User Guidance for Creating Precise and Accessible Property Specifications

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Property Specification Problem

- A property focuses on describing one particular aspect of system behavior
  - Even with such focus, it can still be difficult to write a property correctly
- A property should be precise and accessible
  - precise enough to support unambiguous communication and automated analyses
  - accessible enough to be readily understood

Transfusion Property

After receiving a physician order for a lab test and before obtaining a blood specimen, the nurse must verify that the specimen vial label is correct before labeling the vial.

Our Approach

- Provides property templates that explicitly show subtle variations as options
  - Extends property patterns
    [Dwyer, Avrunin, & Corbett 1998; 1999]
- Provides multiple views of the property
  - Views chosen to support precision, accessibility, and user guidance
  - User can work with one or more of the views
    - Changes made in a view are reflected in the others
- Implemented prototype tool, Propel

Outline

- Background
- Question Tree View
- Evaluation

Transfusion Property

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Events:

- receive-order
- obtain-specimen
- verify-label
- label-vial

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- obtain-specimen
- verify-label
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behavior describes the restrictions on occurrences of events

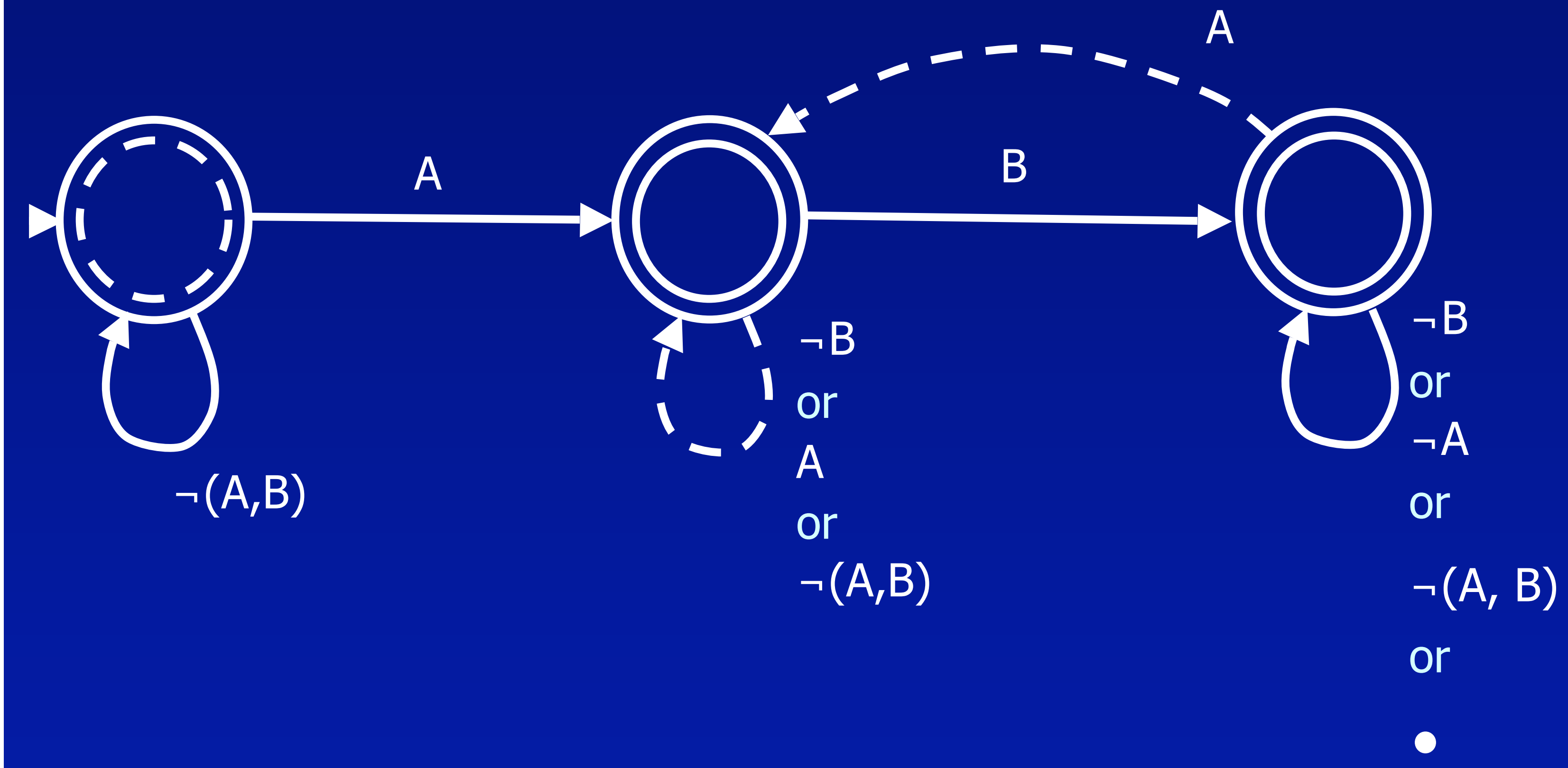
scope describes the parts of the event sequences within which the behavior restrictions apply

Two Property Views

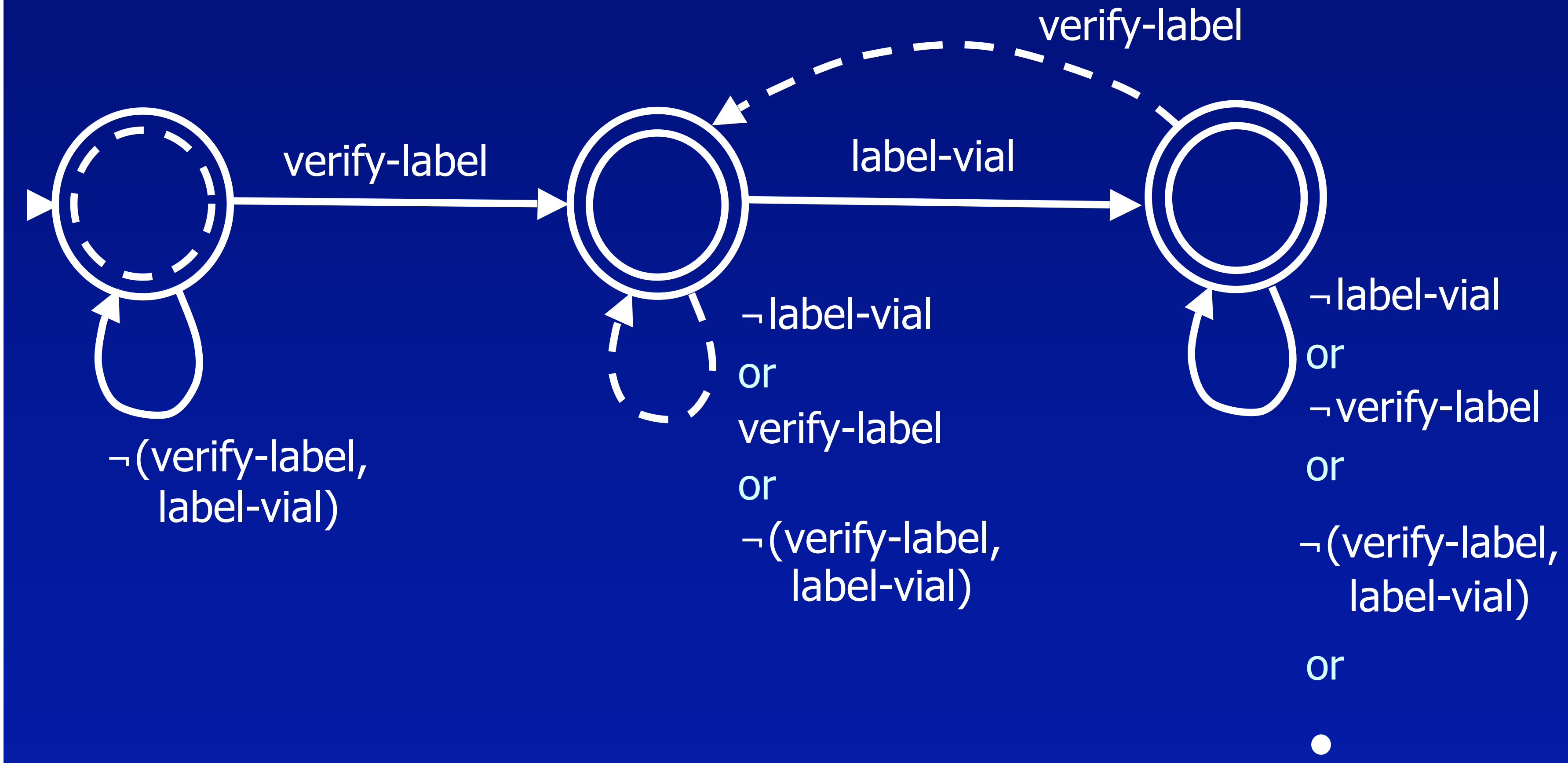
- Precision: Finite-State Automaton (FSA) template view
  - extends FSA notation

- Accessibility: Disciplined Natural Language (DNL) template view
  - based on natural language

Finite-State Automaton (FSA) Template



Finite-State Automaton (FSA) Template



verify-label

label-vial

verify-label

¬(verify-label,
label-vial)

¬label-vial
or
verify-label
or
¬(verify-label,
label-vial)

¬label-vial
or
¬verify-label
or
¬(verify-label,
label-vial)
or
●

Disciplined Natural Language (DNL) Template

label-vial cannot occur unless **verify-label** has already occurred.

▼ **label-vial**

is not required to occur.

Before the first **verify-label** occurs, the events in the alphabet of this property, other than **label-vial**, can occur any number of times.

After **verify-label** occurs and before the first subsequent **label-vial** occurs:

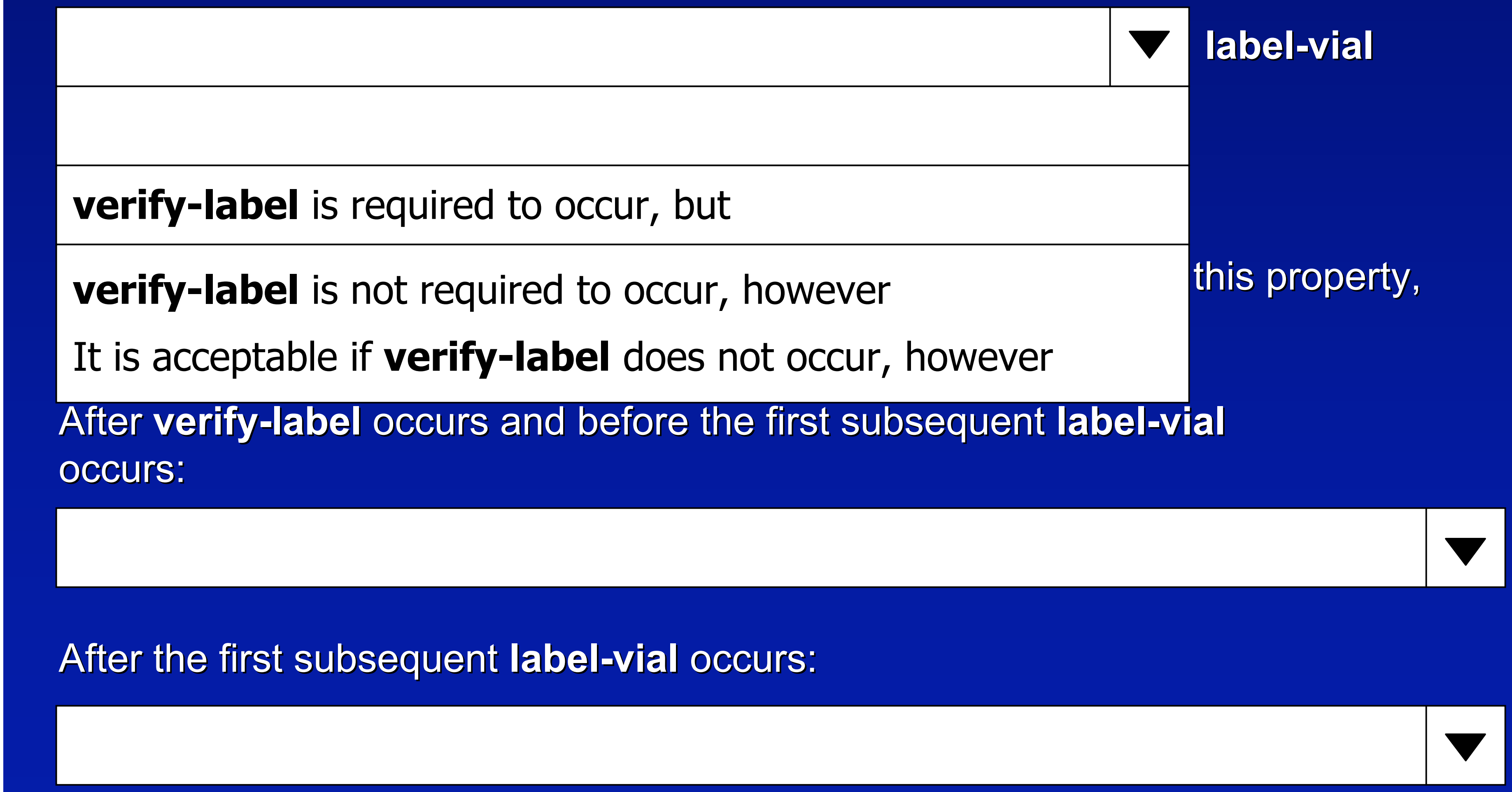
▼

After the first subsequent **label-vial** occurs:

▼

Disciplined Natural Language (DNL) Template

label-vial cannot occur unless **verify-label** has already occurred.



▼ **label-vial**

verify-label is required to occur, but

verify-label is not required to occur, however

It is acceptable if **verify-label** does not occur, however

this property,

After **verify-label** occurs and before the first subsequent **label-vial** occurs:

▼

After the first subsequent **label-vial** occurs:

▼

Propel Templates

SCOPES

Name
Global
Before **end**
After **start**
Between **start** and **end**

BEHAVIORS

Name	Intent
Response	**A** results in **B**
Precedence	**A** enables **B**
Absence	**A** never occurs
Existence	**A** must occur

Question Tree View

- Problem: users need guidance to choose appropriate scope and behavior

- Question Tree View is designed to provide this guidance
  - One tree for scope and one for behavior

- Question Trees are also useful for resolving detailed options

Behavior Question Tree

- How many events of primary interest are there?
  - One event
  - Two events

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Behavior Question Tree

- How many events of primary interest are there?
  - One event
  - Two events
    - How do **verify-label** and **label-vial** interact?
      - **verify-label** causes **label-vial** to occur
      - **label-vial** cannot occur until after **verify-label** has occurred

Behavior Question Tree

- How many events of primary interest are there?
  - One event
  - Two events
    - How do **verify-label** and **label-vial** interact?
      - **verify-label** causes **label-vial** to occur
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Behavior Question Tree

- How many events of primary interest are there?
  - One event
  - Two events
    - How do **verify-label** and **label-vial** interact?
      - **verify-label** causes **label-vial** to occur
      - **label-vial** cannot occur until after **verify-label** has occurred
        - Is **verify-label** required to occur at least once, whether or not **label-vial** eventually occurs?

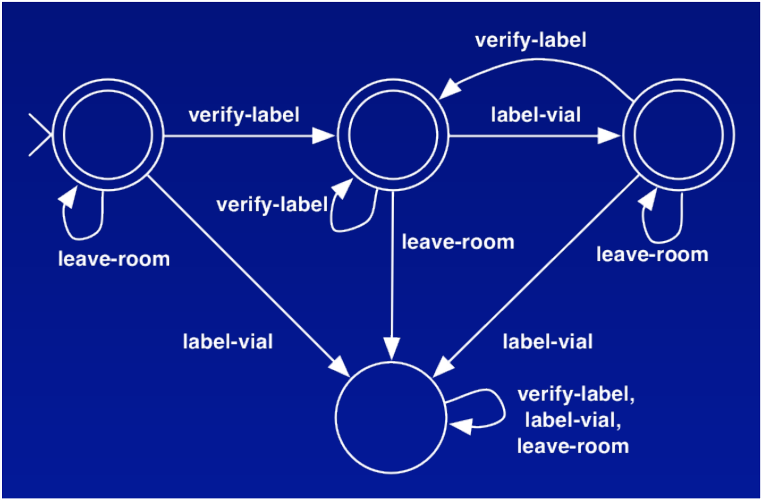
. . .

[insert Propel tool demo here]

Example Completed Behavior

event alphabet: {**verify-label**, **label-vial**, **leave-room**}

- How many events of primary interest are there?
  - One event
  - Two events
    - How do **verify-label** and **label-vial** interact?
      - **verify-label** causes **label-vial** to occur
      - **label-vial** cannot occur until after **verify-label** has occurred
        - Is **verify-label** required to occur at least once?
          - Yes, **verify-label** is required to occur at least once
          - No, **verify-label** is not required to occur at least once
        - After **verify-label** occurs, can **verify-label** occur again before the first subsequent **label-vial** occurs?
          - Yes, **verify-label** can occur multiple times before the first subsequent **label-vial** occurs
          - No, **verify-label** cannot occur again before the first subsequent **label-vial** occurs
        - After **verify-label** occurs, can events in the alphabet of this property, other than **verify-label** or **label-vial**, occur before the first subsequent **label-vial** occurs?
          - Yes, other events in the alphabet of this property can occur before the first subsequent **label-vial** occurs
          - No, other events in the alphabet of this property cannot occur before the first subsequent **label-vial** occurs
        - After the first subsequent **label-vial** occurs:
          - **label-vial** cannot occur again until after another **verify-label** occurs. **verify-label** can occur and if it does, then the situation is the same as when the first **verify-label** occurred, meaning that all restrictions described on the events will again apply
          - both **verify-label** and **label-vial** can occur any number of times and do not impose any restrictions on the occurrences of any future events
          - **verify-label** can occur any number of times, but **label-vial** cannot occur again. Further occurrences of **verify-label** do not impose additional restrictions on the occurrences of any future events
          - **label-vial** can occur any number of times, but **verify-label** cannot occur again. Further occurrences of **label-vial** do not impose additional restrictions on the occurrences of any future events
          - neither **verify-label** nor **label-vial** can occur again



label-vial cannot occur unless **verify-label** has already occurred.

It is acceptable if **verify-label** does not occur, however, and if it does not occur then **label-vial** can never occur. Even if **verify-label** does occur, **label-vial** is not required to occur.

Before the first **verify-label** occurs, the events in the alphabet of this property, other than **label-vial**, can occur any number of times.

After **verify-label** occurs and before the first subsequent **label-vial** occurs:

- no events in the alphabet of this property, other than **verify-label**, can occur;
- **verify-label** can occur any number of times.

After the first subsequent **label-vial** occurs:

- the events in the alphabet of this property, other than **verify-label** or **label-vial**, could occur any number of times;
- **label-vial** cannot occur again until after another **verify-label** occurs;
- **verify-label** can occur and if it does, then the situation should be regarded as exactly the same as when the first **verify-label** occurred, meaning that all restrictions described on the events would again apply.

Evaluations

- Used Propel in four real-world case studies

- Completed a small study to see how well people understand the Disciplined Natural Language view

Case Studies

- Four medical safety case studies
  - Blood Transfusion (UMass School of Nursing)
  - Chemotherapy (Baystate Medical Center)
  - Emergency Department (Baystate Medical Center)
  - Blood Bank (Defense Blood Standard System)
- ~80 properties total

Case Studies: Methodology

- Elicited properties from domain experts via interviews or existing documentation

- Elucidated property details:
  - For most properties, used Propel alongside domain experts
  - For a few properties, domain experts used Propel directly

- Domain experts reviewed Propel property specifications and worked with us to improve them

Case Studies: Observations

- Current implementation can express ~80% of the properties

- Cannot yet express:
  - certain property compositions

    e.g., chaining (6), blocking (3), nested scopes (3)
  - event disjunction/conjunction (3)
  - real-time properties (2)

Case Studies: Observations

- Different distribution of behavior frequencies than in property patterns survey
[Dwyer et al. 1999]

	Pattern Survey	Case Studies
Response	44%	21%
Precedence	5%	63%
Absence	15%	1%
Existence	5%	1%

- Roughly the same high percentage of properties are covered

Case Studies: Observations

- Different domain experts were comfortable with different property views
- Asking domain experts to carefully specify subtle details
  - made them aware of common interpretation errors
  - heightened their awareness of safety hazards in practice
  - changed the language they used
  - prompted the creation of new properties

Disciplined Natural Language (DNL) Study

- Completed a small study to see if people interpret the DNL as we intended

- Selected a diverse sample of properties
- Asked participants to translate DNL into FSAs
  - 14 participants: Computer Science graduate students and technical staff
  - Gave each person 1 simple “training” property and 3 more complex properties
- For each translated FSA, estimated how “closely” that FSA and the Propel FSA matched

DNL Study: Observations

- Comparing translated FSAs to Propel FSAs:

	all FSAs (42)	no Between-scope FSAs (28)
exact match	40%	57%
"close" match (incl. exact matches)	64%	82%

- It is difficult to clearly express Between scope's subtle details precisely in natural language
- Participants interpreted most of the DNL the way we intended

Related Work

- Requirements Formalisms
  e.g. Graphical or tabular approaches
- Processing Natural Language (NL) for Requirements Engineering
  e.g. Fuchs, Schwertel, & Schwitter, 1998;
  Gervasi & Zowghi, 2005;
  Breaux, Vail, & Anton, 2006;
  Gervasi & Ambriola, 2006
- Using brief NL notes alongside formal models
  e.g. Dwyer, Avrunin, & Corbett, 1999;
  Drusinsky, 2004;
  Mondragon & Gates, 2004
- Developing NL and formal model in parallel
  e.g. Konrad & Cheng, 2005

Future Work

- Address gaps in Propel expressibility
  - Support both state- and event-based properties
  - Support property compositions

- Provide guidance for how to decompose a property into a behavior and a scope

- Perform more in-depth evaluations of Propel

Summary

- Case studies are ongoing
  - Now ~100 properties
- Initial findings are very promising
  - Good coverage of encountered properties
  - Propel property specifications provide precision and appear to be reasonably accessible
    - Domain experts’ responses are very positive

Thanks!