The Ontology of Fields as a Foundation for Conceptual Modeling

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1. Extended Abstract

As any discipline matures, its research communities reflect on the epistemological foundations that support their research and discuss how the discipline can, and should, progress. This type of introspection is typically observed in the natural sciences, where researchers question the nature of their fields, the standards of rigor applied, and the impact of their work. As researchers in conceptual modeling, we should continually reflect on, and discuss, the theories and practice of conceptual modeling to ensure its ongoing relevance and consistency with the advancements in information technologies.

Today there are novel advances in the current information technology (IT) landscape that challenge our theories of conceptual modeling. Consider platforms such as Google and TikTok. These and many other modern IT systems exhibit much less defined boundaries between digital and real-world interactions than the traditional standalone systems such as an installed AutoCAD software, or even an ERP system which operated within defined process limits. This boundary-less nature of many systems makes it very difficult to understand, predict and control where their influence starts and ends. These systems often extend beyond their primary functions – search and social media - into areas such as advertising, e-commerce, and artificial intelligence, creating interconnected ecosystems. These platforms are also integrated with in-house and third-party applications and websites, blurring the lines of their operational scope. For example, Google has integrated search into another one of its platforms known as Google Home (devices and services for a smart home). Similarly, TikTok relies on CapCut, an external video editing app to ensure their videos have state of the art effects. Last, these platforms user bases span global demographics, connecting with various cultural, social, and economic spheres, complicating the identification of distinct boundaries. Accurately modeling these systems and shaping the progression of their designs and impact are becoming increasingly complex and difficult.

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Conceptual modeling scholarship has traditionally built its theoretical foundations from ontology, a branch of philosophy [6, 17]. This includes a rich tradition of developing their own ontologies and adopting and enhancing existing ontologies from other fields [6, 8, 18]. Two ontologies developed by the conceptual modeling community include DOLCE [4] and The Unified Foundational Ontology [7]. Prominent ontologies that have been imported and shaped conceptual modeling include Bunge [2] and Searle [14]. However, none of these ontologies has offered us a solution or way forward handle the landscape of IT described above.

Traditionally, conceptual modeling has followed the ontology of individual substances, which suggests reality consists of independent substances, often described as objects, entities, individuals, or things [1, 2, 9]. These substances possess properties or attributes and experience changes, leading to events and processes. This perspective is best represented by Bunge's ontology, which asserts that the world is composed of "things" that are substantial individuals [2]. However, this perspective may limit our ability to model and capture nuances represented in our world.

To continue aligning conceptual modeling with modern IT landscape, we consider an alternative ontology. Although the traditional ontology of individual substances is useful in many situations, it may encounter limitations when dealing with today's IT. Notably, a similar challenge has been identified in philosophy and the natural sciences. For example, advances in physics led to the assertion that "there are no particles, only fields" [10:211; emphasis added]. This conclusion was reached based on the accumulation of evidence from various scientific disciplines.

One novel direction for conceptual modeling would be to consider an *ontology of fields.* While this ontology has been recognized in modern philosophy [13], it has not found its footing in conceptual modeling yet. In consideration of this potential opportunity, we describe aspects of the *ontology of fields* in order to consider it as a new foundational basis for conceptual modeling.

A unique aspect of the ontology of fields is the notion of a *field.* The concept of a *field* is central in both modern science and philosophy, offering a valuable model for understanding reality. A field is defined as any physical or conceptual entity that displays varying values across space and time, driven by the oscillations that form and maintain these fields. By embracing the scientific notion of a field, we can conceptualize a wide range of aspects of existence.

Fields provide powerful flexibility during analysis. Fields can be analyzed by studying properties at specific points within them, and also considered more broadly as an entity with global or even emergent properties in and of itself. For instance, a particular point in the sky modeled as a field might have attributes like its chemical composition (e.g., concentration of oxygen or helium molecules). However, when considered collectively, other properties of interest emerge such as air temperature and humidity. These properties might also be considered compared to other points in the sky. That is fields have multiple properties which can be represented in a hyperplane -- a conceptual space with numerous dimensions reflecting different types of properties. Variations in these properties appear as patterns, such as peaks, plateaus, and valleys, where peaks typically signify areas with high concentrations of mass, energy, or charge. Further, these latter properties of the sky can be considered against another field such as a mountain. By integrating the concept of fields from physics and geography, the ontology of fields provides new perspectives for conceptual modeling which we consider next.

First, if conceptual modeling were to include the ontology of fields, we would now have a conceptual basis to consider different levels of abstractions for modeling that are layered together. Some conceptual models, such as data flow diagrams [15], already provide this mechanism, albeit absent of any theoretical basis. Similarly, use cases often encourage modeling as cloud, kite, sea, fish, and clam levels. Further, different types of conceptual models now have a basis from which to be explored as multiple models are often used in practice [3]. This idea of abstraction also has efficacy for data analytics. As data is pooled together, we now have a mechanism for how its levels or layers of abstraction might impact the results of prediction models.

Second, the notion of shifting modeling perspectives from individual objects to fields, may result in new conceptual modeling constructs. It could be that some properties depicted in conceptual models are only relevant as we move from the individual object focus to the focus on fields. Similarly, when one considers conceptual models at the level of the objects themselves, properties about fields may become less pertinent. Finding the right level of abstraction to present a conceptual model is still an open debate in the field. However, one approach might be to consider field properties for conceptual models that can be represented in the abstraction of individual objects much like, for example, a derived attribute in an entity relationship (ER) diagram. Another example of emergent properties found in conceptual models is the idea of attributes on relationships in the ER diagram. While some research has proscribed this on the basis of lack of ontological clarity [5], with the ontology of fields we can now permit emergent properties, such as attributes on ER diagram relationship constructs, as they would be ontological clear with respect to the ontology of fields.

Third, novel conceptual modeling approaches can be undertaken with the ontology of fields. From a cognitive perspective, it has long been recognized there different classification theories can be used to create conceptual models [12]. One work, initiated by Lakoff [11], indicates how humans can classify things in seemingly non-intuitive ways. From a conceptual modeling perspective, similar objects have traditionally been modeled together. However, with the ontology of fields, we open up an entirely new possibility. For example, in ER diagrams, entities that have different properties can be collectively modeled together in the same entity type when we use the ontology of fields. Just as different individual objects can be contained in a field, now there is not a push to maintain uniformity in entities of entity types of the ER diagram. Indeed, novel conceptual modeling approaches are starting to emerge that recognize the power of this flexibility [12]. In practice, we are observing more heterogeneity and flexibility of data collected and collocated in NoSQL and data lake data storage technologies.

Fourth, it is recognized that fields can change over time. At one minute, a mountain might exist. However, after a sudden and violent earthquake occurs, that very mountain might be leveled to rubble. Unfortunately, conceptual models themselves have remained somewhat static and stagnant after their creation, often leaving those who consult them wonder if they are current [19]. The ontology of fields explicitly encourages conceptual modeling to consider how some aspects of a model might change over time. As the pace of IT and systems are changing at unprecedented rates, we need a better way to model dynamic and complex systems. This includes, as we described earlier, how to integrate platforms together with ill-defined boundaries, even as the services offered in the platform might continue to evolve and change themselves. This goes beyond just modeling of the architecture of the systems, but instead the data that might be collected through the use of various platforms.

We are excited to continue to explore how the ontology of fields can lead to new ways of thinking about and designing conceptual models and their subsequent systems. The ontology of fields introduces new vocabulary and conceptual tools that correspond with modern IT. We also posit that both current and emerging technologies will benefit from the ontology of fields, as it offers a comprehensive understanding of dynamics and interactions. We intend the ontology of fields to supplement the existing ontologies while opening up new exciting possibilities and approaches to conceptual modeling [16].

Applying field theory to conceptual modeling encourages a holistic view, considering the entire ecosystem of interactions and dynamics rather than primarily isolated components. Modeling fields with characteristics such as peaks (analogous to mountains) and valleys could help us better represent and understand the dynamic nature of IT today. As many modern applications are inherently field-like, with ill-defined boundaries, viewing these IT through the lens of a field ontology acknowledges their interconnected nature. The ontology of fields is intended to additionally address the need for flexible representations.

Although still in its early development stages, the ontology of fields could potentially become a foundation for significant conceptual modeling research. Future research will need to expand and apply the ontology of fields to demonstrate its feasibility and effectiveness.

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