Towards Interoperable Ontologies: Blood Test Ontology with FOAF

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Abstract— **Healthcare systems around the globe are changing their information systems in order to be able to share and reuse patients' information not only in a department where the information is produced, but also between the departments of an organization and also among the different health organizations or other institutions. For this purpose, lots of data standards and ontologies are developed in the health care domain. `BloodTestOntology`, which is introduced in this work, describes the substances found in the blood to help physicians in making a diagnosis. Friend of a Friend (FOAF), a well-known ontology for defining personal information, is extended to define required relations for the health care domain. `BloodTestOntology` is integrated with extended FOAF ontology in order to create an interoperable treatment system with other information systems. The proposed model can be used for personalized treatment suggestion systems.**

Keywords- BloodTestOntology; Extended FOAF; Healthcare Information Systems; Interperability; Semantic Web.

I. INTRODUCTION

Information technology attempts to meet the demands for all kinds of services from anywhere and at anytime, with the help of today's current technologies and Internet infrastructure. Internet activities like e-commerce, banking, paying taxes, tourism, etc. have become common, as well as the searching for information and using the social media [1]-[5].

Healthcare is a lifelong requirement for any person. The healthcare domain is an area where people, different organizations and various institutions get services, as well as provide services at the same time. To meet the requirements of receiving and delivering health care services with high quality, efficiency and also ensuring continuity, means using resources that are geographically dispersed. Also, more privatized structures have emerged. As a result, the patients' health information has become dispersed and specialized.

Health authorities also began to create health information systems for healthcare services with the successful implementations of information technologies in various domains. The preliminary applications are the systems that record the administrative data like patients' name, surname, address, insurance, etc.

It is desirable to be able to share and reuse the data not only in the system where the data is produced, but also between the systems that need that data. Until recently, it was not reasonable to share a patient's data between the departments of healthcare organizations. Reusing health data of a person in any health organization where he/she is admitted for a health service can accelerate the diagnostic process, while reducing material costs in healthcare.

The Semantic Web is defined as the extension of the current Web where information is given in a well-defined meaning and leads to a better collaboration between computers and humans [6]. The Semantic Web studies focus on developing domain specific ontologies, as well as semantic recommendation systems and decision support systems for defining semantic rules using these ontologies.

In recent years, lots of different ontologies in various domains have been developed with the increasing popularity of the Semantic Web studies. Although interoperability between systems is desired, the developed ontologies must be reusable. When these ontologies are examined, it is seen that the ontology can be used only in the system for which it is developed, whereas it is impossible to share and reuse information between different systems.

Blood is a red liquid that circulates the whole body by vessels. The main task of the blood is to transport the necessary oxygen and nutrients to the cells. When a patient consults a physician with any complaint, after listening to the patient's medical history, the physician requests some medical tests. The priority is always given to the blood tests in order to analyze the substances found in the blood.

`BloodTestOntology`, which is introduced in this work, aims to model the substances measured from the blood during the blood test with the help of the Semantic Web technologies. Blood Test Ontology describes the blood tests being done in the health field, the relationships between these tests, their results and the rules. Thus, developing a knowledge base for a system that can query and reuse the stored information of the personalized test results of blood tests would be provided.

Friend of a Friend (FOAF) is a project that is the most common document to represent the demographical properties of a person. It is represented in RDF (Resource Description Framework) [29]. FOAF is widely used inside various domains to describe personal information [7].

In this work, FOAF is used to describe the patients' information with demographic and dynamic properties and also to describe the personal health information. Connecting FOAF with the `Blood Test Ontology` to use personal information descriptions in FOAF provides an interoperable, personalized and more manageable personal data. A personal health care system needs not only personal information, but also information about the person's parents and/or his/her family. Defining this information with FOAF must support extendable, open and sharable data that could be used as the basic description to create a personalized health information system. By using FOAF, the patient can have full control over his/her data and the system can give a personalized experience to him/her during his/her own treatment.

The paper is organized as follows. Section 2 presents the relevant related work. Section 3 explains the knowledge representation and development of the `BloodTestOntology`. A brief explanation is given for the extended FOAF ontology. Later, the integration of extended FOAF and `BloodTestOntology` is described. Finally, Section 4 concludes and outlines the direction of the future work.

II. RELATED WORK

The healthcare domain is one of the few areas that has a huge amount of domain knowledge. If the ontologies developed in the health care domain are examined, it is seen that the studies focus on defining the medical terms of the domain [8]. Infectious Disease Ontology (IDO) [9] [10], Saliva Ontology (SALO) [11] and Blood Ontology (BLO) [12] are ontologies that are described by formal ontology languages. IDO provides a consistent terminology, taxonomy, and logical representation for the domain of infectious diseases [9]. IDO has 185 concepts, but does not ahve any object properties between these concepts and data properties. IDO covers the terms common for all infectious diseases, but diseases themselves are not defined in the ontology. SALO [11] is defined as a consensus-based controlled vocabulary of terms and relations dedicated to the salivaomics domain and to saliva-related diagnostics. SALO is an ongoing exploratory initiative. BLO is designed to serve as a comprehensive infrastructure to allow the exploration of information relevant to scientific research and to human blood manipulation [12]. It is an ongoing project and the development of the ontology is still a work in progress. BLO describes the structure, diseases and abnormalities of the blood.

FOAF is a vocabulary [30] to define personal information using people-related constructions in a structured data. This personal information includes demographic information such as name, family name and birthday in addition to online information such as mailbox, homepage, URL and much more. FOAF is used in many different applications. In research areas, such as distributed access right management [13], policy and profile integration [14] and Social Web Integration [15], FOAF is widely used to represent personal information in addition to social/friendship networks. Profiling and linking personal information is an important asset for collaborative filtering recommender systems. Film Trust [16] is one of the collaborative recommender systems that use FOAF to represent all kinds of personal information. Moreover, FOAF is used to interview the overall social information [17] and user preferences [18] [19]. Analysis of FOAF documents shows that most used FOAF attribute is `mbox_sha1sum`, which is the unique representation of email address and a necessity for FOAF vocabulary. FOAF is also used to infer characteristics of user habits [20]. All of these applications use FOAF. FOAF is the most used RDF vocabulary due to its simplicity, well documented and easily applied tools, such as FOAF-o-Matic [31] and FOAFpress [32].

III. CONNECTING FOAF WITH BLOOD TEST ONTOLOGY

A. Blood Test Ontology

In the health care domain, blood tests contain information that might be used by any clinic. The same tests are unfortunately performed repeatedly when the patient goes to different clinics in the same hospital or different hospitals. This causes waste of time for the diagnosis of disease as well as an increase in healthcare costs.

Blood tests can be used for the following reasons:

- to analyze the general state of a person’s health,
- to confirm the presence of a bacterial or viral infection,
- to see how well certain organs, such as the liver and kidneys, are functioning,
- to screen for certain genetic conditions, such as cystic fibrosis or spinal muscular atrophy,
- to check what medications the person is taking,
- to analyze how well the person’s blood is clotting,
- to diagnose diseases and conditions such as cancer, HIV/AIDS, diabetes, and coronary heart disease,
- to find out whether the person has risk factors for heart disease.

The blood test results may fall outside the normal range for many reasons. Abnormal results might be a sign of a disorder or disease. On the other hand, diet, menstrual cycle, physical activity level, alcohol intake, and medications can also cause abnormal results. Many diseases and medical problems can not be diagnosed with blood tests alone. However, blood tests can help the physician to learn more about the patient's health status. Blood tests can also help to find potential problems early, when treatments or lifestyle changes may work best.

`BloodTestOntology`, developed in this work, aims to model the substances measured from the blood during the blood test by using Semantic Web technologies. It describes the blood tests being done in the healthcare domain, the relationships between these tests, the results of these tests and the rules about them according to the related domain.

`BloodTestOntology` provides information about the blood test results to physicians, health workers and patients. In this work, we aim to represent the recent blood test result status with the `BloodTestOntology` and to use it as a part of an information base for the clinical information system. Thus, it could be used to give services to patients and health workers to organize blood information, to support the clinical decision system and to improve the clinical trials. The primary objectives of the `BloodTestOntology` are performing interoperability, sharing information and providing reusability in the healthcare domain.

`BloodTestOntology` has $\mathcal{ALCRIQ(D)}$ DL expressivity with 159 classes, 75 object properties and 35 data properties. The main goal of developing this ontology is using it as an information base for clinical information system. The `BloodTestOntology` is still being developed and extended with new concepts, object and data properties with domain experts from Ege University, Faculty of Medicine [33] according to the Medical Faculty's implementation clinics.

`BloodTestOntology` has a hierarchical structure as seen in Fig. 1. A medical test can be any test that is applied to a patient to assess patient's general state of health. In `BloodTestOntology`, these tests correspond to the human body fluids, such as blood, saliva, stool and urine with the concepts of `BloodTest`, `SalivaTest`, `StoolTest` and `UrineTest`, respectively.

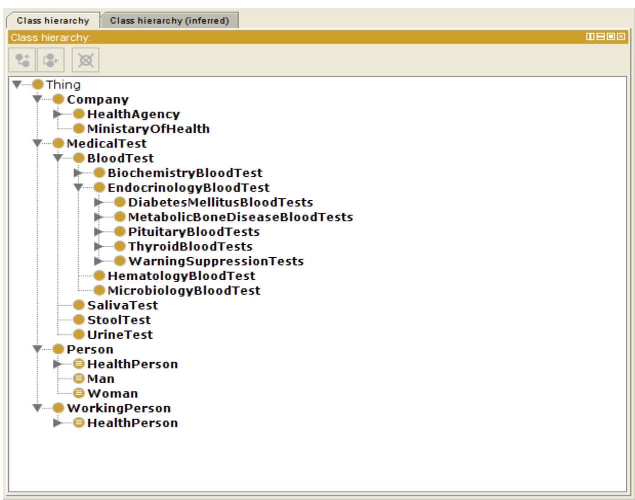

Figure 1. The basic concepts of The `BloodTestOntology`.

In this work, we have focused on the substances of the blood that are measured to analyze a patient's general state of health. The core concepts of a blood test that are defined in `BloodTestOntology` like FT3, FT4, HDL Cholesterol, LDL Cholesterol, etc. do not exist in the current blood ontologies in the literature. In hospitals, the blood is analyzed in four different laboratories that are endocrinology, biochemistry, microbiology and hematology, respectively. By taking these situations into consideration, we classified the blood test concept into four sub-concepts: `EndocrinologyBloodTest`, `BiochemistryBloodTest`, `MicrobiologyBloodTest` and `HematologyBloodTest`. For example, the blood tests like `Hemogram` and `Giemsa` are defined as sub-concepts of `HematologyBloodTest`, blood tests about thyroid like `TSH`, `FT3` and `FT4` are defined as sub-concepts of `EndocrinologyBloodTest`. As the reference values may vary according to the test laboratory, patients' age or gender, the reference values of the substances, which are test concepts, are not defined as data properties.

B. Integrating Blood Test Ontology and FOAF

The data can be reused between the systems without changing its given definition in order to provide interoperability. Using ontologies as the information base for the systems, the given definition of data can be provided. However, creating ontologies for the specific domain makes it difficult to get data with its metadata. For this purpose, integrating ontologies with the concepts that have the same meaning presents a useful solution.

Defining personal information as a concept in ontologies is quite familiar (more than 1,000 RDF documents have defined terms containing 'person') [21]. Literature works [22]-[27] provide a vision and various examples of FOAF extensions that can be used to support Web-based information systems. In [28], a comparison of FOAF documents is given.

In this work, FOAF ontology is integrated with the `BloodTestOntology` through the concept "`Person`". First, we extended FOAF ontology with proper data and object properties. The difference between our extended FOAF ontology and the FOAF is given in Table 1. For example, FOAF has only one object property "`knows`". However, in our extended ontology the new object properties, "`has Age`", "`hasIncome`", "`hasOccupation`", etc. are inserted.

Later, the concept "`Person`" in `BloodTestOntology` is imported from the extended FOAF ontology. In this way, data properties like "`firstname`", "`surname`", "`birthday`" and "`agevalue`" can be used in `BloodTestOntology` without describing these properties again. The relation between these ontologies is shown in Fig. 2.

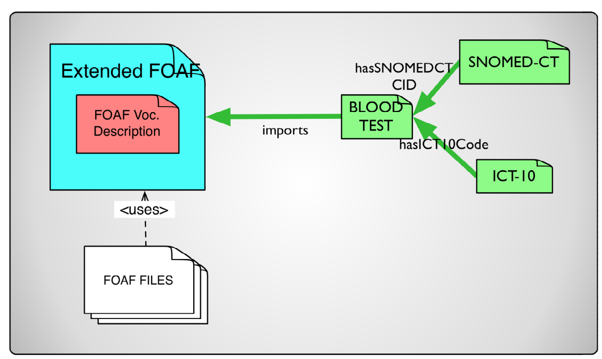

Figure 2. The structure of the integrated model.

As seen in Fig. 2, `BloodTestOntology` also includes the related SNOMED-CT [34] conceptIDs and ICD-10 [35] codes. Thus, when there will be another information system using the SNOMED-CT vocabulary, that system could exchange health information with a clinic information system which is using `BloodTestOntology` as the information base.

TABLE 1. THE EXTENDED FOAF ONTOLOGY.

Class Definition	**Information**	**SubClass/SuperClass**
Income	Income values of a Person/Income Set of a Profile	None
Occupation	Occupation of a Person/Occupation Set of a Profile	None
Age	Age Value of a Person/Age Values Set of a Profiles	None
Object Type Properties	**Domain**	**Range**
hasAge	Person	Age
hasIncome	Person	Income
hasOccupation	Person	Occupation
hasProfiles/isProfileOf	Person/MetaProfile:Profile	MetaProfile:Profile/FOAF:Person
hasPreferences/isPreferenceOf	Person/MetaPreference:Preference	MetaPreference:Preference
preferredDomain	Person	PreferenceVersusDomain
Data Type Properties		
ageValue	Age	xsd:integer
incomeValue	Income	xsd:integer
occupationValue	Occupation	xsd:string
Is	one of{income, Age}	xsd:integer
can-be	Occupation	xsd:string

IV. CONCLUSIONS

In this work, an information base that would be the knowledge base for a treatment system has been created to provide interoperability and to reuse health data. In order to perform this, the health standards ICD-10 codes and SNOMED-CT ConceptID are inserted inside the `BloodTestOntology`. Therefore, if any information system using SNOMED-CT vocabulary or ICD-10 codes that system could exchange health information with a clinic information system that is using `BloodTestOntology` as the information base.

Although blood tests are not sufficient to diagnose diseases, some blood tests named markers can show certain diagnostic results. For example, if a patient's Anti-HCV test is positive, this person can have chronic Hepatitis-C virus infection. Hepatitis-C is usually spread by blood-to-blood contact, so blood transfusion must not be done from these patients. The patient's family and friends can be at risk for this infection. By integrating FOAF ontology with the `BloodTestOntology`, the risk group could be determined easily with the defined rules.

As known, some blood test results have different reference values for genders or ages. Defining domain specific health rules on the integrated extended FOAF with `BloodTestOntology` can also support the creation of personalized treatment suggestions for patients. As taught in medical schools that *there is no illness, there is the patient*; it could be used to give services to patients and health workers to organize blood information, to support the clinical decision system and to improve the clinical trials.

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