From Natural Language Requirements to Rigorous Property Specifications

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The World We Live In

- Software developers write requirements in
  - Natural language
  - UML state diagrams and other mostly semantic-free notations
  - Or not at all
- Not precise enough to be used as the basis for
  - Consistency checking
  - Design and implementation
  - Test planning and verification
- Requirements and the system diverge!

Seat Control Properties

- A request for horizontal movement of the seat base gets priority over the front tilt motor if activated at the same time
- When the front tilt is requested to move upward and then the rear tilt motor is requested to move downward, only the front tilt motor will move
- When the horizontal base is requested to move forward and then requested to move backward, there is a minimum 50ms pause between changes in direction
- The rear tilt switch has priority over a recall message

Seat Control Property 1

- A request for horizontal movement of the seat base gets priority over the front tilt motor if activated at the same time
  - Need domain experts to clarify
    - "gets priority"
    - "if activated at the same time"
      start of activation at the same instant, or
      overlap of intervals where both are on?

Absence of (front_tilt_move) Between (horiz_req_on AND front_tilt_on) and horiz_req_off

Property Specifications Need to Be…

- Accessible
  - so that we understand what they're saying
- Precise
  - so that we can tell unambiguously whether a particular behavior satisfies or violates the property
- The problem is that…

  these goals usually conflict

Accessible

- Natural language is accessible (and most requirements are specified in it)
  - When the call button is pushed at a floor, the elevator cannot come to the floor more than once without opening its doors.
- But this is not precise or rigorous enough
  - What if the button is pushed repeatedly?
  - Does elevator have to come to the floor at all?
    - …

Precise Version of Example

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- But this is not really accessible (even for experts!)

Requirements for Requirements

- Provide a sound basis for design and implementation
  - Accessible and Precise
- Amenable to consistency and other analyzes
  - E.g. View all requirements that deal with the tilt operation
  - Check that these are consistent with each other
- Provide a sound basis for testing and verification

Must provide enough value to make the investment worthwhile!

Our Approach

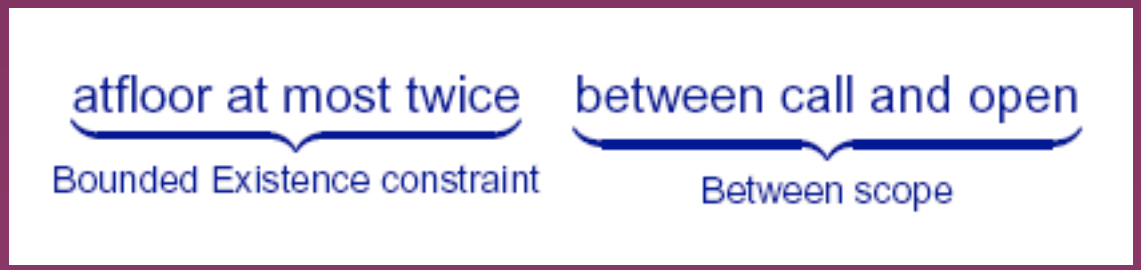
- Provide NL templates
  - Based on commonly occurring patterns
  - Expose the options that must be considered
  - Acceptable to developers
- Map to a precise formal notation
  - Basis for consistency analysis and verification
- Multiple views
  - Providing both should help and reassure developers

Build upon Specification Patterns

- Specification patterns [Dwyer, Avrunin, Corbett, 1999] intended as high-level abstractions
  - Generalized description of commonly-occurring requirements
  - Parameterizable
  - Formalism-independent
- Modeled on Design Patterns
  - Leverage experience of system developers by capturing description of good solutions to recurring design problem

Scopes and Constraints

- Each pattern has a constraint and a scope
  - Constraint gives requirement for behavior of system in that scope
  - Scope gives the extent of execution over which the constraint must hold



From Patterns to Formal Notations

Constraints

Absence	Never
Existence	Eventually
Universality	Always
Bounded Existence	Eventually n times
⋮	
Response	*action* results in *response*
Precedence	*action* enables *response*
Chain Response	*action* results in $resp_1$ $resp_2$ . . .
⋮	

Scopes

Global	Full execution
After *Q*	After first *Q*
Before *R*	Before first *R*
Between *Q* and *R*	Between any *Q* and next *R*
After *Q* until *R*	Between any *Q* and next *R*, if any

- Pattern system gives mappings from constraint-scope combinations to several formal notations (e.g., regular expressions, various temporal logics, etc.)

But Subtle Details are Critical

- Consider the following property:
  After the close-door button is pushed,
  the elevator doors are closed
- Response constraint with Global scope, but there are many questions about precise intent:
  - If button pushed repeatedly, should doors close repeatedly?
  - What, if anything, can occur between pushing the button and the doors closing?
  - Can the doors close without the button being pushed?
  - Does the button have to be pushed?

Property Specification Frameworks Need to Support

- Accessiblity
  - » Easily understandable by specifiers and users
- Precision
  - » Unambiguous, suitable for use with testing and verification tools
- Elucidation
  - » Specifier needs to have carefully addressed questions about details

PROPEL

- Extend the specification patterns:
  - » Represent pattern by template that explicitly shows options
    - – Help specifier consider relevant subtleties and alternatives
- Represent templates using two notations
  - » One is accessible (Disciplined Natural Language)
  - » One is mathematically precise (automata)
  - » Template representations are linked-- specifier can work with both simultaneously
- Decision tree for selecting the right pattern
  - » Constraint and scope

demo

What Next?

- Need to complete initial prototype of tool
- Several directions for further development:
  - Explore solution space
  - Investigate other ways of organizing properties and options
  - Support other precise formalisms
  - Explore integration with various testing/verification tools
  - Evaluation

Explore Solution Space

- Consider options for scopes
- Reexamine interaction between scopes and constraints
- Use decision tree for all options
  - Don’t bother with patterns at all
- Improve NL representation

Other Ways of Organizing Properties/Options

- Parameterization and Composition
  - Replace parameters in patterns by more complicated expressions
  - Certain replacements are fine but other are likely to be incorrect—not well understood in general
  - Composition of properties: chain patterns are simple versions

Support Other Precise Formalisms

- Other event-based formalisms
- State-based formalisms (e.g., the temporal logics)
  - Describe execution in terms of which propositions are true at a particular time
  - Some properties are more naturally expressed in state-based formalism
    - While mode is level_flight, landing gear switch is always disabled.
  - Options may be different for state-based formalisms
- Formalisms dealing with both states and events
  - Some properties naturally involve both states and events
    - While use_count is less than 10, registering a request always leads to resource_acquisition

Organizing Properties/Options

- Libraries of properties for a single system
  - Check for consistency, completeness
  - Refinement of property statements as systems passes through stages of development
  - Evolution of properties as system evolves

Integration with Testing/Verification Tools

- Integrate with other tools
  - » Make (correct) specification easier for users
  - » Interpret feedback from tool (e.g., execution violating property) directly in terms of property specification

Evaluation

- Want to evaluate if PROPEL approach is useful and discover ways to improve it
- Controlled experiments extremely expensive and difficult
- Looking for suitable case studies

Concluding Questions

- Can we help bridge the gap between informal intent and precise specification?
  - Elucidation: Encourage specifiers to think about and resolve the issues
- Can we provide a NL framework that is "comforting" to developers?
  - » NL improves high-level understanding
  - » Increases acceptance

Concluding Questions

- Can we provide a NL framework that is both “comforting” to developers, and rigorous enough to support analysis?
- How should we evaluate success
  - » Will specifiers choose to use this approach?
  - » Will specifiers update their requirements with this approach?
  - » Will this approach be used to support upstream activities?

Questions?