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Automating Analysis of Qualitative Preferences in Goal-Oriented Requirements Engineering

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26th IEEE/ACM International Conference on Automated Software Engineering (ASE), November 6–12, 2011

Objective

Obtain a correct design for a system that is more preferred than any other correct design.

- **Correct design**: a set of goals & tasks that provide the system's required functionality
- Preference analysis quickly becomes difficult as systems become more complex
- Analysis needs to be able to handle **tradeoffs** between sets of optional goals
- **Qualitative preference valuations** allow effective reasoning without false "accuracy"

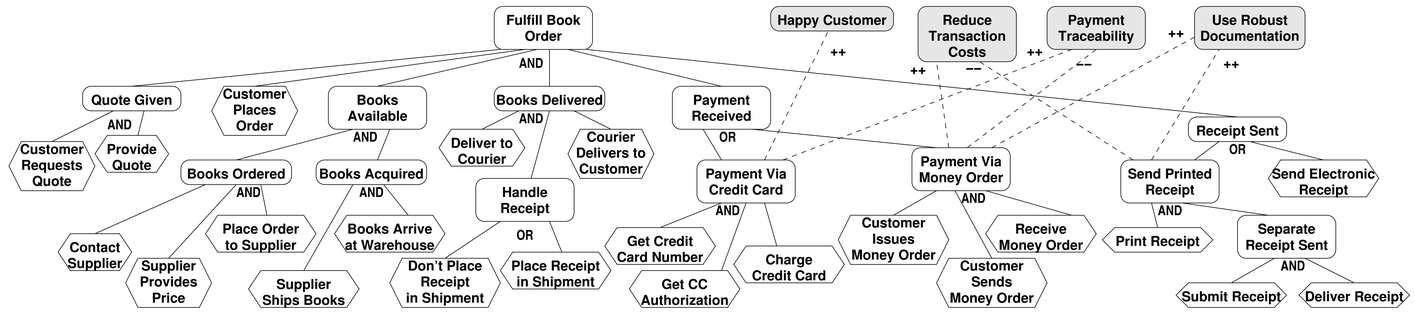
Goal-Oriented Requirements Engineering

Defines a system's requirements in terms of a **goal model** [Yu and Mylopoulos, ICSE 1994]

- **Root goal:** overall purpose or functionality of system
- **Required goals:** conditions, outcomes, or world states to achieve
- **Tasks:** partially or fully realize a goal
- **Optional goals:** desirable but not required (e.g., non-functional properties).

An optional goal is satisfied if it has both:

1. No BREAK ($--$) links from satisfied goals
2. $\geq$ 1 MAKE ($++$) link from a satisfied goal



(example goal model adapted from Liaskos et al., RE 2010)

Finding the Most Preferred Correct System Design(s)

1. Optional Goal Tradeoffs

Consider the following preferences from the proposed system's users:

1. If **robust documentation** is used, **payment traceability** is more important than **reducing transaction costs**.
2. If **transaction costs are reduced** at the expense of **customer satisfaction**, then **using robust documentation** takes precedence over ensuring **payment traceability**.
3. If **robust documentation** is not provided, **payments should be traceable** even at the expense of reduced **customer satisfaction** and increased **transaction cost**.

2. Translate Tradeoffs into CI-Nets

A **conditional importance network** or **CI-net** [Bouveret et al., IJCAI 2009] consists of statements of the form

$$S^+, S^- : S_1 \succ S_2$$

In English:
"If all propositions in S^+ are true and all propositions in S^- are false, then the set of propositions S_1 is preferred to the set S_2."

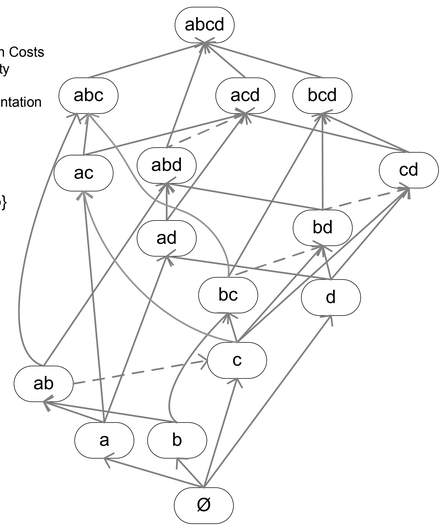
A set of optional goals γ_1 is preferred to another set γ_2 if one of the following is true:

1. **Monotonicity:** γ_1 has at least one more optional goal than γ_2
2. **Importance:** The goals in γ_1 are preferred to those in γ_2 according to a CI-net statement

- Several sets of optional goals, arranged in order so that each successive set is preferred to the previous set, form an **improving flipping sequence**.
- The set of all improving flipping sequences for a CI-net can be drawn as an **induced preference graph (IPG)**:

a: Happy Customer
b: Reduce Transaction Costs
c: Payment Traceability
d: Use Robust Legal Documentation

CI-net statements
{d} ; {} : {c} ; {b}
{b} ; {a} : {d} ; {c}
{} ; {d} : {c} ; {a,b}



3. Compute Total Order over Sets of Optional Goals

No need to perform all pairwise comparisons! Instead:

1. Transform CI-net into induced preference graph
2. Use NuSMV (`http://nusmv.fbk.eu`) to verify that IPG is cycle-free and compute total order over all sets of optional goals

4. Use Total Order to Guide Search for Preferred Design(s)

1. Look at the most-preferred set of optional goals (i.e., all of them)
2. Examine all correct designs (using NuSMV) to see if any design supports this set; if so, these are most preferred
3. If no correct design satisfies all optional goals in set, look at the next less-preferred set in the ordering
4. Repeat steps 2 and 3 until a design is returned or all sets are exhausted

Preliminary Results

Goal Model	*Required Goals*	*Tasks*	*Optional Goals*	*CI-net Rules*	*Mean Total Run Time (s)*	*Calls to Pref. Reasoner*	*Mean Time for Pref. Reasoning (s)*
Bookseller [Liaskos et al., RE 2010]	13	22	4	3	0.52	3	0.47
Trentino Transport [Sebastiani et al., CAiSE 2004]	24	40	3	3	0.47	2	0.34
Online Shop [Liaskos et al., CAiSE 2011]	7	16	3	2	0.22	1	0.17

Related Work

- Liaskos et al., RE 2010
  - Supports precedence constraints & optional subgoals of required goals
  - Quantitative, not qualitative, preference valuations
- Sebastiani et al., CAiSE 2004; Ernst et al., ER 2010
  - Ernst et al. use HELP/HURT labels for partial support/denial of optional goals
  - Both express simple qualitative preferences between pairs of goals ($s_A \succ s_B$)
- Methods based on Analytic Hierarchy Process (AHP)
  - Quantify preferences & rank relative importance of single options
  - Do not represent conditional preferences

Future Directions

- Test our approach on industrial-scale goal models
- Add support for precedence constraints
- Add support for partial satisfaction of optional goals (HELP/HURT links)
- Integrate preferences of multiple stakeholders
- Apply framework to related problems, e.g., software product line engineering

Supported in part by NSF grants CCF0702758 and CCF1143734

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