Adding Temporal Intention Dynamics to Goal Modeling

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Motivating Example

• Morgan is a working at a bank entering the home loan market.

• Building a system to accept, assess, and manage loans.

• Use goal modeling to evaluate alternatives.

• Decision: *Whether to outsource loan application assessment to a credit bureau to perform in-house.*
Assess Applications Model

Assess Applications

Assess Applications In-house

Assess Applications by Credit Bureau

Determine Assessments

Produce Quality Assessments

Receive Assessments

Retain Quality Assessments

Build Assessment System

Understand Current Monetary Conditions

Develop Audit Assessment Procedures

Legend
† and-decomposition
⬆ or-decomposition
Assess Applications Model

- Assess Applications
  - Assess Applications In-house
  - Assess Applications by Credit Bureau
    - Produce Quality Assessments
    - Receive Assessments
      - Retain Quality Assessments
      - Develop Audit Assessment Procedures
  - Understand Current Monetary Conditions
  - Determine Assessments
    - Build Assessment System

Legend:
- † and-decomposition
- ‡ or-decomposition
- ✔ satisfied (true)
- ✗ denied (false)
Assess Applications Model

Assess Applications

Assess Applications In-house

Assess Applications by Credit Bureau

Determine Assessments

Produce Quality Assessments

Receive Assessments

Retain Quality Assessments

Build Assessment System

Understand Current Monetary Conditions

Develop Audit Assessment Procedures

Forward Analysis

Legend
† and-decomposition
↑ or-decomposition
✔ satisfied (true)
✗ denied (false)
Motivating Example

• A large number of mortgage loans defaulted.

• Morgan returns to the model for clarity.

• Realizes element satisfaction is not how originally assigned.

• New questions arise.
Motivating Example

New Questions

• If the bank built the assessment system would it eventually result in “Assess Applications” being satisfied?

• If “Retain Quality Assessments” Varies over time could “Assess Applications” be satisfied?

• What is the long-term result of choosing the credit bureau?

• What is the best option for the long-term.
Problem

- Early-phase requirements modeling assumes:
  - all model elements have a value
  - model values are constant
- In reality intentions and relationships in the environments are not constant.
Contributions

• Understand the impacts of dynamically changing intentions on decision making

• Enrich goal models
  • intentions with dynamically changing evaluations
  • temporally delayed dependency relationships
Outline

• Motivating Example - Loan Assessment

• **Modeling Dynamic Intentions**

• Analysis Techniques with Dynamic Intentions
  • Simulation
  • Static Analysis

• Conclusion and Future Directions
Dynamic Intentions

Assess Applications

Assess Applications In-house

Assess Applications by Credit Bureau

Determine Assessments

Produce Quality Assessments

Receive Assessments

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Build Assessment System

Understand Current Monetary Conditions

Develop Audit Assessment Procedures

Legend
† and-decomposition
↑ or-decomposition
Dynamic Intentions

Set-Stay-Set Positive

Patterns:

\[
\begin{array}{cc}
T & t_n \\
F & t_n \\
\end{array}
\]

Examples:

Receive Assessments

Build Assessment System
Dynamic Intentions

Monotonic Positive

Patterns:

Pay off Student Loans

Become Educated
Dynamic Intentions

Stochastic

Patterns:

T  ⬛ ▬ ▬ ▬ ▬

F  ⬛ ▬ ▬ ▬ ▬

Examples:

Retain Quality Assessments

Maintain Employment
Dynamic Intentions

User Defined

Patterns:

$\begin{align*}
\text{T} & \quad t_0 \quad t_i \quad t_n \quad t_\infty \\
\text{F} & \quad \quad \quad \quad \quad \quad \\
\end{align*}$

Example:

Develop Audit
Assessment
Procedures
# Dynamic Intentions

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set-Stay-Set Positive (SSS+)</td>
<td>stochastically changing until a static-state of ✔ (or true) is reached</td>
</tr>
<tr>
<td>Set-Stay-Set Negative (SSS−)</td>
<td>stochastically changing until a static-state of ✗ (or false) is reached</td>
</tr>
<tr>
<td>Monotonic Positive (M+)</td>
<td>its value will be “more true” or trend toward ✔ (or true) as time progresses</td>
</tr>
<tr>
<td>Monotonic Negative (M−)</td>
<td>its value will be “less true” or trend toward ✗ (or false) as time progresses</td>
</tr>
<tr>
<td>Stochastic (RND)</td>
<td>changes in satisfaction level are non-deterministic or random</td>
</tr>
<tr>
<td>User Defined</td>
<td>its value is a stepwise function defined by the modeler</td>
</tr>
</tbody>
</table>
Outline

• Motivating Example - Loan Assessment

• Modeling Dynamic Intentions

• **Analysis Techniques with Dynamic Intentions**
  • Simulation
  • Static Analysis

• Conclusion and Future Directions
Simulation

- If the bank built the assessment system would it eventually result in “Assess Applications” being satisfied?

- If “Retain Quality Assessments” varies over time could “Assess Applications” be satisfied?

- What is the long-term result of choosing the credit bureau?

- What is the best option for the long-term.
Simulation

Extended i* Model:

- i* model
- intention dynamics
- relationship dynamics
- timing constraints

Model Simulator

Timing Visualization
# Simulation

<table>
<thead>
<tr>
<th>Inputs (Intentions)</th>
<th>t0</th>
<th>t1</th>
<th>t2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set-Stay-Set Positive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receive Assessments</td>
<td>T</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td><strong>Stochastic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receive Quality Assessments</td>
<td>T</td>
<td>F</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intermediate Nodes</th>
<th>t0</th>
<th>t1</th>
<th>t2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessed by Credit Bureau</td>
<td>T</td>
<td>F</td>
<td></td>
</tr>
</tbody>
</table>

**Constraints:** Receive Assessment $\geq$ Receive Quality Assessment
Simulation

Inputs (Intentions)

Set-Stay-Set Positive

Stochastic

Constraints: Receive Assessment >= Receive Quality Assessment
Simulation

Inputs (Intentions)

Set-Stay-Set Positive

Stochastic

Receive Assessments

Receive Quality Assessments

Intermediate Nodes

Assessed by Credit Bureau

Constraints: Receive Assessment $\geq$ Receive Quality Assessment

Assess Applications by Credit Bureau

Receive Assessments

Retain Quality Assessments

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Simulation

Inputs (Intentions) | t0 | t1 | t2 | t3 | t4 | t5 | t6 | t7 | t8 | t9
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
Receive Assessments | T | F | T | F | T | F | T | F | T | F
Receive Quality Assessments | T | F | T | F | T | F | T | F | T | F
Intermediate Nodes | T | F | T | F | T | F | T | F | T | F
Assessed by Credit Bureau | T | F | T | F | T | F | T | F | T | F

Constraints: Receive Assessment >= Receive Quality Assessment
Simulation

Printing IStar Model: Loan Example - Assess Application Sub-model

Intenstions:
<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Type</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>Assess Application</td>
<td>OI</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>Assessed In-house</td>
<td>AI</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Assessed by Credit Bureau</td>
<td>AI</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Receive Assessments</td>
<td>MP</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Receive Quality Assessments</td>
<td>MP</td>
<td>2</td>
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<tr>
<td>5</td>
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<td>6</td>
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<td>MP</td>
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<td>Produce Quality Assessments</td>
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<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Understand Monetary Conditions</td>
<td>MP</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Audit Assessments Procedures</td>
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Intention Links:
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<th>Name</th>
<th>Type</th>
<th>Source</th>
<th>Target</th>
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<tr>
<td></td>
<td>OR</td>
<td>Assess Application</td>
<td>Assess Application</td>
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<tr>
<td>6</td>
<td>OR</td>
<td>Assessed by Credit Bureau</td>
<td>Assess Application</td>
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<tr>
<td>6</td>
<td>AND</td>
<td>Receive Assessments</td>
<td>Assessed by Credit Bureau</td>
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<td>AND</td>
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<td>Determine Assessments</td>
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<td>6</td>
<td>AND</td>
<td>Produce Quality Assessments</td>
<td>Assessed In-house</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>MAKE Understand Monetary Conditions</td>
<td>Produce Quality Assessments</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>HELP Audit Assessments Procedures</td>
<td>Produce Quality Assessments</td>
</tr>
</tbody>
</table>

Would you like to (a) interrupt after every Epoch, (b) set a breakpoint, (w) watch a variable, (v) change a value, (f) run the full simulation?

Performing analysis now:

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</tbody>
</table>

Assess by Credit Bureau Satisfied.

Assess Application Satisfied. (Short-term)

TypeOI | AI | AI | MP | R | NT | MP | MP | MP | MP
<table>
<thead>
<tr>
<th></th>
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<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Assess by Credit Bureau Satisfied.

Assess Application Satisfied. (Long-term)


Finished analysis now. Assess Application Satisfied.

Short-term result recommendation: Assessed by Credit Bureau.

Long-term result recommendation: Assessed In-house.
Simulation

- If the bank built the assessment system would it eventually result in “Assess Applications” being satisfied?

- If “Retain Quality Assessments” Varies over time could “Assess Applications” be satisfied?

- What is the long-term result of choosing the credit bureau?

- What is the best option for the long-term.
Static Analysis

• Can we make any guarantees about when “Assess Applications by Credit Bureau” will be satisfied?

• Can we make any guarantees about when “Assess In-house” will be satisfied?
Static Analysis

• Can we make any guarantees about when “Assess Applications by Credit Bureau” will be satisfied?

• Can we make any guarantees about when “Assess In-house” will be satisfied?
Static Analysis

Extended i* Model:

- i* model
- intention dynamics
- relationship dynamics
- timing constraints

Static Analysis

Model Valid?

Function Computation
• Question: Can we make any guarantees about when “Assess In-house” will be satisfied.

![Diagram of Static Analysis Process]

- Assess Applications In-house
  - Determine Assessments
  - Produce Quality Assessments
  - Build Assessment System
    - Understand Current Monetary Conditions
      - Develop Audit Assessment Procedures

The diagram shows the process flow with decision points marked by T (true) and F (false) outcomes at specific time points $t_b$, $t_m$, and $t_n$.
Static Analysis

• Question: Can we make any guarantees about when “Assess In-house” will be satisfied.

Assess Applications In-house

[Diagram showing decision flow with conditions]

Build Assessment System

Understand Current Monetary Conditions

Develop Audit Assessment Procedures

Assess Applications In-house

Determine Assessments

Produce Quality Assessments

Build Assessment System

Understand Current Monetary Conditions

Develop Audit Assessment Procedures

(t >= t_b) -> true

(t < t_m) -> true

(t < t_n) -> false and (t >= t_p) -> true
Static Analysis

(solver
 (< t0 t1 t2 t3 t4 t5 t6 t7 t8 t9 t10)
 (forall ((a Bool) (b Bool)) (= (X a b) (and a b)))
 (forall ((a Bool) (b Bool)) (= (O a b) (or a b)))
 (forall ((a Bool) (b Bool)) (= (M a b) (or a b)))
 (forall ((t Int)) (=> (>= t t4) (C t)))
 (forall ((t Int))
     (and (=> (and (>= t t5) (< t t12)) (D t))
          (=> (and (> t t0) (< t t3)) (not (D t)))
     )
 (forall ((t Int)) (= (and (> t t0) (< t t8)) (E t)))
)
 (X (X (C t) (C t)) (X (D t) (E t)))

The resulting function has the following values:
[ t0 , t3 )
  Fully Denied
[ t3 , t4 )
  Unknown
[ t4 , t5 )
  Unknown
[ t5 , t6 )
  Fully Satisfied
[ t6 , t7 )
  Fully Satisfied
[ t7 , t8 )
  Fully Satisfied
[ t8 , t9 )
  Fully Denied
[ t9 , t12 )
  Fully Denied
Static Analysis

- Question: Can we make any guarantees about when “Assess In-house” will be satisfied.

\( ((t \geq \max(t_b, t_p)) \text{ and } (t < t_m)) \rightarrow \text{true} \)

\[ t_x = \max(t_b, t_p) \]

\[ t_0 \quad t_x \quad t_m \quad t_\infty \]

T

F

Diagram:

- Assess Applications In-house
- Determine Assessments
- Produce Quality Assessments
- Build Assessment System
- Understand Current Monetary Conditions
- Develop Audit Assessment Procedures
Static Analysis

- Can we make any guarantees about when “Assess Applications by Credit Bureau” will be satisfied?

- Can we make any guarantees about when “Assess In-house” will be satisfied?
Motivating Example

Review

• Morgan is modeling a system to accept, assess, and manage loan applications for a bank entering the home loan market.

• Decision: *Whether to outsource loan application assessment to a credit bureau to perform in-house.*

• Result: Provide additional evidence that enables Morgan to make an improved decision.
Outline

• Motivating Example - Loan Assessment
• Modeling Dynamic Intentions
• Analysis Techniques with Dynamic Intentions
  • Simulation
  • Static Analysis
• Conclusion and Future Directions
Summary

Assess Applications Model

Dynamic Intentions
Set-Stay-Set Positive

Patterns:

<table>
<thead>
<tr>
<th></th>
<th>T</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>T</td>
</tr>
</tbody>
</table>

Examples:
- Receive Assessments
- Build Assessment System

Simulation

Static Analysis

- Question: Can we make any guarantees about when “Assess In-house” will be satisfied.

\[(t \geq \max(t_0, t_2)) \land (t < t_0) \implies \text{true} \]

\[t_x = \max(t_0, t_2)\]

\[t_0 \quad t_x \quad t_2 \quad t_{\infty}\]

T

F

Constraints: Receive Assessment \(\Rightarrow\) Receive Quality Assessment
Related Work

• Classifying **goal type** by achievement type.  
  [Regev and Wegmann, 2005]

• **Risks** as events that satisfy goal satisfaction.  
  [Asnar et al., 2011]

• **Real-time timing** properties as goals.  
  [Letier et al., 2002]

• **Temporal ordering** constraints and **simulation** in goal models.  
  [Cheong and Winikoff, 2005][Gans et al., 2003]

• Goals as dynamic entities in **runtime goal monitoring** and **adaptive systems**.  
  [Robinson, 2005][Bencomo et al., 2010] [Baresi et al., 2010]  
  [Vrbaski et al., 2012][Dalpiaz et al., 2013]

• Goal **propagation** algorithms.  
  [Chung et al., 2000][Giorgini et al., 2005][van Lamsweerde, 2009]  
  [Amyot et al., 2010][Horkoff and Yu, 2014]
Future Work

• Developing a tool to enable user studies

• Extend our analysis for:
  • Delayed dependencies
  • Different types of dependencies

• Validation
Future Work

• Developing a tool to enable user studies

• Extend our analysis for:
  • Dynamic Relationships
  • Different types of dependencies
  • Validation
Dynamic Relationships

- Two kinds:
  - Delayed Impact
  - Altered Relationship Type

- Antibiotics
  - ST: helps
  - LT: hurts
Questions?
Contributions:

- understand the impacts of dynamically changing intentions on decision making
- enrich goal models
  - intentions with dynamically changing evaluations
- temporally delayed dependency relationships