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# Designing an intelligent ontological system for traffic light control in isolated intersections

Maryam Keyarsalan, Gholam Ali Montazer*

*Information Technology Engineering, Tarbiat Modares University, P.O. Box 114115-179, Tehran, Iran*

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ABSTRACT

This paper models the traffic light control domain using a fuzzy ontology and applies it to control isolated intersections. Proposing an independent module for reusing traffic light control knowledge is one of the most important purposes of this paper. In this way, software independency increases and other software development activities, such as test and maintenance, are facilitated. The ontology has been developed manually and evaluated by experts. Moreover, the traffic data is extracted and classified from images of intersections using image processing algorithms and artificial neural networks. According to predefined XML schema, this information is transformed to XML instances and mapped onto the fuzzy ontology for firing suitable fuzzy rules using a fuzzy inference engine. The performance of the proposed system is compared with other similar approaches. The comparison shows that it has a much lower average delayed time for each car in each cycle in all traffic conditions as compared with the other ones.



## 1. Introduction

As a result of an increase in urban traffic, the limited capacities of road network and developing technological aspects in traffic tools and approaches, many entities, relations, situations and rules have entered traffic light control domain and transformed it into a knowledge area. Modeling knowledge of this domain helps traffic agents and applications manage traffic efficiently regarding real-time conditions. One of the most appropriate ways for comprehensive knowledge modeling of such domains is using ontology concept (Gómez-Pérez et al., 2004). "Ontology is a formal, explicit specification of a shared conceptualization." (Gruber, 1994). The previous models are fundamental infrastructures of ontology construction to build a shared domain of knowledge with semantic richness. In addition to the importance of ontology as conceptualization formalism, it has the potential power to reason over the represented data. This ability will improve in making decisions about performance and other non-functional features in intelligent systems (Lera et al., 2006). In recent years, research studies on ontology are becoming a new hot topic in different activities such as Artificial Intelligence, Knowledge Management, Semantic Web, E-business and several other application areas (Lera et al., 2006). One of these domains is intelligent traffic systems (ITS). Some efforts have been made into this area by presenting and using ontologies for detecting traffic congestion (Murray and Liu, 1995), managing non-urban road meteorological incidents (Tomás and García, 2005), driving advisory systems (Avram et al., 2006) and sharing and integrating an information platform for intelligent transportation systems (Zhai et al., 2007). The purpose of this paper is to present a traffic light control ontology (TLCO) for reusing the knowledge of this context and control the isolated intersections efficiently. This new approach applies an intelligent agent that uses knowledge of fuzzy TLCO for decision making. This system uses the images of intersections taken by installed surveillance cameras. These images are processed by image processing algorithms and exploiting a neural network approach and then sent to an intelligent agent. In Section 2, we will briefly explain a background of the technologies utilized in this work including semantic web technologies, intelligent agent technologies and traffic light control approaches. In Section 3, the architecture of the new system is presented which is based on layered semantic web architecture (Berners-Lee et al., 2001). Section 4 describes the traffic light control fuzzy ontology building step-by-step based on Methontology (Gómez-Pérez et al., 2004). Information extraction from intersection images is explained in Section 5. In Section 6, the operation of intelligent system is described completely and finally the proposed approach is evaluated in Section 7 and the discussions and conclusions are stated.

## 2. Background

This section explains the technologies applied in this work including semantic web technologies specially ontology and fuzzy

* Corresponding author. Tel.: +98 21 82883990.
*E-mail address:* montazer@modares.ac.ir (G. Ali Montazer).

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ontology. Moreover, state of the art of traffic light control approaches is presented briefly.

### 2.1. Semantic web technologies

"The semantic web is defined as an extension of the current web in which information is given well-defined meaning; better enabling computers and people to work in cooperation" (Berners-Lee et al., 2001).There are several layers in the semantic web architecture suggested by Berners-Lee shown in Fig. 1. The development of the semantic web proceeds in steps, each step building a layer on top of another. At the bottom layer there is XML, a markup web language which represents web documents in a structured format with a user-defined vocabulary. It is particularly suitable for sending documents across the web. At the next higher layer, RDF is located as a basic data model, such as the entity-relationship model, for writing simple statements about Web objects (resources). The RDF data model has an XML-based syntax. Besides RDF, there is RDF Schema which provide modeling primitives for organizing web objects into hierarchies. It can be used as a primitive language for writing ontologies. But there is a need for more powerful ontology languages such as OWL that expands RDF Schema and allows the representations of more complex relationships between web objects. This knowledge representation language can describe wide-spread features about properties and classes, such as all kinds of relations between classes, cardinality, equality, richer typing of properties, characteristics of properties and enumerated classes (Grigoris and Van Harmelen, 2004).

Although ontologies are the backbone technology of the semantic web, the core concept of the term "ontology" originally is borrowed from philosophy and it has gained substantial popularity in computer science and information systems since less than twenty years ago (Hepp, 2007). There are many formal definitions of ontology which have changed and evolved over the years, but one of the most complete definitions belongs to Studer (Angele et al., 1998), who says: "Ontology is a formal, explicit specification of a shared conceptualization. Conceptualization refers to an abstract model of some phenomenon in the world by having identified the relevant concepts of that phenomenon. Explicit means that the type of concepts used and the constraints on their use are explicitly defined. Formal refers to the fact that the ontology should be machine-readable. Shared reflects the notion that an ontology captures consensual knowledge, that is, it is not private of some individual, but accepted by a group" (Gómez-Pérez et al., 2004). By ontologies, users and systems can communicate through an easy information exchange and integration. Nevertheless, since the application domains, in which the predominant information is vague are not unambiguously discrete, a theoretical formalism founded upon conventional ontology may fail to represent it. One more point to bear in mind is the fact that fuzzy knowledge has an integral role to play in applications including knowledge and information that is uncertain, unstructured and unpredictable, such as text mining, multimedia information systems, medical informatics, machine learning and natural language processing. In this approach, fuzzy ontology can be regarded as an extension to the conventional ontology (Zhai et al., 2008). In the present paper, we have adopted a definition of fuzzy ontology presented by Zhai et al. (2008).

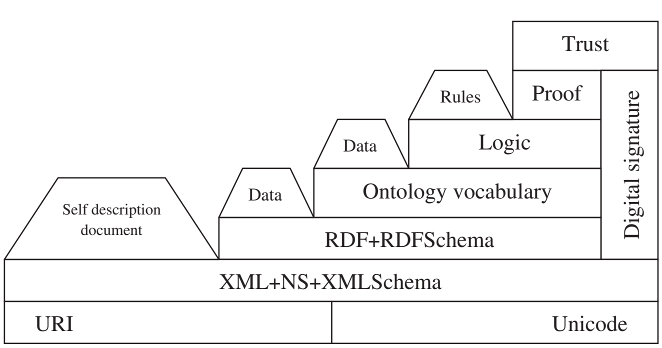


**Fig. 1.** A layered approach to the semantic web.

The fuzzy domain ontology is used to model domain expert knowledge. There are several methodologies for ontology construction such as Cyc method (Lenat and Guha, 1990), KACTUS approach (Schreiber et al., 1995) and Methontology (Gómez-Pérez et al., 2004). Among others Methontology has been proposed to ontology construction by the Foundation for Intelligent Physical Agents (FIPA), which promotes inter-operability across agent-based applications (Gómez-Pérez et al., 2004). Some ontology tools such as ODE and Protégé support Methontology. One of the key decisions to make in the ontology development process is to select the language (or set of languages) in which the ontology will be implemented. In the past decades, several ontology implementation languages have been created, such as RDF and OWL all of which are based on XML. Among these languages, OWL covers most of the features of the others and completes them (Gómez-Pérez et al., 2004). So, the TLCO has been constructed based on Methontology and implemented by OWL in Protégé 3.4.

### 2.2. Traffic light control approaches and intelligent agents technologies

There are two main different kinds of traffic signal control approaches. The first strategy is the fixed-time and the second one is traffic responsive strategy. In the fixed time approach, the predefined plan determines the optimal green lights duration and the optimal cycle time based on day and time. The essential aim of such approaches is to minimize the total waiting time. Obviously, this kind of traffic light control strategy has precise disadvantages. Its main weakness is its inability to adjust itself with regard to real-time environmental traffic conditions such as vehicle and pedestrian congestions. The second approach means the traffic-responsive strategy was proposed to solve this problem by applying some detective tools, such as inductive loops or pattern-recognition digital cameras. In this way, the new approach is able to measure real-time conditions and decide effectively. In recent years, several kinds of traffic light control systems in this category have been proposed (Yan et al., 2008). According to Wiering et al. (2004), traffic responsive strategy includes in the expert systems, prediction based optimization, fuzzy logic based, evolutionary algorithms, reinforcement learning and intelligent agents' categories. Among them, some methods such as fuzzy logic (Henry et al., 1998; Murat and Gedizlioglu, 2005; Nair and Cai, 2007; Zarandi et al., 2009; Karakuzu and Demirci, 2009; Chong et al., 2009) and intelligent agents (Hirankitti and Krohkaew, 2007; Tubaishat et al., 2007; Sirisaengtaksin and Safin, 2009; Oliveira and Camponogara, 2010) and also a combination of them are more considerable. The main reason for applying fuzzy logic is its capability to model intrinsic uncertainty involving traffic light control at junctions and intersections like human operators. "The simplicity of this approach compared to mathematical models, makes fuzzy logic a desired approach in developing the controller" (Nair and Cai, 2007) .We were also persuaded to use fuzzy logic in creation of the TLCO. In addition to applying fuzzy logic, "intelligent agents systems have been successful in solving unstructured problems (for which adequate models are not known), in the replacement of and assistance to humans, in solving high abstraction problems