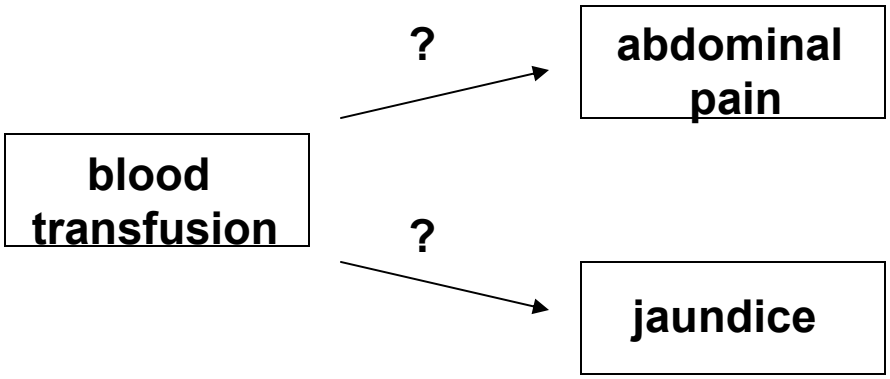
- **Keeping track of multiple forms of temporal relations (Kahn '75)**
  - **The time line**
    - **"On Dec. 12 last year . . ."**
  - **Special reference events**
    - **"Three days after I was hospitalized in 1965 . . ."**
  - **Temporal Ordering Chains**
    - **"It must have been before I graduated from high school."**

- **Constraint propagation (Kohane '87)**
  - **Primitive relation: e1, e2, *l*ower, *u*pper bounds**
  - **Heuristics for propagation based on semantic grouping**

$3 \leq T(E2)-T(E1) \leq 5$
$2 \leq T(E3)-T(E2) \leq 7$
Therefore
$l=5 \leq T(E3)-T(E1) \leq 12=u$



Exploiting Temporal Relations



- transfusion precedes both abdominal pain and jaundice *implies* transfusion-borne acute hepatitis B
- as in 1, but only by one day
- jaundice occurred 20 years ago, transfusion and pain recent
- Can be very efficient at filtering out nonsense hypotheses.

Postdiction

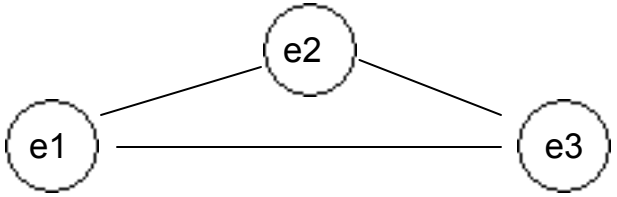
See **Long, Reasoning about State from Causation and Time in a Medical Domain, *AAAI 83***

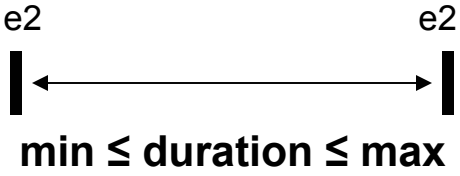
Temporal Representation can be Complex

Time

The usual:

- **point, intervals, constraints**





min ≤ duration ≤ max

- **timelines, reference events, fuzz, …**

The unusual

- **cyclic edema**
- **focal glomerulonephritis**
- **patterns of fever**

Systems issues

- **flow of "now"**
- **supporting the illusion of "instantaneous" decision-making within a temporal reasoner**
  - **correcting the past**

The Surprisingly Normal pH

- Diarrhea causes bicarbonate (alkali) loss
- Vomiting causes acid loss
- Therefore, normal pH is a manifestation of {diarrhea + vomiting}!

Reasoning from Models

- Model handles all possible interactions, without having explicitly to anticipate them all
- Reasoning: Fit parameters to a physiological model, then predict consequences to suggest
  - other expected findings
  - reasonable interventions
- Qualitative models
- Combining associational and model-based reasoning

Guyton's Model of Cardiovascular Dynamics

Long's Clinical Model of Heart Failure Predictions for Mitral Stenosis with Exercise

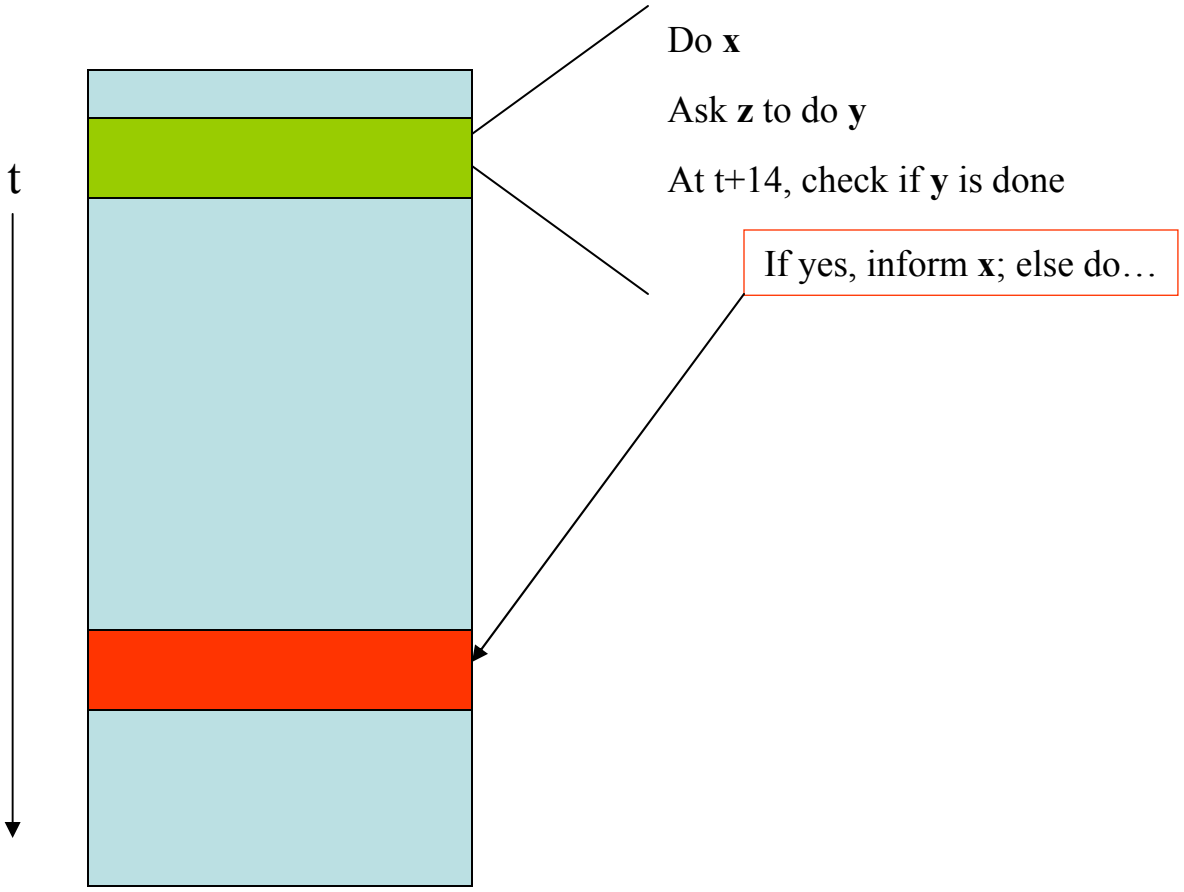
Physiological Knowledge

"All variations in myocardial contractile activity can be expressed as displacements of the force-velocity curve. However, there are two fundamental ways in which the force-velocity curve can be shifted. … *Harrison's (6th ed.)*

What is Workflow?

- Coordination
  - CSP, where some of the processes are people
  - Checking that others are “on track”
- Resource allocation
- Design of rational human-institution-technology systems

Workflow Engine
≈ discrete-event simulator



“Sequential” processes become complex conditional processes

- No “dropped balls”
- Every step must be checked for completion, retraction, substitution, explicit abandonment, …
- If check fails, must initiate process to “work around”, retry, etc.
- People must acknowledge information
  - E.g., 2-way pagers