

DEXi Suite: Renewing Qualitative Multi-Criteria Decision Modeling Software

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ABSTRACT

Multi-criteria decision analysis (MCDA) is an approach to solving decision problems having multiple and possibly conflicting objectives. MCDA proceeds by decomposing the problem into multiple dimensions (criteria, attributes), measuring decision alternatives along these dimensions, and aggregating those partial evaluations into final assessments. On this basis, alternatives are selected and/or ranked. MCDA models developed in this way can be embedded in Decision Support Systems to support recurring decision processes.

DEX (Decision Expert) is a hierarchical, qualitative and rule-based MCDA method, particularly suitable for sorting and classification decision problems. DEX has been always supported with software that helped decision makers to formulate decision models in terms of attributes, their structure and decision rules, and to employ them in the evaluation and analysis stages. To date, the main and *de-facto* implementation of DEX was a Windows desktop program called DEXi (<https://kt.ijs.si/MarkoBohanec/dexi.html>). DEXi has been conceived more than 20 years ago and is becoming increasingly difficult to maintain and extend.

In this paper, we present work in progress aimed at developing a new generation of DEX software, called *DEXi Suite* (<https://dex.ijs.si/dexisuite/dexisuite.html>). With the aim to gradually replace DEXi, the new implementation follows a number of technical, user-oriented and methodological objectives: using modern programming languages and environments, backward compatibility with DEXi, supporting all relevant platforms, introducing new modeling features, etc. Currently, *DEXi Suite* consists of five components: *DEXiLibrary*, a central class library implementing DEX, *DEXiWin*, a desktop program implementing all DEXi functionality, and *DEXiEval*, *DEXiPy* and *DEXiR*, packages for using DEXi models from the command line and in Python and R environments, respectively. In the paper, these components are described in more detail, and *DEXiWin* is illustrated using an employee-selection use case. Future plans include development of two more components, a DEX-modeling API and Web application.

Keywords: Multi-Criteria Decision Analysis, Decision Support, Software, DEX (Decision Expert), DEXi Suite

INTRODUCTION

Multi-criteria decision analysis (MCDA) is an established and effective methodological approach to solving hard decision problems that involve multiple and possibly conflicting objectives [1]. MCDA methods generally help decision makers in formulating the decision problem, identifying key objectives, formulating criteria, developing multi-criteria decision models and using them for decision-making tasks such selection, evaluation, ranking and analysis of decision alternatives. MCDA is often supported by software tools [2], which are particularly beneficial in the stages of model development (model creation and editing, elicitation of decision makers' preferences) and assessment/analysis of

alternatives. In the case of recurring decision problems, it is often necessary to incorporate decision models in other software products, such as decision support systems [3].

Over the years, more than 200 MCDA methods have been developed, which differ greatly in terms of decision problem formulation, preference elicitation and types of preference information, desired features of a preference model, and construction of the decision recommendation [4]. In this paper, we focus on one of them, DEX (Decision EXpert) [5]. DEX has been conceived as a fusion of MCDA and artificial intelligence, and is generally characterized as a full-aggregation, hierarchical, qualitative and rule-based MCDA method [5]. DEX is particularly suitable for sorting or classification decision tasks, which are aimed at assigning decision alternatives to predefined categories, which are either preferentially ordered (“sorting”) or not (“classification”). Giving just three examples from 2022, DEX was used for decisions on cereal-legume intercroppings [6], assessing health and self-care ability [7] and selection of crop species for saltwater aquaponics [8]. Recently, DEX models have been incorporated in three large-scale decision support systems for severe accident management in nuclear power plants [9], assessment and management of soil functions [10], and assessment and management of sustainability of legume agri-food value chains (<http://pathfinder.ijs.si>).

Since 2000, the method DEX has been implemented in terms of free software called DEXi (<http://kt.ijs.si/MarkoBohanec/dexi.html>). DEXi is a desktop application for MS Windows that supports an interactive creation and editing of all components of DEX models (attributes, their hierarchy and scales, decision tables, and alternatives) and provides methods for the evaluation and analysis of decision alternatives (what-if analysis, “plus-minus-1” analysis, selective explanation, comparison of alternatives, option generator). There are also additional DEXi-related software tools that facilitate using DEXi models in different environments, such as command line, Java, C#, and HTML (<https://dex.ijs.si/dexiclassic/dexiclassic.html>).

While still maintained, fully operational and used worldwide, DEXi has become rather aged. There are two technical reasons that make it really hard to maintain and improve: using old technology (Delphi, which was actually great and ahead-of-time in the 1990s, but is now lagging behind with the lack of free development tools and skilled developers) and insufficiently modular/flexible software architecture. On the other hand, the demand is increasing for including more and more features in DEXi, and supporting state-of-the-art software standards and environments. All these were strong motivational factors for pursuing a thorough reconstruction of DEX-related software, which is reported in this paper.

In what follows, we first formulate the requirements and expectations for the new generation of DEX software. Then, we describe five software components that currently constitute the new *DEXi Suite* (<https://dex.ijs.si/>). Among these, we illustrate the main modeling software DEXiWin with two screenshots solving a simple employee-selection task. The paper is concluded with a summary and plans for future development.

METHODS

Objectives and Requirements

The design and implementation of *DEXi Suite* was guided by technical, software architectural, methodological and user-oriented objectives and requirements.

Technical aspects. We wanted to move towards using modern programming languages and development environments, hoping to simplify the development, extend the life cycle of products, attract young developers and facilitate using the software in all major environments (various operating systems, the web). While the web-based approach seems the ultimate longterm option, we first had

to focus on upgrading the available code to a suitable cross-platform class library and implementing desktop applications. For that, we chose the modern Pascalbased programming language Oxygene (<https://www.remobjects.com/elements/oxygene/>).

Software architecture. The objective is to redesign software architecture to make it more adaptive for change. Before in DEXi, model-editing and user-interface code were somewhat intermixed, and the code was scattered among different software components and tools. For *DEXi Suite*, we deemed it necessary to design a single central class library to be used by all software components and to detach it from the user-interface functionality.

Methodological improvements. The objective is to include long-awaited extensions of the DEX method that are often needed in practice. While the wish list is longer, *DEXi Suite* already implements the following new features:

- Representing and evaluating decision alternatives in terms of probabilistic and fuzzy value distributions (while DEXi supports only representations with sets).
- Using numeric attributes as inputs to DEXi models. Consequently, DEXi models have been extended with components that implement numeric scales and discretization functions.
- Extending methods for the analysis of decision alternatives: target analysis (an improved version of DEXi's "option generator") and plus-minus analysis (a generalization of DEXi's plus-minus-1 analysis).

User-oriented requirements. First, the new software is required to be fully backward compatible with DEXi, so that old DEXi models could be used in *DEXi Suite* without change. Second, while DEXi is free-to-use, but not open-source software, all the new software is to be released as open-source under liberal licenses (GPL or MIT, depending on the component). Last but not least, there is a long list of required user-interface improvements that range from very detailed, such as consistent use of colors, to general ones, e.g., improved and entirely new functionality for handling reports and charts.

Software Components

DEXi Suite (<https://dex.ijs.si/dex.html>) currently consists of five software components, called DEXiLibrary, DEXiWin, DEXiEval, DEXiPy and DEXiR. They are all in the *beta* development stage, which means that they are fully functional, but may still have bugs, require additional testing and are incompletely documented.

DEXiLibrary is a core component of *DEXi Suite*, providing all classes and methods for representing and operating on DEX models. This includes classes for representing DEX attributes, scales, functions, alternatives and whole models, as well as methods for the evaluation and analysis of alternatives. The functionality of DEXiLibrary is deliberately restricted to the level that can be easily ported to different platforms and thus excludes all user-interface functionality. Currently, DEXiLibrary targets the Java and .NET platforms, and makes the respective class libraries (`jar` and `dll`), which can be dynamically linked to and used by other software components.

DEXiWin is a desktop program for Microsoft Windows aimed at gradually replacing DEXi. It implements all DEXi's features (apart some obsolete data formats) and adds all new features that are implemented in the DEXiLibrary. It also introduces many small, but important improvements in the user interface, for instance displaying model components in userselectable columns, graphical display of model structure, tree-structured display/editing of evaluation results, consistent use of colors for displaying "good" and "bad" values, etc. See the example below.

DEXiEval, *DEXiPy* and *DEXiR* facilitate using DEX models in environments other than DEXiWin. DEXiEval is a command-line utility for evaluating decision alternatives. DEXiPy and DEXiR are software packages

for using DEX models in the environments of programming languages Python and R, respectively. All these components are fully compatible with the new features of *DEXi Suite*.

ILLUSTRATIVE EXAMPLE

Let us illustrate DEXiWin with two screenshots using the employee-selection example, adapted from [5] to highlight new features. This demo model is aimed at the assessment of applicants for a Project Manager position in a small company. The tree of attribute consists of 14 attributes, grouped into subtrees *Educat*, *Years* and *Personal*.

Figure 1 shows the main model-editing page of DEXiWin with displayed attributes' structure, descriptions and scales. Apart from a substantially redesigned interface in comparison with DEXi, the essential novel feature is the introduction of numeric input attributes, in this case *ExperYears* and *AgeYears*. The former is preferentially ordered and the latter is not. Both are discretized into qualitative attributes *Experience* and *Age*, respectively, using discretization functions (not shown here).

Figure 2 then shows the evaluation of five employee candidates. Among them, the candidate E illustrates the concept of using probability distributions. For this candidate, her communication abilities are unknown (denoted '*') and her leadership ability is assessed fifty-fifty between 'appropriate' and 'more'. The aggregation guided by decision rules formulated in the model (not shown here) and following the probabilistic propagation finally leads the final assessment of 'unacceptable' or 'excellent' with probabilities 0.25 and 0.75, respectively.

CONCLUSIONS

DEXi Suite is work in progress aimed at delivering a new generation of software tools for supporting the qualitative multi-attribute method DEX. At this point, the main contributions of this development are technical and user-oriented: using modern programming languages and development environments, redesigning the software for change, consistent and rich user interfaces. Methodological advances are moderate: introducing numerical attributes, discretization functions and evaluation using value distributions. These were all known before, but now they are for the first time consistently and completely implemented in DEX software.

One of the important goals has not been reached yet: availability of DEX software in all relevant platforms. DEXiWin works only on MS Windows. To reach the goal, two additional components are planned for *DEXi Suite*: an API (Application Programming Interface) supporting DEX-model operation on a server, and a single-page web application providing a user interface for accessing those services. Other future activities include extensive testing of *DEXi Suite*, possibly on real-world use cases, writing documentation and adding new functionality, such as representing decision tables with decision trees, pruning evaluation of alternatives at given attributes, and supporting probabilistic/fuzzy decision rules.

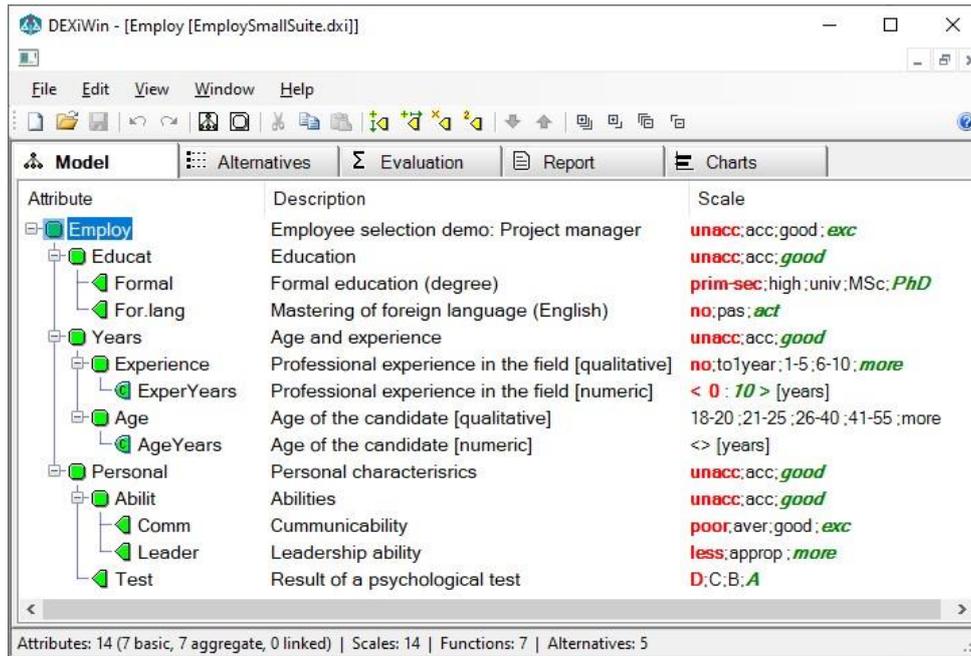


Figure 1: DEXiWin: Model-editing page displaying the Employ model

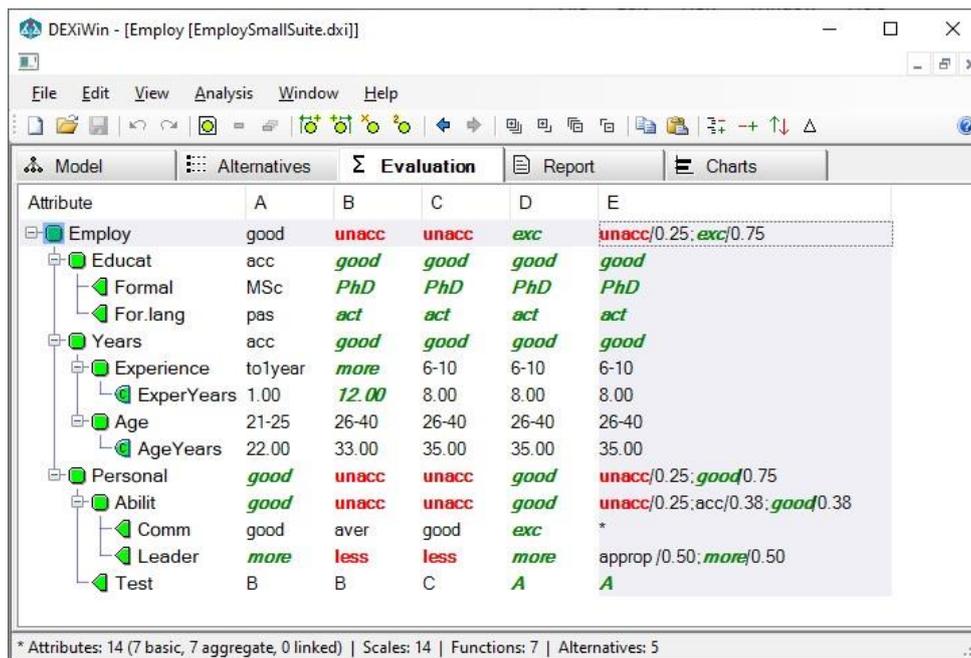


Figure 2: DEXiWin: Evaluation page displaying five employee candidates **ACKNOWLEDGMENT**

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