Iterative, Interactive Analysis of Agent-Goal Models for Early Requirements Engineering

RE Seminar
DISI, University of Trento

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Iterative, Interactive Modeling

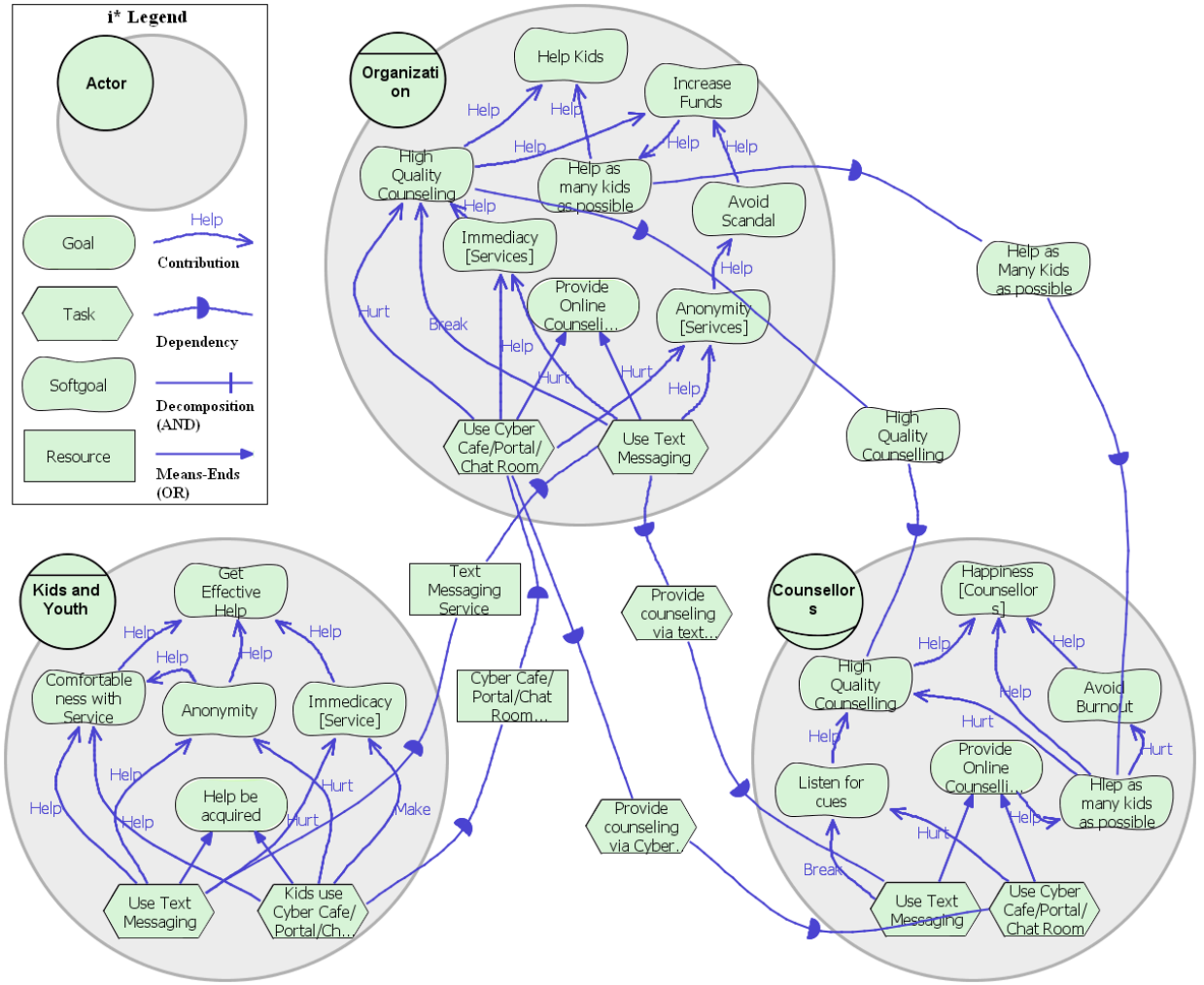
- Models are helpful in the development of software systems:
  - Means of abstraction
  - Communication
  - Convergent understanding
- Models support analysis:
  - Using the structure or contents of the model to answer questions
- It is challenging to know when a model is (sufficiently) accurate or complete
- We need: methods and tools to guide modelers in an interactive process of model iteration
  - Leading to more stable and complete models and improved analysis

Iterative, Interactive Modeling

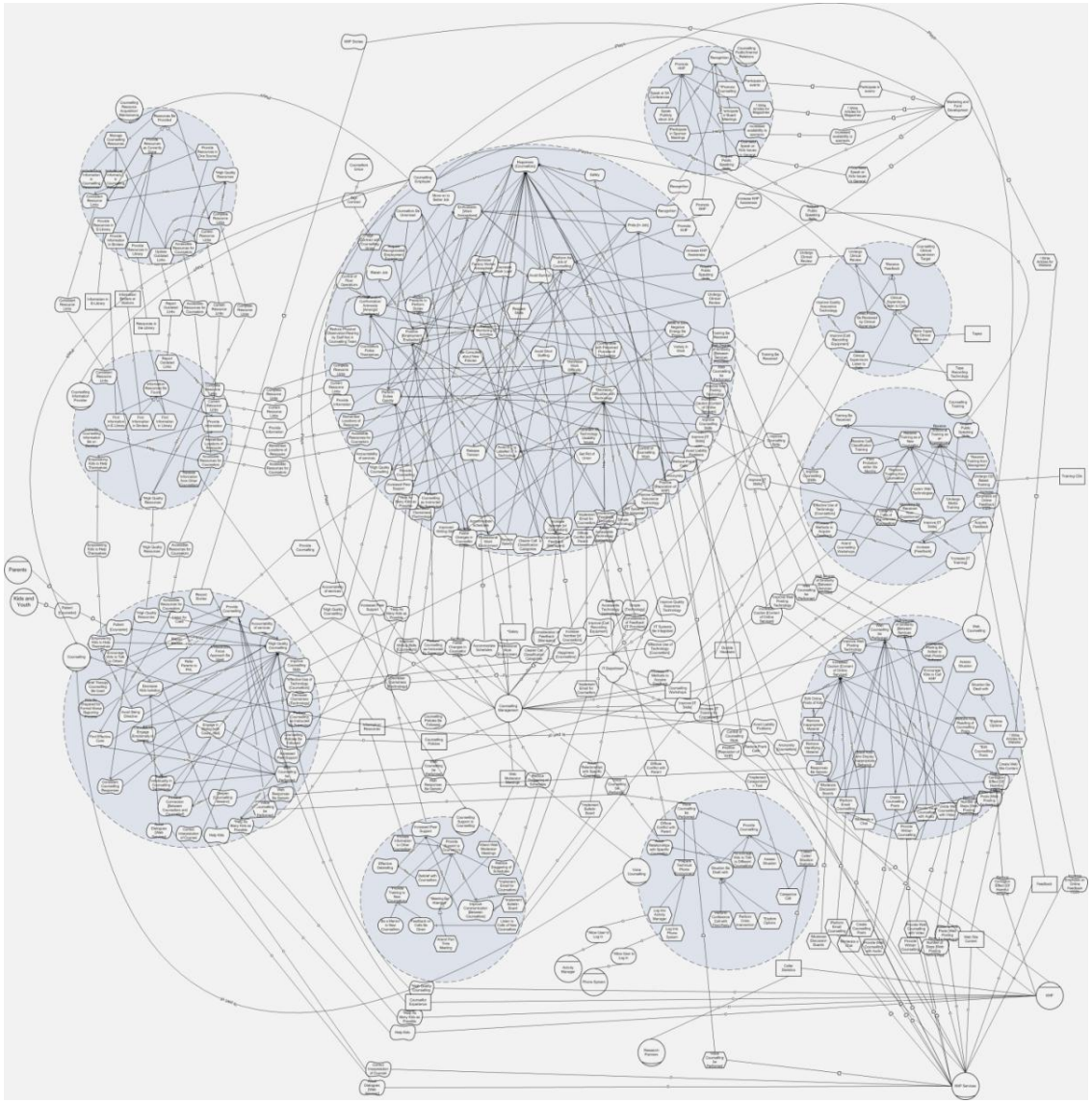
- In **Early Requirements Engineering (ERE)**, when models describe **what will be**, it is especially challenging to make models sufficiently complete and correct
- ERE focuses on understanding the domain and the (often conflicting) needs of the stakeholders enough to gain a high-level understanding of the required functionality for the system-to-be
  - Domain information in early project stages is often incomplete
  - Success of the system often relies on important non-functional success criteria
  - Involvement of key stakeholders is important
  - Key decisions concerning project scope or functionality are made
- Goal models are useful for ERE modeling and analysis
  - NFR, i*, KAOS, Tropos, GRL, etc.
- Existing goal model analysis procedures are typically automated or require detailed information

Motivating Example: Youth Counseling Organization

- A not-for-profit organization that focuses on counseling for youth over the phone, but must now expand their ability to provide counseling via the Internet

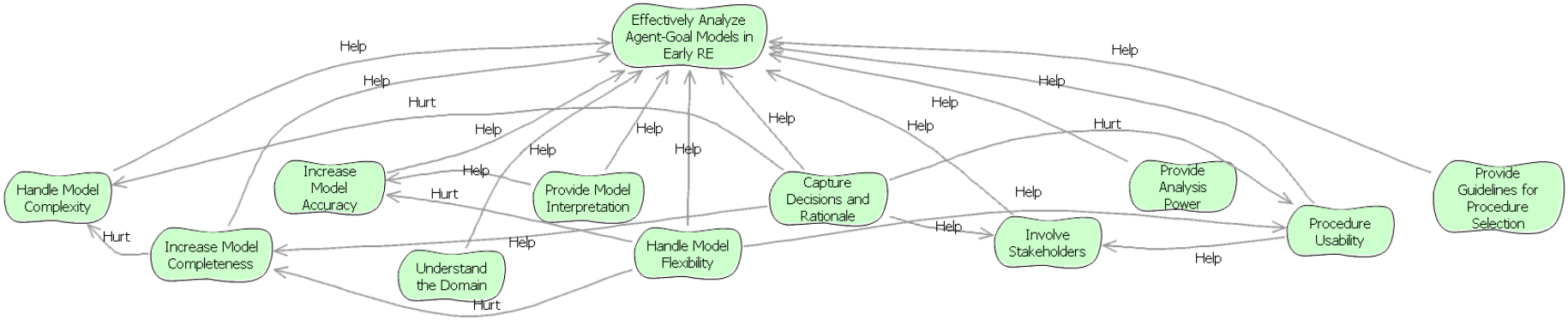


Motivating Example: Youth Counseling Organization



Challenges in Agent-Goal Model Analysis for Early Requirements Engineering

- Model Complexity
- Model Completeness
- Model Accuracy
- Domain Understanding
- Model Interpretation
- Model Flexibility
- Decision Rationale
- Stakeholder Involvement
- Analysis Power
- Procedure Usability
- Procedure Selection

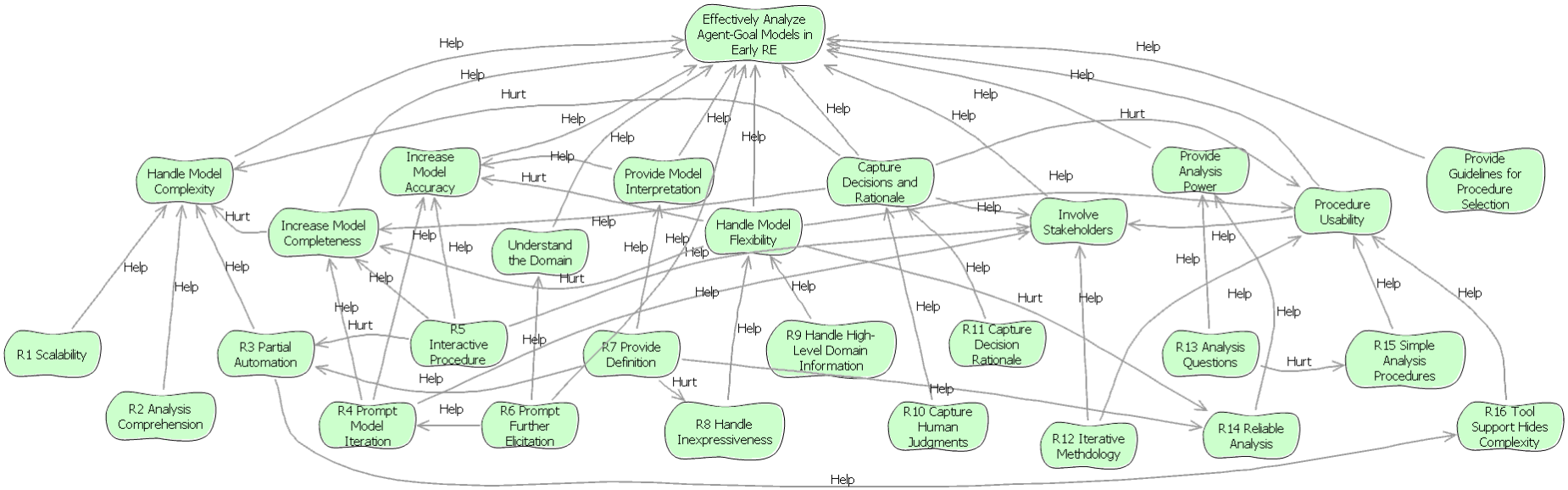


Requirements for Early RE Agent-Goal Model Analysis

- **Model Complexity**
  - R1 Scalability
  - R2 Analysis Comprehension
  - R3 Partial Automation
- **Model Completeness & Accuracy**
  - R4 Model Iteration
  - R5 Interactive Procedure
- **Domain Knowledge**
  - R6 Prompt Further Elicitation
- **Model Interpretation**
  - R7 Definition
- **Model Flexibility**
  - R8 Handle Inexpressiveness
  - R9 Handle High-Level Domain Information
- **Decision Rationale**
  - R10 Human Judgments
  - R11 Decision Rationale
- **Stakeholder Involvement**
  - R12 Iterative Methodology
- **Analysis Power**
  - R13 Analysis Questions
  - R14 Reliable Analysis
- **Procedure Usability**
  - R15 Simple Analysis Procedures
  - R16 Tool Support Hides Complexity
- **Procedure Selection**

Requirements for Early RE Agent-Goal Model Analysis

- Challenges in Agent-Goal Model Analysis for Early Requirements Engineering
  - Synergies and Conflicts



Thesis Statement

- Framework for Iterative, Interactive Analysis of Agent-Goal Models in Early RE
  - Provide methods, algorithms, and tools
- Address challenges in Early RE Agent-Goal Model Analysis
  - Aim to provide analysis power, improve model quality, increase domain knowledge…
- Framework validation
  - Provide tools and methods which are usable in practice
- We claim that such contributions will ultimately lead to the development of more effective software systems

Iterative, Interactive Agent-Goal Model Analysis Framework

- Goal Model Analysis Review
- Selection Criteria (SAC'11)
- Forward Satisfaction Detailed Comparison (REJ'11)
- Reflective Analysis and Definition of i* (RiGIM'08, iStar'08)
- Forward Evaluation (Caise'09 (short), PoEM'09, IJISMD'10)
- Backward Evaluation (iStar'08, ER'10)
- Analysis Visualization (REV'10)
- Human Judgment Checks (iStar'11)
- Suggested Methodology (Caise'09, PoEM'09, IJISMD'10, PoEM'10)
- Implementation (iStar'11)
- Framework Validation ((coauthor) HICSS'07, REFSQ'08, (first author) PoEM'09, IJISMD'09, PoEM'10, REV'10)

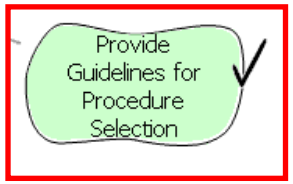
Related Work

- Existing approaches to goal model analysis
  - Forward and backward satisfaction propagation: (Giorgini et al., 2004), (Amyot et al., 2010), (Letier & van Lamsweerde, 2004)…
  - Metrics: (Franch, 2006)…
  - Planning: (Bryl et al., 2007)…
  - Simulation: (Gans et al., 2004)…
  - Model Checking: (Fuxman et al., 2004)…
- Other approaches
  - Goal model development approaches
  - Goal model visualization approaches
  - Analysis methods in RE and business

Horkoff, Depth Oral'08; Horkoff & Yu, SAC'10

Procedure Selection Guidelines

- Abundance of goal model analysis approaches
  - What are the differences?
  - When would I use one and not another?
- Have provided a survey of methods
  - What methods are available?
  - What types of analysis questions can these methods answer?
  - What types of goal modeling constructs do the procedures support?
  - What information is needed in order to use the methods?
- Mapping and Selection
  - What available methods can be applied to achieve which kinds of usage objectives?
  - How can we use this information to advise on selection?



Horkoff & Yu, SAC'10

Goal Model Analysis Approaches: Classification and Additional Information

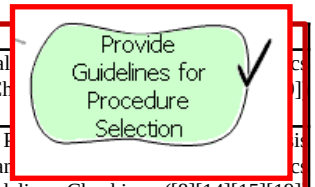
	Approach							Analysis Results			Additional Notation Supported			Analysis Scope	
Approach	**Satisf Forwds**	**Satisf Backwds**	**Human Interv**	**Metrics**	**Plan-ning**	**Simu-lation**	**Model Check**	**Qual**	**Quant**	**Binary**	**Depend-encies**	**Soft-goals**	**Contrib. Links**	**Global**	**Local**
Jureta et al., 2008, 2010	N	Y	N	N	N	N	N	N	N	Y	N	Y	N	Y	N
Chung et al., 2000	Y	N	Y	N	N	N	N	Y	N	Y	N	Y	Y	Y	N
Giorgini et al., 2002, 2004a	Y	N	N	N	N	N	N	Y	Y	Y	N	M	Y	Y	N
Giorgini et al., 2004b	Y	Y	N	N	N	N	N	Y	N	Y	N	M	Y	Y	N
Giorgini et al., 2005	Y	Y	N	N	N	N	N	Y	N	Y	M	Y	Y	M	Y
Ernst et al., 2010	Y	Y	M	N	N	N	N	Y	N	Y	N	M	Y	Y	Y
i* Evaluation, Horkoff, 2006	Y	N	Y	N	N	N	N	Y	N	Y	Y	Y	Y	Y	N
Maiden et al., 2007	Y	N	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	N
Z.151, 2008, Amyot et al., 2010, Pourshahid et al., 2011	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Asnar & Giorgini, 2006	Y	Y	N	N	N	N	N	Y	M	Y	N	M	Y	Y	N
Barone et al., 2011	Y	N	N	N	N	N	N	Y	Y	Y	N	M	Y	Y	N
Letier & van Lamsweerde, 2004	Y	Y	N	N	N	N	N	N	Y	Y	M	N	N	Y	N
van Lamsweerde, 2009	Y	N	N	N	N	N	N	N	Y	Y	N	Y	M	Y	N
Franch & Maiden, 2003	N	N	N	Y	N	N	N	N	Y	N	Y	Y	N	Y	N
Franch et al., 2004	N	N	N	Y	N	N	N	M	Y	N	Y	Y	N	Y	Y
Franch, 2006	N	N	Y	Y	N	N	N	Y	Y	N	Y	Y	Y	Y	Y
Kaiya et al, 2002	N	N	N	Y	N	N	N	N	Y	Y	N	N	M	Y	N
Tanabe et al., 2008	Y	N	N	Y	N	N	N	N	Y	Y	N	N	M	Y	N
Bryl et al., 2006a	N	N	N	Y	Y	N	N	N	Y	Y	Y	N	N	M	Y
Bryl et al., 2009a	N	N	Y	Y	Y	N	Y	M	Y	Y	Y	N	N	M	Y
Asnar et al., 2007	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	M	Y	Y	N
Liaskos et al., 2011	N	N	M	N	Y	N	N	Y	Y	Y	N	M	N	Y	N
Gans et al. 2002	N	N	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	N
Gans et al, 2003a, 2004	N	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	M	M
Gans et al., 2001, 2003b	N	N	N	Y	N	Y	M	N	Y	Y	Y	N	N	Y	N
Wang & Lesperance, 2001	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N
Fuxman et al., 2001, 2003	N	N	M	N	N	N	Y	N	N	Y	Y	Y	N	Y	M
Giorgini et al., 2004c	N	N	N	N	N	N	Y	N	N	Y	Y	N	N	Y	N
Bryl et al., 2006b	N	N	N	N	Y	N	Y	N	N	Y	Y	N	N	Y	N

Classification by analysis approach, result, notation supported, and scope

Summarize additional information needed (e.g., cost, preference, metrics)

	Additional Information	Required by
1	Goal Cost	Satisfaction Analysis: (Giorgini et al., 2005)(Asnar et al., 2007) (Giorgini et al., 2004b)(Asnar & Giorgini, 2006), Planning: (Bryl et al., 2006a)
2	Risk	Satisfaction Analysis: (Asnar & Giorgini, 2006), Planning: (Asnar et al., 2007)
3	Textual Arguments	Satisfaction Analysis:(Maiden et al., 2007) , Metrics, Model Checking: (Kaiya et al., 2002)
4	Probabilistic Information	Satisfaction Analysis: (Giorgini et al., 2005) (Letier & Lamsweerde, 2004)
5	Events and Treatments	Satisfaction Analysis: (Asnar & Giorgini, 2006)
6	Importance/Priority	Satisfaction Analysis: (Asnar & Giorgini, 2006) Planning: (Liaskos et al., 2011)
7	Actor Capabilities	Planning: (Bryl et al., 2006a, 2007) (Asnar et al., 2007), Model Checking: (Bryl et al., 2006a):
8	(Pre/Post) Conditions/ Temporal Information	Planning: (Liaskos et al., 2011) Simulation: (X. Wang & Lespérance, 2001) (Gans et al., 2003a) (Gans et al., 2005) (Gans et al., 2003b), Model Checking: (Fuxman et al., 2001) (Fuxman et al., 2003)
9	Delegation/Ownership	Model Checking: (Gans et al., 2002) (Bryl et al., 2006b):
10	Trust	Planning: (Asnar et al., 2007), Simulation: (Gans et al., 2003b), Model Checking: (Giorgini et al., 2004c) (Bryl et al., 2006b):
11	Speech Acts	Simulation: (Gans et al., 2003b)
12	Confidence and Distrust	Simulation: (Gans et al., 2003b)
13	Preferences	Satisfaction Analysis: (Jureta et al., 2008, 2010), (Ernst et al. 2010) Planning: (Liaskos et al., 2011) Model Checking: (Kaiya et al., 2002)
14	Cardinalities	Simulation:(X. Wang & Lespérance, 2001), Model Checking: (Fuxman et al., 2003)
15	Domain specific formula	Satisfaction Analysis: (A Pourshahid et al., 2008) (Barone et al., 2011) (Letier & Lamsweerde, 2004)
16	KPIs/Metrics/Gauges	Satisfaction Analysis: (Pourshahid et al., 2008) (Pourshahid et al., 2011) (Barone et al., 2011) (Lamsweerde, 2009)
17	Mandatory/Optional Requirements	Satisfaction Analysis: (Jureta et al., 2008, 2010), (Ernst et al., 2010) Planning: (Liaskos et al., 2011)

Mapping Procedures to Objectives

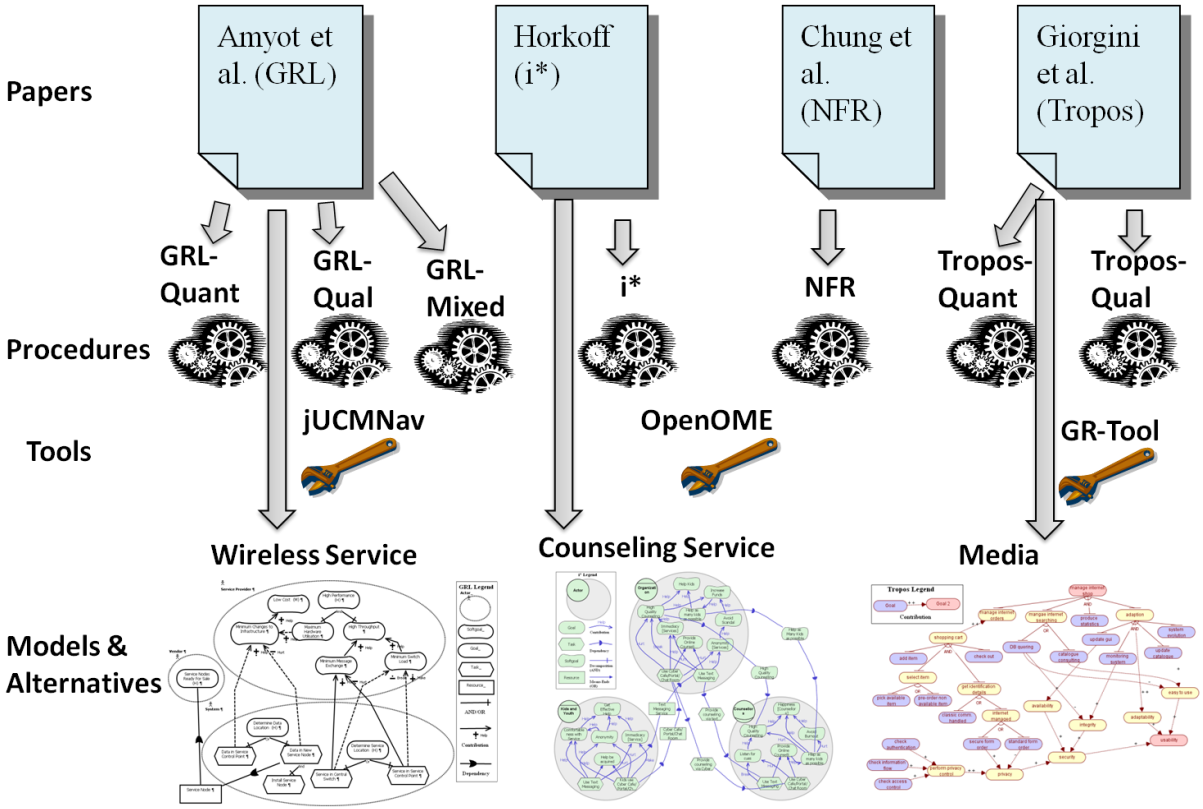


Objectives

Procedures

Category	Guidelines	Recommended Procedures
Domain Understanding	QU1. Does the domain contain a high degree of social interaction, have many stakeholders with differing goals, or involve many interacting systems?	**Yes. Try:** Agent Approaches: i*/GRL Satisfaction Anal ([11][12][13]) Tropos Metrics, Planning, or Model Ch SNET([16][17][18])
	QU2. Do you need to understand details of the system at this point? Do you have access to detailed information such as cost, probabilities, and conditions? Can you express necessary or desired domain properties?	**Yes. Try:** Quantitative or Detailed Information: Tropos ([3][21][22][23]) KAOS Satisfaction Analysis ([31]) GRL Quan ([11][12][13]) Tropos Planning ([4][6][7][8]) Tropos Modeling Checking ([8][14][15][19] SNET([16][17][18][18]) i* Simulation([34]), or Model Checking: Tropos ([8][14][15][19] SNET([16][18])
Communication	QC1. Do you need to communicate with stakeholders? Validate requirements in the model? Justify recommendations?	**Yes. Try:** Forward Satisfaction Approaches: NFR([9]) Tropos([3][21][22][23]) KAOS([31] i*([26][33]) GRL([1])
Model Improvement	QM1. Are you confident in the accuracy, structure, and completeness of domain knowledge and models?	**No. Try:** Interactive Approaches: NFR([9]) i*([26][27][33]) Tropos([4][7]) SNET([16][18]) i* Metrics([11])
	QM2. Would you like to verify critical properties over the model?	**Yes. Try:** Model Checking: Tropos([8][14][15][19]) SNET([16][18])
Scoping	QS1. Do you need to determine system scope?	**Yes. Try:** Agent Approaches: i*/GRL Satisfaction Analysis ([1][26] [27][33]) i* Metrics ([11][12][13]) Tropos Metrics, Planning, or Model Checking ([4][6][7][8][14][15][19]) SNET ([16][18])
Requirements Elicitation	QE1. Do you need to find more high-level requirements? Are you looking f prompt further elicitation?	**Yes. Try:** Interactive Approaches: NFR([9]) i*([27][27][33]) Tropos([4][7]) SNET([16][18]) i* Metrics([11])
	QE2. Do you need to find detailed system requirements?	**Yes. Try:** Quantitative or Detailed Information: Tropos Probabalistic Satisfaction Analysis ([3][21][22][23]) KAOS Satisfaction Analysis ([31]) GRL Quant. Analysis ([1]) i* Quant. Metrics ([11][12][13]) Tropos Planning ([4][6][7][8]) Tropos Modeling Checking ([8][14][15][19] SNET([16][17][18][18]) i* Simulation([34])
	QE3. Do you need to consider non-functional requirements difficult to quantify?	**Yes. Try:** Approaches supporting softgoals or contributions: NFR([9]) i* Satisfaction Analysis ([26][27][33]) Tropos Satisfaction Analysis ([3][21][22][23]) Tropos Model Checking([14][15] GRL([1]) i* Metrics([11][12][13]) SNET([16][17][18])
	QE4. Do you need to capture domain assumptions?	**Yes. Try:** Approaches using Satisfaction Arguments: i* Satisfaction Arguments [33]
Requirements Improvement	QR1. Are you working with a system where safety/security/ privacy/risks or other specific properties are critical considerations?	**Yes. Try:** Analysis over Specific Constructs or Metric Approaches: KAOS([31]) i* Metrics([11][12][13]) AGORA([30]) Tropos Risk, Trust, and Security([3][4] [8][19]) SNET Trust([17])
	QR2. Do you need to find errors and inconsistencies in requirements?	**Yes. Try:** Model Checking: Tropos([8][14][15][19]) SNET([16][18])
Design	QD1. Are you aware of a sufficient number of high-level design alternatives?	**No. Try:** Agent, Planning, Forward and Backward Satisfaction Approaches: NFR([9]) i* Satisfaction Analysis ([26][27][33]) Tropos Planning([4][6][7][8]) KAOS([31]) GRL Forward Satisfaction Analysis([1]) SNET Planning([16][18])
	QD2. Are you aware of a sufficient number of detailed design alternatives?	**No. Try:** Quantitative Planning, Forward and Backward Satisfaction Approaches: KAOS Satisfaction Analysis ([31]) GRL Forward Satisfaction Analysis([1]) Tropos Planning([6][7] SNET Planning([16][18])
	QD3. Do you need to evaluate and choose between high-level design alternatives?	**Yes. Try:** Satisfaction Analysis, Metrics and Agent Approaches: KAOS Satisfaction Analysis([31]) i* Forward Satisfaction([26][33]) GRL Satisfaction Analysis([1]) i* Metrics([11][12][13]) Tropos Risk([4])
	QD4. Do you need to evaluate and choose between detailed design alternatives?	**Yes. Try:** Quantitative or Detailed Information: Tropos Probabalistic Satisfaction Analysis ([3][21][22][23]) KAOS Satisfaction Analysis ([31]) GRL Quant. Analysis ([1]) i* Quant. Metrics ([11][12][13]) Tropos Planning ([4][6][7][8]) Tropos Modeling Checking ([8][14][15][19] SNET([16][17][18][18]) i* Simulation([34])
	QD5. Do you need to find acceptable processes?	**Yes. Try:** Planning Approaches: Tropos Planning([4][6][7][8]) SNET Planning([16][18])
	QD6. Do you need to test run-time operation before implementation?	**Yes. Try:** Simulation Approaches: SNET([16][17][18]) i* Simulation([34])

Forward Satisfaction Techniques: Detailed Comparison



- Analysis results over "softer" models (dependencies, softgoals) can differ greatly between procedures with different model interpretations
- Goal model analysis should be used as a heuristic, not an oracle
- Emphasizes the other benefits of goal model analysis

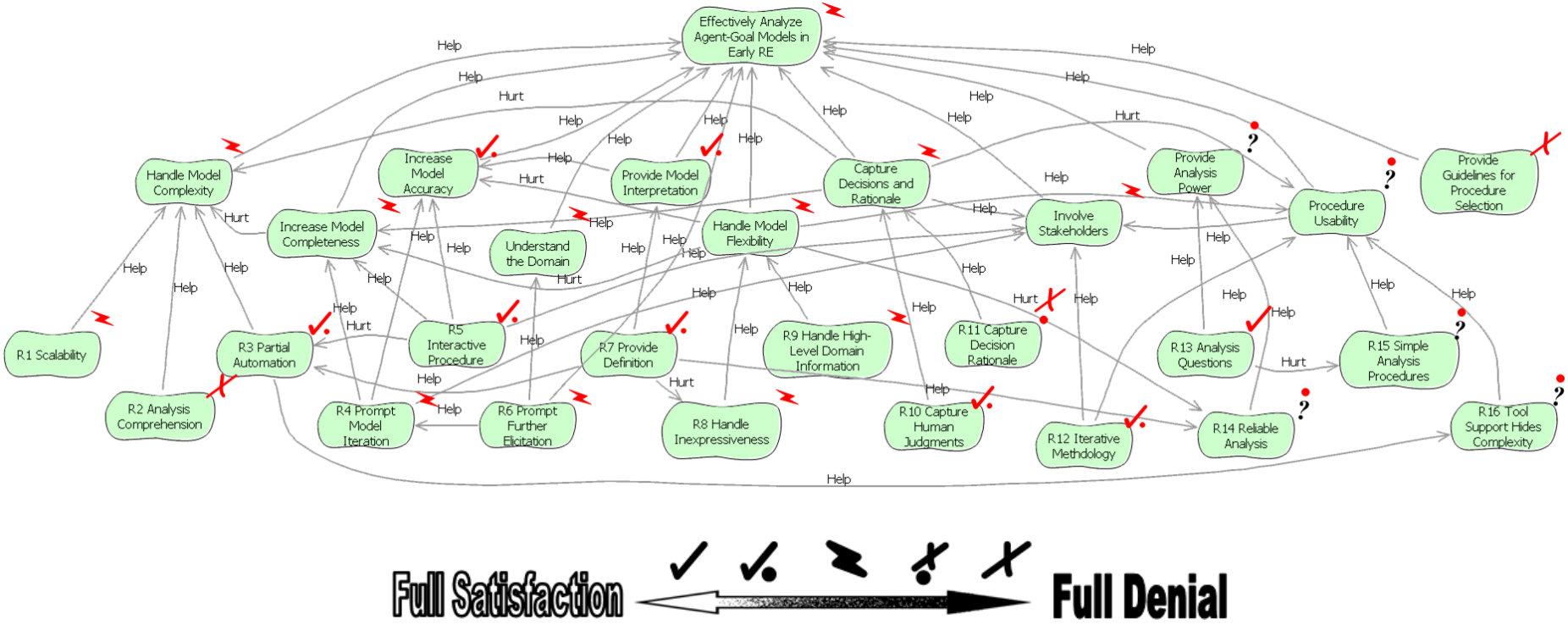
Horkoff & Yu, REJ'11

Suitability of Existing Goal Model Analysis Approaches for Early RE

- Model Complexity
  - Some argue for scalability
  - Few address analysis comprehension
  - Almost all are fully automated
- Model Completeness & Accuracy
  - Only a few mention iteration over models
  - Most are not interactive
- Domain Knowledge
  - Not addressed explicitly
- Model Interpretation
  - Several formal interpretations
- Model Flexibility
  - Most are formal or quantitative
  - Many require additional information
- Decision Rationale
  - Only a few capture human judgment or design rationale
- Stakeholder Involvement
  - Many do not provide methodology
  - Existing methodologies mostly focus on analysis and not iteration
- Analysis Power
  - Many analysis questions can be answered
  - Reliability addressed indirectly via examples and case studies
- Procedure Usability
  - Most do not address usability of procedure or tool support
- Procedure Selection
  - Not addressed

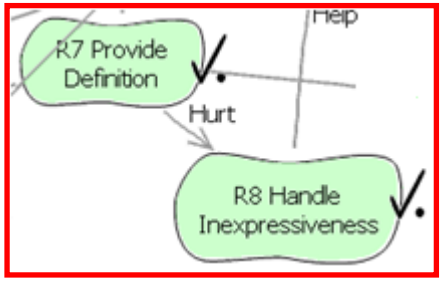
Suitability of Existing Goal Model Analysis Approaches for Early RE

- Satisfaction Analysis for the Requirements for analysis of Agent-Goal Models in Early RE based on a Combination of Existing Work



Reflective Analysis and Formal Definition of i*

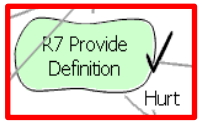
- As i* has been adopted and used, it's use has evolved
- Survey 15 student projects and 15 academic papers using i*
- Looking for variations from "U of T" style
- Lead to the creation of strict and loose i* syntax
  - List of i* sytnax errors and warnings



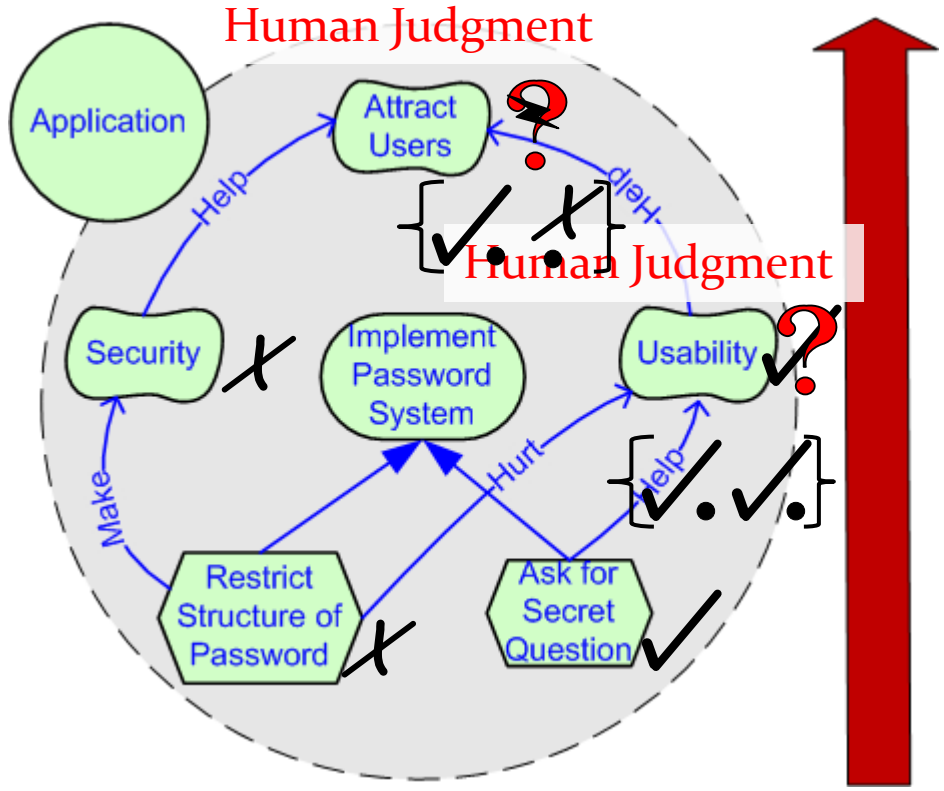
- Create more precise definition of i* which to help remove ambiguity in the syntax and support semi-automated analysis
  - E.g., **Definition: agent-goal model.** *An i* model is a tuple* M = <I, R, A>, *where* I *is a set of intentions,* R *is a set of relations between intentions, and* A *is set of actors.*
- Definition aims to support common variations (warnings)

Horkoff et al., RiGIM'08; Horkoff & Yu, ER'10; Grau et al., iStar'08, i* Wiki, 2010

Iterative, Interactive, Forwards Satisfaction Analysis



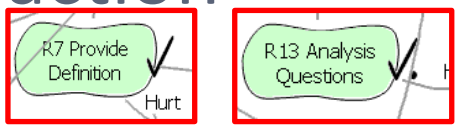
- An analysis alternative is given in the model and its effects are propagated "forward" through model links
- Propagation defined using qualitative labels through model links
- Interactive: user input (human judgment) is used to decide on partial or conflicting evidence "What is the resulting value?"
- Adapted from Horkoff (2006) (MSc Thesis)
  - Described in new formalism
    - Forward propagation axioms
  - Updated algorithm, *O(n)*
  - Readdress convergence & termination



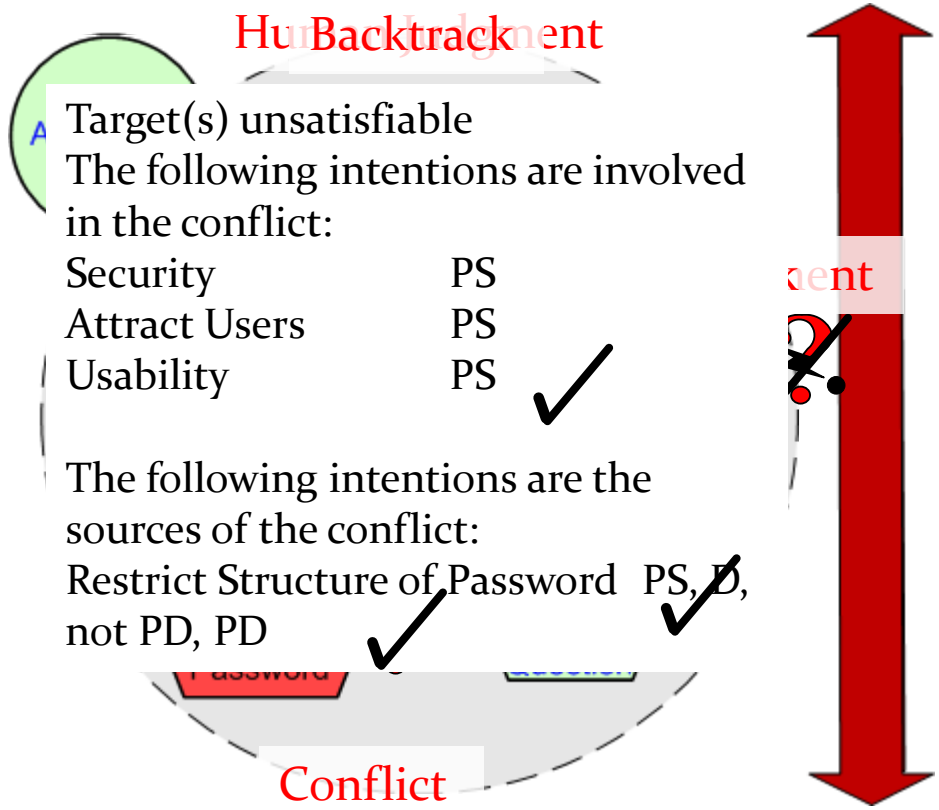
What if...?

Horkoff & Yu, Caise'09 (short), PoEM'09, IJISMD'10, ER'10

Iterative, Interactive, Backward Satisfaction Analysis



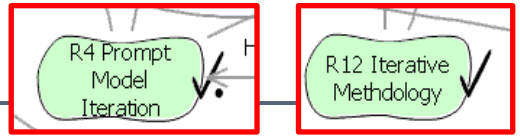
- A target is placed on the model and its affects are propagated "backward" through model links
  - Asks for human judgment "What incoming values could produce the target value?"
  - Model is iteratively encoded in CNF form and passed to a SAT solver
    - Backward propagation axioms
  - Modify and expand encoding from (Giorgini et al., 2004b)
    - Single analysis value per goal
    - More analysis values
    - Extra i* syntax
  - Model restrictions: no mixture of links, no cycles
  - Algorithm worst case $O(6^q(\ln^2 + n(\text{zChaff})))$



Is this possible...? How?

Horkoff & Yu, iStar'08, ER'10

A Methodology for Agent-Goal Model Creation and Analysis

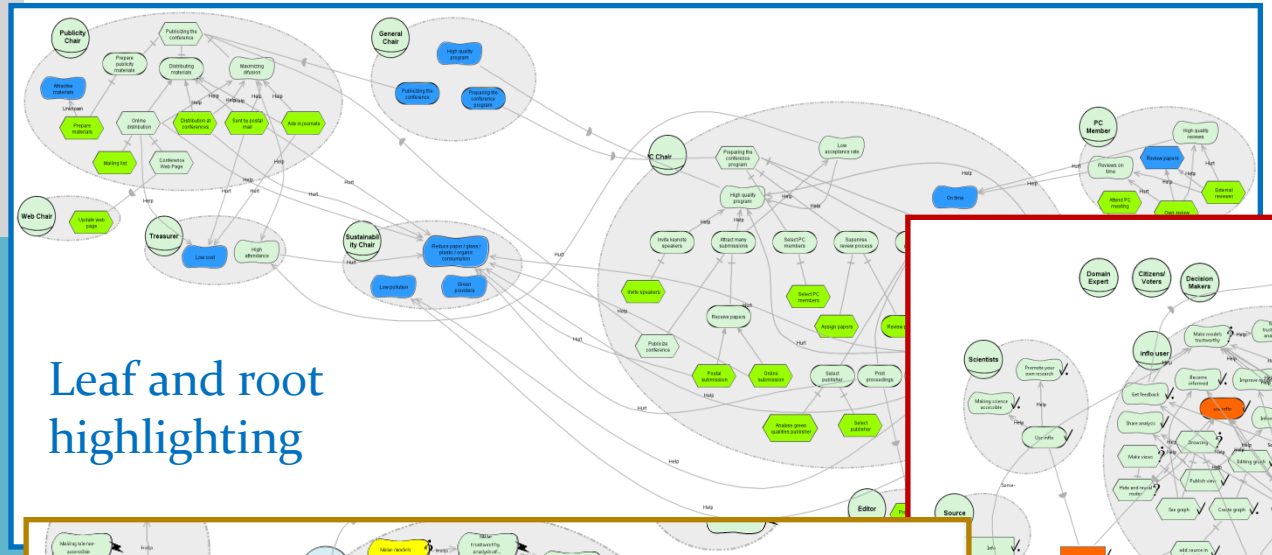


Apply the following steps iteratively:

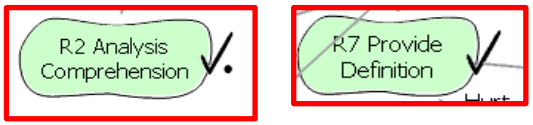
- **Stage 1: Purpose and Elicitation**
  - Identify scope or purpose of the modeling process.
  - Identify modeling participants and/or model sources.
- **Stage 2: Model Creation**
  - Identify relevant actors and associations.
  - Identify relevant dependencies.
  - Identify actor intentions.
  - Identify relationships between intentions.
- **Stage 3: Analysis**
  - Alternative Effects (Forward Analysis)
    - Identify all leaf intentions in the model, evaluate:
      - Implementing as much as possible.
      - Implementing as little as possible:
      - Reasonable Implementation Alternatives.
  - Achievement Possibilities (Backward Analysis)
    - Identify all roots in the model, evaluate:
      - Maximum targets.
      - Minimum targets.
      - Iteration over minimum targets.
  - Domain-Driven Analysis (Mixed)
    - Use the model to answer interesting domain-driven questions.

Horkoff & Yu, PoEM'09, IJISMD'10

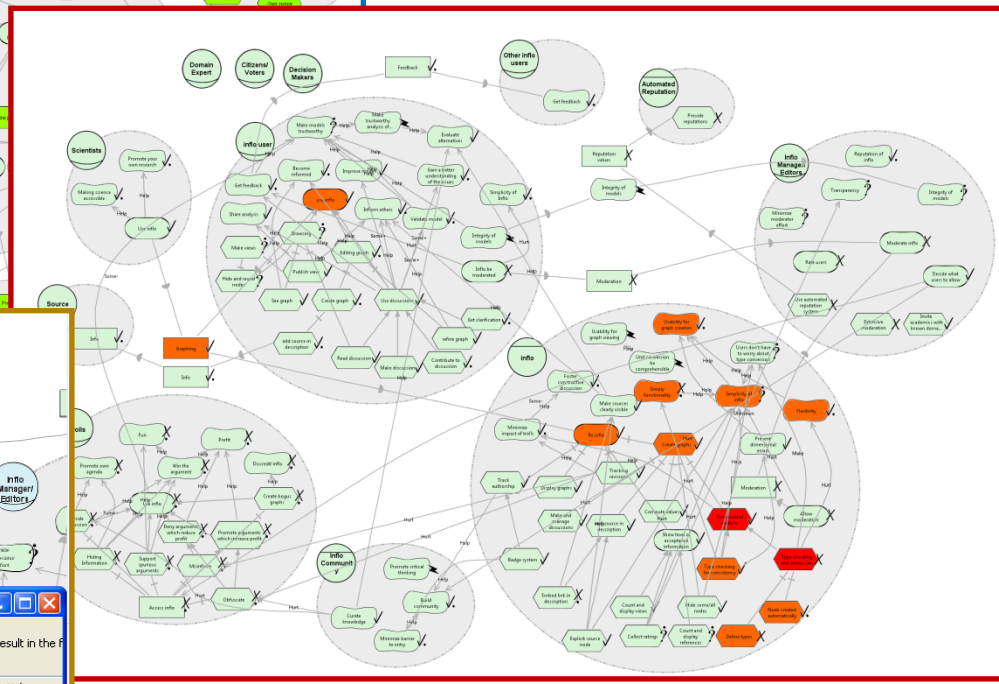
Visualization Techniques for Analysis

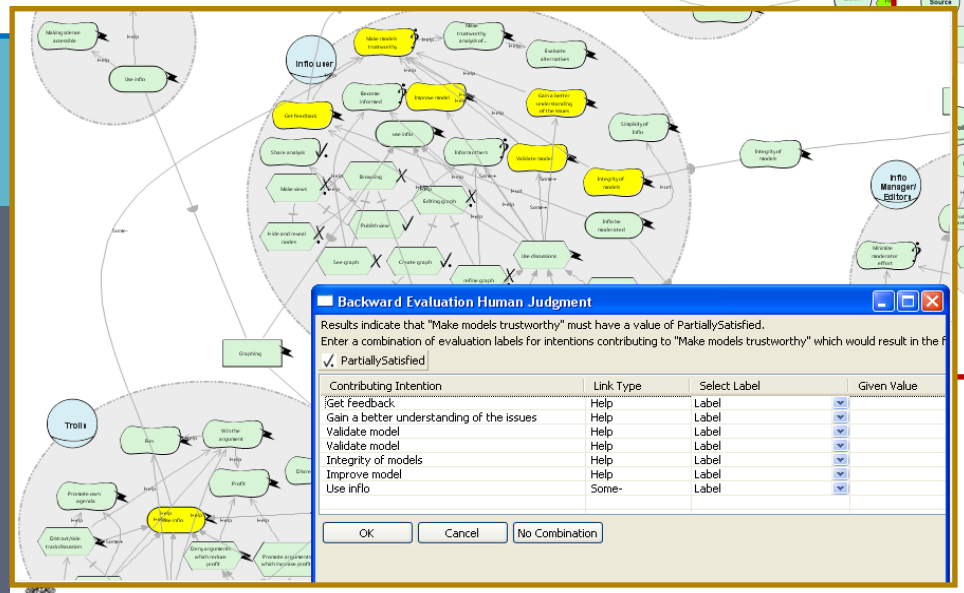


Leaf and root highlighting



Conflict highlighting



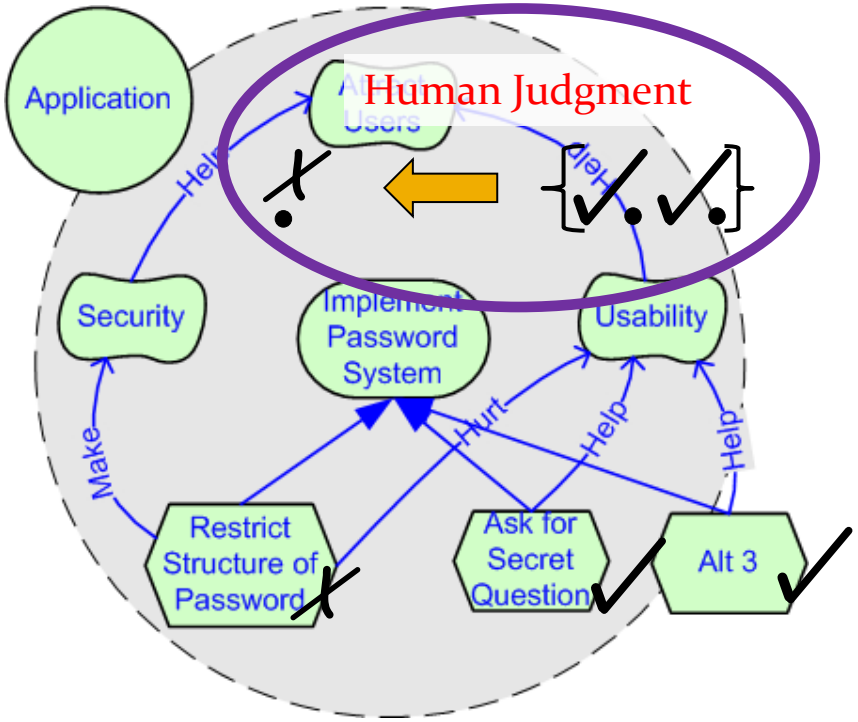


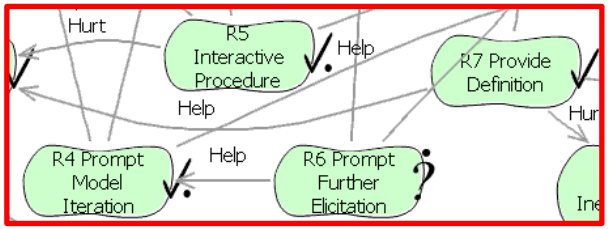
Human judgment highlighting

Horkoff & Yu, REV'10

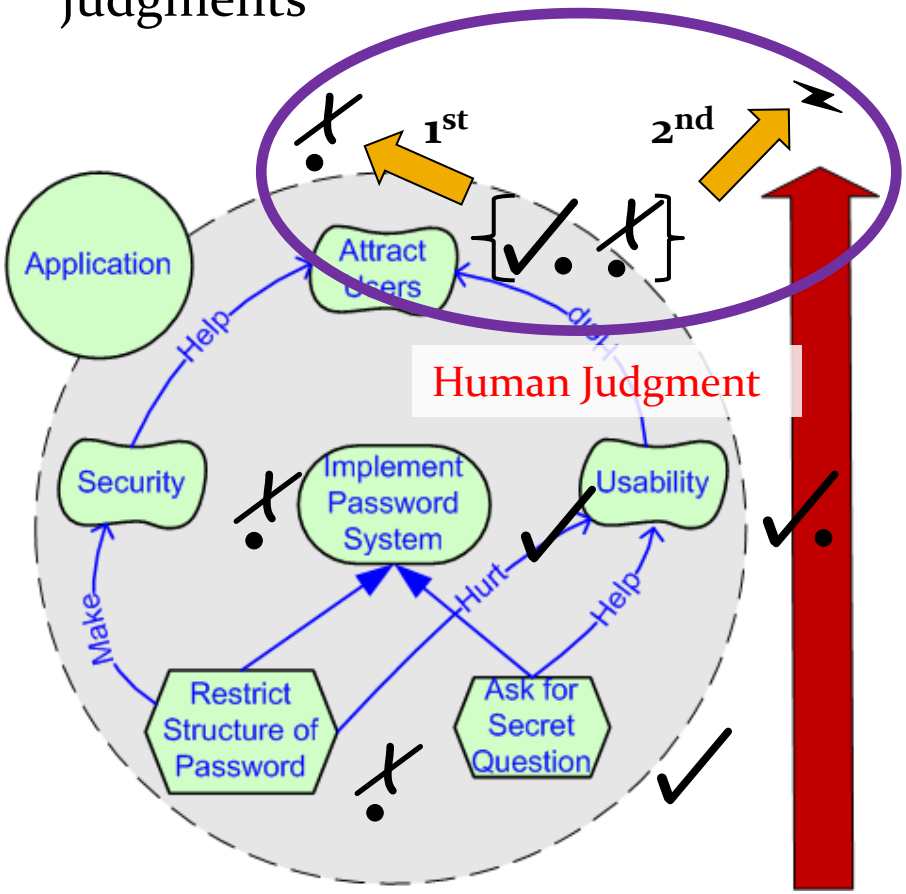
Detecting Judgment Inconsistencies to Encourage Model Iteration in Analysis

- Consistency with the model



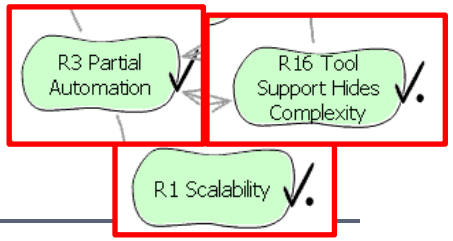


- Consistency with previous judgments



Horkoff & Yu, iStar'11

Tool Support: OpenOME



Project Explorer

Analysis Buttons

Tree View

Canvas

Outline View

Alternatives Tab

Judgments Tab

Palette

Horkoff, Yu &Yu, iStar Tool Fair'11

Framework Validation: Manual Forward Procedure Application

- Analyzing effects of Trusted Computing
- Modeling strategy documents (FIS Strategy, USA Security Strategy)
- Counseling Service
  - Stage 1 (Horkoff, 2006): Understanding organization and technology options
  - Stage 2 (Horkoff, 2006): Requirements for revised online counseling system
  - Stage 3: Knowledge management needs and options
    - Analyzing effectiveness of knowledge transfer agents (Strohmaier et al., HICSS'07)
    - Analysis as part of pattern application (Strohmaier et al., REFSQ'08)
- Contributions and Lessons
  - Demonstrated cognitive scalability, answered domain questions, described viewpoints
  - Analysis reveals disconnected models, incomplete strategies, strategy achievability
  - Analysis helped to evaluate and compare technology options, alternative system features, and knowledge management interventions
  - Evidence of model and domain knowledge iteration
  - Models were too large – importance of scoping
- Exploratory Experiment – comparing ad-hoc vs. systematic forward analysis
  - Systematic analysis provoked model changes and questions beyond ad-hoc analysis

Horkoff, Yu & Liu, PST'06; Horkoff & Yu, PoEM'09, IJISMD'10, Strohmaier et al. HICSS'07, REFSQ'08

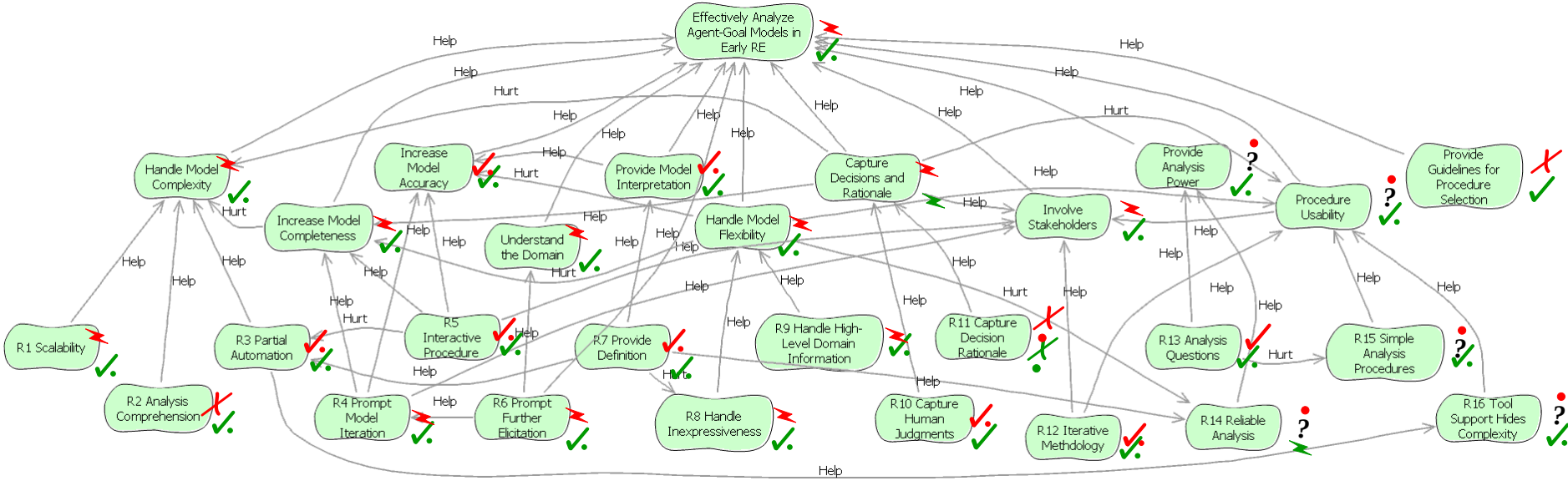
Framework Validation: Forward and Backward Implementation

- Individual Case Studies (10 students with i* experience)
  - Compare effects of ad-hoc vs. systematic forward and backward analysis
  - Five follow-up studies to test visualizations
- Group Case Study: inflo modeling tool
- Quantitative and qualitative analysis of model changes, audio recordings, and video

- Results
  - Participants had some difficulty analyzing large models created by others
  - No significant difference in the model changes and questions asked using ad-hoc vs. systematic analysis
  - Systematic analysis was well-received and generally usable
  - Systematic analysis increased analysis coverage, interpretation consistency, and revealed model incompleteness
  - Group analysis lead to some interesting discussion and model iteration
  - Needed domain-driven questions – lead to creation of methodology (sanity checks)
- Conclusion
  - Analysis is most effective when participants are motivated by realistic situations and driving domain questions

Framework Contributions

- Requirements Engineering
- Agent-Oriented Software Engineering
- Goal-Oriented Requirements Engineering
- Model-Driven Engineering
- Agent-Goal Modeling
- Analysis of Early Requirements
- Reasoning with Conflicts



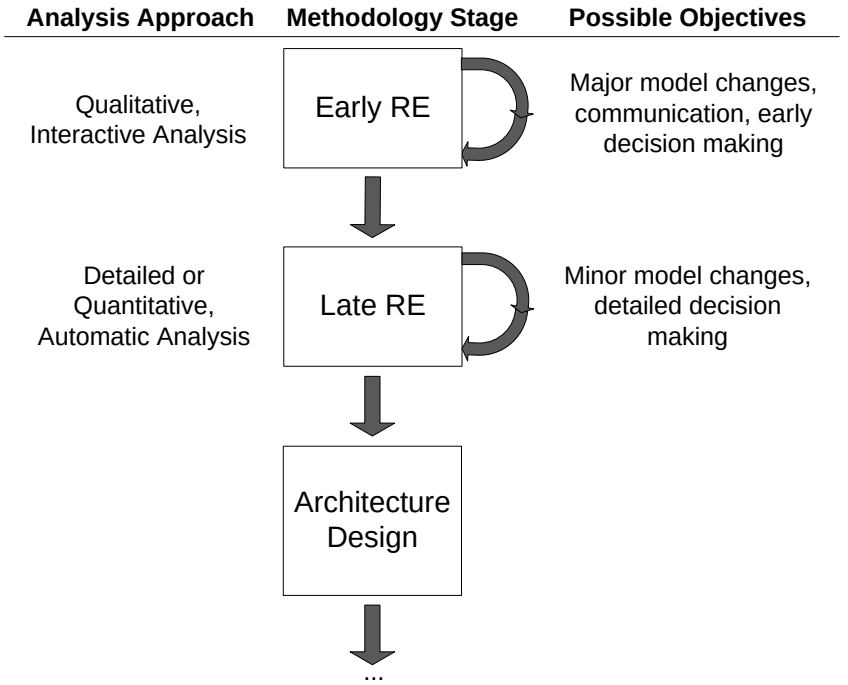
- Combination of existing approaches
- Contributions of current Framework

Limitations

- Goal Modeling Limitations
  - Scalability, comprehension, learning curve
- Generalizability
  - Applied to i*. Other goal modeling frameworks?
- Validation Results
  - Mixed results
  - Model iteration and elicitation primarily occurred in realistic studies with experienced modelers
  - Results due to interactive analysis or careful examination of model?
  - Fully-automatic provoke same benefits? Level of automation/interactivity
- Validation Study Design
  - Realistic domain and motivation – hard to measure benefits
  - Controlled study – hard to emulate realistic domain and motivation

Future Work

- Additional Framework Features
  - Judgment Rationale and Assumptions
  - Varying Levels of Automation
  - Handling Iteration over Models and Analysis Results
  - Further visualizations
- Future Directions
  - From Early to Late RE
  - Confidence in Analysis Results
  - Analysis of uncertain models



Thank you

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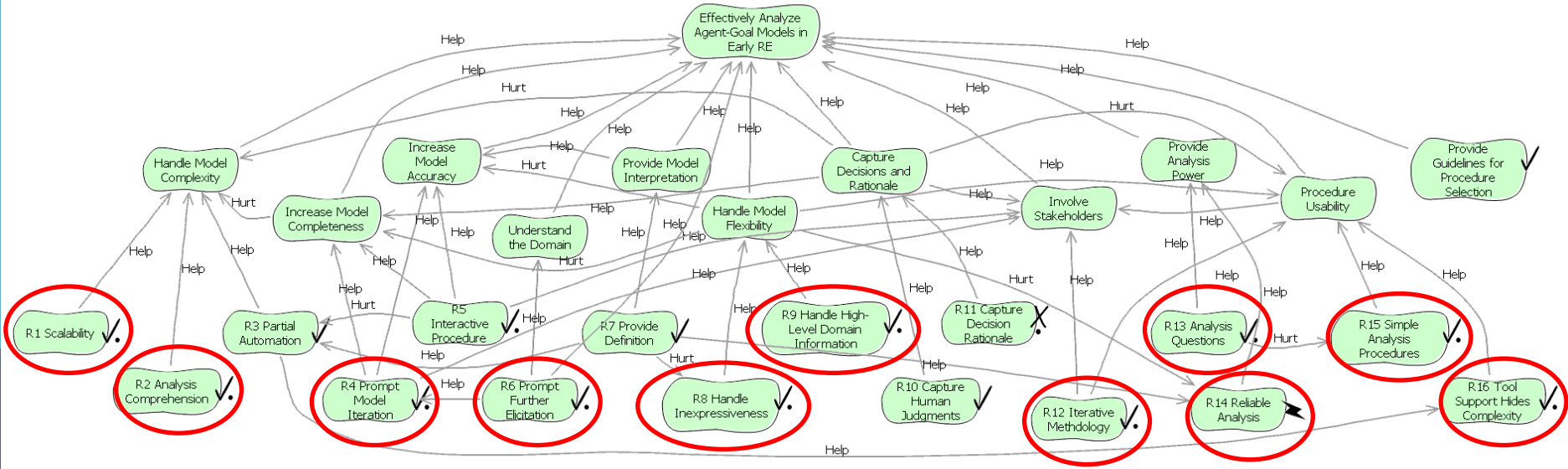
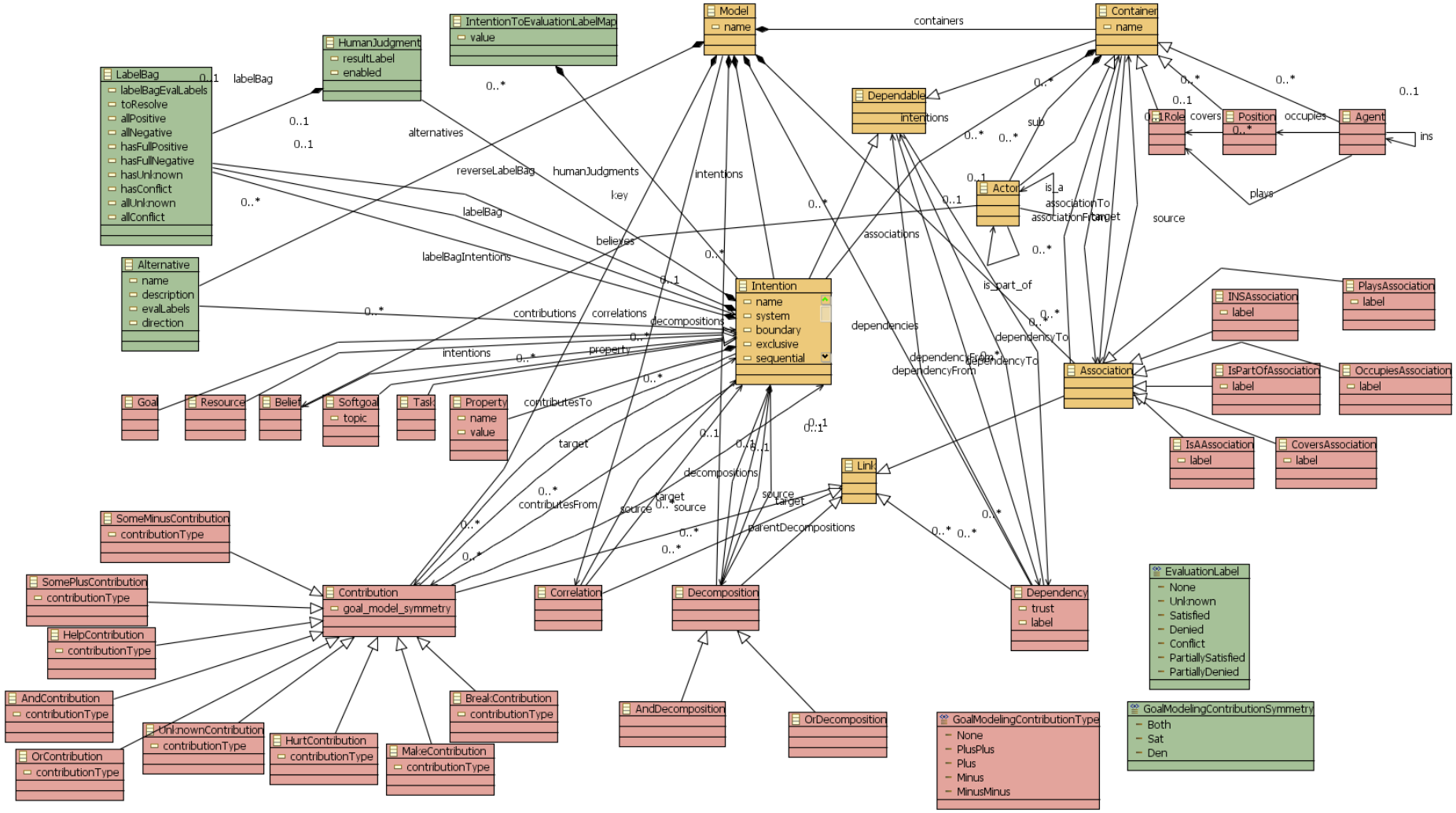
Validation Contributions

- Contributions of validation studies to the Requirements for analysis of Agent-Goal Models in Early RE



Tool Support: Metamodel



Tool Support: Scalability Tests

Time Measures	Model 1		Model 2		Model 3	
	Alt 1	Alt 2	Alt 1	Alt 2	Alt 1	Alt 2
Num Judgments in Analysis	2	2	15	15	23	22
Num Intentions receiving Judgments	2	2	9	9	16	16
Max Judgment Time	4.109	4.875	5.813	6.390	19.734	15.078
Min Judgment Time	2.750	4.297	2.531	2.141	2.718	2.969
Average Judgment Time	3.429	4.586	4.328	3.930	8.048	6.296
Total Judgment Time	6.859	9.172	64.922	58.954	185.106	138.517
Total Computation Time	0.25	0.156	1.547	3.499	3.347	3.436
Total Analysis Time						

Timing (Seconds) and Statistic Results for Forward Analysis Runs

Timing (Seconds) and Statistic Results for Backward Analysis Runs

Time Measures	Model 1		Model 2		Model 3	
	Alt 1	Alt 2	Alt 1	Alt 2	Alt 1	Alt 2
Num Judgments in Analysis	5	3	4	2	1	5
Num Intentions receiving Judgments	2	2	1	2	1	2
Max Judgment Time	9.594	13.078	145.453	36.219	9.766	40.547
Min Judgment Time	3.047	2.062	2.032	12.813	9.766	4.438
Average Judgment Time	7.187	25.906	55.523	24.516	9.766	18.162
Total Judgment Time	35.937	8.635	222.094	49.032	9.766	90.814
Num Non-judgment Messages	2	2	4	1	1	4
Total Time for Non-judgment Messages	4.796	9.077	72.220	2.265	3.437	49.984
Total Computation Time	0.579	17.616	30.905	1.047	2.391	150.765
Total Analysis Time	41.312	35.328	325.219	52.344	15.594	291.563