On Fuzzy-Logic-Based Ontology Decision Support System for Government Sector

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Abstract: In recent years, a number of developed countries have employed ontology in e-government projects. This paper focuses on developing prototype architecture for intelligent decision support systems that can help top political decision makers in Kuwait. The system is intended to be used to strengthen bilateral economic relationship between Kuwait and friendly nations. Typically, such decisions are influenced by certain factors and variables that are based on scattered, unstructured, heterogeneous and vague information. The location of such information can be anywhere in different domains. In this paper, the information will be taken from the political and investment domains. A natural language is thus needed to describe such information which requires human knowledge for interpretation.

The Information and Communication Technologies (ICT) has radically changed the way governments, deliver services to citizens, businesses and organizations. ICT support consists of, providing a large range of government information and services online such as health care, education, social services. The uses of ICT facilitate online citizens' participation to government processes and decision making, and helps in reorganizing government processes. Therefore, many applications have been developed in various government's departments [5, 17, 18, 25], aimed at providing and enhancing delivery of services to citizens, businesses and organizations. However, little work has been done in building knowledge base on ontologies that facilitate the communication between stakeholders and that identify the processes and describe the data of these applications.

In this research, we propose to use ontology to integrate the scattered information resources from the political and investment domains. The process will start with extracting key concepts and relations between sets of information and integrate fuzzy logic with ontology. We will present a case study and we propose to build ontology in the domain of bilateral economic relationship in Kuwait to obtain a solution that is more suitable for solving the uncertainty and reasoning problems in this intelligent decision support system. The indented users are the top political decision makers for the purpose of strengthening bilateral economic relationship between Kuwait and friendly nations.

Keywords: Fuzzy Logic, Decision Support Systems, Ontology, Knowledge Base System, Fuzzy-Logic-Based Ontology, Government system.

1. Introduction

It is in the interest of every nation to foster good bilateral relationship with other countries. The existing relationships between countries can be described from a variety of perspectives, such as historical, respectable, friendly, neighboring, traditional, religious, political and economical ones. Apart from such a variety of relationships, all nations seek to build bridges of cooperation with other countries in various ways. One way is to build this relationship by strengthen the economic relationships, where many factors and variables that influence the promotion of economic relationship should be taken into account. These variables and factors are diversified and may be found in different places in various economic sectors. From the research viewpoint, the challenges lie in recognizing, finding, and extracting these different variables. A responsible decision-maker takes the

accountability to promote and strengthen bilateral economic relationship that requires a good access to well structured information relevant to his/her decisions. Unfortunately, in reality, the actual input to such a decision making process is quite, unstructured non-centric and scattered in different domains including the political and investment domains. This makes it extremely difficult for the decision maker to understand the concepts, restraints, and facts existing in these domains with their properties and relationship. It is usually empirical for a decision support process to be able to assess the different factors, variables and relationships between them in order to reach proper decisions. Examples of different factors and variables that may be assessed in the decision making process include, but are not limited to: stand and position of the inquires about nations with the regional and global issues, security and stability, the ability of the nation to invest, the disclosed position of the nation in the fight against terrorism, the position of the nation on combating weapons of mass destruction, and the position of the nation in cooperation and facilitating investment matters. It is essential to be able to understand complete set of factors and variables and identify relationships between them. Due to the existence of various factors influencing decision making for strengthening the economic relationship with other countries, there is an urgent need to develop a proper system so as to achieve adequate yet accurate data gathering and analysis, and produce precise and certain output useful to the decision makers. In Kuwait, the scattered data mostly lies in various governmental sectors including Kuwaiti Fund for Development, Kuwait Investment Authority, Ministry of Foreign Affairs, Prime Minister Office, Embassies of Kuwait, and Decision Maker Office.

For Example, Ministry of Foreign Affairs Sector is responsible for bilateral relations for international and regional levels. The information about agreement with other countries can be found in this sector. On the other hand, the information of bilateral trade can be found in Kuwait Investment Authority. Both of these sectors fall under different domains and are equally inter-dependant on each other for the decision making process when it comes to strengthening the bilateral relationships. Since traditional empirical decision making has been an inefficient process. We focus in this paper on generating ontology. Ontology can be defined as a group of information in a specific domain, which helps to acquire knowledge, and share it. Ontology is used for several years in Engineering (IC) and the Artificial Intelligence (AI) for structuring domain concepts. The concepts are gathered and are regarded as basic bricks for expressing knowledge in the field it covers. Ontology is useful to share knowledge, build consensus, and build knowledge base systems. Many projects of ontology are implemented such as the Semantic Web. The fundamental problem is to respect the diversity of languages and representations of the world, while allowing the exchange of information. Gehrmann et al [11, 12] introduced the concept of ontology in order to support management system audit. The main aim of this paper is developing prototype architecture for intelligent decision support systems that can help decision makers in political domain. A new methodology of ontology decision support system will be presented. We introduce in this paper the concept of ontology and show the characteristics of the decision support system in a particular domain. In this paper, we focus on proposing a system for generating ontology by extracting knowledge from various data resources. These sources may have various forms such as textual data, knowledge base, and regular documents. Different approaches to characterize or define fuzzy ontology are studied. One such approach that we adopt in this paper is the construction of fuzzy ontology for a specific domain which was presented in Uraiwan Inyaem et al.[27].

2- Definition of Ontology

The ontology is simply defined as a set of concepts (classes) and the relationship between these concepts. Ontology, is also defined as an explicit specification of a conceptualization [27] often considered as a reusable and shareable model. Geographical ontology can be used for exploration, and extraction information and also for inter operation of GIS [20]. Ontology is defined as mentioned above, a common vocabulary for persons who need to share information in a specific domain. Different ontology are used in different domains (Geography, Biology, etc.) to share common understanding of the structure of information among people or software agents, to analyze domain

knowledge, and enable reuse of domain knowledge. definition in our case: we define an ontology as a description of concepts in a domain (classed, concepts) when the properties of each concept describe various features and attributes of the concept (properties, roles), and Slots that describe properties of classes and instances. According to [27], ontology is an explicit specification of conceptualization. Conceptualization is basically how we express our views through words, expression of concept and elements, and relations between entities. This definition stresses on the application of the common ontology in different application as well as translating the language text or the documentation to defined terms. Similar related work was done by Yuemi et al. [29] where they proposed ontology structure with their concepts, properties, and with some fuzzy linguistic variable ontology. In addition, they specified the definition of fuzzy relation as a set of membership degrees associated with a set of the relations in the concepts of the domain ontology. Fuzzy ontology is based on the concept that each index object is related to every other object in the ontology with a degree of membership assigned to that relationship based on fuzzy set theory.

3- Building an Ontology

Building ontology is an iterative process that consists in different steps. The first step consists in defining the classes of the ontology, and arranging them in a taxonomic hierarchy. After relating between the classes and specifying the super classes and subclasses, we start the second step in which we should define slots, describe the allowed values for them and filling in the values for slots for instances. The third step consists in creating a knowledge-base by defining individual instances, filling the slots with specific values and adding restrictions to slots.

4- Domains of application

Ontology has been very commonly and used in different applications, ontology was applied in the field of health, in terms of fighting against malaria disease, where the concepts and techniques were presented using precise conceptualization. Zimmermann [30] has combined the fuzzy logic rules with the ontology to improve the importance of sharing knowledge with heterogeneous agent to interact in open environment. Similar related work comes from researchers in the field of geographical information where intelligent modules are used by users receiving decision support for spatial analysis functions for multiple sources are used. It provides users with the necessary knowledge to complete a task with reduced error [7]. More recent work for fuzzy ontology was presented by Jun Zhai et al. [16], where fuzzy ontology was used to create an extension to standard ontology.

The proposed fuzzy domain ontology consisted of 5-tuple extension. To assist in presenting the concepts, a concept is considered as classes in ontology was put forward with a set of properties which include 5-tuple (ontology concept, property values, linguistic qualifiers to control the strength of a property value, the restriction facts, and the universe of discourse). For example, "price" is a property of concept "fruit". The value of the "price" may be either fuzzy concept, "cheap", or fuzzy number, "around 50". The linguistic qualifiers may be either "very little" or "close to", therefore the final value of "price" may be "very cheap" or little expensive" as was illustrated in Jun Zhai, et al. [16]. Fuzzy ontology can provide more choices for attributes description of an object. It also has stronger ability to express uncertainty than an ordinary fuzzy set. There are several kinds of approaches for constructing a fuzzy ontology. Note that fuzzy sets have been applied to many fields including artificial intelligence and decision-making analysis.

5- Ontology in E-government domain

In recent years, many countries used ontology in e-government projects [4, 23]. Apostolou et al [2] was presented the OntoGov project that aims to develop an ontology platform in order to facilitate the consistent configuration and reconfiguration of e-government services. A methodology for building ontology in the social care domain within the context of e-government has been presented by Bettahar et al.[4]. Gomez-Perez et al., 2006 was presented an ontology-based model to retrieve efficiently the documents in government. More recent work for ontology in government was presented by Ortiz-Rodriguez [22], where used a set of government ontologies to represent Mexican

local government processes. Further work for Ontology has been presented by Alexopoulos et al.[1] in order to detect fraud in e-government system. Other Ontologies has been built to facilitate transactions between companies across EU countries [15]. In addition Salhofer et al., [24] has described an approach to present a model of ontologies for the e-government domain as a basis for an integrated e-government environment.

6- Methodology

In the literature, different methodology approaches for building ontology have been proposed by Fernandez-Lopez [19] ; Beck and Pinto, [3]; Calero et al. [6]. Until now, there is no standard method used for building ontology. The approach described in this paper was adopted from Noy and McGuinness [21] and Fernandez-Lopez [19] ontology modeling approach. Another approach to build ontology from existing ontologies or from scratch was presented by Carelo et al.[6]. Our ontology will cover the two main important government sectors in Kuwait, Kuwait Investment Authority (KIA), and Ministry of Foreign Affairs (MFA). It is important in the first step to know how these two sectors model and present their major trends, concepts broken down them into objectives, actions, norms, and principles to enable us to describe the domain and the relationship between them and understand the complexity when making decision and how building an Ontology can be helpful and benefic for decision makers. The second step consists in identifying the ontology concepts for them including the definition of classes and subclasses, characterize the properties between classes, shared elements, and description of entities in these classes. This will enable us to describe the domain and the relation between them. The aim of conducting the ontology approach is to provide an insight into how knowledge is represented and handled via different perspectives software tools. A system will be developed using software tools for modeling and implementing the ideas and applications of this ontology. Possible software tools include Protégé which is an ontology editor and knowledgebase framework and Fuzzy Logic Toolbox that extends the technical computing environment with tools for designing systems based on fuzzy logic.

Before defining the classes of the Ontology, we should determine, specify the domain that this ontology will cover and define the goal of use of the Ontology. Ontology is built to provide answers to specific questions that we should specify also at this level. Competency questions should be asked at this level such as for example in our case: does the country X look forward towards the reactivation of the peace process in the Middle East? Is the country X intervening in the affairs of other countries, either directly or indirectly? The output of the answers may vary from "yes", "no", maybe","some time", "always", "never", "not clear",etc. The second step consists in verifying the existing of Ontology in the domain that can be extended. As mentioned before, there are a lot of existing ontology for different domains such as DAML ontology library, UNSPSC ontology which provides terminology for products and services, and RosettaNet and other ontology for different domains except the political one. The third step consists in listing the main terms that will be used in the ontology without considering overlaps between them such as ware, peace; in the fourth step we should choose the approach to define the classes and the hierarchy. There are two different approaches, the top down and the bottom up; in this paper the first approaches will be followed. We start by defining the most general concepts then adds different specifications (kind of) of those concepts During the fifth step, we should find the properties of classes and decide for each term to which class it belongs before adding it as a slot such as intrinsic, extrinsic, relationships between different members of the class. Examples in our case: "controlledBy", "enable", "provide", "affect", "engaged", "enrichedBy"… We should mention here that every subclass inherit all slots from superclasses. Step six consists in defining the facets of the slots such as, the cardinality, type, allowed values, instance with the relationship to another instance, and define the domain of the slot which means defining the classes to which a slot is attached. And the last step consists in creating the instances by choosing the class and filling in the slot values.

7- Problem definition and case study

A serious problem that the decision maker faces is the difficulty in building an efficient political decision support system, since 80% of the

information is hidden in unstructured or semi-structured documents [9]. The difficulty mainly lies in extracting and attracting these different variables in different patterns. In this research, we aim to develop a formal method using ontology-based system to support decision-makers towards strengthening the economic bilateral relationship requiring structured information. The existing methods for facilitating decision making are mostly unstructured and the data are scattered in different domains. This overwhelms the decision maker with the responsibility of not only understanding not only the concepts, restraints, facts existing in that domain but also their properties, the relationship between them and the location of every data in these sectors as well as their functionalities. Table 1 illustrates different sectors (ministries) with different domain and their respective functionalities and responsibilities.

Table 1: Different sectors(Ministries) with different domains and their respective functionalities and responsibilities.

Sector/ Ministry	**Domain**	**Department**	**Function / Responsibility**
Ministry of Foreign Affairs	Political Domain	Bilateral Agreement	1) Assigns agreement between Kuwait and other countries
			2) Includes type of agreement
			3)Includes State of agreement
			4)Status of agreement
			5)Execution date of agreement
Kuwait Investment Authority	Investment Domain	Bilateral Trade	1) Responsible for most Investment transactions between Kuwait and other countries
			2) Includes type of imports
			3) Includes type of exports
			4) Includes value of imports
			6) Includes investment in assets, bonds, stocks, real Estates, alternatives

In Table 1, we select two departments, political and investment respectively, from two different domains in multiple sectors. The first department is the Bilateral Trade department in the investment domain falling into the Kuwait Investment Authority sector. The responsibility of this department lies in assigning agreement between Kuwait and other countries. The second department is the Bilateral Agreement department in the political domain which comes under Ministry for Foreign Affairs sector which is responsible for most investment transactions between Kuwait and other countries. As shown in table 1, the data and information that are required for top political decision maker in order to strengthen the economic bilateral relationship for the decision maker to be extracted from various departments is scattered, vague, heterogeneous and unstructured.

8- Purposes of the Ontology

One of the methods for determining the scope of an ontology is to write a list of questions that an ontology-based knowledge should respond, called questions of jurisdiction [14]. It will be later from litmus test: Did Ontology contains sufficient information to respond to this kind of questions? Responses require a particular level of detail or the representation of a particular domain? These jurisdictional issues are just a draft which did not need to be exhaustive. Our approach consisted of building a set of questions which needed to be answered by the ontology in order to fulfill its purposes. The concepts of the ontology are terms that define the domain or activities carried out in the domain [4]. Starting from this list of questions, the ontology includes information about the different elements and different types of conditions to be taken into account to make the good choice and recommendation about investing or not in a specific country. Here are some possible questions asked during the process of decision making in the strengthening of bilateral economic relationships with other nations: "does this country look forward

towards the reactivation of the peace process in the middle east? Is this country intervening in the affairs of other countries, either directly or indirectly? Is this the State has an interest in the development of the Iranian nuclear file? Is this the State interested in the security and stability in Iraq The output of the answers may vary from "yes", "no", "maybe"," some time", "always", "never", "not clear",…etc.

9- Proposed Ontology

Ontology plays a major role in the availability of sharing the information [16]. As mentioned above, the data needed by the decision maker in political area is uncertain and scattered. By using ontology, decision makers, will be able to take better decisions in less time. We will start by representing a model diagram consisting of classes, subclasses, elements that are important in the domain with relationship properties. This diagram can be used as an illustrative description for any future needs. We will propose an ontology structure with their concepts, properties. We will use ontology to represent and organize different domain knowledge in terms of concepts, properties, relations and axioms. Fuzzy ontology is based on the concept that each index object is related to every other object in the ontology with a degree of membership assigned to the relationship based on fuzzy set theory. We will employ a fuzzy ontology as an extension of domain ontology for solving the uncertainty problem for political domain. Using this developed model of ontology and fuzzy logic, we will share information from different domains with others to present high level of knowledge for the political decision maker to make decisions. We create a decision model that facilitates the decision maker in the decision making process in the political field. Uraiwan Inyaem et al [28] specified the processes of fuzzy ontology for terrorism domain. The terrorism domain has comparable attributes to the political domain. Hence, we will use a similar approach for the construction of fuzzy ontology. The first step in this process is to input the unstructured data. We have started developing this input by proposing the following set of questions that are asked during the process of decision making for strengthening bilateral economic relationships with other nations. Table 2 depicts an initial attempt to formalize these unstructured data inputs.

Table 2: Unstructured data input tabular illustration

Sectors	Kuwait Investment Authority	Ministry for Foreign Affairs
	Answers on Type Of Imports	Answers for Questionnaire on Peace Affairs
	Answers on Type Of Exports	Answers for Questionnaire on Iran Affairs
	Answers on Type Of Financial Aid	Answers for Questionnaire on Nuclear Affairs
	Answers on Financial Contributions	Answers for Questionnaire on Middle East Affairs
	Answers on Support Facilities for Investment	Answers for Questionnaire on Terrorism

After this step, we will have to complete the process by 1) specifying the definition of related concepts in the domain and their relation 2) clarifying the generation of domain ontology, 3) extending the domain ontology to fuzzy ontology, and 4) applying the fuzzy ontology in to the specific domain of political decision making for strengthening the bilateral economic relationships. Fig 1 describes the complete process of the construction of fuzzy ontology which makes use of the specific domain [28].

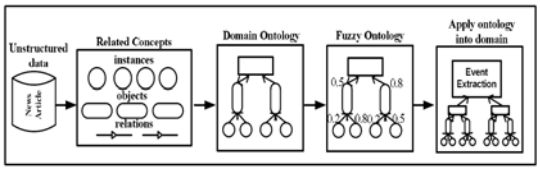

Fig.1: Process of Construction of fuzzy ontology for the Specific Domain

The Object paradigm ontology (OP) for bilateral trade is presented in Fig 2.

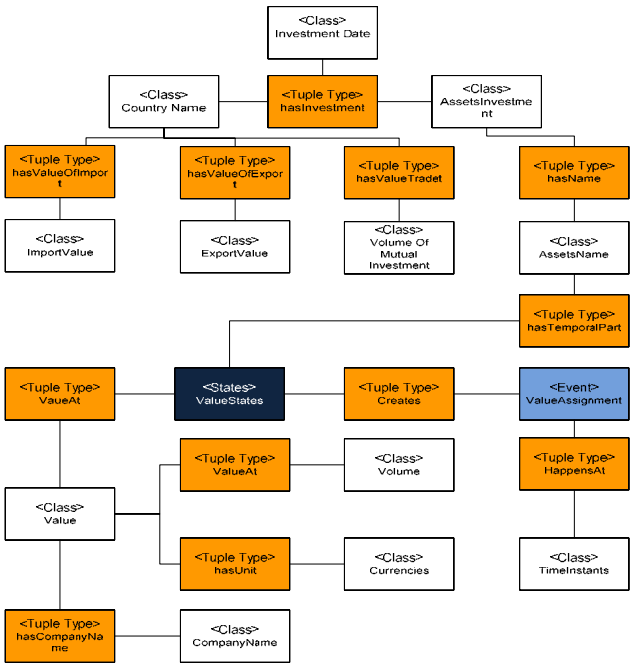

Fig.2: Object paradigm ontology (OP) for bilateral trade

10- Conclusion & Future directions

In this paper, we introduce the proposal to develop a fuzzy ontology approach and discuss how to conduct this approach in two main important government sectors representatives in Kuwait; the Kuwait Investment Authority and Ministry of Foreign Affairs. To build this ontology, it is very important to understand how these two sectors represent their major trends, break concepts down them into objectives, actions, norms, and principles. This will help in identifying the proper ontology concepts for them (e.g. classes and subclasses), characterizing the properties between them, sharing all elements, describing the entities in those classes, and describing the domain and the relationships between them. The aim of conducting the fuzzy ontology approach is to provide an insight into how knowledge can be represented and handled in order to support the decision maker with help from the intelligent decision process. Different methods and different questionnaire may be used to assess the validity of the method and approach. We tend to be convinced to conclude that we can develop a system based on implementing a fuzzy ontology over the investment and political domain that will enable the decision maker to make intelligent political and economic decisions for bilateral economic relations and therefore a good of the return on investment for such system.

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