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Research on conceptual modeling: Themes, topics, and introduction to the special issue

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ABSTRACT

Conceptual modeling continues to evolve as researchers and practitioners reflect on the challenges of modeling and implementing data-intensive problems that appear in business and in science. These challenges of data modeling and representation are well-recognized in contemporary applications of big data, ontologies, and semantics, along with traditional efforts associated with methodologies, tools, and theory development. This introduction contains a review of some current research in conceptual modeling and identifies emerging themes. It also introduces the articles that comprise this special issue of papers from the 32nd International Conference on Conceptual Modeling (ER 2013).

1. Introduction

The field of conceptual modeling was founded approximately 40 years ago with roots at the intersection of database, artificial intelligence, and programming language research. Early efforts to share ideas among these communities led to the use of the term *conceptual model*, with one of the earliest and most widely acknowledged conceptual modeling languages being Chen's Entity-Relationship (ER) model [13]. This model is well-known for its simplicity and elegance, and is based upon the two main constructs of entities and relationships. The ability to model data effectively and to easily separate logical from physical database design was a key contribution of this early work in conceptual modeling. This seminal paper has inspired decades of related research, and "the ER model" has become virtually synonymous with "database design." The ER model is widely used for communication among developers, domain experts, and users regarding the features of a proposed information system.

Conceptual modeling involves capturing various aspects of the real world, and representing them in the form of a model that can be used for communication [43]. More specifically, conceptual modeling focuses on "capturing and representing human perceptions of the real world" in such a manner that they can be included in an information system [60]. The outcome of the conceptual modeling activity is usually a diagram or model that can then be translated into a relational or some other logical model [58,59]. The adequacy of a conceptual model is based on how well it is able to promote a common understanding among human users [43].

Conceptual modeling has continued a tradition of capturing and representing the data needed in real-world applications. Research on conceptual modeling includes a focus on tools, techniques, theories, and modeling languages. The field of conceptual modeling is inherently multi-disciplinary, incorporating researchers and professionals from academia and industry, from computer science,

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management information systems, data engineering, knowledge engineering, artificial intelligence, and other areas (see, e.g. [14,32,42,52] to name a few).

Throughout its history, conceptual modeling research has, in essence, been a study in finding higher and more suitable forms of abstraction (see, e.g. [56]) to aid in efficient and effective software construction. Most researchers consider the purpose of conceptual modeling to be developing software that meets the needs of a business or organization (see, e.g. [32,65]). Thus conceptual modeling research tends to demonstrate practical applications, tools, and techniques associated with the proposed theories.

The conceptual modeling activity of "formally describing some aspects of the physical and social world around us for purposes of understanding and communication" [43] requires assessment of how well the model captures a real world problem or situation for which an information system is being designed, and how well it facilitates communication between developers and users. Promoting a common or shared understanding between members of a development team is increasingly important with global, distributed systems development teams [40,48].

From its beginning, the field of conceptual modeling built on work like the ER model [13] and the binary relationship model (see, e.g. [1,54]). Since then the discipline has grown substantially, with researchers exploring many topics related to database design (e.g. [59]), knowledge representation (e.g. [16,42]), ontological analysis (e.g. [25]), and software engineering (e.g. [57,66]). It has also been applied to a wide range of topics dealing with the development and implementation of information systems, including the Internet of Things [7], modeling languages [19,36,67], social network analysis [15,37], semantic understanding [8,34], provenance [49], enterprise modeling [21], biology [47,50], mobile devices [20], cloud computing [2,51], modeling for user-generated content [38,39], and Data Warehouses and Business Intelligence (BI) applications [68–70].

As the complexity of information systems development initiatives has evolved, so has conceptual modeling, providing abstract, interesting, and novel ways in which to capture the real world. The International Conference on Conceptual Modeling[1] has remained the leading conference in the area of information systems and database design, attracting world-class researchers from around the world, who work in both academia and industry. This introduction to the *Data & Knowledge Engineering* special issue on ER 2013 first identifies some of the important and emerging areas of research in conceptual modeling as reflected in that meeting. It then provides an overview of each of the papers that appear in this special issue before concluding with a summary and discussion of future aspects of conceptual modeling.

2. Research themes

Many specific areas provide much opportunity for continued research in conceptual modeling. Since conceptual modeling is needed for most information systems development activities, this section only mentions some of the most notable topics.

Some of the main themes that emerged from the ER 2013 conference [44] included: theories of concepts and ontologies underlying conceptual modeling, methods and tools for developing and communicating conceptual models, techniques for transforming conceptual models into effective implementations, the relationship between big data and conceptual modeling, advances in business process modeling, and applications of conceptual modeling. An overview of the papers from several of these areas is provided below. This section first addresses two of the major themes: ontology and big data.

2.1. Ontology theories and concepts

The term "Ontology" means the study of existence, and, in philosophy, ontology is a branch of metaphysics that considers the fundamental nature of being [26]. Work from philosophy, such as the writings of physicist/philosopher Mario Bunge [9,10] and others (e.g. [53]), has influenced researchers studying ontological dimensions of conceptual modeling. A significant alignment exists between ontology and conceptual modeling, in that applied ontology starts with the explicit creation of models of the world to clarify what exists [23]. Likewise, understanding and communication are primary objectives of conceptual modeling.

For the past two decades, topics related to ontology development as well as ontological foundations of conceptual modeling have appeared as part of the scientific program of the annual International Conference on Conceptual Modeling (see, e.g. [20,24,25,27–29,33,60]) and elsewhere (e.g. [6,26,46,55,61–63]).

For several years, the International Conference on Conceptual Modeling has also attracted workshops where the role of ontology has played a major part. These workshops include, for example, Foundations and Practices of UML, Ontologies and Conceptual Modeling, Modeling for Data-Intensive Computing, Conceptual Modelling of Services, and Web Information Systems Modeling. The growing influence of ontology in conceptual modeling research has led to the discovery of ontological patterns and also anti-patterns [25]. Thus, we are learning both things we *should* do and things we *should not* do with conceptual modeling languages.

Similar to the field of conceptual modeling, the field of ontology naturally attracts multi-disciplinary teams. As Guarino and Musen point out, ontology is a cross-cutting area that "embrace[s] conceptual modeling issues both in artificial intelligence and in conventional software engineering" [23]. They further emphasize the need for research into "the theoretical aspects of ontological analysis"

[1] See http://conceptualmodeling.org.