Interoperability of REHABROBO-ONTO

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Neurological injuries are the leading cause of serious, long-term disability.

- Each year 17M people suffer stroke worldwide (60% survives)
- Currently 26M stroke survivors are estimated worldwide
- 1 in 6 people will suffer stroke in their lifetime

- Physical rehabilitation therapy is indispensable for treating neurological disabilities.
- Physical therapies are more effective when they are intense, repetitive and targeted.
Manual Rehabilitation

- Manual therapies are labor intensive and place high physical burden on therapists.
- Repetitive and physically involved rehabilitation therapies are costly.
- Due to high cost of manual labor, access to stroke rehabilitation is limited.
- Patient progress cannot be measured frequently and quantitatively.
- Accuracy and effectiveness of therapies are hard to track.
Rehabilitation Robots

- Robot assisted rehabilitation devices help decrease physical burden of the therapists and application related costs.
- Devices can quantitatively measure patient progress and make customized, interactive treatment feasible.
- They increase reliability, accuracy and effectiveness of physical therapy sessions.

AssistOn-SE (Yalcin and Patoglu, 2012)
Motivation

- As the number of rehabilitation robots increase, the information about them (e.g., properties of robots, targeted joint movements) also increases.

- Information in unstructured forms (e.g., text in publications) make it harder to access the requested knowledge and automatically reason about it (e.g., finding the rehabilitation robots that target shoulder movements).

- Interdisciplinary nature of rehabilitation robotics requires integration of further knowledge from related disciplines, such as physical medicine.

- There have been efforts for standardizing terminology as well as assessment measures for rehabilitation robots (e.g., by European Network on Robotics for Neurorehabilitation, IEEE-RAS Ontologies for Robotics and Automation Working Group).
RehabRobo-Onto

- The first formal rehabilitation robotics ontology.¹
- Designed considering suggestions of the rehabilitation robotics researchers and physical medicine experts.
- Developed in OWL 2 DL with OWL/XML syntax, using Protégé.
- Open-access and available on the cloud.²

¹Dogmus, Gezici, Patoglu, Erdem. Developing and maintaining an ontology for rehabilitation robotics. KEOD 2012.
²Dogmus, Papantiou, Kilinc, Yildirim, Erdem, Patoglu. Rehabilitation robotics ontology on the cloud. ICORR 2013.
Answering Queries about Rehabilitation Robots

- What are the robots that target some wrist movements with actuation='series elastic'? 
- What are the publications with clinical study and that do not reference any robots with active degree of freedom ≤ 1? 
- What are the movements that are targeted by some robots with (some intervention time or with all targeted disorders)? 
- What are the robots with no targeted disorder or (with intervention time!=‘chronic’ and with motion capability=‘grounded’) or with no disorder level?
We developed a software, REHABROBO-QUERY, with an intelligent and interactive user interface that allows

- robotics researchers to add/modify information about their rehabilitation robots,
- robotics researchers and physical medicine experts to ask queries in natural language.³

REHABROBO-QUERY is accessible on the cloud via Amazon Web Services.

³Dogmus, Erdem, Patoglu. Answering natural language queries about rehabilitation robotics ontology on the cloud. KEOD 2014.
RehabRobo-Query

What are the robots
What are the movements
What are the users
What are the publications
What are the effort metrics
What are the kinematic aspect metrics
What are the movement quality metrics
What are the muscle strength metrics
What are the psychomotoric aspect metrics

Query:

Answer

Next
RehabRobo-Query

Query: What are the robots that target some WRIST MOVEMENTS
RehabRobo-Query

Query: What are the robots that target some WRIST MOVEMENTS with actuation
RehabRobo-Query

Query: What are the robots that target some WRIST MOVEMENTS with actuation = 'series elastic'
Query: What are the ROBOTS that target some wrist movements with actuation = 'series elastic'? 

- AssistOn-Mobile
**RehabRobo-Query on the Cloud**

Interoperability of **RehabRobo-Onto**

Interdisciplinary nature rehabilitation robotics necessitate complex queries over different knowledge resources.

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

What are the body parts that can be affected by some forearm robots?

- FMA models the concepts “Ulna” and “Radius” as constitutional parts of “Forearm”, and regional parts of “Skeleton of forearm”.
- Both “constitutional_part_of” and “regional_part_of” are properties that are subproperties of “part_of”.

![Diagram showing the relationships between bone organs, forearms, and movements](image-url)
Integration with SWRL Rules

\[
\begin{align*}
\text{Forearm}(?x) & \rightarrow \text{ForearmMovements}(?x) \\
\text{ForearmMovements}(?x) & \rightarrow \text{Forearm}(?x) \\
\text{ForearmMovements}(?x) & \rightarrow '\text{Skeleton of forearm'}(?x) \\
'\text{Skeleton of forearm'}(?x) & \rightarrow \text{ForearmMovements}(?x)
\end{align*}
\]
Querying with **SPARQL usingPellet**

What are the body parts that can be affected by some forearm robots?

```sparql
SELECT DISTINCT ?bodyPartLabel
WHERE {
  ?movement rdf:type rr:JointMovements.
}
```

Pellet returns the following values for `?bodyPartLabel`:

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

Earlier work on \textsc{RehabRobo-Query}...

- Expressing queries about \textsc{RehabRobo-Onto} in natural language

- Answering these queries using automated reasoners

- Guiding the users to ask questions and presenting their answers in an understandable way
Discussion

Earlier work on REHABROBO-QUERY...

- Expressing queries about REHABROBO-ONTO in natural language
  - REHABROBO-CNL: A controlled natural language for queries
- Answering these queries using automated reasoners
  - Transformation of REHABROBO-CNL queries into SPARQL queries
- Guiding the users to ask questions and presenting their answers in an understandable way
  - Interactive, intelligent user interface for query answering
Discussion

Ongoing and future work on REHABROBO-QUERY...

- Expressing queries about REHABROBO-ONTO and other knowledge resources in natural language
  - INTERREHABROBO-CNL: A controlled natural language for queries

- Answering these queries using automated reasoners
  - Representing SWRL rules
  - Transformation of INTERREHABROBO-CNL queries into SPARQL queries

- Guiding the users to ask questions over multiple knowledge resources and presenting their answers in an understandable way
  - Interactive, intelligent user interface for query answering