Available at
www.ElsevierComputerScience.com
POWERED BY SCIENCE DIRECT®

Information Systems 30 (2005) 89–118

www.elsevier.com/locate/infosys

A comprehensive framework for modeling set-based business rules during conceptual database design ☆

Sudha Ram[a], Vijay Khatri[b,*]

[a] Department of MIS, Eller College of Business and Public Administration, University of Arizona, 430 McClelland Hall, Tucson, AZ 85721, USA

[b] IS Department, Kelley School of Business, Indiana University, 1309 East Tenth Street, BU 560, Bloomington, IN 47405-1701, USA

Received 7 November 2002; accepted 27 October 2003

Abstract

Business rules are the basis of any organization. From an information systems perspective, these business rules function as *constraints* on a database helping ensure that the structure and content of the real world—sometimes referred to as *miniworld*—is accurately incorporated into the database. It is important to elicit these rules during the analysis and design stage, since the captured rules are the basis for subsequent development of a *business constraints* repository. We present a taxonomy for set-based business rules, and describe an overarching framework for modeling rules that constrain the cardinality of sets. The proposed framework results in various types constraints, i.e., *attribute*, *class*, *participation*, *projection*, *co-occurrence*, *appearance* and *overlapping*, on a semantic model that supports abstractions like *classification*, *generalization/specialization*, *aggregation* and *association*. We formally define the syntax of our proposed framework in Backus-Naur Form and explicate the semantics using first-order logic. We describe partial ordering in the constraints and define the concept of *metaconstraints*, which can be used for automatic constraint consistency checking during the design stage itself. We demonstrate the practicality of our approach with a case study and show how our approach to modeling business rules seamlessly integrates into existing database design methodology. Via our proposed framework, we show how explicitly capturing data semantics will help bridge the semantic gap between the real world and its representation in an information system.

Keywords: Data semantics; Conceptual modeling; Business rules; Database design

1. Introduction

Business rules are an important asset of any organization [1]: they represent decisions that are made to achieve enterprise objectives [2] and reflect the business policies of an enterprise [3]. While a business policy is a general statement or direction for an organization, a business rule defines or constrains some aspect of a business, asserts business structure and influences the behavior of an enterprise [4]. From an information systems perspective, these business rules function as constraints on a database helping ensure that the structure and content of the real world—sometimes

☆ Recommended by P. Loucopoulos.

*Corresponding author. Tel.: +1-812-855-2581; fax: +1-812-856-3355.

E-mail addresses: ram@bpa.arizona.edu (S. Ram), vkhatri@indiana.edu (V. Khatri).

0306-4379/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/j.is.2003.10.008

referred to as *miniworld*—is incorporated into the database. Business rules need to be captured during the conceptual design stage, as the modeled rules are the basis for subsequent development of a business constraints repository. During conceptual database design, a *conceptual model* provides a notation and formalism that can be used to construct a high-level description of the real world, referred to as a *conceptual schema*. However, extant conceptual models provide limited support for set-based business rules, more specifically, rules that constrain the structure or cardinality of sets. These set-based cardinality requirements specified for an enterprise and enforced on a database are also referred to as *business constraints* in this paper. We present a taxonomy for set-based business rules and describe a framework that is based on various types of conceptual modeling abstractions. We define an overarching framework, which would help elicit set-based cardinality requirements during conceptual design. Further, we explicate the semantics using first-order logic. We show how the proposed framework integrates with extant conceptual design methodology and describe how a formally defined framework can be embedded into an existing design-support environment in a straightforward manner.

The ability of an organization to understand and manage its business rules plays a key role in its operational efficiency and market competitiveness [1]. Eliciting business rules helps organizations understand their own operating environment [5]. From a database perspective, business rules dovetail with relational technology [6] as a database may be considered as a collection of propositions. Many conceptual models have been proposed that capture the meaning and structure of the data. However, most of them [7–10] capture only a limited range of constraint types. In order to overcome these problems, constraint definition languages and constraint enforcement systems have been developed to provide declarative support for expressing constraints [11–14]. However, constraint definition languages are more oriented towards logical database design than conceptual design. Complex constraints expressed in these languages can be hard to understand by users and they may be inadequate for communicating business rules between users and database designers. Prior studies, e.g., [15,16], attribute project failures to the lack of identifying real needs during conceptual design. Moreover, the inability to model business rules may even result in inconsistent enforcement [1]. Initially the business rules captured in information systems may be synchronized with the intended policies; however, the subsequent maintenance may introduce inconsistencies resulting in information systems that constrain the ability of the businesses to change. Therefore, there is a need for a formal approach to comprehensively capture business rules at the conceptual design stage. Direct representation of these rules in a database system can be used to ensure that constraints are uniformly enforced for all users [14]. Additionally, these constraints that are embedded in the database can be used for query optimization techniques [17]. Reasoning on embedded constraints has also been used in fields such as semantic query processing and knowledge discovery in databases. Maintenance—estimated to be around 60–80% of project cost [18]—forms the largest expenditure in a typical information systems project. The explicitly captured business rules can help manage system evolution [19], and enhanced system understanding can help ease the maintenance of information systems. Explicit documentation of business rules results in a better understanding of applications resulting in decreased maintenance and testing costs, increased consistency of business practices within and across applications, and improved administration of business rules [5]. Hence, identifying and embedding business constraints in the schema during conceptual database design has ramifications for creation and maintenance of the database system, and the overall operational efficiency and adaptability of an enterprise to a changing business environment.

Consequently, prior research [2,20–24,27] emphasizes the need for eliciting business rules and the ability to dovetail rules with a constraints repository. Rosca et al. [2] describe many benefits of explicitly modeling business rules during conceptual design: (i) helps analyze the completeness and consistency of the operating principles of an enterprise; (ii) enables top-down analysis of how