Interoperability of RehabRobo-Onto

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Introduction

The leading cause of permanent disability in developed countries is due to neurological injuries, such as stroke [1]: among 15 million people that suffer from stroke, 5 million are left permanently disabled each year. While physical rehabilitation therapy is indispensable for treating neurological disabilities, repetitive and high intensity therapies place high physical burden on the therapist and significantly increase the cost of such treatments. These challenges have led to design and development of various robot-assisted rehabilitation devices to bear the physical burden of rehabilitation exercises, while therapists are employed as decision makers.

As the number of rehabilitation robots increase, the information about them also increases, but most of the time in unstructured forms (e.g., as text in publications), which make it harder to access the requested knowledge and reason about it. Consider, for instance, finding out the flexion/extension range of motion (RoM) of the rehabilitation robot AssistOn-SE [2], or finding the rehabilitation robots that target shoulder movements and have at least 210° RoM for the flexion/extension movements of the shoulder.

Also, due to interdisciplinary nature of rehabilitation robotics, sometimes requested knowledge requires integration of further knowledge from related disciplines (e.g., physical medicine). Consider, for instance, finding rehabilitation robots that can be used to treat a patient with rotator cuff lesions. For that, we need to know that rotator cuffs are muscle units for moving the shoulder, and that, for patients with rotator cuff lesions, abduction and flexion movements of the shoulder should not have more than 90° RoM.

Motivated by these challenges, we have designed and developed the first formal rehabilitation robotics ontology, called RehabRobo-Onto [3], to represent knowledge about rehabilitation robotics in the structured form of OWL [4,5]. The main concepts and their relations are illustrated in Figure 1. In this abstract, we continue our studies RehabRobo-Onto by discussing its interoperability with the available knowledge resources, towards personalized physical rehabilitation therapies.

Methods

We investigate the interoperability of RehabRobo-Onto over complex queries, like:

> *FMA1.* What are the body parts that can be affected by some forearm robots?
>
> *FMA2.* What are the rehabilitation robots that do not affect a joint under synovial joint of free limb segment?
>
> *DO1.* What are the rehabilitation robots that can be used to treat shoulder impingement syndrome and that target the shoulder scapular elevation/depression?
>
> *DO2.* What are publications that reference some rehabilitation robots that can be used to treat hip enthesopathy?

These queries require integration of RehabRobo-Onto with relevant knowledge resources. For instance, the query *FMA1* requires some knowledge about human anatomy, which can be extracted from Foundational Model of Anatomy (FMA) [6]. Meanwhile, the query *DO1* requires some knowledge about some human diseases, which can be extracted from Human Disease Ontology (DO) [7].

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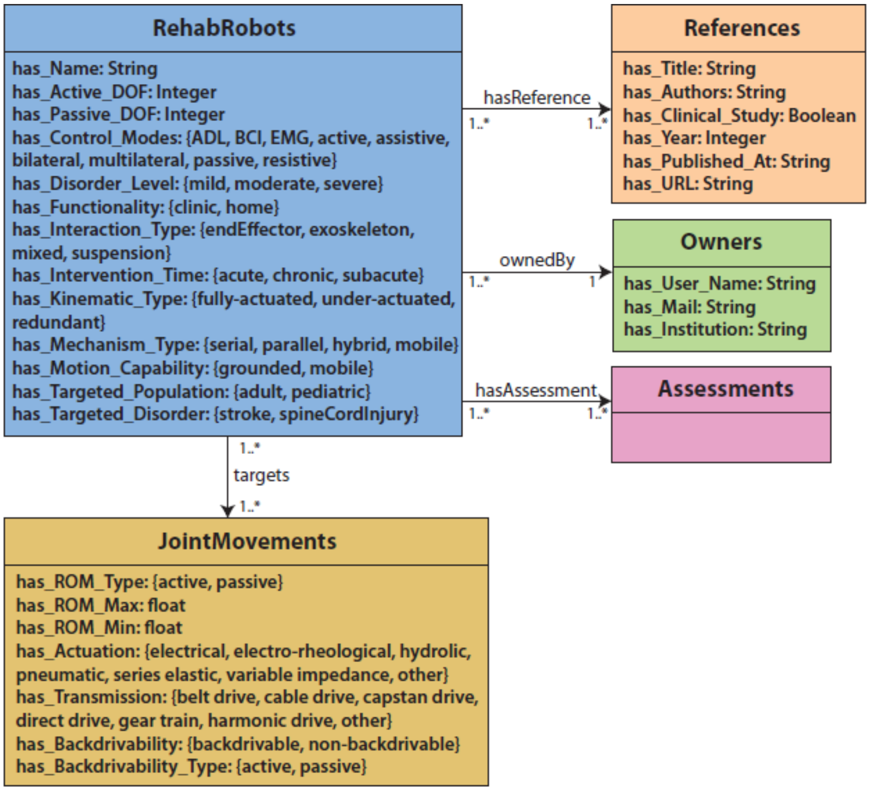

Figure 1 REHABROBO-ONTO with main classes [3, Fig.1]

By means of such complex queries over RehabRobo-Onto, right rehabilitation robots for a particular patient or a physical therapy can be found or designed. This further paves the way for translational physical medicine (from bench-to-bed and back) and personalized physical medicine.

To answer such complex queries, we may need additional information for integration of relevant knowledge. We utilize SWRL [8] to integrate relevant concepts. For instance, FMA models the concepts “Ulna” or “Radius” as constitutional parts of “Forearm”, and as regional parts of “Skeleton of forearm”, as shown in Figure 2. Both “constitutional_part_of” and “regional_part_of” are properties that are subproperties of “part_of”.

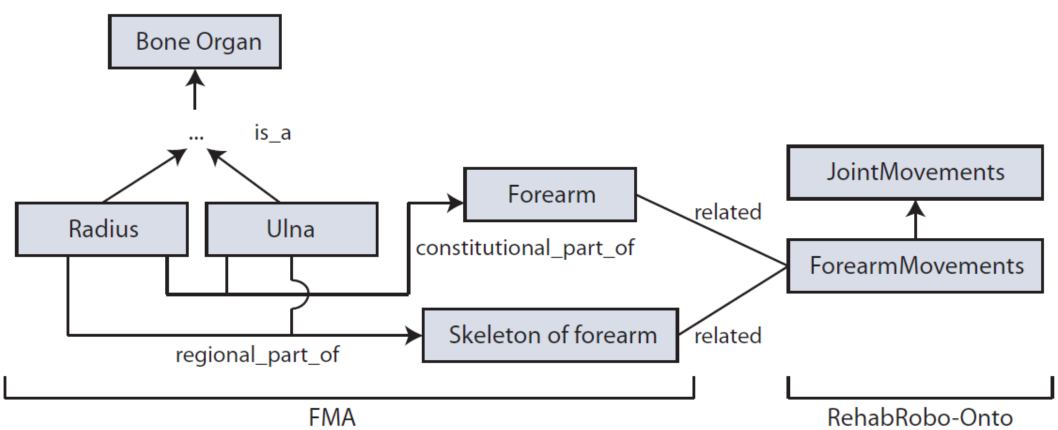

Figure 2 Hierarchy and integration of concepts in FMA relevant for FMA1.

These body parts are related to the joint movements by SWRL rules. To answer *FMA1*, we consider the following SWRL rules to identify the body parts that can be affected by forearm pronation or supination movements.

```
Forearm(?x) -> ForearmMovements(?x)
ForearmMovements(?x) -> Forearm(?x)
ForearmMovements(?x) -> 'Skeleton of forearm'(?x)
'Skeleton of forearm'(?x) -> ForearmMovements(?x)
```

With the availability of such SWRL rules, we represent the queries as SPARQL queries [9]. For instance, the following SPARQL query expresses *FMA*1.

```
SELECT DISTINCT ?bodyPartLabel
WHERE {
     ?robot rdf:type rr:ForearmRobots.
     ?robot rr:targets ?movement.
     ?movement rdf:type rr:JointMovements.
     ?movement rdf:type ?fmaConcept.
     ?bodyPart rdfs:subClassOf ?restriction.
     ?restriction owl:onProperty fma:part_of.
     ?restriction owl:someValuesFrom ?fmaConcept.
     ?bodyPart rdfs:label ?bodyPartLabel.}
```

With the SWRL rule stating that the instances of forearm pronation/supination movement are related to concepts about forearm, we can obtain related concepts in FMA using the variable of the related movement and `rdf:type` predicate.

Once we formulate the queries in SPARQL, we can compute answers using Pellet [10]. For instance, for the query *FMA1*, Pellet returns the following values for `?bodyPartLabel`:

```
"Radius", "Superficial fascia of forearm", "Vasculature of forearm",
"Neural network of forearm", "Ulna", "Skin of forearm" .
```

In a similar way, we can compute answers to various complex queries: identify a variety of complex queries with the help of experts, identify the additional information needed to answer such queries, represent the additional information in SWRL and the queries in SPARQL, and use an automated reasoner to find answers.

Results and Discussions

We have identified a variety of complex queries about rehabilitation robots, their targeted joint movements, and their relevant publications, that may be useful for treating a particular disease or targeting some part of the body. These queries necessitate further knowledge about human anatomy and human diseases. We have formulated these queries in SPARQL so that answers can be found using Pellet over relevant ontologies, with the help of SWRL rules linking the ontologies.

Our ongoing work involves integration of these ontologies with the patient data as well. In this way, we can answer complex queries, like

> What are the lesion locations of the patients that have been treated with the rehabilitation robot AssistOn-SE?

These queries take us further towards more personalized rehabilitation therapies using more appropriate rehabilitation robotics devices.

The design and development of a software platform to integrate RehabRobo-Onto with relevant knowledge resources is a part of our ongoing work.

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