Experiment MOTORE++ Home Based Rehabilitation (proof of concept)

MOTORE++: A new Rehabilitation Robot for the upper limb: refinement and experimental trials

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Version 1
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26.11.2015		

1 Publishable Summary

The goal is to develop a rehabilitation robot named MOTORE++ aimed to restore upper limb functionality in patients with neurological diseases and to assess his performance. This is a new haptic portable device, the first suitable for home based rehabilitation. Starting from a prototype developed in the last years, the project aims at delivering a small omnidirectional robot moving on *transwheel*, interacting with a patient providing assistance and force feedback during rehabilitation sessions. The software will allow to select among several exercises. Biomechanical studies of the interaction with the robot and on the arm impedance during exercises will be part of the Echord experiment.

During the last months the device underwent into a remote rehabilitation simulation in order to verify the possibility to lent the robot at home or in a rehabilitation center while the therapist or the medecinre are in a hospital. The results of a Tuscan funded project have been collected and used for ECHORD++.

2 Home based rehabilitation simulation

During the experimentation phase of the research project ASSO, funded by Regione Toscana, a simulation of home based rehabilitation has been set up and tested extensively.

The experimentation was made at the Auxilium Vitae institute in Volterra. The research project consisted in setting up a collaborative framework for the management of an integrated set of devices for the rehabilitation of patients needing care from multiple hospitals/premises.

The goal of the experimentation was to simulate how could a patient perform the rehabilitation at home, unsupervised. When the patient is admitted, he is assessed by the medical staff using traditional tools (assessment of motor skills with Fugl-Meyer or Ashworth assessment) and a rehabilitation strategy is decided for this patient. After this point, the rehabilitation starts. During the rehabilitation sessions, the medical staff would provide low assistance to the patient (to simulate home rehabilitation). They would just have to help the patient sit down in front of the robot and start up the exercises. At home, these operations could be performed by a relative. During the experimentation, no other *ambient intelligence* devices were used. It was considered that using these kind of sensors would be cumbersome, with difficulties of installation, and these information would have been useless for assessing the recovery of the patient.

Information about the (simulated) home rehabilitation was being sent to a remote server, and medical staff could access it (given the necessary authorisations and privilege levels) to judge the progress of the patient and take informed decisions about how to change the rehabilitation in order to improve it.

The remote server has been set up in the data center of one of the partner companies, and it has been set up as to permit access only to the staff of Auxilium Vitae. To avoid privacy issues, all data has been stripped of identification details. All patients have been given an unique id by the staff of Auxilium Vitae and they have been entered into the database only using this id. The table associating the patient identities with their IDs was never shared and Auxilium Vitae kept a hard copy of it.

The framework architecture allowed the integration of several components and so the integration required that:

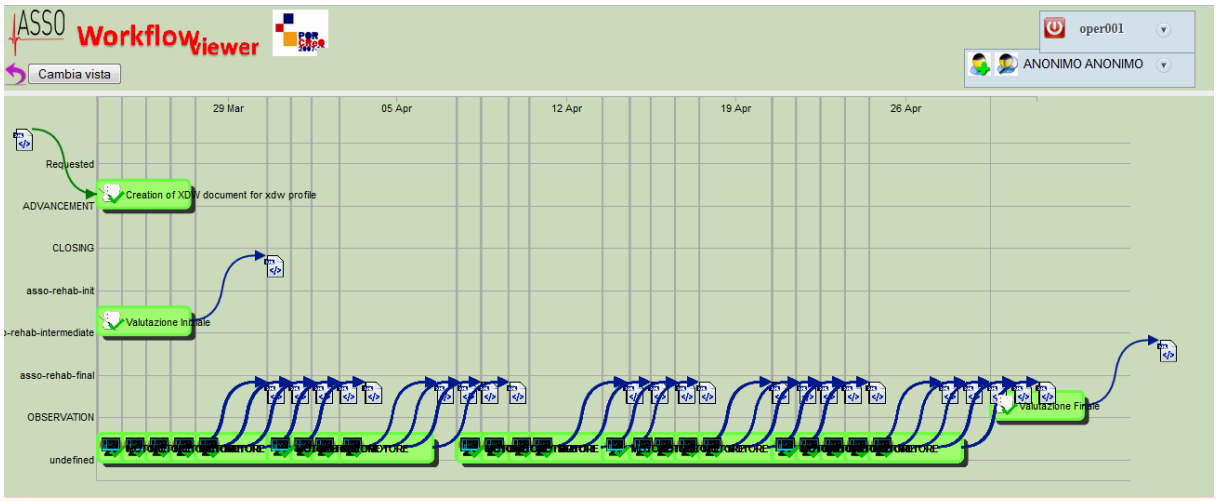
- The physiotherapists associate a unique ID with each patient and enter this ID both in the server database and in the robot software.
- The physiotherapists had to make an initial assessment of each patient using traditional tools and enter these assesments in the service website
- The robot PC had to produce a report after each exercise and send this report to the server, using the anonimous ID to identify the patient
- The physiotherapists had to make intermediate assesments and a final assesment and enter these assesments in the service website

In order to allow the robot software to communicate with the rest of the infrastructure it has been necessary to define a communication protocol for rehabilitation sessions data. The server-side application that has been used in this platform is the document handling platform called DEDALUS X1V1. The data sent to the server was XML-formatted and the was being sent through a service oriented interface.

After each rehabilitation exercise, the PC running the robot software would send an XML document containing exercise data to the server (exercise settings, exercise results, and a handful of images that could be used to summarize the exercise results at a glance). As stated earlier, sensitive data is not being sent away. The medical staff can insert a clinical assessment of the patient in the document stream by entering it directly in the service website; a data entry page has been designed for the purpose.

Thus, the stream of documents pertaining to a patient contains traditional evaluations (inserted by medical staff) and robot evaluations (sent automatically by the robot's PC at the end of each exercise). The stream of documents could be accessed by the authorised medical staff, so that they could examine it and take decisions regarding the treatment.

An example of a patient therapy workflow is shown in the picture below:



The default view shows the whole therapy cycle, but a user can zoom in the time-scale and open individual documents to examine them.

The stream of documents puts together quantitative information that comes from the robot therapy with qualitative information that comes from medical evaluations. In this way it's possible for the medical staff to judge if the patient has reached a recovery plateau and can therefore end the therapy since it is not effective anymore.

This has been an important aspect of the experimentation, according to the medical staff, since traditionally it has always been very difficult to recognize this effectiveness plateau since traditional assessments are very time consuming and cannot be performed very often. Moreover, these data will remain accessible even during later stages of the treatment, so that other operators could be able to consult them to gather precious information on how to steer the therapy of a patient.

The figure below is a descriptive diagram of the whole system. The setup at the Auxilium Vitae hospital (which simulates the patient's home), the remote server running X1V1 (the document handling platform) and the remote certificate server.

MOTORE++

Bluetooth
Real Time Data

MOTORE++ PC

Auxilium Vitae Set Up

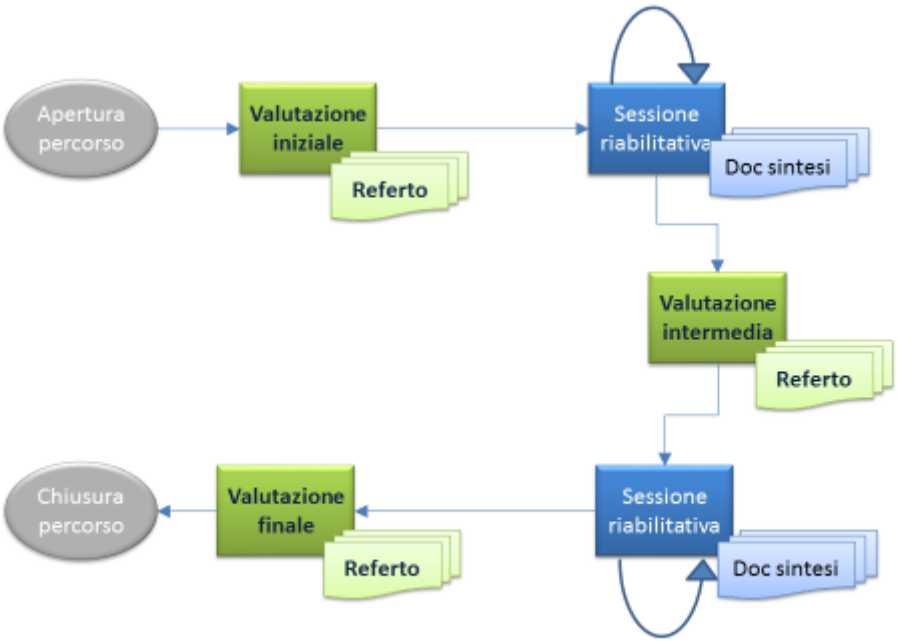
Remote Server X1V1
with patient database

SOAP

3 Results

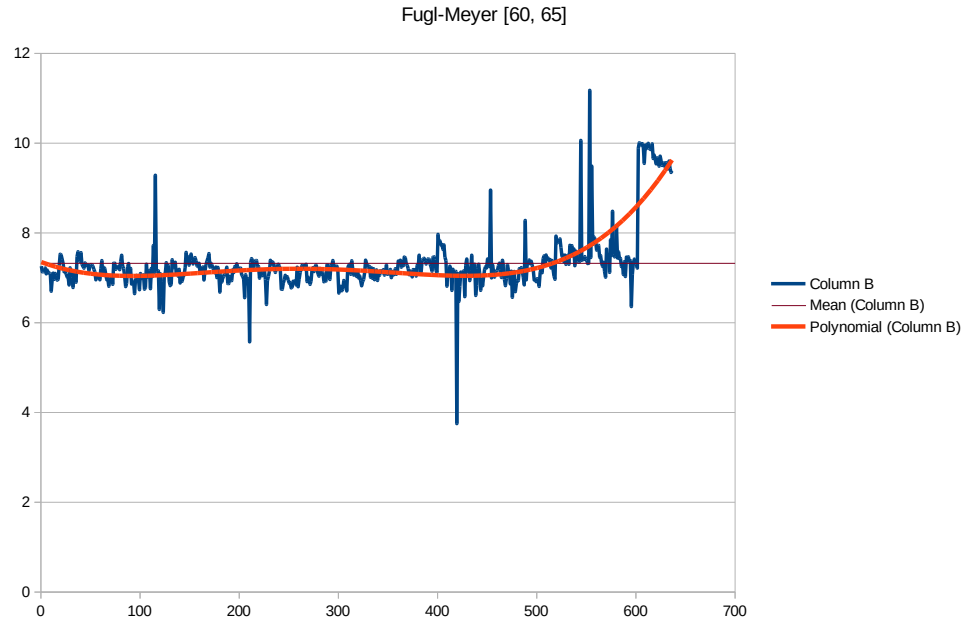
Since this experimentation was made within the scope of a research project, the set up hasn't only been used for a demo or a proof-of-concept, but instead it has been used for the full rehabilitation cycle of 21 patients. These patients have been enrolled for a month of therapy. Their rehabilitation protocol consisted of four weeks of treatment. The medical staff was supposed to assess the patients three times during their rehabilitation cycle: at the admission, after the second week and at the end of the cycle. During the robotic therapy, they would exercise for 45 minutes a day, 5 days per week.

The following figure shows the rehabilitation cycle of a patient. After admission (apertura percorso) the patient is assessed by the medical staff (valutazione iniziale) and a report is produced (referto). The patient performs his daily rehabilitation (sessione riabilitativa). After every exercise a summary document is produced (doc sintesi). After two weeks the medical staff performs another assessment (valutazione intermedia) and the patient continues the rehabilitation for two more weeks. At the end of the rehabilitation a final assessment is made (valutazione finale) and the rehabilitation cycle ends (chiusura percorso). If the patient will have to do another cycle, another workflow will be opened.



So, during this experimentation 4850 exercises in total have been done. The statistics of the robot said that it had covered 46km covered by MOTORE++ during the therapy.

The following figure shows an example of a rehabilitation of one patient. The patient was admitted to the experimentation with a Fugl-Meyer score of 60 and at the end of the cycle was assessed with a Fugl-Meyer score of 65. The graph shows the scores given to the patient by the robot's software. On the x axis is the number of the exercise done by the patient. On the y axis is the score (from 1 to 10) given to the patient's performance.



3.1 Example

The following is an example of an XML document sent to the remote server:

```
<soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
<soap:Header/>
<soap:Body>
<PutRequest xmlns="urn:dedalus:rlus:rlpnotes:types">
<document xmlns="urn:dedalus:rlp">
       <metadata>
              <parameter name="id">6_2</parameter>
              <parameter name="subjectid">bcc324da-946b-4af6-b493-bd0ce3ac5e4b</parameter>
              <!-- the step id in the workflow -->
              <parameter name="taskid">Prova_Gino_2015_01_27__18_08_35</parameter>
              <!-- the measurement device unique identifier (could be the serial number) -->
              <parameter name="deviceid">1080</parameter>
              <parameter name="device.description">MOTORE</parameter>
```

```
	</metadata>
	<payload>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter    name="observation.property.description">Type    of    game</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">Memory</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter name="observation.property.description">Scenario</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">3 Coppie</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter  name="observation.property.description">Number  of  repetitions</parameter>
			<parameter name="observation.uom">int</parameter>
			<parameter name="observation.value">2</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter              name="observation.property.description">Affected Arm</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">Rig</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter name="observation.property.description">X size</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">Pic</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter name="observation.property.description">Y size</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">Pic</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter   name="observation.property.description">Scenario   position (left, center, right)</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">Cen</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter name="observation.property.description">Clockwise</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">Ava</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter name="observation.property.description">Speed</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">Nor</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter     name="observation.property.description">Passive     motion</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">False</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter    name="observation.property.description">Correction    force (stiffness)</parameter>
			<parameter name="observation.uom">string</parameter>
			<parameter name="observation.value">Rig</parameter>
		</record>
		<record>
			<parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
			<parameter             name="observation.property.description">Resistance (weight)</parameter>
```

```
                        <parameter name="observation.uom">string</parameter>
                        <parameter name="observation.value">Med</parameter>
                </record>
                <record>
                        <parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
                        <parameter name="observation.property.description">Viscosity</parameter>
                        <parameter name="observation.uom">string</parameter>
                        <parameter name="observation.value">Flu</parameter>
                </record>
                <record>
                        <parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
                        <parameter               name="observation.property.description">Overall
score</parameter>
                        <parameter name="observation.uom">single</parameter>
                        <parameter name="observation.value">7,93427</parameter>
                </record>
                <record>
                        <parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
                        <parameter  name="observation.property.description">Duration  of  exer-
cise</parameter>
                        <parameter name="observation.uom">single</parameter>
                        <parameter name="observation.value">10,38495</parameter>
                </record>
                <record>
                        <parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
                        <parameter  name="observation.property.description">Autonomy  of  patient
(regarding time)</parameter>
                        <parameter name="observation.uom">single</parameter>
                        <parameter name="observation.value">1</parameter>
                </record>
                <record>
                        <parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
                        <parameter            name="observation.property.description">Normalised
speed</parameter>
                        <parameter name="observation.uom">single</parameter>
                        <parameter name="observation.value">0,1975466</parameter>
                </record>
                <record>
                        <parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
                        <parameter  name="observation.property.description">Precision  of  pati-
ent</parameter>
                        <parameter name="observation.uom">single</parameter>
                        <parameter name="observation.value">0,9761613</parameter>
                </record>
                <record>
                        <parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
                        <parameter  name="observation.property.description">Autonomy  of  patient
(regarding work)</parameter>
                        <parameter name="observation.uom">single</parameter>
                        <parameter name="observation.value">1</parameter>
                </record>
                <record>
                        <parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
                        <parameter  name="observation.property.description">Number  of  correct
trials (where applies)</parameter>
                        <parameter name="observation.uom">int</parameter>
                        <parameter name="observation.value">0</parameter>
                </record>
                <record>
                        <parameter name="observation.timestamp">2015-01-27T18:08:35</parameter>
                        <parameter name="observation.property.description">Total number of tri-
als (where applies)</parameter>
                        <parameter name="observation.uom">int</parameter>
                        <parameter name="observation.value">0</parameter>
                </record>
        </payload>
</document>
<ns3:RLUSPutRequestSrcStruct
                xmlns:ns3='http://www.omg.org/spec/RLUS/201212/RLUStypes'>
                <ns3:RLUSsemantic-signifierName>rlpnotes</ns3:RLUSsemantic-signifierName>
                <ns3:SecurityContext>
                <ns3:SourceIdentity identityName="MOTORE"/>
                        </ns3:SecurityContext>
                <ns3:CBRContext>
                <ns3:CBRName>Motore - Auxilium Vitae Volterra</ns3:CBRName>
                        <ns3:NetworkName>localhost</ns3:NetworkName>
                        <ns3:NetworkAddress>127.0.0.1</ns3:NetworkAddress>
                </ns3:CBRContext>
```

```
        </ns3:RLUSPutRequestSrcStruct>
        <writeCommandEnum>INSERT</writeCommandEnum>
</PutRequest>
</soap:Body>
</soap:Envelope>
```

4 Deviations & Reasons

Nothing to mention.