Chapter 14
Morphological Ontology Design Engineering:
A Methodology to Model Ill-Structured Problems

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ABSTRACT

In the Social-technical domain scientists are often confronted with a class of problems that are termed messy, ill-structured or wicked. These problems address complex issues that not well-defined, contain unresolvable uncertainties, and are characterized by a lack of common agreement on problem definition. This chapter proposes a new mixed methods research technique, Morphological Ontology Design Engineering (MODE), which can be applied to develop models for ill-structured problems. MODE combines three different research methodologies into a single, methodology. MODE draws from research paradigms that include exploratory and descriptive research approaches to develop models. General morphological analysis offers a systematic method to extract meaningful information from domain experts, while ontology based representation is used to logically represent domain knowledge. The design science methodology guides the entire process. MODE is applied to a case study where an ontological model is developed to support the implementation of a South African national cybersecurity policy.

INTRODUCTION

The purpose of this chapter is to show how the sum of various research methodologies can be combined to provide a more powerful mixed methods research methodology (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) to model ill-structured problems. An ill-structured problem is characterised by a high degree of uncertainty and conflicts about values. This research methodology focuses on understanding the messiness of real world problems resulting in the development of constructs, models, methods or instantiations. Fritz Zwicky, the father of General Morphological Analysis (GMA) stated that "... within the final and true world image everything is related to everything, and nothing can be discarded a priori as being unimportant" (Ritchey, 1998).

The proposed hybrid methodology, referred to as Morphological Ontology Design Engineering (MODE), will combine two qualitative research techniques (design science and general morphological analysis) with a quantitative methodology (ontology based representation) to present a holistic artefact. MODE draws on the strengths of different research paradigms and is used to develop models for difficult domains. Domains are areas of expertise that can be used to create models. Domain knowledge in this chapter refers to knowledge of specialists or focus groups in an area of human endeavour or a specialised discipline. These models capture and represent domain knowledge, and support the development of solutions to problems areas in the domain. The authors apply the MODE methodology to the cybersecurity environment to develop a multi-layered, multi-dimensional domain model. Ontologies are used to present knowledge in such a way that computers can interpret and do some reasoning with this knowledge. An ontology normally consists of a set of entities and relations that describes a particular knowledge domain.

On a high level, the design science methodology guides the entire MODE process. This methodology involves a series of approaches with the intent of producing new theories, artefacts, and practices (Peffers, et al, 2007). Constructs conceptually describe the problem and solution domain and can be refined throughout the design cycle. Models describe the relationships among the constructs of the artefact, and therefore can be regarded as the problem and solution statements. Methods provide an algorithm or guideline on how to perform a task in solving a particular problem. Instantiations are the technical implementation of a construct, model and method within the operational environment.

The extraction of information from subject experts is a challenge that is addressed in MODE via a variation of the classic GMA method developed by Fritz Zwicky (Ritchey, 1998). GMA is a facilitated process where subject experts work together to collect and classify domain information. In order to represent the extracted knowledge in a meaningful format for the design of an artefact, an ontology is developed. An ontology is a semantic technology that enables a rich representation of domain knowledge. It provides a formal, encoded description of domain knowledge: all the entities, their attributes and their inter-relationships are represented. The output of the MODE methodology is a single shareable model of the environment (developed from the ontology component), agreed-upon by subject experts (developed from the GMA component).

MODE can be applied by any researcher to solve problems in a multi-layered, multi-dimensional problem space where there are uncertainties. The focus of this mixed methods methodology is to model problems that are ill-defined and difficult to model with normal qualitative and quantitative techniques. The uniqueness of MODE lies in the physical model derived from qualitative information that is presented in a quantitative methodology. The research team requires the inclusion of a GMA facilitator and an ontology engineer in the research team. In small research projects, this role can be done by one

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