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LOGISTICS OPTIMIZATION USING ONTOLOGIES

Hayder I. Hendi, Adeel Ahmad, Mourad Bouneffa, and Cyril Fonlupt ^{*†}

Abstract. Logistics processes involve complex physical flows and integration of different elements. It is widely observed that the uncontrolled processes can decline the state of logistics. The optimization of logistic processes can support the desired growth and consistent continuity of logistics. In this paper, we present a software framework for logistic processes optimization. It primarily defines logistic ontologies and then optimize them. It intends to assist the design of a computational knowledge-base tool for better utilisation of the logistic resources. The defined ontologies share the knowledge domain of logistics and optimization. The knowledge-base incorporates the standard optimization techniques, along with the definition of ontologies to resolve logistic problems. It can help to better understand the inherent complexities of logistic problems.

Keywords. Logistics, Ontologies, Classification of logistic problems, Optimization methods, Protégé

1 Introduction

The logistics connect vast amounts of events, activities, and actors. The involved complexity can generate difficult situations to be analyzed for process improvement [Rushton et al., 2014]. We believe ontologies can help in this matter. It potentially contributed in solving integration problems in information systems [Kayikci and Zsifkovits, 2013]. It can extend the research work for the harmonization of heterogeneous information and resources for knowledge discovery [Fensel, 2001, Kalfoglou and Schorlemmer, 2003]. Many individual ontologies have been adapted for logistics [Anand et al., 2012, Moussas et al., 2013]. Ontologies in logistics are mostly focused on supply chain management, and often, these didn't consider the complex logistic problems, like the logistic optimization [Leukel and Kirn, 2008]. However, the current logistic ontologies have not yet achieved a consensual acceptance and maturity.

In this paper, we define and specialize logistic ontologies for optimization purpose. These are further extended to cope with the logistic problems, encountered due to the heterogeneity of involved elements. It assists the end users, in this case the developers, in exchanging semantic

information to share the domain knowledge and the instance knowledge for optimization. It requires, formerly, to investigate the optimization related knowledge and artifacts, while laterly, to establish common vocabularies, nomenclatures, and taxonomies, among them. An artifact, in our study, represents an activity, event, actor, resource, or any document that can influence the other related elements. A relation is a dependence transient that signifies the strength of influence among involved elements, although it evaluates the nature of dependence. We further define the interoperability, integration, and reuse of artifacts, and their optimization with the help of ontologies. It may support the development of algorithms, models, libraries, and simulation tools to minimize the logistics problems.

The rest of the paper is organized as follows; In the section 2, we discuss the context of our approach. The section 3 provides a brief overview of the ontology based approach. The section 4 presents a detailed analysis of logistics ontologies. In section 5, we describe optimization problems which basically exploits the concerned logistic problem. We discuss in detail, the design of optimization ontologies, in section 6. The section 7, provides a brief note on application of defined ontologies, along with an insight on their implementation. Later, in section 8, we conclude the contents of this paper.

2 Related work

In the literature, we find numerous work regarding logistic ontologies. The authors, in [Leukel and Kirn, 2008], propose an approach, regarding the supply-chain management. They devise the core elements of logistic ontologies where the top level ontologies are *process* class having the subclasses *plan*, *source*, *make*, *deliver*, *return*, and the *metrics*. We also find the ontologies defined in [Scheuermann and Hoxha, 2012, Hoxha et al., 2010], where the authors presents an approach to achieve flexibility and decentralization in supply chain configuration and management. They define the top level ontologies for *process*, *service*, *resource*, and *service level parameter*. The logistics resource concept is further specialized into more specific concepts. The *transportation mean*, *warehouse* and *human resources* are derived as the subclasses. Logistics KPI are specialized, among others, into

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sub concepts of Delivery Flexibility and Delivery Reliability. These are in general insufficient to address the logistic issues.

The currently available optimization ontologies focus on the problem field (e.g. design, simulation, and modeling) and they include an optimization part for the solution [Miller et al., 2004]. SoPT [Han et al., 2011], ONTOP [Witherell et al., 2006] and GOO [Moussas et al., 2013] are the closest to our work. General Optimization Ontology (GOO) is designed and structured with the main focus on the optimization. The authors developed the basic concepts common to all optimization problems that are required by the core part of the ontology. The first aim has been to support automatic selection of the appropriate optimization tool for a given optimization problem. ONTOP (Ontology for Optimization) has been developed to facilitate engineering problems. The preliminary work began with the development of a Finite Element Model (FEM) knowledge-capturing tool. ONTOP’s structure provides the means to identify feasible optimization techniques, for a given design optimization problem. Likewise, SoPT, the ontology for Simulation OPTimization includes concepts from both conventional/mathematical programming and simulation optimization. SoPT aims to describe simulation optimization methods and help detect the correct tool for each specific case. It facilitates component reuse, especially in systems where simulators and optimizers are loosely-coupled.

To create flexible optimization ontologies, it is necessary to decompose it in two parts, the core or common part of and the domain or application specific part of the ontologies. The major goal of the optimization ontology remains to provide a formalization of a generic design improvement cycle so that the iterative nature of the product design process can be effectively captured and described for both human and simulation workflows.

3 Architecture of logistics ontologies framework

Although, we restrain our focus on the conceptualization of logistic ontologies but the main objective of this research work remains to develop a software suite to better exploit the logistic resources. It is therefore, we first define the logistic ontologies and later on, the optimization ontologies, to simplify the task. The global architecture of our framework is shown in the figure 1. It attempts to develop an environment that receives the user queries through an interface of query search engine. Which then exploits our knowledge-base with the help of generalized rules. The rules actually represents the generalized dependencies among different related elements of the system in consideration. The knowledge-base contains the facts in form of logistic and optimization ontologies, which are subsequently integrated with software suite ontologies, as per user requirements.

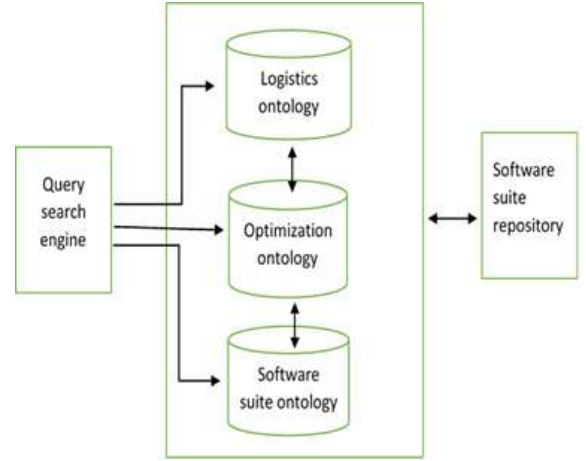


Figure 1: Global architecture of logistics ontologies framework

4 Logistics ontologies

The objective of the logistics ontologies is to capture the essence of the logistic domain. Typically, it contains the concepts, relations, axioms, individuals and assertions. The proposed logistic ontologies define the top level classes as “*process, service, resource, performance, supply chain, activity, and logistic problem*”, as shown in figure 2. These are further extended into subsidiary classes e.g. logistic process is a sub-class of process and supply-chain. Likewise, the logistic service is a sub-class of service and vice-versa.

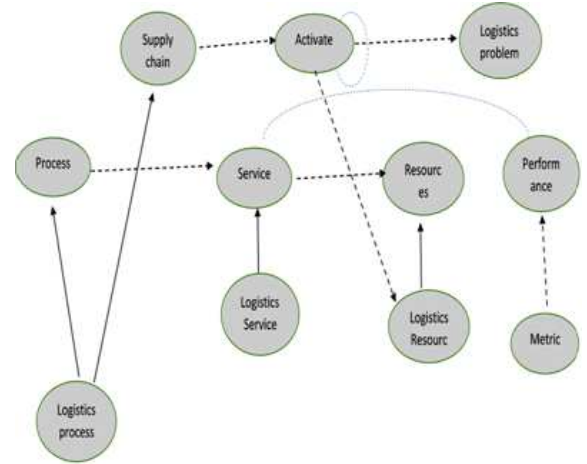


Figure 2: Top level ontologies for logistics

5 Logistics optimization problems

The logistic systems have many resources that provide services for customers and suppliers. It essentially requires optimization methods for resource management and services provision, in order to perform activities in

an optimized way; respecting the minimum cost and time. Among others, the major logistic problems can be categorized as transport problem and airline schedule problem. These further integrates the resource management problems, such as supply-chain management and people management, etc. Similarly, we classify the logistics optimization problems into three major categories depending on the type of problem, which are [Onsel, 2009]:

- Supply-chain management problems
- Airline optimizations problems
- People management problems

As summarised in figure 3, the supply-chain management problems are, in general, the aggravations of issues arising from transportation, location, and inventory management. Whereas the airline optimization problems are mostly contributed from the issues arising from revenue, schedule planning, and aircraft load planning.

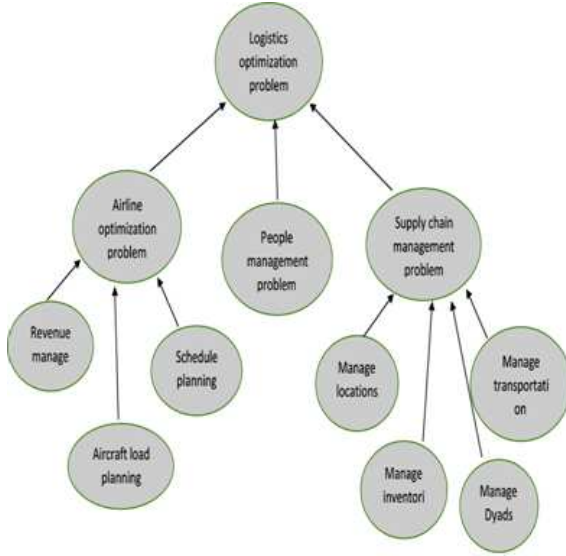


Figure 3: Classification of logistic optimization problems

6 Conceptualization of optimization ontologies

The core optimization ontologies must include the definitions for typical optimization problems along with the descriptions of the methods applied to solve an optimization task. The basic structure of these ontologies should support optimization processes. It should also focus on how to select and apply a suitable solution for the encountered optimization problem. It reflects that the ontology classes must eventually cover all entities that concur in an optimization task. Accordingly, we categorise optimization as follows:

- optimization problem model

- optimization method model

- optimization component

The figure 4 explains dependencies among the top level optimization ontologies. The *Optimization* class basically extended by the *optimization component*, *optimization problem*, and *optimization method* classes, whereas the *logistic problem* class is addressed by *optimization method* class, in this regard.

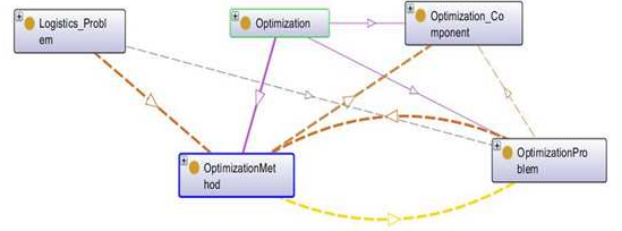


Figure 4: The top level optimization ontologies

In the following sections, we briefly narrate the optimization components, optimization problems, and optimization methods.

6.1 Optimization components

The optimization problem is generally encompassed around multiple components. These components actually describe the nature of optimization problem, depending on the component type. These components are notified as artifacts in our knowledge-base whereas, specifically their classification is as follows (also shown in figure 5):

- Data
- Objective function
- Constraints
- Parameter

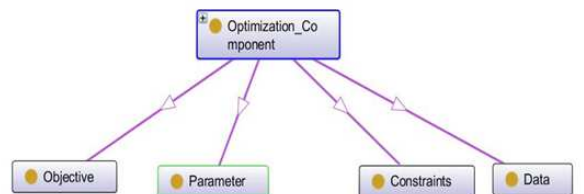


Figure 5: Optimization components

6.2 Optimization problems

The optimization problem basically depends on the nature of involved components. These can be addressed by one of the following problems [Hillier and Lieberman, 2001]:

- Continuous optimization versus discrete optimization
- Unconstrained versus constrained
- Non, one, or many objectives
- Deterministic optimization versus stochastic optimization

Likewise, as shown in figure 6, the type of optimization problem depends on the problematic component such as objective function or constrained, etc. These are further extended into subsequent classes for better understanding, as given below:

- Linear object function
 - integer problem
 - parametric linear problem
- Nonlinear object function
 - convex function problem
 - fractional object function problem
 - geometric object function problem
 - linearly constrained problem
 - multi-variable unconstrained problem
 - non-convex problem
 - quadratic problem
 - separable problem
 - unconstrained problem
- Stochastic
- Dynamic
- Network
 - maximum flow problem
 - minimum spanning tree problem
 - shortest path problem

6.3 Optimization methods

The applied optimization method depends on the type of problem and the component involved. Respective to the problem, these can be as follows (figure 7):

- Nonlinear programming method
 - gradient search method

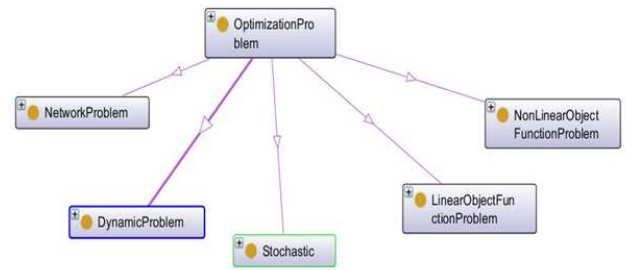


Figure 6: Optimization problems

- karush-kuhu-tucker
- key property of separable programming
- modified simplex method
- one dimensional search method
- sequential linear approximation
- sequential unconstrained minimum

- Linear programming method
 - interior point method
 - simplex method
 - upper bound technique
- Network programming method
 - network simplex method
- Approximate method
 - Heuristic method
 - Meta heuristic method
 - * Tabu search
 - * Genetic algorithms
 - * Ant colony algorithms
 - * Simulated annealing method

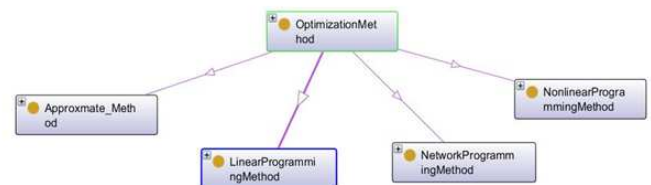


Figure 7: Optimization methods

Currently, we are focussing more on the Meta-heuristic methods for experimentation purposes. The inherent ontologies of meta-heuristic optimization methods are shown in figure 8.

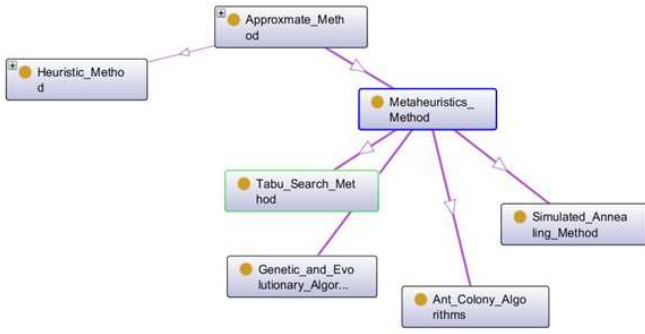


Figure 8: Meta heuristic methods

7 Ontologies application design

We have been experimenting with the logistic ontologies and the consequent query analysis with the help of Protégé framework¹. It is one of the most widely used, open-source ontological engineering tool developed, by a group of researchers at Stanford university. We followed protégé 4.2 as an implementation mechanism and computational environment to conceptualize our logistic and optimization ontologies. The top level classes of logistic and optimization ontologies, along with their sub-classes are shown in figure 9.

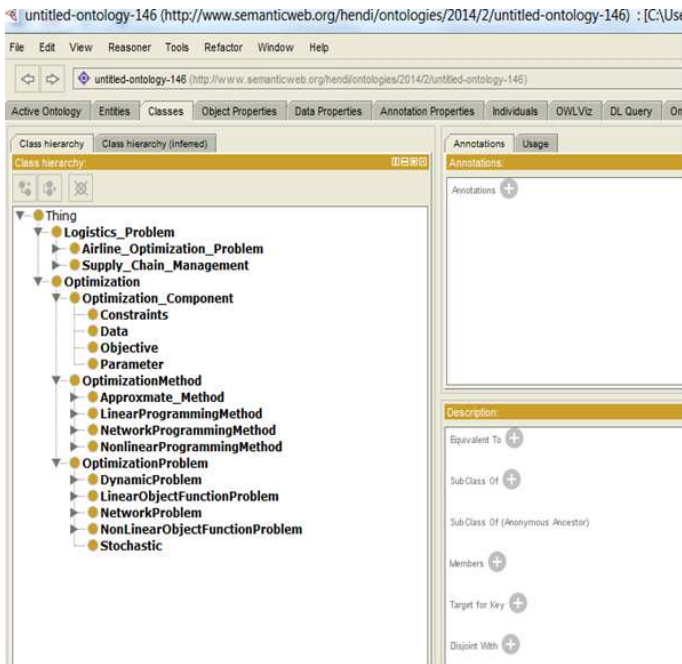


Figure 9: Top level classes of optimization ontologies in protégé

The top level roles of ontologies, as shown in figure 10, are the followings:

- *hasComponent* is a role, its domain is *optimization problem* and range is *optimization component*

¹<http://protege.stanford.edu/>

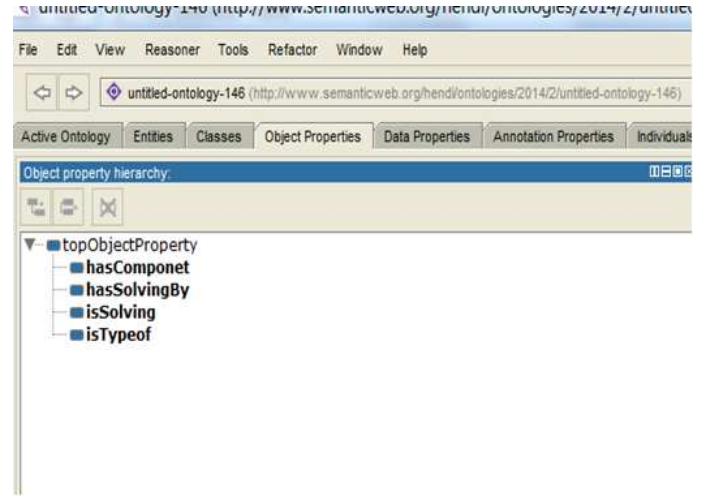


Figure 10: Roles of optimization ontologies in protégé

- *hasSolvingBy* is a role, its domain is *optimization problem* and range is *optimization method* and its inverse role *isSolving*
- *istypeof* is a role, its domain is *logistics optimization problem* and range is *optimization problem*

For instance, let's consider a routing problem, which can be a specialised class of transportation management in supply-chain management of logistic, as explained in section 5. In particular, this role can be used to retrieve results of a query related to the vehicle routing. In our ontologies *Vehicle routing problem* is a subset of *Transportation Management* class, as shown in figure 11. It has a role *hasTypeOf* with *Travelling Sales Person* is an *Integer Problem* which is actually a subset of *Linear Objective Function problem*, as depending on the problem component. The *Travelling Sales Person problem* has role *hasSolvingBy* to *Methods* class.

8 Conclusion

We devise ontologies for logistic and further extends them for optimization of logistic resources. These ontologies are intended to design a knowledge-base system, capable to support users in a general purpose software suite development. The conceptualization of optimization ontologies contributes in the identification of optimization components, optimization problem and exploitation of a significant optimization method for the logistic problem resolution.

We extend the currently available ontologies to adapt them specifically for logistics and optimization problems, but the application problem are different. We classify the problems and the corresponding optimization methods along with the ontologies definition. GOO (for instance) contains the top level of ontology problems, methods and algorithms; its application remains limited. The opti-

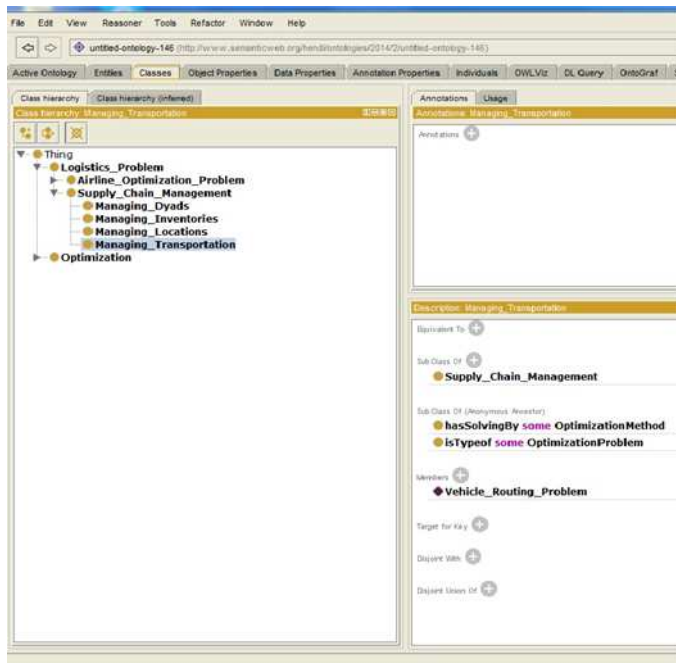


Figure 11: The ontologies for Vehicle Routing Problem

mization methods in GOO are similar to the optimization algorithms. While considering the ONTOP ontologies, where the authors, classifies the optimization types either as continuous problem or as discrete programming. Moreover, the continuous programming is classified as constrained and unconstrained, where the linear programming is sub-class of constrained programming. It conflicts the classification concept of integer programming, where it is sub-class of linear programming which, in turn, is a sub-class of discrete programming. Also the non-linear programming is classified as two sub-classes of both unconstrained and constrained programming, in ONTOP. In the current work, we exploit the inherent relationship between the optimization problem and the problematic component (i.e components involved in the problem) to classify the optimization problem. Furthermore, we classify the optimization methods into classical methods and approximate methods.

In the future we intend to develop an exhaustive framework to support users in the development of logistic software applications.

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