Modeling and Reasoning with Changing Intentions: An Experiment

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Problem:
We investigate the effectiveness and usability of
• Evolving Intentions,
• Simulation over Evolving Intentions, and
• GrowingLeaf

Practitioners:
• Improves decision making in early-RE
• Consider short-term and long-term impacts of alternatives
A City is evaluating waste management options for its Citizens.

Options: Build Green Centre
        Build Landfill / Dump (large, small)

Choose the best alternative(s) using goal modeling.
Waste Management Example

City
- Build Large Dump
- Build Small Dump
- Build Green Centre

Citizens
Waste Management Example
Waste Management Example

Leaf Intentions

- Use Current Dump
- Use New Dump
- Build Large Dump
- Build Small Dump
- Build Green Centre
- Manage City Waste
- Reduce Operating Costs
- Positive City Image
- Process Green Waste
- Recycling Education Program
- Quality of Waste Separation
- Environmental Concern
- Willingness to Separate Waste

Depends on: Space in Dump

Makes: Citizens

Depends on: Environment Concern

Contribution: Recycling Education Program

Dependency: Process Green Waste

Decomposition: Reduce Operating Costs

Goal: Process Green Waste

Actor: Build Green Centre

Task: Process Green Waste

Soft Goal: Environmental Concern

Resource: Build Green Centre
Waste Management Example

Root/Top Goals

Leaf Intentions
Waste Management Example

How does building a green centre and not building a dump affect the top/root goals?
How does building a green centre and not building a dump affect the top/root goals?
Waste Management Example

Question: How does satisfying and not satisfying (deny) affect the top/root goals?

Answer: It satisfies partially satisfies but partially denies
Waste Management Example

How do changes in Environmental Concern affect the City's root-level goals over time?
Previous Work

“Looking into the Crystal Ball: Requirements Evolution over Time.” [RE’16]

• *Allow* goal model *intentions to change* over time [Evolving Intentions (EIs)]

• *Understand the impacts* of dynamically changing intentions *on decision making* [Simulation over Evolving Intentions (EI-Sim)]

• *Tooling* for modeling and analyzing intentions that change over time. [GrowingLeaf]
Evolving Intentions

Leaf Goals
Evolving Intentions

intentions whose evaluations change over specified time intervals
Evolving Intentions

Elementary Functions

Stochastic (R):

Increase (I):

Constant (C):

or

Decrease (D):

Increase (I):
Evolving Intentions

Denied-Satisfied (DS)

Patterns:

\[ t_n \]

Examples:

- Build Small Dump
- Build Large Dump
- Build Green Centre
<table>
<thead>
<tr>
<th>Description</th>
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<td>Satisfied-Denied</td>
<td>the satisfaction evaluation remains <em>Satisfied</em> until ( t_i ) and then remains <em>Denied</em></td>
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<td>the satisfaction evaluation remains <em>Denied</em> until ( t_i ) and then remains <em>Satisfied</em></td>
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<td>changes in satisfaction evaluation become “more true” to a <em>maxValue</em> at ( t_i ) and then remains constant at <em>constantValue</em></td>
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Simulation over Evolving Intentions

Leaf Intentions
Simulation over Evolving Intentions

Given:
• evolving intentions (over leaf intentions)
• initial states in the model
• forward analysis over each time point

create a random path
Simulation over Evolving Intentions

How do changes in *Environmental Concern* affect the City's root-level goals over time?

R: Stochastic, C: Constant, D: Decrease, DS: Denied-Satisfied
Question: How do changes in the city's root-level goals affect the city's root-level goals over time?

Answer: Affects Satisfying Recyling Education Program mitigates the effect of denied Environmental Concern.
GrowingLeaf

http://www.cs.toronto.edu/~amgrubb/growing-leaf
Research Questions

• (RQ1) How do Evolving Intentions (EIs) affect modelers’ ability to capture model elements that change over time?  
  Control: Stochastically Evolving Intentions (SEIs)

• (RQ2) How does Simulation over Evolving Intentions (EI-Sim) affect modelers’ understanding and ability to reason about a goal model with time?  
  Control: Repeated Forward Analysis (Rep-FA), Simulation over Stochastically Evolving Intentions (SEI-Sim)

• (RQ3) How do modelers evaluate GrowingLeaf after completing modeling and analysis tasks?
Research Questions

• (RQ0) Do modelers perform similarly on basic cognition tests, given a consistent training protocol?

• (RQ1) How do Evolving Intentions (EIs) affect modelers’ ability to capture model elements that change over time?
  Control: Stochastically Evolving Intentions (SEIs)

• (RQ2) How does Simulation over Evolving Intentions (EI-Sim) affect modelers’ understanding and ability to reason about a goal model with time?
  Control: Repeated Forward Analysis (Rep-FA), Simulation over Stochastically Evolving Intentions (SEI-Sim)

• (RQ3) How do modelers evaluate GrowingLeaf after completing modeling and analysis tasks?
Outline

• Motivating Example & Background
  • Evolving Intentions (EIs)
  • Simulation over Evolving Intentions (EI-Sim)
  • Tooling: GrowingLeaf

• Study Design

• Results

• Implication, Threat to Validity, & Reflections
# Tools & Videos

## Tools

<table>
<thead>
<tr>
<th>Name</th>
<th>Rationale</th>
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<td>GrowingLeaf-EI-Sim (Tool-EI)</td>
<td>Learning of EIs and EI-Sim</td>
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<td>GrowingLeaf-SEI-Sim (Tool-SEI)</td>
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<td>GrowingLeaf-Forward Analysis (Tool-FA)</td>
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<td>EI</td>
<td>Evolving Intentions</td>
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<td>EI-Sim</td>
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<td>SEI-Sim</td>
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<tr>
<td>RQ0</td>
<td>Video 0A</td>
<td>Reviewed goal modeling concepts/notations &amp; introduced Tool-FA.</td>
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<td>Video 0B</td>
<td>Introduced forward analysis with Tool-FA.</td>
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# Study Protocol

Legend: section topic, video watched, tool used

<table>
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<tr>
<th>Subject Groups</th>
<th>Group A (n = 5)</th>
<th>Group B (n = 5)</th>
<th>Group CA (n = 3)</th>
<th>Group CB (n = 2)</th>
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Recorded Answers & Completion Times
Subjects

- graduate students (9 Masters, 6 PhD)
- basic understanding of RE & proficient in English
- recruited through mailing list and intro course

Subject self-reported familiarity rating:

- **requirements engineering**: 33%
- **i* (or iStar) modeling language**: 67%

- 53% Somewhat Familiar
- 27% Moderately Familiar + Extremely Familiar
- 13% Slightly Familiar
- 7% Not At All Familiar + Slightly Familiar
- 13% Not At All Familiar + Slightly Familiar

Not At All Familiar + Slightly Familiar

Moderately Familiar + Extremely Familiar
Outline

- Motivating Example & Background
  - Evolving Intentions (EIs)
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RQ0: Baseline Test Between-Subject

Research Question: Do modelers perform similarly on basic cognition tests, given a consistent training protocol?

Findings:
• Subjects *performed similarly* on basic cognition tests
• *Enables comparison* between groups in RQ1-RQ3
RQ1: Evolving Intentions

Research Question: How do Evolving Intentions (EIs) affect modelers’ ability to capture model elements that change over time?

Findings:

- Subjects understood EIs and SEIs
- Subjects evaluated intentions with EIs and SEIs
- EIs were found to be intuitive

Legend:
- EI: Evolving Intention
- SEI: Stochastically Evolving Intention
RQ1: Evolving Intentions

Identify which elements in this model change over time?
RQ1: Evolving Intentions

Identify which elements in this model change over time?

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Position: **Leaf, Root, Neither**

- Group A identified two additional functions.
RQ1: Evolving Intentions

Identify which elements in this model change over time?

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</tbody>
</table>

- Primarily Leaf Nodes Identified
- Root and Intermediate Nodes also identified
- Position: Leaf, Root, Neither

• Group A identified two additional functions.
RQ1: Evolving Intentions

Identify which elements in this model change over time?

<table>
<thead>
<tr>
<th>Elements</th>
<th>LR</th>
<th>A1</th>
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Position: **Leaf, Root, Neither**

- Group A identified two additional functions.
RQ1: Evolving Intentions

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Position: Leaf, Root, Neither

• Group A identified two additional functions.
RQ2: Simulation over Evolving Intentions

Research Question: How does Simulation over Evolving Intentions (EI-Sim) affect modelers’ understanding and ability to reason about a goal model with time?

Findings:

• EI-Sim and SEI-Sim improved understanding of model structure
• EI-Sim improved reasoning about goal models over time (significant slower)
• Rep-FA proved difficult for time-focused questions

Legend:
EI-Sim: Simulation over Evolving Intention
SEI-Sim: Simulation over Stochastically Evolving Intentions
Rep-FA: Repeated Forward Analysis
Assume you can sequentially complete both “Build Green Centre” and “Build Small Dump”. Which order is best for the top goals (use simulation/forward analysis to evaluate the alternatives)? Why?

Group A (EI-Sim):
- subjects that used EI-Sim and obtained meaningful results
- 2 subjects used only the Constant (C) function

Group B (SEI-Sim):
- subjects chose the correct answer looking at the structure of the model

Group C (Rep-FA):
- subjects chose the best alternative and ignored ordering
RQ2: Simulation over Evolving Intentions

Evaluate RQ2 Completion Times

Kruskal-Wallis Rank Sum Test

• *Null Hypothesis*: No difference between groups
  
  \( p = 0.054 \) arguably significant

Dunn’s Post-Hoc Pair-wise Comparison Test

• *Group A took significantly longer* (avg. 6 minutes)

  Group B \( p = 0.0098 \) & Group C \( p = 0.045 \)

• no significant difference between Group B & C
RQ3: GrowingLeaf Tool

Research Question: How do modelers evaluate GrowingLeaf after completing modeling and analysis tasks?

Findings: • Subjects rated GrowingLeaf highly and found it usable
RQ3: GrowingLeaf Tool

Rate your level of satisfaction with the tools:

- **modeling functionality**: 0%
- **ease of use**: 13%
- **appearance**: 0%
- **analysis functionality**: 7%

**Graph:**
- Completely + Mostly + Somewhat Dissatisfied: 0%
- Neither Satisfied or Dissatisfied: 13%
- Somewhat + Mostly + Completely Satisfied: 87%
- Completely Dissatisfied: 93%

No significant difference between tool version.
RQ3: GrowingLeaf Tool

What suggestions or changes would you recommend to the developers of this goal modeling tool?

- Clear all intention evaluation and function labels
- Highlight and unhighlight leaf and root intentions
- Syntax checking

See paper for additional recommendations…
Summary of Results

• ELs were suitable to the task of identifying and representing intentions over time

• EL-Sim improved the subjects’ ability to reason about goal models over time

• GrowingLeaf was found to be effective and usable
Outline

• Motivating Example & Background
  • Evolving Intentions (EIs)
  • Simulation over Evolving Intentions (EI-Sim)
  • Tooling: GrowingLeaf

• Study Design

• Results

• Implication, Threat to Validity, & Reflections
Implications for Research

• understand why not all Group A subjects used EI-Sim effectively
• subjects paid closer attention to the content of some models but not others 😕
Implications for Education

- subjects had difficulty with the Depends link
- SEI-Sim can be used in teaching to help subjects understand
  - the structure of the model
  - forward propagation rules
Threats to Validity

Conclusion Validity

- low sample size → low statistical power 😞

Internal Validity

- self-reported understanding of RE and iStar

Construct Validity

- evaluation apprehension 😞

External Validity

- not generalizable to other populations / domains
- model size not representative
Reflections

Problem: How to effectively study learning?

_Ideal: Controlled experiment within a course (with Grades)_

Our Approach:

• Control for level of past experience 😐
• Apply Learning Theory
  • Bloom’s Taxonomy: remember, understand, 😊 apply, analyze, evaluate, and create
• Run multiple pilots to expose tacit learning 😊
Reflections

Problem: Inherent bias studying your own tool/technique

*Ideal: Get independent researcher to run study*

Our Approach:

- Use third person instead of “my/our” tool/technique 😊
Reflections

Problem: Inherent bias studying your own tool/technique

Ideal: Get independent researcher to run study

Our Approach:

• Use third person instead of “my/our” tool/technique

How would you recommend I improve my tool?

VS.

What suggestions or changes would you recommend to the developers of this goal modeling tool?
Reflections

Problem: Inherent bias studying your own tool/technique

Ideal: Get independent researcher to run study

Our Approach:
- Use third person instead of "my/our" tool/technique 😊
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Our Approach:

- Use third person instead of “my/our” tool/technique 😊
- Use formal experiment protocol:
  - Handouts 😊
  - Videos (with non-researcher’s voice over) 😊
Reflections

Problem: Inherent bias studying your own tool/technique

*Ideal: Get independent researcher to run study*

Our Approach:

- Use third person instead of “my/our” tool/technique 😊
- Use formal experiment protocol:
  - Handouts 😊
  - Videos (with non-researcher’s voice over) 😊
- Use formal data analysis protocol:
  - Understand data analysis procedure before study 🙄?
  - Analyze data after collection is complete 😑?
  - Use non-parametric statistics (unknown distribution) 😊
Supplemental Information

Supplementary Information for “Modeling and Reasoning with Changing Intentions: An Experiment”

In this paper, we report on a between-subjects experiment we conducted with fifteen graduate students familiar with requirements engineering. The experiment investigates the effectiveness and usability of Evolving Intentions, Simulation over Evolving Intentions, and GrowingLeaf.


This page discusses supplemental material. It is recommended that you read the paper prior to continuing here.

Materials

Here are the study materials.

Study Protocol:
- Consent Form
- Study Questions
- Prize Draw Form
- Study Follow-up Form

Models:
- Trusted Computing Model: png
- Network Administrator Model: png
- Waste Management Model: png

Videos and Handouts:
- Video 0A, iStar Handout
- Video 0B, Forward Analysis Handout
- Video IEL, Evolving Intentions Handout
- Video ISEI, Stochastically Evolving Intentions Handout
- Video IIESI
- Video IIAPA

Tool Versions:
- GrowingLeaf-EL-Sim (Tool-EL)
- GrowingLeaf-SEI-Sim (Tool-SEI)
- GrowingLeaf-Forward Analysis (Tool-FA)

R Files:
- R File

Subject Recruitment:
- Study advertisement email
- Graduate class Message Board advertisement
- Emails to schedule experiment

http://www.cs.toronto.edu/~amgrubb/archive/RE17-Supplement
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- Video PB, Forward Analysis Handout
- Video PC, Evolving Intentions Handout
- Video PDE, Stochastically Evolving Intentions Handout
- Video IIEI
- Video IIEII
- Video IIEIII
- Video IIEIV

Tool Versions:
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Useful for other tool or modeling studies
Summary

Results:

• Evolving Intentions were intuitive
• EI-Sim increased the subjects’ understanding and produced meaningful results
• GrowingLeaf was found to be usable

Future work will improve this study:

• larger sample size and larger models
• different populations and domains

Study methodology and materials available for reuse
Questions?
Modeling and Reasoning with Changing Intentions: An Experiment

Study methodology and materials:

http://www.cs.toronto.edu/~amgrubb/archive/RE17-Supplement

Tool:

http://www.cs.toronto.edu/~amgrubb/growing-leaf/

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amgrubb@cs.toronto.edu