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On augmenting database design-support environments to capture the geo-spatio-temporal data semantics ☆

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Abstract

A database design-support environment supports a data analyst in eliciting, articulating, specifying and validating data-related requirements. Extant design-support environments—based on conventional conceptual models—do not adequately support applications that need to organize data based on time (e.g., accounting, portfolio management, personnel management) and/or space (e.g., facility management, transportation, logistics). For geo-spatio-temporal applications, it is left to database designers to discover, design and implement—on an ad-hoc basis—the temporal and geospatial concepts that they need to represent the miniworld. To elicit the geo-spatio-temporal data semantics, we characterize guiding principles for augmenting the conventional conceptual database design approach, present our annotation-based approach, and illustrate how our proposed approach can be instantiated via a proof-of-concept prototype. Via a proof-of-concept database design-support environment, we exemplify our annotation-based approach, and show how segregating "what" from "when/where" via annotations satisfies ontologic- and cognition-based requirements, dovetails with existing database design methodologies, results in upward-compatible conceptual as well as XML schemas, and provides a straightforward mechanism to extend extant design-support environments.
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1. Introduction

A design support environment is a combination of a software tool *and* structured development methodology; the former automates the software process, while the latter defines the process to be

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automated [1]. Prior research shows that design-support environments help reduce time and money spent on a project, and can help improve the quality of the end-product [2] and the effectiveness of software development [3]. However, extant database design-support environments (e.g., ERWin[1], ERStudio[2])—based on conventional conceptual models—do not adequately support applications that need to organize data based on time (e.g., accounting, portfolio management, personnel management) and/or space (e.g., facility management, transportation, logistics). *Conventional conceptual models*, e.g., [4,5], provide a mechanism to elicit data semantics related to "what" is important for an application rather than the "when" and "where" semantics. Underlying the temporal and geospatial (or geographic) applications outlined above are temporal and geospatial data, collectively referred to as *geo-spatio-temporal data*. For geo-spatio-temporal applications, it is left to the database designers to discover, design and implement—on an ad-hoc basis—the temporal and geospatial concepts that they need to represent the "miniworld," or an aspect of the real world [5]. To augment a database design-support environment that would help elicit the data semantics related to space and/or time—at an abstract-level independent of implementation—we characterize guiding principles, propose a geo-spatio-temporal conceptual design approach, and illustrate how the proposed approach can be instantiated via a proof-of-concept prototype.

Via a proof-of-concept design-support environment, we exemplify our geo-spatio-temporal conceptual design approach that advocates: (i) first eliciting requirements using a conventional conceptual model *without considering geospatial or temporal aspects* (i.e., "what"); and only then (ii) annotating the conventional schema to capture the geo-spatio-temporal requirements (i.e., "when/where"). An abstraction provides a mechanism to focus on selective details while deliberately omitting others [6]. Our proposed approach, based on orthogonality of "what" from "when/where," enables a supplementary level of abstraction via annotations. This approach is embodied in the proof-of-concept prototype, a DesIgn-Support environment for geo-SpaTIotemporaL data (DISTIL). Via DISTIL, we illustrate how guiding principles associated with geo-spatio-temporal conceptual modeling can be the basis for the development of a geo-spatio-temporal design-support environment. While our annotation-based approach is consonant with prior research [7–10], we explicate how annotations along with syntactic orthogonality (of "what" from "when/where") can be the basis for: (i) enabling separation of concerns (i.e., "what" from "when/where") for data analysts; (ii) defining an upward compatible geo-spatio-temporal design approach; (iii) development of upward compatible geo-spatio-temporal schemas (both conceptual and XML); and (iv) augmenting extant design-support environments in a straightforward manner. Prior research posits that requirements specification is difficult because of human problem-solving limitations [11] and that problem solvers can effectively handle 7 ± 2 chunks of information [12]. By defining a methodology that segregates "what" from "when/where," we provide an approach that will help ameliorate information overload during elicitation and validation of data-related requirements.

The research reported in this paper integrates and extends previous work by the authors. Previously [13,14], we have abstractly shown the semantics of geo-spatio-temporal annotation grammar. A preliminary version of DISTIL was presented at a conference [15]. In this paper, we discuss guiding principles underlying an annotation-based approach, and illustrate how the proposed approach can be the basis for augmenting an existing database design-support environment; we, thus, demonstrate practical implications of our annotation-based approach. We show how segregating "what" from "when/where" via annotations satisfies cognition-based requirements, dovetails with existing database design methodologies, results in upward-compatible schemas, and provides a straightforward mechanism to extend an extant design-support environment. Via DISTIL, we illustrate how orthogonality (i.e., segregation of "what" from "when/where") and upward

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