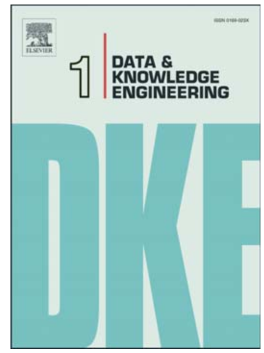
Accepted Manuscript



Research on Conceptual Modeling: Themes, Topics, and Introduction to the Special Issue

Veda C. Storey, Juan C. Trujillo, Stephen W. Liddle

PII: S0169-023X(15)00047-6
DOI: doi: 10.1016/j.datak.2015.07.002
Reference: DATAK 1528

To appear in: *Data & Knowledge Engineering*

Please cite this article as: Veda C. Storey, Juan C. Trujillo, Stephen W. Liddle, Research on Conceptual Modeling: Themes, Topics, and Introduction to the Special Issue, *Data & Knowledge Engineering* (2015), doi: 10.1016/j.datak.2015.07.002

Research on Conceptual Modeling: Themes, Topics, and Introduction to the Special Issue

Veda C. Storey[a], Juan C. Trujillo[b], Stephen W. Liddle[c]

[a] *J. Mack Robinson College of Business, Georgia State University, Atlanta, GA 30302-4015 U.S.A.*
[b] *University of Alicante, 03690 Alicante, Spain*
[c] *Marriott School of Management, Brigham Young University, Provo, UT 84602, U.S.A.*

Abstract

Conceptual modeling continues to evolve as both practitioners and researchers reflect on the challenges of modeling and implementing data-intensive problems that continue to 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.

Keywords: Conceptual modeling, big data, business process modeling, ontologies, modeling tools, modeling techniques, applications

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 it 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.

Email addresses: vstorey@gsu.edu (Veda C. Storey), jtrujillo@dlsi.ua.es (Juan C. Trujillo), liddle@byu.edu (Stephen W. Liddle)

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, 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]). 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]). 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], social network analysis [15, 37], semantic understanding [8, 34], provenance [49], enterprise modeling [21], biology [47, 50], mobile devices [20], cloud computing [2, 51], and modeling for user-generated content [38, 39].

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

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

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. Section 3 gives an overview of papers in several of these areas, and this section 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, 28, 29, 33, 60]) and elsewhere (e.g. [6, 26, 46, 55, 61, 62, 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” along with research “that delve[s] deep into the nuances of modeling real content" [23]. There is much that still needs to be done in this area [22], and this will likely continue to be an active and important area of conceptual modeling research.

2.2. Big Data and Conceptual Modeling

The ER 2013 conference included three keynote speakers who presented their research and insights on themes associated with big data concepts. These were: David Embley's "Big Data: Conceptual Modeling to the Rescue" [18]; Marie-Aude Aufaure's "What's Up in Business Intelligence? A Contextual and Knowledge-based Perspective" [4]; and Surajit Chaudhuri's "Big Data and Enterprise Analytics". Additional industry presentations echoed this theme.

Big data has become well-known as described by the V's of volume, variety, velocity, and veracity, each of which brings its own unique challenges for conceptual modeling. The volume of big data is now often considered in petabytes and exabytes. The variety of big data reflects heterogeneous sources, including traditional database structures, sensors and sensor networks, user-supplied web content, and scientific projects such as the Large Hadron Collider or the Square Kilometre Array telescope network. The phenomenal rate of acquisition reflects the velocity of big data. The veracity refers to issues of trustworthiness and uncertainty.

It is difficult for humans to comprehened the scale of big data. The first keynote reports that "the NSA data center being built in Utah within 35km of our university purportedly is designed to store at least zettabytes (10^{21} bytes) and perhaps yottabytes (10^{24} bytes) of data" [18]. As reported in Wikipedia, "According to the CSIRO, in the next decade, astronomers expect to be processing 10 petabytes of data every hour from the Square Kilometre Array (SKA) telescope. The array is thus expected to generate approximately one exabyte every four days of operation. According to IBM, the new SKA telescope initiative will generate over an exabyte of data every day. IBM is designing hardware to process this information."[2]

How are conceptual-modeling researchers responding to the challenges of dealing with big data? As our understanding and advancement of tools and techniques to deal with big data for predictive analytics [17] and other applications increases, accurate representation and modeling of data is crucial (see, e.g. [4, 5]). With respect to conceptual modeling, an important first observation [18] is that the main thrust of conceptual modeling has always been about organizing data [13]. However, this traditional approach has now been challenged as can be understood in terms of the big data "V's." The volume is too big; the variety has too much heterogeneity; the velocity has data being generated too fast; and the veracity gives rise to too much uncertainty. Thus, traditional conceptual modeling tools and techniques need to be reconsidered (also see [38]). Embley and Liddle suggest that these can be handled at least in some contexts by automated harvesting and organization of data, as well as evidence-based reasoning [18].

Research in knowledge management has recognized that the overwhelming magnitude of data is difficult to manage but very valuable if meaningful information can

[2]`https://en.wikipedia.org/wiki/Exabyte`, retrieved June 2015

be extracted. Search engines have advanced in the last two decades in efforts to deliver the most relevant content to their users. However, issues of content and semantics have been, and continue to be, major challenges [11, 51]. Business intelligence and data analytics initiatives have been developing web analytics techniques to mine user-generated content in the form of unstructured data to perform sentiment analysis and other types of intelligence analysis on consumer opinions and needs, in an attempt to create new business opportunities [4, 12].

The era of big data is here to stay. To capitalize on the many available opportunities that arise when "data poor" applications become "data rich," conceptual modeling researchers will need to continue to develop models, tools, and techniques to deal with these relatively new challenges.

3. Overview of Special Issue Papers

The papers in this special issue reflect several main themes, including ontologies, software development and conceptual modeling, semantic richness in conceptual models, and business process modeling. These papers are extended versions of work presented at ER 2013 [20, 30, 33, 35, 41, 45, 64]

3.1. Ontologies

The paper "Ontology-Based Mappings" by Giansalvatore Mecca, Guillem Rull, Donatello Santoro, and Ernest Teniente investigates the difficult problem of mapping a source schema to a database when a rich ontology is available. The authors develop a translation algorithm for doing so. The authors formally represent and test their proposed expressive language for view definitions. With the rapid evolution of the Semantic Web and increased adoption of ontologies, this research advances the goal of incorporating richer ontology schemas into the data translation process.

A second paper in the area of ontologies, entitled "An Ontology-Driven Unifying Metamodel of UML Class Diagrams, EER, and ORM2", is by Maria Keet and Pablo Fillottrani. The authors propose a unified ontology-driven metamodel of the static structural entities of three main language families: UML class diagrams, ER/EER, and ORM/ORM2. The metamodel constitutes a theoretical foundation for CASE tool development that supports all three language families, facilitating both the expression of inter-model assertions across models represented in different languages and converting a model from one language into another. The authors illustrate two practical use cases of the metamodel and further provide a qualitative assessment of inter-model assertions.

3.2. Software Development and Conceptual Modeling

The paper "Improving Conceptual Data Models through Iterative Development" by Tilmann Zäschke, Stefania Leone, Tobias Gmünder, and Moira C. Norrie facilitates agile development of information systems by introducing the concept of evolvability as a model quality characteristic. "Evolvability" refers to the expected implications of future model refactorings in terms of the complexity of the required database evolution algorithm and the expected volume of data. The authors propose extending the agile development cycle by using database profiling information to recommend conceptual-model transformations that will improve system performance. The authors also analyze the flow of semantic information and, finally, make an interesting case for the use of object databases in agile development environments.

A second paper that addresses the theme of improving the conceptual-model development process is by Van Le, Sebastian Link, and Flavio Ferrarotti. Their paper, "Empirical Evidence for the Usefulness of Armstrong Tables in the Acquisition of Semantically Meaningful SQL Constraints", examines how Armstrong tables can help developers acquire requirements in SQL semantics. For this purpose, the authors empirically measure the usefulness of Armstrong tables. They tackle this problem from two angles, showing both how (1) Armstrong tables help with recognizing most meaningful SQL constraints, and (2) Armstrong tables do not help with recognizing meaningless SQL constraints. This paper demonstrates how using theoretically sound sample data can help developers interact with domain experts to acquire domain semantics more effectively and accurately.

3.3. Semantic Richness in Conceptual Models

The article entitled "The *Baquara*^{2} Knowledge-based Framework for Semantic Enrichment and Analysis of Movement Data" by Renato Fileto, Cleto May, Chiara Renso, Nikos Pelekis, Douglas Klein, and Yannis Theodoridis proposes a conceptual model for annotating movement data, which is becoming more ubiquitous in the current age of smartphones and wearable computing. The authors' proposed model supports geoSPARQL queries referring to movement segments, their annotations, and relationships. In this model, developers annotate movement segments with classes and instances that come from existing ontologies and Linked Open Data collections. Experiments with geo-referenced social media data and Linked Open Data assess the effectiveness of an algorithm to annotate movement segments with visited points of interest, and the viability of the proposed approach for movement data enrichment and analysis.

One need look no further than the headlines of the news press to see security requirements as another area where additional semantic richness could be beneficial in our complex modern computing environment. In their paper, "Managing Security Requirements Conflicts in Socio-Technical Systems", Elda Paja, Fabiano Dalpiaz, and Paolo Giorgini present an extended version of STS-ml, a security requirements modeling and reasoning approach for specifying secure socio-technical systems. It provides the semantics of the language constructs and a set of modeling primitives to represent socio-technical systems, their participants, their important assets, and their security needs. STS-ml employs multi-view modeling by arranging its modeling primitives into three different, yet complementary, views that together represent the overall STS-ml model for a proposed system.

3.4. Business Process Modeling

The paper "Improving Business Process Intelligence by Observing Object State Transitions" by Nico Herzberg, Andreas Meyer, and Mathias Weske addresses the lack of event information in manual business process execution environments. During such business process executions, several events happen and certain documents get manipulated. The approach that Herzberg et al. present utilizes the information about the manipulation of documents, i.e., the state transitions of the data objects—so-called "object state transition events"—to reason about enablement and termination of business process activities. This creates a solid basis for process monitoring and analysis. The paper discusses a methodology to create the required design-time artifacts that assist with run-time monitoring. The authors demonstrate the applicability of object state transition events by means of a proof-of-concept implementation of their approach.

4. Conclusion

Challenges in conceptual modeling of how to capture and represent the real world for inclusion into information systems continues to evolve as business and society require increasingly complex and interconnected systems. In an era of big data, mobile computing, social networks, and sophisticated systems applications, the need for effective conceptual modeling tools and methodologies is arguably more important than in previous generations of information systems development.

This *Data & Knowledge Engineering* special issue on ER 2013 intends, in part, to serve as a platform for identifying and understanding contemporary issues and challenges in conceptual modeling for information systems development. The selected papers highlight several emerging areas of research. Taken together, the seven papers in this special issue illustrate a representative snapshot of the kinds of conceptual-modeling related work that researchers are conducting in this active and important field. Indeed, conceptual modeling has much to offer to emerging technologies for business practices and society. We look forward to the future advances that will continue to be initiated by this research community.

Acknowledgements

We wish to thank the Editor-in-Chief of *Data & Knowledge Engineering*, Dr. Peter Chen, for his strong support for this special issue. He shares a conviction of the importance of conceptual modeling in contemporary business practices and information systems development, which is so critical for the sustainability and evolution of this area. We also thank Michael Chua, *Data & Knowledge Engineering* Journal Assistant for his help in producing this special issue.

We are grateful to our excellent group of reviewers who carried out the review process in a timely manner while still meeting the high expectations of a scholarly journal. We thank the authors of these submissions who chose to submit their research to our special issue.

This article was supported, in part, by the J. Mack Robinson College of Business at the Georgia State University and the Marriott School of Management at Brigham Young University.

References

[1] J.-R. Abrial. Data semantics. In *IFIP Working Conference Data Base Management*, pages 1–60, 1974.

[2] B. Andersson, M. Bergholtz, and P. Johannesson. Resource, process, and use - views on service modeling. In S. Castano, P. Vassiliadis, L. V. S. Lakshmanan, and M. Lee, editors, *Advances in Conceptual Modeling - ER 2012 Workshops CMS, ECDM-NoCoDA, MoDIC, MORE-BI, RIGiM, SeCoGIS, WISM, Florence, Italy, October 15-18, 2012. Proceedings*, volume 7518 of *Lecture Notes in Computer Science*, pages 23–33. Springer, 2012.

[3] P. Atzeni, D. W. Cheung, and S. Ram, editors. *Conceptual Modeling - 31st International Conference ER 2012, Florence, Italy, October 15-18, 2012. Proceedings*, volume 7532 of *Lecture Notes in Computer Science*. Springer, 2012.

[4] M. Aufaure. What's up in business intelligence? A contextual and knowledge-based perspective. In Ng et al. [44], pages 9–18.

[5] C. Batini. Data quality vs big data quality: Similarities and differences. In *Proceedings of the 1st International Workshop on Modeling for Data-Intensive Computing, Florence, Italy*, 2012.

[6] P. Bera, A. Burton-Jones, and Y. Wand. Guidelines for designing visual ontologies to support knowledge identification. *MIS Quarterly*, 35(4):883–908, 2011.

[7] A. Berre and M. Missikoff. Panel: Modeling for the future internet. In Jeusfeld et al. [31], pages 526–527.

[8] S. Bowers and L. M. L. Delcambre. Using the uni-level description (ULD) to support data-model interoperability. *Data & Knowledge Engineering*, 59(3):511–533, 2006.

[9] M. Bunge. *Treatise on Basic Philosophy: Vol. 3: Ontology I: The Furniture of the World*. Reidel, Boston, Massachusetts, 1977.

[10] M. Bunge. *Treatise on Basic Philosophy: Vol. 4: Ontology II: A World of Systems*. Reidel, Boston, Massachusetts, 1979.

[11] S. Ceri, E. D. Valle, D. Pedreschi, and R. Trasarti. Mega-modeling for big data analytics. In Atzeni et al. [3], pages 1–15.

[12] H. Chen, R. Chiang, and V. Storey. Business intelligence and analytics: From big data to big impact. *MIS Quarterly*, 3(4):1165–1188, December 2012.

[13] P. Chen. The entity-relationship model—toward a unified view of data. *ACM Transactions on Database Systems*, 1(1):9–36, March 1976.

[14] I. Davies, P. F. Green, M. Rosemann, M. Indulska, and S. Gallo. How do practitioners use conceptual modeling in practice? *Data & Knowledge Engineering*, 58(3):358–380, 2006.

[15] U. Dayal, C. Gupta, M. Castellanos, S. Wang, and M. García-Solaco. Of cubes, dags and hierarchical correlations: A novel conceptual model for analyzing social media data. In Atzeni et al. [3], pages 30–49.

[16] L. M. L. Delcambre and D. Maier. Models for superimposed information. In P. P. Chen, D. W. Embley, J. Kouloumdjian, S. W. Liddle, and J. F. Roddick, editors, *Advances in Conceptual Modeling: ER '99 Workshops on Evolution and Change in Data Management, Reverse Engineering in Information Systems, and the World Wide Web and Conceptual Modeling, Paris, France, November 15-18, 1999, Proceedings*, volume 1727 of *Lecture Notes in Computer Science*, pages 264–280. Springer, 1999.

[17] V. Dhar. Data science and prediction. *Commun. ACM*, 56(12):64–73, Dec. 2013.

[18] D. W. Embley and S. W. Liddle. Big data - conceptual modeling to the rescue. In Ng et al. [44], pages 1–8.

[19] D. W. Embley, S. W. Liddle, and O. Pastor. Conceptual-model programming: a manifesto. In *Handbook of Conceptual Modeling*, pages 3–16. Springer, 2011.

[20] R. Fileto, M. Krüger, N. Pelekis, Y. Theodoridis, and C. Renso. Baquara: A holistic ontological framework for movement analysis using linked data. In Ng et al. [44], pages 342–355.

[21] F. Gailly, S. Casteleyn, and N. Alkhaldi. On the symbiosis between enterprise modelling and ontology engineering. In Ng et al. [44], pages 487–494.

[22] N. Guarino. Ontological analysis and conceptual modeling: achievements and perspectives. In P. Garbacz and O. Kutz, editors, *Formal Ontology in Information Systems - Proceedings of the Eighth International Conference, FOIS 2014, September, 22-25, 2014, Rio de Janeiro, Brazil*, volume 267 of *Frontiers in Artificial Intelligence and Applications*, page 5. IOS Press, 2014.

[23] N. Guarino and M. A. Musen. Applied ontology: Focusing on content. *Applied Ontology*, 1(1):1–5, 2005.

[24] N. Guarino and C. A. Welty. Ontological analysis of taxonomic relationships. In *Conceptual Modeling - ER 2000, 19th International Conference on Conceptual Modeling, Salt Lake City, Utah, USA, October 9-12, 2000, Proceedings*, pages 210–224, 2000.

[25] G. Guizzardi. Ontological patterns, anti-patterns and pattern languages for next-generation conceptual modeling. In E. S. K. Yu, G. Dobbie, M. Jarke, and S. Purao, editors, *Conceptual Modeling - 33rd International Conference, ER 2014, Atlanta, GA, USA, October 27-29, 2014. Proceedings*, volume 8824 of *Lecture Notes in Computer Science*, pages 13–27. Springer, 2014.

[26] G. Guizzardi and T. A. Halpin. Ontological foundations for conceptual modelling. *Applied Ontology*, 3(1-2):1–12, 2008.

[27] G. Guizzardi, G. Wagner, R. de Almeida Falbo, R. S. S. Guizzardi, and J. P. A. Almeida. Towards ontological foundations for the conceptual modeling of events. In Ng et al. [44], pages 327–341.

[28] R. S. S. Guizzardi, X. Franch, G. Guizzardi, and R. Wieringa. Ontological distinctions between means-end and contribution links in the i* framework. In Ng et al. [44], pages 463–470.

[29] B. Henderson-Sellers, T. McBride, G. Low, and C. Gonzalez-Perez. Ontologies for international standards for software engineering. In Ng et al. [44], pages 479–486.

[30] N. Herzberg, A. Meyer, O. Khovalko, and M. Weske. Improving business process intelligence with object state transition events. In Ng et al. [44], pages 146–160.

[31] M. A. Jeusfeld, L. M. L. Delcambre, and T. W. Ling, editors. *Conceptual Modeling - ER 2011, 30th International Conference, ER 2011, Brussels, Belgium, October 31 - November 3, 2011. Proceedings*, volume 6998 of *Lecture Notes in Computer Science*. Springer, 2011.

[32] N. Juristo and A. M. Moreno. Introductory paper: Reflections on conceptual modelling. *Data & Knowledge Engineering*, 33:103–117, 2000.

[33] C. M. Keet and P. R. Fillottrani. Toward an ontology-driven unifying metamodel for UML class diagrams, eer, and ORM2. In Ng et al. [44], pages 313–326.

[34] S. La-Ongsri and J. F. Roddick. Incorporating ontology-based semantics into conceptual modelling. *Information Systems*, 52(0):1–20, 2015. Special Issue on Selected Papers from {SISAP} 2013.

[35] V. B. T. Le, S. Link, and F. Ferrarotti. Effective recognition and visualization of semantic requirements by perfect SQL samples. In Ng et al. [44], pages 227–240.

[36] S. W. Liddle. Model-driven software development. In *Handbook of Conceptual Modeling*, pages 17–54. Springer, 2011.

[37] G. R. Lopes, M. M. Moro, L. K. Wives, and J. Palazzo Moreira de Oliveira. Collaboration recommendation on academic social networks. In J. Trujillo, G. Dobbie, H. Kangassalo, S. Hartmann, M. Kirchberg, M. Rossi, I. Reinhartz-Berger, E. Zimányi, and F. Frasincar, editors, *Advances in Conceptual Modeling - Applications and Challenges, ER 2010 Workshops ACM-L, CMLSA, CMS, DE@ER, FP-UML, SeCoGIS, WISM, Vancouver, BC, Canada, November 1-4, 2010. Proceedings*, volume 6413 of *Lecture Notes in Computer Science*, pages 190–199. Springer, 2010.

[38] R. Lukyanenko and J. Parsons. Is traditional conceptual modeling becoming obsolete? In Ng et al. [44], pages 61–73.

[39] R. Lukyanenko, J. Parsons, and Y. F. Wiersma. The IQ of the crowd: Understanding and improving information quality in structured user-generated content. *Information Systems Research*, 25(4):669–689, 2014.

[40] W. Maass, V. C. Storey, and T. Kowatsch. Effects of external conceptual models and verbal explanations on shared understanding in small groups. In Jeusfeld et al. [31], pages 92–103.

[41] G. Mecca, G. Rull, D. Santoro, and E. Teniente. Semantic-based mappings. In Ng et al. [44], pages 255–269.

[42] G. W. Mineau, R. Missaoui, and R. Godin. Conceptual modeling for data and knowledge management. *Data & Knowledge Engineering*, 33(2):137–168, 2000.

[43] J. Mylopoulos. Conceptual modeling and Telos. In P. Loucopoulos and R. Zicari, editors, *Conceptual Modeling, Databases, and CASE: An Integrated View of Information Systems Development*, pages 50–68. John Wiley & Sons, Inc., 1992.

[44] W. Ng, V. C. Storey, and J. Trujillo, editors. *Conceptual Modeling - 32th International Conference, ER 2013, Hong-Kong, China, November 11-13, 2013. Proceedings*, volume 8217 of *Lecture Notes in Computer Science*. Springer, 2013.

[45] E. Paja, F. Dalpiaz, and P. Giorgini. Managing security requirements conflicts in socio-technical systems. In Ng et al. [44], pages 270–283.

[46] J. Parsons and X. Li. An ontological metamodel of classifiers and its application to conceptual modelling and database design. In C. Parent, K. Schewe, V. C. Storey, and B. Thalheim, editors, *Conceptual Modeling - ER 2007, 26th International Conference on Conceptual Modeling, Auckland, New Zealand, November 5-9, 2007, Proceedings*, volume 4801 of *Lecture Notes in Computer Science*, pages 214–228. Springer, 2007.

[47] O. Pastor. Conceptual modeling meets the human genome. In Q. Li, S. Spaccapietra, E. S. K. Yu, and A. Olivé, editors, *Conceptual Modeling - ER 2008, 27th International Conference on Conceptual Modeling, Barcelona, Spain, October 20-24, 2008. Proceedings*, volume 5231 of *Lecture Notes in Computer Science*, pages 1–11. Springer, 2008.

[48] S. Purao, W. Maass, V. C. Storey, B. J. Jansen, and M. C. Reddy. An integrated conceptual model to incorporate information tasks in workflow models. In Atzeni et al. [3], pages 487–500.

[49] S. Ram and J. Liu. A semantic foundation for provenance management. *J. Data Semantics*, 1(1):11–17, 2012.

[50] S. Ram, K. Zhang, and W. Wei. Linking biological databases semantically for knowledge discovery. In I. Song, M. Piattini, Y. P. Chen, S. Hartmann, F. Grandi, J. Trujillo, A. L. Opdahl, F. Ferri, P. Grifoni, M. C. Caschera, C. Rolland, C. Woo, C. Salinesi, E. Zimányi, C. Claramunt, F. Frasincar, G. Houben, and P. Thiran, editors, *Advances in Conceptual Modeling - Challenges and Opportunities, ER 2008 Workshops CMLSA, ECDM, FP-UML, M2AS, RIGiM, SeCoGIS, WISM, Barcelona Spain, October 20-23, 2008. Proceedings*, volume 5232 of *Lecture Notes in Computer Science*, pages 22–32. Springer, 2008.

[51] O. M. Sangupamba, N. Prat, and I. Comyn-Wattiau. Business intelligence and big data in the cloud: Opportunities for design-science researchers. In M. Indulska and S. Purao, editors, *Advances in Conceptual Modeling - ER 2014 Workshops, ENMO, MoBiD, MReBA, QMMQ, SeCoGIS, WISM, and ER Demos, Atlanta, GA, USA, October 27-29, 2014. Proceedings*, volume 8823 of *Lecture Notes in Computer Science*, pages 75–84. Springer, 2014.

[52] K. Schewe and B. Thalheim. Conceptual modelling of web information systems. *Data & Knowledge Engineering*, 54(2):147–188, 2005.

[53] J. R. Searle. *The Construction of Social Reality*. Free Press, New York, 1995.

[54] M. Senko. Information systems records, relations, sets, entities, and things. *Information Systems*, 1(1):3–13, 1975.

[55] G. G. Shanks, E. Tansley, and R. Weber. Using ontology to validate conceptual models. *Commun. ACM*, 46(10):85–89, 2003.

[56] M. Shaw. Toward higher-level abstractions for software systems. *Data & Knowledge Engineering*, 5:119–128, 1990.

[57] I. Song and E. A. Forbes. Schema conversion rules between EER and NIAM models. In T. J. Teorey, editor, *Proceedings of the 10th International Conference on Entity-Relationship Approach (ER'91), 23-25 October, 1991, San Mateo, California, USA.*, pages 417–444. ER Institute, 1991.

[58] V. C. Storey. Relational database design based on the entity-relationship model. *Data & Knowledge Engineering*, 7:47–83, 1991.

[59] T. Teorey, D. Yang, and J. Fry. A logical design methodology for relational databases using the extended entity-relationship model. *ACM Computing Surveys*, 18(2):197–222, June 1986.

[60] Y. Wand, V. C. Storey, and R. Weber. An ontological analysis of the relationship construct in conceptual modeling. *ACM Trans. Database Syst.*, 24(4):494–528, Dec. 1999.

[61] Y. Wand and R. Weber. An ontological analysis of some fundamental information systems concepts. In *Proceedings of the 9th International Conference on Information Systems, ICIS 1988, Minneapolis, Minnesota, USA, 1988*, page 35. Association for Information Systems, 1988.

[62] Y. Wand and R. Weber. An ontological model of an information system. *IEEE Trans. Software Eng.*, 16(11):1282–1292, 1990.

[63] Y. Wand and R. Weber. On the deep structure of information systems. *Inf. Syst. J.*, 5(3):203–223, 1995.

[64] T. Zäschke, S. Leone, T. Gmünder, and M. C. Norrie. Optimising conceptual data models through profiling in object databases. In Ng et al. [44], pages 284–297.

Vitae

Veda C. Storey is the Tull Professor of Computer Information Systems and Professor of Computer Science at the J. Mack Robinson College of Business, Georgia State University. Her research interests are in conceptual modeling, intelligent information systems, data analytics, and design science. She has published in *MIS Quarterly*, *Information Systems Research*, *ACM Transactions on Data Bases*, *Data & Knowledge Engineering*, and *IEEE Transactions on Knowledge and Data Engineering*. She has served as a guest senior editor for *MIS Quarterly* for special issues in design science research and business intelligence and data analytics. She currently serves on the steering committee of the International Conference on Conceptual Modeling.

Juan C. Trujillo is a Full-Time Professor at the Department of Software and Computing Systems in the University of Alicante (Spain) and the leader of the Lucentia Research Group. His main research topics include Business Intelligence applications, Big Data, Business Intelligence 3.0, data warehouse development, OLAP, data mining, UML, MDA, and data warehouse security and quality. He has also participated in the official registration of different tools related to Data Warehouse modelling. He has advised 11 PhD students and published more than 180 papers in different highly impact conferences such as the ER, UML or CAiSE, and 38 papers in highly ranked international journals (JCR) such as the DKE, DSS, ISOFT, IS, or JDM. He has also been co-editor of nine special issues in different JCR journals (e.g. DKE). He has also been PC member of different events and JCR journals such as ER, CIKM, ICDE, DOLAP, DSS, JDM, or DKE, and PC Chair of DOLAP'05, DAWAK'05–'06, FP-UML'05–'09, MoDIC'12 and ER'13. Currently, he is a Senior Editor of the Decision Support Systems (DSS) Journal (Q1). Further information on his main research publications can be found at `http://www.informatik.uni-trier.de/~ley/db/indices/a-tree/t/Trujillo:Juan.html`. Moreover, Juan C. Trujillo has been Principal Investigator of many Regional and National Research Projects; and Knowledge-Transfer Projects related to Business Intelligence. Finally, Juan C. Trujillo holds the international credential of the Project Management Professional (PMP®) awarded by the prestigious Project Management Institute (PMI).

Stephen W. Liddle is the J. Owen Cherrington Professor of Information Systems and academic director of the Rollins Center for Entrepreneurship and Technology at the Marriott School of Management, Brigham Young University. His research interests include conceptual modeling, model-driven development, mobile computing, and ontology-based information extraction. He has published in *Data & Knowledge Engineering*, *Annals of Operations Research*, *Journal on Data Semantics*, and *Quality Engineering*, along with other respected journals and peer-reviewed conference venues. He currently serves on the editorial board of *Data & Knowledge Engineering* and as chair of the steering committee for the International Conference on Conceptual Modeling.