Techne

Towards a new generation of requirements modeling languages with goals, preferences and inconsistency handling

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Starting point: Three basic questions in RE

1. **What information should be elicited from the stakeholders?**

2. **What models should be used to represent that information?**

3. **What questions should these models be able to answer?**

Starting point: Three basic questions in RE

1. **What information should be elicited from the stakeholders?**
   An ontology for requirements that defines the categories of information to elicit.

2. **What models should be used to represent that information?**
   Modeling primitives for concepts and relations from the ontology, the instances of which make a req. model.

3. **What questions should these models be able to answer?**
   For example:
   - Is the model consistent?
   - Which requirements in it are satisfied?

Formal specification methods (FSMs)

A formal specification method can answer all three questions.
For example, use Z to record and analyse requirements.

Purchase0

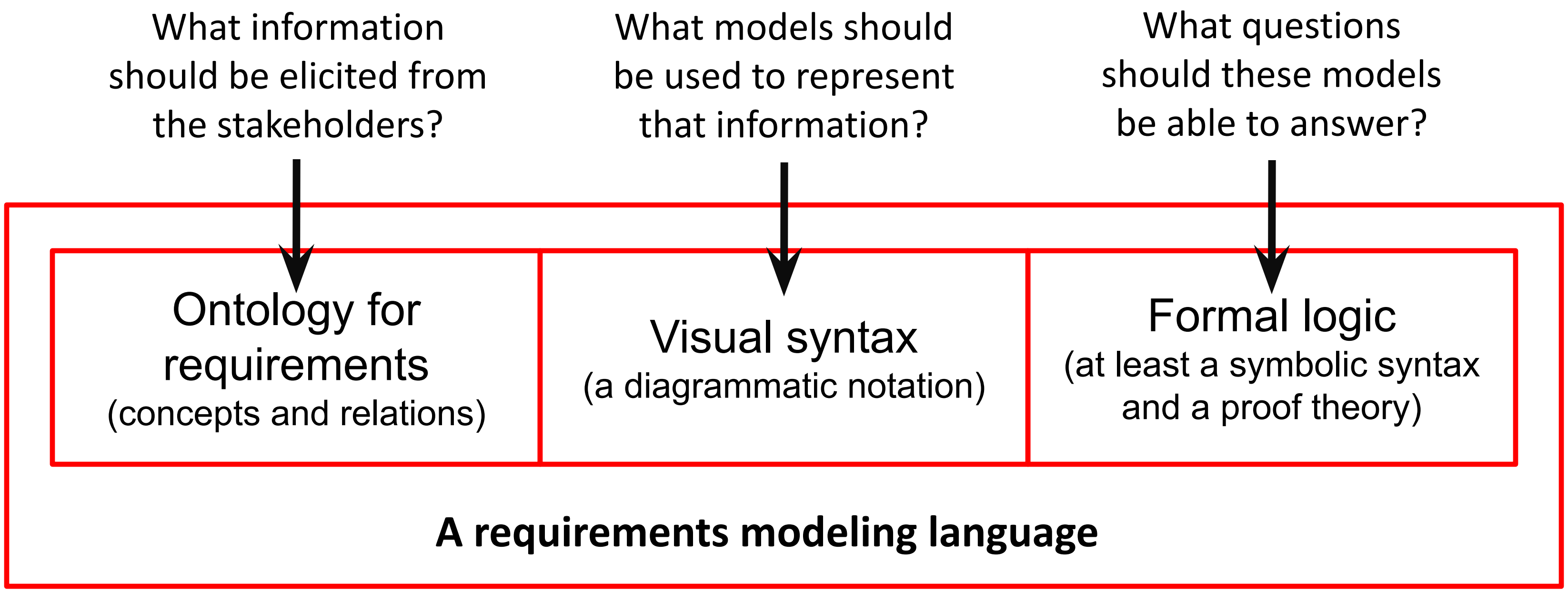
$TicketsForPerformance0$
$TicketsForPerformance0'$
$s? : Seat$
$p? : Person$

$s? \in seating \setminus \mathbf{dom}\, sold$
$sold' = sold \cup \{s? \mapsto p?\}$
$seating' = seating$

Some arguments against the use of FSMs for **all** three tasks:

- Ontologies in FSMs are too simple, i.e., so simple as to give no guidance for requirements elicitation.
- Structuring of the description (req. model) not meaningful for RE.
- Inconsistencies are seen as bugs.

Requirements modeling languages (RMLs)



Some examples:

"Original" RML	Greenspan, Borgida, Mylopoulos. *Info. Sys.*, 11(1), 1986.
ERAE	Dubois, Hagelstein, Rifaut. *Philips J. of Res.*, 43(3-4), 1988.
KAOS	Dardenne, van Lamsweerde, Fickas. *Sci. Comp. Prog.*, 20(1-2), 1993.
i-star	Yu, Mylopoulos. *ICSE*, 1994.
Tropos	Castro, Kolp, Mylopoulos. *Info. Sys.*, 27(6), 2002.
Formal Tropos	Fuxman, Liu, Mylopoulos, Roveri, Traverso. *Req. Eng.*, 9(2), 2004.

New requirements problem (Jureta, Mylopoulos, Faulkner @ RE 2008)

Given the elicited

domain assumptions

goals

quality constraints

softgoals

tasks

Find

tasks & domain assumptions which

satisfy all mandatory goals and quality constraints,

and if feasible, satisfy many preferred requirements

and many optional requirements.

Why new?

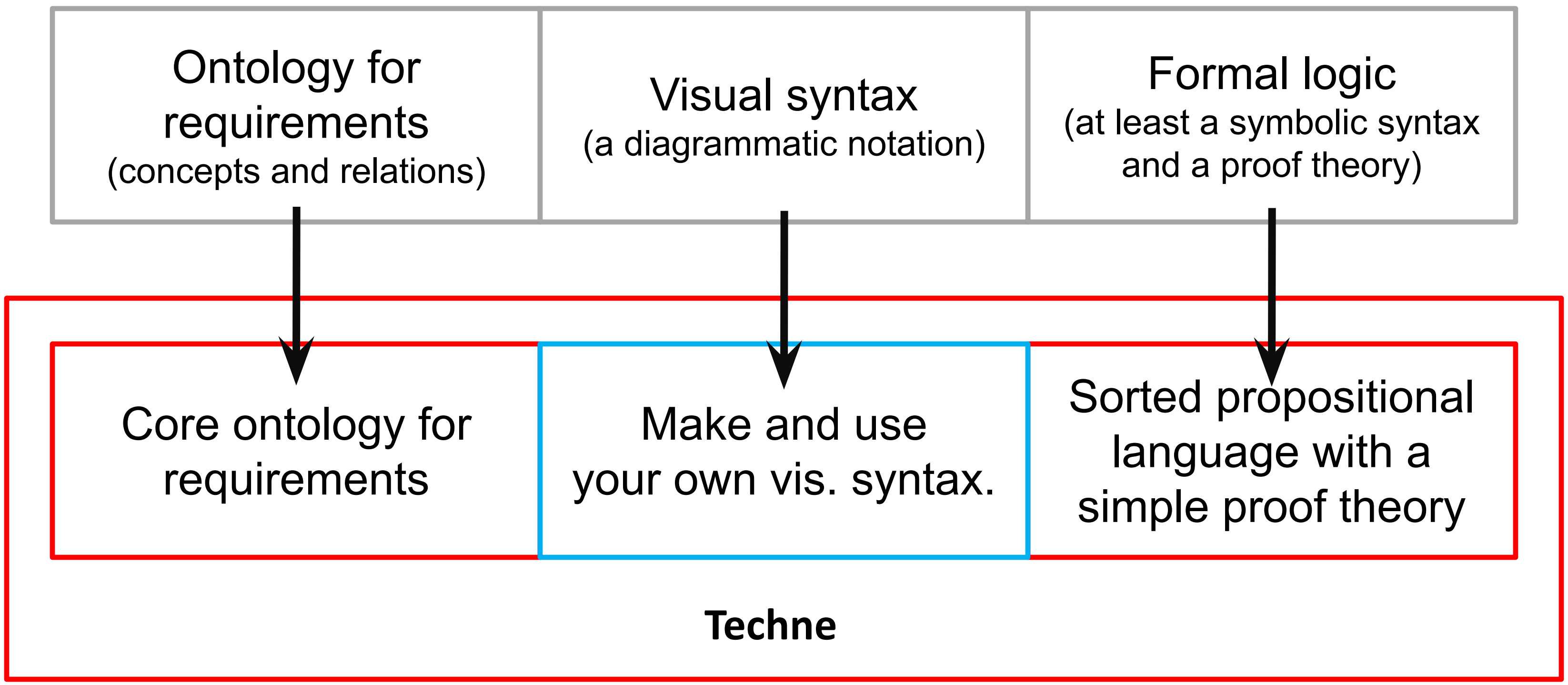
1. Ontology is different,
2. not all inconsistencies are bugs (some signal alternative solutions),
3. preferences are needed to compare alternative solutions,
4. requirements can be optional or mandatory, or neither.

Techne structure (1/2)

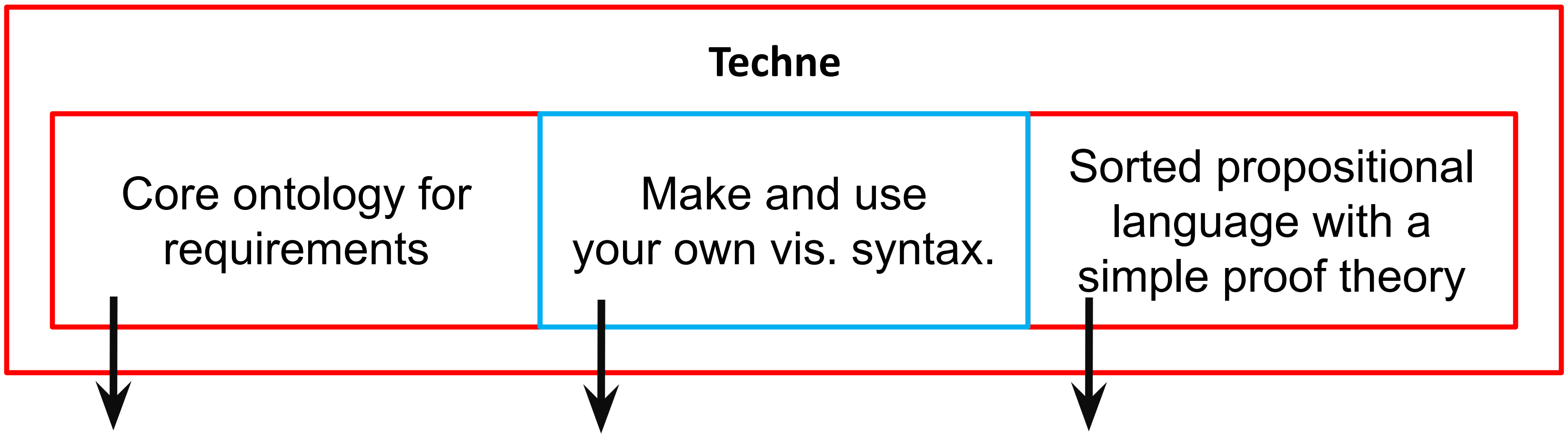
Overall aim:

Make the simplest RML that would include all conceptual and other tools needed to define and solve a particular instance of the new requirements problem.

Result:



Techne structure (2/2)



Concepts:
- -Goal
- -Quality constraint
- -Softgoal
- -Domain assumption
- -Task

Relations:
- -Inference
- -Conflict
- -Preference
- -Is-mandatory
- -Is-optional

Techne is an "abstract" RML. To make it "concrete", the simplest way is to add a visual syntax.

One sort per concept.

Inference and conflict formalized using implication and modus ponens.

Other relations are not used in the proof theory.

Techne features

Techne includes features for:

1. **Classification**
   to identify concepts instantiated by elicited information.

2. **Relation**
   to identify the relations between concept instances.

3. **Modeling**
   To record concept instances and relations between them.

4. **Analysis**
   To draw conclusions from the model.

Techne features: Classification

Classification

to identify concepts instantiated by elicited information.

Suppose we elicited the following about an online music service:

Abbreviation:

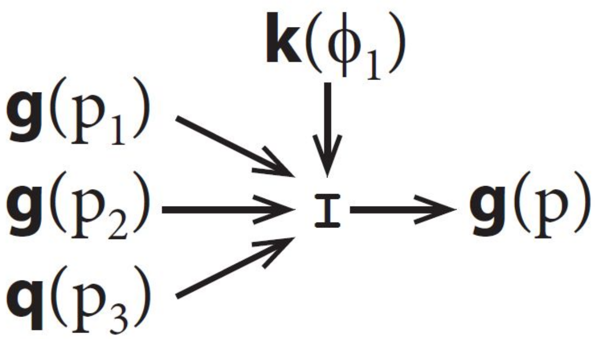
- Deliver music to clients via an online audio player. → **g**(p_1)
  Goal.
- The audio bitrate should be at least 128kb/s. → **q**(p_2)
  Qualty constraint.
- Buffering should be short before the music starts playing. → **s**(p_3)
  Softgoal.
- The user will select the artist and album to play. → **t**(p_4)
  Task.
- If the user is not a subscriber, then she cannot play music. → **k**(p_5)
  Domain assumption.

Techne features: Relation (1/6) Inference relation

Inference relation

When a requirement is the immediate consequence of another set of requirements, the former is called the conclusion, the latter the premises, and they stand related through the inference relation.

Example



g(p): Generate revenue from the audio player.

g(p_1): Display ads in the audio player.

g(p_2): Target text ads according to users' profiles.

q(p_3): Maintain the player free to all users.

$k(\phi_1), g(p_1), g(p_2), q(p_3) : g(p)$

Remarks

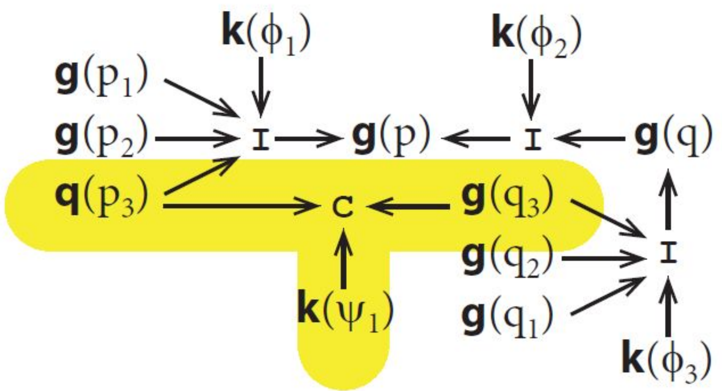
The refinement relation from KAOS and the decomposition relation from i-star can be represented as the inference relation in Techne.

Techne features: Relation (2/6) Conflict relation

Conflict relation

The conflict relation stands between all members (two or more) of a minimally inconsistent set of requirements.

Example



g(q): Charge subscription to users.

g(q_1): Music database restricted to subscribers.

g(q_2): Users can subscribe.

g(q_3): Music player for subscribers only.

[illegible]

[illegible]

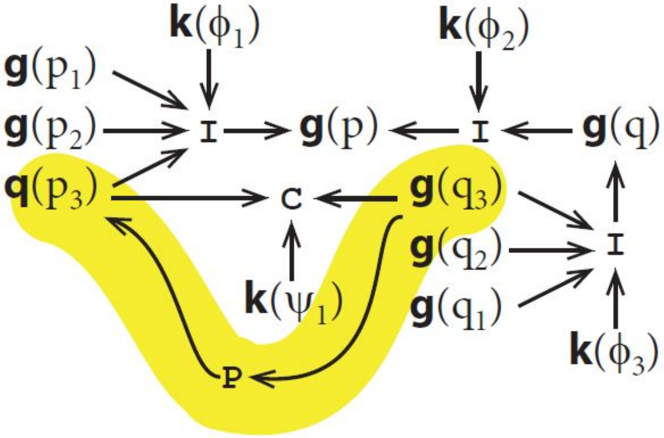
[illegible]

Techne features: Relation (3/6) Preference relation

Preference relation

If a requirement is strictly more desirable than another one, then there is a preference relation between them and by strictly, we mean that they cannot be equally desirable.

Example



g(q_3): Music player for subscribers only.

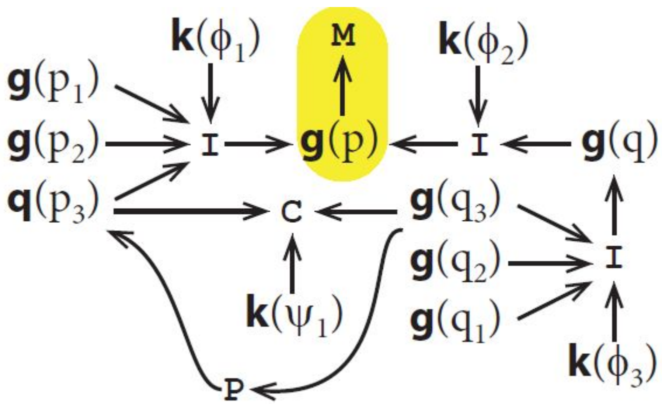
q(p_3): Maintain the player free to all users.

Techne features: Relation (4/6) Is-mandatory relation

Is-mandatory relation

The is-mandatory relation on a requirement indicates that the requirement must be satisfied.

Example



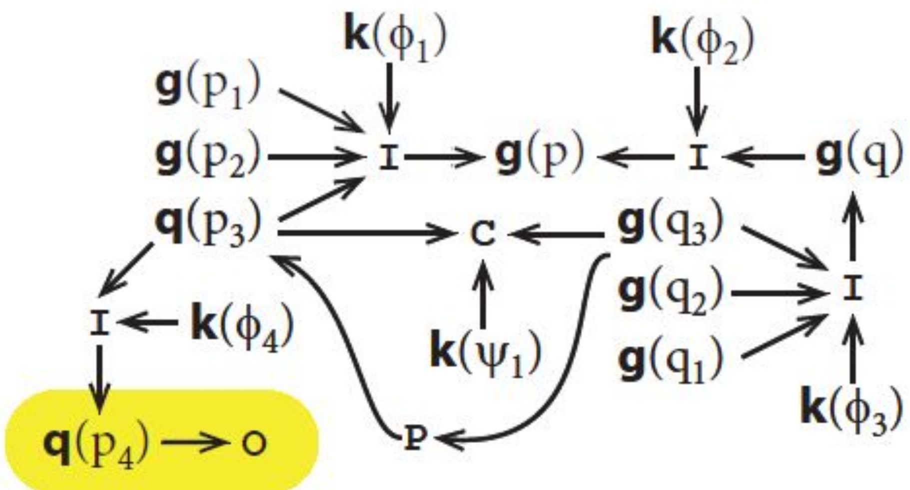
The figure shows that g(p) is a mandatory requirement.

Techne features: Relation (5/6) Is-optional relation

Is-optional relation

The is-optional relation on a requirement indicates that it would be desirable if that requirement was satisfied, but failure to do so will not produce dissatisfaction.

Example



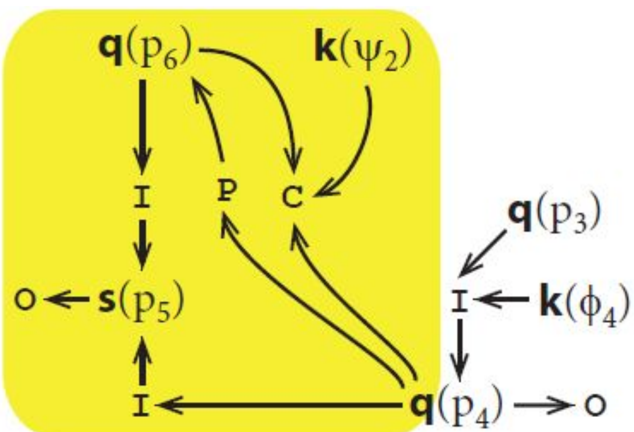
g(p_4): Listen to music in an average of no more than three clicks.

Techne features: Relation (6/6) Approximation relation

Approximation relation

A set of requirements can be an approximation of a softgoal if it is assumed that, once its members are satisfied, the softgoal will be satisfied to some extent.

Example: two approximations of $\mathbf{s}(p_5)$



$\mathbf{s}(p_5)$: It is easy for new users to access music.

$\mathbf{q}(p_4)$: New user needs five clicks on average to music.

$\mathbf{q}(p_6)$: New user needs ten clicks on average to music.

Remarks

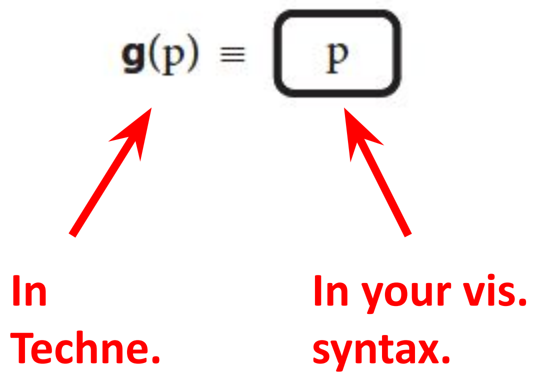
- As different approximations may satisfy the same softgoal to different extents, preference relations can be added between the members of different approximations.
- Approximation is simply a different informal reading of the inference relation.

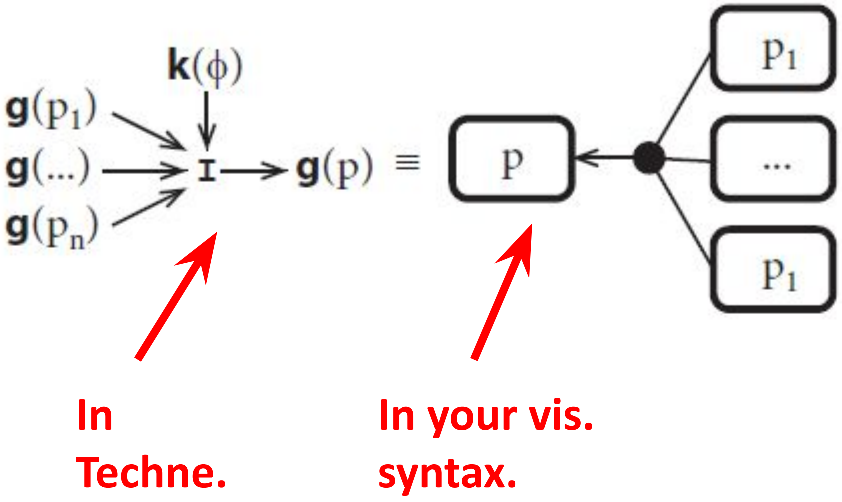
Techne features: Modeling

Q: How to make a visual syntax for Techne?

A: For each expression type in Techne, define an expression type in your visual syntax, and map one to the other.

Example of a KAOS-like visual syntax





Techne features: Analysis (1/4)

Aim: Find candidate solutions to the requirements problem

A **candidate solution** is a **maximally consistent subset** of all requirements in an r-net, in which **all leaf nodes are either domain assumptions or tasks**.

Why **maximally** consistent?

We **assume** that it is better to satisfy more than less requirements. However, one could define other solution concepts (e.g., a solution could be a minimally consistent and non-trivial subset).

Why **leaves must be domain assumptions and tasks**?

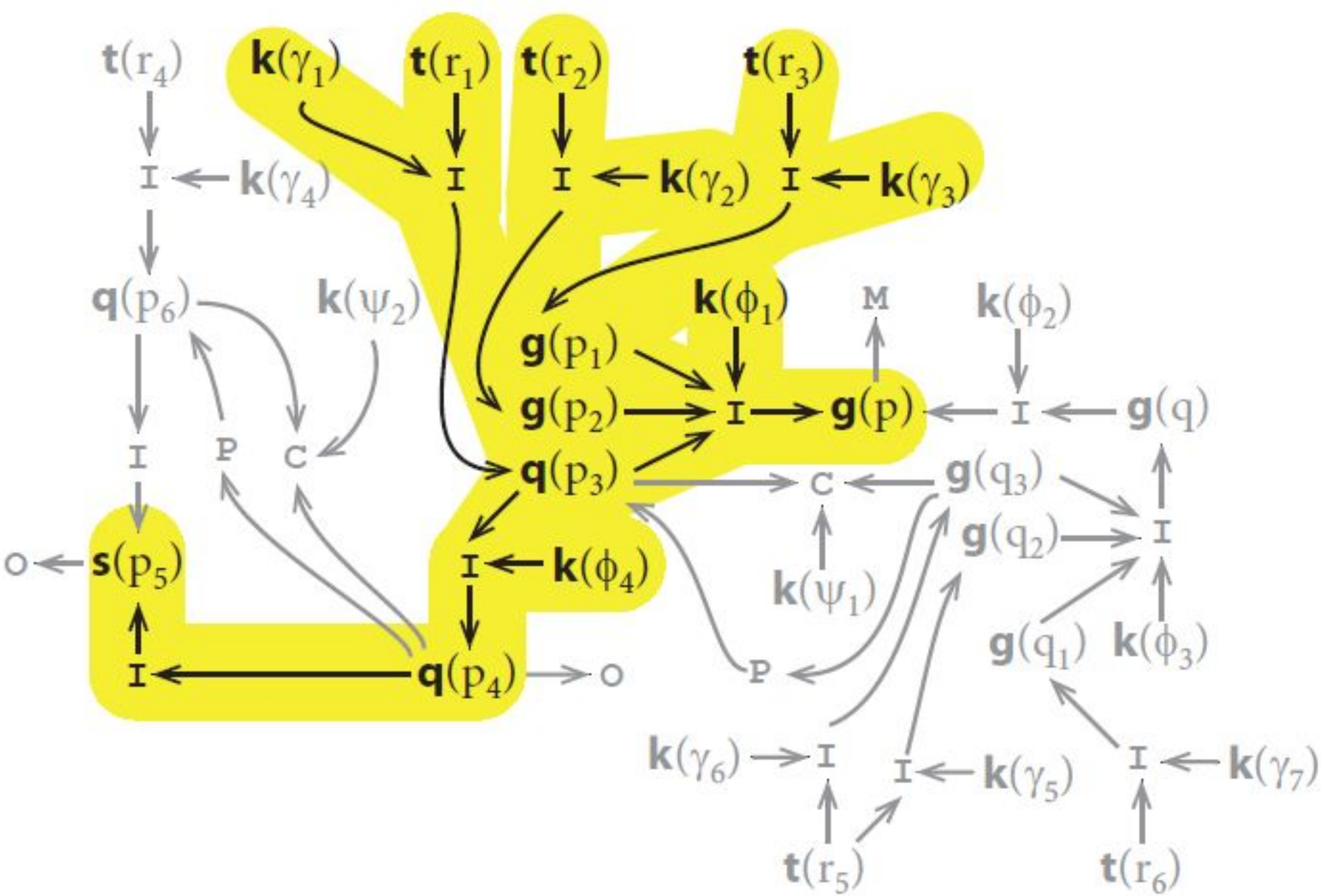
Because if a goal, quality constraint, or softgoal was a leaf, it would mean we do not know how to satisfy that goal.

Why **candidate** solution?

An r-net – if inconsistent – will include more than one maximally consistent subset of requirements, so we search for candidates and then choose one candidate as the solution.

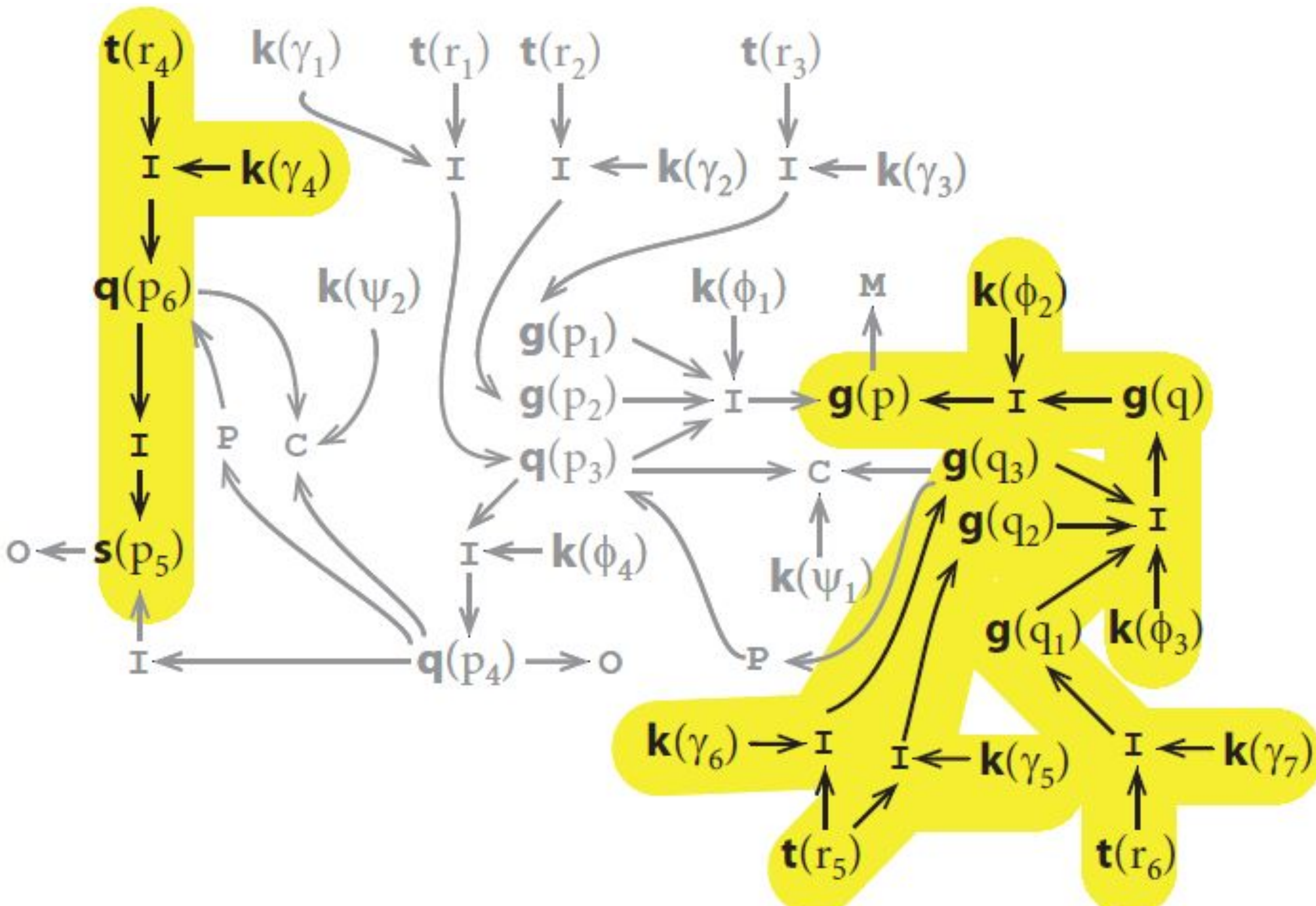
Techne features: Analysis (2/4)

Example of a candidate solution, call it A:



Techne features: Analysis (3/4)

Example of another candidate solution, call it B:



Techne features: Analysis (4/4)

Given several candidate solutions, we produce a comparison table:

	$\mathtt{P} : \mathbf{g}(q_3)$	$\mathtt{P} : \mathbf{q}(p_4)$	$\mathtt{O} : \mathbf{q}(p_4)$	$\mathtt{O} : \mathbf{s}(p_5)$
$\mathcal{S}_A$	no	yes	yes	yes
$\mathcal{S}_B$	yes	no	no	yes

The comparison table for candidate solutions A and B shown on previous slides.

The comparison table tells us:

1. which candidate includes which preferred requirement,

2. which candidate includes optional requirements.

Limitations of Techne

- Finding candidate solutions requires consistency checks, so doing so is computationally costly.

- Inconsistency handling can be much more sophisticated than in Techne, although Techne includes the basics.

- More elaborate proof theories could be more useful.

- No object-orientation.

- No task sequencing.

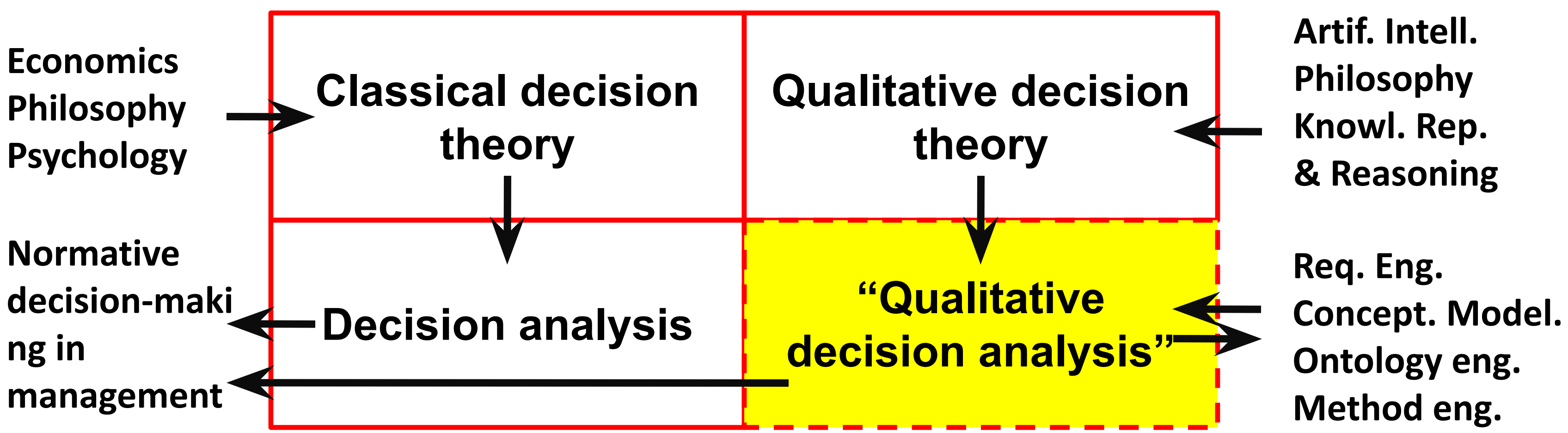
- No temporal constraints.

Current work

- **Automated identification of candidate solutions** in r-nets.

- More sophisticated **inconsistency handling**.

- Use of Techne as a basis for **qualitative decision analysis**, i.e., decision-making when information is qualitative, imrecise, incomplete, and so on. The idea is to approach decisions problems in other fields as design problems and use contributions from RE and conceptual modeling to construct and assess alternatives, and decide.



Thank you :-)

Techne

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What is decision theory?

In economics, a theory of how a rational decision maker chooses among options – this encompasses the study of:

1. **What information does she use to choose?**
   Usual ontology of decision theory:
   - Alternative (a course of action);
   - Outcome (anticipated effect/result of an alternative);
   - Probability (as a measure of uncertainty);
   - Utility (as a measure of desirability).

2. **What decision rule does she apply to single out one option?**
   Usual idea: maximize expected utility.
   Newer variants address empirical observations which contradict the predictions from the usual axioms (e.g., von Neumann & Morgenstern's).

-R. C. Jeffrey. *The Logic of Decision. Univ. Chicago Press, 1990.*
-M. D. Resnik. *Choices: An Introduction to Decision Theory. Univ. Minnesota Press, 1987.*
-J. M. Joyce. *The Foundations of Causal Decision Theory. Cambridge Univ. Press, 1999.*
-J. Von Neumann, O. Morgenstern. *Theory of Games and Economic Behavior. Princeton Univ. Press, 1956.*

What is decision analysis? (1/4)

Why did decision analysis develop?

Classical decision theory is concerned with what to choose, and offers a generic justification (e.g., highest expected utility) for the adoption of an option.

> "In reality and in the most general way, pure economic equations simply express the fact of a choice, and can be obtained independently of the notion of pleasure and pain.... For us, is sufficient to note the fact of individual choice, without investigating the psychological or meta-physical implications of such a choice.... We do not inquire into the causes of men's actions: the observation of the fact itself is sufficient."
> (Pareto, 1900, *cit. in* Marchionatti & Gambino 1997)

Classical decision theory makes two useful simplifications, as it abstracts from:

1. the rationale for a choice;
2. the procedures applied to identify alternatives, outcomes, utility and probability estimates.

-R. Marchionatti, E. Gambino. Pareto and Political Economy as a Science: Methodological Revolution and Analytical Advances in Economic Theory in the 1890s. *The Journal of Political Economy* 105(6):1322-1348, 1997.

What is decision analysis? (2/4)

“Decision analysis” is a synonym to “applied classical decision theory”.

Decision analysis is normative, it aims to suggest better/best ways to choose in realistic decision settings.

Most prominent efforts (overlapping):

1. Decision analysis at Stanford, Harvard – since the 1960s.
   (e.g., Ronald Howard, Ralph Keeney, Howard Raiffa, etc.)

2. Multi-criteria decision making (all over the place).
   (e.g., legend says that it started with Benjamin Franklin, who allegedly used a simple argumentation process to make choices – i.e., write down pro and contra arguments for an alternative, see which attacks which, and then adopt the choice if it is justified, i.e., a pro argument wins.)

-R. A. Howard. Decision analysis: Applied decision theory. Proc. 4th Int. Conf. Operational Research, 1966.
-R. L. Keeney, H. Raïffa. Decisions with multiple objectives: preferences and value tradeoffs. Wiley, 1976.
-W. Edwards, R. F. Miles, D. Von Winterfeldt (Eds.). Advances in decision analysis. Cambr. Univ P., 2007.

What is decision analysis? (3/4)

Decision analysis adopts the ontology and decision rules from classical decision theory, emphasizing that its contribution lies in the use of conceptualizations of decision theory for the structuring and analysis of complex decision situations.

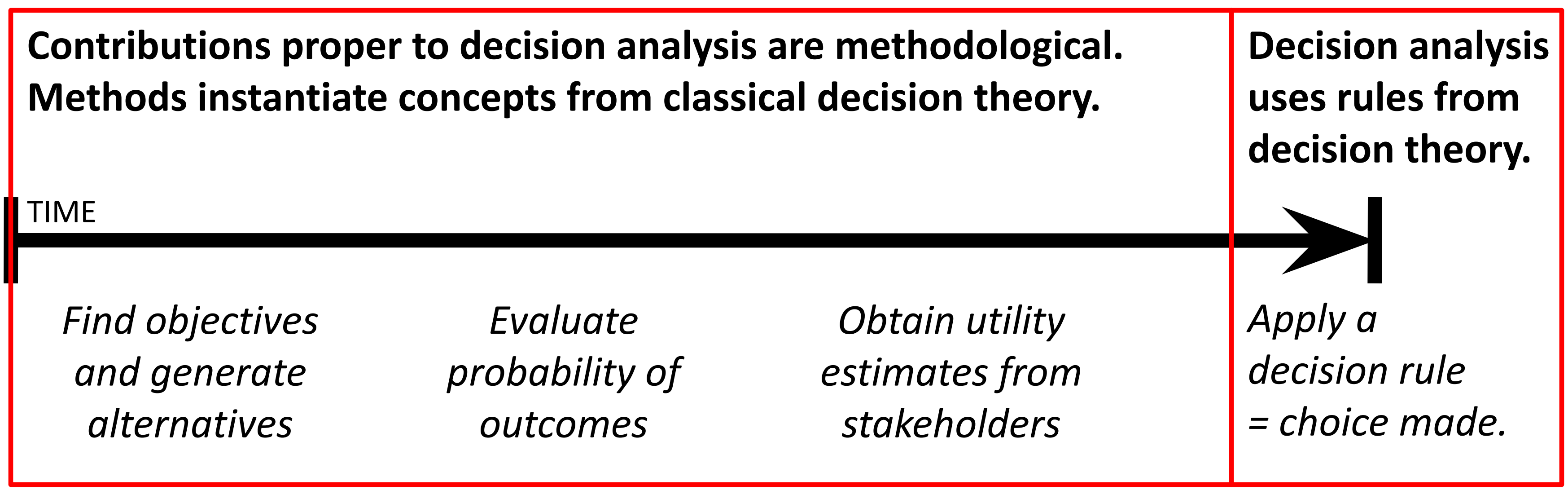
> **1. INTRODUCTION**
>
> Decision theory in the modern sense has existed for more than a decade. Most of the effort among the present developers of the theory has been devoted to Bayesian analysis of problems formerly treated by classical statistics. Many practical management decision problems, however, can be handled by formal structures that are far from novel theoretically. The world of top management decision making is not often structured by simple Bernoulli, Poisson, or normal models.
>
> Indeed, Bayes's theorem itself may not be so important. A statistician for a major company wrote a report in which he commented that for all the talk about the Bayesian revolution he did not know of a single application in the company in which Bayes's theorem was actually used. The observation was probably quite correct—but what it shows by implication is that the most significant part of the revolution is not Bayes's theorem or conjugate distributions but rather the concept of probability as a state of mind, a 200-year-old concept. Thus the real promise of decision theory lies in its ability to provide a broad logical basis for decision making in the face of uncertainty rather than in any specific models.
>
> The purpose of this article is to outline a formal procedure for the analysis of decision problems, a procedure that I call "decision analysis." We shall also discuss several of the practical problems that arise when we attempt to apply the decision analysis formalism.

-R. A. Howard. Decision analysis: Applied decision theory. Proc. 4th Int. Conf. Operational Research, 1966.

What is decision analysis? (4/4)

As an applied decision theory, decision analysis keeps the ontology of classical decision theory.

1. To measure uncertainty, subjective probability [1,2] is used.
2. To estimate desirability, decision analysis uses utility.
3. To identify the optimal alternative, decision analysis uses variants of expected utility theory [3-5].



4. B. de Finetti. *Theory of Probability*. Wiley, 1974.
5. J. Pearl. *Probabilistic Reasoning in Intelligent Systems. Morgan Kaufmann, 1988.*
6. J. Von Neumann, O. Morgenstern. *Theory of Games and Economic Behavior.* Princeton Univ. Press, 1956.
7. P. J. H. Schoemaker. The expected utility model. *J. Economic Literature*, 20(2):529-563, 1982.
8. C. Starmer. Developments in non-expected utility theory. *J. Economic Literature*, 38(2):332-382, 2000.

What if:

-Quantitative probability estimates are not available?
-Quantitative utility estimates are not available?
-Von Neumann & Morgenstern's axioms are violated (e.g., transitivity of preference)?
-Objectives and preferences change over time?
-Decision outcomes are refinable?

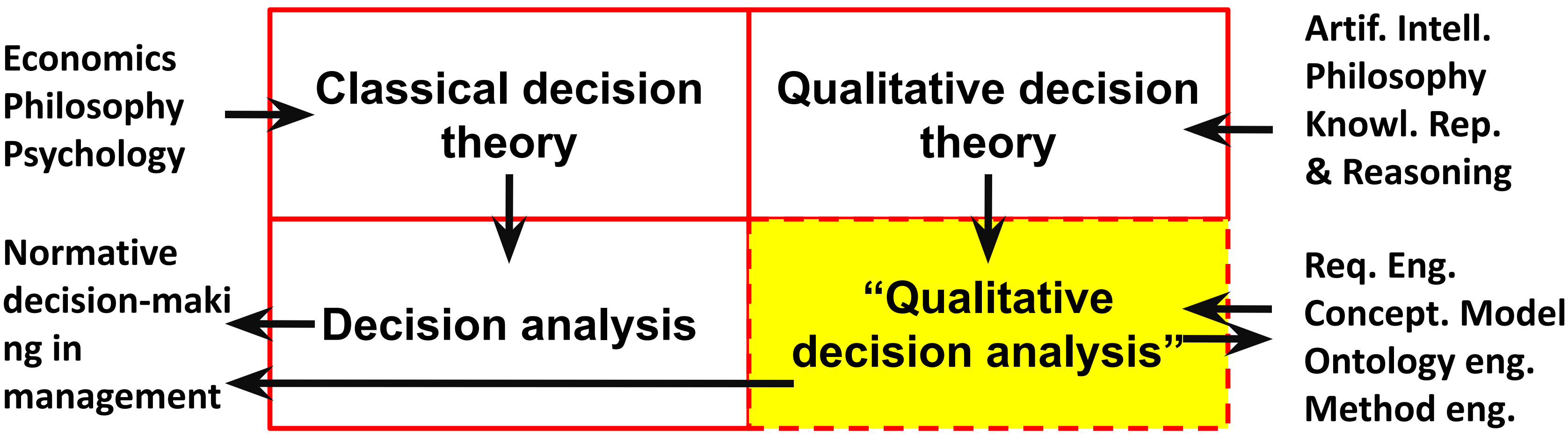
(I.e., an outcome is refinable if it can be decomposed so as to search for the utilities and/or probabilities of its "parts" and only then compute its aggregate utility and probability.)

Stated otherwise, which conceptualizations are to use when the decision maker has variously imprecise, vague, incomplete, conflicting, and unstable/changing qualitative decision information and advice from potentially non-expert stakeholders? This question is the focus of **qualitative decision theory**.

-J. Pearl. From conditional oughts to qualitative decision theory. In Conf. Uncertainty in Artif. Intel., 1993.
-R. Brafman, M. Tennenholtz. On the axiomatization of qualitative decision theory. In Conf. Artif. Intel., 1997.
-D. Dubois, H. Prade, R. Sabbadin. Decision-theoretic foundations of qualitative possibility theory. *Eur. J. Op. Res.* 128:459-478, 2001.
-J. Doyle, R. H. Thomason. Background to Qualitative Decision Theory. *AI Magazine*, 20(2) 55-68, 2000.
-S. Hanson. Preference-based Deontic Logic. *J. Phil. Logic* 19:75-93, 1990.
-H. Fargier, R. Sabbadin. Qualitative decision under uncertainty. *Artificial Intell.* 164(1-2):245-280, 2005.
-P. M. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial Intell.* 77:321-357, 1995.

Where does requirements engineering fit?

Requirements engineering is a field in which we can discuss questions pertaining to a “qualitative decision analysis”.



-I. Jureta, J. Mylopoulos, S. Faulkner. Revisiting the core ontology and problem in req. eng. In RE08.

-I. Jureta, J. Mylopoulos, S. Faulkner. A core ontology for requirements. *Applied Ontology* 4(3-4):169-244, 2009.

-I. Jureta, J. Mylopoulos, S. Faulkner. Analysis of multi-party agreement in requirements validation. In RE09.

-I. Jureta, J. Mylopoulos, S. Faulkner. Towards a Theory of Requirements Elicitation: Acceptability Condition for the Relative Validity of Requirements. *CoRR abs/0902.0924*, 2009. Online: http://arxiv.org/abs/0902.0924

-I. Jureta, A. Borgida, J. Mylopoulos, N. Ernst. Techne. Tech. Rep. CSRG-606, University of Toronto, 2010. Online: http://www.jureta.net/papers/techne-re10-v1_5-long.pdf

(+ much of the other papers on my DBLP page.)

Towards a qualitative decision analysis

Some of the key questions:

1. What is the formulation of the qualitative decision problem? [1,2]
2. What conceptualizations are relevant? [1,2]
3. What qualifies as a solution to the qualitative decision problem? [5]
4. How to find a solution to the qualitative decision problem? [5]
5. How is the formulation of the qualitative decision problem related to the quantitative ones?
6. What body of knowledge is needed to analyze qualitative decision information when constructing solutions? [6,7]

7. I. Jureta, J. Mylopoulos, S. Faulkner. Revisiting the core ontology and problem in req. eng. In RE08.
8. I. Jureta, J. Mylopoulos, S. Faulkner. A core ontology for requirements. *Applied Ontology* 4(3-4), 2009.
9. I. Jureta, J. Mylopoulos, S. Faulkner. Analysis of multi-party agreement in requirements validation. In RE09.
10. I. Jureta, J. Mylopoulos, S. Faulkner. Towards a Theory of Requirements Elicitation: Acceptability Condition for the Relative Validity of Requirements. *CoRR abs/0902.0924*, 2009. Online: http://arxiv.org/abs/0902.0924
11. I. Jureta, A. Borgida, J. Mylopoulos, N. Ernst. Techne. Tech. Rep. CSRG-606, University of Toronto, 2010. Online: **http://www.jureta.net/papers/techne-re10-v1_5-long.pdf**
12. I. Jureta. *Analysis of Advice*. Manuscript in progress. Some chapters available at: **http://jureta.net/papers/jureta-analysis-of-advice-partial-draft.pdf**
13. I. Jureta, S. Faulkner. *EIMI-B311: Decision Making & Requirements Engineering*. Lecture at the Louvain School of Management – FUNDP, held for the first time to undergraduate students in Sept.-Dec. 2009.

(+ much of the other papers on my DBLP page.)

What is Techne / What Techne should be? (1/3)

Several views, not incompatible (but sometimes misleading):

"Techne is a/the new Tropos/KAOS/i*/etc."

(True, in the sense that it is a "framework for RE" but misses the point. ***Techne is not yet another RE…****)*

"Techne is a framework for the resolution of the (new?) requirements problem."

(True, but Techne is ***not specific to RE****)*

"Techne is a framework for decision making in design."

(True, but just how general is it?)

What is Techne / What Techne should be? (2/3)

The representation part:

1. *Core concepts [RE08]*

   Goals, Domain assumptions, Plans, Evaluations, and concepts that specialize these.

2. *Core (non-order) relations [hinted at in REJ08; more in RE09]*

   Generalization of refinement, means-ends, decomposition, dependency, satisfaction, achievement, operationalization, etc. relations, via two relations: inference and attack, inspired by argumentation.

3. *Core order relations [RE08; Applied Ontology Nov. 2009]*

   Preference, Priority (i.e., preference over preferences), and uncertainty.

4. *Relations between concepts, but also, relations between relations [RE09 + long version of RE09 at Arxiv – see my DBLP]*

What is Techne / What Techne should be? (3/3)

The reasoning part:

1. *Nonmonotonic consequence relation [preliminary in RE09]*

   Design/engineering activity involves the acquisition and revision of knowledge, so that inference is defeasible: conclusions are tentative, open to revision, inferences can be “unmade” by new information. This is in contrast to classical (first-order) logic, whose inferences, being deductively valid, can never be "undone" by new information.

2. *Paraconsistent consequence relation [Techne Tech.Rep.]*

   We cannot have an explosive consequence relation: i.e., we must not have $\{A , \neg A\} \vdash B$; *i.e., we reject the ex contradictione quodlibet* principle.

3. Techne theory vs. Argumentation framework

   It should be possible to reformulate a theory in Techne into an (preference) argumentation framework, but this is very far from straightforward. If so, then we can reformulate a Techne theory as a logic program, if not, then unclear.

From Techne to (qualitative) decision theory/analysis

So now, we have a formulation of the decision problem that was not available in decision analysis. The formulation of decision analysis remained the same over the last 40 years.

We also have a body of knowledge in Conceptual Modeling, KR&R, RE, which we can use in order to construct a general framework for "qualitative decision analysis".

Perhaps we can offer something more intuitively appealing and practically relevant than what decision analysis was doing since the 1960s.

This is what Techne is about.

Ongoing work / Overview of the research project

The long-term aims are (for at least one decade, longer is more realistic):

1. Construct, refine, and empirically test novel conceptualizations, mathematical models, and methodologies for qualitative decision analysis;

2. Specialize by applying to, e.g., organizational decision making, negotiation, medical decision making, policy making;

3. Make a (interdisciplinary?) research group around this;

4. Write new, give, and improve lectures on these topics primarily at the Louvain School of Management.

Current state of the project

-Core ontology and requirements problem formulation are available (for use, criticism, and revision); a bunch of other “first steps” are available;

-Current version of Techne is conceptually and formally “stable”;

-Lecture at the LSM Namur, in 2009-2010 “EIMI-B311 Decision making & Requirements engineering” (+ book in progress).

-Current involvement:

- -U. of Namur
- -U. of Toronto
- -U. of Trento
- -Rutgers U.
- -Fondazione Bruno Kessler
- -You? :-)