Applying Cognitive Theories to Evaluate Conceptual Models in Systems Analysis

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ABSTRACT

Conceptual models have been evaluated along the dimensions of modeling complexity (how easy is it to create schemas given requirements?) and readability (how easy is it to understand the requirements by reading the model schema?). In this work, we update COGEVAL, a propositional framework based on cognitive theories to evaluate conceptual models. We synthesize work from cognitive literature to develop the framework, and show how it can be used to explain earlier empirical results as well as existing theoretical frameworks. We illustrate how COGEVAL can be used as a theoretical basis to design an empirical test of readability of a conceptual model. Unlike much of the earlier empirical work on readability, our approach isolates the effect of a model-independent variable (degree of fragmentation) on readability. From a practical perspective, our findings will have implications for both creators of new models and practitioners who use currently available models to create schemas.

Keywords: Analysis Techniques, Cognitive Mapping, Database Conceptual Design, Database Requirements Analysis, Information Analysis Techniques

INTRODUCTION

Conceptual models are important in the area of information systems (IS) development. Essentially, a conceptual model is a method of documenting elements of an underlying reality. Model schemas may be used as: a) a method of either informally or formally documenting end-user requirements, which are initially articulated in a natural language like English; and/or b) a method of optimally designing the subsequent IS. A commonly used example of both a) and b) is the use of the Entity Relationship Model (ERM) (Chen, 1976) to capture end-user requirements for constructing a relational database application. Once the requirements are documented in an ERM schema, the ERM schema can then be mapped, using well-known rules, to a measurably good relational schema design. Over a hundred conceptual models have been proposed for requirements modeling (Olle, 1986), with over 1000 brand name methodologies utilizing these models (Jayaratna, 1994).

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Several desirable attributes of modeling methods have been proposed in earlier work. These include: a) the adequacy or completeness of the modeling method in being able to represent the underlying reality (Amberg, 1996; Bajaj & Ram, 1996; Brosey & Schneiderman, 1978; Erickson & Siau, 2007; Kramer & Luqi, 1991; Mantha, 1987; Moynihan, 1996), b) the readability of the modeling method’s schemas (Aquirre-Urreta & Marakas, 2008; Hardgrave & Dalal, 1995; Shoval & Frummerman, 1994), and c) how easy it is to use the modeling method to represent requirements (Bajaj, 2000; Bock & Ryan, 1993; Kim & March, 1995; Kramer & Luqi, 1991; Shoval & Even-Chaime, 1987; Siau & Cao, 2001). Many earlier works consider both the effectiveness and the efficiency aspects of a) and b) (Bajaj, 2002; Wand & Weber, 2002). Modeling effectiveness is the degree to which modelers can correctly create the schema of a model, for a given requirements case. Modeling efficiency is the amount of effort expended to create the schema. Similarly, readability effectiveness is the degree to which readers of schema can correctly recreate the underlying requirements. Readability efficiency is the amount of effort taken by readers of a model schema to recreate the requirements.

Past approaches used to evaluate these models can be broadly categorized into theoretical and empirical work. Theoretical approaches have utilized a-priori frameworks to analyze models. Examples of these frameworks include the Bunge-Wand-Weber framework (BWW) (Wand & Weber, 2002; Weber, 2003) that has its basis an ontology previously proposed by Bunge. Models are evaluated based on the degree to which their constructs match the constructs in the Bunge ontology. A second example is a set of content specifications proposed in earlier work (Bajaj & Ram, 1996), that analyze models based on the degree to which the specification is fulfilled by the model. A third example of a-priori frameworks is the use of quantitative metrics such as the number of concepts (constructs) in a model, the degree of relationship between constructs, etc. (Bajaj, 2000; Castellini, 1998; Siau & Cao, 2001). These quantitative metrics can be used to compare models without the need for empirical work. A fourth example (Aquirre-Urreta & Marakas, 2008) uses a comprehensive framework consisting of ontological foundations, modeler and user training, semantic equivalence of conceptual models, and modeling practices to explain why different studies reveal different results. While all of these approaches offer insights into different models, in general several are axiomatic, i.e., they have not been empirically validated (Bajaj, 2002).

Empirical approaches in the past have primarily focused on comparing existing models. In most cases, subjects were either given a set of requirements and asked to create a model schema or given a schema and asked to reconstruct the requirements. Based on subjects’ responses, the models under consideration were comparatively evaluated for modeling effectiveness, modeling efficiency, readability effectiveness or readability efficiency. Commonly used controls include subjects’ experience with a model, and their level of training in using the model. Examples of past studies include (Batra, Hoffer, & Bostrom, 1990; Burton-Jones & Straub, 2006; Hardgrave & Dalal, 1995; Kim & March, 1995; Maes & Poels, 2007; Shoval & Frummerman, 1994).

While the results of earlier empirical studies have shown how one model may have compared with another for the same set of requirements, there has been very little attempt to explain why any differences were observed. There has been lack of a theoretical basis for the hypotheses that were examined in empirical work, or for explaining findings. For example, finding that the extended ERM (EER) schema is more or less readable than the object–oriented (OO) model (Booch, 1994) schema for a case does not indicate why this was observed. The problem is that existing models view reality in differing ways, and hence differ from each other along several dimensions. While recent work such as in (Erickson & Siau, 2007) has attempted to simplify certain aspects of the Unified Modeling Language (UML) it is still a difficult problem to isolate what aspect of a model may cause...
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