Qualitative multi-attribute decision method DEX: Theory and practice

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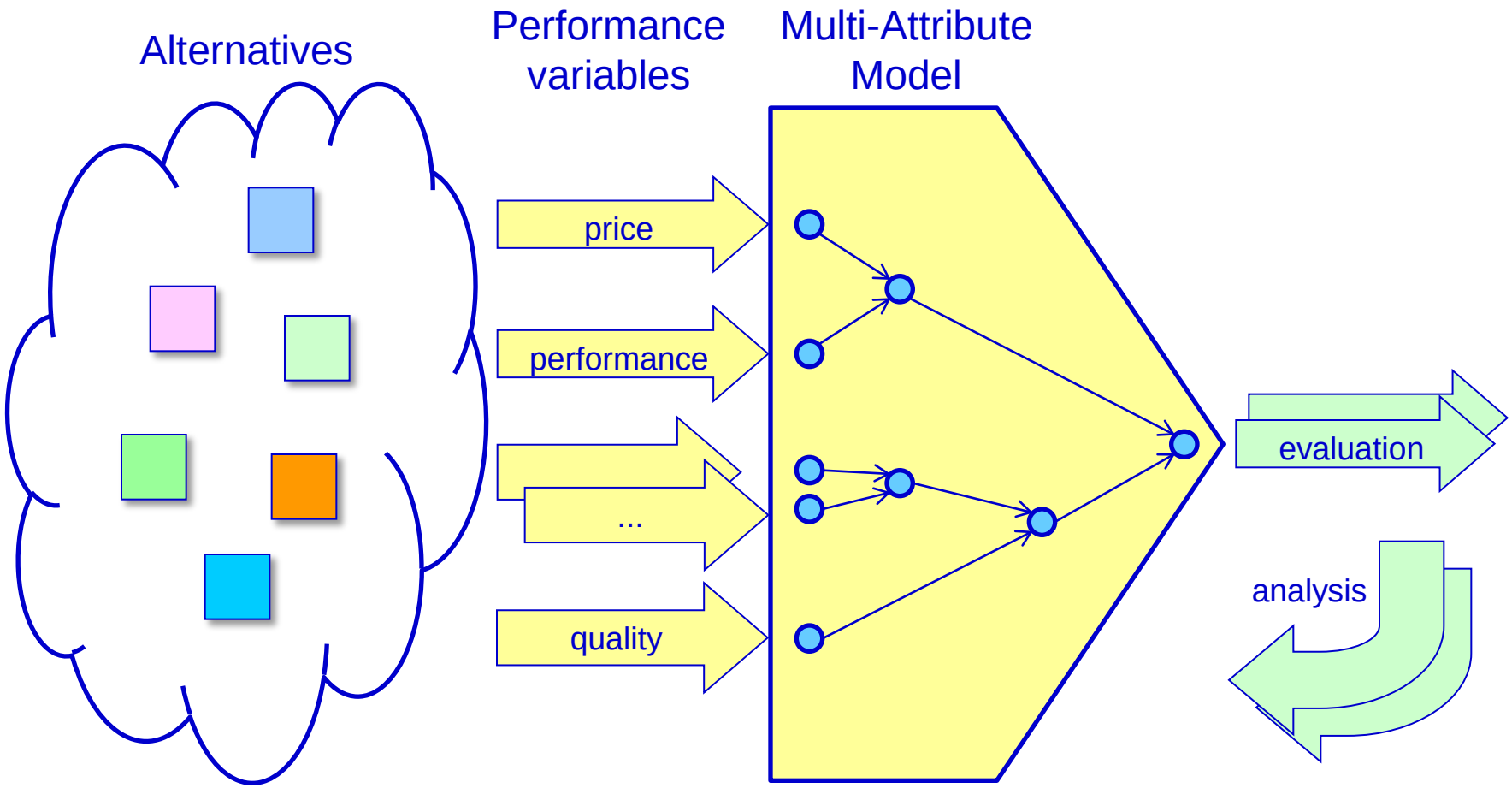
Outline

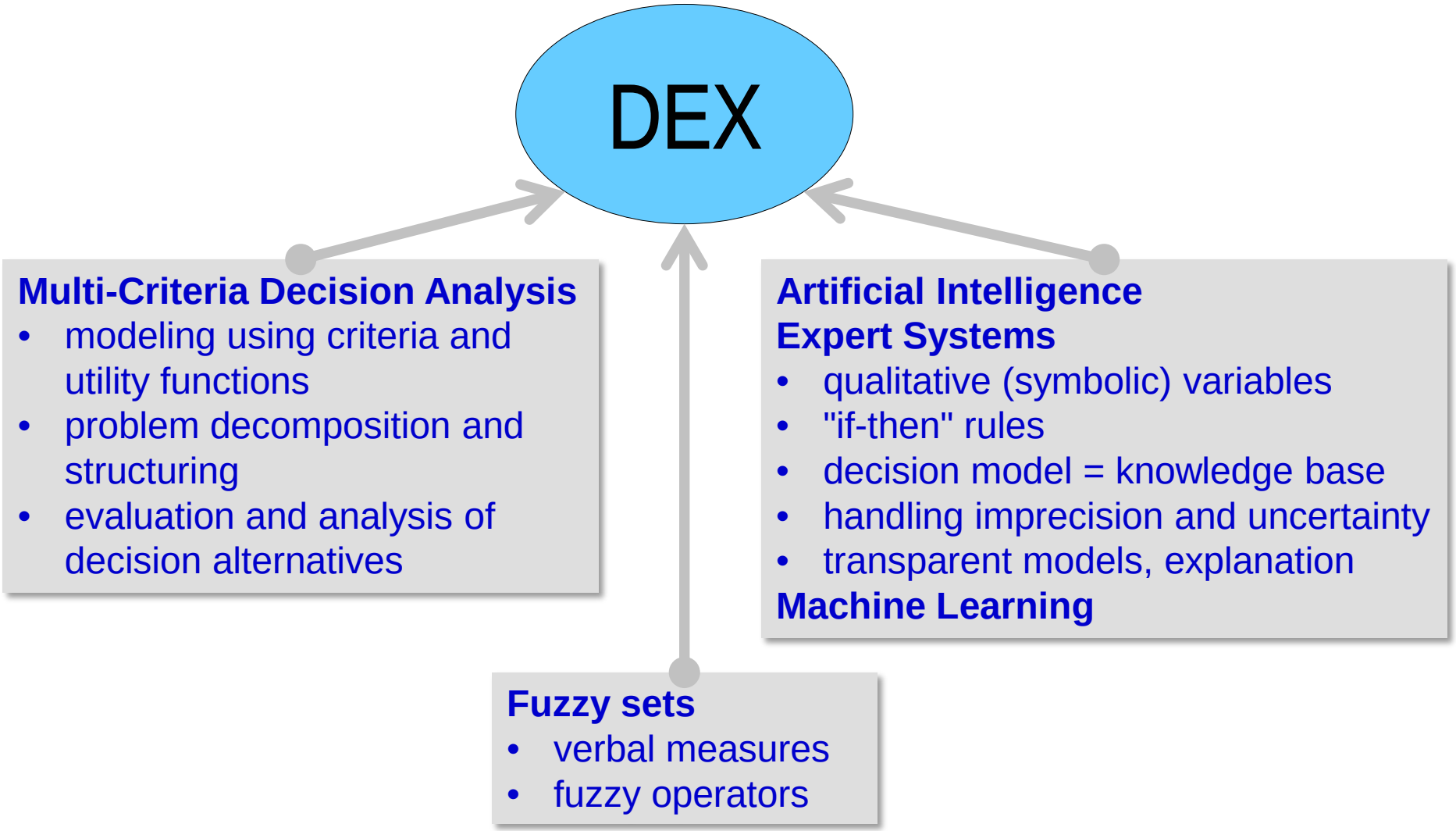
- Method DEX
  - Informal introduction
  - Formal representation of DEX models
  - Methods for development and exploitation of DEX models
- Software
- Applications

What is DEX?

Decision Support, Multi-Attribute Modeling Methodology



What is DEX?


DEX
Multi-Criteria Decision Analysis
• modeling using criteria and utility functions
• problem decomposition and structuring
• evaluation and analysis of decision alternatives
Artificial Intelligence
Expert Systems
• qualitative (symbolic) variables
• "if-then" rules
• decision model = knowledge base
• handling imprecision and uncertainty
• transparent models, explanation
Machine Learning
Fuzzy sets
• verbal measures
• fuzzy operators

Multiattribute Decisionmaking Using a Fuzzy Heuristic Approach

JANET EFSTATHIOU AND VLADISLAV RAJKOVIČ

Abstract—**Multiattribute decisionmaking (DM) is treated as a special kind of structured human problem solving. Emphasis is placed on the use of the available knowledge about utilities, which is obtained by combining heuristics and traditional aggregation methods. In this way, the problem of partial utilities and their interdependence may be solved. A fuzzy approach to DM is described, incorporating linguistic variables, relations, and algorithms. It is summarized in a formal model and illustrated by an example.**

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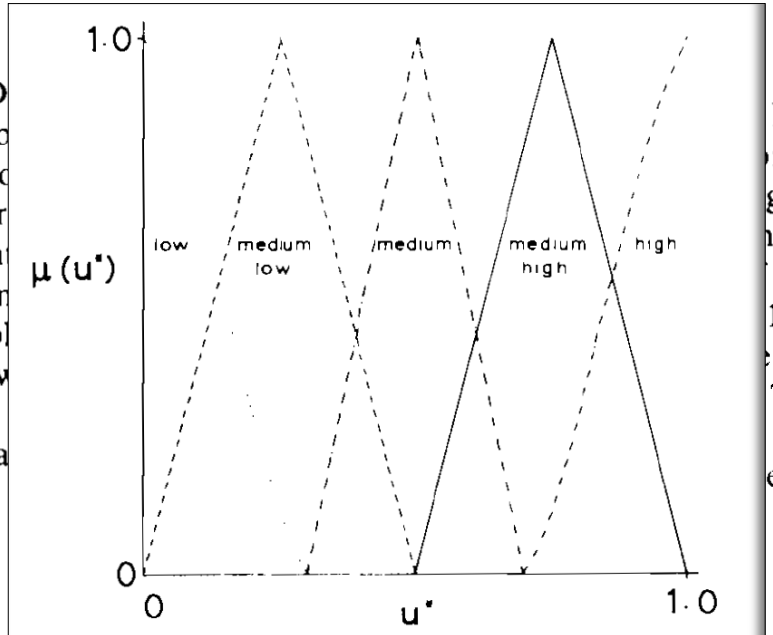


Fig. 1. Definitions of verbal utility values on U^*, [0, 1].

TABLE I
PARENTS

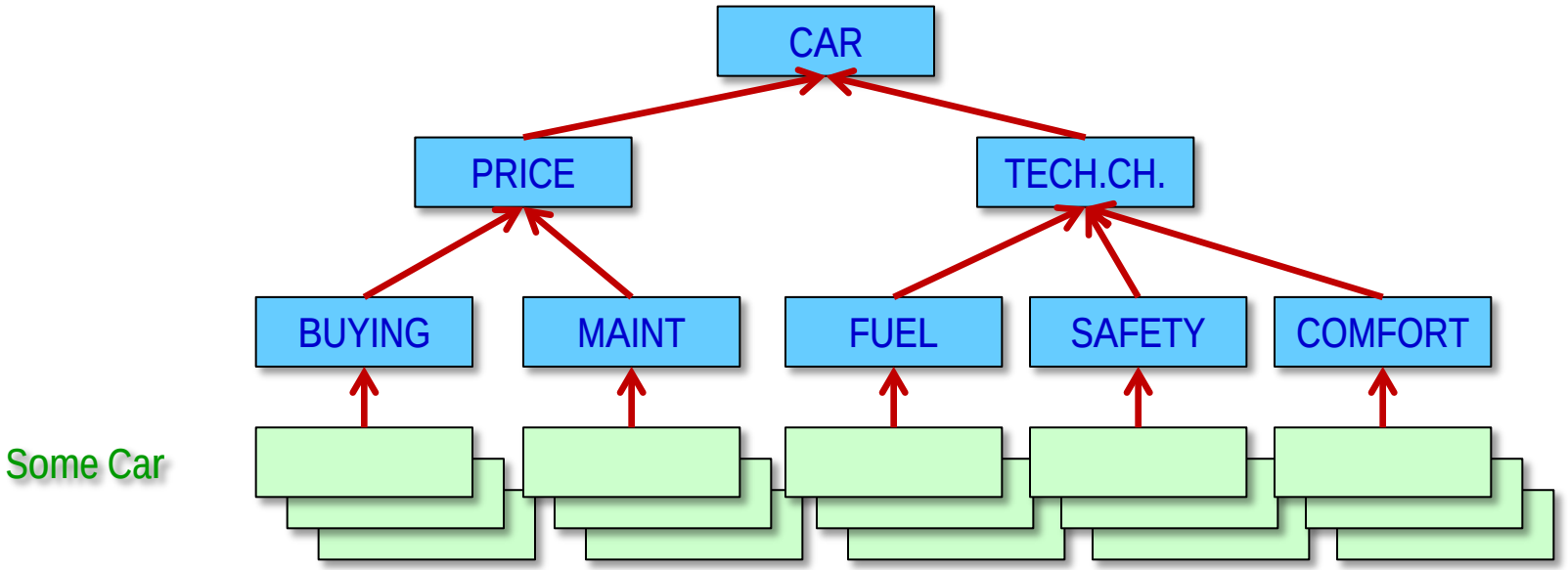
D1 Nature	D2 Performance	D3 Size	D4 Price	Utility
sc, non-sc	good	S	cheap	v^3 high
"	"	"	reas.	v high
"	"	"		
"	"	"	dear	low
sc, non-sc	good	med. small	cheap	v^2 high
"	"	"	reas.	high
"	"	"	dear	low
sc, non-sc	good	med. large	cheap	med.
"	"	"	reas.	med. low
"	"	"	cheap	low
sc, non-sc	med.	small	cheap	v^3 high
"	"	"	reas.	high
"	"	"	dear	v low
sc, non-sc	med.	med. small	cheap	high
"	"	"	reas.	med. high
"	"	"	dear	v low
sc, non-sc	med.	med. large	reas.	low
sc, non-sc	poor	small	reas.	med. high
sc, non-sc	good, med, poor	large	cheap, reas, dear	v^3 low

DEX

Method for qualitative multi-attribute modeling

DEX is similar to other multi-attribute methods:

1. Multiple attributes, hierarchically structured
2. Evaluation of alternatives: bottom-up aggregation

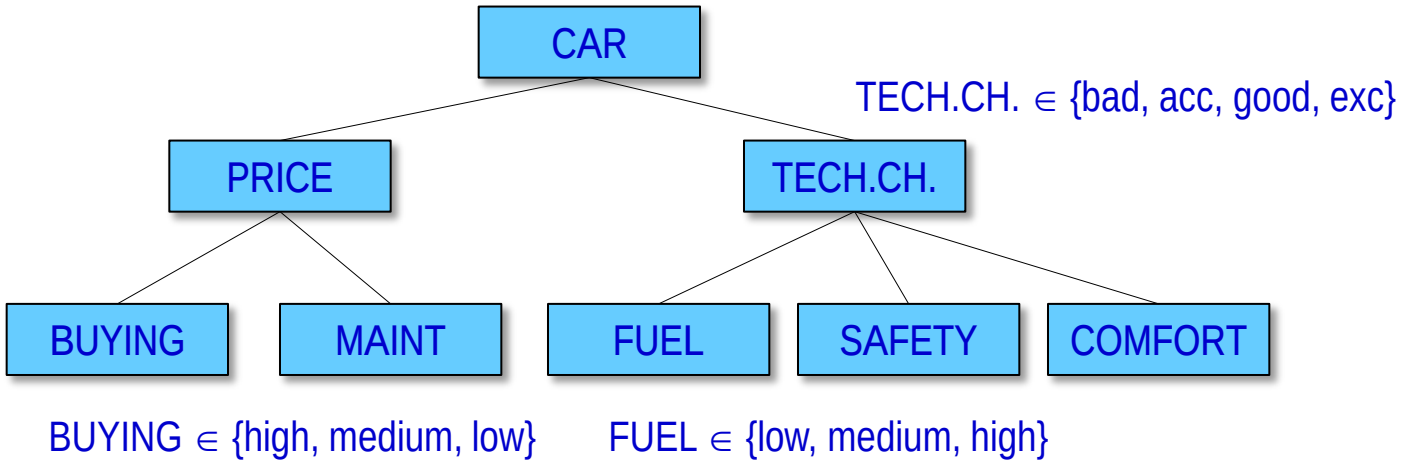


DEX

Method for qualitative multi-attribute modeling

DEX is different from the majority of multi-attribute methods:

1. Attributes are discrete, symbolic, qualitative

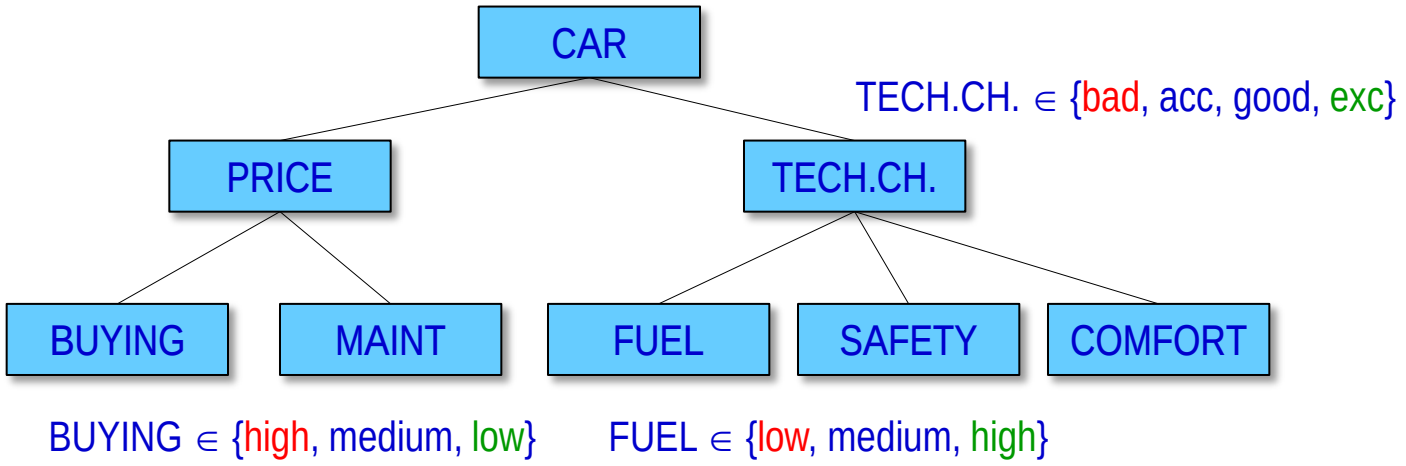


DEX

Method for qualitative multi-attribute modeling

DEX is different from the majority of multi-attribute methods:

1. Attributes are discrete, symbolic, qualitative
   Attribute scales can be unordered (categorical),
   but are typically preferentially ordered (increasing or decreasing)

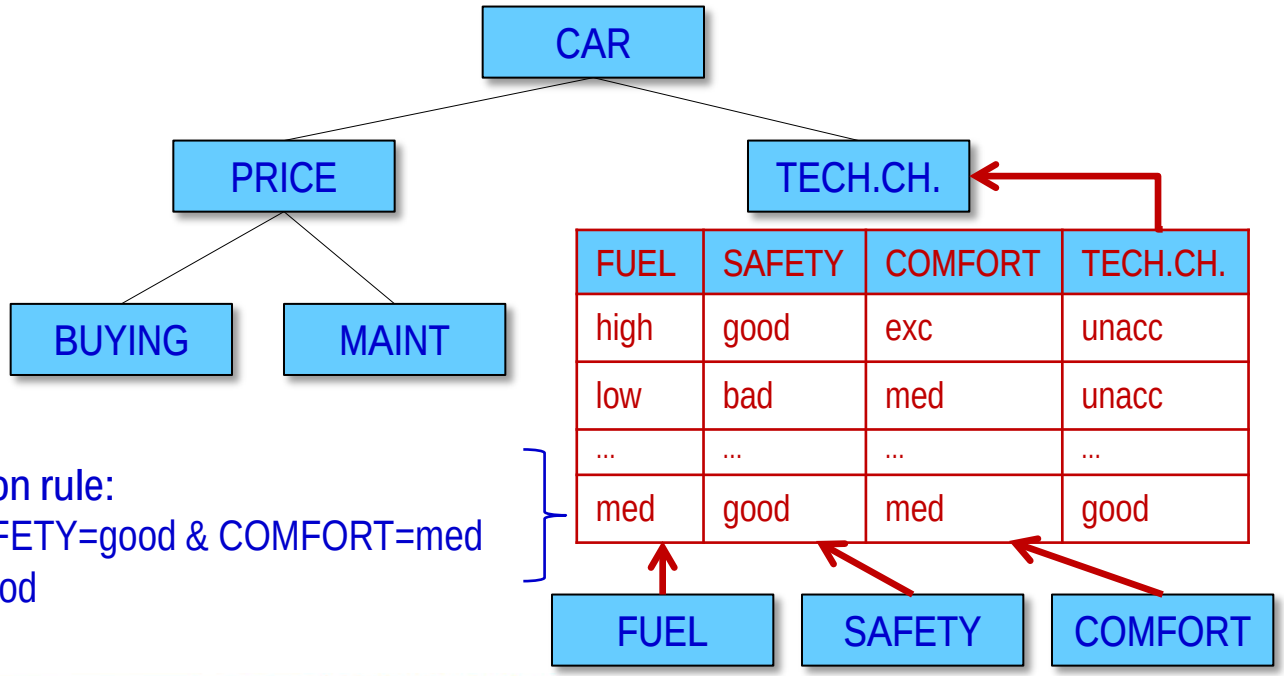


DEX

Method for qualitative multi-attribute modeling

DEX is different from other multi-attribute methods:

2. Evaluation of alternatives (aggregation) is defined by *decision tables*



Elementary decision rule:
if FUEL=med & SAFETY=good & COMFORT=med
then TECH.CH.=good

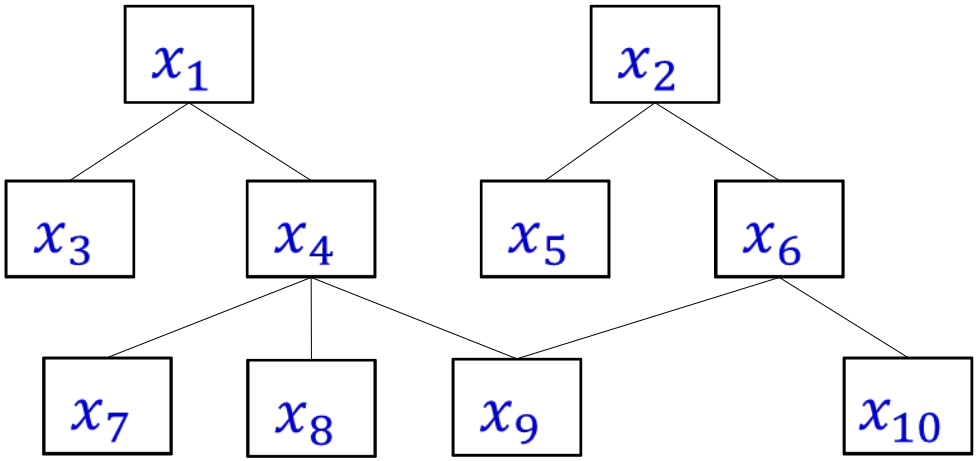
DEX Model: Formal Representation

Model: $M = (X, S, D, F)$

Attributes: $X = \{x_1, x_2, \ldots, x_n\}$

Hierarchy: $S: X \rightarrow 2^X$ descendants of X

so that $\forall x \in X: x \notin S^*(x)$ no cycles



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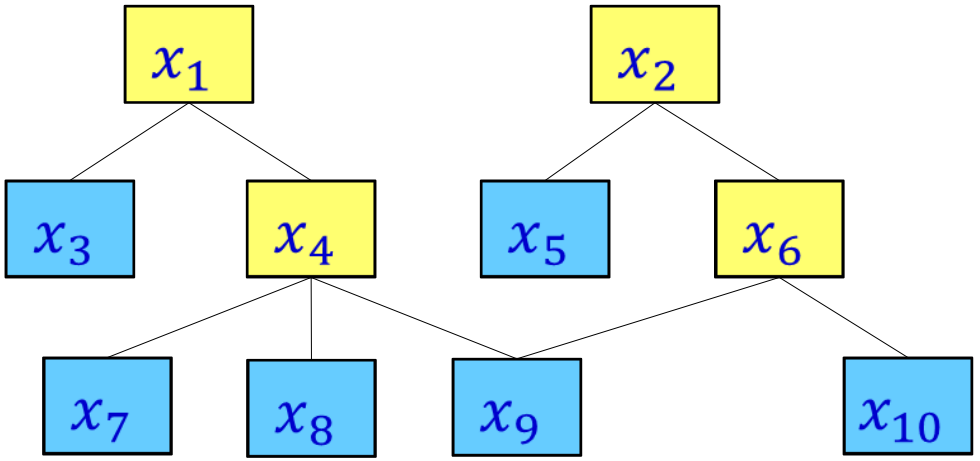

aggregate attributes

basic attributes - inputs

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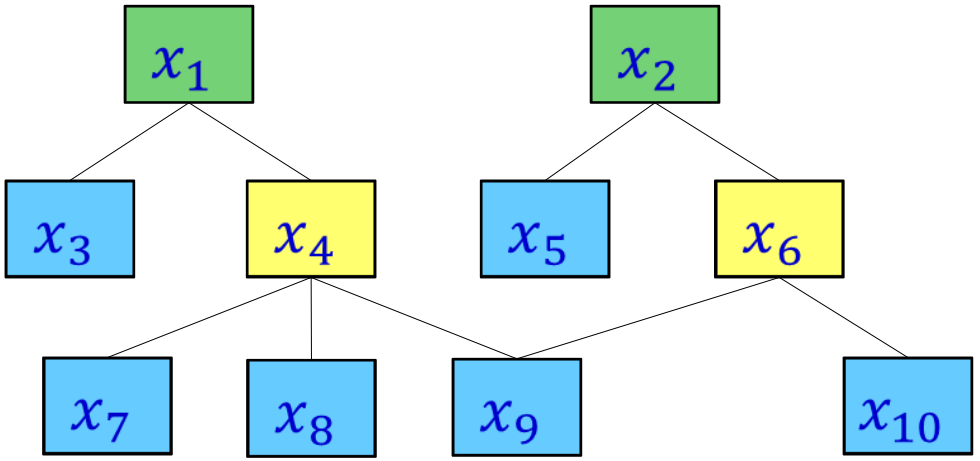


outputs

aggregate attributes

basic attributes - inputs

DEX Model: Formal Representation

Model: $M = (X, S, D, F)$

Value scales: $D = \{D_1, D_2, \dots, D_n\}$

for $i = 1,2, \dots n$:

$$x_i \in D_i$$

$$D_i = \left\{v_i^1, v_i^2, \dots, v_i^{d_i}\right\}, d_i > 1$$

For an increasing D_i: $v_i^j \preccurlyeq_i v_i^{j+1}, j = 1,2, \dots, d_i - 1$

For a decreasing D_i: $v_i^{j+1} \preccurlyeq_i v_i^j, j = 1,2, \dots, d_i - 1$

Each D_i is partitioned into B_i, N_i, G_i so that

$$D_i = B_i \cup N_i \cup G_i \text{ and } B_i \preccurlyeq_i N_i \preccurlyeq_i G_i$$

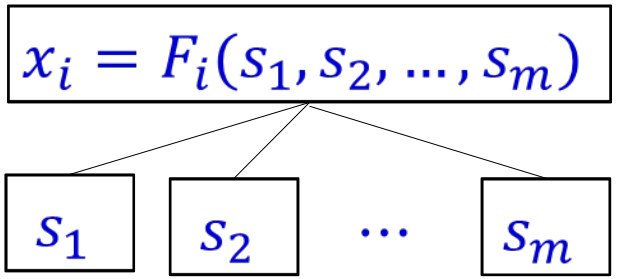
DEX Model: Formal Representation

Model: $M = (X, S, D, F)$

Utility (aggregation) functions:

$$F = \{F_i | x_i \text{ is aggregate}\}$$

$$F_i: \times_{s \in S(x_i)} \rightarrow E_i, \text{ total}$$



Possible formulations of E_i:

"Basic": $E_i \equiv D_i$

if SAFETY=good & COMFORT=med **then** TECH.=good

"Practical": $E_i \equiv$ interval over D_i

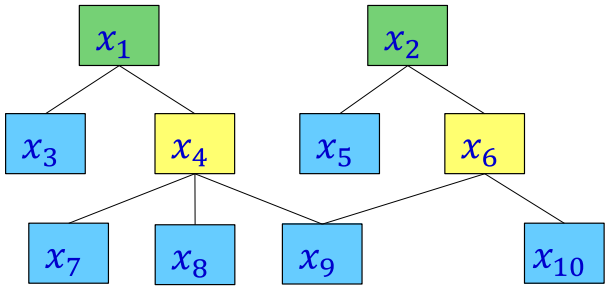
if SAFETY=good & COMFORT=good **then** TECH=[good,exc] (or ≥good)

"Extended": $E_i \equiv$ distribution over D_i (probabilistic, fuzzy)

if SAFETY=good & COMFORT=med **then** TECH=(good/0.7; exc/0.3)

DEX Method: Dynamic Aspects

Creation



Usage

How to:

- Obtain model and its components?
- Verify model and its components (e.g. for completeness and consistency)?
- Deal with uncertainty?
- Ensure transparency, comprehensibility?
- Support model dynamics?

How to:

- Obtain and represent data about alternatives?
- Deal with incomplete, uncertain data?
- Explain and justify results?
- Validate results?
- Carry out the analyses? Which analyses?
- Assess the quality of decision?

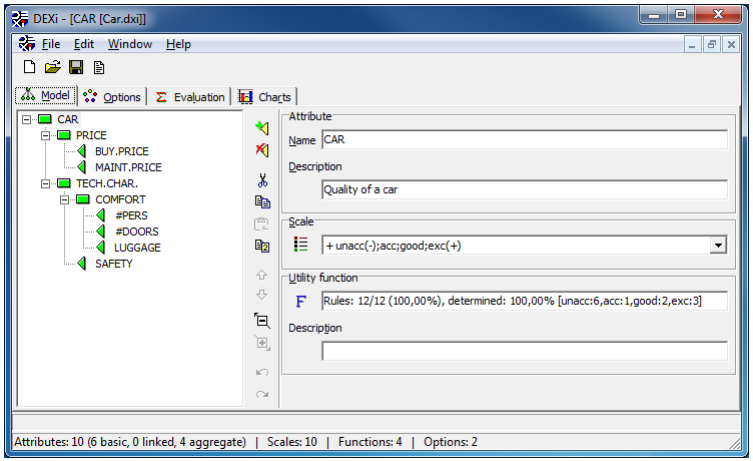
DEXi:

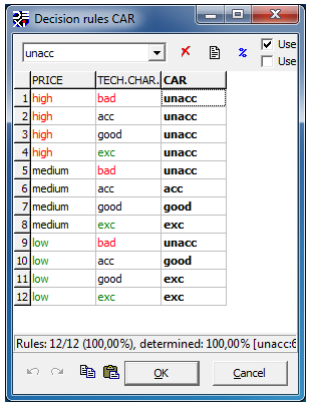
Program for Multi-Attribute Decision Making

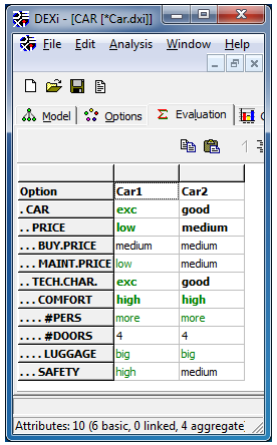
http://kt.ijs.si/MarkoBohanec/dexi.html

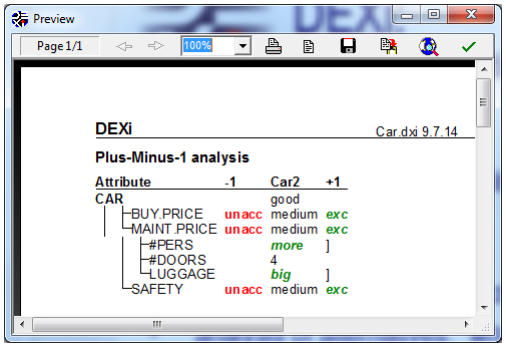
Functionality:

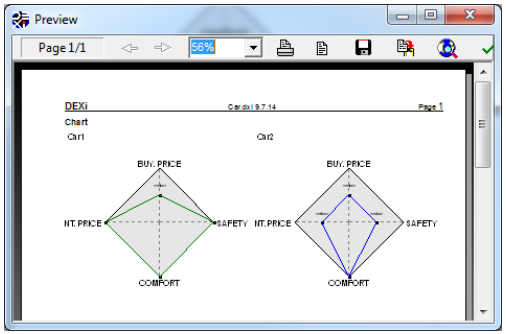
- creation and editing of qualitative DEX models:
  - model structure
  - decision tables
- acquisition and evaluation of alternatives
- analysis of alternatives: “what-if”, “±1 analysis”, comparison of alternatives, selective explanation
- tabular and graphical reports



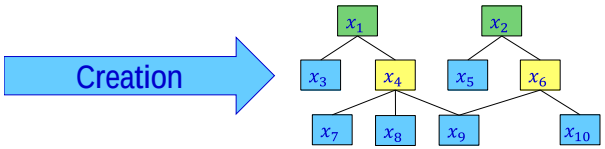






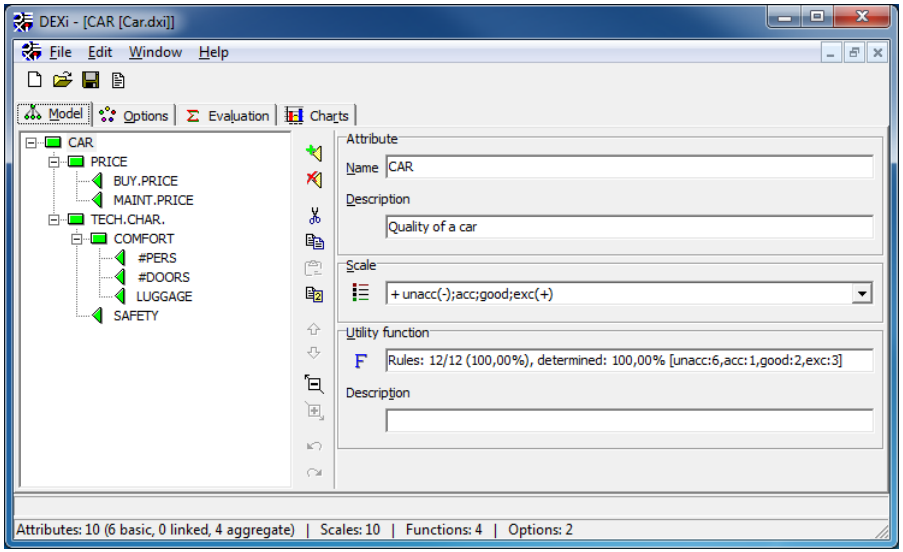


DEX Method: Model Creation



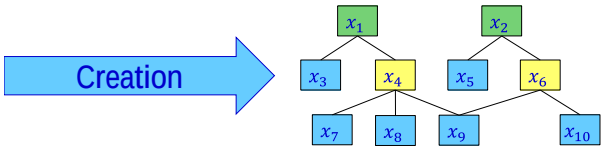
Obtaining attributes, their value scales and model structure:

- Expert modeling, 'hand-crafting',
  following guidelines and 'rules of thumb'



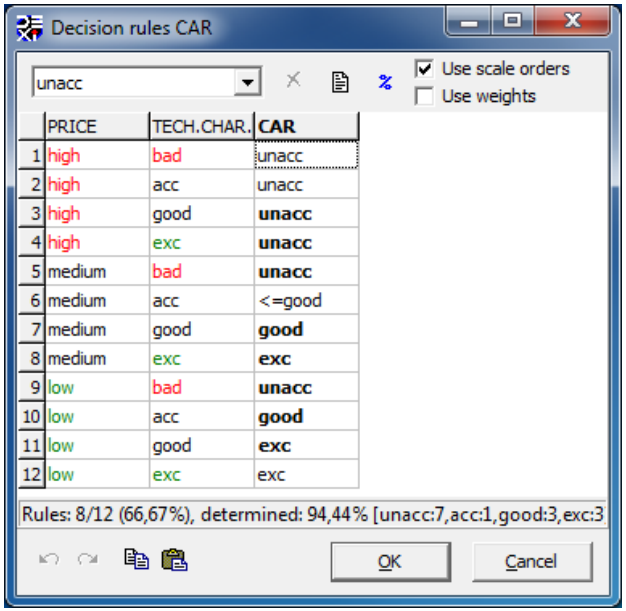
- Machine learning from data (methods: HINT, Model Revision)

DEX Method: Model Creation



Acquisition of decision tables and decision rules

- Active support
- Three “strategies”:
  - Direct
  - ‘Use scale orders’ (based on dominance)
  - ‘Use weights’ (based on attributes’ weights)
- Validation:
  - Consistency (based on dominance)
  - Completeness (% determined function values)
- Principle:
  - ‘The user is always right’ (but warned if considered to be in error)



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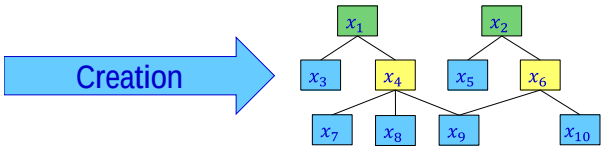
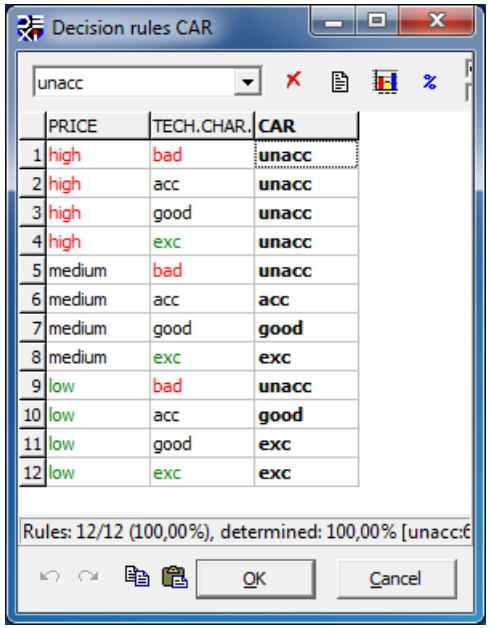
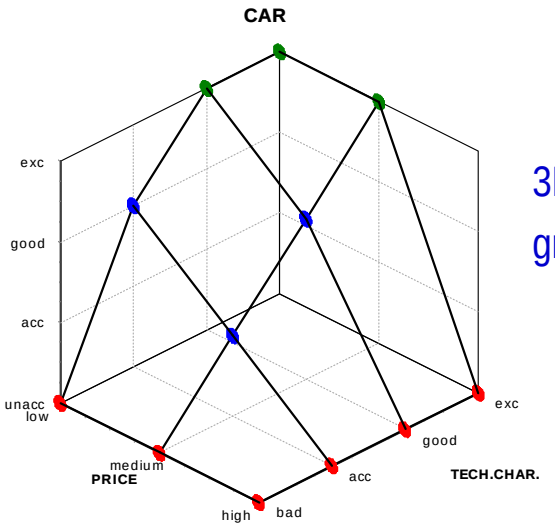


Transparency: Representation and visualization of decision rules



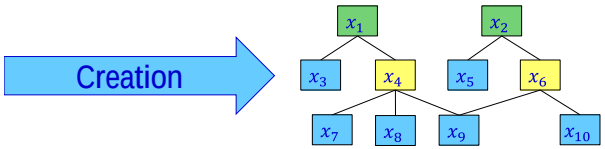
	PRICE	TECH.CHAR.	CAR
	60%	40%	
1	high	*	unacc
2	*	bad	unacc
3	medium	acc	acc
4	medium	good	good
5	low	acc	good
6	>=medium	exc	exc
7	low	>=good	exc

Aggregate rules

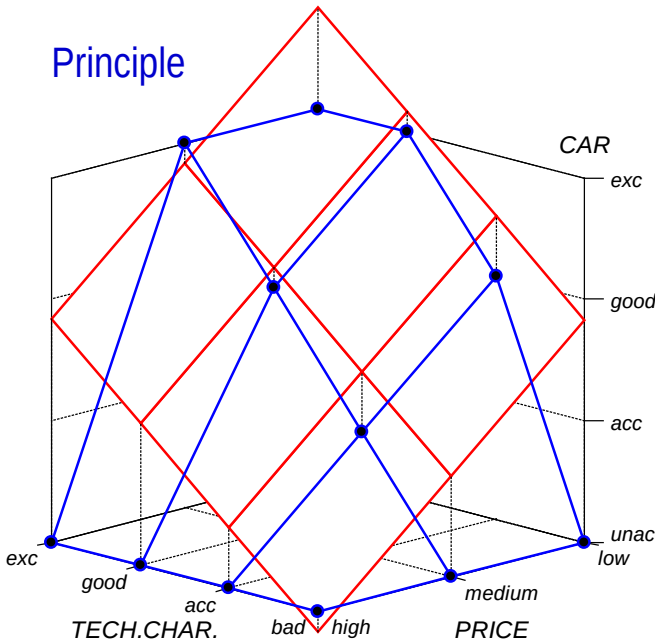


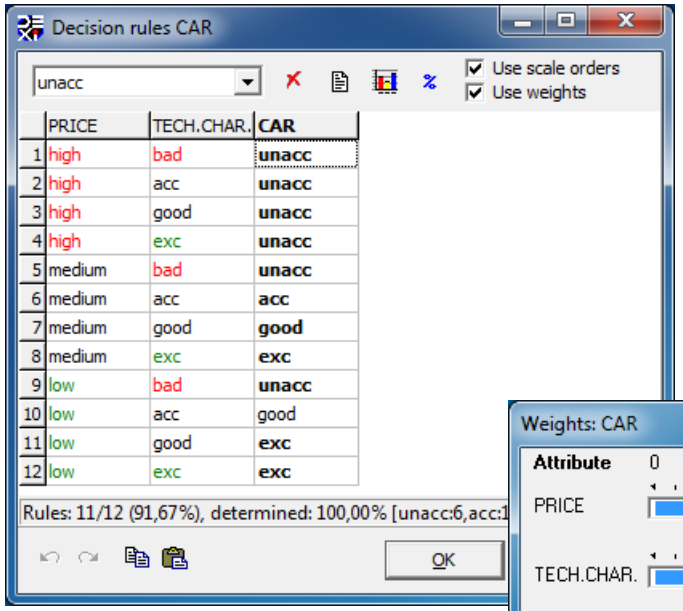
3D point-by-point graphic

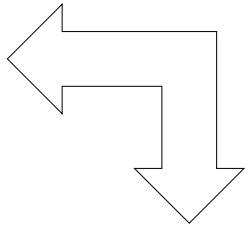
DEX Method: Model Creation

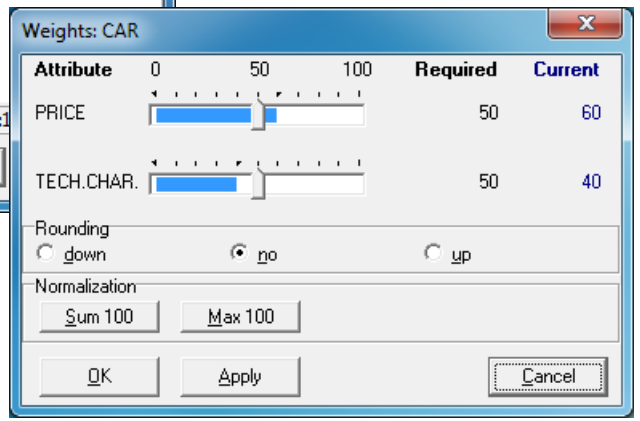


Bridging the gap between qualitative and quantitative value functions









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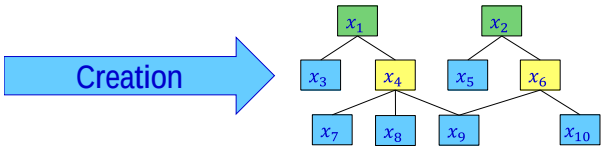


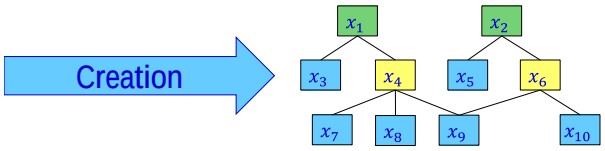
Handling changes of model structure and components:

- Adding, deleting, moving, connecting attributes and subtrees
- Adding, deleting, moving, joining attribute values

Principles:

- Preserve the available information as much as possible
- Perform operations ‘behind the scene’ (with due warnings)

DEX Method: Model Creation



Handling changes of model structure and components:

- Adding, deleting, moving, connecting attributes and subtrees
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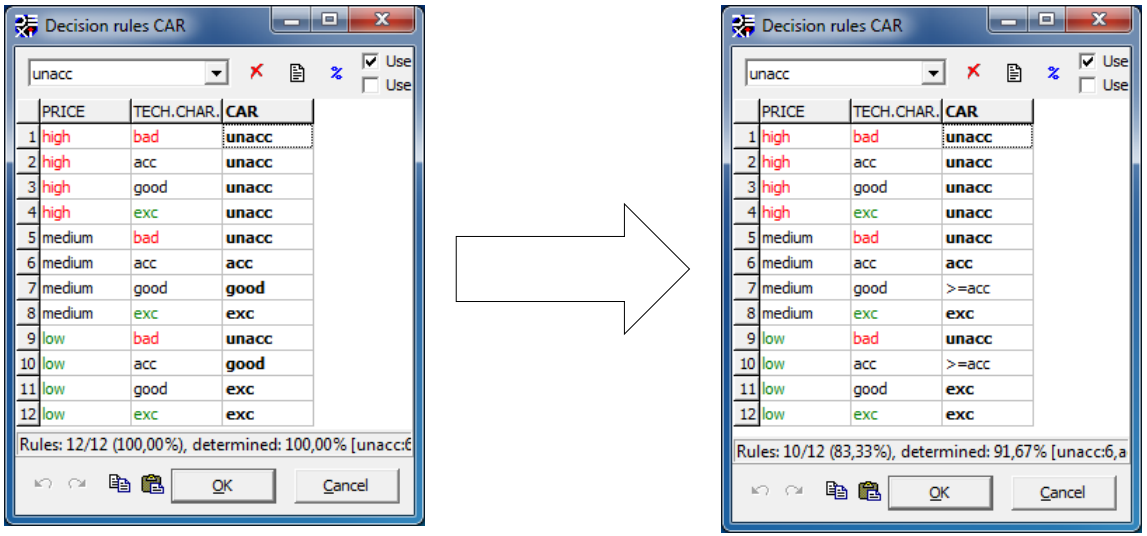
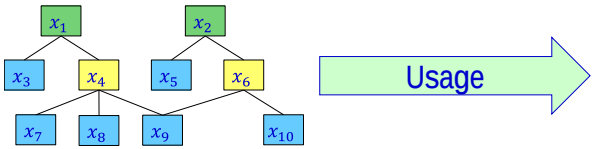
Example: delete attribute value ‘good’ of CAR



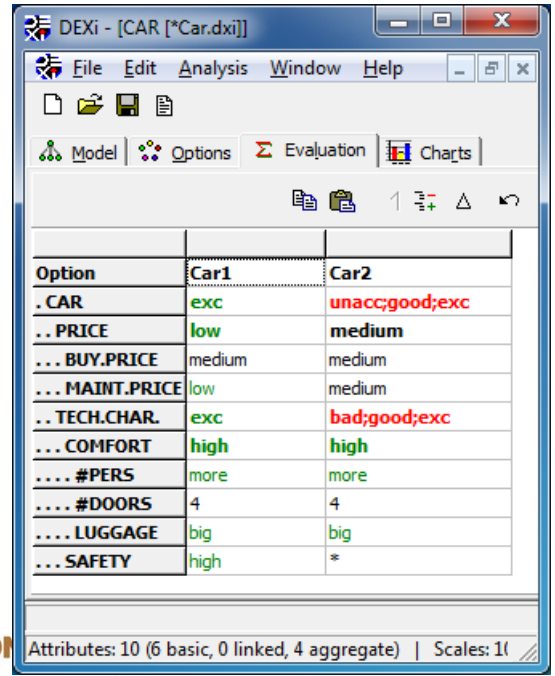
DEX Method: Model Exploitation



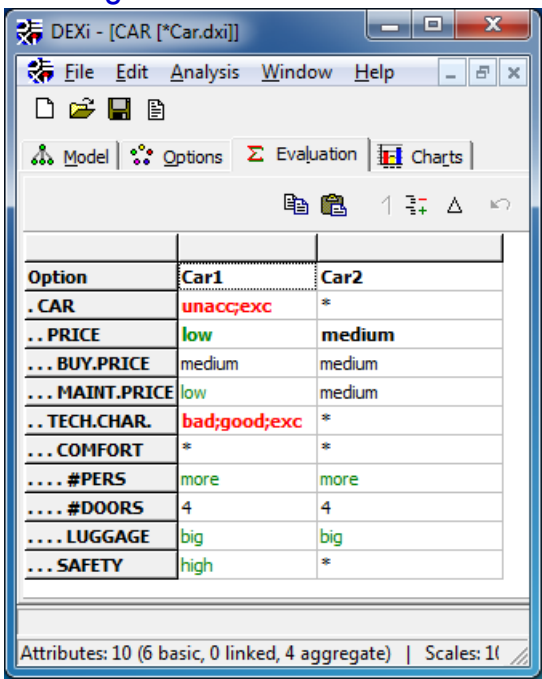
Evaluation of alternatives:

- Bottom-up table lookup
- Principle: Use all available information (even when data or rules are incomplete)
- Handling uncertainty:
  - interval/set values
  - probability distribution
  - fuzzy distributions

Missing data



Missing decision table COMFORT



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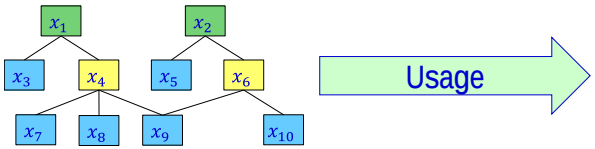
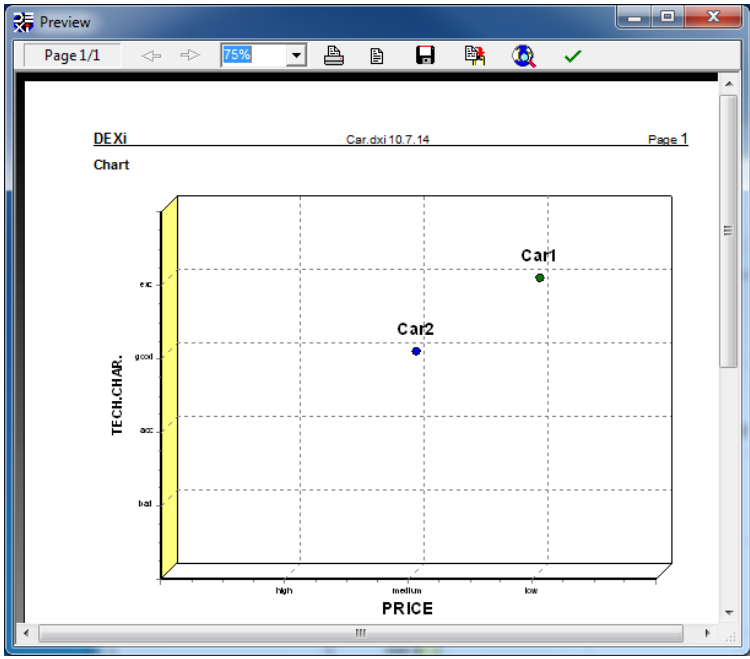
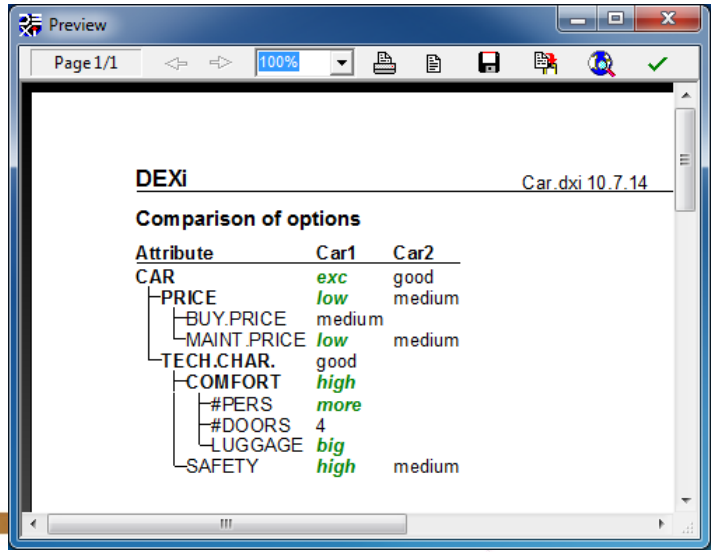
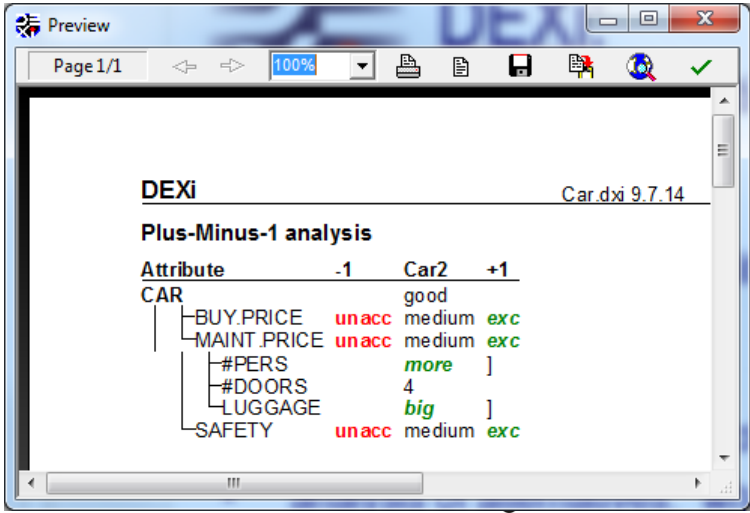


Analysis of alternatives:

- "What-if analysis"
- "±1 analysis"
- Compare alternatives
- Selective explanation







DEX Milestones

Methodology
- initial development

Software
- DECMAK
- “toolbag”

First applications
- HW and SW selection
- personnel mgmt
- nursery schools

Methodology
- integration

Software
- DEX
- Vredana

National applications
- Housing Fund
- Ministry Sci-Tech
- Talent System
- industry
- medicine

Related
- HINT

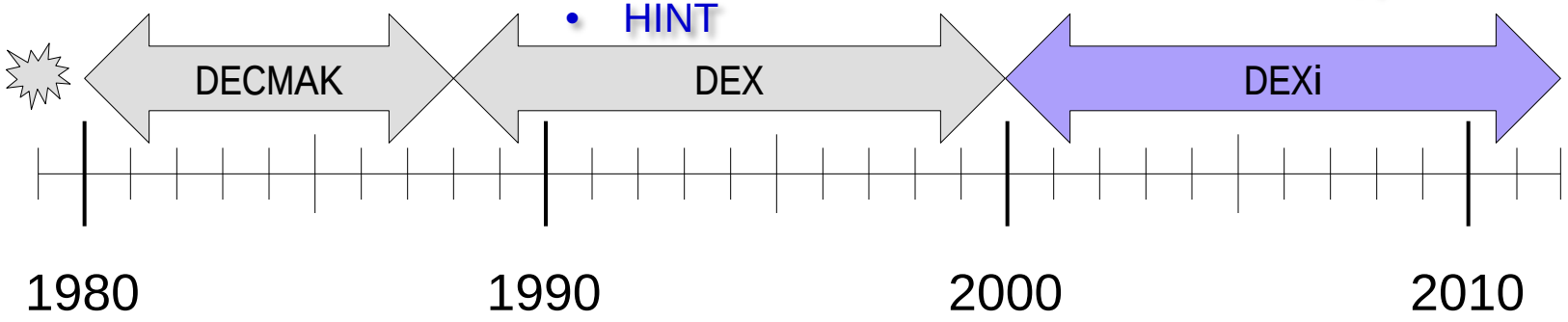
Methodology
- further improvement

Software
- DEXi

Education

International applications
- Sol-Eu-Net
- agronomy, GMO
- project evaluation
- finance

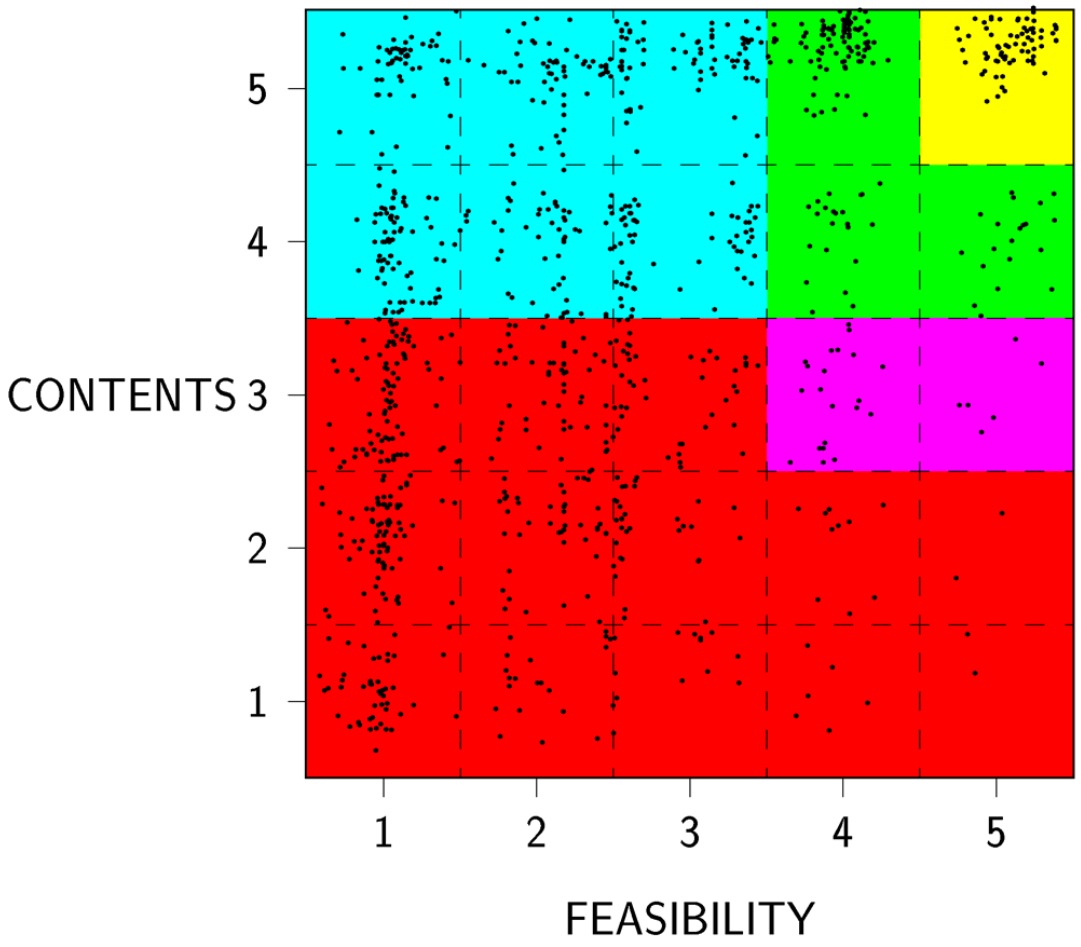
Related
- model revision, proDEX



Evaluation of R&D Projects

- Overall project evaluation
  - Contents evaluation
    - Evaluation of goals
    - Evaluation of objectives
  - Feasibility evaluation
    - Evaluation of external feasibility
    - Evaluation of internal feasibility

- Evaluation of goals
  - Direct benefits
    - Development benefits
      - Mastering of new technologies
      - Ecological impacts
      - Employment impacts
        - Employment generation
        - Impact on employment structure
    - Economic benefits
      - Impact on marketing
        - Opening of new markets
        - Anticipated share of export
        - Impact on decreasing imports
      - Anticipated profit
      - Decrease of energy or raw materials
  - Indirect social benefits
    - Level of social benefits
      - Area of influence
      - Field of influence
    - Impact on restructuring of the economy
    - Importance for state defense
  - Conformity with the development strategy of RS



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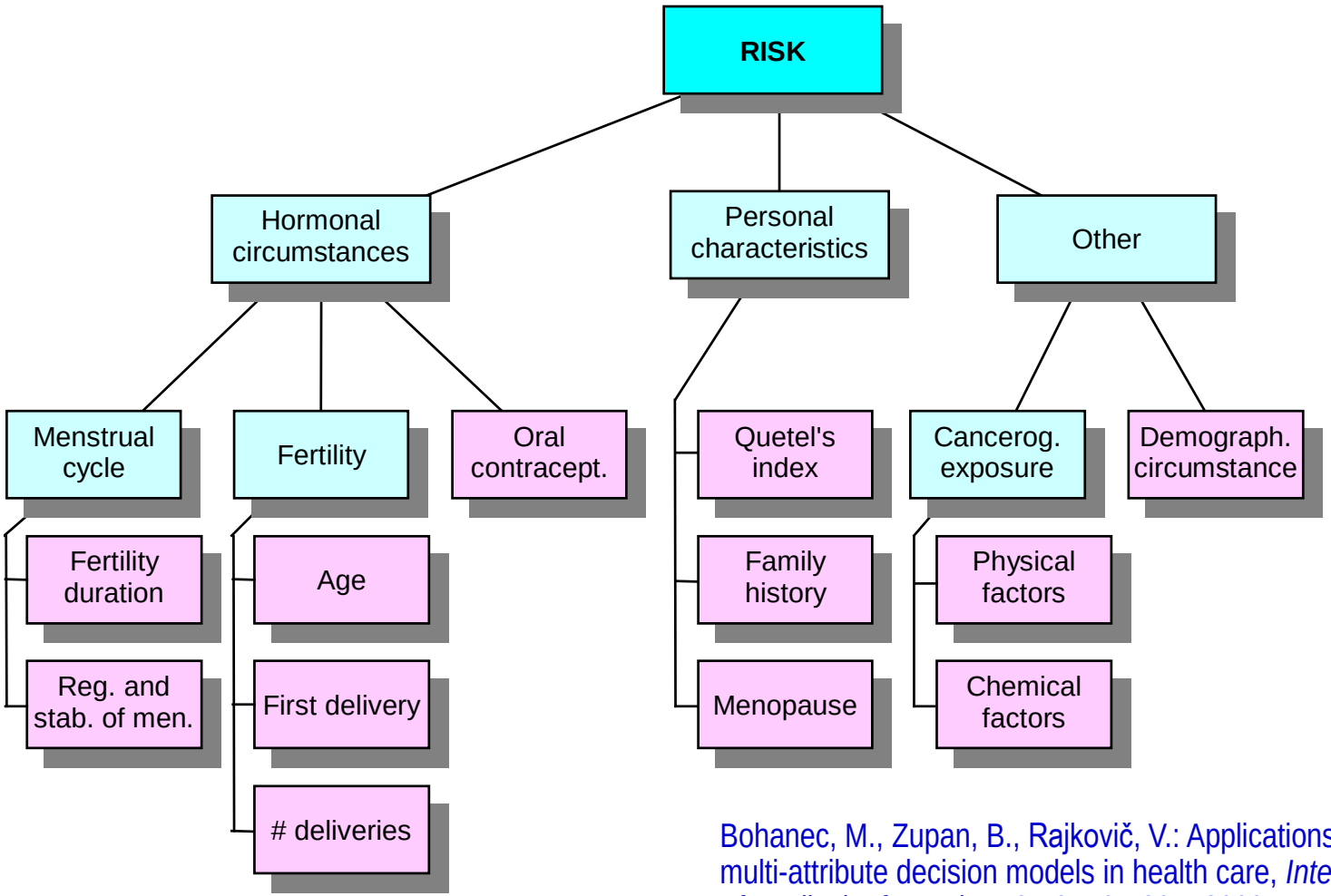

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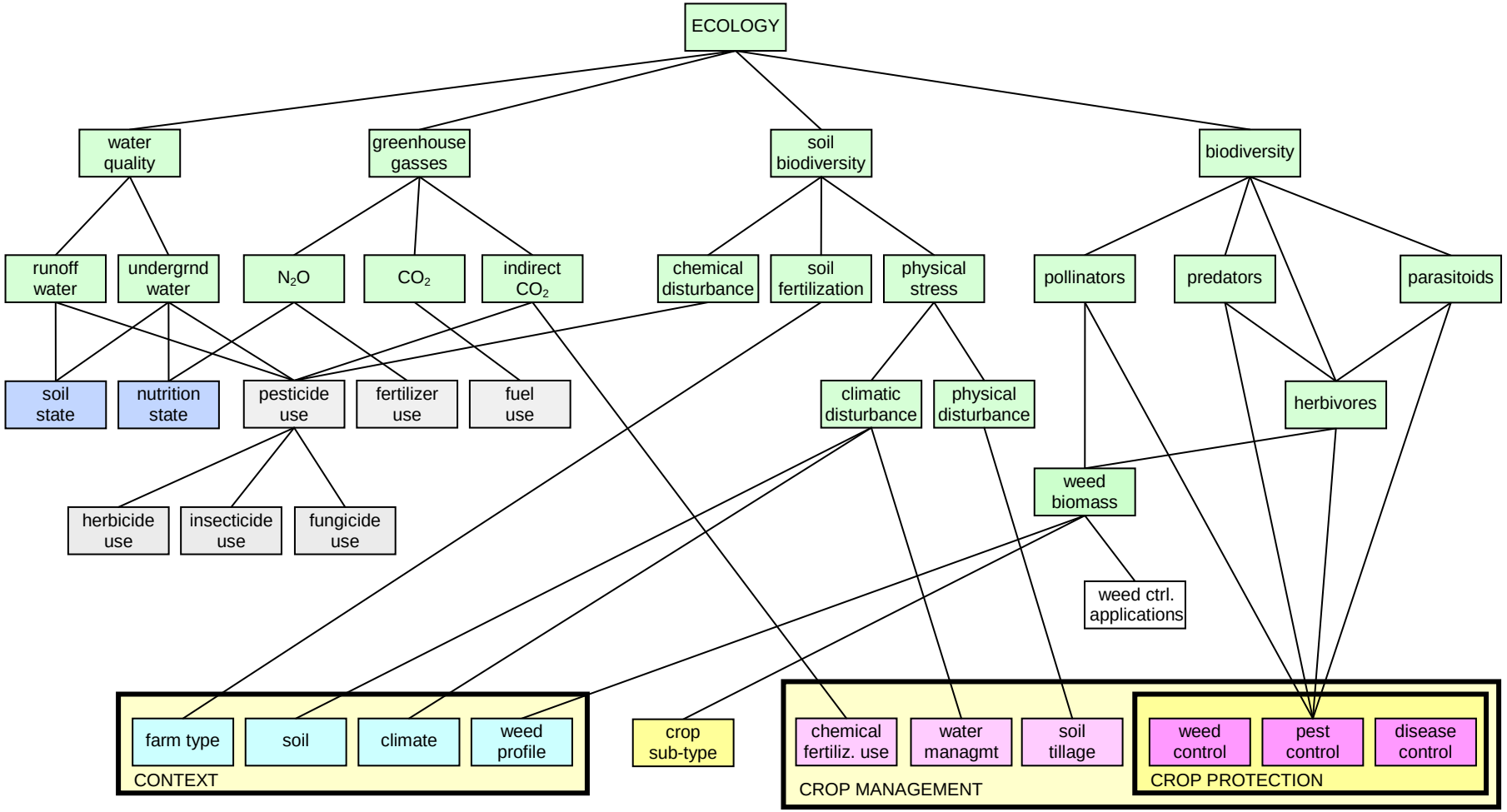

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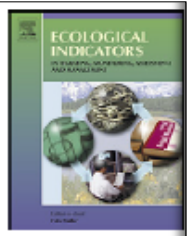

Assessing innovative cropping systems with DEXiPM, a qualitative multi-criteria assessment tool derived from DEXi

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ARTICLE INFO

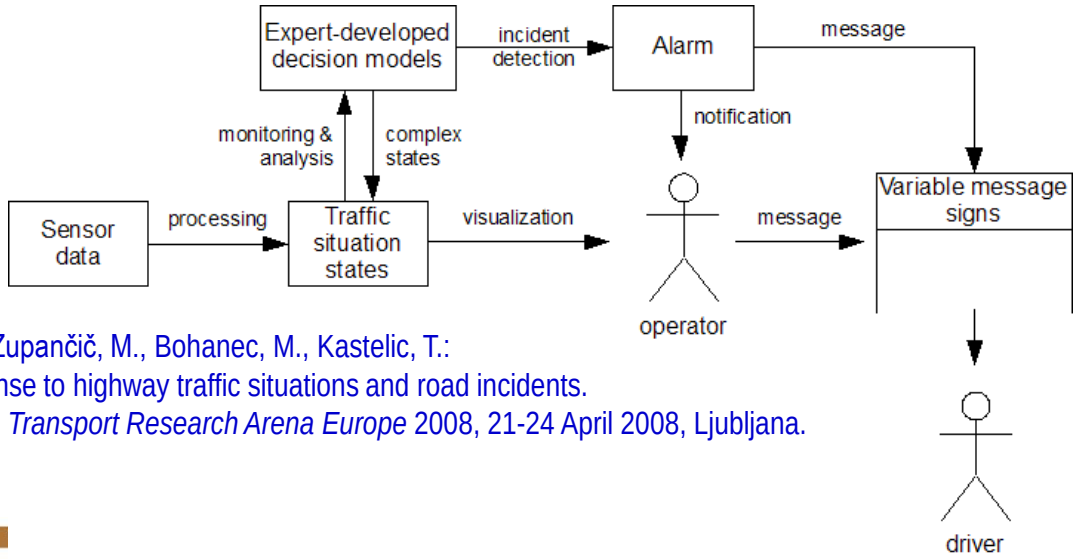
Article history:
Received 6 May 2011
Received in revised form
14 November 2011
Accepted 14 November 2011

Keywords:
Cropping system
Integrated pest management
Sustainability assessment
Ex ante
Qualitative Multi-Attribute Decision Models
DEXi

ABSTRACT

Modern intensive agriculture has to face the challenge of feeding the world's growing population while reducing its environmental impacts. Assessing in an *ex ante* way the sustainability of innovative cropping systems will increase the efficiency of the innovation process. To this aim, DEXiPM (DEXi Pest Management) has been developed for *ex ante* assessment of the sustainability of arable cropping systems, particularly integrated crop management systems with a limited use of pesticides. It has 75 basic indicators describing the cropping system and the context of the assessment, and 86 aggregated indicators, assessing the usual three dimensions of sustainability in terms of social, environmental and economic issues. DEXiPM was implemented to assess and compare current and innovative winter crop- and maize-based cropping systems for a French region. The evaluation results showed that innovative cropping systems with a limited use of pesticides can have a better overall sustainability, despite the fact that some of the indicators can be negatively impacted. DEXiPM is a relevant tool to evaluate the sustainability of actual cropping systems, to diagnose their strong and weak points and, on this basis, to encourage discussions during the design of innovative cropping systems that will afterwards be tested in fields. The design of DEXiPM is also based on a state of the art on agricultural sustainability which led to point out

Traffic Control Center



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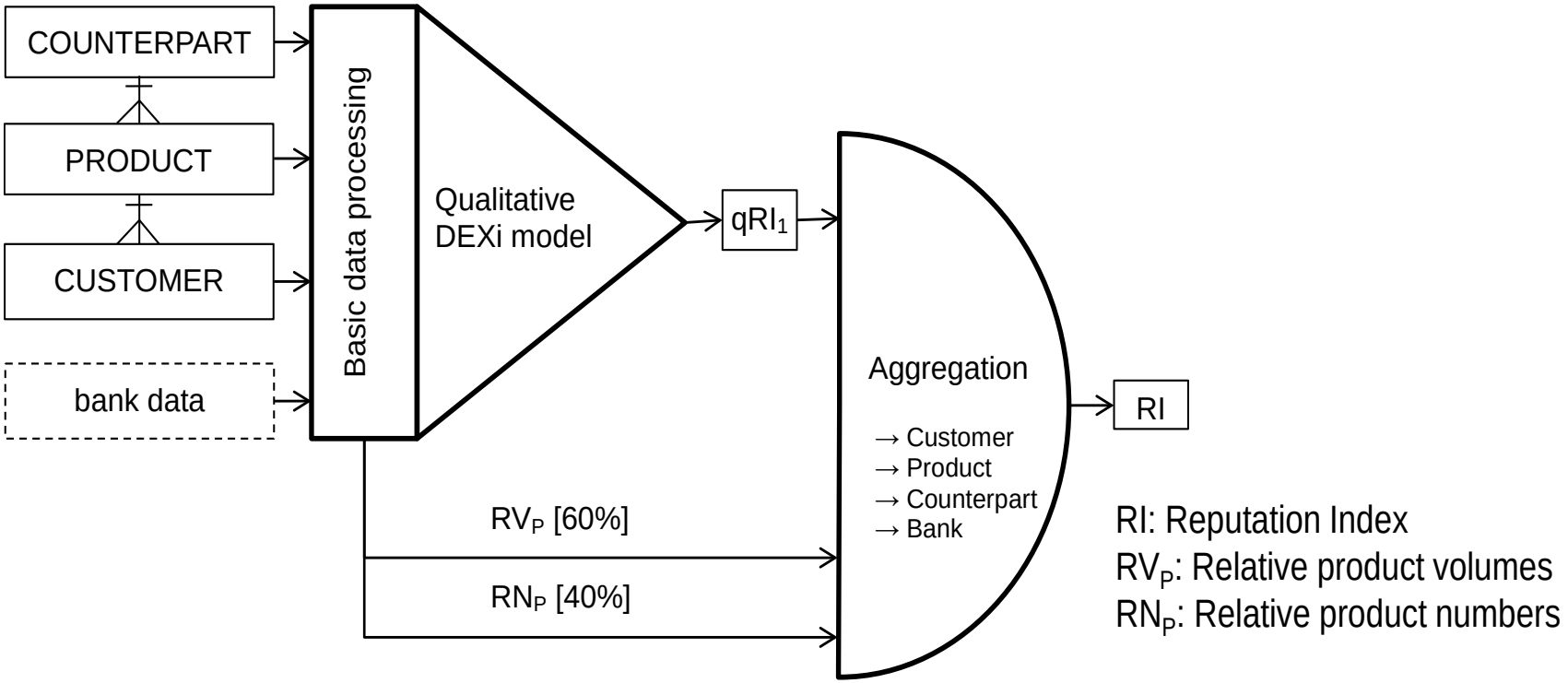

DEX: Experience

- Suitable problems:
  - sorting/classification problems
  - difficult problems (many attributes and/or many alternatives)
  - problems that require human judgment, analysis, justification and explanation
  - problems with prevailing qualitative (rather than quantitative) indicators
  - finding solutions requires expert knowledge (decision rules)
  - uncertainty (incomplete knowledge, imprecise or missing data)
- Characteristics:
  - relatively simple and fast development of models
  - qualitative models are less precise/discriminative than quantitative
  - thus less suitable for choosing and ranking
- Trend: from decision to evaluation systems

Summary

- DEX:
  - Multi-Attribute decision modeling methodology
  - A pioneering approach, combining multi-criteria decision modeling with rule-based expert systems
- Contributions:
  - Scientific, technical and practical
  - Three generations of software: DECMAK, DEX, DEXi
  - Hundreds of real-life applications
- Status:
  - 30+ years old, but alive: internationally recognized, actively used in new projects, taught in schools, still developing
- Future:
  - DEXi software: maintenance
  - Development of new, extended, more powerful methodology
  - Implementation on new architectures (software library; java, Web, mobile)

Thank you for your attention