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Construction of Liver Fibrosis Diagnosis Ontology From Fuzzy Extended ER Modeling:
Construction of FibrOnto From an EER Model

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ABSTRACT

Liver fibrosis diagnoses is a critical and core research study field due to its importance to the patient's life. Moreover, electronic health records (EHR) contain wealthy semantics connected to liver diseases yet ontological implementation is still a challenge. Ontology however, can play critical roles in E-health as a formalization of medical terminologies and decision support system knowledge base. But since clinical data contains a lot of data that is imprecise and vague, classical approaches of ontology construction would not be fruitful. However, Fuzzy ontology, an extension of the crisp ontology that requires different development methodology, can be implemented in this field due to its previous success in modeling semantic knowledge in various domains. In this article, the authors construct a fuzzy ontology by using a fuzzy extended entity relationship (EER) data model for liver fibrosis diagnosis. The resulting ontology is complete and consistent because it is based on a formal methodology of mapping the EER model into a fuzzy ontology.

KEYWORDS

Clinical Decision Support System, Conceptual Modelling, Electronic Health Records, Fuzzy EER Model, Fuzzy Ontology, FuzzyDL, Liver Fibrosis, Semantic Web

1. INTRODUCTION

This study focuses on liver fibrosis disease due to its importance, where it is result in increasing death-rate in Egypt. Viral Hepatitis C is a chronic liver disease that causes fibrosis then subsequently liver cirrhosis. This fibrosis makes changes to the architecture of the liver and disrupts its normal functions, leading to liver cancer on the long term (Suk, 2015). Liver fibrosis consists of five stages: f_0: negative fibrosis, f_1: mild fibrosis, f_2: significant fibrosis, f_3: cirrhosis, and f_4: significant cirrhosis (Badria, 2007). Since this disease is a very critical issue for chronic HCV patients, the investigation of all the related features 'demographic, laboratory test, clinical data and risk factors

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diseases' was needed to accurate prediction of the diagnosis, thus, save money and life, and help experts to take an appropriate decision for treatment (Keltch, 2014). Poor diagnosis will lead to significant liver fibrosis, cirrhosis or to the liver's end-stage failure (Suk, 2015). The technology of health information systems and medical devices in clinical domains increased rapidly in biomedical engineering, since such technology produces a vast amount of medical data (Kolias, 2014). However, the storage and retrieval of this produced data is difficult, and it also contains hidden, unexploited knowledge. Therefore, to overcome these problems, the scientific community suggests the usage of semantic web services (Kolias, 2014), which aims at creating ontology based on machine-processable web contents (Tho & Hui, 2006). Clinical decision support systems CDSSs are considered as intelligent information systems, which based on knowledge base formalization integrated with patient clinical data to assist physicians in their practices (Galopin, 2015). The core role of ontologies is the knowledge formalization. Therefore, it is required a set of mathematical processes and relations to construct an ontology (Maedche & Staab, 2001). Since the construction of ontology is a complicated process, there were multiple methods and tools to create patterns from different data sources such as the development of free texts (Maedche & Staab, 2000), dictionaries (Hearst, 1992) and data models (Carvalho, 2017). Using the aforementioned resources, since the data models have a widespread use in information systems, the data conceptual modeling was attracted in data modeling and management. Many formats have been used to construct ontologies such as Unified Modeling Language (UML) (Zhang & Ma, 2013), relational models (Ma, 2011), and object-oriented data models (zhang, 2010). Yet, Classical data models and the methods of building ontology are not enough to deal with inaccurate information common in the real world, especially in the medical domain (Maedche & Staab, 2001). For example, if an old-patient case has a chronic infection of Viral Hepatitis C and has high serum bilirubin (SB) laboratory test, this patient has almost Jaundice with high degree and has the majority diagnosis is liver cirrhosis. Hence, the problem is how to deal with fuzzy information with ontology and data model as extended entity relationship (EER) model.

In the daily life, we often use terms such as (almost, majority) that contain certain ambiguous or uncertainties that traditional system could not understand. Fuzzy logic (Zadeh, 1965), with its concepts make the intelligent system closer to human methods. Fuzzy systems were extensively studied to manage the storage of fuzzy data and fuzzy query capability (Galindo, 2004). Galindo et al., (2004) dealt with the EER model as a tool for dealing with fuzzy data, where they defined the fuzzy EER aspects related to the aggregation and specialization. Furthermore, Ma (2009) proposed the mapping of EER schema from the relational database schema.

The common conceptual data models (e.g., Entity Relationship ER model) graphically represent data as entities which are objects in the real world, relationships connect different entities to each other, and some constraints (Galindo, 2006). The EER model has the ability to expand such specification of entities into new types (superclass, subclass, and categories) (Galindo, 2006). The EER model can handle fuzzy values such as; fuzzy attributes and fuzzy degrees (Galindo, 2006). The fuzzy ontology represents complex entities and complex relationships among entities. Fuzzy ontologies have been implemented in several non-medical domains including, a fuzzy ontology in transportation proposed by Houda et al. (2010), and a fuzzy ontology in tourism proposed by researchers in (Liu, 2013). regarding to the medical domain, fuzzy ontologies have been implemented in various domains such as; diabetes diagnosis and cancer diseases (El-Sappagh & El-Mogy, 2017; Elhefny, 2017). Yet it must be noted that this paper is the first CDSS based on fuzzy ontology in the hepatic fibrosis domain.

The conceptual model plays a principle role in medical data modeling and ontology construction. The remainder of the paper is organized as follows: Section 2 proposes literature review for the related studies; Afterwards, Section 3 discusses some preliminaries; Then, Section 4 presents the proposed Liver Fibrosis Diagnosis $\left(F_{LFD}\right)$ conceptual model; Then, Section 5 presents the implementation of the fuzzy ontology and ontology evaluation; finally, the last section provides a conclusion.

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