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ABSTRACT

The 3D-Conceptual Domain Model is a conceptual prototype that structures research problems associated with architectural and interior design into simpler yet systematized components. This theoretical model practices decomposition and classification theories by organizing and breaking down knowledge via categories and classifications. These theories, originally used in mathematics and business research, are implemented into the research of developing built environments. The profession of architecture and interior design can practice this conceptual model based on three system levels; human, building and architectural. For example, the human level system is initially measured by the user to determine the criteria of research based on the given scenario. The response to the human level system is a set of architectural and built options. This study, termed the 3D-Conceptual Domain Model, is intended for the user in the domain of architecture and interior design to evolve his/her methods of research.

Keywords: *knowledge model, 3D domain model, human level system, building level system, architectural level system, system approach*

Introduction

Models are one of the most fundamental tools used to solve problems in architectural research. A knowledge model is an abstract, simplified version of the real world. Models are created to easily understand, perceive, and contextualize problems; subsequently, helping to better solve them. Indeed, "a model for a scientist is a way in which human thought processes can be amplified (Churchman, Whitton, Claridge, & Theng, 1984). A model assists architects in translating thoughts into an image of reality. The complexity of the model depends on the objectives, goals, and processes being deployed. Models represent and are able to manipulate various factors more easily and quickly than if one was working with a true-to-life object. Models are classified based on the disciplines in which they are used, such as management and business, artificial intelligence, and environmental science. These models are mostly associated with various design methods since their aim is to "articulate" the methodology.

Modeling is the schematic representation of an information system. According to Mylopoulos, "knowledge modeling is the activity of formally describing some aspects of the physical and social world around us for purposes of understanding and communication" (Kalampokis, Tambouris, & Tarabanis, 2008). A knowledge model itemizes the options and criteria in a way that allows each one to be studied individually.

Materials and Methods

Traditionally the design of interior spaces happens through practice, embracing 'evidence based design' approaches. These approaches are based on other disciplines (sociology, psychology, environments) and formulating the design in a case-specific formula. 'Evidence-based design' formed the majority of efforts in research related to architectural design (Foqué, 2011). However, descriptive knowledge of a status quo is not sufficient to support design 68 decisions that target the future conditions of buildings. There is a need to develop more knowledge when designing for new states of buildings and on how to assess them. Furthermore, more recently (late 20th century) there has been a need to generate knowledge that goes beyond the support of case-specific design through the work of Christopher Alexander (A Pattern Language) and Constance Perin (With Man Wind). Designers in practice often find it difficult to translate 'evidence' from other disciplines into practical application, especially when knowledge is very abstract (Eliasson, 2000; Vos et al., 2008). Additionally, time constraints or simply the nature of assignments can make it hard for design professionals to find relevant evidence that can inform their designs.

The deductive solving approach is based on the conditions facilitating achieve research objective. It starts from existing knowledge and leads to new knowledge, or an additional provision to meet the objective (Wilson, 2014).

Interrogating the objective in the early stages of the design process is the goal of the systems approach. The systems approach is a step-by-step procedure that allows the designer to identify the needs and criteria leading to the generation of the optimal solution to any given problem.

Physical and Conceptual Models

Models can be divided into Physical and Conceptual characteristics. Physical models look like an object, such as building prototypes and photographs, and are a trend in architecture and interior design. These models can be analogous where a group of components represent a certain object (e.g. set of lines representing a map). On the other hand, conceptual models are those which frame the object in an abstract way using language or symbols, numbers (Moshaver, 2021). Conceptual concepts that present the relationships in descriptive and numerical terms are used to present the order, relationship, and sequence of the systems.

Domain Knowledge Models (DKM): A Type of Conceptual Model

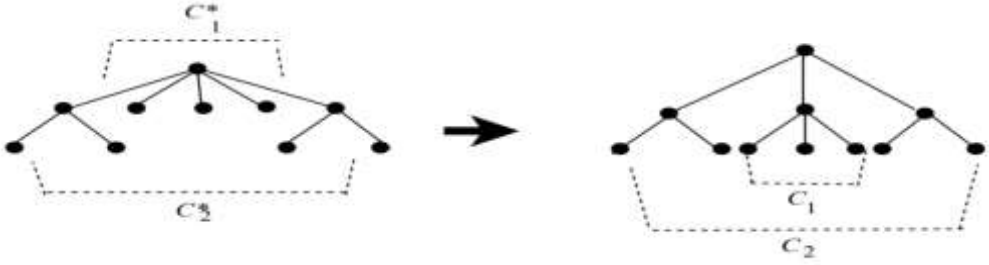
Domain knowledge models are a type of conceptual model used to simplify and highlight important concepts and discover links between related information regarding a specific field of study. They are constructed through the use of concept mapping, which is a two-dimensional model that represents the relationships between concepts by pairing related theories (Leake et al., 2003). It allows for the sharing of knowledge in a manner that is easy to understand. These models are used to abstract a concept in order to change how the users think about it (Thalheim, 2011).

Classification Theory: In his article, "Classification Theory and the Number of Non-Isomorphic Models", Brad Hart notes that:

> "The goal of classification theory is to discover lines between classes that have structure theory and those that do not. The results of classification theory for a particular class can be variously viewed as evidence for or against the existence of a structure theory for that class. A secondary issue in classification theory is the selection of the classes to examine" (Hart, 1993, p.43)

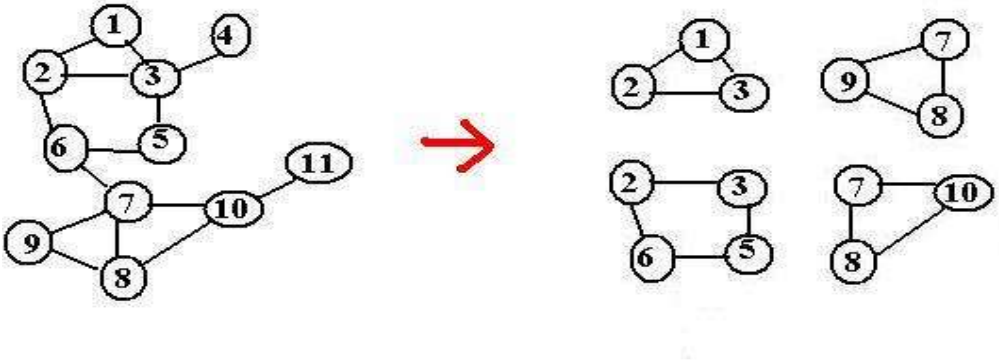
Figure 1 shows the application of classification theory in the mathematical theory of graphs. Such an approach can be taken with respect to building criteria and components. For instance, the classification of building systems as it pertains to structure, envelope, services, partitions, and equipment was inspired by the classification theory, where building components are grouped into distinct categories based on their role (Moshaver, 2013).

Figure 1. *Mathematical Theory of Graph Classification (Mirkin, 2013)*



Decomposition Theory: This theory shows that every component of a system can be decomposed into smaller organized arrangements, which can then be studied. The aim of decomposition theory is to present complex structures as simpler components (Figure 2). The simpler components achieved can be translated into the form (Bratteli & Robinson, 2012).

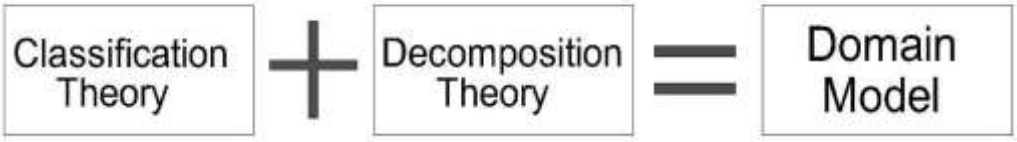
Figure 2. *Example of graph decomposition theory (Gusfield, Bansal, Bafna, & Song, 2007)*



Decomposition theory is used to break down building systems into manageable building elements. For example, a structured system can be broken down into the following building fundaments: post, beam, slab, foundation, etc. Each building element can be modified/designed separately within the framework of its system.

In the 1980s, decomposition and classification theory were used to generate mathematical knowledge models. Later, these theories inspired design and business knowledge models and eventually were used in other disciplines. The combination of classification theory and decomposition theory creates the foundation of domain models widely used in design research (Figure 3) (which will be explained in the next section) (Moshaver & Mehdizadeh, 2014).

Figure 3. *Creation of Domain Model*

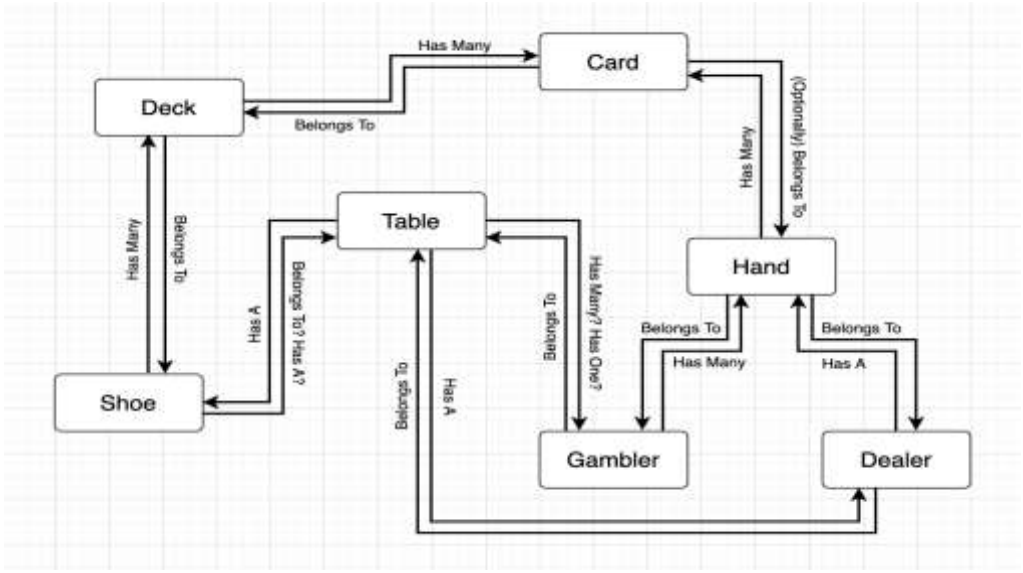


In their article "The Core of Domain Model", Oosterm describes the domain model as such:

> "a type of conceptual model that incorporates representations of behaviour and data at the same time. It includes the various entities, their attributes and relationships, plus the constraints governing the conceptual integrity of the structural model elements comprising that problem domain." (van Oosterom et al., 2006, p.653)

A domain model Blackjack mapping is where the relationship between different entities are defined. Such a model consists of first building the entities (objects and stakeholders) such as a deck, card, table, dealer, and gambler; and lastly, creating the relationship between the entities, such as "has a", "has many", and "belongs to". Based on the entities and relations between them, the following domain model can be deduced (Figure 4).

Figure 4. *Domain Modeling of Blackjack Game Based on Stakeholder and Objects (Schiller & Gobet, 2012)*



Results: 3D- Domain Knowledge Model for Interior and Architectural Research Problems

A 3D domain model is a type of domain model incorporating several

conceptual views, where each view is pertinent to a particular subject area of the domain or to a subset of the domain model that is of interest to a stakeholder (Moshaver, 2019). It often represents database entities, using simple diagramming techniques to illustrate one-to-one, one-to-many, and many-to-many relationships within the system (Al-Kamha, Embley, & Liddle, 2008).

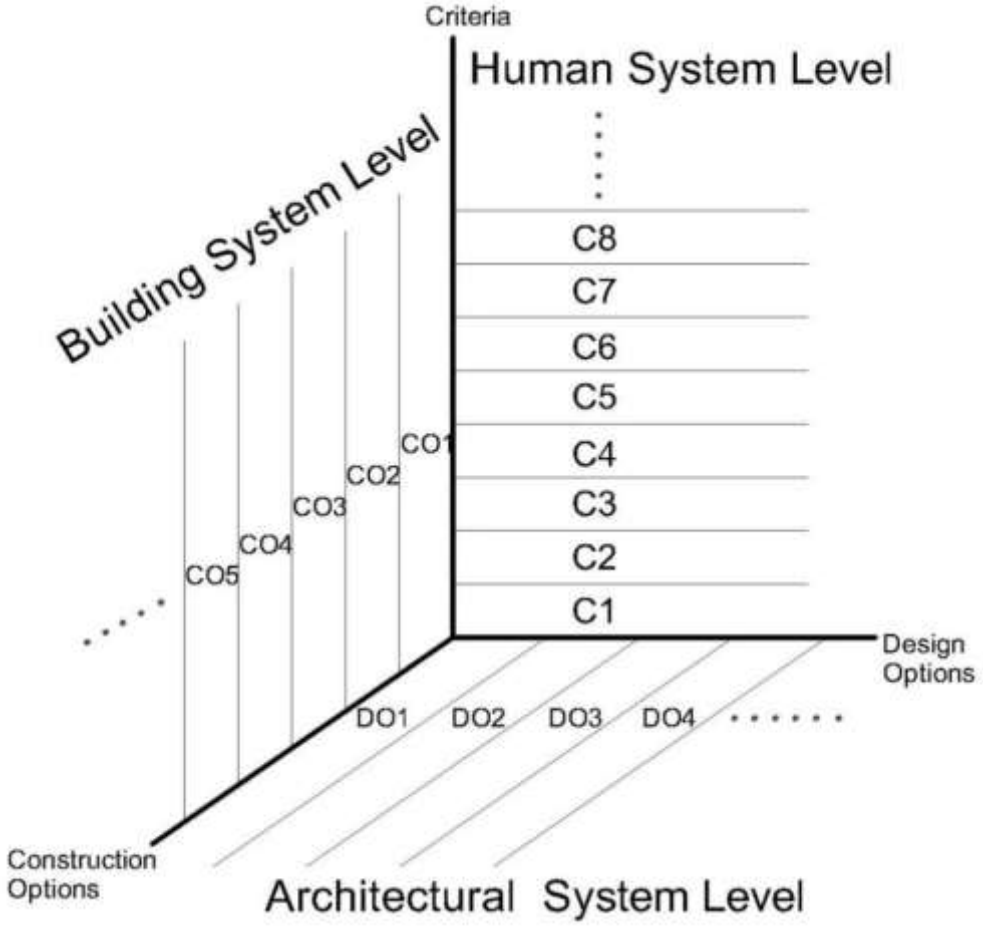
The type of conceptual domain model that can be used for architectural and interior design research problems is the 3D Domain model. In their book, *Enhancing Building Performance*, Malory-Hill, Preiser, and Watson (2012) propose a domain model to visualize the complexity of performance measures in designing a floor plan (Mallory-Hill, Preiser, & Watson, 2012). The model contains three levels:

1) Human levels
2) Building levels
3) Architectural levels

In this domain model, the human-level is associated with the criteria of the user, such as soundproofing or spatial comfort. The building level is associated with construction options such as STC value, R-value, etc. The architectural level is associated with the design options such as window design and passive ventilation solutions. The building system level are those that quantitatively measure the success of an option, whereas architectural system level must be qualitatively assessed based on the literature and expert judgements (Steskens & Loomans, 2010). For example, visual privacy is an architectural system level, as it can be accommodated by floor plan design. By contrast, soundproofing is a building system level measuring the noise level between two dwelling units.

The model employs the systems approach to show increasing scalar dimensions and combinations of human–environment interactions at various performance levels. The aim is to break problems and solutions into a manageable number of items (Figure 5).

Figure 5. *3D Domain Model. Criteria (C), Construction Options (CO), and Architectural Options (DO)*



The 3D domain model, which interconnects all the above levels, will allow different design and construction options to respond to one criterion. For example, requiring certain lighting levels in the kitchen (human level) can be provided through architectural and construction choices. An architectural option may provide natural light through windows and a construction option may provide artificial lighting.

Discussion and Conclusion

Implementation of Conceptual models into research problems has been significantly employed in business and cybernetics; yet, such concepts can be used in built environment research. The domain model is a type of conceptual model that has been used in cybernetics and computer science; however, this paper explains how it can be used in architecture and interior design research problems. Such a model can help designers connect the human needs to design and construction needs. This conceptual model can be translated to the physical

model (e.g., a floor plan) or cladding design. In a situation where the researcher/ designer implements different solutions, such a model can help organize the options in response to the needs. The designer can further find the best option or prioritize one option for another.

The deduced model can be expanded in other areas of the built environment such as urban planning and landscape. Furthermore, such a model can be modified to be used by other stakeholders for example the user in the context of housing. In addition, the deduced 3D domain model can be expanded parametrically with Grasshopper and Dynamo creating a parametric 3D domain model.

The intuitive aspect of architectural and interior design researches lead us needing conceptual models which differ from the conceptual models in science and engineering (which are mainly quantitative). In these models, the creativity of designer/researcher comes to account in a way that the model would have both the intuitive and analytical aspects. Such an approach is used in RtD (Research through Design) methodology, which would be subject of future research papers.

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