UNIVERSITÀ DEGLI STUDI
DI TRENTO

Goal Oriented Requirements Engineering: Basics, Past, Current, and Future Work

Jennifer Horkoff
DISI, University of Trento

Invited talk visiting: Departamento de Informática,
Universidad Técnica Federico Santa María
May 23rd, 2013

Outline

- GORE (Goal-Oriented Requirements Engineering) Motivation
- Goal Model Basics
  - Example Application
  - Example: Goal modeling with i*
  - Frameworks and further examples
- GORE Extensions/Applications: Past and Current Work (Selected Examples)
  - Goal Model Analysis
  - Uncertainty
  - Business Intelligence
  - Adaptation & Evolution
  - Run-time Analysis
  - Security
  - Alignment & Evolution
- Community & Events
- Tool Support
- Challenges & Open Topics
- References

Why Goal-Oriented Requirements Engineering?

- Most systems today are socio-technical, e.g.,
  - E-business; E-learning; E-health; E-government
  - Energy, environment, transportation
- Complex relationships among stakeholders
  - Help stakeholders understand their needs:
    - E.g., security, privacy, trust, profitability, market positioning, strategic alliances, intellectual property, …
  - Help each other achieve what they want
  - Understanding "why", not just "what"
- Technology embedded into stakeholder lives
- Goal-Oriented Requirements Engineering
  - Captures stakeholder needs (goals), interrelationships (dependencies), relationships with technology, alternative requirements, and tradeoffs amongst alternatives

Example Application: Strategic Requirements Analysis for Kids Help Phone

- Kids Help Phone (KHP) is a not-for-profit organization which provides counseling for Canadian children and youth.
- Traditionally, KHP has provided counseling via phone
- As new technology is introduced, KHP wanted to go where the kids are: the web
- How can counseling services be effectively provided on-line?
- How can the organization continue to ensure:
- Anonymity? Confidentiality? Quality of Service?

Easterbrook, Yu, Aranda, Horkoff, Strategic Requirements Analysis for Kids Help Phone

Example Application: Security Requirements of a WiFi-based Navigation System

- In a WiFi-based navigation system, users navigate inside buildings using WiFi access points
- The system could use existing WiFi access points or could install new access points
- Using existing access points saves money

Location estimation

Security issues: WiFi access points may be switched off

Golnaz Elahi, Eric Yu, "Trust Trade-off Analysis for Security Requirements Engineering"

Example Application: "Greening" of ICSE Conference

- ICSE'09 wanted to "go green", cutting down it's eco footprint
- The conference must balance this goal with other factors affecting overall conference success, including:
  - Quality program, satisfied attendees, quality venue, good keynotes, positive relationship with sponsors, financial success, quality workshops, involvement of industry,…
- How can we reason over and make tradeoffs between sustainability and other goals?


J. Cabot, S. Easterbrook, J. Horkoff, J. N. Mazon, L. Lessard, S. Liaskos: Integrating Sustainability in Decision-Making Processes

Goal-Oriented Requirements Engineering

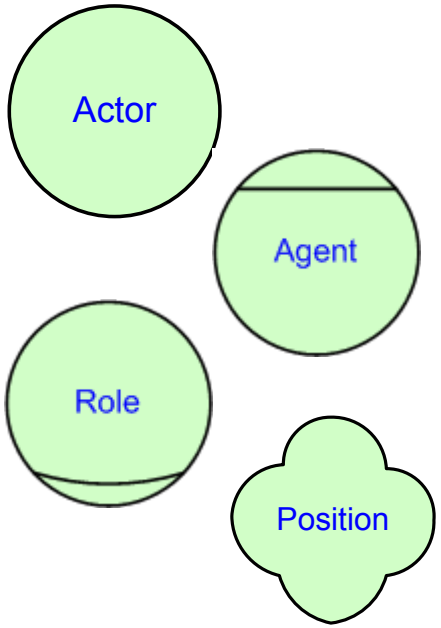
- GORE aim to capture both social and technical aspects of computer systems.
- In GORE, we want to capture:
  - Agents
  - Goals of agents
  - Dependencies between agents
  - Relationships between agents
  - Alternative solutions
  - Relationships between goals
  - Goal satisfaction
- We typically capture these aspects using graphical models.

Example Goal Modeling Framework: i* (Distributed Intentionality)

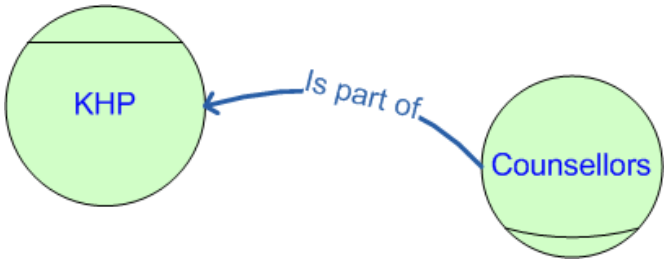
- i* is divided into two types of diagrams
- Strategic Dependency (SD) Diagram
  - Who is involved (technical and social actors)?
  - What do they need from each other (dependencies)?
  - What is the nature of their dependencies?
    - Achieve a goal? Precisely defined?
    - Perform a task?
    - Provide a thing/entity?
- Strategic Rational (SR) Diagram
  - "Opens-up" each actor
  - Provides the "how" and "why" for dependencies
  - Goal refinement
  - Goal alternatives
  - Explores trade offs

i* Strategic Dependency Diagram (1)

- Actors: General type
  - Agent: software or social agent:
    - E.g. Counseling System, ICSE, Web Service, KHP
  - Role: collection of responsibilities
    - E.g. Client, Kid, Counselor, PC Chair
  - Position: collection of roles
    - E.g. Counseling Manager

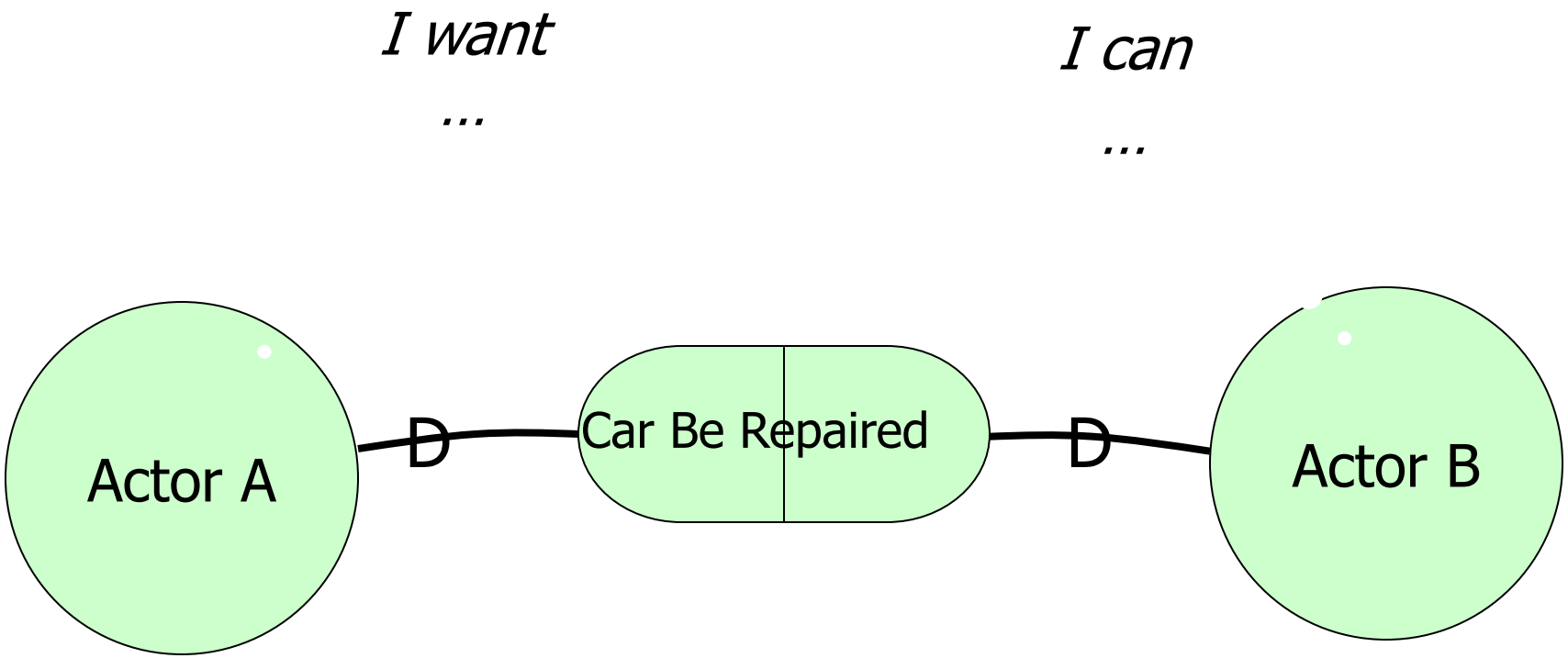


- Actor Associations:
  - Plays, is-a, occupies, ins, is part-of



- These concepts can be used to draw actor association diagrams

Strategic Dependency Relationship



i* Strategic Dependency Diagram (2)

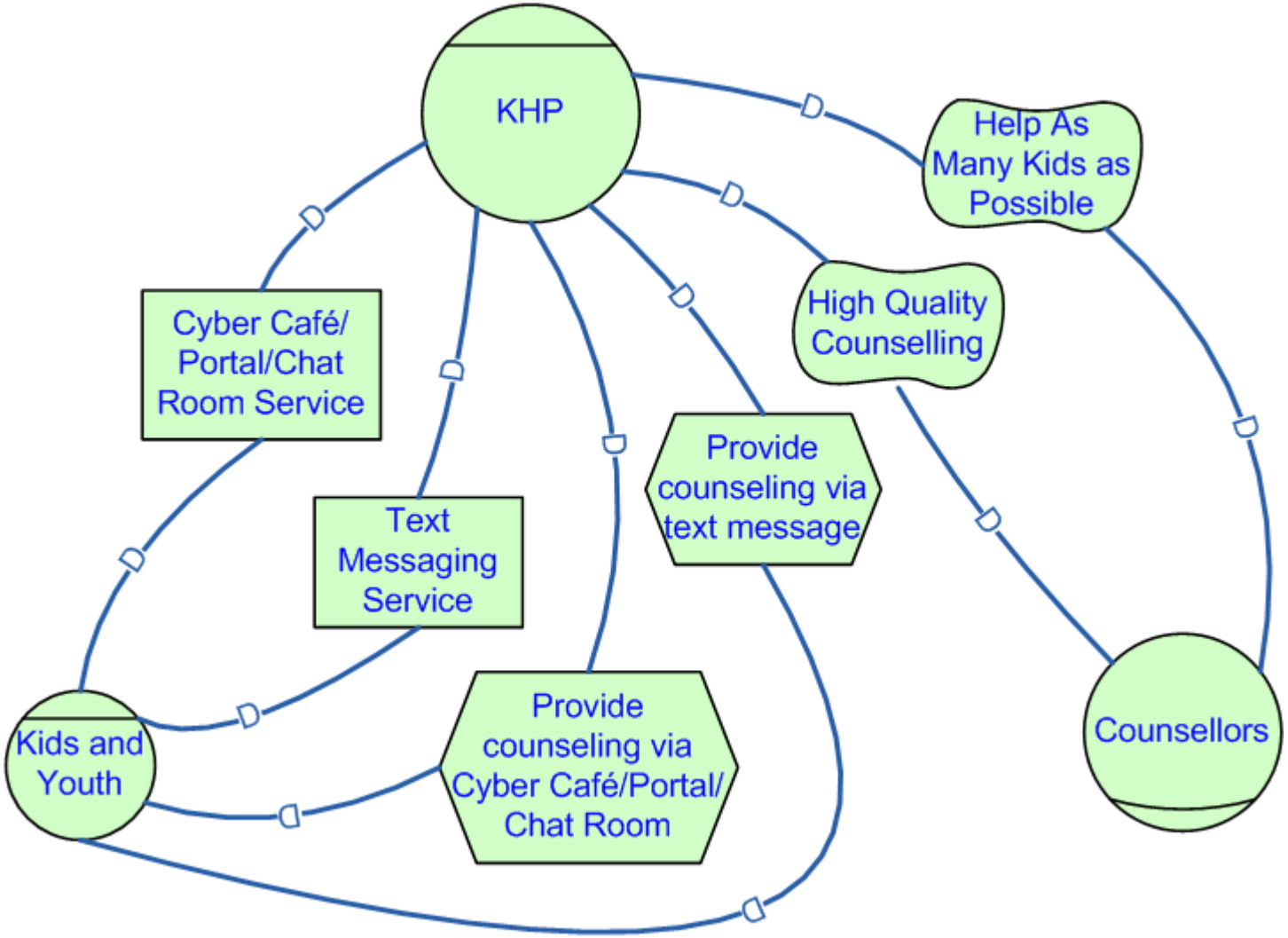
- Goal Dependency: I want you to achieve my goal, I don't care how

- Task Dependency: I want you to achieve this task, in an agreed upon way

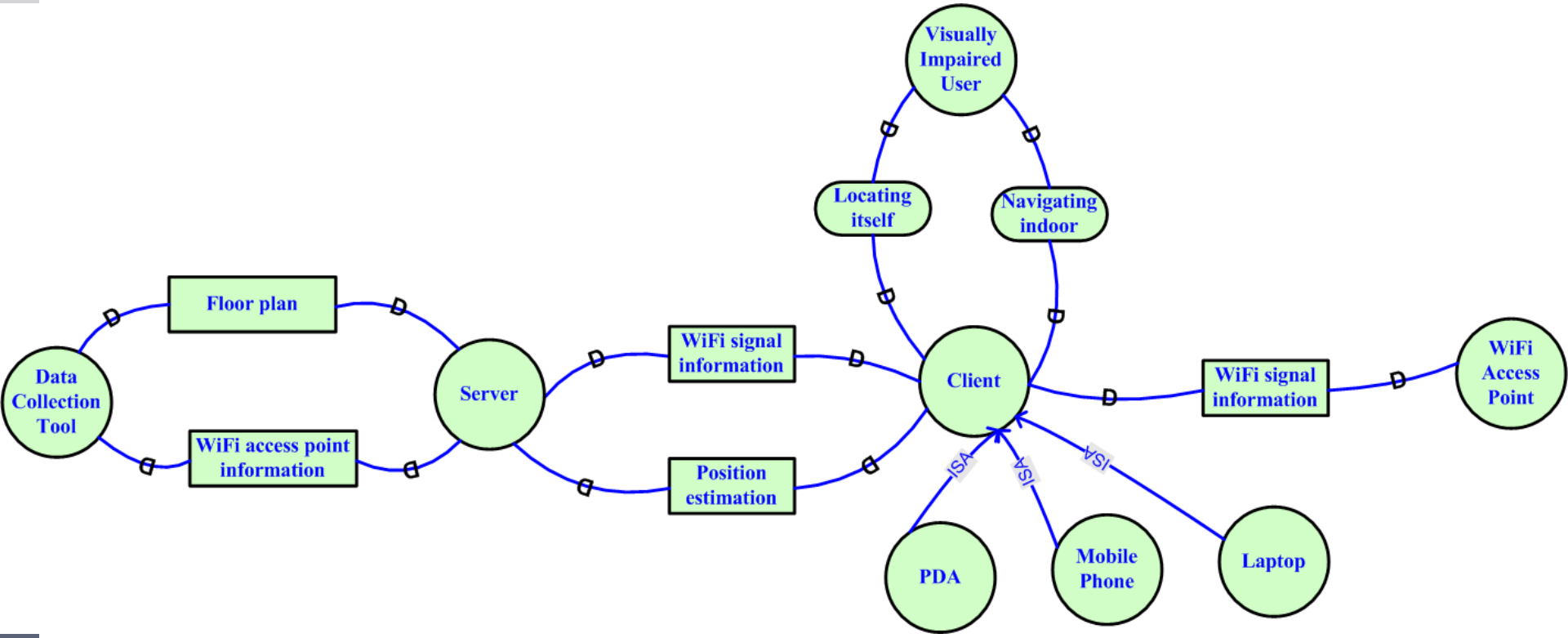
- Resource Dependency: I want you to provide this thing (entity)

- Softgoal Dependency: I want you to achieve my goal, which is fuzzy, not clear-cut

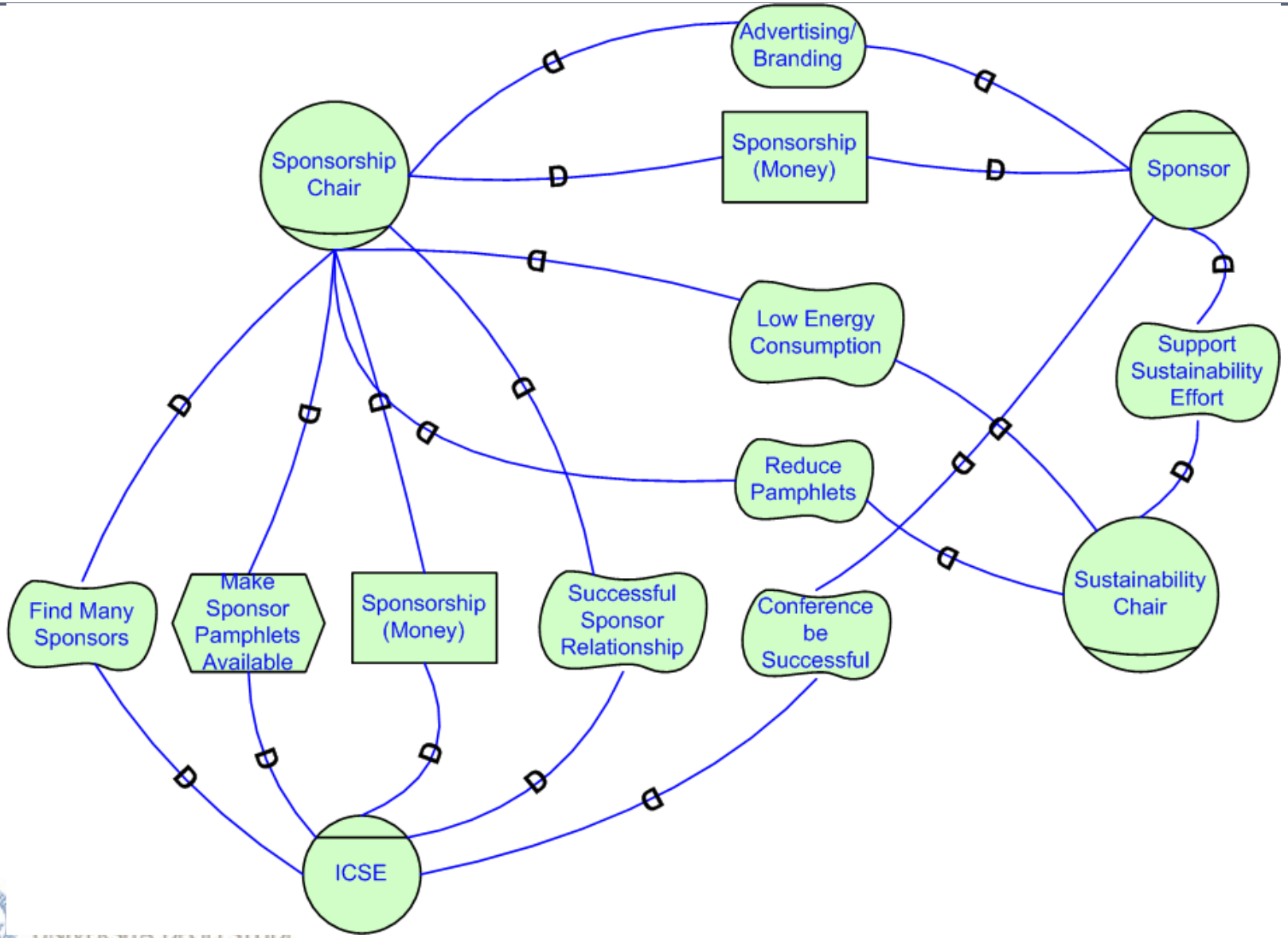
Strategic Dependency (SD) Example: KHP



SD Example: WiFi-based Navigation System

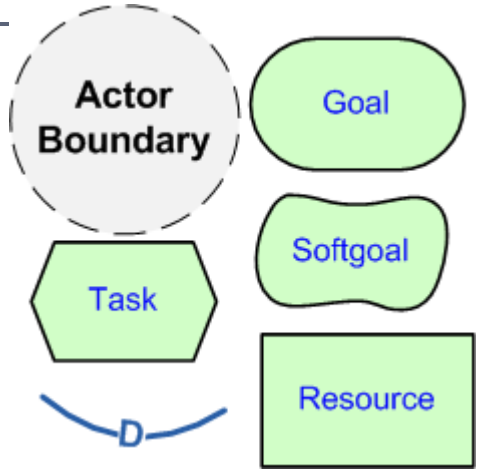


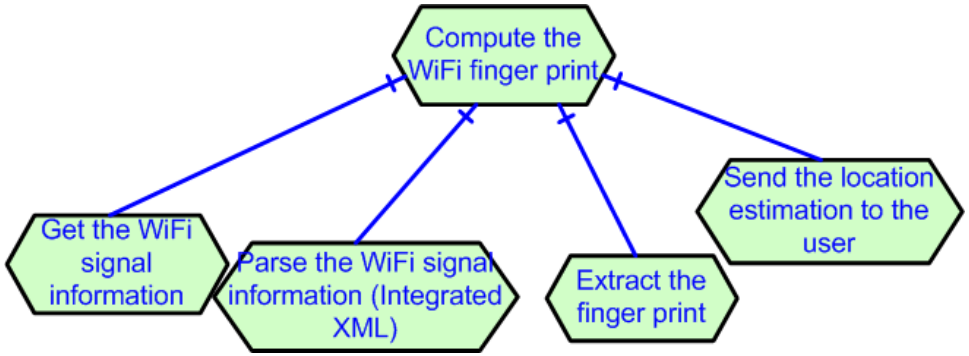
SD Example: “Greening” of ICSE Conference

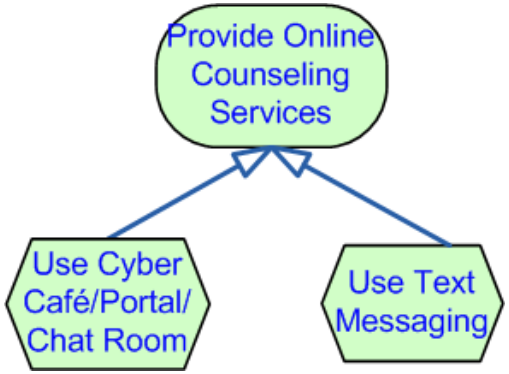


i* Strategic Rationale Diagrams

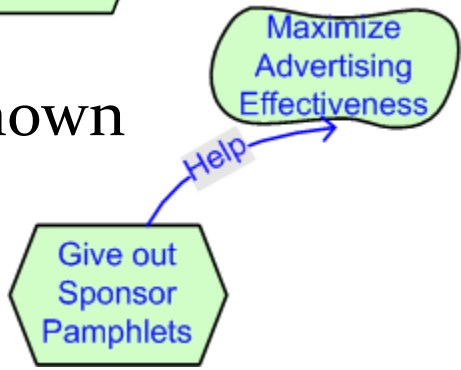
- Actor boundaries
- Goals, Softgoals, Tasks, Resources
- Dependencies (as before)
- Decomposition (AND), Means-Ends (OR)



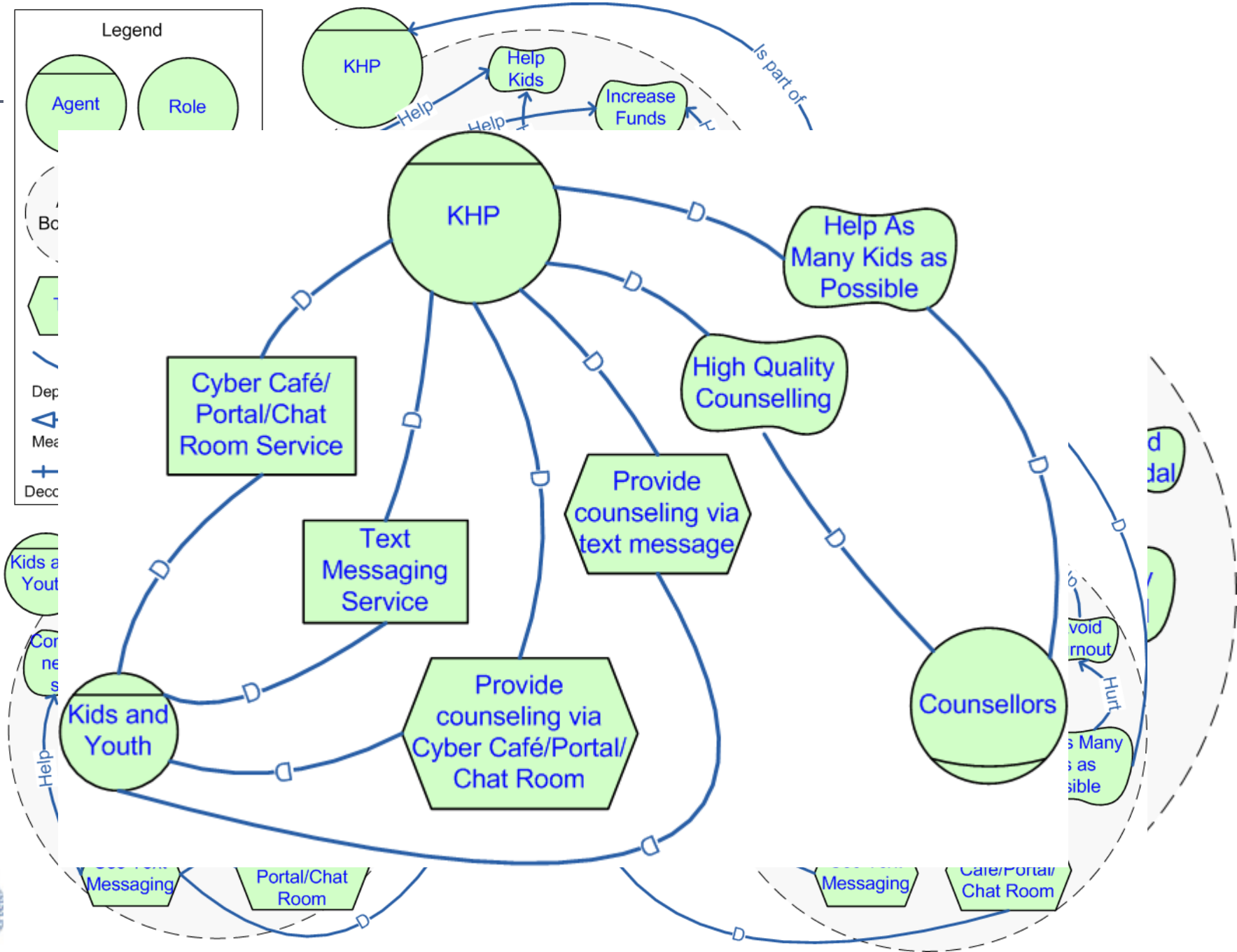




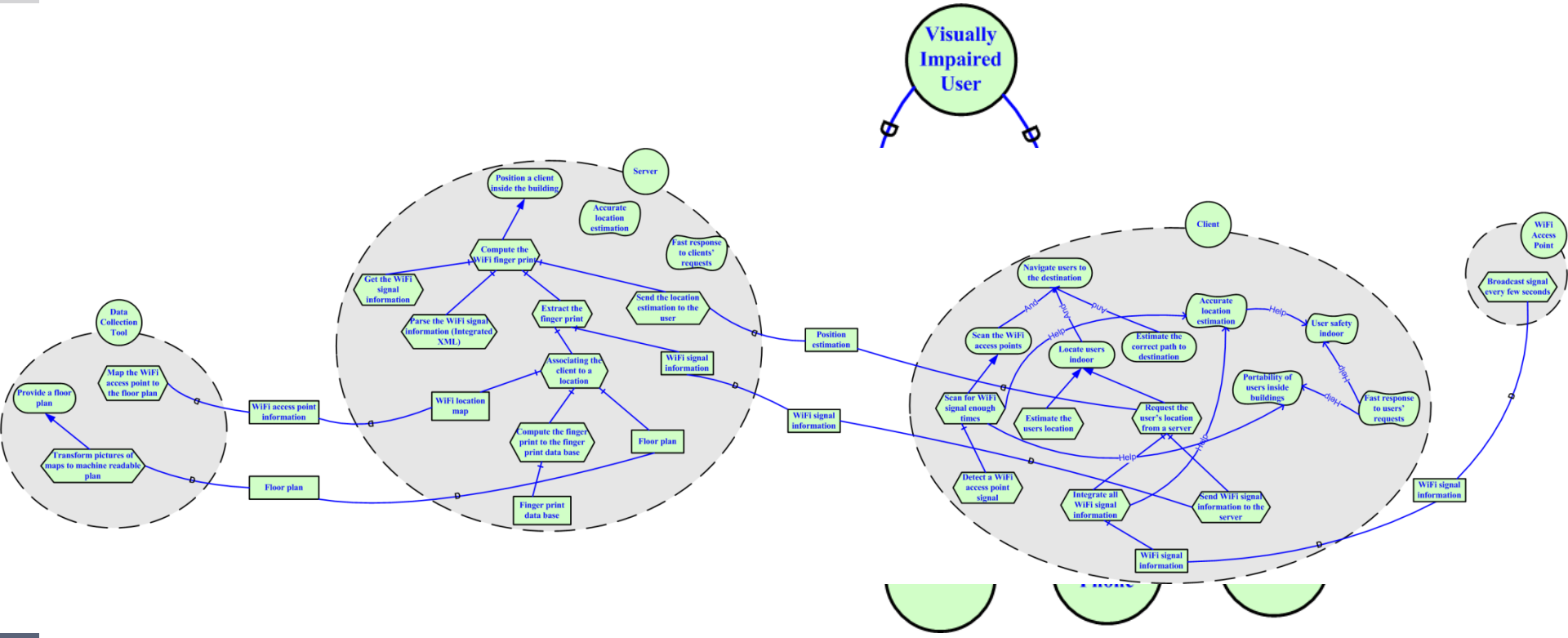
- Contribution: Make, Help, Hurt, Break, Unknown



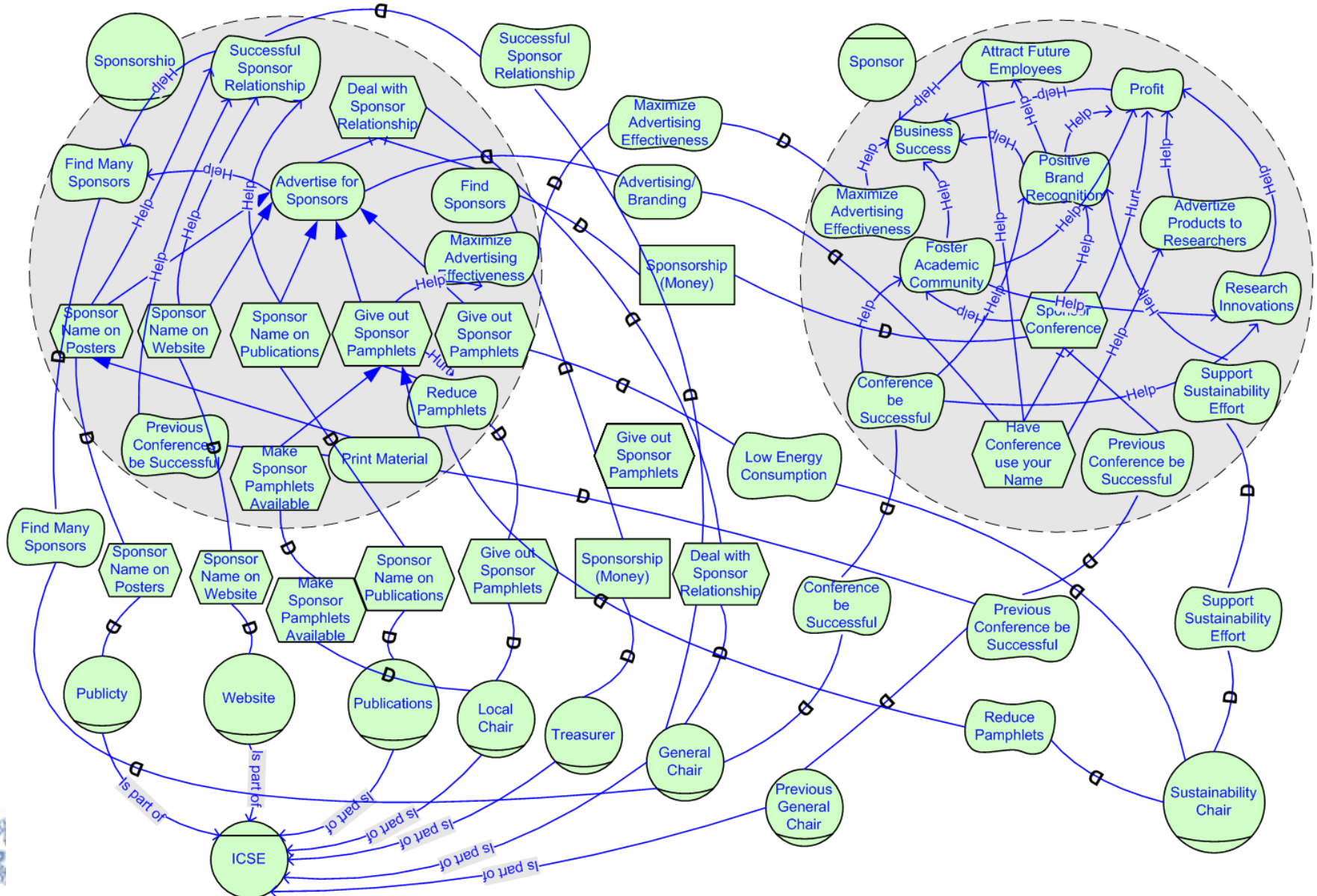
S


Legend
Agent
Role
KHP
Help Kids
Increase Funds
Is part of
Help
Help
KHP
Help As Many Kids as Possible
Cyber Café/ Portal/Chat Room Service
High Quality Counselling
Text Messaging Service
Provide counseling via text message
Provide counseling via Cyber Café/Portal/ Chat Room
Kids and Youth
Counsellors
Hurt
Messaging
Portal/Chat Room
Messaging
Chat Room

SR Example: Wifi (high-level overview)



SR Example: ICSE Greening



GORE Frameworks

- There are several different approaches to goal-oriented modeling:
  - KAOS (Knowledge Acquisition in autOmated Specification of software systems) *(Dardenne, A., Lamsweerde, VAN, & Fickas, S. (1993))*
    - Formal modelling of functional and non-functional requirements
  - NFR (Non-Functional Requirement) Framework *(Chung, L., Nixon, B. A., Yu, E., & Mylopoulos, J. (2000))*
    - Focus on NFR graphs, softgoals
  - i* Framework (Distributed Intentionality) *(Yu, E. (1997))*
    - Added actors and dependencies
  - GRL (Goal-Oriented Requirements Language) *(Amyot, D. (2003))*
    - Simplified i* linked to Use Case Maps
  - Tropos *(Bresciani, P., Perini, A., Giorgini, P., Giunchiglia, F., & Mylopoulos, J. (2004))*
    - i* + agent-oriented methodology
  - Techne *(Jureta, I. J., Borgida, A., Ernst, N. A., & Mylopoulos, J. (2010))*
    - Operationalized softgoals with quality constraints, added domain assumptions
- Examples in this presentation have used i*

Many More Motivating Examples…

- Air Traffic Control
  - Lockerbie (City University London), Bush (NATS, UK), Maiden (City University London), Blom, Everdij (National Aerospace Laboratory (NLR), The Netherlands)
  - Paja, Dalpiaz, Giorgini (University of Trento, Italy), Paul (Thales Research and Technology, France), Meland (SINTEF, Norway)
- Agile Adoption in Telecommunications
  - Chiniforooshan, Yu (University of Toronto), Annosi (Ericsson Research Italy)
- Civil Construction
  - Alencar (Dep. Eletrônica e Sistemas), Castro (Centro de Informática), Menezes (Dep. Engenharia Civil, Universidade Federal de Pernambuco, Brazil), Silva, Santos (Centro de Informática)
- Adverse Event Management in Healthcare
  - Ahmadi Behnam and Daniel Amyot (University of Ottawa), Forster (The Ottawa Hospital)
- … From the iStar Showcase'11: http://www.cs.toronto.edu/km/istar/iStarShowcase_Proceedings.pdf

Benefits of Goal Modeling

- Elicit stakeholder needs
- Facilitating cognitive understanding of stakeholder needs, dependencies, etc.
- Communication between and among stakeholders and analysts
- Shared understanding
- Making explicit what was implicit (goals, softgoals, dependencies)
- Capturing alternative requirements and solutions
- Selecting alternative solutions, trade off analysis
- …

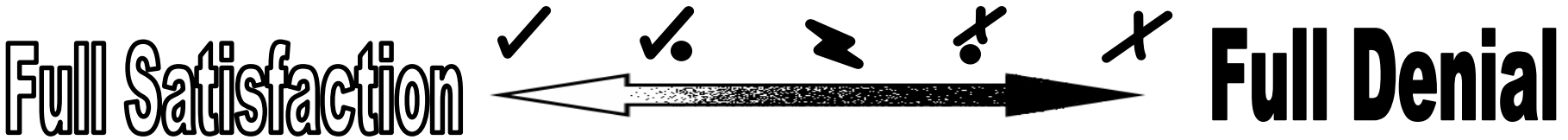
Outline

- GORE (Goal-Oriented Requirements Engineering) Motivation
- Goal Model Basics
  - Example Applications
  - Goal modeling with i*
  - Frameworks and further examples
- **GORE Extensions/Applications: Past and Current Work (Selected Examples)**
  - Goal Model Analysis
  - Uncertainty
  - Business Intelligence
  - Adaptation & Evolution
  - Run-time Analysis
  - Security
  - Alignment
- Community & Events
- Tool Support
- Challenges & Open Topics
- References

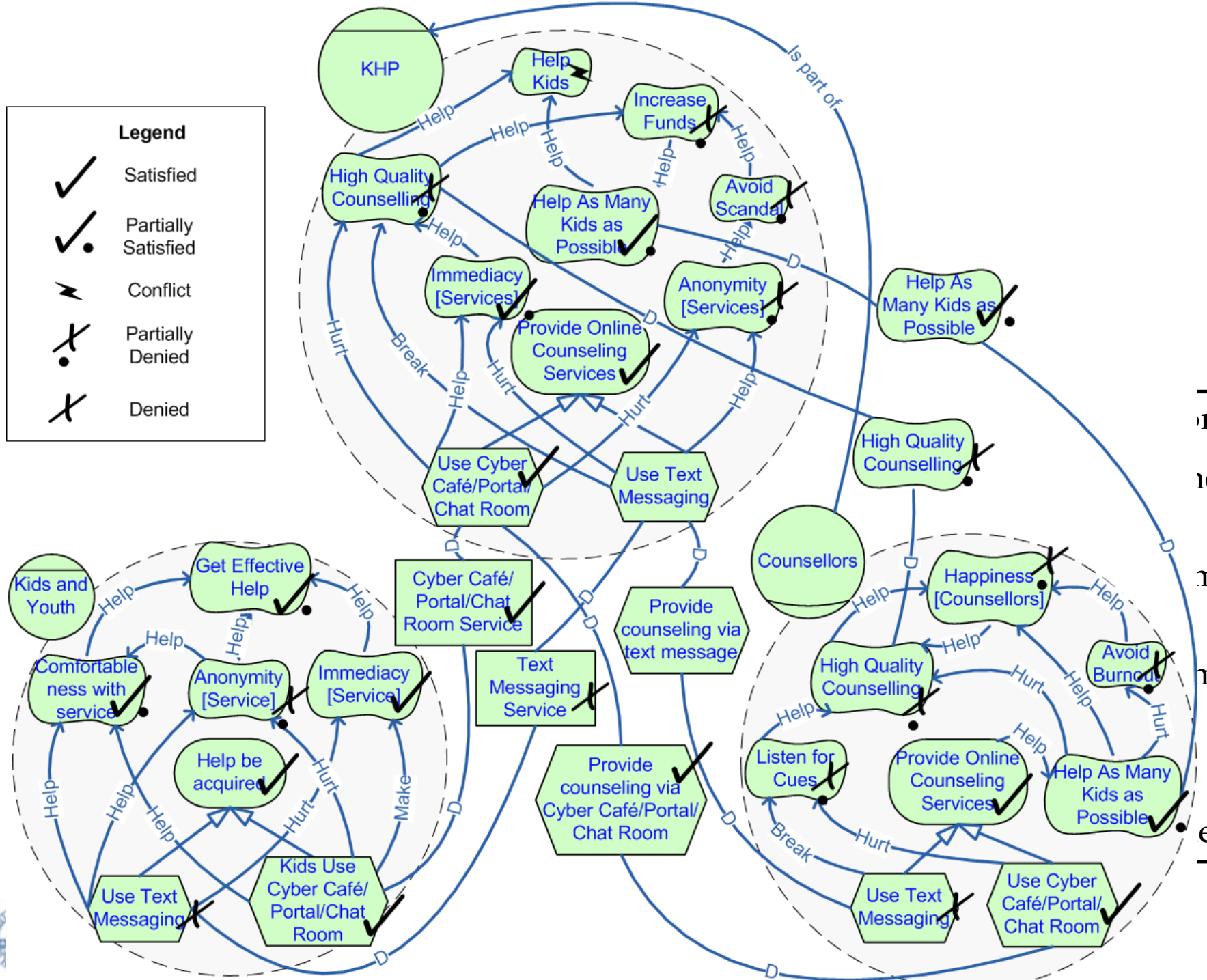
Goal Model Analysis

- Many existing approaches for analyzing goal models
  - 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)…
- See Horkoff & Yu 2011, 2012 for surveys and comparison

- We pick an example approach for illustration: qualitative, interactive analysis, Horkoff & Yu (2009, 2010)
- Use qualitative labels to represent degree of satisfaction



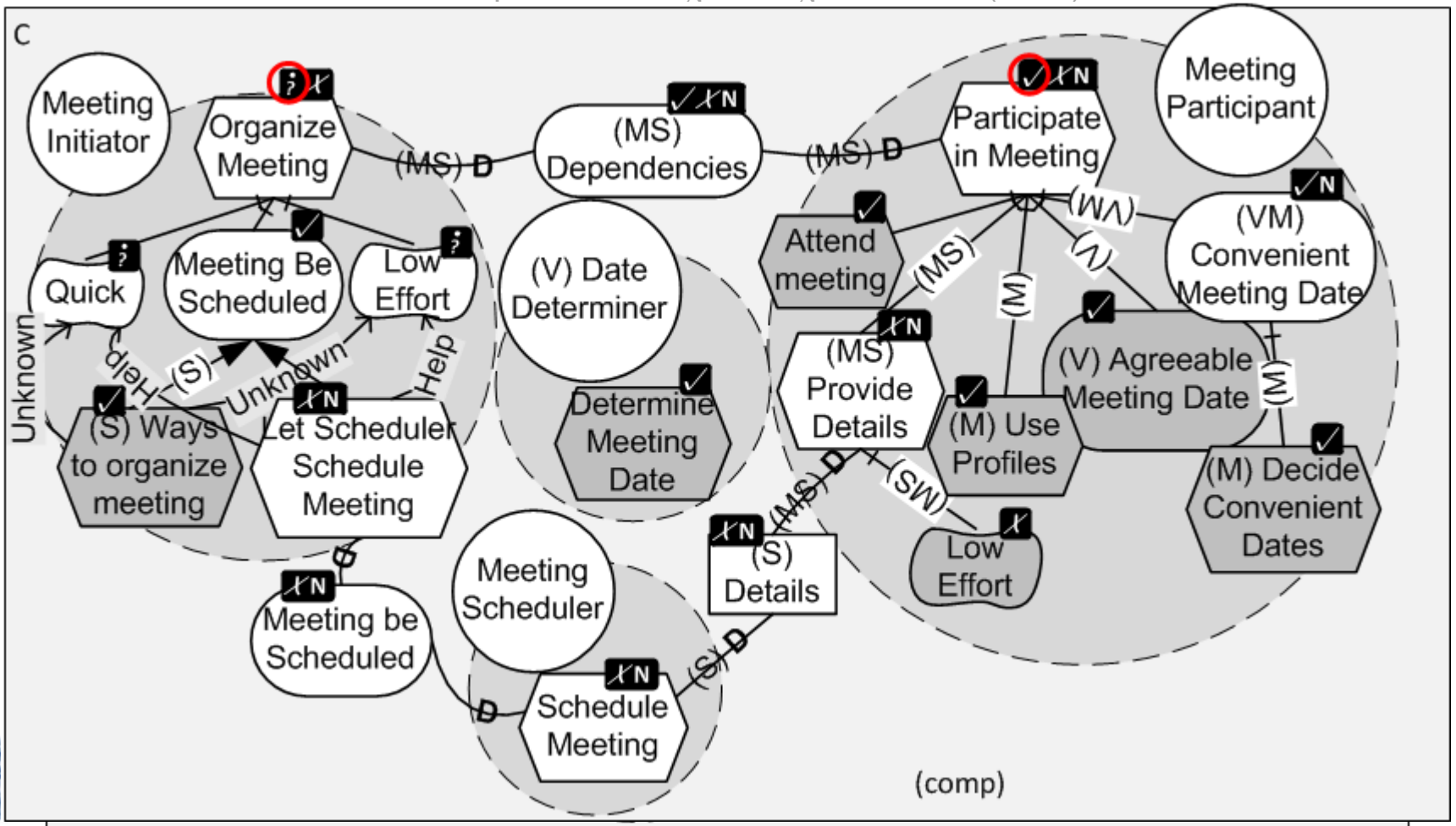
- Propagate labels throughout the model using propagation rules
- Use human judgment to resolve conflicts


Legend
Satisfied
Partially Satisfied
Conflict
Partially Denied
Denied
KHP
Help Kids
Increase Funds
High Quality Counselling
Help As Many Kids as Possible
Avoid Scandal
Immediacy [Services]
Anonymity [Services]
Provide Online Counseling Services
Use Cyber Café/Portal/ Chat Room
Use Text Messaging
Is part of
Help As Many Kids as Possible
High Quality Counselling
Counsellors
Happiness [Counsellors]
Avoid Burnout
High Quality Counselling
Listen for Cues
Provide Online Counseling Services
Help As Many Kids as Possible
Use Text Messaging
Use Cyber Café/Portal/ Chat Room
Kids and Youth
Get Effective Help
Comfortable ness with service
Anonymity [Service]
Immediacy [Service]
Help be acquired
Use Text Messaging
Kids Use Cyber Café/ Portal/Chat Room
Cyber Café/ Portal/Chat Room Service
Text Messaging Service
Provide counseling via text message
Provide counseling via Cyber Café/Portal/ Chat Room
Help
Hurt
Break
Make
D

Capturing Uncertainty in Goal Models

- In RE, common to uncover uncertainty over model structure
- Use the MAVO formal uncertainty framework to capture uncertainty in GM

  Salay, Chechik, Horkoff. *Managing Requirements Uncertainty with Partial Models*, in Proceedings of the 20th IEEE International Requirements Engineering Conference (RE'12)

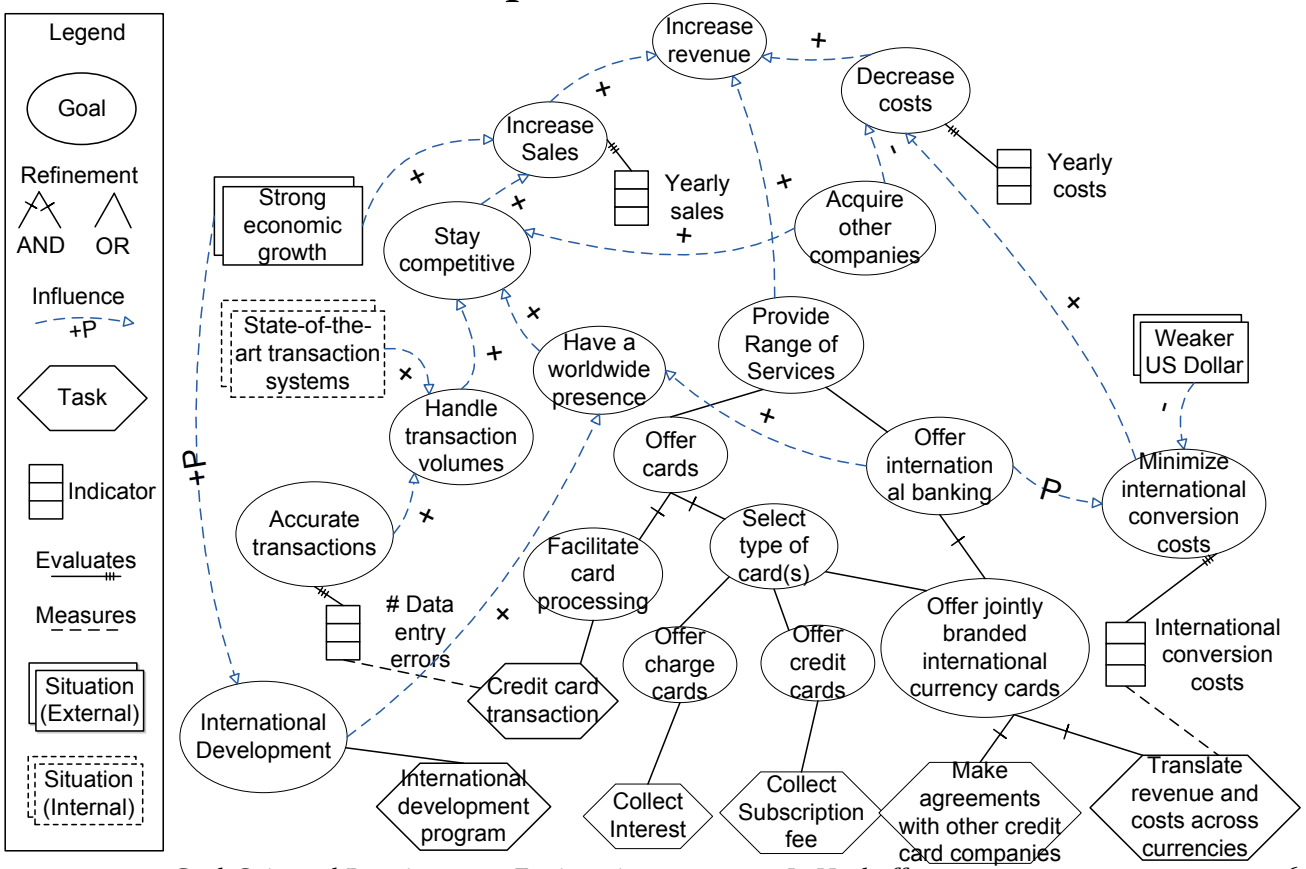


Business Intelligence Modeling

- Business Intelligence analyzes and displays business data, allowing businesses to monitor and strategize
- We raise the level of abstraction of BI systems via a modeling language using familiar business concepts

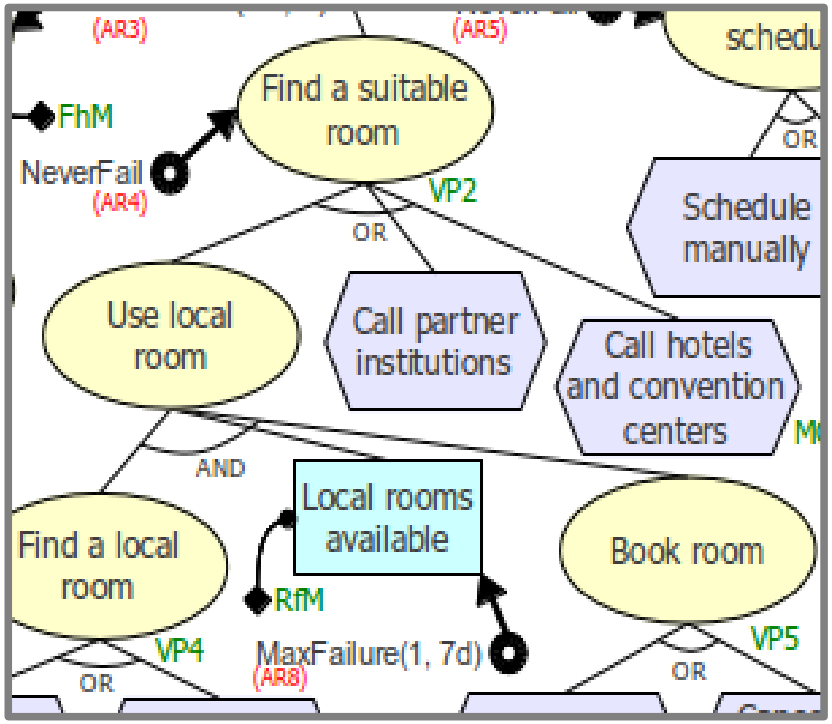
Horkoff, Borgida, Mylopoulos, Barone, Jiang, Yu, Amyot. Making Data Meaningful: The Business Intelligence Model and its Formal Semantics in Description Logics, in (ODBASE 2012)

Horkoff, Barone, Jiang, Yu, Amyot, Borgida, Mylopoulos. Strategic Business Modeling: Representation and Reasoning, Software and Systems Modeling (2012)



Adaptation and Evolution

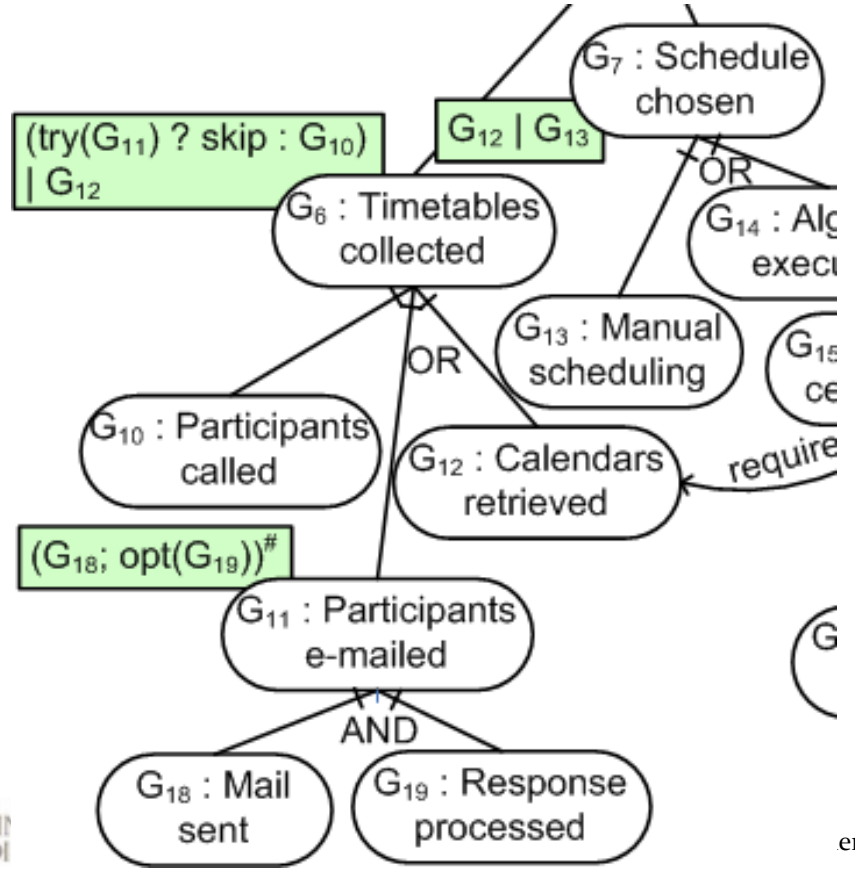
- Many approaches use goal models as part of requirements-aware runtime monitoring, adaptation, and evolution.
- For example: Zanshin (Souza, Lapouchnian, Angelopoulos, Mylopoulos, Requirements-driven software evolution. In: Computer Science – Research and Development, Springer, 2012)

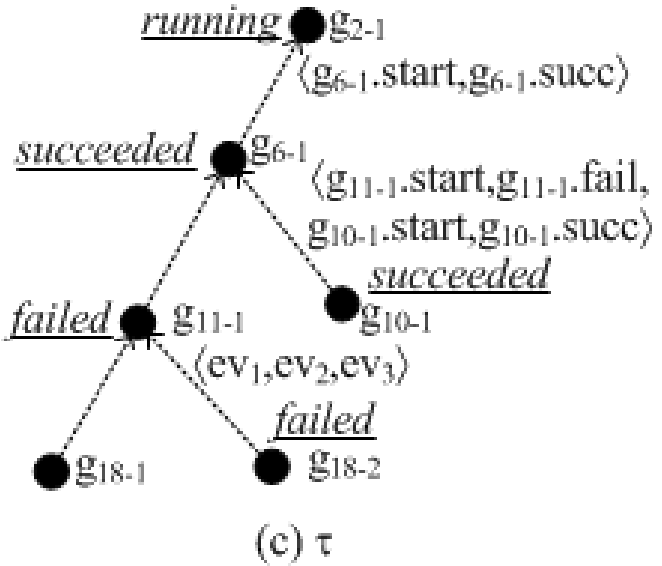


- Requirements specifications represented as goal models (Techne foundation);
- Awareness reqs: "Goal 'Find a suitable room' should never fail / should have 90% success";
- Parameters for reconfiguration (examples):
  - OR-refinements / variation points (VP2);
  - Control variables (RfM = Rooms for Meetings);

Run-time Analysis

- Goal models are not suited as is for run-time analysis:
  - They are defined in terms of goal classes
  - Don't consider behavior or multiple instances
- We add behavior information to create Runtime Goal Models, then use runtime traces to create Runtime Goal Instances





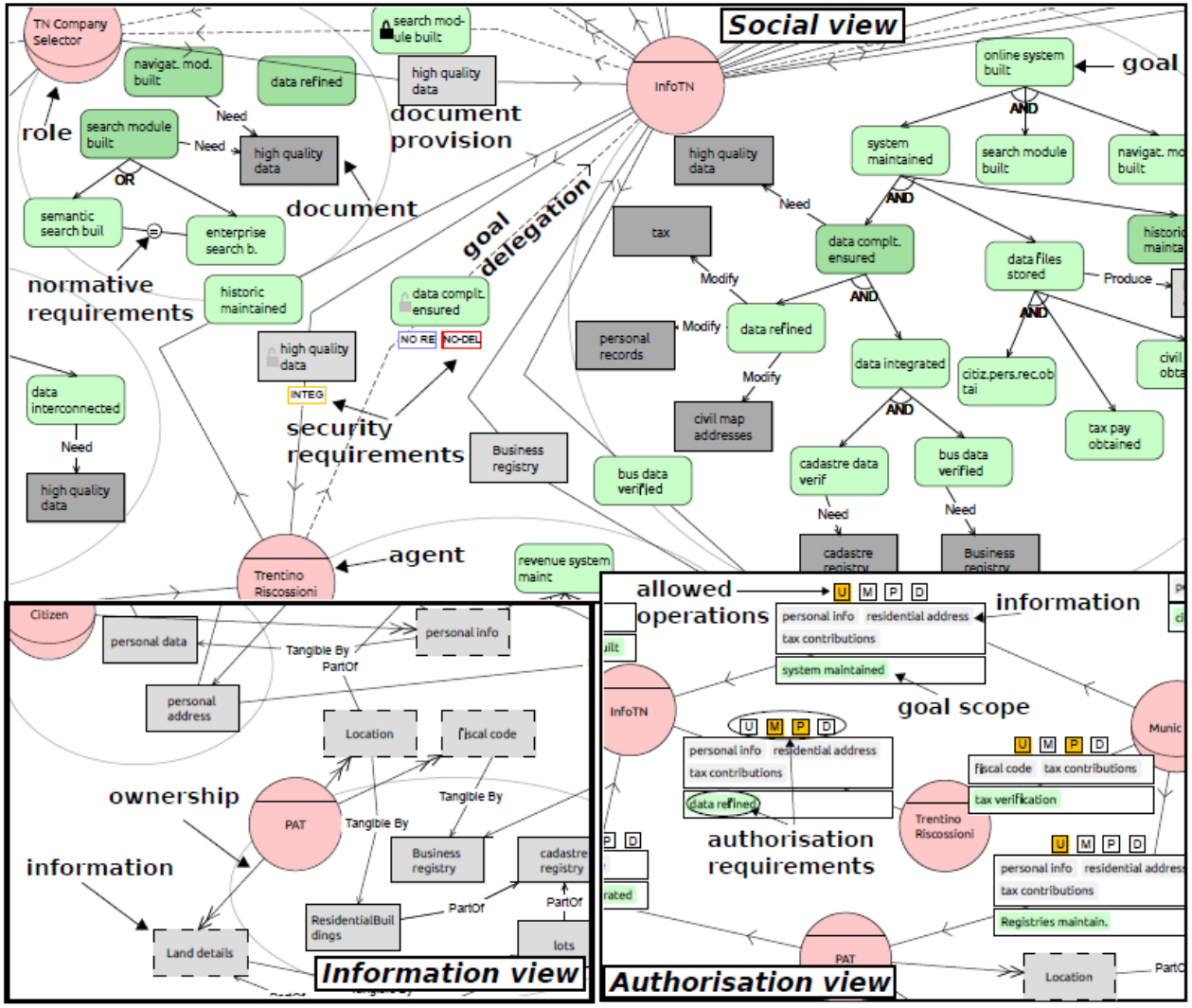
(c) τ

$\tau = \langle ev_1{:}g_{18\text{-}1}.start,\ ev_2{:}g_{18\text{-}2}.start,\ ev_3{:}g_{18\text{-}2}.fail,\ ev_4{:}g_{10\text{-}1}.start,\ ev_5{:}g_{10\text{-}1}.succ \rangle$

Dalpiaz, Borgida, Horkoff, Mylopoulos, Runtime Goal Models, RCIS'12 Invited Paper

Security Analysis

- Many approaches take a goal-oriented perspective on software security analysis
- For example, STS-ml is a goal-oriented language focusing on commitments, delegations, documents, and security requirements
- Analysis finds security requirements conflicts

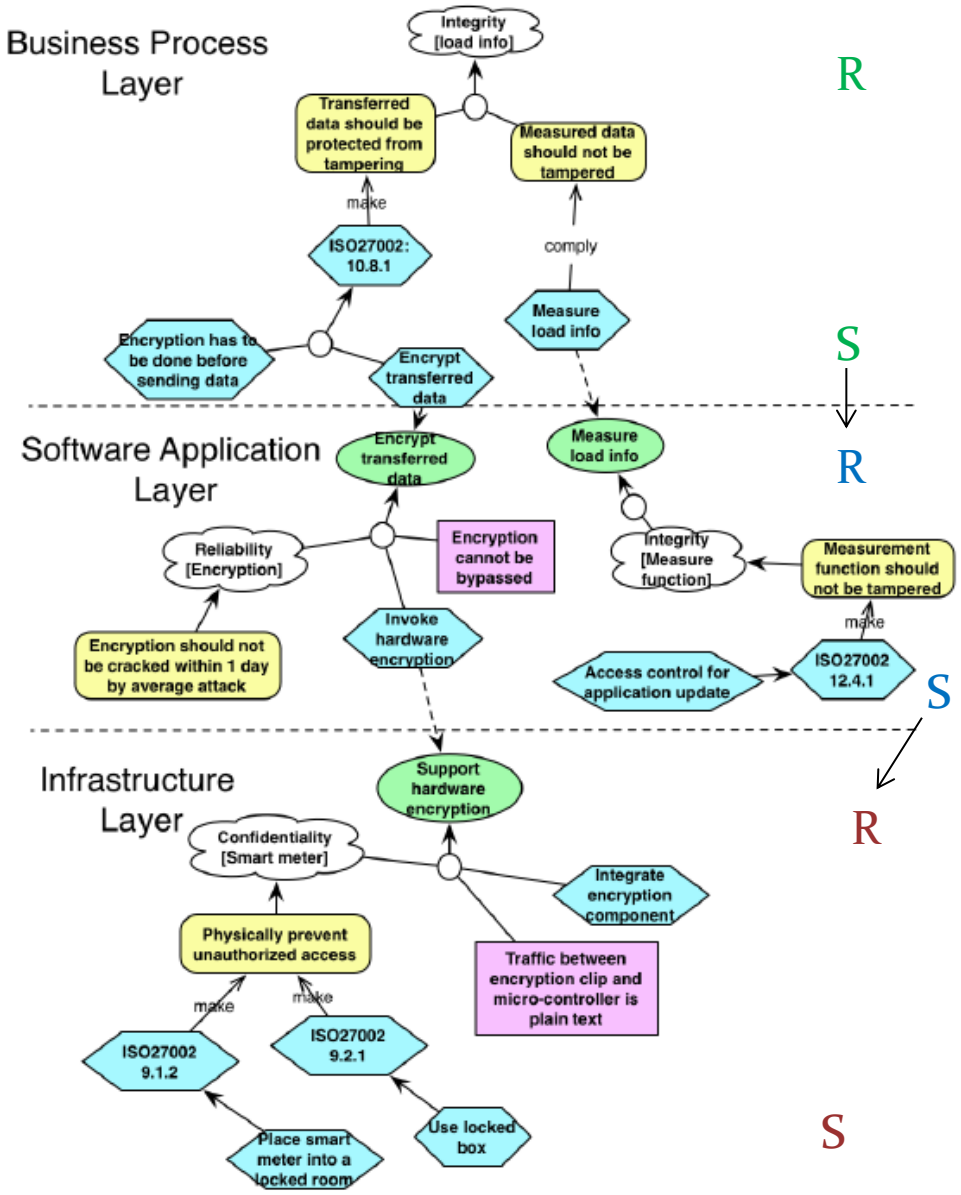


Elda Paja, Fabiano Dalpiaz, and Paolo Giorgini, Identifying Conflicts in Security Requirements with STS-ml , DISI Technical Report (December 2012)

Alignment & Evolution

- Approaches aim to use goal-oriented languages to align social-technical system levels: business processes, software, infrastructure
- Inspired by Zave & Jackson requirements formalization: S, D |- R
- *Li, Mylopoulos, Multi-layer Security Requirement Model, University of Trento, Thesis in progress*

- Alignment work with an emphasis on security alignment: *Salnitri, Dalpiaz, Giorgini , Aligning Service-Oriented Architectures with Security Requirements In: OTM 12*



Outline

- GORE (Goal-Oriented Requirements Engineering) Motivation
- Goal Model Basics
  - Example Applications
  - Goal modeling with i*
  - Frameworks and further examples
- GORE Extensions/Applications: Past and Current Work (Selected Examples)
  - Goal Model Analysis
  - Uncertainty
  - Business Intelligence
  - Adaptation & Evolution
  - Run-time Analysis
  - Security
  - Alignment
- **Community & Events**
- Tool Support
- Challenges & Open Topics
- References

Community & Events

- iStar Workshop
  - iStar'13 co-located with CAiSE'13, June 17th-18th, Valencia, Spain
  - http://www.cin.ufpe.br/~istar13/
- RIGiM (Requirements, Intentions, and Goals in Conceptual Modeling)
  - RIGiM'13 co-located with ER'13, November, Hong Kong
  - https://sites.google.com/site/rigimworkshop13/
- iStar Showcase
  - Co-located with RE'13, July, Rio de Janeiro?
- i* Wiki:
  - http://istar.rwth-aachen.de/tiki-index.php
- Incomplete i*-related publication list:
  - http://istar.rwth-aachen.de/tiki-index.php?page_ref_id=4
- i* Linked-in group: http://www.linkedin.com/groups/istar-modeling
- i* Citeulike: http://www.citeulike.org/groupfunc/14571/home

Tool Support

- See http://istar.rwth-aachen.de/tiki-index.php?page=i%2A+Tools for a list of available i*-related tools, for example:
  - OME, OpenOME, GR-Tool, ST-Tool, jUCMNav, Adoxx-istar, IStar Tool, the RE-Tools, STS-Tool, CSRML Tool, BIM-Tool, TAGOOn Tool, …
- Tool fair as part of iStar'11 and iStar'13
- Existing effort to introduce a common interchange language, iStarML: http://www.upc.edu/gessi/istarml/
- Current effort at the University of Trento to create an online goal-oriented tool development community to support code-sharing and discussion

Challenges & Open Topics

- Scalability
  - Modularity
- Usability
  - Model validation
  - Stakeholder comprehension
- Alignment with existing RE and SE models/methods/languages
- Standardization (?)
  - Language
  - Tools
- Industry adoption

Conclusions

- Goal-oriented requirements engineering emphasizes the social and intentional aspects of system development
  - Explicitly address users goals
  - Who? How? Why?
- Several approaches/frameworks to goal modeling
- Many approaches for goal analysis
- Many extensions/applications
- Active community
- Several challenges and open issues
  - More work to be done!

References (1)

- Presentation Sources:
  - E. Yu: Strategic Business Modeling with *i** . Presented at CASCON Workshop on Requirements-Driven Business Process Modelling and Performance Management. Markham, Ontario, Canada, October 29, 2008
  - E. Yu: Social Modeling and *i** - Themes and Variations. Seminar presented at Tilburg University, The Netherlands, June 9, 2009
  - E. Yu, J. Castro, A. Perini: Strategic Actors Modeling with i*. RE 2008 – Tutorial.
  - J. Horkoff, G. Elahi, Goal-Oriented Requirements Engineering Languages and Applications, Lecture, University of York, Toronto, CA

- Case Studies:
  - Golnaz Elahi, Eric Yu, "Trust Trade-off Analysis for Security Requirements Engineering," pp.243-248, 2009 17th IEEE International Requirements Engineering Conference, 2009 http://www.cs.toronto.edu/~gelahi/Trust-REo8.pdf
  - S. Easterbrook (PI), E. Yu (PI), J. Aranda, J. Horkoff, M. Strohmaier, Y. Fan, M. Leica, and R. Abdul Qadir:
    - Strategic Requirements Analysis for Kids Help Phone. U of T DCS Undergraduate Open House.
    - Kids Help Phone: Understanding the Counselling Service through Requirements Modelling. Presented to KHP, Nov. 2004.
  - J. Cabot, S. Easterbrook, J. Horkoff, J. N. Mazon, L. Lessard, S. Liaskos: Integrating Sustainability in Decision-Making Processes: A Modelling Strategy. ICSE 2009 New Ideas and Emerging Results (NIER'09).

References (2)

- GORE Frameworks
  - KAOS: Dardenne, A., Lamsweerde, VAN, & Fickas, S. (1993). Goal-directed requirements acquisition. Science of Computer Programming, 20(1-2), 3-50. Elsevier Science B.V.
  - NFR: Chung, L., Nixon, B. A., Yu, E., & Mylopoulos, J. (2000). Non-Functional Requirements in Software Engineering. Conceptual Modeling Foundations and Applications (Vol. 5, pp. 363–379). Kluwer Academic Publishers.
  - i*: Yu, E. (1997). Towards modelling and reasoning support for early-phase requirements engineering. Proceedings of ISRE 97 3rd IEEE International Symposium on Requirements Engineering, 97, 226-235. IEEE Comput. Soc. Press.
  - GRL: Amyot, D. (2003). Introduction to the User Requirements Notation: learning by example. Computer Networks, 42(3), 285-301. Elsevier.
  - Tropos: Bresciani, P., Perini, A., Giorgini, P., Giunchiglia, F., & Mylopoulos, J. (2004). Tropos: An Agent-Oriented Software Development Methodology. Autonomous Agents and MultiAgent Systems, 8(3), 203-236. Springer.
  - Techne: Jureta, I. J., Borgida, A., Ernst, N. A., & Mylopoulos, J. (2010). Techne: Towards a New Generation of Requirements Modeling Languages with Goals, Preferences, and Inconsistency Handling. 2010 18th IEEE International Requirements Engineering Conference (pp. 115-124).

References (3)

- GORE Analysis
  - J. Horkoff, E. Yu, Interactive Analysis of Agent-Goal Models in Enterprise Modeling International Journal of Information System Modeling and Design, IGI-Global.
  - Jennifer Horkoff, Eric Yu, Finding Solutions in Goal Models: An Interactive Backward Reasoning Approach, ER'10 Springer
  - J. Horkoff, E. Yu. Comparison and Evaluation of Goal-Oriented Satisfaction Analysis Techniques. Requirements Engineering Journal (REJ). 1-24. Springer.
  - Jennifer Horkoff, Eric Yu. Analyzing Goal Models – Different Approaches and How to Choose Among Them. Requirements Engineering Track - Fourth Edition, part of the 26th ACM Symposium on Applied Computing (SAC'11).
- Business Intelligence
  - Jennifer Horkoff, Alex Borgida, John Mylopoulos, Daniele Barone, Lei Jiang, Eric Yu, Daniel Amyot. *Making Data Meaningful: The Business Intelligence Model and its Formal Semantics in Description Logics*, in (ODBASE 2012)
  - Jennifer Horkoff, Daniele Barone, Lei Jiang, Eric Yu, Daniel Amyot, Alex Borgida, John Mylopoulos. *Strategic Business Modeling: Representation and Reasoning, Software and Systems Modeling (2012)*
- Uncertainty
  - Rick Salay, Marsha Chechik, Jennifer Horkoff. *Managing Requirements Uncertainty with Partial Models*, in Proceedings of the 20th IEEE International Requirements Engineering Conference (RE'12)

References (4)

- Adaptation & Evolution
  - Souza, V.E.S., Lapouchnian, A., Robinson, W.N. and Mylopoulos, J. Awareness Requirements. In: Software Engineering for Self-Adaptive Systems II, LNCS 7475, Springer, 2013.
  - Souza, V.E.S., Lapouchnian, A. and Mylopoulos, J. System Identification for Adaptive Software Systems: A Requirements Engineering Perspective. In: 30th International Conference on Conceptual Modeling (ER'11), Brussels, Belgium. November, 2011.
  - Souza V., Lapouchnian A. and Mylopoulos J. , Requirements-Driven Qualitative Adaptation In: 20th International Conference on Cooperative Information Systems (CoopIS'12)
  - Souza, V.E.S., Lapouchnian, A., Angelopoulos, K. and Mylopoulos, J. Requirements-driven software evolution. In: Computer Science – Research and Development, Springer, 2012 (online first: http://www.springerlink.com/content/q312828017lk8240/)
- Run-time Analysis
  - Fabiano Dalpiaz, Alexander Borgida, Jennifer Horkoff, John Mylopoulos (2013) Runtime Goal Models. In Proceedings of the 7th IEEE International Conference on Research Challenges in Information Science (RCIS 2013). Invited paper.
  - Borgida, Dalpiaz, Horkoff, Mylopoulos, Requirements Models for Design- and Runtime: A Position Paper, MISE'13

References (4)

- Security
  - Elda Paja, Amit K. Chopra, and Paolo Giorgini (2012), *Trust-based Specification of Sociotechnical Systems*, *DKE Special Issue ER'2011 (To Appear)*.
  - Elda Paja, Fabiano Dalpiaz, Mauro Poggianella, Pierluigi Roberti, and Paolo Giorgini, *Modelling Security Requirements in Socio-Technical Systems with STS-Tool*, CAiSE'12 Forum.
  - Elda Paja, Fabiano Dalpiaz, and Paolo Giorgini, *Identifying Conflicts in Security Requirements with STS-ml* , DISI Technical Report (December 2012) Pdf.
  - http://www.sts-tool.eu/
- Alignment
  - Tong Li, John Mylopoulos, Multi-layer Security Requirement Model, University of Trento, Thesis in progress
  - Salnitri M., Dalpiaz F. and Giorgini P. , Aligning Service-Oriented Architectures with Security Requirements In: OTM 12

- http://www.lucretius.eu/publications/

Thank you!

Questions?

horkoff@disi.unitn.it

http://disi.unitn.it/~horkoff/

www.cs.utoronto.ca/~jenhork