PROJECT REPORT

Technische Universität Berlin
Department of Civil Systems Engineering
Modeling Engineering Products

Ontological Modeling

Individual Assignment I

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INTRODUCTION

Today, Ontological Modeling has emerged as a transformative force in the dynamic landscape of civil engineering, revolutionizing the concept and representation of complex systems. The construction process is driven by information[1]. In the past, construction workflows (CWs) information was primarily acquired using manual methods, which tend to be expensive, inefficient, inaccurate, and subject to delay[23].

A project's design steps, as well as its components and their relationships, can provide very valuable information before design, during construction, and even after finishing the civil system for maintenance purposes, such as inspection processes, life cycle analyses, and so on.

In Civil System Engineering, Ontological Modeling is emerging as a vital methodology for representing knowledge in a structured and semantic manner. The term "ontology" originated from philosophy and refers to the study of existence. In the computer science domain[4]. Gruber defines ontology as the "explicit formal specification of a conceptualization."

This assignment is an introduction to an ontology modeling tool called protege. Since protege provides graph visualization, it allows you to browse through components of a civil system and their relationships. This allows to identify and understand complex patterns, identify potential areas of improvement, and make informed decisions. Additionally, it allows users to easily share their findings with others.

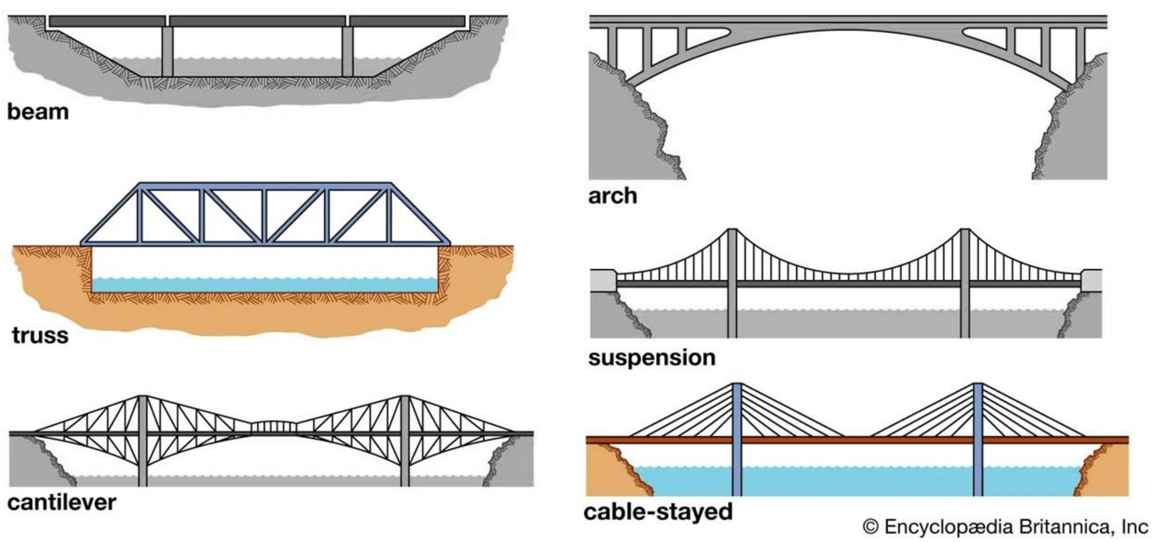
The purpose of this assignment report is to examine the theoretical underpinnings and practical applications of ontological modeling, with a particular emphasis on its implementation in steel bridge design and engineering.

referring to of Noy and McGuinness, some of the reasons of develop an ontology are:

• To share common understanding of the structure of information among people or software agents.
• To enable reuse of domain knowledge.
• To make domain assumptions explicit.
• To separate domain knowledge from the operational knowledge.
• To analyze domain knowledge.

An exhaustive examination of the technical intricacies of steel bridges was conducted in this phase of the study. To uncover the nuanced aspects of steel bridge systems, extensive research was conducted, ranging from the rich collection at the TU Berlin library to diverse online repositories. This investigation focused on comprehensively identifying the principal functions and components integral to these structures, with an emphasis on unraveling their physical, functional, and logical dimensions. As a result of this preliminary phase, a visually informative system sketch was produced, accompanied by a meticulously traced reference list for transparency and credibility.

A fundamental concept crucial to the conceptual design of steel bridges drove the subsequent development of the ontology. This ontological model aims to capture the intricate interplay between structural elements, materials, and functionalities that are characteristic of steel bridge engineering. Its primary objective is to provide robust support for knowledge representation, particularly in the realm of parametric modeling. By doing so, the ontology functions as a valuable tool, helping designers and engineers to analyze and conceptualize steel bridge structures. The synthesis of technical insights, visual representation, and ontological modeling lays the foundation for a holistic understanding of steel bridges, demonstrating the symbiotic relationship between comprehensive research and innovative

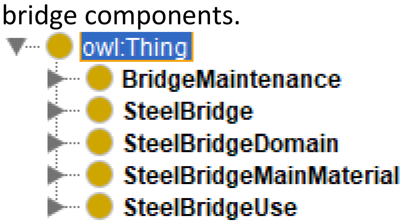


knowledge representation in the field of civil system engineering. In addition to the foundational elements of the ontology developed for steel bridge conceptual design, two distinct design options were incorporated. The first design option depicts a Cable Steel Bridge, highlighting the specificities associated with this structural approach. Cable-supported elements are nuancedly portrayed, emphasizing their unique role and characteristics within the broader context of steel bridges.

A contrasting yet equally vital design option is the Truss Steel Bridge. In this design choice, truss components are intertwined, highlighting their distinct structural features and functionalities. The model becomes more versatile by including this option, accommodating the diverse design considerations civil engineers may encounter when conceptualizing steel bridges.

Ontological Modeling Journey with Protégé: Where Logic Meets Engineering

The heart of the report lies in the ontological modeling process within Protégé. In accordance with the methodological insights of Krötzsch et al. and tutorial, the chosen system-the steel bridge-was meticulously decomposed.
SteelBridge, SteelBridgeDomain, SteelBridgeMainMaterial, BridgeMaintenance, and SteelBridgeUse have been introduced as classes, creating a logical hierarchy that reflects the complexity of these models. The hierarchy makes it easier to access information quickly, as well as keep track of changes to bridge components.



In order to provide a concise overview of the applications of the logical axioms used during the modelling process, the axioms were systematically summarized here:

1. SteelBridge:
A Steel Bridge is defined by having either BridgeOption1 or BridgeOption2 as its design.

2. SteelBridgeDomain:
The structural domain of a Steel Bridge is specified by having components like AbutmentSubstructure, FoundationSubstructure, PierSubstructure, CablesSuperstructure, DeckSuperstructure, PrimaryMemberSuperstructure, SecondaryMembersSuperstructure, and TrussSuperstructure.

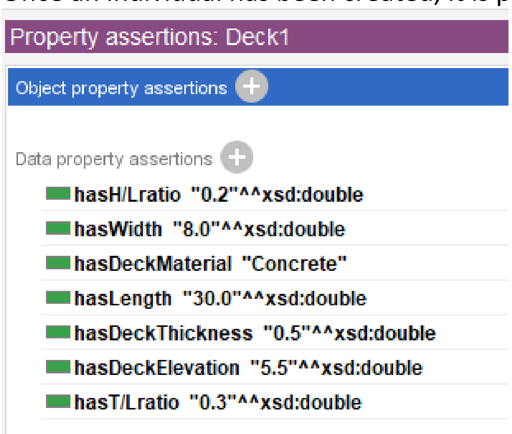
3. SteelBridgeMainMaterial:
The main material of a Steel Bridge can be Concrete, HighStrengthSteel, StainlessSteel, or WeatheringSteel.

4. BridgeMaintenance:
Bridge Maintenance is characterized by having a lifespan (expressed as an integer), a repair protocol (specified by RepairProtocol), and a requirement for regular inspection (RegularInspection).

5. SteelBridgeUse:
The use of a Steel Bridge can be classified as AutoUse, PedestrianUse, RailwayUse, or TransportUse.

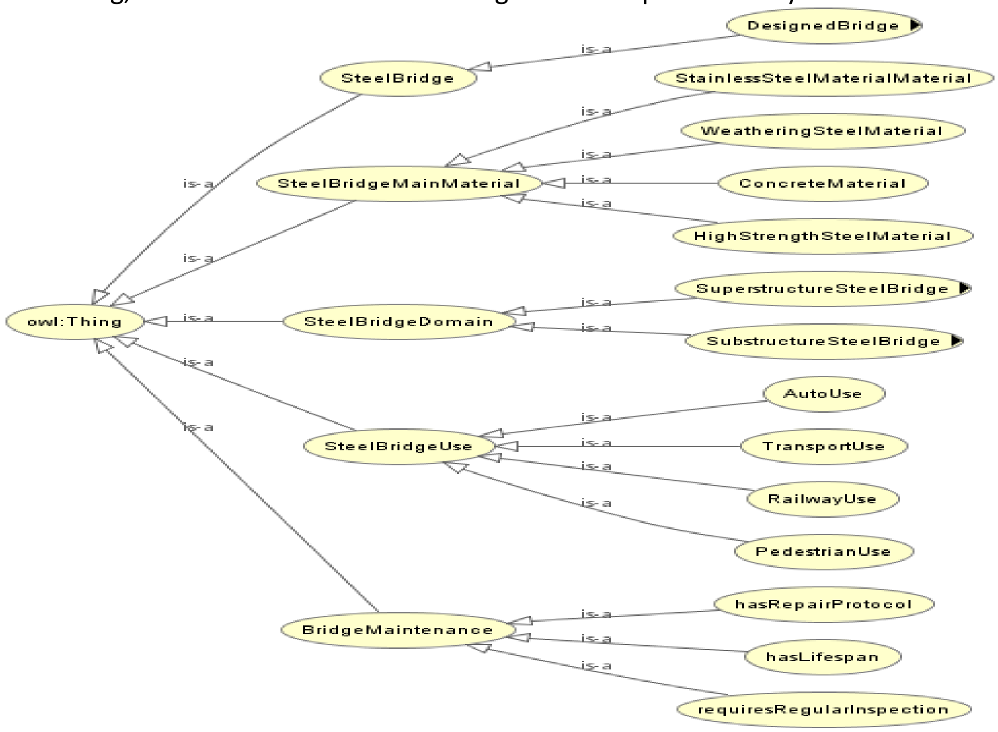
after establishment of hierarchies the next step was specification of object properties.
I decided to have two design option. One for truss steel bridge and one for cable steel bridge.
next step is Creation of individuals and defining the data properties. The creation of individuals and defining data properties in Protégé occurs through the instantiation of specific objects (individuals) within our ontology and their association with specific data values. As a result of this step, real-world entities and their characteristics can be represented in a structured and machine-readable manner.

Once an individual has been created, it is possible to define data properties for that individual.



The creation of individuals and the definition of data properties essentially populates the ontology with specific instances and attribute values, thus making it a representation of concrete entities and their characteristics. Ontologies with structured representations facilitate automated reasoning and analysis, enabling them to be applied to a variety of applications, including parametric modelling and structural analysis of steel bridges.
The graph below shows the OWLViz graph. This diagram provides a visual representation of the intricate relationships and dependencies between the various components of my ontology. Ontology developers, domain experts, and other stakeholders can benefit from this high-level overview. using this graph while

modelling, I was able to find some missing relationships and fix my model.



Competence Questions: Unveiling the Essence of Ontology Development

An ontology development specifically designed for Cable and Truss Steel Bridges is dissected through the lens of competence questions, providing an overview of the purpose, scope, intended users, and intended use of each design:

Is there a purpose to what we are doing?

In the Cable Steel Bridge design, the ontology accurately represents the intricate structural, material, and functional characteristics of cable-supported structures. As an example, it details the CablesSuperstructure, which is responsible for supporting the bridge, and DeckSuperstructure, which is responsible for detailing the surface of the bridge. Alternatively, in the Truss Steel Bridge design, the ontology captures precisely the complexities of truss-supported structures, including entities such as TrussSuperstructure and PrimaryMemberSuperstructure, highlighting their vital roles in maintaining the bridge's integrity.

In what sense is the project scope defined?

The scope of the ontology for Cable Steel Bridges extends from the foundational components, such as AbutmentSubstructure and FoundationSubstructure, to the superstructural elements, such as CablesSuperstructure and DeckSuperstructure. It provides an understanding of how these components interact in order to form a cohesive and functional bridge system. As part of the Truss Steel Bridges ontology, it covers substructures such as AbutmentSubstructures and PierSubstructures, as well as superstructures such as TrussSuperstructures and SecondaryMembersSuperstructures, providing a holistic view of the bridge's structure.

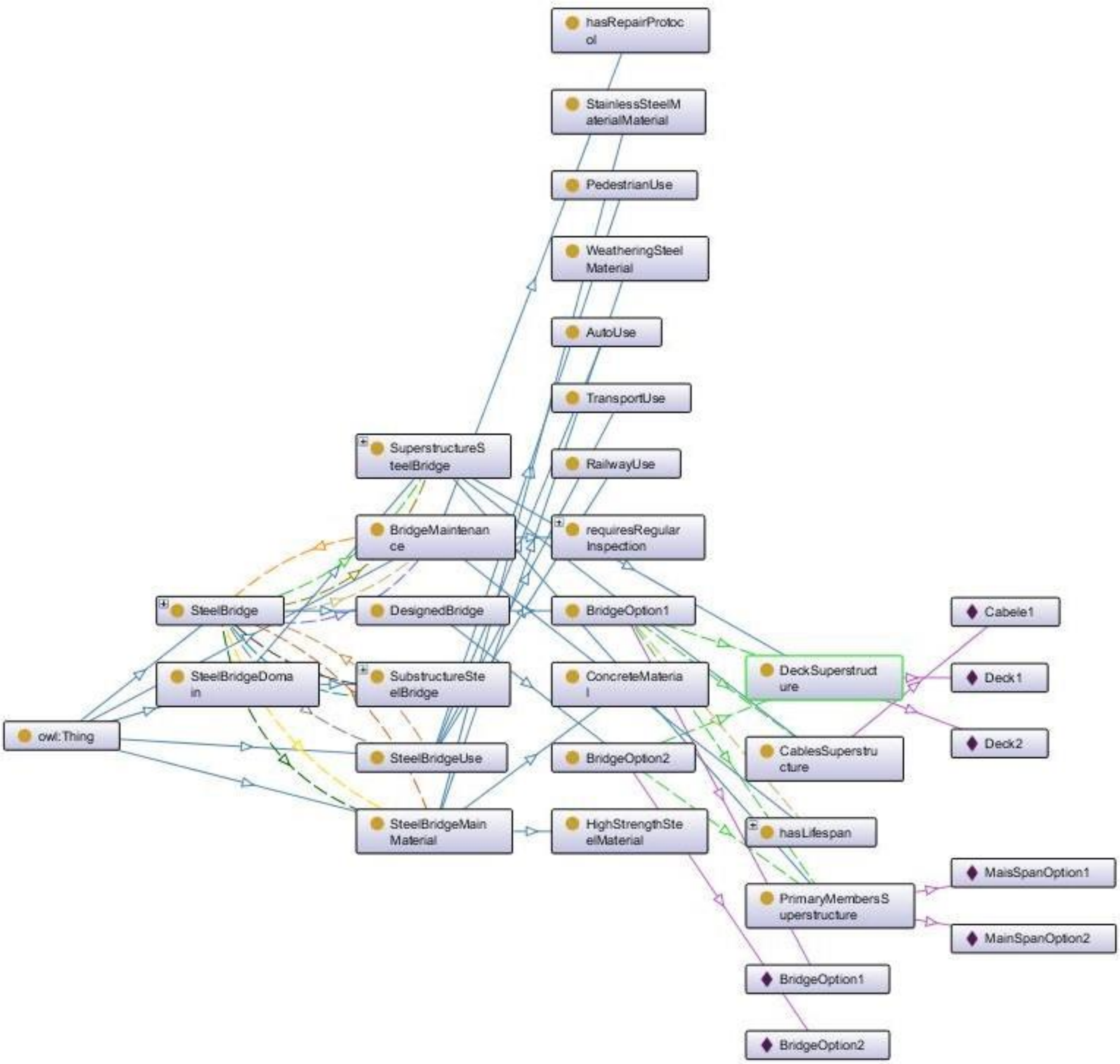
In designing and developing Cable and Truss Steel Bridges, the ontology becomes an indispensable companion. With the help of the ontology, designers are able to collaboratively navigate the complex decisions involved in the design of these specialized structures. Whether it is a civil engineer assessing the load-bearing capacity of TrussSuperstructure members or an architect visualizing CablesSuperstructure's aesthetic integration, the ontology caters to a wide range of professionals involved in the design and construction of bridges.

An ontology in Protégé serves as a decision-support tool for cable and truss steel bridges during the conceptual design phase. Using it, designers and engineers are able to make informed decisions, ensuring the structural integrity and functional efficiency of the bridges. For instance, in the Cable Steel Bridge design, the ontology might assist in optimizing the placement of cables for maximum support, while in the Truss Steel Bridge design, it might assist in selecting the appropriate materials for PrimaryMemberSuperstructures to withstand specific loads.

With Protégé, ontologies become more than a repository of knowledge - they become intelligent guides, allowing professionals to navigate the complexities of Cable and Truss Steel Bridge conceptualization with precision and clarity. The ontology enhances the decision-making process in the field of bridge engineering by providing a structured and detailed representation of these designs.

CONCLUSION

To summarize, this report has explored the complex landscape of ontological modeling as applied to steel bridges in civil engineering. From the foundational insights gained through background research to the logical precision instilled into the ontological model within Protégé, to the practical engineering examples, the journey underscores the crucial role of ontological modeling in enhancing the conceptualization and design of complex civil engineering systems. This ontological model is a potent tool in the toolbox of civil engineers due to its clarity in presentation, fidelity to logical principles, and tangible applications demonstrated in the engineering examples.



REFERENCE

[1] A shared ontology suite for digital construction workflow, [Journal] / auth. Yuan Zheng Seppo Törmä, Olli Seppänen // Automation in Construction,Volume 132. - 2021. - p. 20.

[2] R. Sacks, R. Navon, I. Brodetskaia, A. Shapira. Feasibility of automated monitoring of lifting equipment in support of project control J. Constr. Eng. Manag., 131 (2005), pp. 604-614,

[3] R. Kärkkäinen, R. Lavikka, O. Seppänen, A. Peltokorpi
Situation picture through construction information management
10th Nordic Conference on Construction Economics and Organization, Tallinn, Estonia (2019), pp. 155-161,

[4] T.R. Gruber
Toward principles for the design of ontologies used for knowledge sharing
Int. J. Human-Comp. Stud., 43 (1995), pp. 907-928,

[5] T. Froese
Models of construction process information
J. Comput. Civ. Eng., 10 (1996), pp. 183-193,

[6] C. Lima, T. El-Diraby, J. Stephens
Ontology-based optimisation of knowledge management in e-construction
J. Inform. Technol. Construct., 10 (2005), pp. 305-327