Qualitative Multiple Criteria Models with Cycles: A Preliminary Study with Method DEX

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Objectives

A preliminary study of introducing cycles into DEX models

*DEX (Decision EXpert):* Hierarchical qualitative (rule-based) multi-criteria method
https://en.wikipedia.org/wiki/Decision_EXpert
Outline

DEX Method:
- Principles
- Some applications

Motivation: Why introducing cycles in DEX?
- Applications in agriculture
- Cycles in other methods, e.g., ANP
- Computational power of the Conway’s Game of Life

Case Study: Evaluation of Researchers

Conclusions
What is DEX?

Decision EXpert
Originates in 1980’s

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 Decision Aid: A Fuzzy Heuristic

JANET EFSTATHIOU

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

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<th>D1 Nature</th>
<th>D2 Performance</th>
<th>D3 Size</th>
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Fig. 6. Point-by-point representation of FORMAL aggregate utility function.

Fig. 8. An example of tree of attributes for an educational qualification.
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

![Attribute Diagram]

- **CAR**
  - **PRICE**
    - **BUYING** \( \in \{\text{high, medium, low}\} \)
    - **MAINT**
  - **TECH.CH.** \( \in \{\text{bad, acc, good, exc}\} \)
  - **FUEL** \( \in \{\text{low, medium, high}\} \)
  - **SAFETY**
  - **COMFORT**
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)

```
CAR

PRICE
BUYING ∈ {high, medium, low}

TECH.CH.

TECH.CH. ∈ {bad, acc, good, exc}

FUEL
FUEL ∈ {low, medium, high}

MAINT
SAFETY
COMFORT
```
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 and COMFORT=med
then TECH.CH.=good
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

http://kt.ijs.si/MarkoBohanec/dexi.html
Cropping Systems: Ecology Part

GMO Presence in Food and Feed

Parkinson’s Disease: Medication Change

Decision rules

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Motor Non-Motor Epidemiologic CarePlan

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Motivation for “DEX with Cycles”

Most MCDM methods employ:
– an inputs $\rightarrow$ output(s) structure: tree or directed graph without cycles
– a step-by-step aggregation of inputs into the output(s)
Motivation for “DEX with Cycles”

However, sometimes we do need cycles in order to represent:

– criteria inter-dependence
– dynamic properties of the alternatives
Some MCDM methods do employ cycles:

- **ANP**: Analytic Network Process (Saaty, 1996)
- **WINGS**: Weighted Influence Non-linear Gauge System (Michnik, 2013)
- **DEMATEL**: Decision Making Trial and Evaluation Laboratory ( Gabus & Fontela, 1972)

**Motivation for “DEX with Cycles”**
Motivation for “DEX with Cycles”

CGL: Conway’s Game of Life (Conway, 1970)

Rules ("B3/S23"): 

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<th>New Status</th>
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<td>2 or 3</td>
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<td>live</td>
<td>&gt; 3</td>
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<td>dead</td>
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<td>dead</td>
<td>not 3</td>
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</table>

Wikipedia: (Camargo, 2008)

Motivation for “DEX with Cycles”

1. CGL is Turing complete: As powerful as any computer with unlimited memory and no time constraints (Berlekamp et al., 1982)
2. CGL can be implemented with DEX models with cycles

---

Apply rules

Count neighbors

\[ \text{N1} \ldots \text{N8} \]

---

**Decision rules**

_CGL_Cell Neighbors *CGL_Cell_

1. **dead** \( \leq 2 \) **dead**
2. \( * \) \( \leq 1 \) **dead**
3. \( * \) \( \geq 4 \) **dead**
4. \( * \) 3 **live**
5. **live** 2:3 **live**
# Case Study: Evaluating Researchers

**Goal:** Assess the quality and perspective of seven university researchers

**Methods:** “DEX with Cycles” and ANP

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</table>
DEX Model Structure with Cycles

Employee

Science
- Sc. Projects
- Papers
- Citations
- Sc. Awards

Education
- Courseware
- Supervision
- Stud.’s Eval.

Contribution to Society
- Soc. Projects
- Soc. Awards
- Memberships

Papers

Citations

Sc. Awards

Supervision

Sc. Projects

Citations

Stud.’s Eval.

Soc. Awards
Implementation

Indirectly in DEXi software (http://kt.ijs.si/MarkoBohanec/dexi.html):

- Converting models with cycles to hierarchies:
  - splitting a dynamic attribute “Name” to: “_Name” (input) and “*Name” (output)
- Implementing an evaluation algorithm similar to CGL:

  set initial values to all input variables $\rightarrow S_0$

  repeat
  
  $S_{t+1} \leftarrow \text{Evaluate}(S_t)$

  until $\exists S \in \{S_0, \ldots, S_t\}$: $S_{t+1} = S$
Model in DEXi

Model structure and scales

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<tr>
<th>Attribute</th>
<th>Scale</th>
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<tr>
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<td>_Citations</td>
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Institut “Jožef Stefan” Ljubljana, Slovenija
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Conclusions

Idea:
- Introduce cycles to qualitative DEX models
- in order to model criteria inter-dependence and dynamic properties of alternatives.

Findings:
- Introducing cycles to DEX is feasible
- and promises to boost their theoretical computational power.
- Cycles break the convenient input → output structure of MCDM models,
- and there are several possible approaches to the evaluation.
- Current implementation: hierarchies of input-output pairs and a CGL-like iteration

Further work:
- Learning on real-life use cases, comparing with other methods, e.g. ANP
- Studying theoretical properties, e.g. convergence, oscillations
2018 Open Conference of the IFIP WG 8.3 on Decision Support Systems
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Thank you

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