Moody’s Physics of Notations: High Impact, Little Support

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Abstract

Domain Specific Languages foster the access of domain expert knowledge in Enterprise Modelling. Platforms, like Eclipse with EMF, MetaEdit+, and AdoXX, support the design of meta-models for Domain Specific Languages and the creation of modelling tools based on these meta-models. Typically, a visual notation is used for modelling and part of the development of modelling tools. Moody’s work on Physics of Notations is a prominent approach to provide guidelines for the design of visual notations. However, while there are tools for language design there is only little research on tool support for language evaluation based on the Physics of Notations. This paper uses a systematic literature analysis to investigate the state of tool support for implementing or evaluating the principles contained in the Physics of Notations approach. Furthermore, the paper provides an outlook to possible future research on tool-based evaluation of visual notations.

Keywords

Physics of Notations, Notation Design, Notation Evaluation, Tool Support

1. Introduction

Moody’s Physics of Notations (PoN) is a prominent framework for the design and the evaluation of graphical notations. Moody based his PoN on a survey of scientific articles regarding notation evaluation. The selected principles are backed by empirical evidence. However, there is a lack of comparability and a lot of ambiguity when the PoN are applied for notation evaluation. A tool support that provides a clear formalization, where applicable, and that standardizes their application may help here. Furthermore, the integration of such a tool support in platforms, like Eclipse with EMF, MetaEdit+, and AdoXX, allowing for the design of meta-models for Domain Specific Languages and the creation of modelling tools based on these meta-models may support notation designers in providing higher quality notations.

This study investigates the potential of such a tool support. While a formalization of some PoN principles is generally possible, we investigated whether such a support is actually used in notation evaluation. Section 2 introduces the PoN and discusses possibilities for tool support in general. Section 3 investigates the PoN application in scientific research. Section 4 provides a short summary and outlook.

2. Moody’s Principles

Moody defines in [1] nine principles for the design of cognitively effective visual notations. These principles will be introduced briefly in the following as they need to be treated differently with regard to a potential tool support for notation evaluation.

Principle of Semiotic Clarity. This principle demands for a one-to-one correspondence between symbols and concepts of the notation. Moody defines four different possible deficits of visual notations with regard to Semiotic Clarity: (1) Symbol Redundancy, if multiple symbols represent the same concept (2) Symbol Overload, if a symbol represents multiple concepts (3) Symbol Excess, if there are

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symbols that do not correspond to a concept of the notation (4) Symbol Deficit, if there are notation concepts without a corresponding symbol. [1]

Principle of Perceptual Discriminability. The main idea of this principle is to make symbols clearly distinguishable from each other. Moody presents a number of suggestions in order to reach this goal, assuring Visual Distance of symbols by using a high number of visual variables like shape, color, size etc. to make them visually different. Shape is the most important visual variable here. Moody calls this fact Primacy of Shape. Further recommendations are the use of text to differentiate between symbols (Textual Differentiation), using unique values for at least one visual variable (Perceptual Popout), and to use more than one visual variable in order to make a difference between symbols (Redundant Coding). [1]

Principle of Semantic Transparency. Semantic Transparency describes extent to which the meaning of a symbol can be derived from its appearance. This can range from semantically immediate symbols where the meaning can be inferred without additional information over semantically opaque symbols where there is no link between appearance and meaning to semantically perverse symbols which imply a wrong meaning for the model user. The performance of a notation with regard to this principle depends on the model users and should thus be evaluated in experiments. However, Moody provides some general recommendations – the use of icons that depict real objects (Perceptual Resemblance) and special graphical relations (Semantically Transparent relations) such as intersections or trees. It can be checked whether these recommendations are implemented in a notation. [1]

Principle of Complexity Management. This principle demands for explicit mechanisms to deal with complexity. A simple measure for model complexity is the number of used elements. With increasing model size limits are reached regarding perception and cognition. Understandability of models suffers. Therefore, notations should provide mechanisms to reduce complexity. The main mechanisms to reach this goal are Modularization and Hierarchy (Levels of Abstraction). [1]

Principle of Cognitive Integration. There should be mechanisms to integrate information from different models. One mechanism would be Conceptual Integration. It provides an overview of the model and its sub-models by pro viding concepts on a high abstraction level that can be combined in order to relate the used sub-models. Perceptual Integration helps the model user with navigation in the model space. [1]

Principle of Visual Expressiveness. While Visual Distance (see above) considers the pairwise difference of concepts with regard to visual variables, Visual Expressiveness addresses the use of visual variables throughout the whole graphical notation. Hence, the question is which number of visual variables is used to express semantics and to distinguish between concepts (Information carrying Variables) and which number of visual variables is not formally used (Free Variables). Moody defines a total of eight visual variables: Horizontal Position, Vertical Position, Size, Brightness, Color, Texture, Shape, and Orientation. The recommendation is to use as much Information-carrying Variables as possible. Consequently, there is a maximum of eight.

Principle of Dual Coding. Generally, text is not a good means to create a visual notation. However, there is a benefit of supporting visual notations by adding text. This can be done by Annotations and by Hybrid Symbols which combine text and graphical objects. [1]

Principle of Graphic Economy. This principle addresses the number of available graphical symbols for modeling. There is a recommended maximum of six symbols. An excess of symbols makes it difficult for the modeler to be aware of the symbols that can be used. Moody suggests three strategies for increasing Graphic Economy: (1) Reduce Semantic Complexity. Hence, the number of used concepts is reduced (2) Introduce Symbol Deficit (3) Increase Visual Expressiveness. [1]

Principle of Cognitive Fit. Here, different visual dialects are suggested for different tasks and audiences. The main assumption underlying this principle is that problem solving performance is influenced by the problem representation, task characteristics, and problem solver skills. Thus, a problem presentation should fit to the other two factors. This again requires involvement of model users for evaluation. [1]

There are also inter-dependencies between the formulated principles for notation design. For example, introducing a Symbol Deficit and thus reducing Semiotic Clarity fosters Graphic Economy.

Assuming a formal description of the visual notation that is mapped to the abstract notation of a meta-model as it is available on the AdoXX platform 1, a formal validation can potentially be performed for the majority of Moody's principles. Taking for example the principle of Semiotic Clarity, just the number of mapping relations between each symbol of the visual notation and each concept of the meta model needs to be analyzed. Thus, a tool-based validation of the adherence to the principles or a metric for principles like Visual Expressiveness seems to be a straightforward way to support notation designers.

There are two principles that require empirical evaluation - Semantic Transparency and Cognitive Fit. Both require the consideration of the cognitive processes of intended notation users. Thus, an experimental design involving the users can help to evaluate the performance of notations regarding these principles. Furthermore, the already mentioned inter-dependencies between the principles require some trade-offs where the optimum might be found empirically. Overall, an empirical evaluation of notations based amongst others on criteria derived from cognitive fit and semantic transparency should be performed since Moody's principles generally provide guidelines but not guaranty that a notation fits its purpose. Besides general tool support for empirical studies there is also a specific potential for tool support in empirical notation evaluation. For example, the coverage of the language syntax should be tracked in such evaluations. Due to the resulting complexity, a tool support would save effort and reduce possible mistakes compared to manually checking the models used in experiments against the formally defined syntax.

3. Systematic Literature Analysis

3.1. Paper Identification and Selection

As a starting point on the article published in 2009 by D. L. Moody "The physics of notations: Toward a scientific basis for constructing visual notations in software engineering" [1]. Based on this article, a forward search in the literature database Scopus2 was carried out. The literature database Scopus was chosen as the database for this since Scopus represents one of the most important literature databases in the field of scientific research. results from other databases such as SpringerLink3, IEEE4 or AISeL5 are also included. Other articles published by Moody in 2009 and 2010, which also deal with the PoN are not considered as further starting points for a forward search due to their relatively low number of citations compared to the 787 of [1].

The general procedure for the selection of the result set of the forward search in the course of the systematic literature analysis is based on the procedure proposed by [2] for a systematic literature analysis. Thus, the analyzed papers were pre-selected on the basis of the titles and then further selected with the help of the abstract. As the last step of the selection process, the papers were then selected on the basis of the contents of their full texts.

The following terms served as inclusion criteria for the first selection step: "Quality", "Experiment", "Evaluation", "Design" and "Analysis" in combination with concrete modelling languages or notations as well as the phrases "visual notations", "graphical syntax" or "visual constructs". Also included were the phrases "application [...] PoN" or "application [...] physics of notations" respectively. Papers have also been included if it was clear from the title that that, for example, an experiment was carried out, but the term "experiment" was not used. Thus, implicit matches to the original terms were also considered, as for example [3]. This first selection step resulted a set being narrowed down to 144 possibly relevant papers. Considering the abstracts in the next step, a check whether actually the evaluation or the design of a visual notation was in focus of the respective papers. This resulted in a set of 77 papers for analysis. During the analysis of the full texts a more papers had to be singled out because the application of design guidelines was only documented rudimentary. Finally, the analysis is based on 48 selected publications.

3.2. Paper Analysis

Table 1 classifies the analyzed papers with regard to their content. Only 12 papers are dealing with the design of visual notations. The remainder primarily focuses on comparison and evaluation of existing notations. Regarding the evaluation setting, we differentiated between empirical (expert surveys, experiments) and analytical approaches. The latter setting - analytical approach – generally involves a manual analysis of the notation with regard to some principles by the authors or by experts. A combination of analytical and empirical settings as suggested in Section 2 can also be seen times in the result set. In addition. or as alternatives to the PoN, other frameworks have been applied by several authors. For example, the Cognitive Dimensions Framework has been applied by [4, 5]. Other authors used the SEQUAL Framework or defined their own approach (e.g., [6, 7, 8, 9]). Three of the papers [10, 11, 12] did not really reveal the evaluation setting or the applied principles.

Table 1
Analyzed Papers (* = addressed)

Paper	Approach		Evaluation Setting		Design
	PoN	Other	Analytical	Empirical	
[13]		*		*	
[3]		*		*	
[8]		*		*	
[6]		*		*	
[10]					
[14]					*
[15]		*		*	
[16]		*		*	
[17]	*		*		*
[18]		*		*	*
[4]		*	*	*	*
[19]	*	*		*	
[20]		*		*	
[21]		*		*	
[22]	*	*		*	
[23]	*	*		*	*
[24]	*		*		
[25]		*		*	
[26]					*
[27]	*		*		
[28]		*	*	*	
[29]	*		*		*
[30]	*		*		*
[31]	*		*		*
[32]	*		*	*	
[33]	*		*	*	
[7]		*		*	
[34]	*			*	
[35]	*			*	
[36]	*			*	
[37]	*		*		
[38]	*		*		
[9]	*	*	*	*	
[39]	*		*		
[40]	*		*		*
[41]	*		*		
[42]	*		*		
[43]	*	*	*	*	
[44]	*		*		
[45]					*
[46]	*				
[47]					*
[48]		*		*	

Paper	Approach		Evaluation Setting		Design
	PoN	Other	Analytical	Empirical	
[49]	*			*	
[5]		*			
[50]					*
[11]					
[12]					

Looking at the potential for a tool based formal validation, the approaches using an analytical setting need to be investigated. No item in the result set provides tool support. With [38, 44, 45] only three papers discuss a formalization of notation design evaluation. However, there is a general agreement of the contributing authors to these papers that design decisions with regard to some of the principles cannot be formally validated. Here, a documentation of decisions and their rationale is recommended. Only one paper [38] suggested a tool support but no implementation has been provided so far. All three approaches to formalization focused on the application of the complete set of Moody's principles and did not consider other frameworks or own principles.

The majority of analytical approaches also focus on the PoN as it is shown in Table 2. A central problem of the lack of formalization is that a lot of paper discuss the application of the principles to evaluated notations but the results are not comparable and sometimes not even well justified. In addition, an analytical validation with regard to Semantic Transparency and Cognitive Fit can be considered at least difficult looking at the discussion in Section 2.

Looking at the potential of a specific tool based support for empirical evaluation, again no example was found in the analyzed papers. Only 13 out of 25 papers had more than 50 participants in the evaluation process, only 7 more than 100. Thus, statistical significance is in question for most of the evaluations. A generalization to a larger group of notation users is problematic. Unfortunately, solutions to that problem are barely discussed. However, a tool support may help to streamline the evaluation process and to lower barriers for potential participants.

Table 2

Addressed Criteria of Analytical Approaches

Principle	Paper
Semiotic Clarity	[10, 24, 29, 30, 31, 37, 40, 27, 32, 39, 41, 42, 46]
Perceptual Discriminability	[10, 24, 29, 30, 31, 37, 40, 27, 32, 39, 41, 42, 46]
Semantic Transparency	[10, 24, 29, 30, 31, 37, 40, 32, 41, 42, 46]
Cognitive Integration	[10, 24, 29, 30, 31, 40, 32, 41, 42, 46]
Cognitive Fit	[10, 24, 29, 30, 31, 37, 40, 42, 46]
Graphic Economy	[10, 24, 30, 31, 37, 40, 27, 32, 39, 41, 42, 46]
Dual Coding	[10, 24, 29, 30, 31, 37, 40, 27, 32, 42, 46]
Visual Expressiveness	[10, 24, 29, 30, 31, 37, 40, 27, 32, 39, 41, 42, 46]
Manageable Complexity	[10, 24, 29, 30, 31, 37, 40, 27, 39, 42, 46]

4. Conclusion and Outlook

This study has shown that the PoN have a high impact considering the number of 787 citations and has little tool support considering only one paper in the Systematic Literature Analysis that considers tool support. However, a lot of problems in notation design and evaluation arise - reduced comparability of results, arbitrary and ambiguous application of principles. The integration of Moody's and other frameworks in platforms for notation design can lower the barriers for empirical evaluations and the well documented (formalized) application of guidelines to notation design. A next planned step is the development of a meta-model-based tool-support for experiment design implemented on the AdoXX platform. A first prototype already exists. Furthermore, a concept of analyzing graphical representations in combination with the meta-model has been developed for this platform.

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