Conceptual Model of External Fixators for Fractures of the Long Bones

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Abstract - Efficiency and effectiveness of a surgery for bone fractures can be achieved by making the proper decisions in a short period of time, based on complete and updated information on the status, type of fracture and the type of fixators used for a particular fracture. This way, the risk of possible complications, caused by the late intervention can be reduced. Application of ontologies contributes to achieving this goal. This paper presents the development of a conceptual model of external fixators used for fractures of long bones. This conceptual model is represented by the ontological framework in which the product ontology is mapped with the ontologies of bones and fractures. In this paper, we present only the process in which the product ontology is extended to describe the two types of the external fixators, namely: external skeletal fixator "Mitković" and hybrid external fixator.

I. Introduction

One of the major challenges of modern health care organizations is to improve the quality of health services. To achieve this goal, health care organizations are using standardized clinical protocols, in many medical domains [1]. These protocols are now represented in variety of different formats, languages and formalisms. This variety is considered as a significant obstacle for interoperability of the models, as well as of the respective systems that are using those models.

One way to resolve this problem, namely, to achieve the unique representation of the clinical models and protocols is to use the ontologies.

According to [2] "An ontology is an explicit specification of a conceptualization." Ontologies can provide a significant contribution to the design and implementation of information systems in the medical domain. The role of ontologies in the integration and harmonization of heterogeneous knowledge sources is already considered by many researches, especially in the field of clinical guidelines and evidence-based medicine [3].

The aim of the work behind this paper is to demonstrate that the ontologies can help in making the decisions regarding conceptually different notions in a healthcare, i.e. medical products and anatomy features.

Since these notions are handled in the different information systems, within or outside the clinical domain, we indirectly aim at demonstrating that these systems can be made interoperable. Namely, based on the common, inter-related models, the respective systems that are using these models may exchange the relevant information, that is by default understood by all of these systems.

In specific, in this paper, we present the development of an ontological model of external fixators that are used for fractures of long bones. The paper considers two types of external fixators:

- The external skeletal fixator "Mitković";
- The hybrid external fixator.

Long bones are bones of the limbs and can be grouped into two categories:

- The bones of the upper limbs, i.e. bones of the hand, which include: Humerus, Radius, Ulna, etc.
- The bones of the lower limbs, i.e. leg bones, which include: Femur, Tibia, Fibula, etc.

The ontology is developed by extending the existing Product ontology. Some features of the bones and fractures for which the specific fixators are used are also modeled to reflect the possible relationships between the fixator ontology concepts and co-related concepts of the bones and fractures ontology.

II. Ontologies in Medicine

The use of ontologies in medicine is mainly focused on data management, i.e. medical terminologies. Data collection (grouping) is becoming one of the most important issues with which the researchers in the clinical domain are faced. Due to the inconsistency of the formats which are used to represent data, it is very difficult to develop generic computer algorithms for their interpretation. Researchers are tending to represent knowledge of their domain in an independent and neutral format so that data can be shared and reused in different platforms. This problem can be solved by using ontologies. Ontologies provide a common framework for structured knowledge representation. Ontological frameworks provide common vocabularies for concepts, definitions of concepts, relations and rules, allowing a controlled flow of knowledge into the knowledge base [4].

Domain of anatomy is domain of medicine in which, so far, ontologies are most commonly used. In the medical domain, the anatomy is a fundamental discipline that represent basis for most medical fields [5]. Formal anatomical ontologies are an important component of the informatics healthcare infrastructure [6], but also they are informatics tools used to explore biomedical databases. Structural relationship that is primarily used in these ontologies is part_of relationship, because the smaller anatomical entities are naturally seen as the components of the larger ones [7].

There are plenty of anatomical ontologies, clinical ontologies or ontologies of other domains in medicine, and some of the most frequently used ontologies are Foundational Model of Anatomy (FMA) and the Edinburgh Human Developmental Atlas (EHDA) ontologies. Anatomy of adult human is comprehensively represented with the FMA [8], and embryonic structures are modeled in EHDA [9].

The above mentioned ontologies, as well as the others that are used in the medical domain, cannot be applied in the development of the ontology for external fixators. The fixators are a type of products, which are used in medicine, and they do not directly represent the human and/or anatomy.

III. Ontological Model of External Fixators

This chapter gives a description of ontology of external fixators. Ontology is created by using OWL (Web Ontology Language) in the software package Protégé. OWL, adopted by the World Wide Web Consortium (W3C), is a semantic markup language designed for publishing and sharing ontologies on the World Wide Web. OWL was developed by expanding the Resource Description Framework (RDF) vocabulary and based on the experience of developing the DAML + OIL Web ontology language [10].

As it was mentioned before, the uniqueness of the stated problem is that it needs to combine the conceptual models of the products with the models of the anatomical features.

For the representation of the fixators, the Product ontology [11] is selected, for the reasons of its simplicity vs. the fulfillment of requirements related to modeling fixators and their features. The product ontology is mapped to UNSPSC product classification scheme [12], by using UNSPSC-SKOS ontology as a mediator. SKOS [13] is a family of formal languages, built upon RDF and RDFS for representation of thesauri, classification schemes, taxonomies or other type of structured controlled vocabulary.

Product ontology consists of the following classes (concepts): part, feature and product; one transitive and one non-transitive property: hasPart and hasFeature; with appropriate inverse properties: isPartOf and isFeatureOf, as well as one data property: hasValue.

In addition, one class (inferred class) is defined as:

```
assembly ≡
((∃hasPart.Part) ∩ (∃isPartOf.Part))
```

Some concepts and features, relative to alignment of the Product ontology with UNSPSC-SKOS ontology are discarded in this overview.

After importing the Product ontology in Protégé, it is extended with a specific information about the external fixators.

The first step was to create a subclass fixator, which belongs to the class of product. There are many different types of fixators, but this paper considers only two types of external fixators, represented as certain instances. External fixator "Mitković is labeled as instance external_fixator, while hybrid fixator is labeled as instance hybrid_external_fixator. Each of these fixators consists of the certain elements. Hence, the next step in the extension of the Product ontology was to create the subclasses of part class that will represent these elements. These elements are, as follows:

- Rod;
- Screw;
- Lateral supporting element;
- Clamping ring on the lateral supporting element 1;
- Clamping ring on the lateral supporting element 2;
- Screw nut;
- Washer;
- Clamping ring plate on the clamp ring 1;
- Clamping ring plate on the clamp ring 2;
- Ring;
- Wire.

Each of these elements represents a subclass of a part class, and each of them contains instances, corresponding to the specific elements of two fixators.

For instance, subclass lateral_supporting_element contains the instance lateral_supporting_element_1. Structural dimensions of elements fixators depend on the certain dimensions, i.e, features, so the feature class contains a subclass named dimension. Class dimension contains subclasses of characteristic features that may affect the structural dimensions of fixator elements. These features are:

- Diameter of the bone;
- Diameter of the lateral supporting element;
- Diameter of the limb;
- Diameter of the ring;
- Diameter of the rod;
- Diameter of the screw;
- Distance from fracture;
- Length of the bone.

Note that some of the features above are the features of the bone and not of the fixator itself. However, these features are represented at the level of the product, in order to facilitate the selection of the proper fixators, based on the features of the bone and its fracture. This aspect of the work behind this paper is published elsewhere.

Each of features of the specific parts are modeled by the respective individuals. For example, class diameter_of_the_bone contains the instance diameter_of_the_bone_1.

Figure 1 shows the class hierarchy of ontology of the external fixators. The only element of the considered external fixators that has the variable dimensions, and depends on the above mentioned features is the rod.

On the dimension i.e. the length of the rod affects the length of the bone (feature length_of_the_bone), while other elements of fixators have standard dimensions, regardless of the length of the bones or other features.

In the paper, as an example, the two lengths for each of the bone are used. Hence, subclass length_of_the_bone contains two instances for each of the long bone, i.e. total of 12 instances (length_of_the_bone_1, length_of_the_bone_2 ... length_of_the_bone_12). Each instance is defined by the data property hasValue and length given in millimeters. Hence, for example, for the length of the bone of 385.22 mm, which is represented with instance, property is defined as:

```
length_of_the_bone_1 hasValue 385.22 mm.
```

For external fixators, there are five different rods in standard dimensions, which can be used for different lengths of bones. Therefore, subclass rod contains 10 instances, 5 per each type of fixator (rod_1, rod_2, ..., rod_10), and each instance is associated with a non-transitive property hasFeature with certain feature length_of_the_bone. This means that the one length of the rod can be applied for fractures of long bones whose length are in a certain range.

The external fixator "Mitković" consists of the following elements: Rod, Screw, Lateral supporting element, Clamping ring on the lateral supporting element 1, Clamping ring on the lateral supporting element 2, Screw Nut, Washer, Clamping ring plate on the clamp ring 1 and Clamping ring plate on the clamp ring 2.

Instances rod_1, rod_2, rod_3, rod_4 and rod_5 are elements of the external fixator "Mitković", while rod_6, rod_7, rod_8, rod_9 and rod_10 are the elements of the hybrid external fixator.

The following rules, related to selection of the specific parts, relative to the length of the bones are given:

- For the length of the bones up to 250 mm, rod_5 or rod_10 are used;
- for the length of the bones of 250-300 mm rod_4 or rod_9 are used;
- for the length of the bones of 300-350 mm rod_3 or rod_8 are used;
- for the length of the bones of 350-400 mm rod_1 or rod_7 are used; and
- for the length of the bones over 400 mm rod_2 or rod_6 are used.

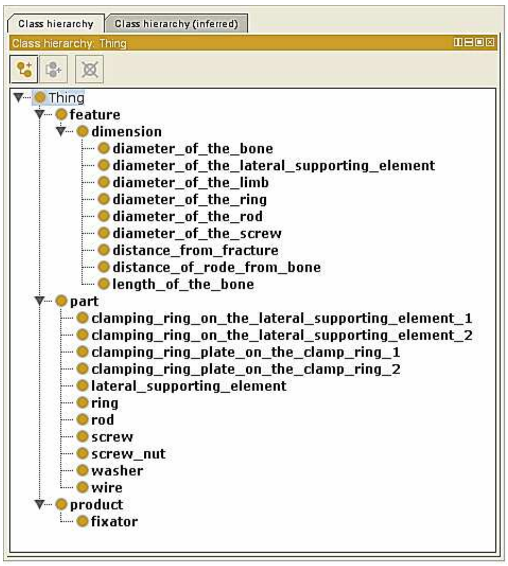

Figure 1. Class hierarchy ontology of external fixators

Relations between rod instances and length_of_the_bone are given below. Each rod corresponds to the different lengths of the bones. For the reasons of simplicity, in the below representations, there are labels of the corresponding lengths.

```
rod_1 hasFeature length_of_the_bone_(1,4,10)
rod_2 hasFeature length_of_the_bone_(2, 3)
rod_3 hasFeature length_of_the_bone_(5, 6, 7)
rod_4 hasFeature length_of_the_bone_12
rod_5 hasFeature length_of_the_bone_(8, 9, 11)
rod_6 hasFeature length_of_the_bone_(2,3)
rod_7 hasFeature length_of_the_bone_(1, 4, 10)
rod_8 hasFeature length_of_the_bone_(5, 6, 7)
rod_9 hasFeature length_of_the_bone_12
rod_5 hasFeature length_of_the_bone_(8, 9, 11)
```

The multitude of the rods above defines the families of the external fixator "Mitković" (external_fixator_1, ..., external_fixator_5) and the hybrid external fixator (hybrid_external_fixator_1, ..., hybrid_external_fixator_5). Transitive property hasPart connects instances of class fixator with instances of subclasses of part classes that represent the integral elements of fixators.

Relations between instances external_fixator_1, ..., 5, and instances of subclasses of part class are given below:

```
external_fixator_1,...,5
hasPart rod_1,..,5
hasPart screw_1
hasPart lateral_supporting_element_1
hasPart
clamping_ring_on_the_lateral_supporting_element_
1_1
hasPart
clamping_ring_on_the_lateral_supporting_element_
2_1
hasPart screw_nut_1
hasPart washer_1
hasPart
clamping_ring_plate_on_the_clamp_ring_1_1
hasPart
clamping_ring_plate_on_the_clamp_ring_2_1.
```

Hybrid external fixator has the identical integral elements as the external fixator "Mitković", with two additional elements: ring and wire.

Relations between the instances hybrid_external_fixator_1,...,5, and the instances the of subclasses of part class are given below:

```
hybrid_external_fixator_1,...,5
hasPart rod_6,..,10
hasPart screw_1
hasPart lateral_supporting_element_1
hasPart
clamping_ring_on_the_lateral_supporting_element_
1_1
hasPart
clamping_ring_on_the_lateral_supporting_element_
2_1
hasPart screw_nut_1
hasPart washer_1
hasPart
clamping_ring_plate_on_the_clamp_ring_1_1
hasPart
clamping_ring_plate_on_the_clamp_ring_2_1
hasPart ring_1
hasPart wire_1.
```

Figure 2 below presents a graphical representation of ontology of external fixators with all its elements and relationships between them.

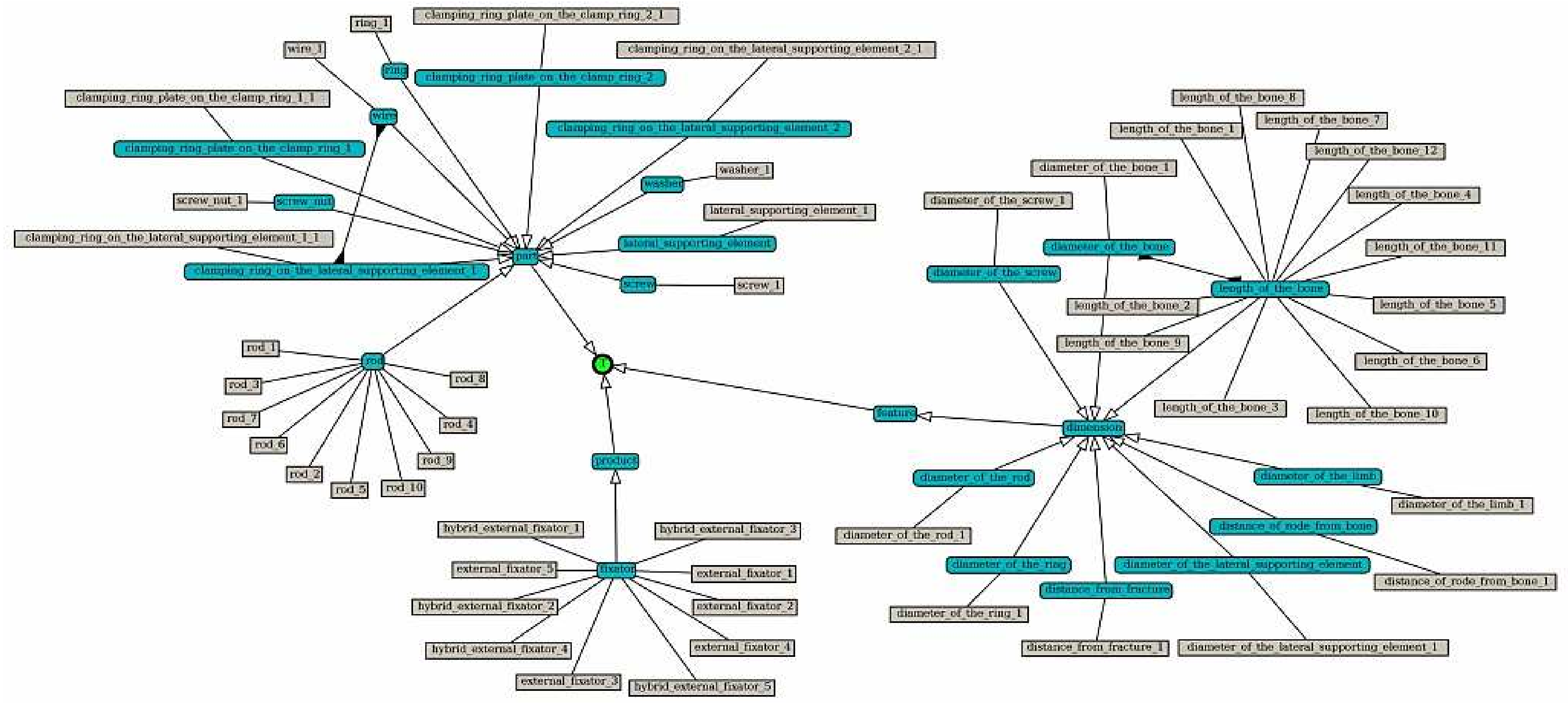

Figure 2. Graphical representation of the ontology of external fixators

IV. Conclusion

With the variety of models, standards, protocols and other formalisms for representing medical concepts and processes, the healthcare domain is one of the most diversified fields and test-beds for ontologies.

Many researches have already demonstrated the number of advantages of using ontologies in a healthcare. Ontologies can help in building more interoperable information systems in healthcare. They can facilitate transferring, re-use and sharing of patient data. Finally, ontologies can support the integration of the necessary knowledge and information in healthcare.

In this paper, we present the approach, in which a medical product can be represented by using the ontologies. Such a representation, when combined with the anatomy models, as well as the models of other concepts, such as the bone fractures, can facilitate the critical decisions which are currently made in the extreme conditions, e.g. during surgeries, thus suffering of many possible risks.

The presented ontology of external fixators, makes the basis for a further work, particularly for the development of an ontological model of fractures of long bones and for determining semantic queries for defining the impact of various factors on the selection of external fixators used for fractures. Currently, these factors, namely the relevant features of the bones are modeled as the features of the fixators parts.

In the future work, the ontology of fixators will be integrated in an ontological framework, consisting of product ontology, bone ontology and fracture ontology, with modeled relationships between the relevant concepts and features.

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