1-1998

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Citation

SIAU, Keng and ROSSI, Matti. Evaluation of information modeling methods: A review. (1998). *1998 31st Hawaii International Conference on System Sciences: Kohala Coast*. 314-323.

Available at: https://ink.library.smu.edu.sg/sis_research/9494

Evaluation of Information Modeling Methods -- A Review

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Abstract

Hundreds of modeling methods are in existence today. Yet practitioners and researchers are zealously "producing" new modeling methods. The "blooming" of modeling methods is not the problem; the lack of standardize techniques for evaluating them is. To further complicate the matter, most of the modeling methods are introduced based on common sense and intuition. Theoretical foundations and empirical evidence are severely lacking. With the current state of affairs, evaluation of modeling methods has become necessary. Comparing modeling methods provides us with the necessary knowledge and understanding on the strengths and weaknesses of each method. This knowledge can also guide us in our quest for the next modeling methods. This paper reviews the various evaluation techniques used by researchers and practitioners. The evaluation techniques are categorized into non-empirical and empirical techniques.

1. Introduction

Unlike tropical rainforests, which are diminishing, the jungle of systems development methods seems to be alive and growing faster than ever [1]. Jayaratna [30] estimated that there are more than 1000 systems development methods in use today. Recent years have also witnessed the appearance of many new systems development paradigms and methods such as object-oriented analysis and design methods, and business process re-engineering methods. Lately, "web" development methods are gaining popularity. Despite some attempts to provide "standard" systems development methods such as Universal Modeling Language (UML) and Object-oriented Process, Environment and Notation (OPEN), it is likely that no one standard method will suit all situations [27]. In fact, there is a trend towards more specialized methods such as EXPRESS/G [28]. The proliferation of modeling methods has prompted Floyd [16] to argue that "we must develop methods for the investigation of methods, concepts for the description and comparison of methods, and criteria for their evaluation and assessment."

There are a number of reasons for comparing methods. Firstly, researchers want to better understand the nature of methods in order to classify and improve them. Secondly, practitioners want to use comparison as a practical tool for selecting methods [1]. Thirdly, method developers want to know the strengths and weaknesses of the various methods. This knowledge will enable them to design better methods. Fourthly, since no one method is suitable for all situations, we need to know when to use a particular method and when not to use a specific method. Comparison of methods provides a viable means for us to gather this information.

Although there are numerous studies on method evaluation and a few conferences dedicated to the cause (e.g., Method Engineering, Workshop on Evaluation of Modeling Methods in Systems Analysis and Design, and CRIS series), we did not find any research article that summarizes the existing literature and provides a comprehensive view on this research area. This paper attempts to do that by surveying existing literature on method evaluation. This paper does not try to come out with new evaluation criteria as there are many in existence today; instead it tries to gather different perspectives on method evaluation research. The nature of discussion in this paper is broad rather than deep, but it provides a good starting point for future research and serves as a reference on the various evaluation techniques.

2. Information Modeling Terminology

Information systems models are constructed according to certain techniques, which can be defined as procedures, possibly with a prescribed notation, to perform a development activity [7]. During information systems development (ISD), various aspects of object systems have to be modeled (e.g. structure, processes, transformations) and solutions defined. This requires a multitude of modeling techniques. Usually these techniques are combined together to form a more or less integrated ISD method. A method is an approach to perform a system development project, based on a specific way of thinking, consisting of directions and rules, structured in a systematic way in development activities with corresponding development products [7]. Some researchers also include the tools, or material resources in the definition of method (e.g. [36]. We, however, make a distinction between the tools and methods because we believe that tools that support modeling methods form a separate discipline of research (e.g., CASE research). Method should also be differentiated from methodology which is the research of methodical systems development.

Every modeling method uses a small set of constructs [53], [54], [55] which defines the vocabulary of the method. Constructs are ideas or images specifically conceived for a given modeling method for the purpose of organizing and representing knowledge about the domain of interest. They can be individual objects, such as entities or data stores; relationships between objects, such as message connections or links; and attributes of objects and relationships, such as entity names or message lengths. Constructs are sometimes termed as components [21], fragments [19], or semantic primitives [49].

With these in mind, we will now review the various modeling method evaluation techniques. In this paper, we categorize evaluation techniques broadly into empirical and non-empirical techniques.

3. Non-Empirical Evaluation Techniques

3.1 Feature Comparison

The first broader attempt to compare methods according to certain "yardsticks" can be found in the Comparative Review of Information Systems (CRIS) series of conferences [43], Olle [44]. The studies in this subcategory were typically based on the idea of using different methods to model the same domain (e.g., the famous conference organization case) and see how the various methods tackle the same problem [43]. This technique soon became the dominant way of comparing methods [44].

Using this research approach, the researchers develop a "checklist" of ideal method features. The checklist is then used to evaluate methods either within the same paradigm (e.g. different structured methods [69], different data modeling methods [60], or different OO methods [24], [25] or across paradigms (e.g., different methodical approaches such as OO versus SA [35], and OO versus process modeling [59]. Representative examples of checklist development are: comparisons of OO methods [38], [12], NIMSAD [30].

The problem with the feature comparison technique is subjectivity. There are at least two levels of subjectivity involved. First, some researchers have to develop the "checklist" and this is often a very subjective task. Second, the criteria are analyzed by researchers (not necessarily the same researchers who came up with the checklist) who usually have to interpret the vague descriptions provided by the method developers. The strength of this research approach is that it is relatively easy to perform if the criteria are well defined.

3.2 Metamodeling

One way of comparing methods is to use their metamodels as a basis for analysis. In its simplest form we can say that a metamodel is a conceptual model of a development method [7]. Consequently, metamodeling can be defined as a modeling process, which takes place at one level of abstraction and logic higher than the standard modeling process [17]. A metamodel captures information about the concepts, representation forms (or signs, cf. [34]), and uses of a method.

Attempts to use a common metamodeling language for method comparison have concentrated on mapping methods to some "supermethod", or comparing models of methods by identifying their common parts [24], [57], [58]. The work of Oei et al. [40], [41], [42] introduced a formal language for modeling methods and transforming them into a method hierarchy. Harmsen and Saeki [20] took this view a little bit further by evaluating four method description languages based on their metamodels. These characterization-based approaches have evolved directly from the feature comparison technique. Despite their similarities, proponents of metamodeling pointed out that the technique is more objective than feature comparison because researchers base their analysis on modeled characteristics rather than ad-hoc compilation of “checklists” and identification of features based on vague documentation of information modeling methods.

3.3 Metrics Approach

The method metrics approach is aimed at analyzing the complexity-based features of methods based on a standardized set of method metrics, as proposed by Rossi and Brinkkemper [45], [46]. This approach analyzes a formal metamodel of a method and computes the metric values. The metric values can be compared to reference values provided in [46], [47]. McLeod has applied function points to compute values for method metrics in [37]. These metrics can provide a valuable aid for method comparison, but a lot of empirical work is needed to validate the metrics.

3.4 Paradigmatic Analyses

Several researchers have presented broad analyses of assumptions behind systems development. The earlier ones were proposed notably by researchers of the so-called Scandinavian school of thought, which questioned the technical focus of methods and their comparisons. Researchers such as Bjørn-Andersen [6] and Bubenko [8], put forth the questions of values and underlying assumptions of methods. This broadened into several general frameworks for method analysis. Examples of these are the Iivari's framework [27], which addresses the contemporary schools of thought of IS. Hirschheim, Klein and Lyytinen analyzed underlying paradigms of methods in several articles [22] and a book [23]. They applied a number of meta-frameworks to position information systems development (ISD) methods according to their view of the way IS should be defined, their view of the intention of ISD, their view of the language, etc. Wood-Harper and Fitzgerald [68] summarized this area of research and identified the major approaches or schools of thought of ISD. Hircheim and Iivari [26] followed the paradigmatic analysis of Burrell and Morgan [11] and identified the views of information systems based on the assumptions the ISD method makes about the development organization and the nature of the systems under development. It is interesting to see that despite the effort of these researchers to widen the scope of method evaluation, they very easily fall into the trap of seeing the newest or broadest approach as the best one. The approaches that are “emancipatory” or “intersubjectivic” are seen categorically superior to technical and individual approaches. While this opinion might be correct, there is little empirical evidence to support it, except the one that the technical approaches have failed quite often.

Although these approaches might not be directly applicable for end users, they could be valuable aids in selecting a method for use within an organization, as Avison and Fitzgerald have pointed out [1]. As organizations work in some practical environment, have certain skills and resources and develop certain types of systems, these general paradigmatic differences in methods can be of great help in fighting through the methodology jungle by at least pointing to the part of the jungle to search for the “best” or most suitable method.

3.5 Contingency Identification

These studies provide an even broader view of the problems of method selection by providing heuristics for minimizing risks and identifying the problems which we try to address with the methods. As the situation at hand and contingencies usually play a big role in actual development process, these rule-of-thumbs can be of great help for practitioners [14], [2], [5]. Davis [14] proposed criteria for selecting the method based on project contingencies such as the problem under investigation and the people who perform the investigation. As some researchers [48] argued, there is a need for multidimensional or triangulation approach, which combines the above mentioned approaches in a way suitable for contingencies of the situation at hand. Avison and Fitzgerald [1] have developed a "multi-level" approach, where they applied a contingency approach together with a paradigmatic analysis and then continued into feature analysis. They claimed that this approach could satisfy the needs of the researchers and at the same time aid the practitioners.

3.6 Ontological Evaluation

Wand and Weber [62], [63], [64], [65] proposed the use of ontological concepts to evaluate information modeling methods. Wand and Weber's ontological model is a modification and extension of the one developed by Bunge [9], [10]. The basic idea is to evaluate the constructs in existing methods by matching them with ontological constructs. Wand and Weber [65] argued that a one-to-one mapping should exist between ontological constructs and modeling constructs. They introduced the notions of construct overload, construct redundancy, construct excess, and construct deficit [65].

(i) Construct overload: when one modeling construct maps into two or more ontological constructs.
(ii) Construct redundancy: when two or more design constructs are used to represent a single ontological construct.
(iii) Construct excess: when a modeling construct does not map to any ontological construct.
(iv) Construct deficit: when an ontological construct does not have any corresponding modeling construct.

Based on the ontological approach, Peter Green [18] evaluated a number of modeling methods. One of the advantages of using ontological model for evaluation is that it is at least derived from a strong theoretical foundation – Bunge's Ontology. However, the question of why Bunge's Ontology was chosen has always been raised.

3.7. Approaches Based on Cognitive Psychology

Since modeling methods are intended to capture the knowledge of the problem domain for the purpose of communication and understanding among the project team members [39] it becomes necessary to understand the cognitive aspect of modeling. Some researchers [53], [51] proposed the use of cognitive psychology theories as the basis for evaluating modeling methods. For example, in Siau et al. [53], the authors proposed the use of informational and computational equivalence, based on the theory by Herbert Simon [56], for comparing information modeling methods. In Siau [51], the author introduced the GOMS (Goals, Operators, Methods, Selection rules) approach, a popular theory in Human-Computer Interaction, as a way to evaluate modeling methods. The use of theories from other disciplines has the benefit that these theories are usually well-developed and tested in their respective disciplines. The strengths and weaknesses of the theories, possible applications of the theories, and how to overcome the limitations of the theories are most likely already documented in the respective disciplines. However, choosing the right theories from the right disciplines to apply is no easy task.

4. Empirical Evaluation Techniques

Empirical evaluation techniques are another means of evaluating information modeling methods. Empiricism is said "to denote observations and propositions based on sense experience and/or derived from such experience by methods of inductive logic, including mathematics and statistics" [13].

4.1 Survey

Survey gathers data on attitudes, opinions, impressions, and beliefs of human subjects via questionnaires. This technique allows testing of a priori hypotheses and offers an iterative approach to the generation of hypotheses. Though this is a popular research methodology in behavioral research, there are few instances where researchers use survey for evaluating information modeling methods. One of the main difficulties of using survey is the low response rate from the recipients of the questionnaires. Typical response rate range from a few percentage points to 30-40 percents. Wand et al. [67] used questionnaires to evaluate the effectiveness and efficiency of DFD and OOA methods over a three year period. They managed to resolve the problem of low response rate by using students as the respondents. Another reason for the unpopularity of survey in modeling methods evaluation research is that it captures perception measures. This, to many researchers, is an unnecessary weakness since we can use objective measures rather than perception measures. However, proponents of survey technique counter-argued by stressing that the adoption of modeling methods by individuals and organizations is based on the perceived usefulness and advantages of the methods rather than some objective measures. In general, survey is a good evaluation technique for information modeling methods, especially if we want to gathers perception information from many geographically dispersed practitioners.

4.2 Laboratory Experiment

Numerous laboratory experiments on comparing modeling methods have been conducted during the last few years (e.g., [3], [4], [15], [29], [32], [52], [54], [55]). In a laboratory experiment, the researcher manipulates the independent variables (e.g., different modeling methods, different modeling constructs) and measures the effect of the independent variables on the dependent variables (e.g., accuracy of modeling, accuracy of interpretation, confidence level, time taken). The beauty of laboratory experiment is its ability to control intervening and confounding variables. Internal validity, which is the potential for determining that the independent variable (and nothing else) caused the observed effects on the dependent variable, is its biggest strength. Comparing modeling methods using laboratory experiment is probably the most popular approach for North American MIS researchers. For example, [3], [4], [15], [29], [32] investigated the differences between modeling methods using laboratory experiments with model construction as the task. Recently, Siau [52], [54], [55] used laboratory experiments to investigate the effect of modeling construct (i.e., relationship construct in their case) on user interpretation of information models. Focusing on individual constructs is a departure from the traditional approach of looking at information modeling method as the level of analysis. The new approach allows the researchers to investigate the effectiveness and efficiency of each construct in information modeling, which is impossible to deduce when modeling method is the level of analysis. Artificiality of the research settings is the main concern with laboratory experiment which limits the generalizability (or external validity) of the results. The simplicity of the experimental tasks is another concern as the tasks are sometimes considered unrealistically simple by practitioners. As such, the best modeling method in the artificial laboratory environment may not be the best in a real world modeling situation. Nonetheless, if determining causality and the ability to control extraneous variables are important, laboratory experiment is the best technique available.

4.3 Field Experiment

To overcome the artificiality of laboratory experiment, field experiment takes place in a "natural setting." The researcher manipulates the independent variables and at the same time trying to control the most important intervening variables (since it is impossible to control all the intervening variables in the field environment). The researcher then measures the effects of the independent variables on the dependent variables by systematic observation of human subjects. Field experiment is more difficult to conduct than a laboratory experiment. Gaining access to organizations is not easy as most organizations are reluctant to let researchers go in to conduct experiments. As such, this is not many field experiments conducted in the area of modeling methods evaluation. Another reason for the paucity of field experiments is that most organizations do not subscribe to a particular modeling method, rather they adapt and modify existing methods for their own use. For example, they might use an object-oriented approach for systems analysis and design but their object-oriented approach is based on "home-make" recipe. One potential confounding variable is running field experiments is the "purity" of subjects – they are usually familiar with a few modeling methods. For example, they might use object-oriented approach but their thinking process is still based on structured analysis. Because of this, the integrity of the experimental results is questionable.

4.4 Case Study

Using this technique a particular subject, group of subjects or organization using one or more modeling methods is observed by the researcher without intervening in any way. No independent variables are manipulated, no control is exercised over intervening variables and no dependent variables are measured. The case study attempts to capture and communicate the reality of a particular environment at a point in time. Since the technique does not require the researchers to intervene in the normal operation of the organizations, the organizations are more susceptible to the idea. The main concern with this approach is the subjectivity of the researchers interpretation. The research site is rarely (if ever) randomly selected. This represents one level of subjectivity. Secondly, the observation is usually interpreted by the researchers alone (or in small group) – another subjectivity. Triangulation is an approach to partly overcome the subjectivity involved in case study. The richness of the data in case study is something that survey and experimentation cannot match.

4.5 Action Research

Action research allows the researcher to become a part of the research – to be affected by and to affect the research. The objective with this approach is not the finite testing of a particular hypothesis but the realization of the "human creative potential." Human subjects in this methodology are "of the essence." This approach allows the researchers to take part in the modeling process (usually as consultants) and report their experience. Not only is the objectivity of the interpretation a concern, but the effect of the researcher involvement in the modeling process is also a problem. Nonetheless, this approach can provide detailed analysis and insight into the modeling methods that are very difficult to capture otherwise.

5. Conclusion

This paper reviews the various techniques that can be used for evaluating information modeling methods. As we can see from the analysis, the evaluation techniques range from technically sophisticated to non-technical (e.g., experience reporting), non-empirically oriented to empirical approaches, and mathematical-based to cognitive or philosophical in nature. The pros and cons of each technique are discussed and some of the existing literature documented. These, we hope, will provide the foundation for selecting an appropriate technique to use. Selecting one technique over another usually means trading off one aspect for another – for example, trading off internal validity for external validity. It should be stressed that none of these techniques is inherently superior to others. The choice of techniques to use in a given situation should be based on the research questions, the environment, the strengths of the researchers, and the opportunities available.

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