Transferring DEXi Qualitative Decision Models into Decision Deck Platform through the XMCDA Standard

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ABSTRACT
DEXi is an educational Multi Criteria Decision Aid (MCDA) computer program aimed at interactive development of qualitative multi-criteria and hierarchical decision models and the evaluation of options. XMCDA is an emerging data standard which enables the representation of Multi Criteria Decision Aid data elements in XML according to a clearly defined grammar. In this paper we investigate the methods and present some solutions of transferring qualitative DEXi decision models into XMCDA. The motivation for this work is to enable the use of DEXi models in the Decision Deck platform, which aims at collaboratively developing Open Source software implementing MCDA software tools.

Key Words: *decision models, multi-criteria decision aid, DEXi, Decision Deck, XMCDA, Diviz*

1 INTRODUCTION

Multi-criteria (or multi-attribute) decision aid (MCDA), also termed multi-criteria decision analysis and multi-criteria decision making (MCDM), is a discipline which aims at supporting decision makers who are faced with making numerous and conflicting evaluations (Belton and Stewart, 2002). Many different MCDA methods have been implemented (Maxwell, 2008), but these software programs were developed in an uncoordinated way: they have very different operational requirements, they use different and incompatible representations of data and decision models, and are, consequently, very difficult to integrate.

Decision Deck (2010) is an initiative to implement functionalities of a large range of MCDA methods within a common Open Source platform. In particular, it provides two components, called XMCDA and Diviz, which facilitate a unified implementation of different MCDA methods. *XMCDA* is an XML schema (W3C, 2008), which specifies a markup language to describe data of MCDA problems. *Diviz* is an open source Java client and server for designing, executing and sharing MCDA methods. Diviz uses XMCDA to make elementary components interoperable. Currently, there are several MCDA methods implemented in Diviz, including Outranking, Alternatives analysis, and Criteria computations.

DEXi (Bohanec, 2008) is a stand-alone computer program for multi-attribute decision making. It facilitates interactive development of qualitative multi-attribute and hierarchical decision models and the evaluation of options. DEXi has been used in many real-life decision problems in the

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areas such as selection and evaluation of computer hardware and software, evaluation of companies and business partners, personnel management, project evaluation, land-use planning, risk assessment in medicine and health-care.

DEXi falls in a broad category of MCDA methods and is therefore a good candidate for the integration in the Decision Deck platform. As a first step to integrate DEXi into Decision Deck, DEXi models have to be represented in XMCDA. In this paper, we address this task and show the ways of transferring DEXi hierarchical decision making models into XMCDA. For illustration, we use a simple car evaluation example.

The structure of this article is as follows. In section 2, we first present the tools we used: DEXi, Decision Deck, XMCDA and Diviz. In section 3, which is the main part of the paper, we investigate the methods of transferring DEXi models into XMCDA. Section 4 concludes the paper and suggests further work on integration of DEXi into the Decision Deck platform.

2 MCDA METHODS AND TOOLS

In this section, we introduce the multi-criteria decision making methods which were used in this work: (1) DEXi as a method that is being transferred to Decision Deck, and (2) Decision Deck platform itself, specifically its XMCDA and Diviz components.

2.1 DEXi

DEXi (Bohanec, 2008) is a MCDA computer program which differs from most conventional MCDA tools in that it uses qualitative (symbolic) attributes instead of quantitative (numeric) ones. Also, aggregation (utility) functions in DEXi are defined by 'if-then' decision rules rather numerically by weights or some other kind of formula. Consequently, a DEXi model includes the following four components:

- attributes: qualitative variables that represent decision sub-problems;
- scales: ordered or unordered sets of symbolic values that can be assigned to attributes;
- tree of attributes: a hierarchical structure representing the decomposition of the decision problem;
- utility functions: rules that define the aggregation of attributes from bottom to the top of the tree of attributes.

Bellow is an example of a DEXi multi-attribute model for the evaluation of cars. Figure 1 shows the hierarchical attribute tree of DEXi car evaluation model, Figure 2 shows the scale of each attribute, and Figure 3 shows the utility function of attribute CAR in this model.

Attribute	Description
CAR	Quality of a car
├**PRICE**	Price of a car
│ ├BUY.PRICE	Buying price
│ └MAINT.PRICE	Maintenance price
└**TECH.CHAR.**	Technical characteristics
├**COMFORT**	Comfort
│ ├#PERS	Maximum number of passengers
│ ├#DOORS	Number of doors
│ └LUGGAGE	Size of the luggage boot
└SAFETY	Car's safety

Figure 1: Hierarchical attribute tree of car evaluation

Attribute	Scale
CAR	unacc; acc; good; ***exc***
├**PRICE**	high; medium; ***low***
│ ├BUY.PRICE	high; medium; ***low***
│ └MAINT.PRICE	high; medium; ***low***
└**TECH.CHAR.**	bad; acc; good; ***exc***
├**COMFORT**	small; medium; ***high***
│ ├#PERS	to_2; 3-4; ***more***
│ ├#DOORS	2; 3; 4; ***more***
│ └LUGGAGE	small; medium; ***big***
└SAFETY	small; medium; ***high***

Figure 2: Attribute scales in the car evaluation model

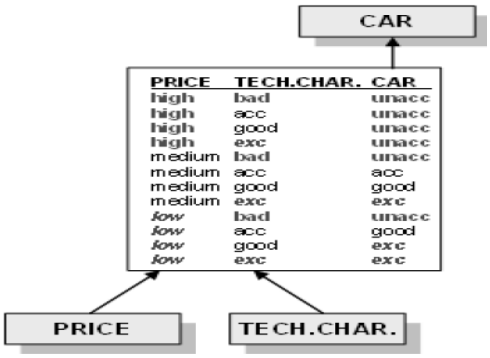

Figure 3: Utility function of attribute CAR

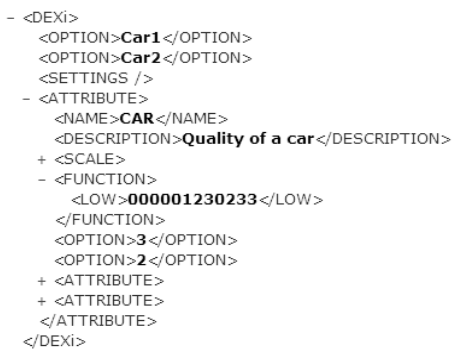

Figure 4: A part of DEXi XML file for car evaluation

In the stage of evaluation and analysis of decision options, DEXi facilitates (Bohanec, 2008): description of options, evaluation of options, analysis of options and reporting. The analysis of options includes 'what-if' analysis, 'plus-minus-1' analysis, selective explanation and comparison of options.

DEXi models, which are created and/or edited in DEXi, are stored in DEXi ('.dxi') files. Essentially, a DEXi file is an XML document, whose structure is illustrated in Figure 4. Therefore, DEXi model files can be processed using the other XML tools.

2.2 Decision Deck

Decision Deck (2010) is a platform for implementing various MCDA methods. Decision Deck provides various software modules (d2, d3, Diviz, XMDCA), which offer a common framework for MCDA methods. Currently, there are several MCDA methods already implemented in Decision Deck: Iris, Rubis, VIP, UTADISGMS and GRIP, Weighted Sum, Concordance/Discordance computation, etc.

2.2.1 XMCDA

XMCDA (Cailloux, 2010) is a data standard for representing MCDA data elements. It is an XML schema which focuses on MCDA concepts and data structures. An XML file is a computer file which obeys the grammar published by the W3C Consortium (2008). An XML schema is a grammar more restrictive than the XML grammar, typically used to define a common language for concepts used in a specific domain of knowledge. XMCDA is such an XML schema, defined for the MCDA practitioners and users. However, it is not restricted to any particular family of MCDA procedures. In this paper, we use the latest version of XMCDA, 2.0.0.

2.2.2 Diviz

Diviz (Bigaret and Meyer, 2010) is a software platform which enables graphical, workflow-oriented design, composition, and deployment of MCDA methods, whose inputs and outputs are XMCDA files. Many algorithms have been integrated in Diviz: Outranking, Alternatives analysis, Criteria computations, etc. There are also supporting components, like *GenerateXMCDAReport*, which validates the input XMCDA files against XMCDA standard and displays the contents in HTML. Figure 5 shows a Diviz workflow that includes the generateXMCDAReport component.

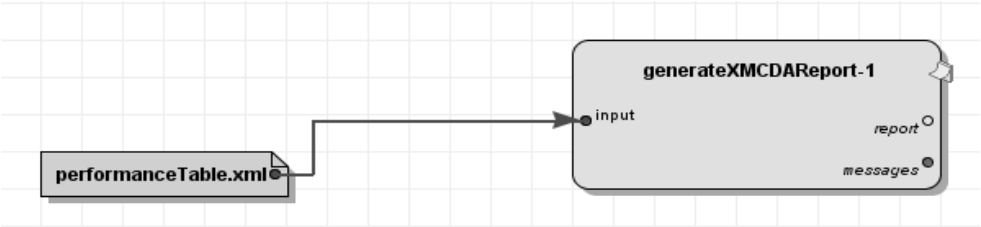

Figure 5: A Diviz workflow including an XMCDA data file and the GenerateXMCDAReport component

3 REPRESENTING DEXi MODELS IN XMCDA

In this section, we investigate the methods and solutions for transferring qualitative DEXi decision models into the XMCDA format. We illustrate the transformation on the car evaluation example, introduced in section 2. All the XMCDA representations have been validated by using the generateXMCDAReport component of Diviz.

3.1 Representing Options

There is an easy translation of decision *options* from DEXi to *alternatives* of XMCDA: instead of DEXi's <option> tag, we use the corresponding <alternative> tag in XMCDA. Figure 6 shows an example of such a representation.

```
<?xml version="1.0" encoding="UTF-8" ?>
- <xmcda:XMCDA xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:xmcda="http://www.decision-deck.org/2009/XMCDA-2.0.0"
    xsi:schemaLocation="http://www.decision-deck.org/2009/XMCDA-2.0.0 http://sma.uni.lu/d2cms/xmcda/_downloads/XMCDA-2.0.0.xsd">
  - <alternatives mcdaConcept="Option">
    - <description>
        <title>List of "Options","Option" corresponds to "alternative".</title>
      </description>
      <alternative id="car1" name="CAR1" />
      <alternative id="car2" name="CAR2" />
    </alternatives>
  </xmcda:XMCDA>
```

Figure 6: XMCDA file describing options of the car evaluation model

```
- <xmcda:XMCDA xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:xmcda="http://www.decision-deck.org/2009/XMCDA-2.0.0"
    xsi:schemaLocation="http://www.decision-deck.org/2009/XMCDA-2.0.0 http://sma.uni.lu/d2cms/xmcda/_downloads/XMCDA-2.0.0.xsd">
  - <hierarchy>
    - <description>
        <title>Tree structure of the model. Each node represent one "Attribute" in DEXi, "Attribute" corresponds to "criterion".</title>
      </description>
    - <node>
        <criterionID>CAR</criterionID>
      - <value>
        - <rankedLabel>
            <rank>1</rank>
            <label>exc</label>
          </rankedLabel>
        </value>
      + <value>
      + <value>
      + <value>
      + <node>
      + <node>
      </node>
    </hierarchy>
  </xmcda:XMCDA>
```

Figure 7: XMCDA file describing DEXi hierarchical attributes of the car evaluation model

3.2 Representing Attributes

The *attributes* of a tree structure in a DEXi model correspond to *criteria* in the XMCDA standard. We employ the tags <hierarchy> and <node> in XMCDA to represent the hierarchical structure of DEXi attributes. DEXi qualitative *scale* values are translated into *rankedLabel* component of XMCDA. Figure 7 shows an XMCDA file which describes DEXi hierarchical attributes of the car evaluation model.

3.3 Representing Utility Functions

For DEXi *utility functions*, which are qualitative and represented as tables (see Figure 3), there is no equivalent concept in XMCDA. XMCDA provides several standard representations of functions (*criteriaFunction*), but they support only functions having one argument; however, DEXi functions have multiple arguments. Another XMCDA concept, *criteriaMatrix*, supports only comparisons of two attributes/criteria. Furthermore, these two data elements cannot be used within a hierarchical structure, such as in DEXi. The best mechanism for representing utility functions thus appears the *performanceTable*, which in its basic form defines, for each alternative and each criterion, the performance of the criterion for that alternative. In our case, we exchange alternatives (which are represented in rows) with DEXi rules from all corresponding utility function tables. As a result, we get a single performance table that defines all the utility functions from a given DEXi model. Table 1 shows a part of the table for the car evaluation model.

Table 1: Utility Function of the car evaluation model, represented in the XMCDA standard

	CAR	PRICE	BUY.PRICE	MAINT.PRICE	TECH.CHAR.
1_CAR	unacc(4)	high(3)			bad(4)
2_CAR	unacc(4)	high(3)			acc(3)
3_CAR	unacc(4)	high(3)			good(2)
4_CAR	unacc(4)	high(3)			exe(1)
5_CAR	unacc(4)	medium(2)			bad(4)
6_CAR	acc(3)	medium(2)			acc(3)
7_CAR	good(2)	medium(2)			good(2)
8_CAR	exc(1)	medium(2)			exe(1)
9_CAR	unacc(4)	low(1)			bad(4)
10_CAR	good(2)	low(1)			acc(2)
11_CAR	exc(1)	low(1)			good(2)
12_CAR	exc(1)	low(1)			exe(1)
1_PRICE		high(3)	high(3)	high(3)	
2_PRICE		high(3)	high(3)	medium(2)	

It is clear that this is not the most suitable representation, but seems the only possible within the current XMCDA standard. For better representation of DEXi utility functions, XMCDA should have been extended with the ability to represent a point-by-point definition of functions having multiple arguments, possibly as an extension of the current *criteriaFunction* and/or *point* tags.

3.4 Representing Evaluations of Options

The *evaluation* in a DEXi model naturally corresponds to *performanceTable* of XMCDA, see Table 2 for an example.

Table 2: Evaluation of the DEXi car evaluation model, represented in the XMCDA standard

	CAR	PRICE	BUY.PRICE	MAINT.PRICE	TECH.CHAR.	COMFORT	#PERS	#DOORS	LUGGAGE	SAFETY
car1	exc(1)	low(1)	medium(2)	low(1)	exe(1)	high(1)	more(1)	4(1)	big(1)	high(1)
car2	good(2)	medium(2)	medium(2)	medium(2)	good(2)	high(1)	more(1)	4(1)	big(1)	medium(2)

4 CONCLUSION

In this paper we have proposed means of transforming DEXi models into the XMCDA standard. The resulting XMCDA files were validated using the Diviz software tools. For most of DEXi components, the translation was straightforward: the tag <option> to <alternative>, <attribute> to <hierarchy> and <node>, <scale> to <rankedLabel>, and option evaluations to <performanceTable>. However, there was no suitable way of representing DEXi utility function (decision rules); for this purpose, we used the most suitable available XMCDA data element, the *performanceTable*. Since this solution is not satisfactory, we propose to extend the XMCDA standard so as to facilitate the point-by-point representation of discrete functions that have multiple arguments. In principle, this is achievable by extending the XMCDA's <point> tag to allow the representation of multi-dimensional (rather than only two-dimensional) points.

In order to more firmly integrate DEXi into Decision Deck, further work will be focused on the automatic transformation of DEXi models into XMCDA, and on implementation of DEXi into the Diviz as a collection of processing components.

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