Problem Frame Transformations:
Deriving Specifications from Requirements

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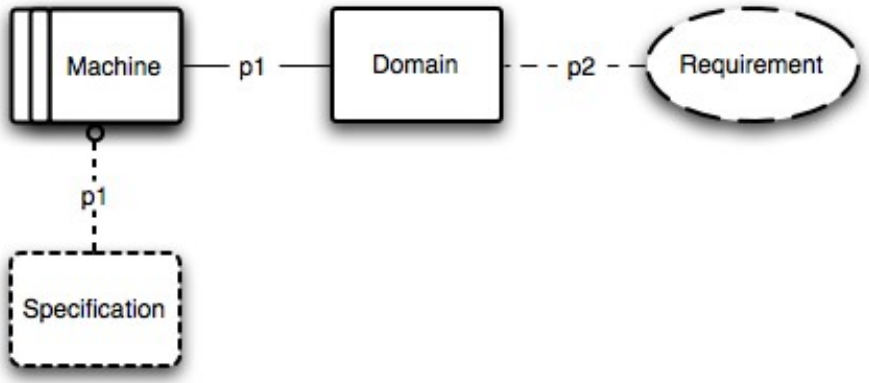
May 23rd, 2006
2nd International Workshop on Applications and Advances in Problem Frames
(IWAAPF'06, part of ICSE'06)

History

- tool for understanding proton therapy machine
- build-then-analyze vs. design-then-build
- local reasoning (local understanding)
- show history (tracability, communication)

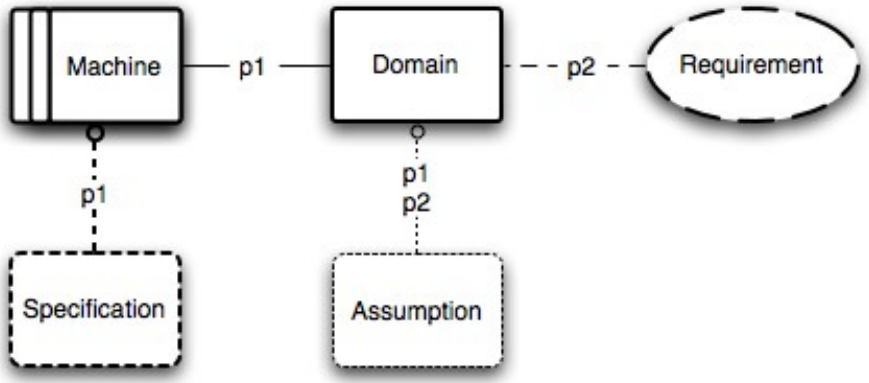
Requirements & Specifications

- does the spec enforce the requirement?



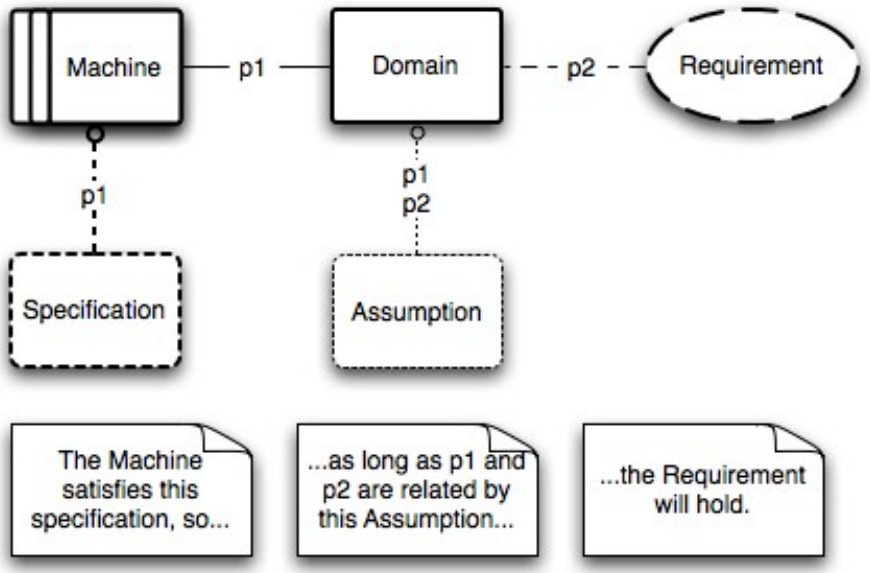
Requirements & Specifications

- does the spec enforce the requirement?
- relies on **domain assumptions**



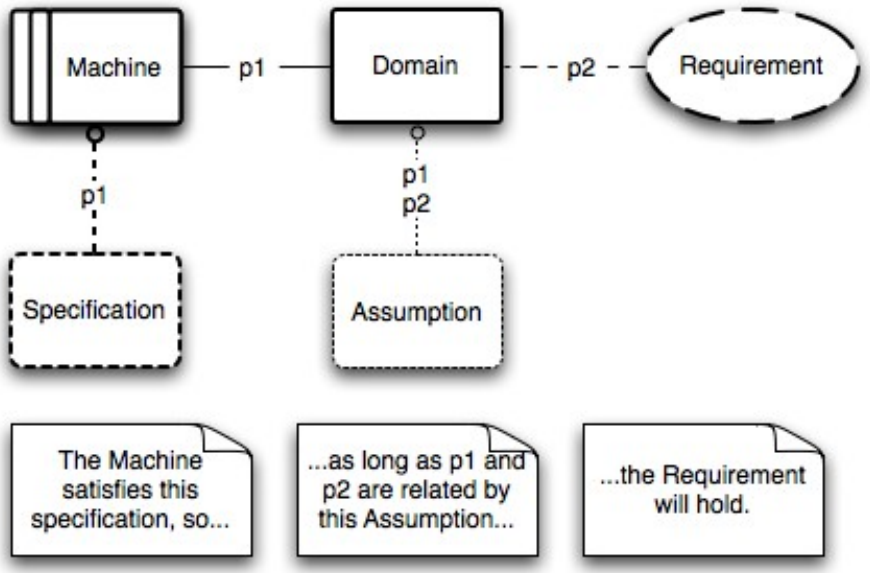
Requirements & Specifications

- does the spec enforce the requirement?
- relies on **domain assumptions**
- conventional solution: catalogue of **frame concerns** derived from prior experience
- template for correctness argument, list of relevant assumptions



Key Observations

- requirement is not a spec **only** because it references phenomena not controlled by the machine
- domain assumption justifies constraining p1 instead of p2
- can incrementally transform requirement into spec plus set of domain assumptions



Transformation Toolkit

- **add** a breadcrumb
- **rephrase** the goal
- **push** an arc
- **split**/**merge** arcs
- **heuristic**: walk the requirement towards the machine

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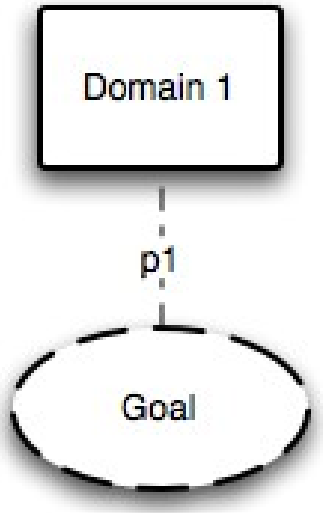

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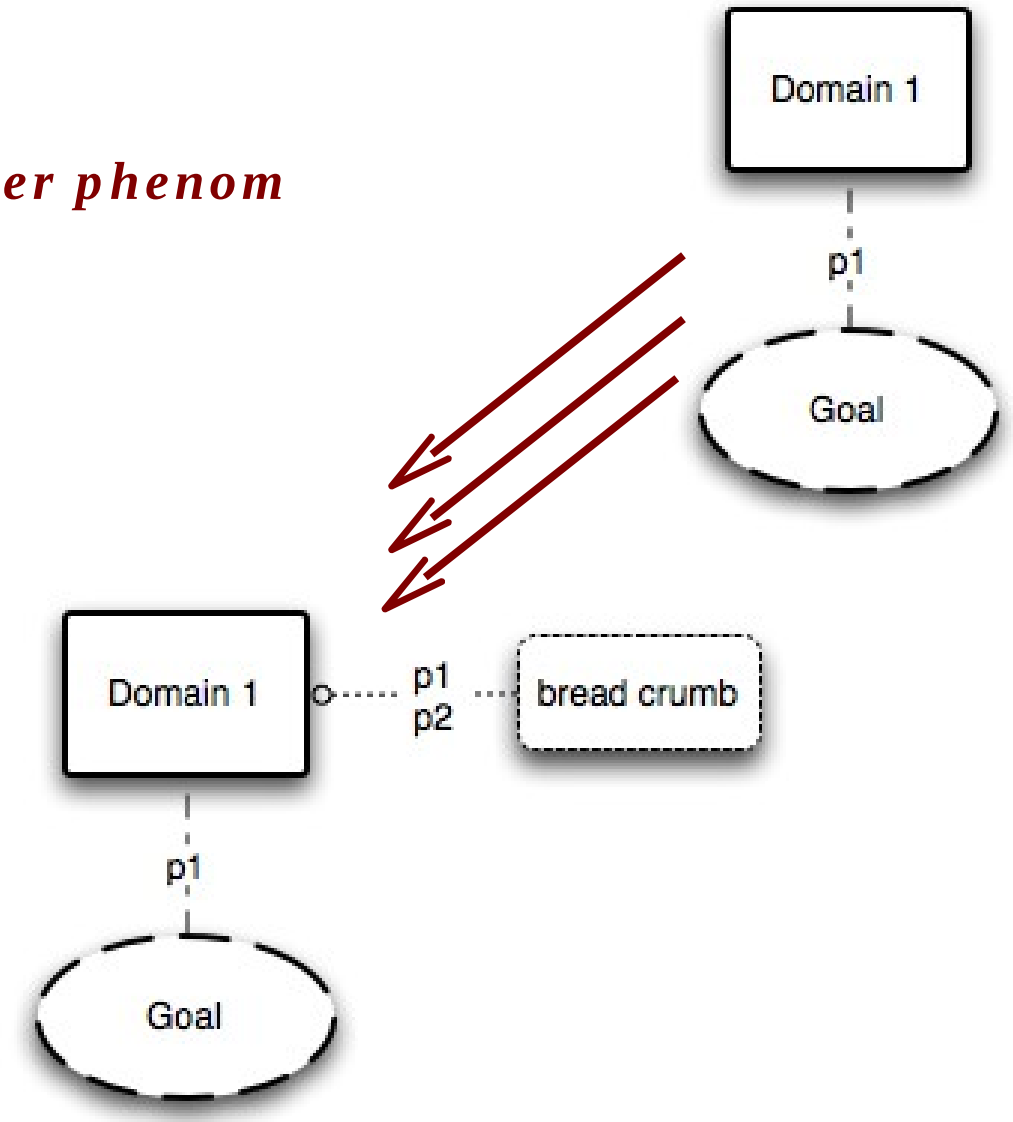

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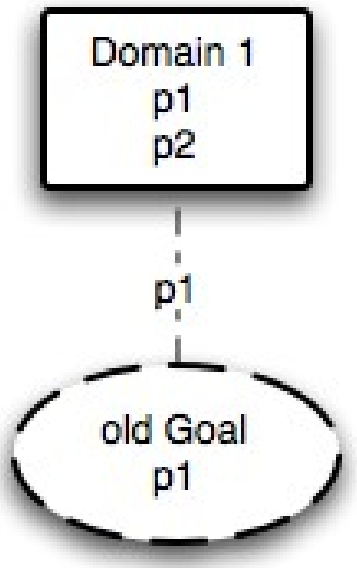

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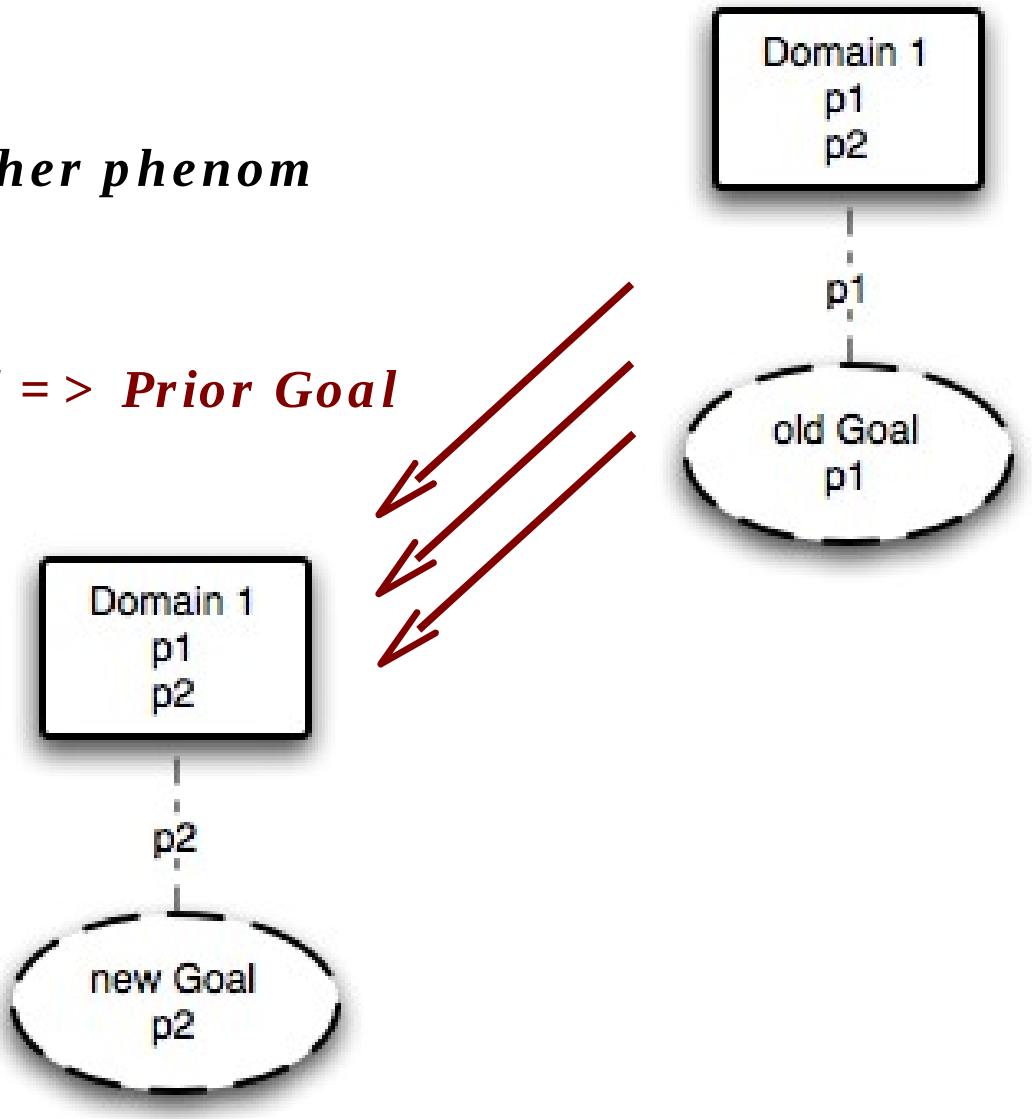

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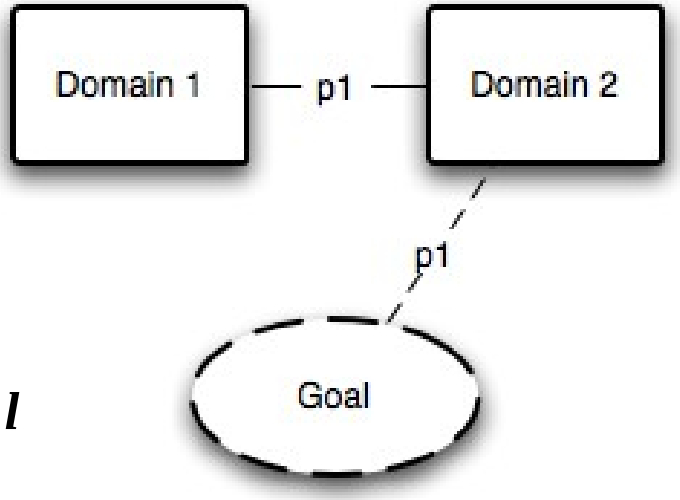

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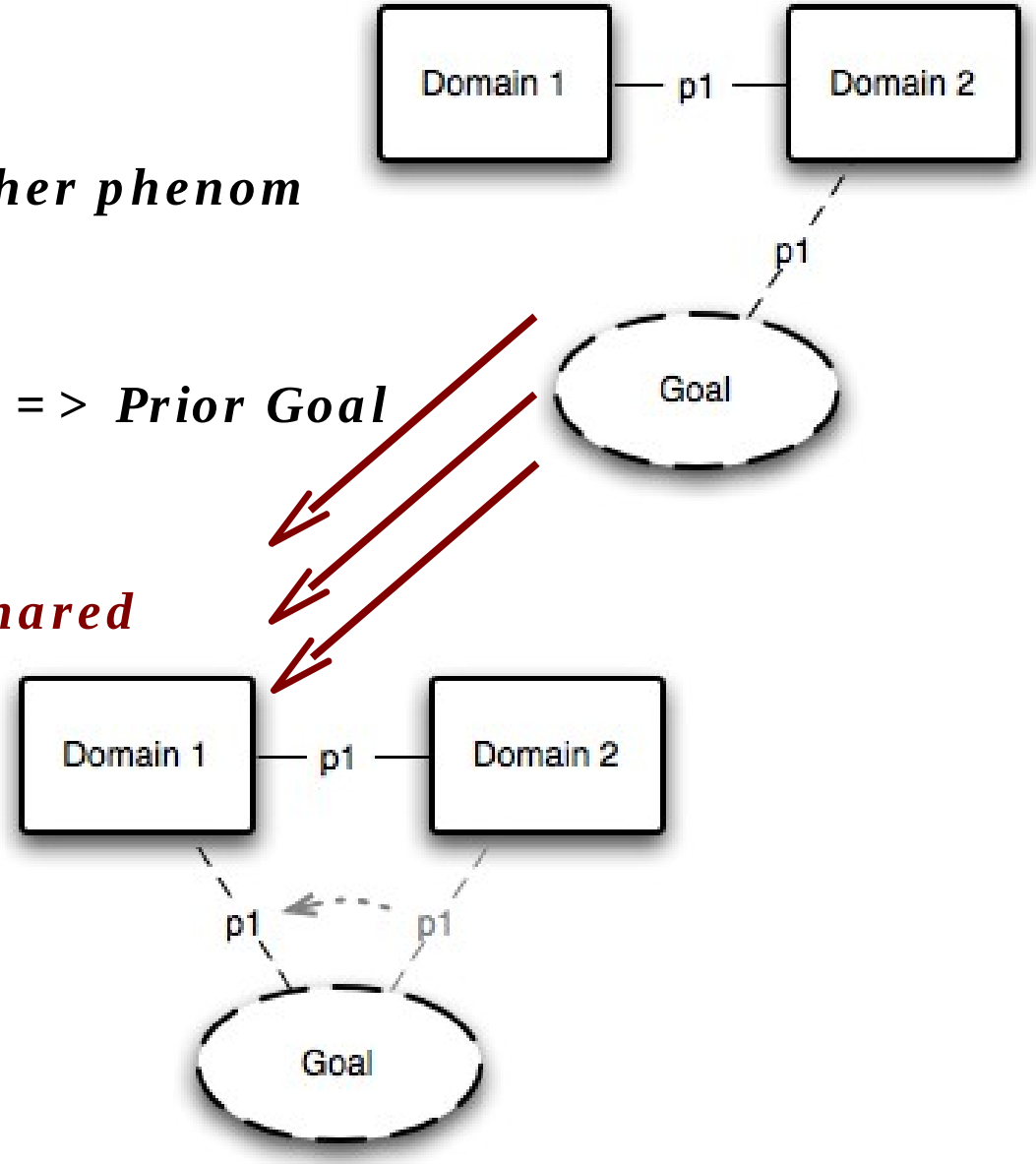

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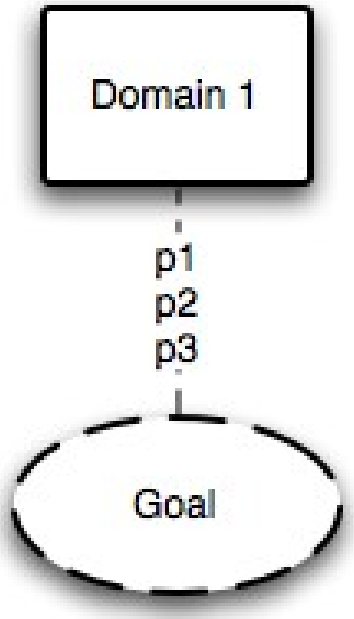

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- **split/merge** arcs

  nothing else changes

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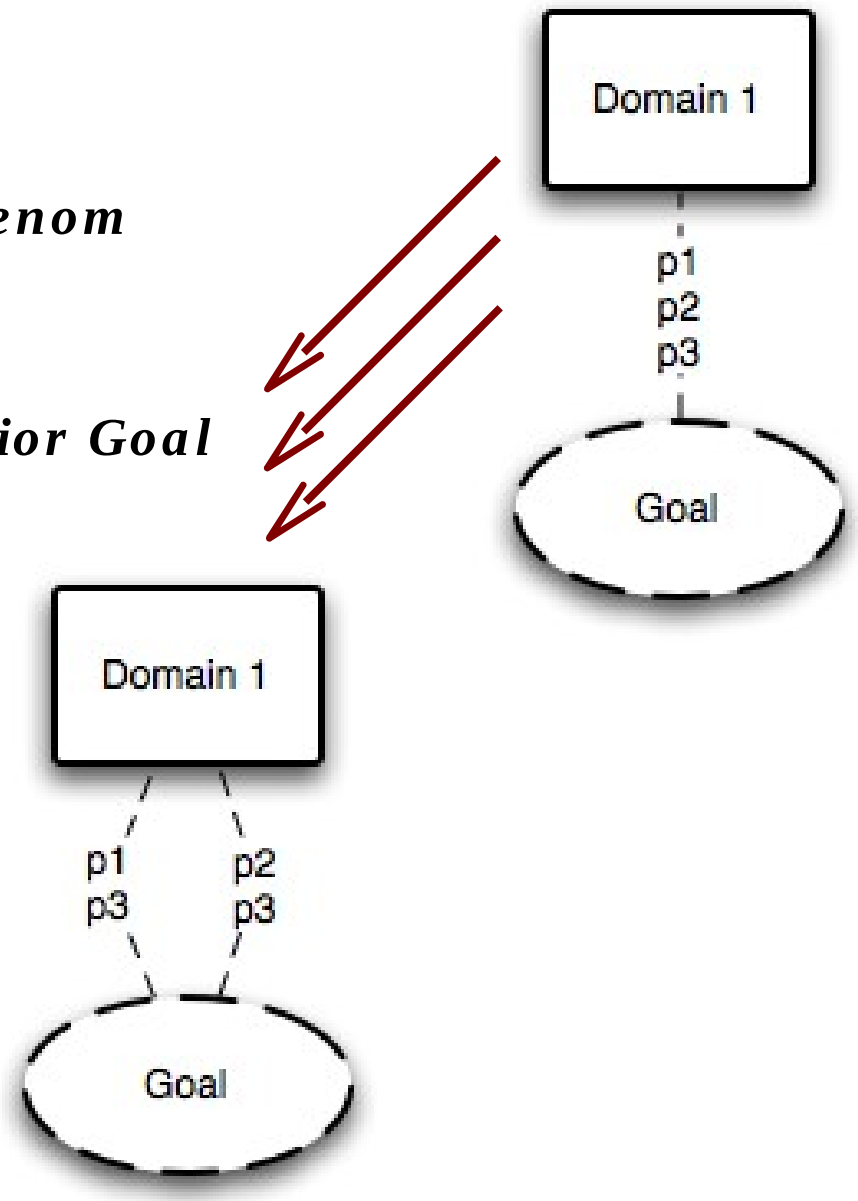
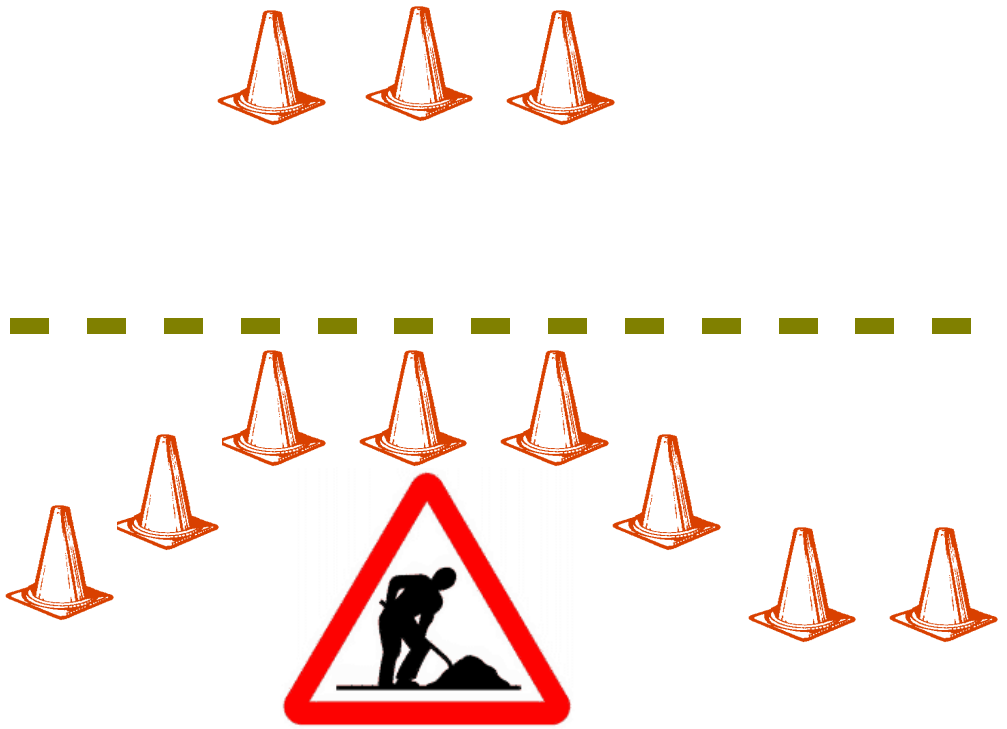


Two-Way Traffic Light



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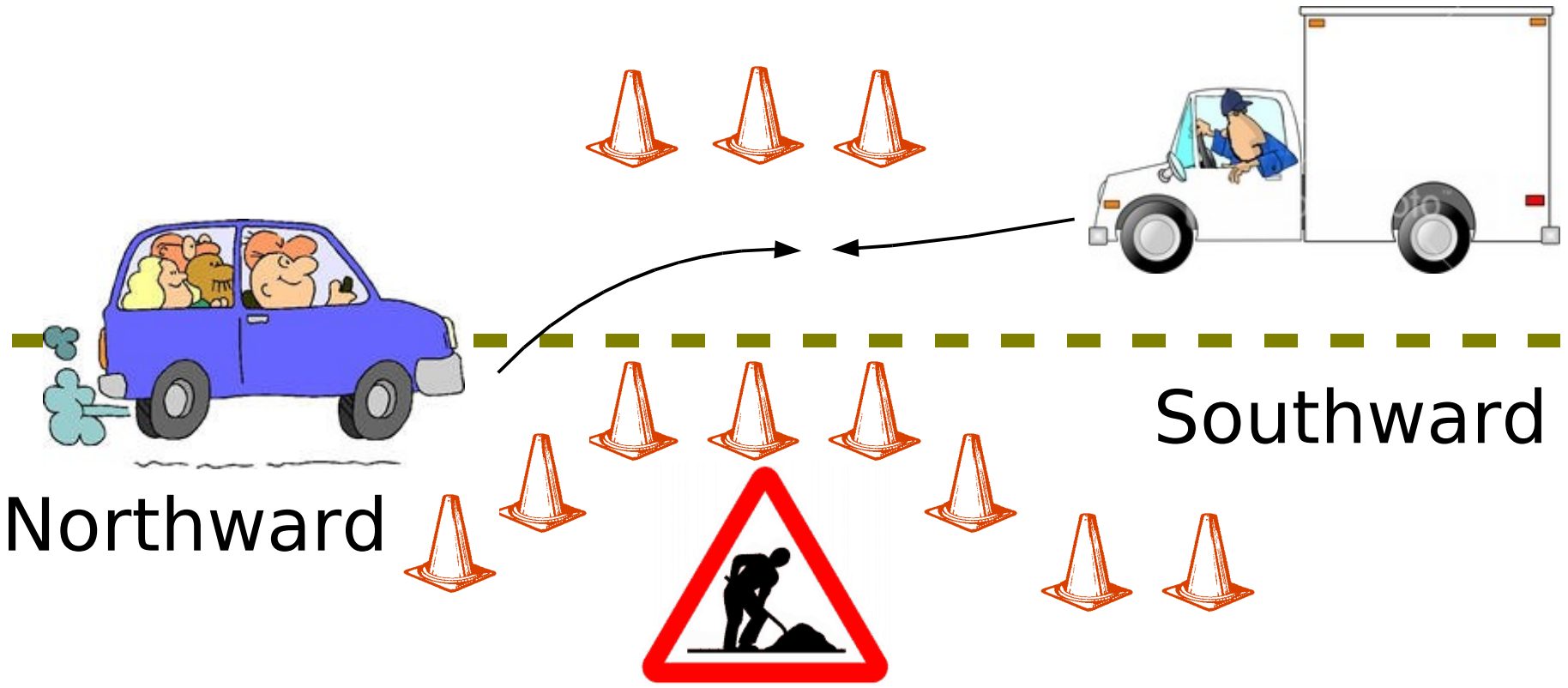

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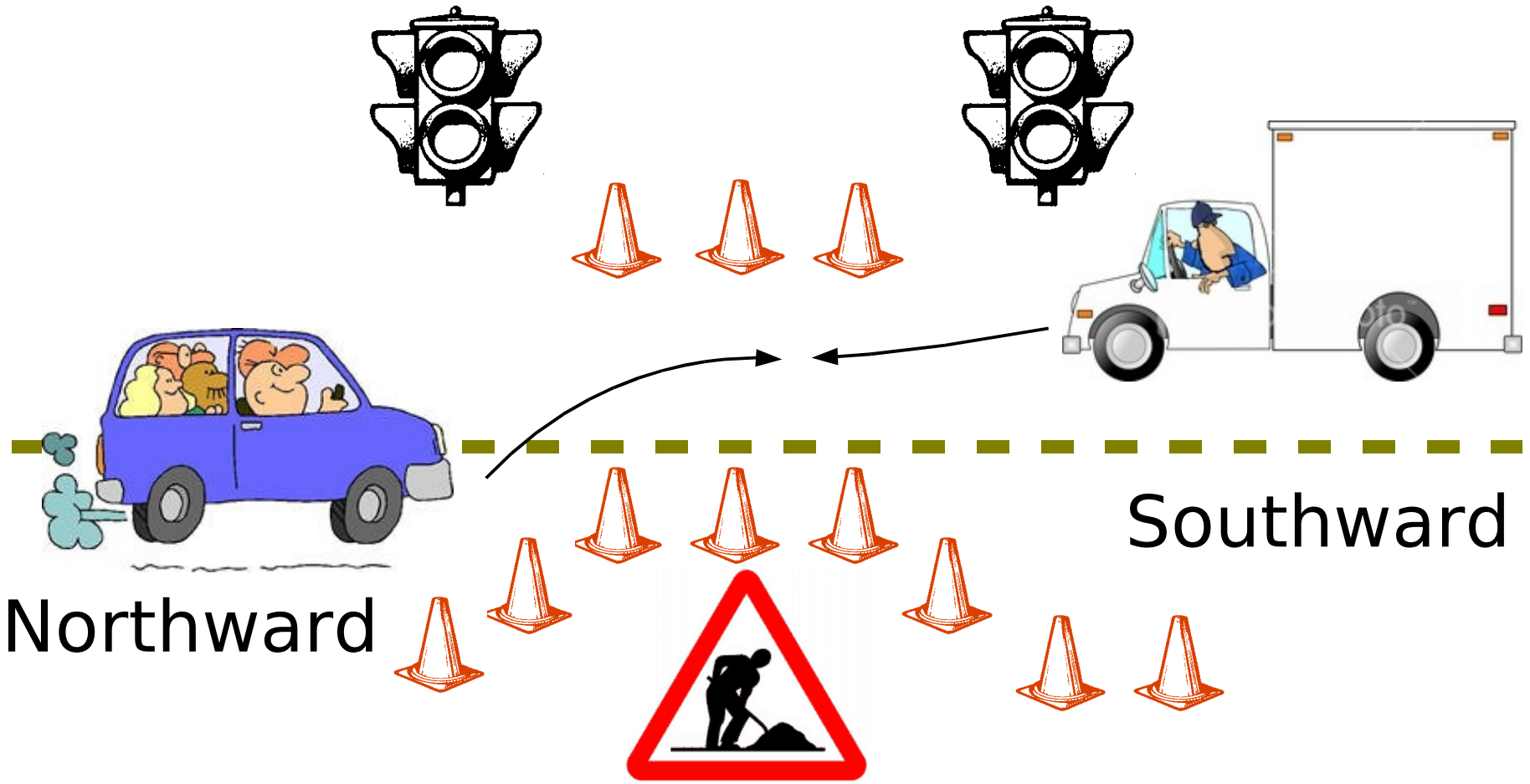

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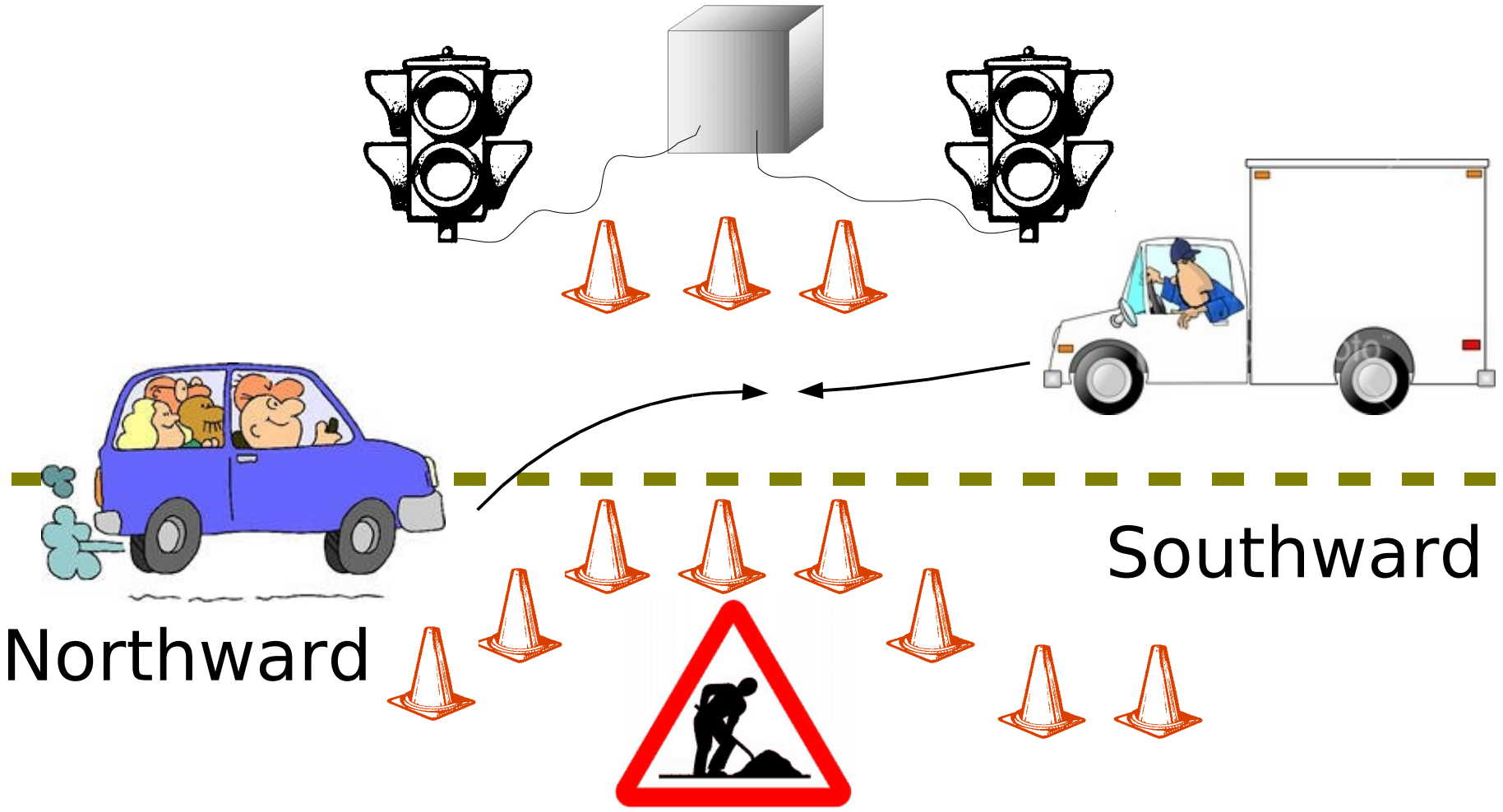

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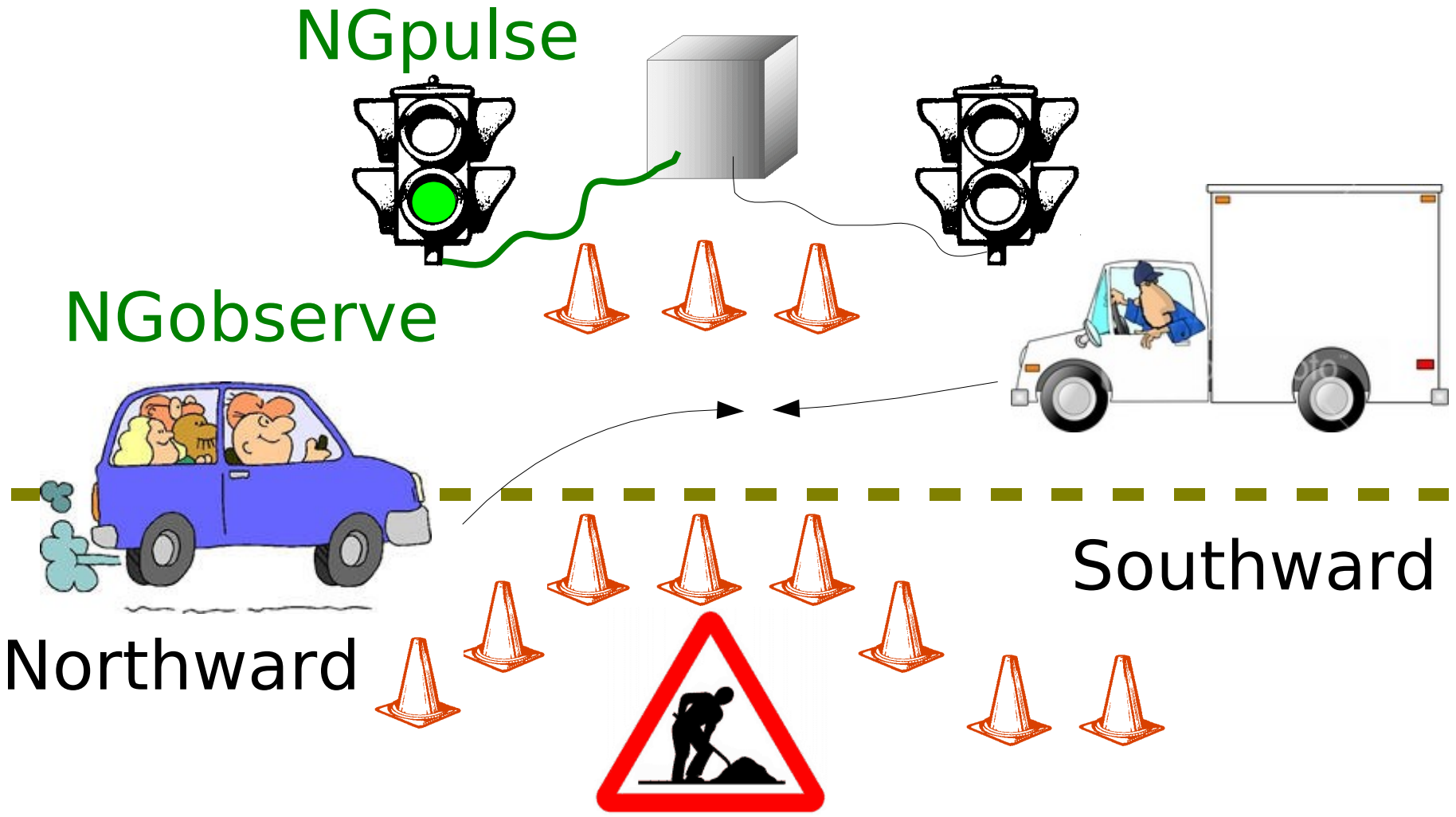

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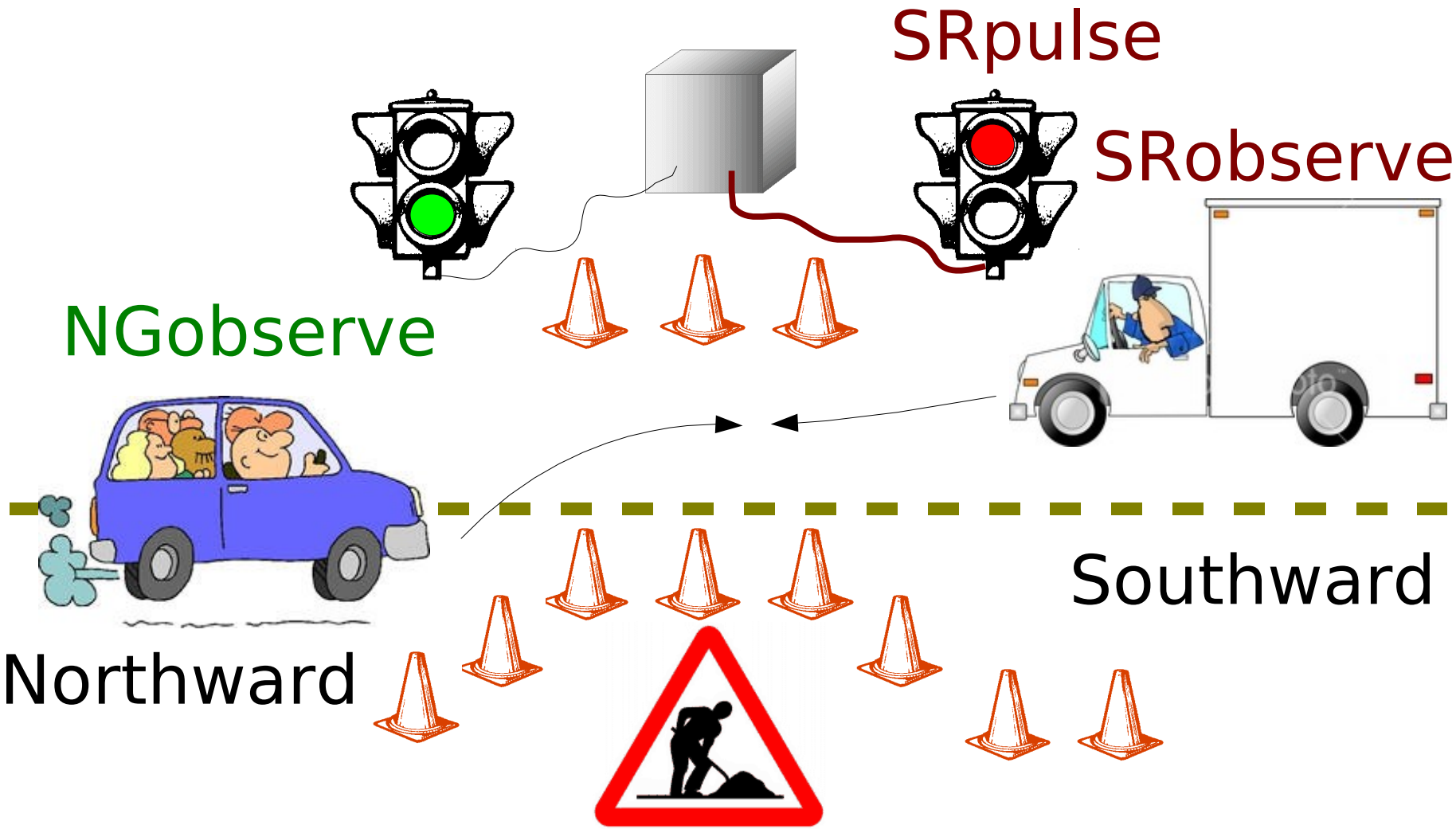

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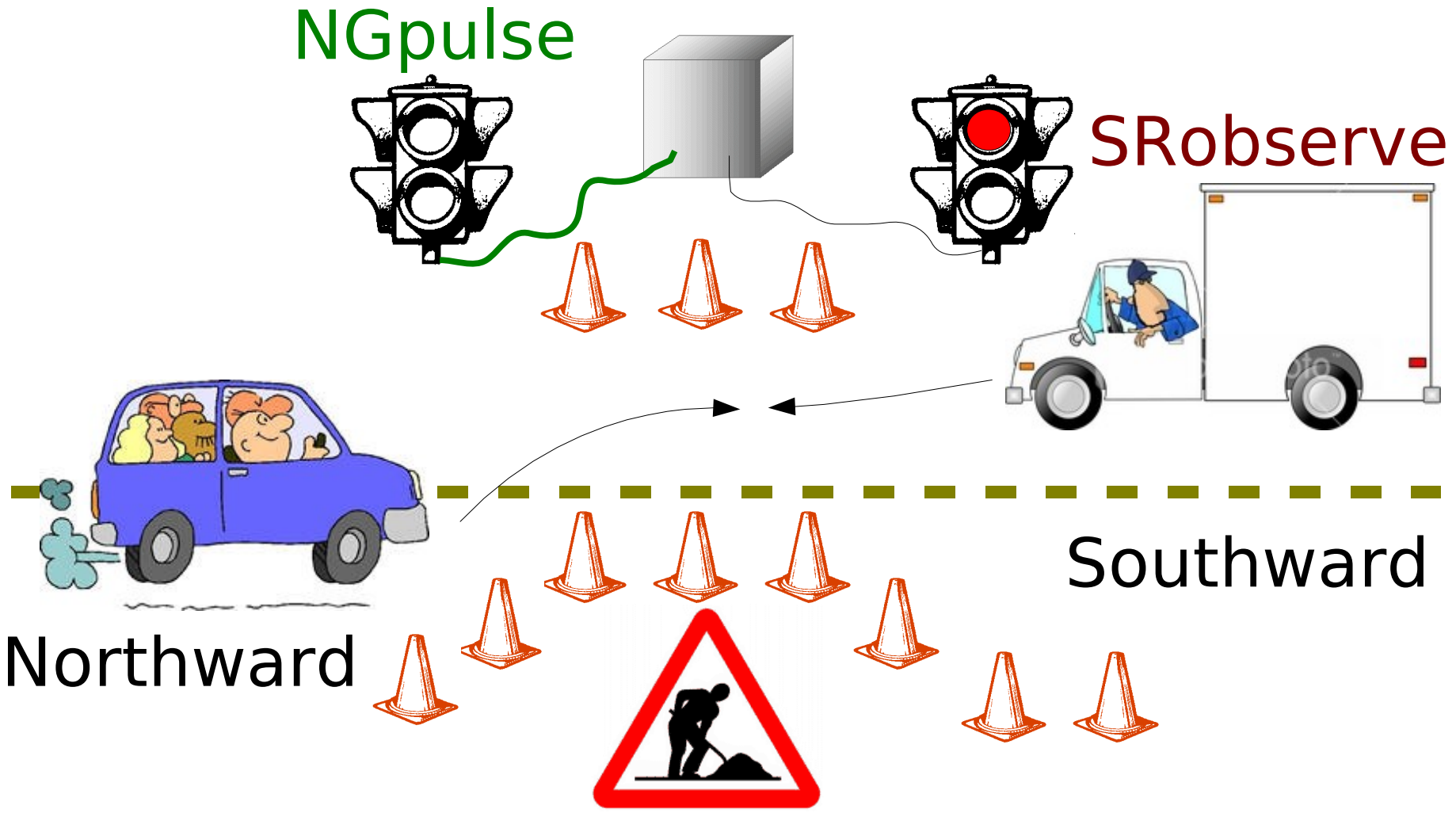

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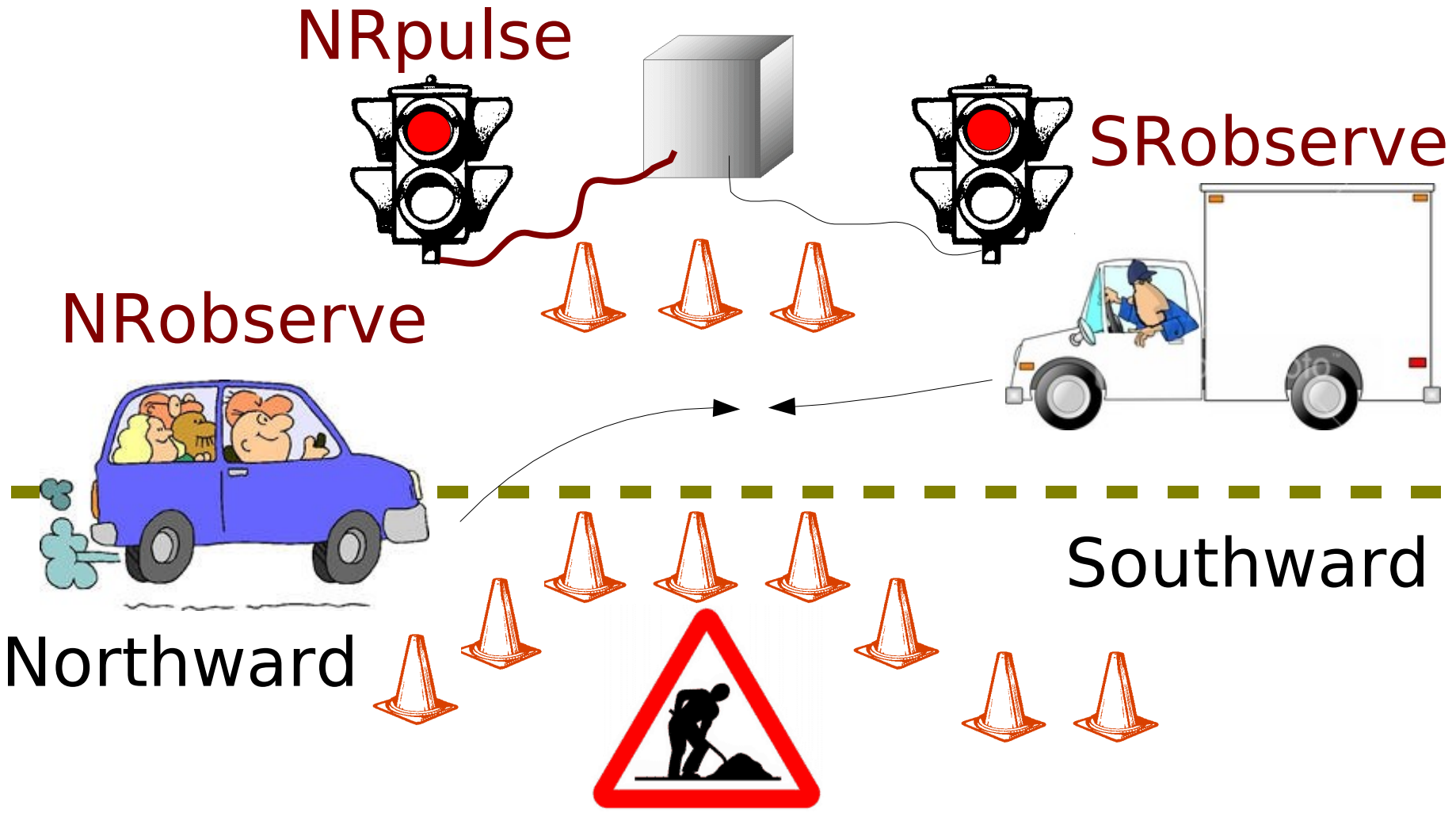

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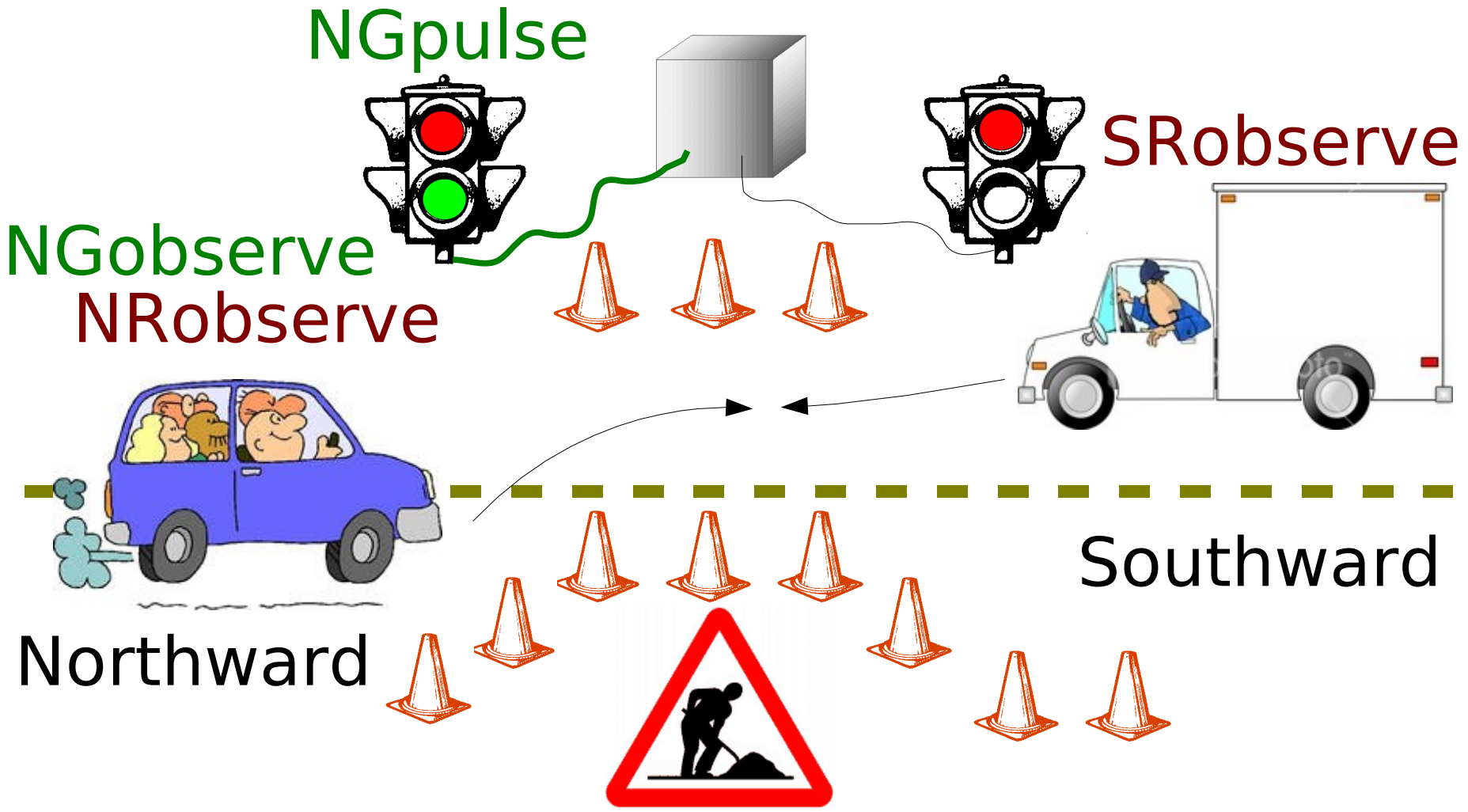
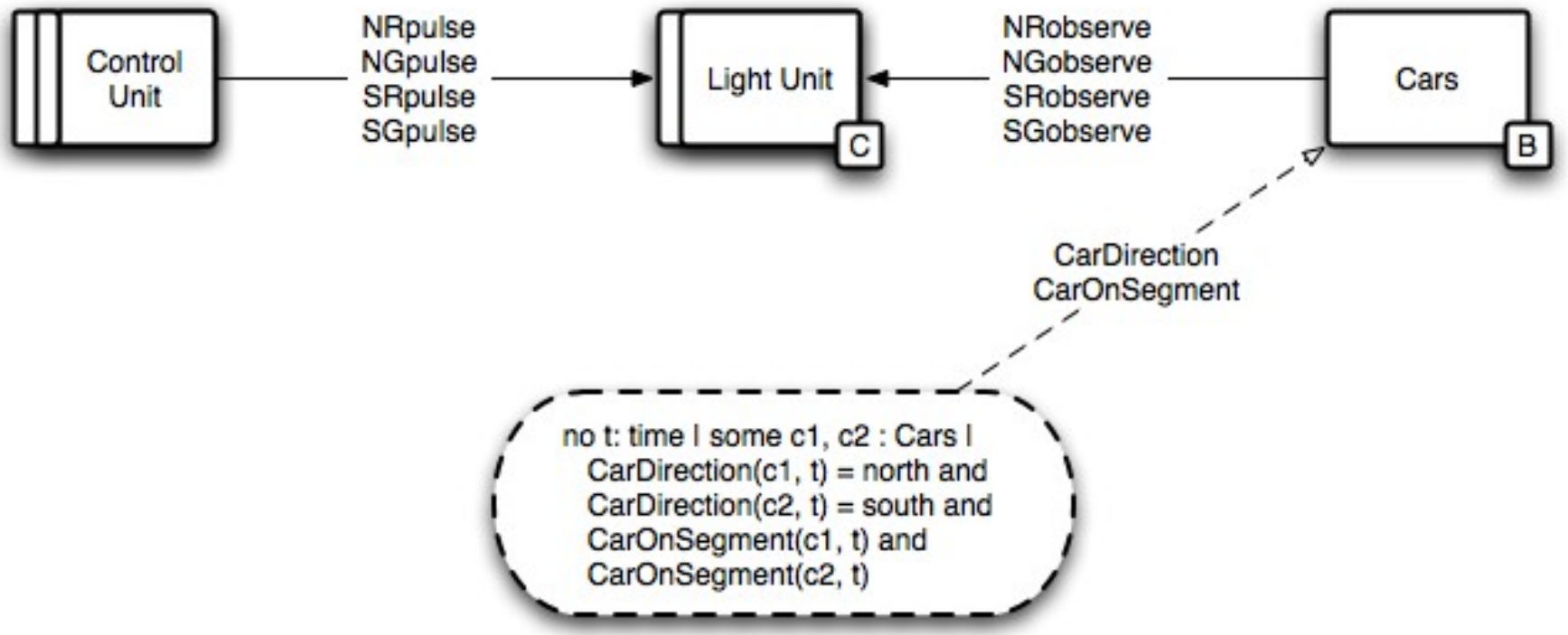
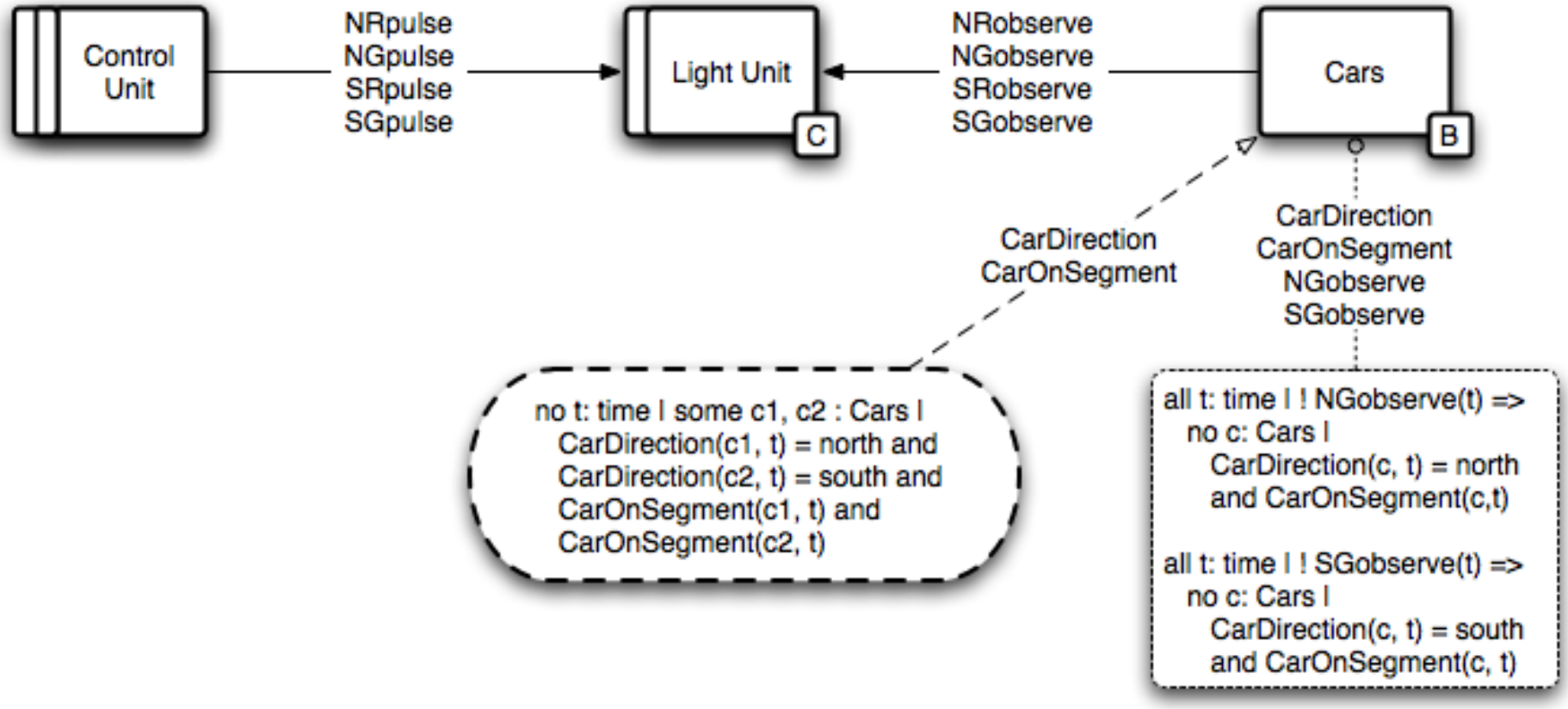


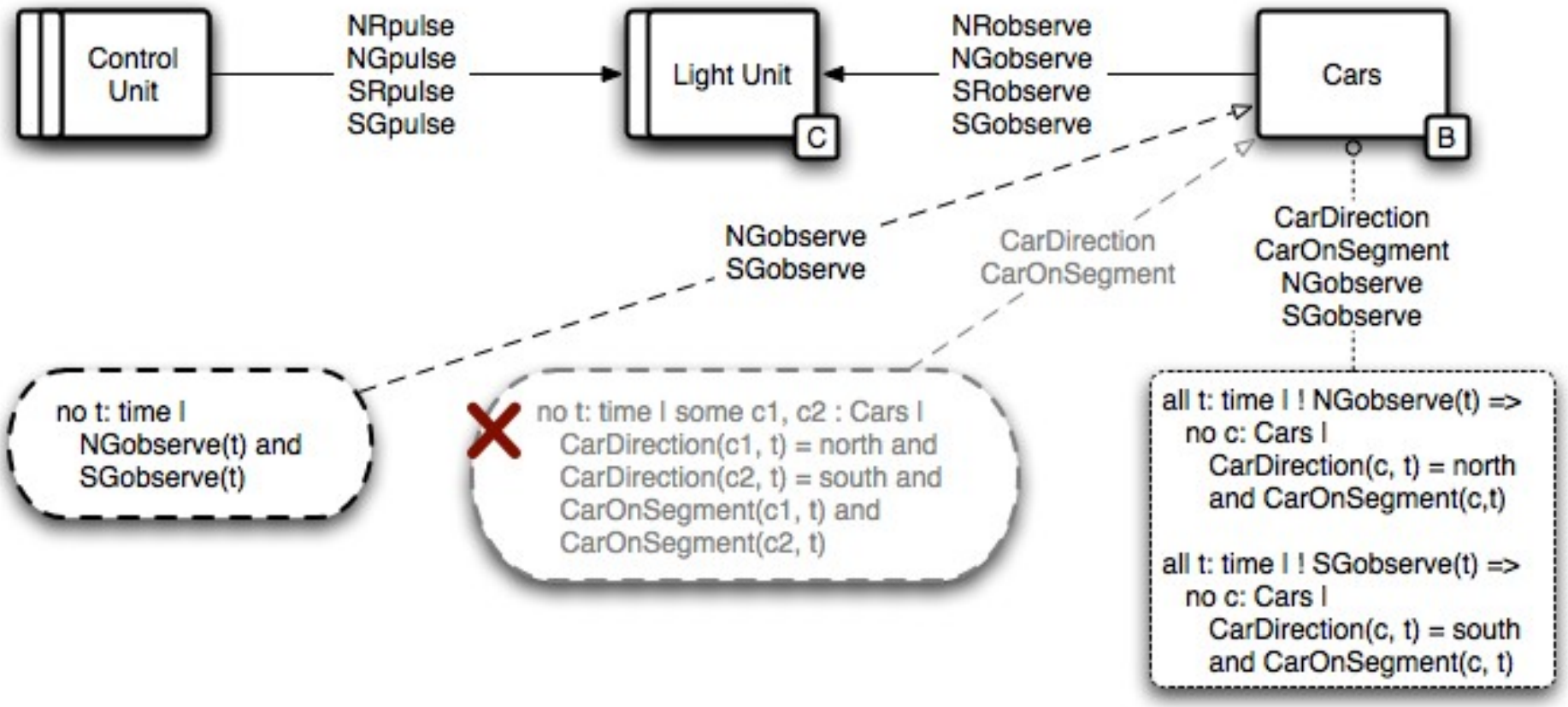
Problem Frame Description



Breadcrumb 1



Rephrase 1


Control Unit
NRpulse
NGpulse
SRpulse
SGpulse
Light Unit
C
NRobserve
NGobserve
SRobserve
SGobserve
Cars
B
NGobserve
SGobserve
CarDirection
CarOnSegment
CarDirection
CarOnSegment
NGobserve
SGobserve
no t: time | NGobserve(t) and SGobserve(t)
no t: time | some c1, c2 : Cars | CarDirection(c1, t) = north and CarDirection(c2, t) = south and CarOnSegment(c1, t) and CarOnSegment(c2, t)
all t: time | ! NGobserve(t) => no c: Cars | CarDirection(c, t) = north and CarOnSegment(c,t)
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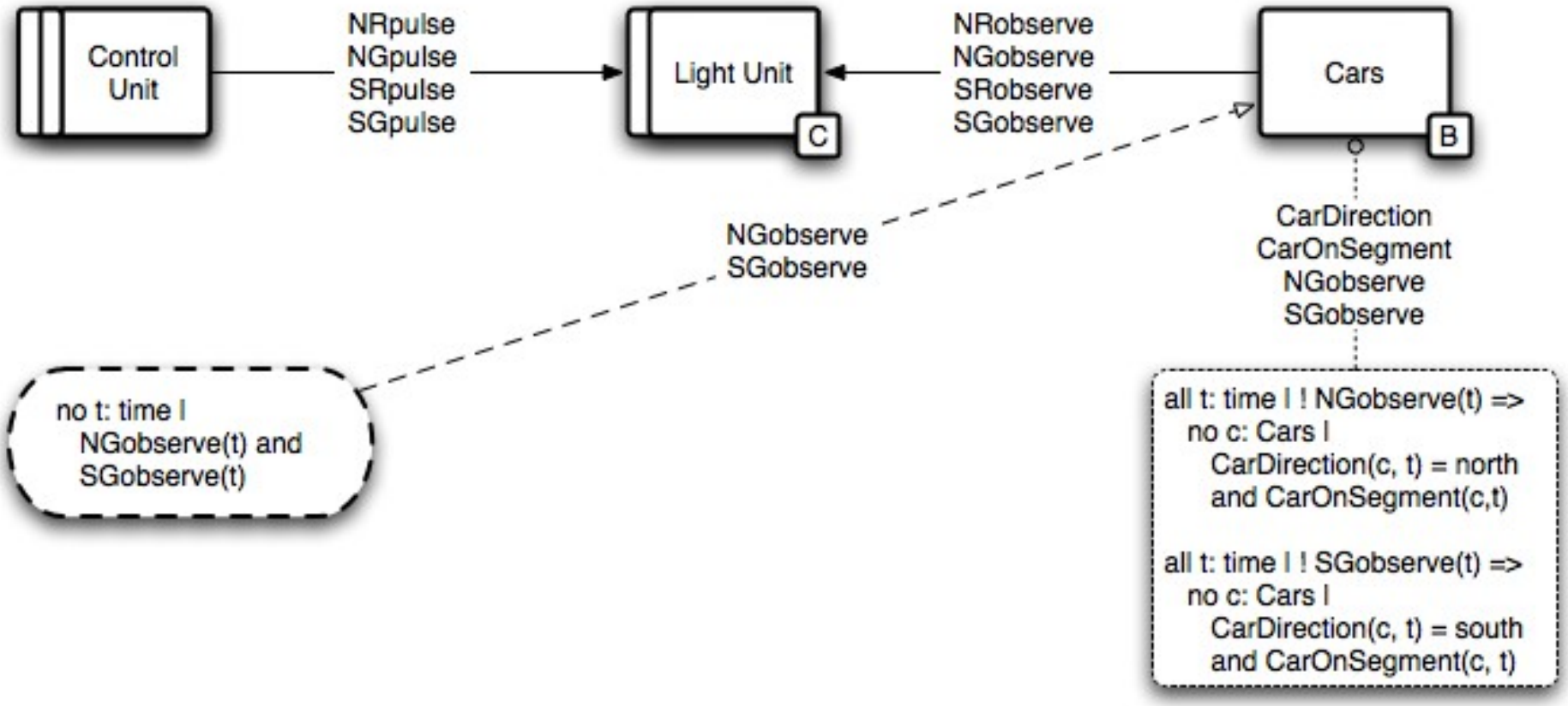
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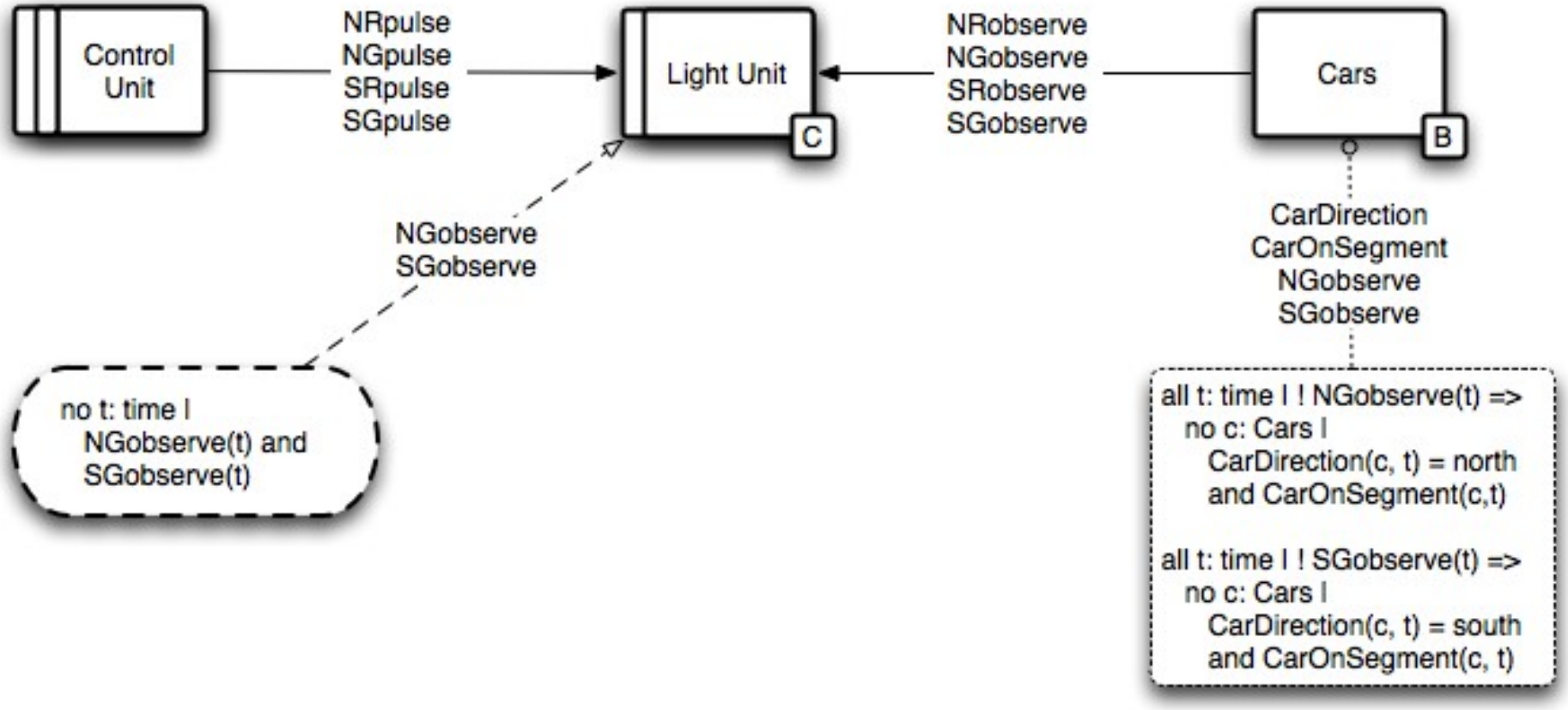
Push 1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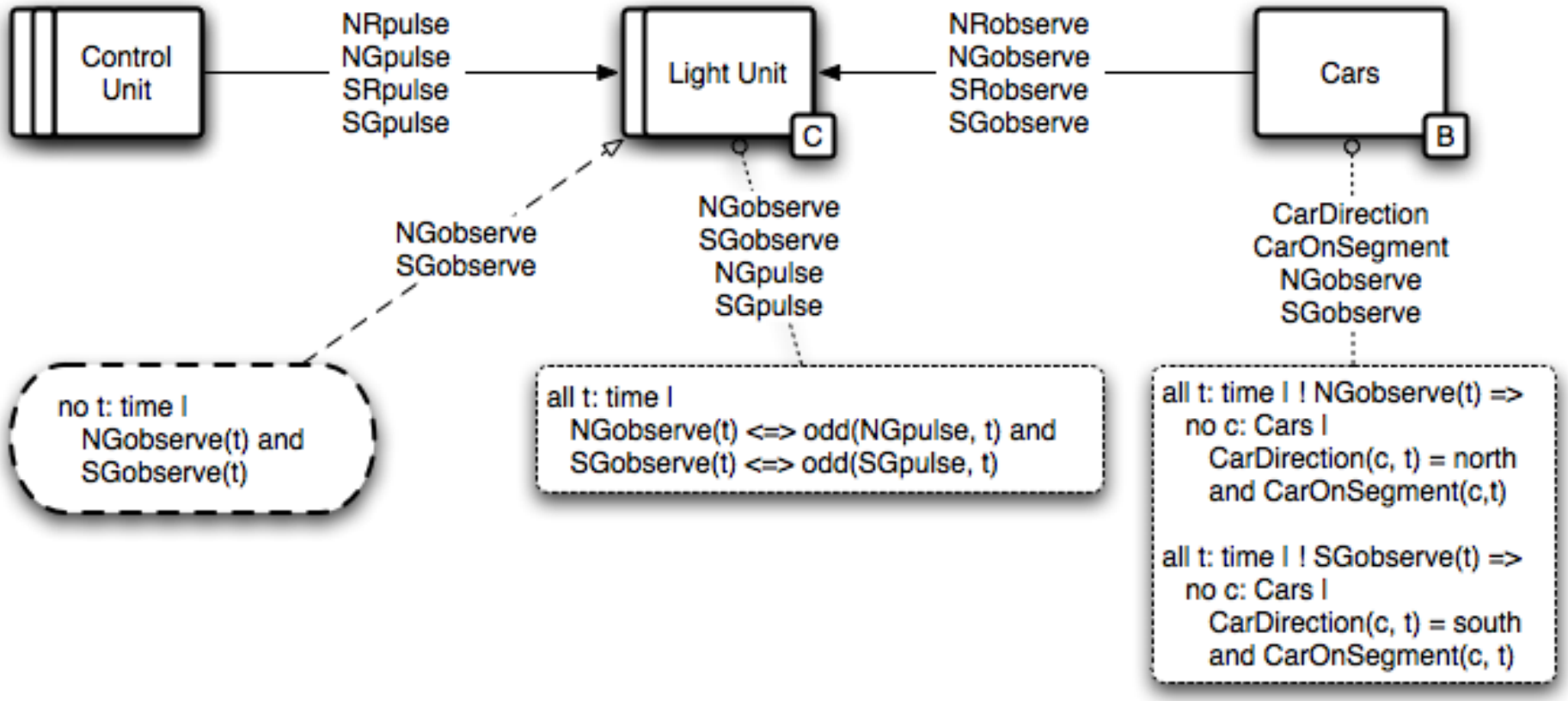
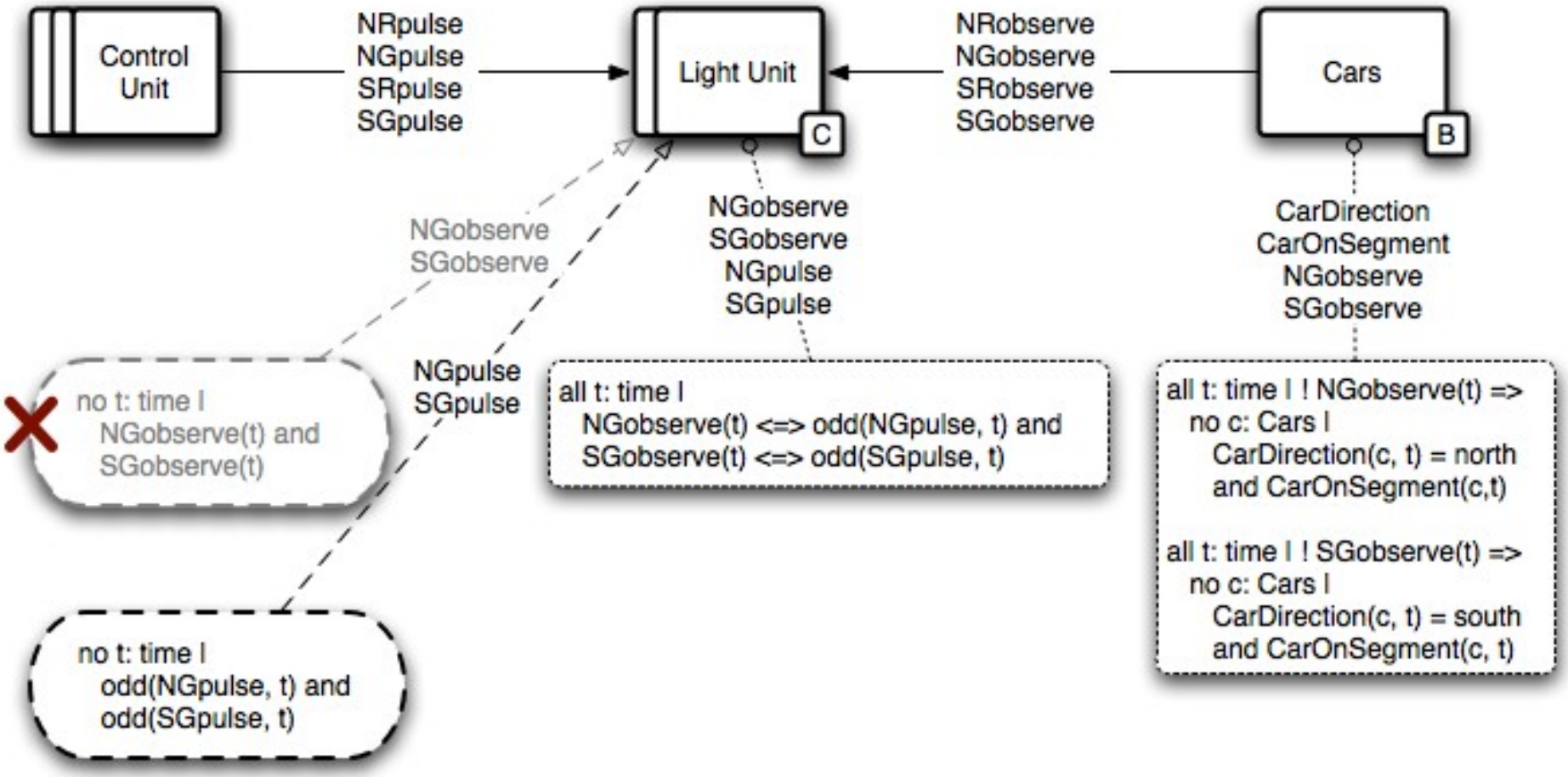
Breadcrumb 2



Rephrase 2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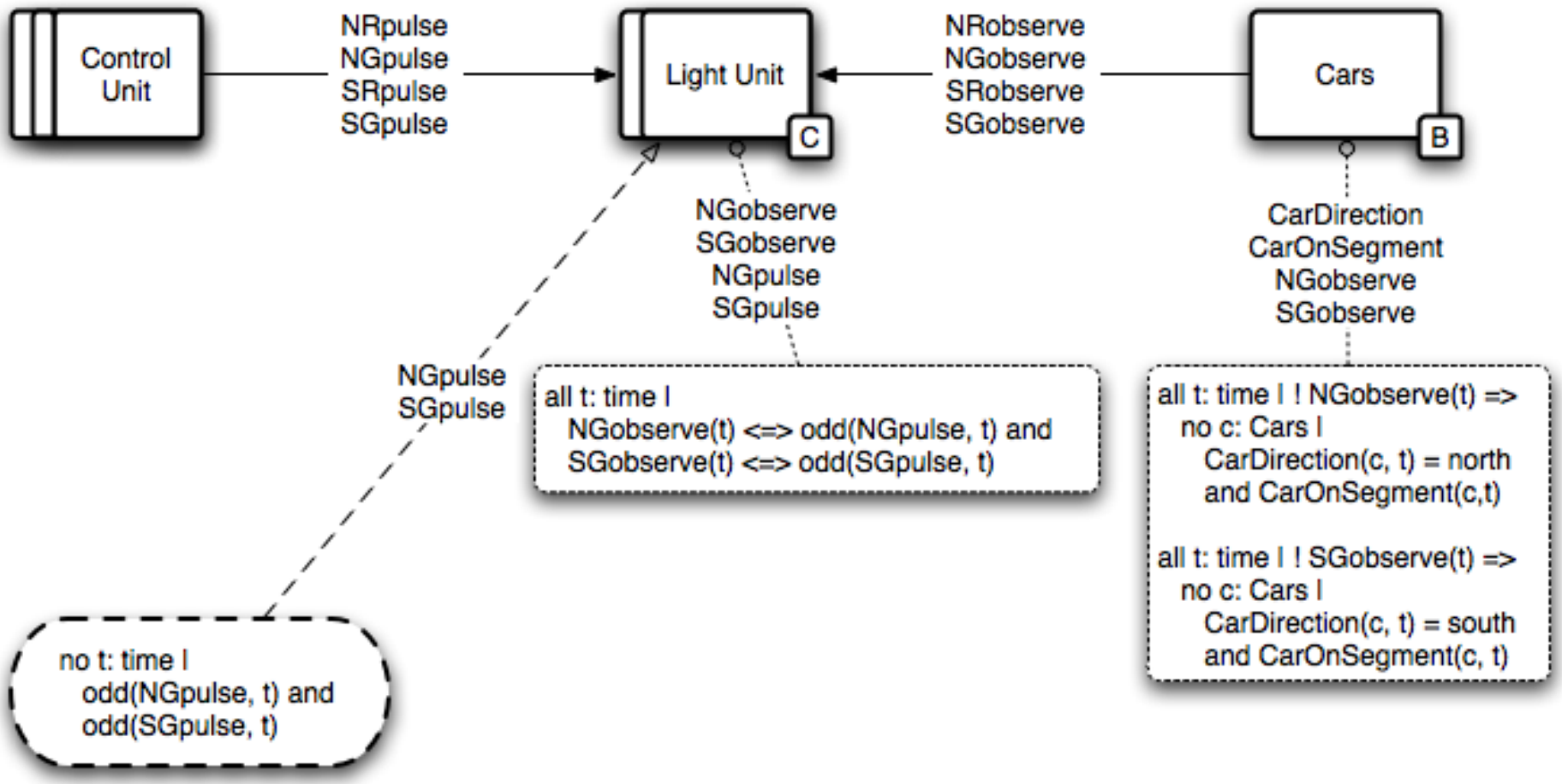
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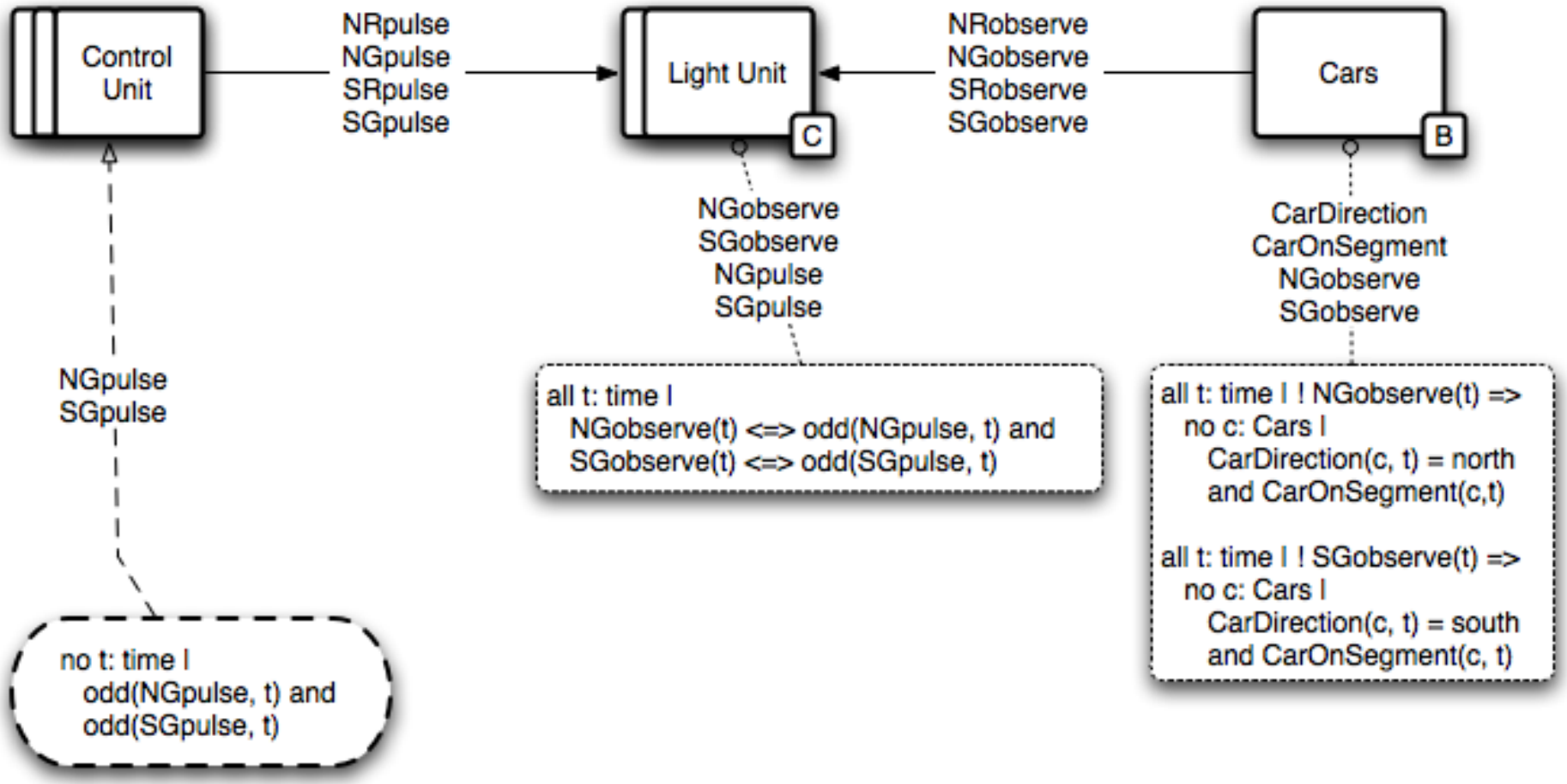
Push 2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Provides

- systematic local reasoning

  $Breadcrumb \wedge Rephrased\ Goal \Rightarrow Prior\ Goal$

- global guarantee

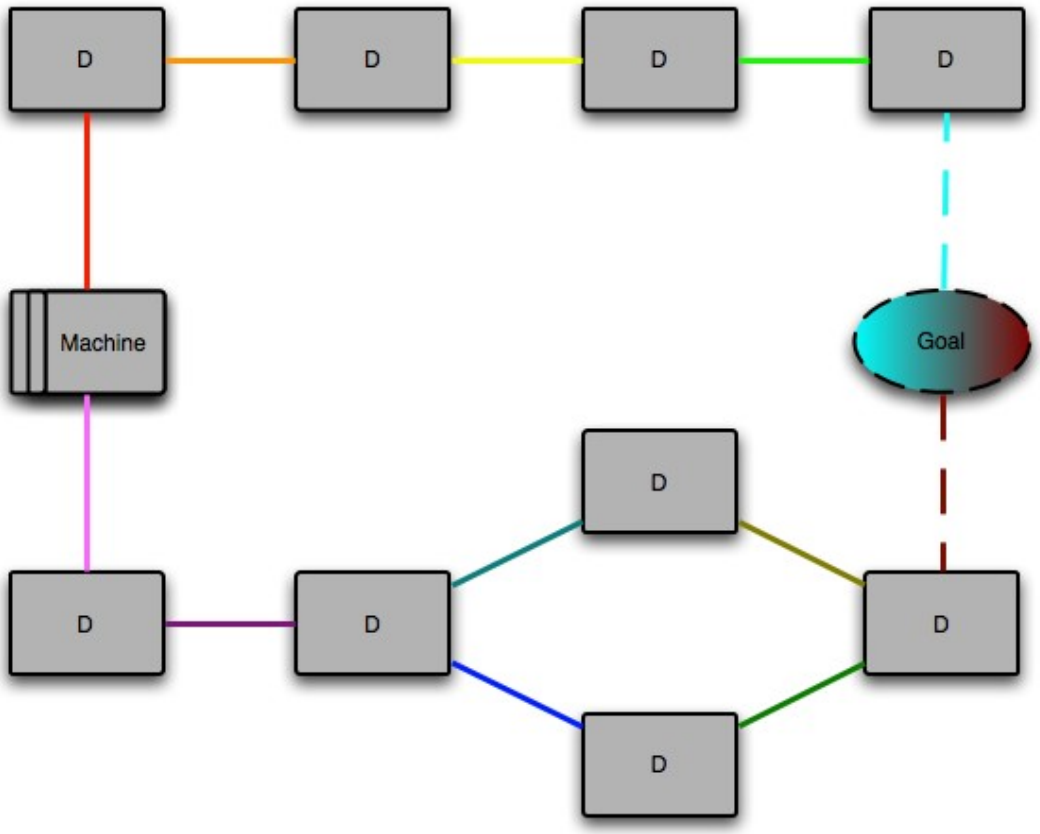
  $Breadcrumb\_0 \wedge \ldots \wedge Breadcrumb\_n \wedge Specification \Rightarrow Requirement$

- tracability: trail of breadcrumbs
- identify unused phenomena
- handle general topologies
- formalize use of frame concern
- local patterns replace global patterns

Difficulties

- systematic not automatic (inescapable)
- readability, implementability, consistency
- which breadcrumb/rewrite?
- which push? split?
- get stuck later on?

Cartoon of Big Example



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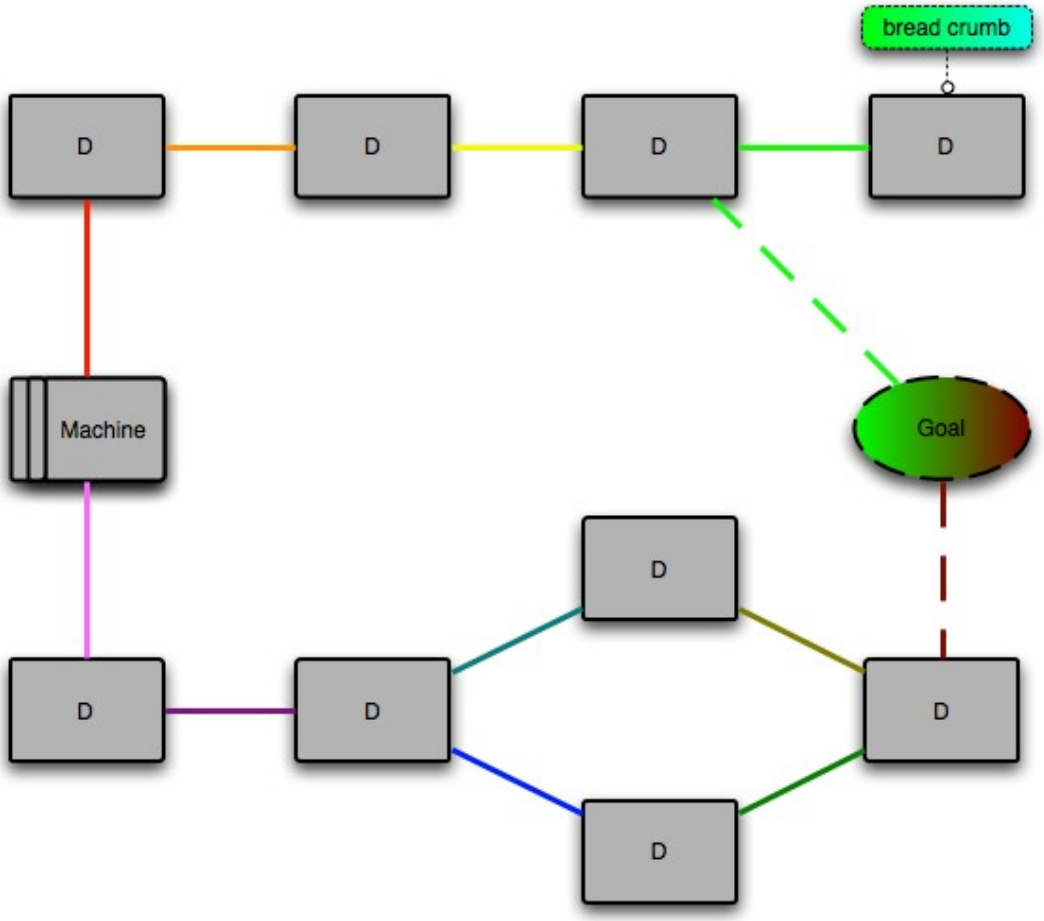

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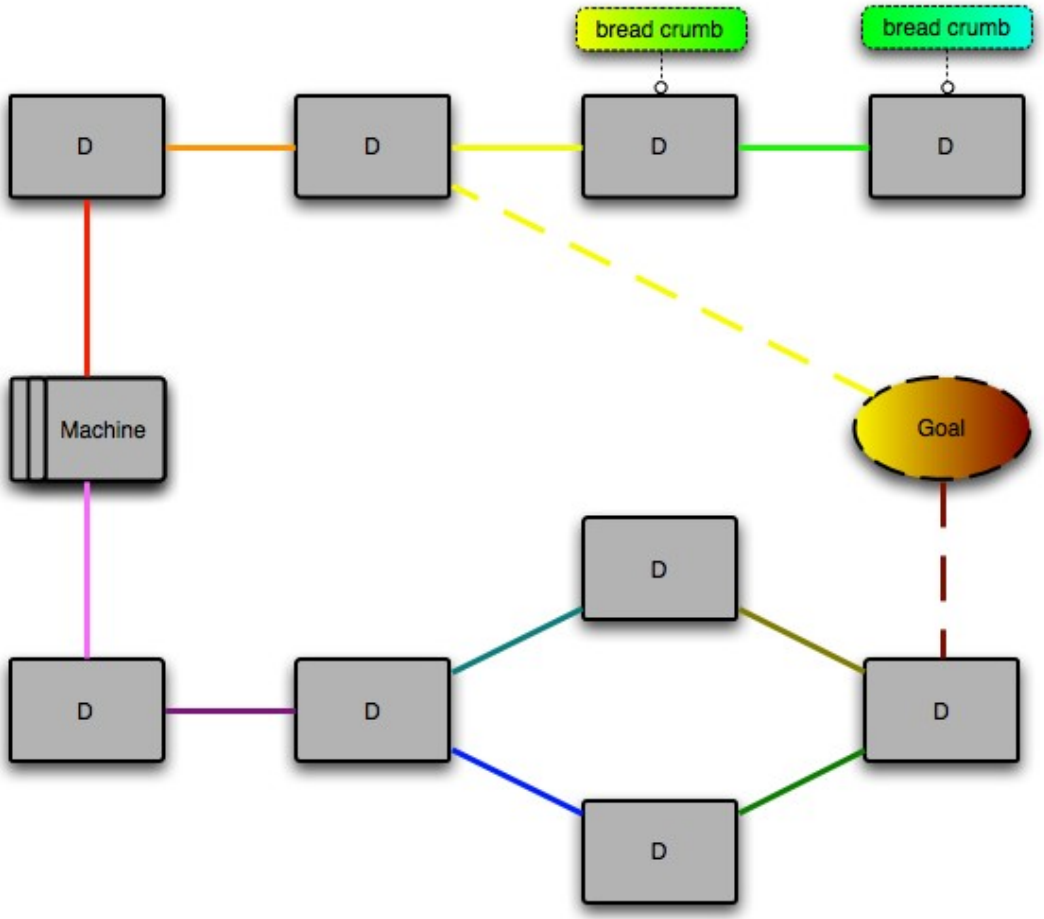

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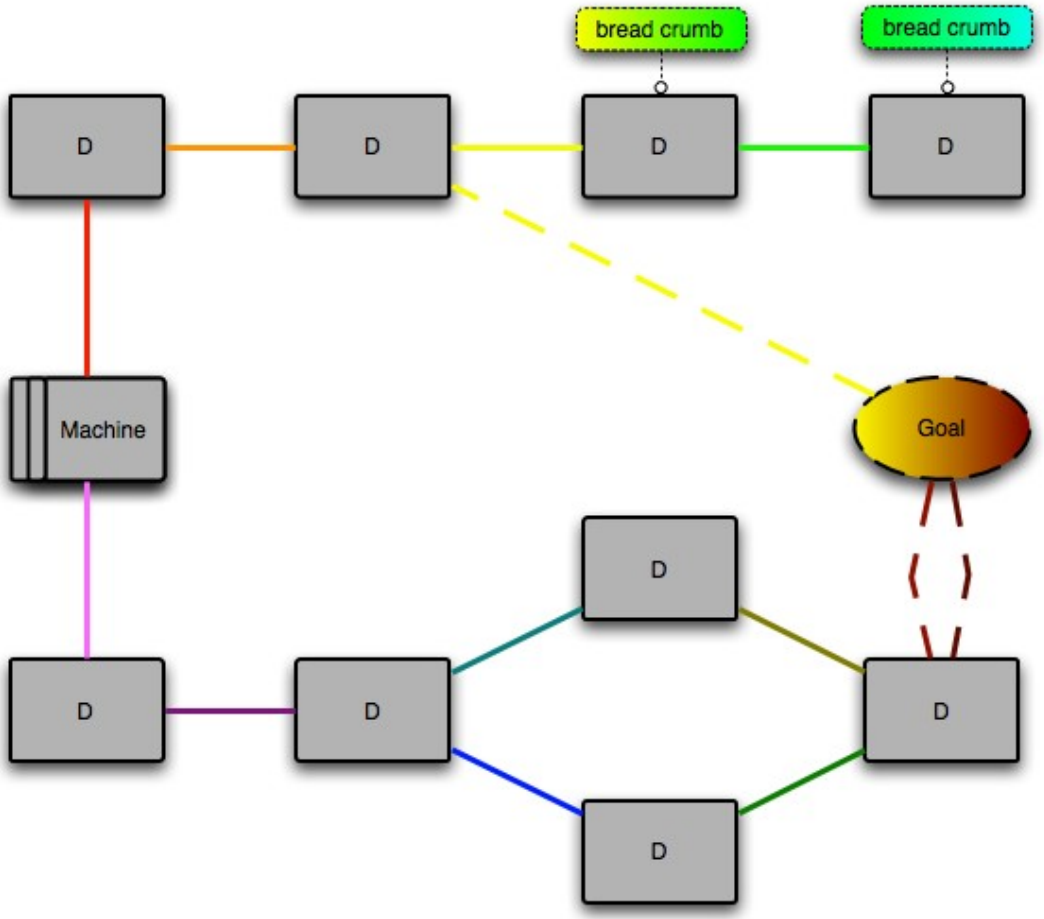

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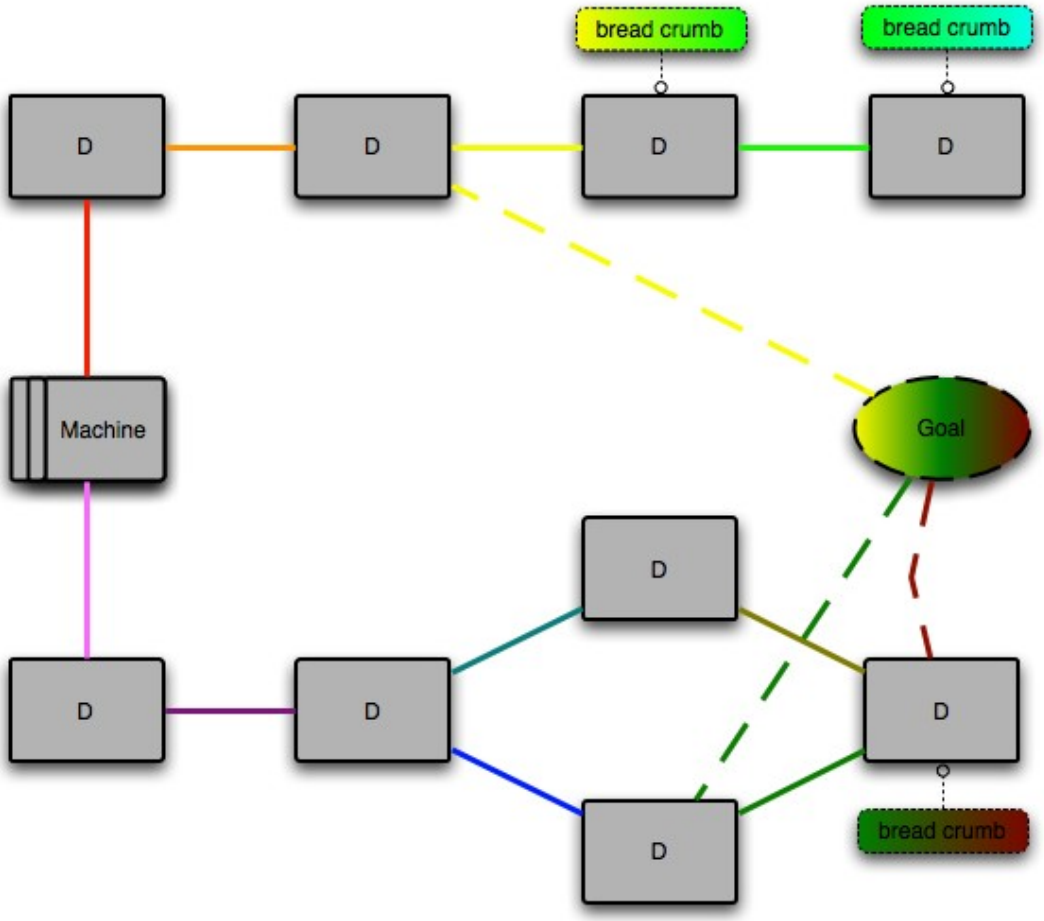

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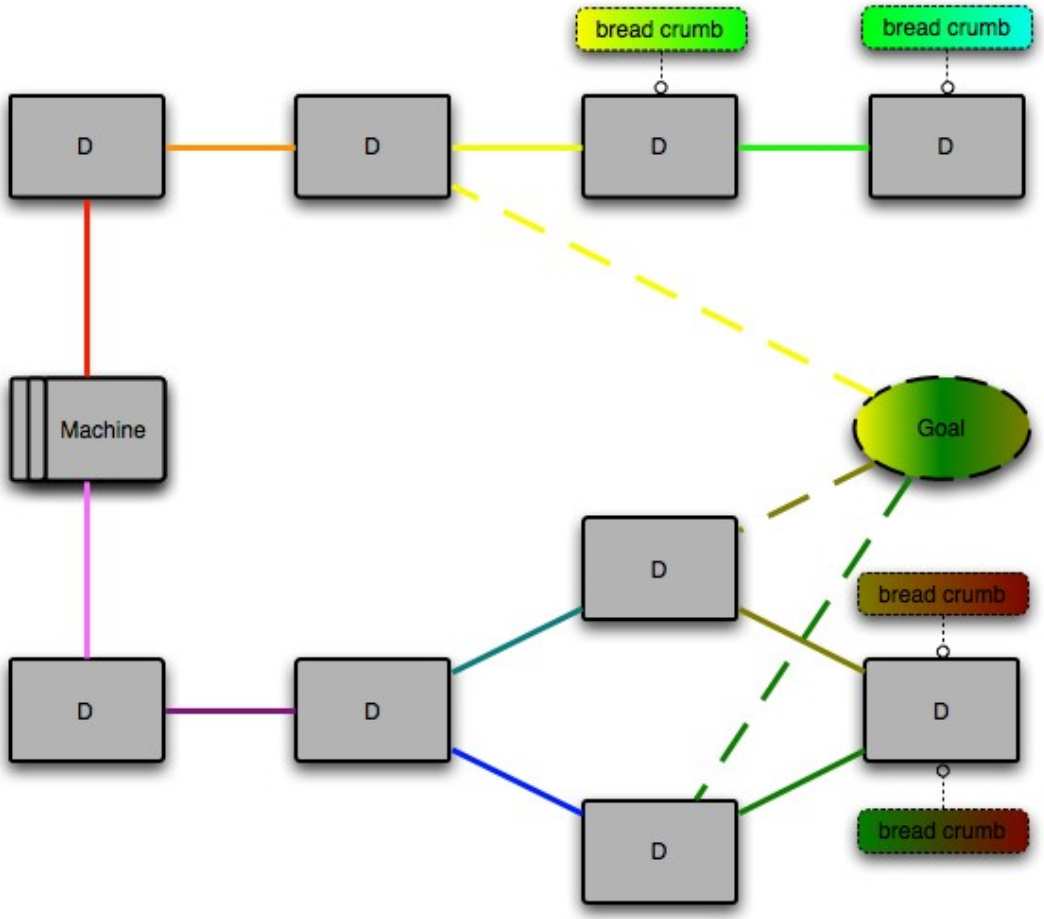

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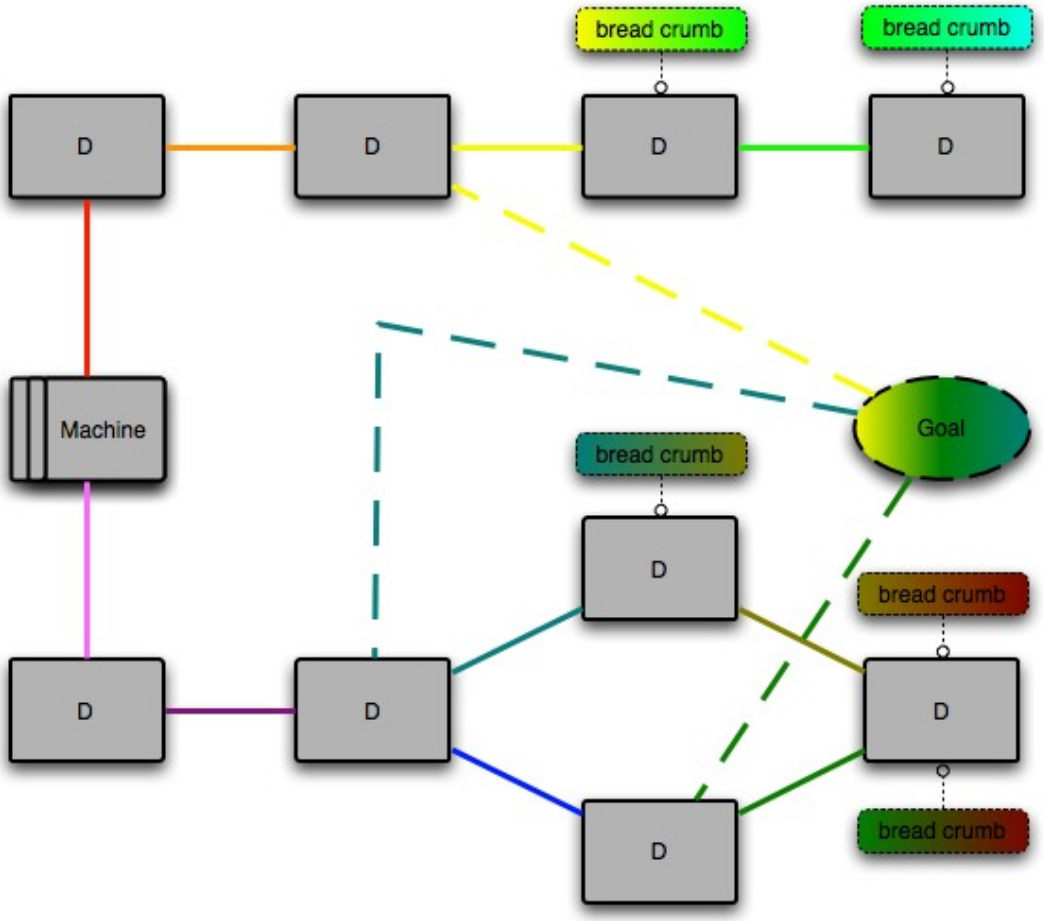

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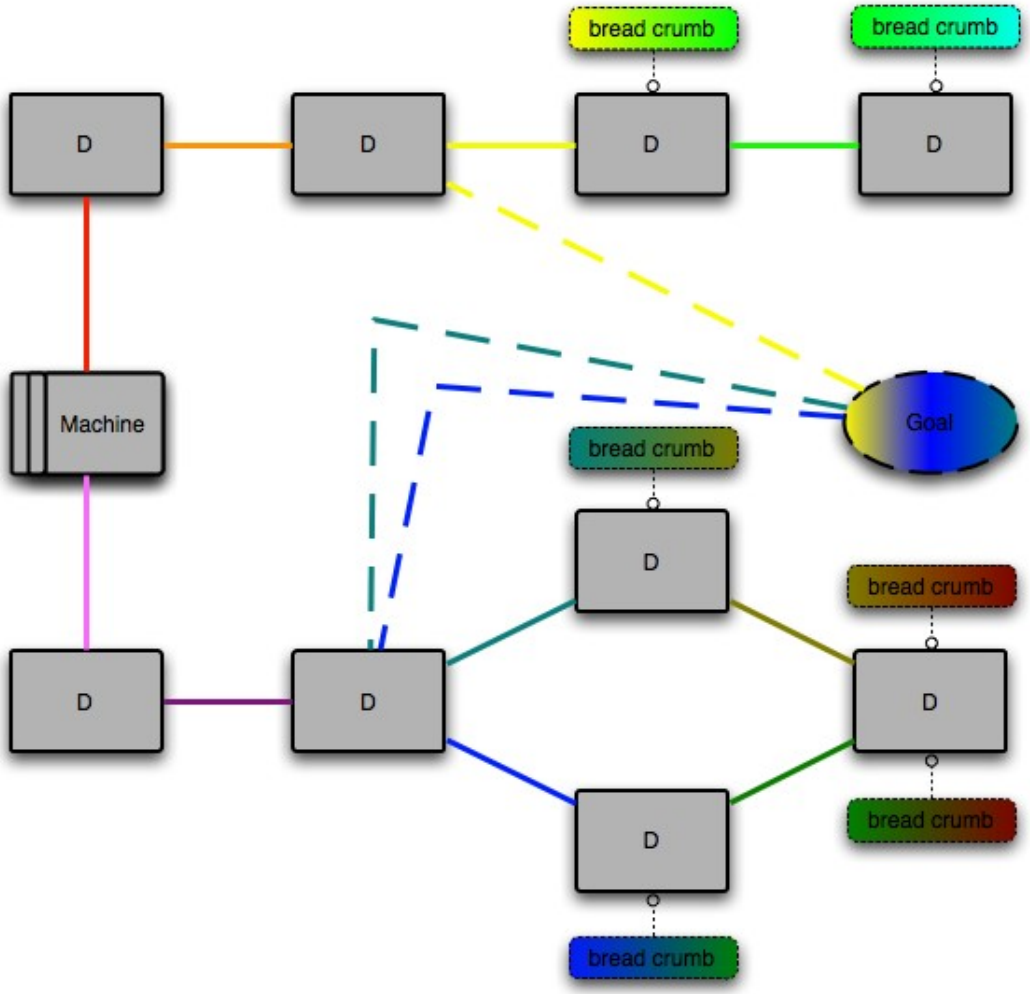

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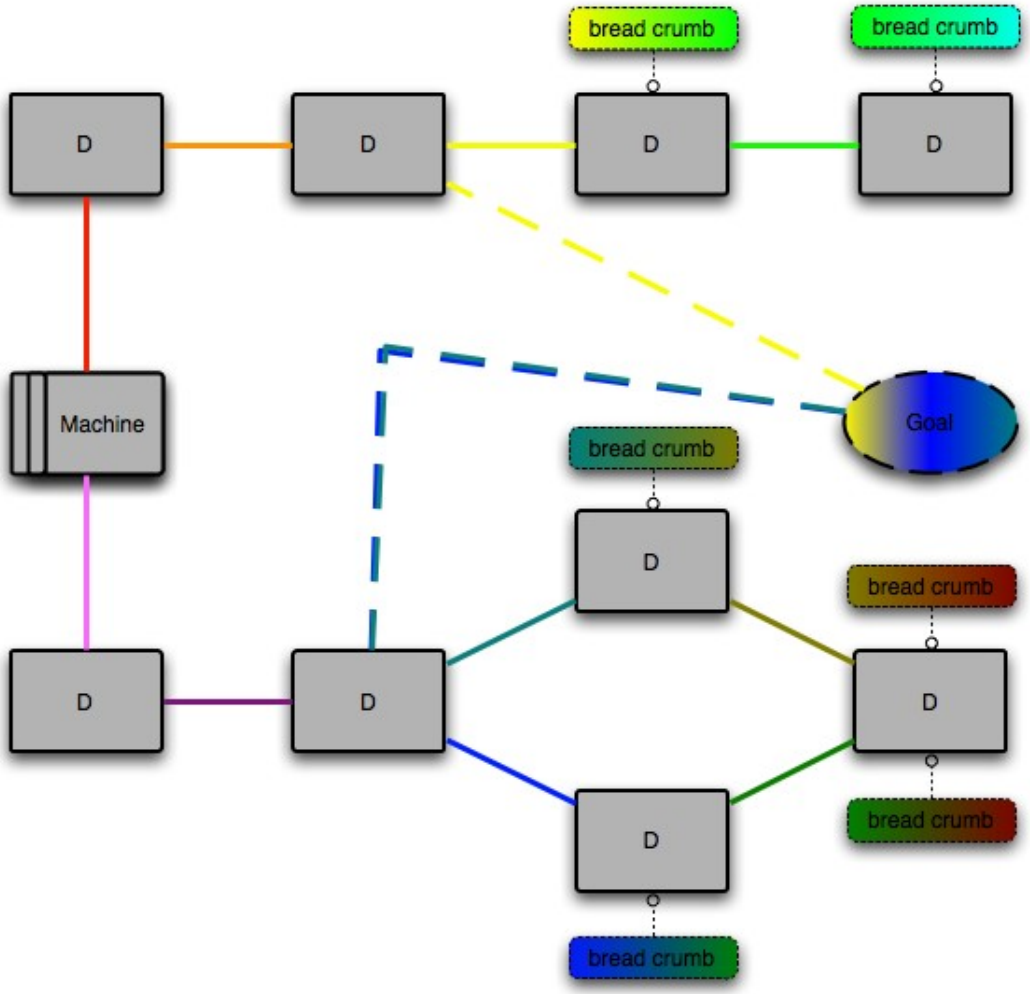

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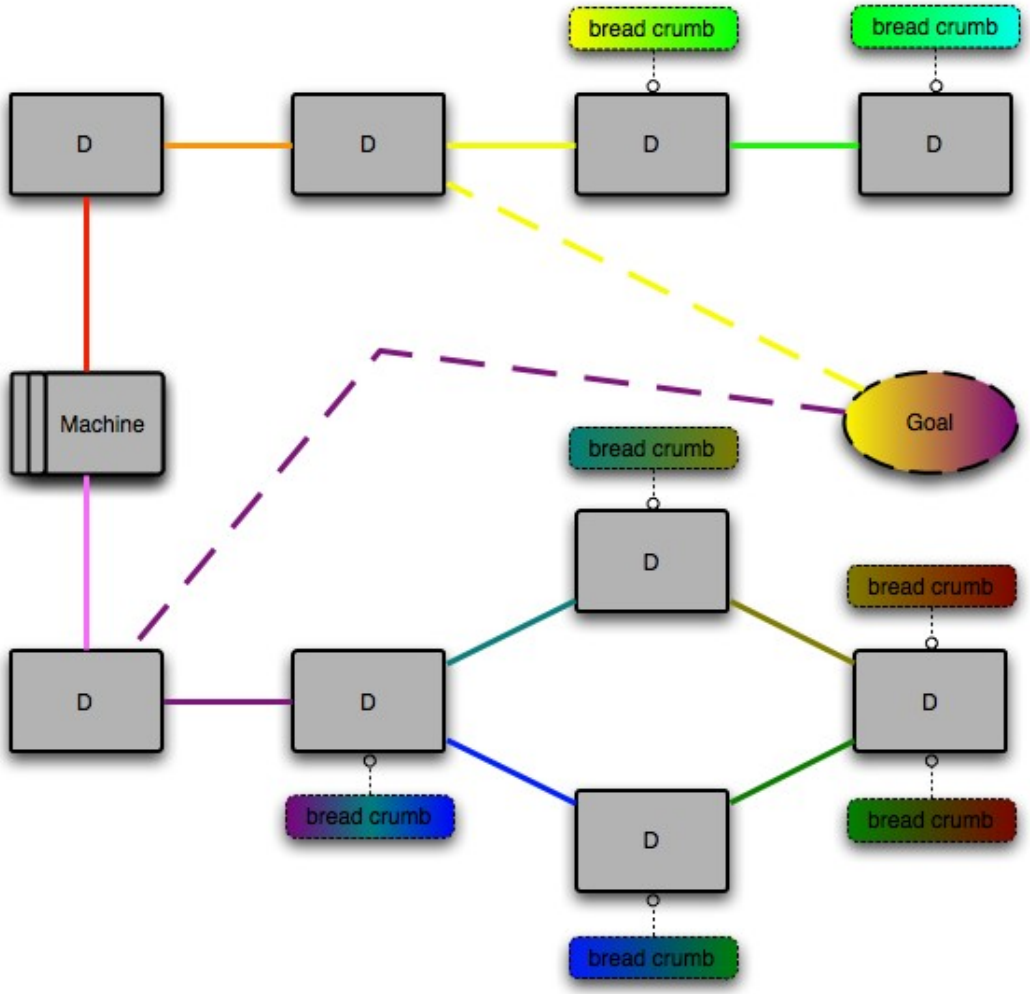

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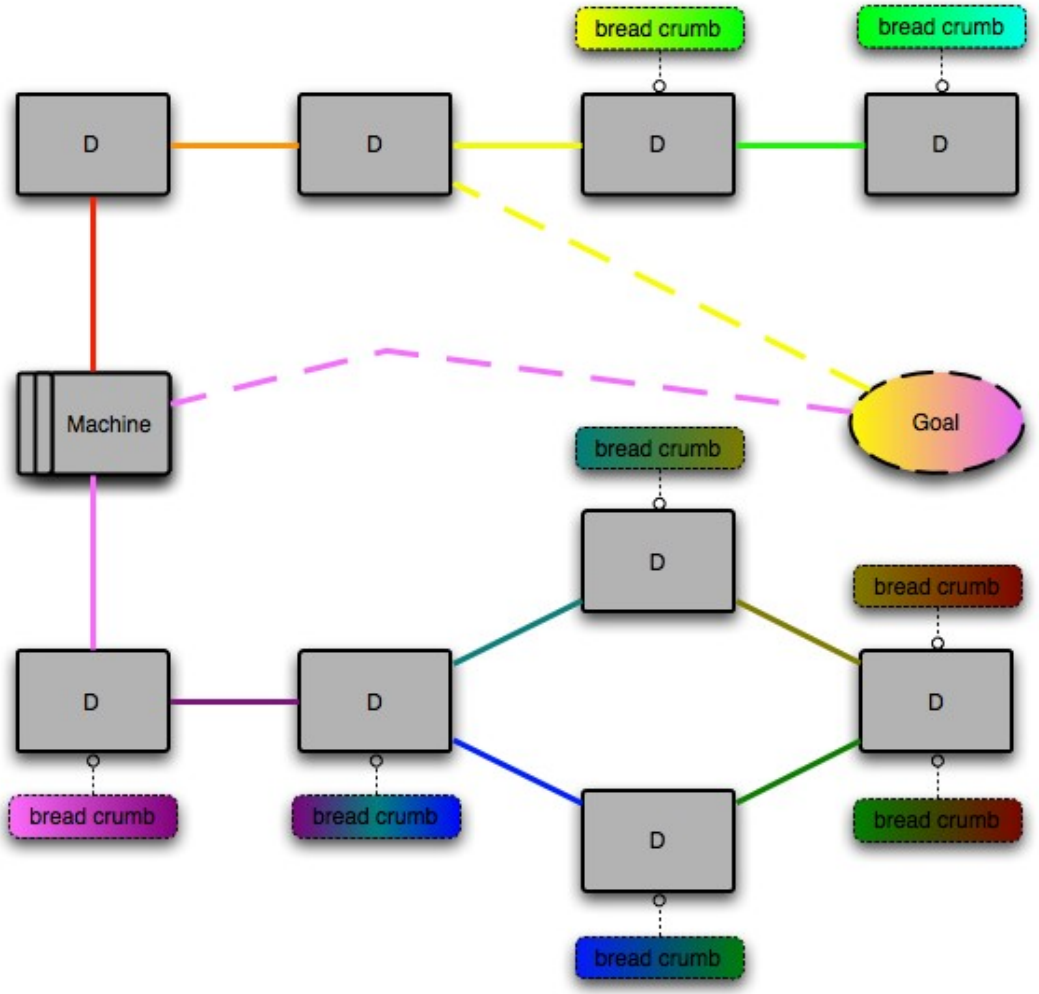
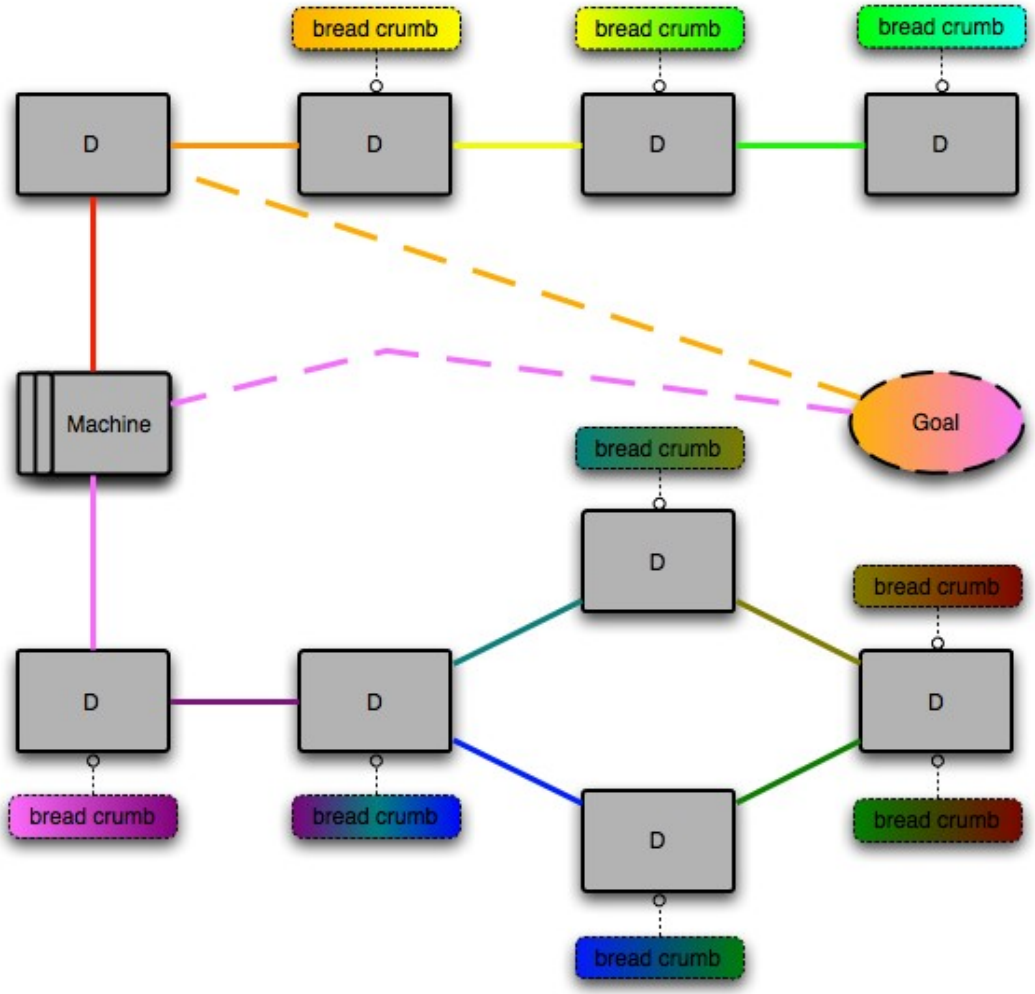
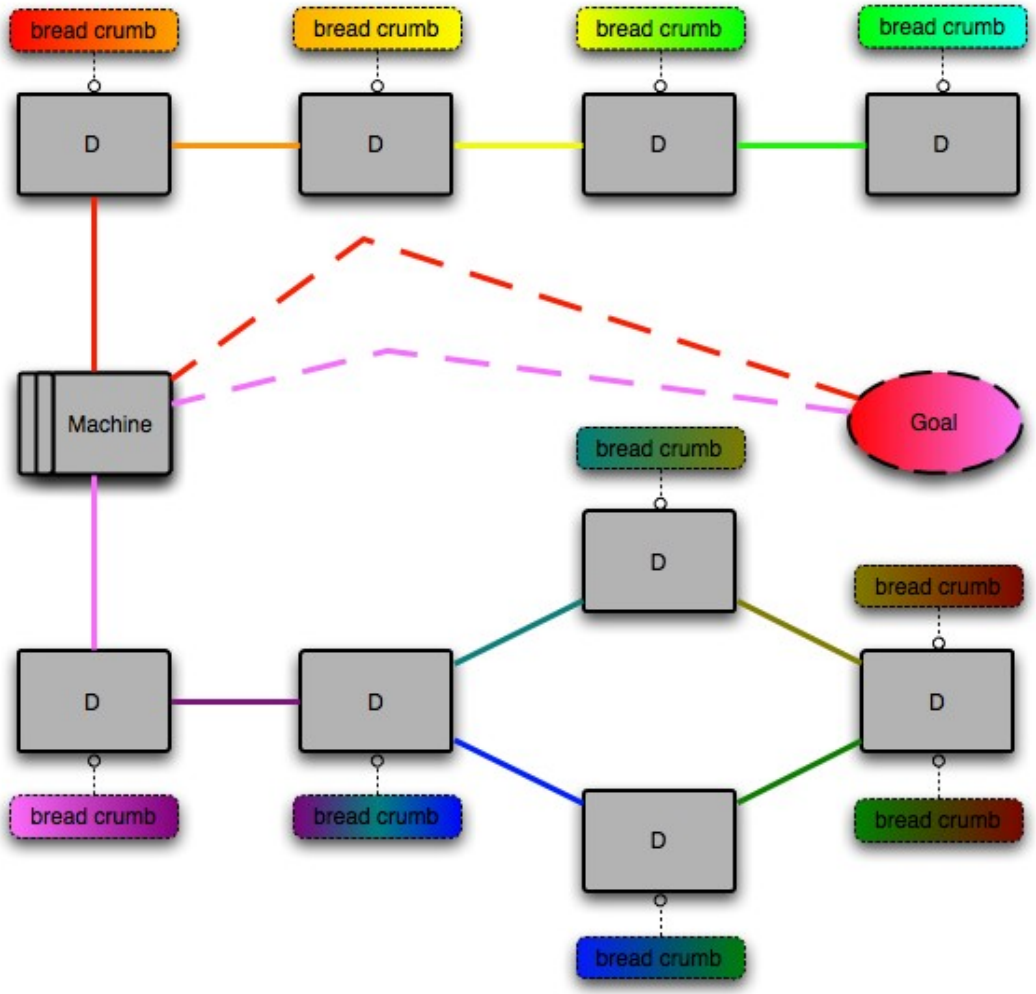


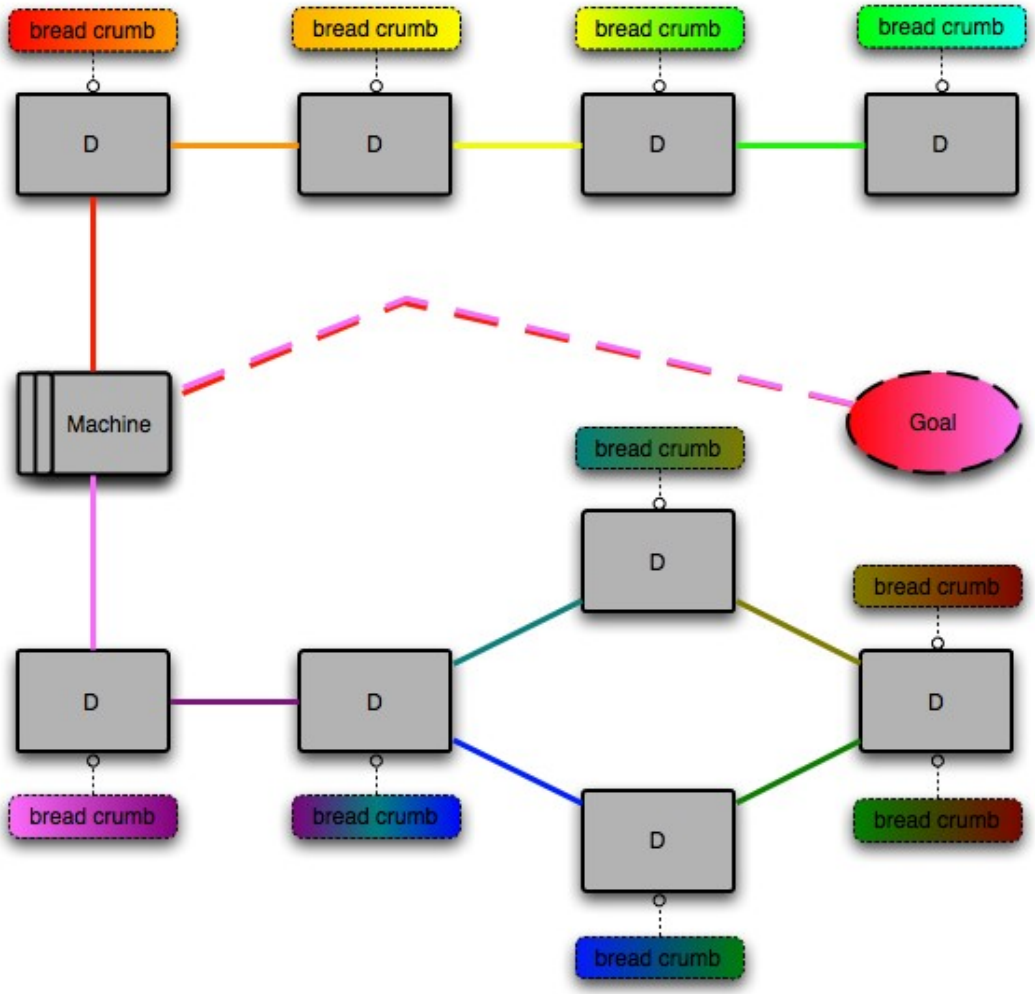
Cartoon of Big Example



Cartoon of Big Example



Cartoon of Big Example

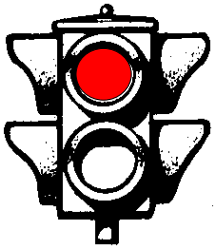


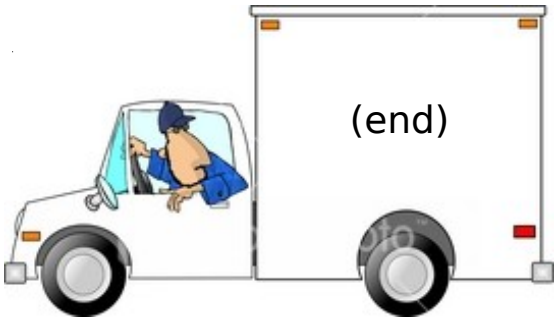
Future Work

- patterns for local steps, concurrent steps
- proton therapy case study / safety case
- example/error progression

Related Work on Problem Frames

- Jackson, Zave (1995) turnstyle example
- Jackson (2001) problem progression
- Rapanotti, Hall, Li (2006) causal reasoning
- Hall, Rapanotti (2006) requirement progression
- Hall, Jackson, Laney, Nuseibeh, Rapanotti (2002, 2004) modeling architectural decisions

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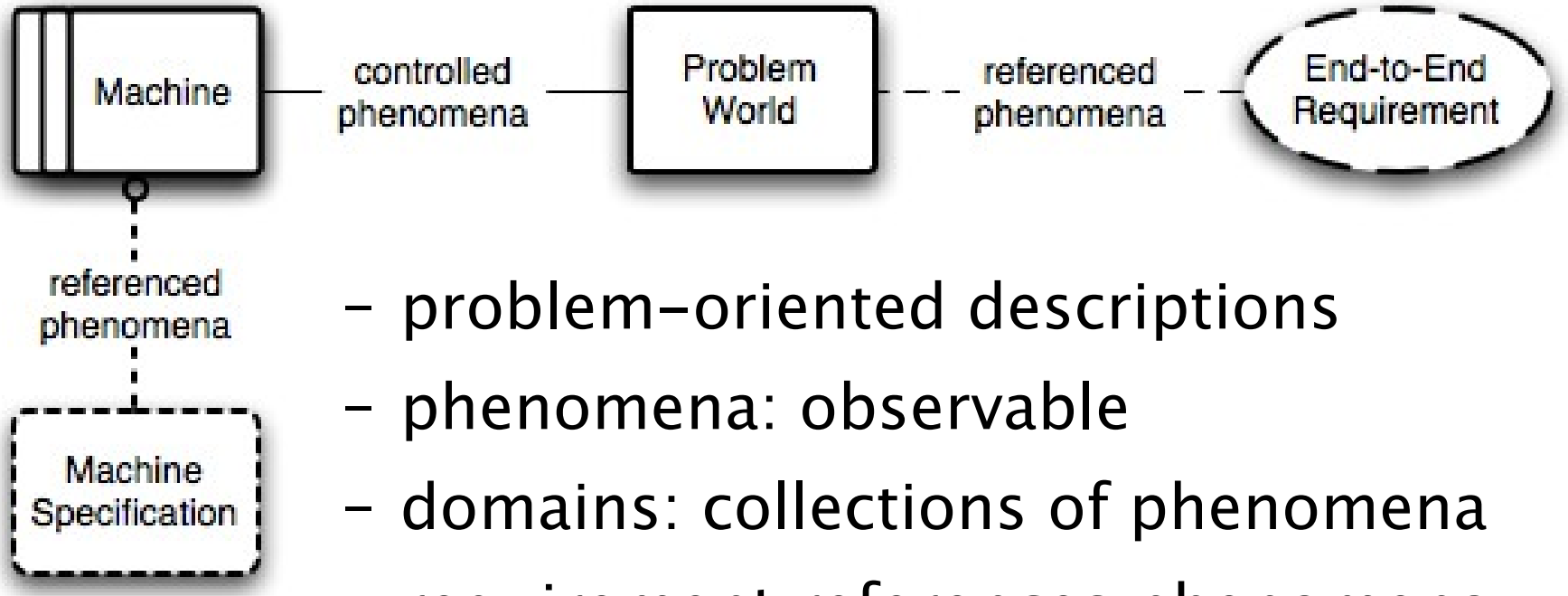
Problem Frames



- problem-oriented descriptions
- phenomena: observable
- domains: collections of phenomena
- requirement references phenomena
- machine controls phenomena to enforce requirement
- specification references controlled phenomena

Typical Transformation

- need to constrain p1 instead of p2

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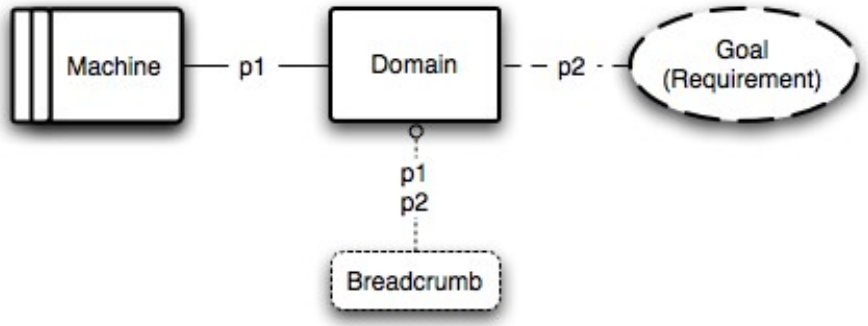
- **add** a breadcrumb assumption relating p1 and p2



Typical Transformation

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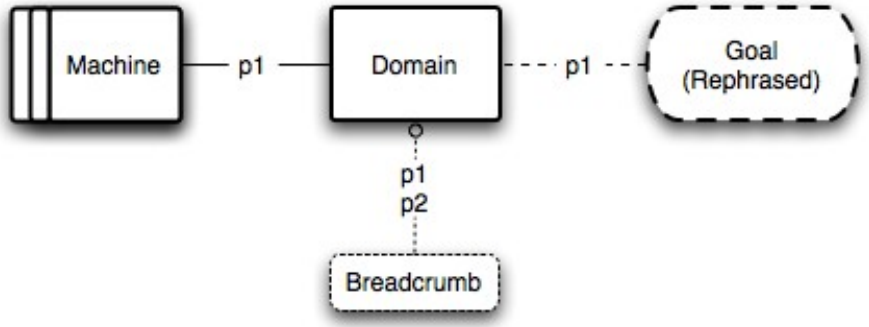
- **rephrase** the goal to reference p1 instead of p2 such that



$$Breadcrumb \wedge Rephrased\ Goal \Rightarrow Prior\ Goal$$

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$$Breadcrumb \wedge Rephrased\ Goal \Rightarrow Prior\ Goal$$

- **push** the goal towards the machine