TEM Journal. Volume 8, Issue 3, Pages 801-805, ISSN 2217-8309, DOI: 10.18421/TEM83-15, August 2019.

Data Management in a Holter Monitoring System

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***Abstract* – The article presents a research on the methods for data organization and building semantic knowledge for a Holter Monitoring System. A conceptual scheme of this ontology is presented. The goal of this research is to study and identify parameters, analyze and classify data in HMS repositories using state-of-the-art technologies for analyzing and storing digital information, and building on-site HMC ontology.**

***Keywords* – Unstructured data, NoSQL, knowledge technologies, ontology, cardiology Holter Monitoring System.**

1. Introduction

The Holter Monitoring System (HMS) is one of the ways to study patients with deteriorated cardiac status from some diseases. As an element of modern specialized medical equipment for patient diagnosis, the HMS has common properties related to patient data and parameters received by software analysis of the HMC digital data. The results and automated analyzes obtained from such a study are a great help for medical doctor specialists to understand the exact condition of the patient and to make an accurate diagnosis.

DOI: 10.18421/TEM83-15
https://dx.doi.org/10.18421/TEM83-15

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Received: 10 April 2019.
Revised: 09 June 2019.
Accepted: 03 July 2019.
Published: 28 August 2019.

In this paper, we present the structure of the HMS digital archive using the expertise gained from its previous work on the semantic annotation of digitized materials. We define an OWL based presentation of the core objects and their relationships in the ontology of the HMS. This ontology extends the NoSQL database that is used to store and manage the data of Holter Monitoring System.

The methodology developed was implemented in the project "Study of the Application of New Mathematical Methods for Cardiac Data Analysis". In our research, we also consider some similar applications and we have explored appropriate approaches and techniques for creating and analyzing digital archives and libraries [6], [7]. Ontologies in the field of medicine have been developed in [3], [9].

2. Data organization techniques

2.1. Unstructured data

The term unstructured data (or unstructured information) refers to information in which we either do not have a predefined data model or are not organized in a predetermined manner. Unstructured information is usually text, but may contain data such as dates, figures and facts.

The data thus defined are distinguished by their very controversial and problematic nature to work with them:

- The term "unstructured" refers to the complete lack of organization in data creation. The term "database" (DB) means that the content of the database is structured. And this is an obvious contradiction;
- An unstructured database is one in which content is not strictly organized, but the model and format of the database is strictly structured;
- The main problem here is the appropriate form of storage so that the data can be reused for future search and querying.

In order to store and manage such a data we can use different approaches:

- Relational databases - the data is organized according to the relational model. Indexing and links allow quick, complex reporting. Leaves flexibility in the data model;
- NoSQL databases - flexibility in the organization that allows scalability. Non-standardized and low-effective search methods in data;
- Ontological and taxonomic models - used as an extra logical level on data management systems. They use metadata to fine-tune queries.

2.2. NoSQL databases

NoSQL databases introduced a new data managing mechanism that uses a flexible model, in contrast to relational database [12]. As a result, the user has a more straightforward design and horizontal scaling of information. A non-relational database is a well-optimized repository containing key-value information. It aims to optimize data adding and retrieving and to improve performance in case of system latency and big data processing. The non-relational database has a significant and growing role in real-time web and large data applications.

The non-relational database has a distributed and fault-tolerant architecture, and information objects are stored on multiple servers. In this way, the system can be protected by adding more servers and then, if a server fails, it continues to work. This database type expands horizontally and is used to manage a large amount of data when performance is more important than the sequence.

A schema of a database is the structure of the system described in a formal language that is supported by the database management system. In relational databases, the schema defines the tables, their fields, and the relationships between them. In NoSQL, the collection is a group of documents, each of which represents a row, and the collection resembles the tables of relational databases. Collections do not have a schema, which means that different types and structure documents can be contained in a collection.

Scaling horizontally means adding more nodes to the system. In NoSQL, data retention can be much faster because it takes the advantage of horizontal scaling and distributes data between nodes.

The features of NoSQL DB described so make them particularly suitable for presenting data related to the holter system. With their help, it is very easy and efficient to describe the different types of features of the various objects in the archives as well as the links between them. It also allows for rapid competitive access to data by multiple users at once, which is the most common case of using such a data.

2.3. Semantic Web

Usage of ontology techniques has its applications in various scientific fields, for example in the digital presentation of cultural heritage [13]. Ontologies have become common, especially in the global network. Ontology provides researchers with tools for sharing data and knowledge in a domain. It contains terms, concepts and relationships between them that could be automatically processed. Using a common language to describe the structure of information is a key point in the development of ontologies [10].

Ontology is a formal description of concepts called classes, properties and limitations [5]. Ontology is a set of objects of these classes representing a knowledge base. Classes represent the concepts in the specific knowledge base. Class hierarchy could also be applied in order to represent more detailed concepts. Properties are used to explain attributes of classes.

3. The Holter system data organization

The aim of this research is to develop an archive containing a detailed description of the system parameters and to develop a digital archive for analysis and storage. Digital archive HMS meets the following parameters:

- To support digital data of different types - text, numbers, graphics, multimedia, etc.
- The data can be unstructured.
- Meta data can be used.

The data in the HMS archive are varied and possible repetitions of some or others missing and divided into several basic types:

- Patient data - names, age, sex, address;
- The patient's health status;
- Holter records – including parameters measured by the ECG, technical data, description of the examination, history and objective status of the patient during the examination, results and other;

- Technical data;
- Medical researcher details;
- A nomenclature of necessary medical data;

Parameters obtained after ECG software analysis:

- HR: Average heart rate;
- Min HR: Minimum heart rate;
- Max HR: Maximum heart rate;
- VE: Chamber extra systole;
- VE Pair: Chamber Pair;
- VE Run: Camera Rhythm;
- VE Big: chamber binomania;

- VE Trig: Chamber trigeminal;
- SVE: atrial extra systole;
- SVE Pair: Atrial Pair;
- SVE Run: Atrial Rhythm;
- SVE Big: Atrial bursa;
- SVE Trig: Atrial Trigeminal Anemia;
- L: Long pause

4. Data management in Holter Monitoring System

The use of ontological and semantic technologies in HMS allows for a great deal of flexibility in the processing of unstructured data obtained from the study. For this purpose, it is necessary to construct an ontological structure describing the field of this research.

4.1. OWL Ontology

We organize data from patient's examination and Holter results in an ontological model. This knowledge base is represented in Figure 1.

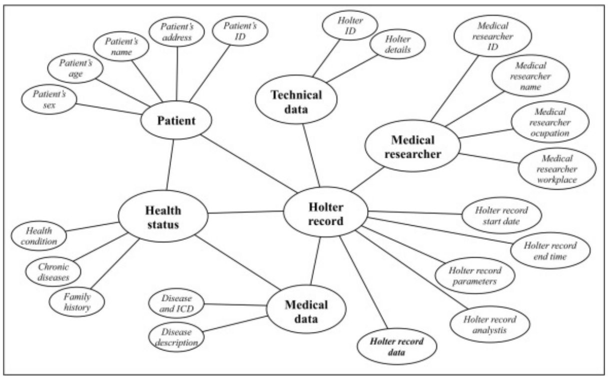

Figure 1. HMS Ontology

This scheme shows the basic HMS ontology classes (Patient, Holter examination, Technical data, Medical researcher, Other medical data, etc.) and their properties. To organize OWL elements of HMS ontology we use Protégé platform [11].

In OWL ontology we have the following elements [1], [2], [4]:

Individuals - objects in the specific domain. In our case this is each different record of Holter examination or patient.

Properties - represents correspondence between individuals. For example, the property <has_been_done_on> might link the individual <EKG_000001> to the individual <Patient_000001>, or the property <has_EKG> might link the individual <Patient_000001> to the individual <EKG_000001>. Properties can have inverses. For example, the inverse of <has_been_done_on> is <has_EKG>. Properties could also have their specific restrictions like functional or transitive.

Classes – these are templates for individuals. For example, the class <EKG> represents individuals that are EKG examinations in our fields of knowledge.

Hierarchy could be applied to classes. An OWL class could also be considered as a set of rules and conditions that individuals should satisfy in order to be a member of the class.

In Protégé platform all classes are in Classes Tab. Initially ontology contains one class called <Thing>. It is the root class of all other classes. Direct sibling of it is the HMS main class <HMS>.

Using the given scheme we add other classes and subclasses.

After that we apply OWL Properties. There are three basic types of properties: Object, Datatype and Annotation. **Object properties** are binary connections between individuals. **Annotation properties** represent metadata of the classes, individuals and properties. **Datatype properties are** used to add limitations to the class states. Properties in Protégé platform are managed in the Object Properties tab.

Example properties:

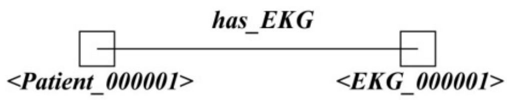

Figure 2. Example 1. An Object property.

An Object property linking the individual <Patient_000001> to the individual <EKG_000001>.

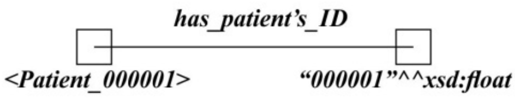

Figure 3. Example 2. A Datatype property.

A Datatype property linking the individual <Patient_000001> to the data literal "000001", of type "xsd:float".

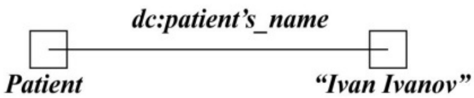

Figure 4. Example 3. An Annotation property.

An Annotation property, connecting the class Patient to the data literal "Ivan Ivanov".

Next step is to use another key point of OWL-DL language - reasoner. Using it we can test if class is a subclass of another class and is it possible for a given class to be instantiated.

4.2. Usage of NoSQL databases and ontologies for data search

The main problem in NoSQL DB is the lack of a schema and a standardized declarative query language. This leads to the need for individual solutions to the problem of choosing a set of data and accessing different parts of the database. For the purpose of managing search in the holter data archive we choose an approach whereby data is stored in a non-relational database. The non-relational database is extended with an ontology model based on the pre-metadata annotation. Different approaches can be used to link the two layers. When using standardized languages for semantic queries like SPARQL, it is possible to use external libraries or to develop specific API functions to translate queries from semantic to procedural level. There are also a number of specialized languages for semantic-procedural access to data in NoSQL database, which in certain situations give a number of advantages over SPARQL or other similar languages.

The approach described above can be implemented successfully in most of the cases of unstructured DB. In the specific case of the bell archive, the data for individual objects is stored in the MongoDB database. MongoDB is a system for processing database databases [8]. Instead of storing information in tables, as with traditional relational databases, MongoDB keeps storing structured information in JSON format with dynamic schemas. This makes integrating information in certain applications much easier and faster. As a mediator between the developed ontology model and the data, Tripod-PHP is used. This is a RDF data management system stored in MongoDB. Tripod-PHP gives a number of productivity benefits in case you:

- The number of queries is large, but the number of queries is relatively small;
- The reading/writing balance in the database is in the order of > 10: 1

Tripod-PHP does not support SPARQL queries, instead uses a SPARQL-like DESCIBE/SELECT language that gives a number of advantages. However, there are also versions of the Tripod library that support SPARQL if this is a requirement for a particular application.

The use of NoSQL database and search ontologies proved to be a good choice for presenting, organizing and retrieving data from the Holter system.

5. Conclusion

The contents of repositories of physiological information should be well structured and efficiently organized - one can seek to locate information easily and quickly, preferably as unstructured data.

Holographic ECG records (24, 48 and 72 hours) are used for the processing and analysis of automated methods because of the huge amount of information that is generated.

To overcome the complexity of writing complex search queries and detecting semantic links between the data, this article focuses on the presentation of knowledge and the interactive generation of requests through ontologies. Presented are researches and methods for semantic web presentation of digital data in the field of medical systems and building ontology for holter monitoring system. Effective organization of unstructured data was also explored, which is a suitable method of organizing data in the field of medical systems.

Acknowledgements

This work has been partially supported by the National Science Fund of Bulgaria within the "Study of the Application of New Mathematical Methods for Cardiac Data Analysis" project, contract No. KP-06N22/5.

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