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E-HandicapScale : an open and secure way to promote and improve diagnostics of disabled patients¹

Use cases for patients with post-stroke hemiplegia to children with cerebral palsy

Laurent Bobelin, Andrès Gil, Christian Toinard

LIFO Computer Science Laboratory of Orléans
 INSA Centre Val de Loire
 88 bld Lahitolle CS 60013 18022 Bourges Cedex, France
 {laurent.bobelin, christian.toinard}@insa-cvl.fr

Dr Marie-Elisabeth Labat

Institute of Education and Motricity
 LADAPT
 Route de Châteauneuf 18570 Trouy Nord, France
 labat.marie-elisabeth@ladapt.net

Abstract—Online web services are nowadays a way to support advanced medicine and diagnostics. International scales for evaluating disabilities and handicaps are now widely available. However, their adoption faces several problems for example in small rehabilitation centers. Online systems could help in promoting their usage. However, existing approaches have limited openness and security. This paper addresses those two major problems. Moreover, the proposed web service improves the usability through an advanced correlation of different scales and regional cohorts. Our work involves different disciplines including Physical Medicine and Rehabilitation Clinicians, Occupational Therapists and researchers in Computer Security.

Keywords—handicap, scales, security, e-service, correlation

I. INTRODUCTION

The evaluation of handicap is a central aim for both Physical Medicine and Rehabilitation (PM&R) physicians and occupational therapists. Different scales usually drive the evaluation of disability (e.g. Flug-Meyer [1] and Barthel [2] for patients with post-stroke hemiplegia, MACS [3] and ABILHAND-Kids [4] for children with cerebral palsy).

English - Order 1					
1.	Opening a jar of jam	<input type="radio"/> Impossible	<input type="radio"/> Difficult	<input checked="" type="radio"/> Easy	<input type="radio"/> ?
2.	Putting on a backpack/schoolbag	<input type="radio"/> Impossible	<input type="radio"/> Difficult	<input checked="" type="radio"/> Easy	<input type="radio"/> ?
3.	Opening the cap of a toothpaste tube	<input type="radio"/> Impossible	<input type="radio"/> Difficult	<input checked="" type="radio"/> Easy	<input type="radio"/> ?
4.	Unwrapping a chocolate bar	<input type="radio"/> Impossible	<input type="radio"/> Difficult	<input checked="" type="radio"/> Easy	<input type="radio"/> ?
5.	Washing the upper-body	<input type="radio"/> Impossible	<input checked="" type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
6.	Rolling-up a sleeve of a sweater	<input type="radio"/> Impossible	<input checked="" type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
7.	Sharpening a pencil	<input type="radio"/> Impossible	<input type="radio"/> Difficult	<input checked="" type="radio"/> Easy	<input type="radio"/> ?
8.	Taking off a T-shirt	<input type="radio"/> Impossible	<input checked="" type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
9.	Squeezing toothpaste onto a toothbrush	<input type="radio"/> Impossible	<input checked="" type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
10.	Opening a bread box	<input type="radio"/> Impossible	<input checked="" type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
11.	Unscrewing a bottle cap	<input type="radio"/> Impossible	<input checked="" type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
12.	Zippering-up trousers	<input type="radio"/> Impossible	<input checked="" type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
13.	Buttoning up a shirt/sweater	<input type="radio"/> Impossible	<input checked="" type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
14.	Filling a glass with water	<input checked="" type="radio"/> Impossible	<input type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
15.	Switching on a bedside lamp	<input checked="" type="radio"/> Impossible	<input type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
16.	Putting on a hat	<input checked="" type="radio"/> Impossible	<input type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
17.	Fastening the snap of a jacket	<input checked="" type="radio"/> Impossible	<input type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
18.	Buttoning up trousers	<input checked="" type="radio"/> Impossible	<input type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
19.	Opening a bag of chips	<input checked="" type="radio"/> Impossible	<input type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
20.	Zippering-up a jacket	<input checked="" type="radio"/> Impossible	<input type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?
21.	Taking a coin out of a pocket	<input checked="" type="radio"/> Impossible	<input type="radio"/> Difficult	<input type="radio"/> Easy	<input type="radio"/> ?

Fig. 1 The 21 items of the ABILHANDS-Kids scale.

Currently, several online services are available for easing the usage of such scales. For example, www.rehab-scales.org provides a web rasch analysis that classifies the considered child according to a statistical study. The rasch statistic has been carried out on a relevant cohort of kids [4]. Fig. 1 shows the ABILHAND form including 21 items. Each item has four possible responses (impossible, difficult, easy, not evaluated).

Fig. 2 shows the classification of the considered child

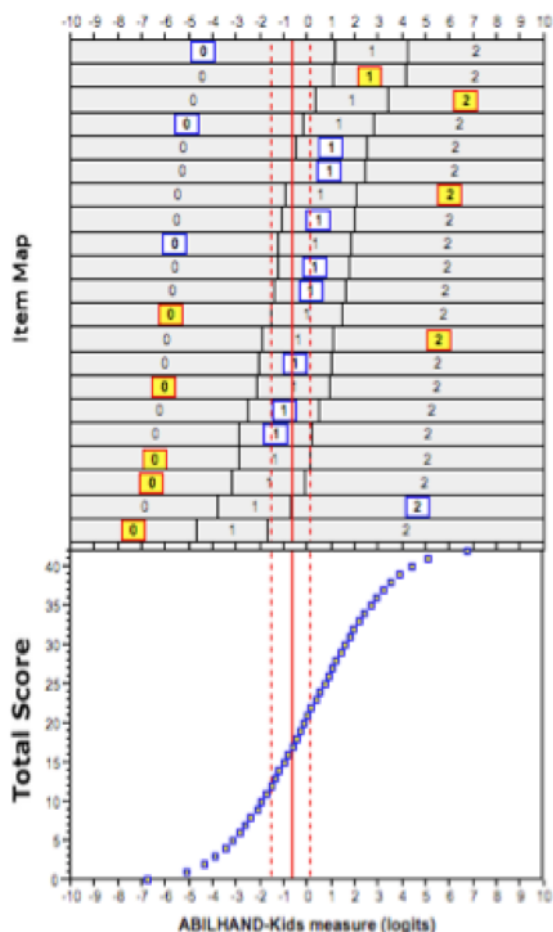


Fig. 2 Child evaluation with the ABILHAND-Kids scale.

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according to the rasch statistics. The red lines present the median and the standard deviation. Thus, the clinician can verify if the child fits with the scale. Moreover, he has some idea about the possible items that can be reached through the rehabilitation program.

Currently, such web sites suffer from at least one of these limitations:

- They usually do not support correlation between several scales. However, such a statistical correlation [5] can be supported in a generic manner.
- The extension of new scales is usually poorly supported. For example, the configuration of the rasch coefficients is not possible.
- The rasch analysis cannot be contextualized or regionalized. For example, the web site cannot compute dedicated statistics for different countries.
- The user cannot recover his evaluations. It could be fine to have a dedicated database storing all the evaluations of a clinician.
- The evaluations cannot be shared with other clinicians or the patients. It is necessary to support collaboration between clinicians and patients.
- The security is poorly addressed. The system must support not only the confidentiality of the patients but also the confidentiality of the clinicians.
- A distributed architecture is really missing. Indeed, the data are stored generally on a central server. Thus, the need for a local and private database is not supported.

This paper addresses these different topics. It presents the general approach and architecture. It presents the current implementation of that approach. Finally, it concludes with future works.

II. GENERAL APPROACH AND ARCHITECTURE

This section presents our novel approach supporting an extensible and cooperative system for serving handicap forms. It describes also the distributed architecture aiming at providing such a secure and advanced scaling of handicap.

A. A novel approach of cooperative, distributed and secure scaling of handicap

The basic idea is to support both opened and advanced services.

The openness is the idea that the proposed solution can be efficiently configured to support dedicated usages. Let us give several examples that are supported by our approach.

First, an entity (e.g. an hospital) has established new rasch coefficients for a dedicated population of hemiplegia and wants to reuse our online site with those coefficients. Our approach enables that entity to reuse and

configure a dedicated scale through a user interface easing the adaptation.

Second, a developer wants to extend our online site with a new scale associated with a rasch study. Our solution eases the integration of new forms and enables to easily add new computation resources for that new scale.

Third, a developer wants to reuse existing forms for adding a correlation between different scales according to his rasch study. The proposed solution supports the correlation of scales and easily can enable to add a rasch correlation between existing forms.

The notion of advanced services is associated with new ways of using a distant web site and new kinds of cooperation between the clinicians and the patients. Again let us give selected examples of services that our solution addresses.

First, the end users can share their evaluations with other users. Thus, a clinician can easily choose to share information with a group of clinicians but also with the patient and his entourage.

Second, an entity or a user can decide to establish a local database giving access to the central database. Thus, our solution enables a user to join his local data (such as including the name of the patients) with the distant evaluations.

Third, a clinician does not have to take of saving his evaluations. Despite, he can correlate the evaluations with local data. The distant evaluations persists whatever the local data persist or disappear.

Fourth, the local databases and the central one do not shared any personal data or quasi-identifiers. Despite those databases have shared keys, those keys cannot be used to deanonymize people.

Fifth, the people have the guaranty that the central database does not include any confidential data or even include quasi-identifiers (i.e. data that can be used to perform deanonymization).

Fig. 3 Distributed secure form

B. A secure distributed architecture

Fig. 3 shows one page of our interface providing a secure filling for the hemiplegia evaluation. The user name is completely irrelevant (i.e. Optdf12!vgNk?.55) and was generated automatically through an administration interface.

A key (i.e. Q@#vgHJ6\$\$5)---&123\$\$@) was also generated for the form. This key enables the end user to recover his evaluation will guarantying an anonym patient. As show in Fig. 4, this key can be stored into a local database with for example the name of the patient. The key can be distributed to whatever user enabling for example a clinician or the patient to see the evaluation inside the E-HandiScale database available in the server. That key is not really confidential since one needs both an account and the receiving of that key in order to retrieve the evaluation from the server. Moreover, the server database does not contain any information (e.g. quasi-identifiers) that could permit to reveal the clinician or the patient.

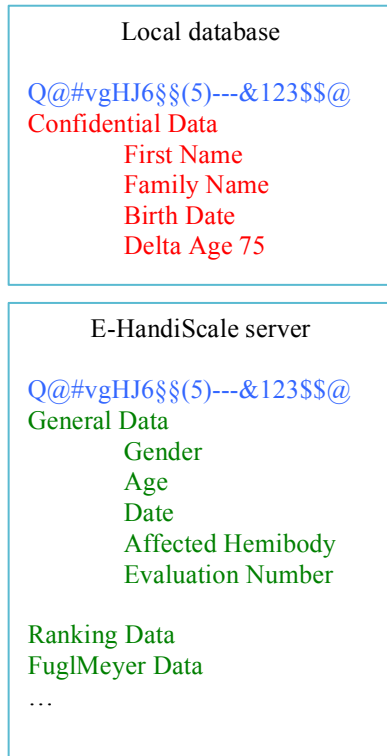


Fig. 4 The distributed secure databases

This architecture is very safe since to retrieve information about a clinician or a patient you need an access to both the systems (i.e. the local database and the E-HandiScale server).

The probability of such a vulnerability is very low. Moreover, in order to reduce again that probability, the different clinicians can have different local databases. Fig. 5 shows the architecture for two clinicians within the same hospital. Thus, even if an attacker succeed to violate the access to the local database of the clinician 1, he can neither access to the database of the clinician 2 nor to the server database since the attacker needs also the safe logins (e.g. Optdf12!vgNk?.55) and passwords (hashed login store into the server database).

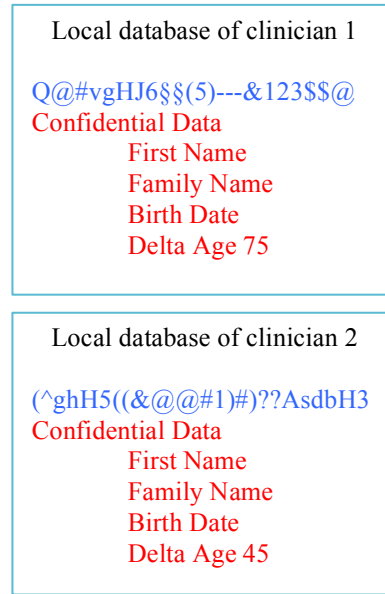


Fig. 5 The distributed local databases

III. THE SOFTWARE ENVIRONMENT

A. Symfony PHP framework and Bootstrap

Our software uses the Symfony PHP framework in order to improve the reliability and the extensibility. The Bootstrap CSS framework enables a responsive web interface. It enforces cross-browser compatibility and consistency for mobile players.

A dedicated bundle, called *measureonline*, furnishes the namespace of our web application.

The Doctrine Object Relational Mapper (ORM) offers an object interface that gives an abstract access to an SQL database.

```

1 # This file is auto-generated during the composer install
2 parameters:
3   database_host: 127.0.0.1
4   database_port: null
5   database_name: measureonline
6   database_user: root
7   database_password: null
8   mailer_transport: smtp
9   mailer_host: 127.0.0.1
10  mailer_user: null
11  mailer_password: null
12  secret: 9ec197f662f2348c96bdbba9fa0bd5360861acf4
13

```

Fig. 6 The configuration of a secure access to the database

Fig. 6 shows that the configuration of Doctrine does not reveal any clear password for accessing to the database.

The security component of Symfony enables 1) authentication through a firewall and 2) authorization that controls different roles.

```

1 # To get started with security, check out the documentation:
2 # http://symfony.com/doc/current/security.html
3 security:
4   encoders:
5     measureonline\UserBundle\Entity\User: sha512
6     # l'encodage des mots de passe
7
8

```

Fig. 7 Protected user passwords

An encoder configuration enables the confidentiality of the end-user passwords. Fig. 7 shows a usage of the

SHA512 to compute the hash for the user passwords. Only the hashes are stored into the password database.

```

14 providers:
15
16   our_db:
17     entity:
18       class: measureonlineUserBundle:User
19       property: username
20

```

Fig. 8 Configuration of the User database

A provider configuration defines the database (i.e. User) for storing the accounts of our bundle. Fig. 8 gives the property required for retrieving the user account from the database.

```

22 firewall:
23   # disables authentication for assets and the profiler, adapt it according to your needs
24   dev:
25     pattern: ^/(_(profiler|wdt)|css|images|js)/
26     security: false
27
28   main_login:
29     # cette expression régulière permet de prendre /login (mais pas /login_check !)
30     pattern: ^/login$
31     anonymous: true # On autorise alors les anonymes sur ce pare-feu
32
33   main:
34     pattern: ^/
35     anonymous: false
36     provider: our_db
37     form_login:
38       login_path: login
39       check_path: login_check
40     logout:
41       path: logout
42       target: /login

```

Fig. 9 Firewall enforcing the authentication

Firewall prevents unauthenticated users from accessing the web sites. Fig. 9 first shows the main_login rule that forces an anonymous user to authenticate through the login page. The main rule authorizes the whole access to the web site.

```

9   role_hierarchy:
10     ROLE_PRO: [ROLE_USER]
11     # ROLE_ADMIN
12

```

Fig. 10 A role hierarchy for the users

The role component enables to associate a role to a user. Fig. 10 shows the configuration of the role ROLE_PRO for the ordinary users (i.e. the clinicians or the patients).

```

/**
 * @Security("has_role('ROLE_PRO')")
 */
public function ajoutAction(Request $request)
{
    // On crée un objet AVCergo
    $AVCergo = new AVCergo();

    // On crée le FormBuilder grâce au service form factory
    $formBuilder = $this->get('form.factory')->createBuilder(FormType::class, $AVCergo);

    // On ajoute les champs de l'entité que l'on veut à notre formulaire
    $formBuilder
        ->add('name', TextType::class)
        ->add('age', IntegerType::class)
        ->add('Gender', ChoiceType::class, array(
            'choices' => array(
                'Masculin' => 'male',
                'Femminin' => 'female'),
        ))
        ->add('Date_evaluation', DateType::class)
        ->add('Date_stroke', DateType::class)
        ->add('hemi', ChoiceType::class, array(
            'choices' => array(
                'Droit' => 'right',
                'Gauche' => 'left'),
        ))
}

```

Fig. 11 A role permission to call a function

Simple assertion (e.g. @Security("has_role())) authorizes the access to a PHP method. Fig. 11 shows the permission for the role ROLE_PRO to call the method that adds an evaluation to the server database.

B. The user interface

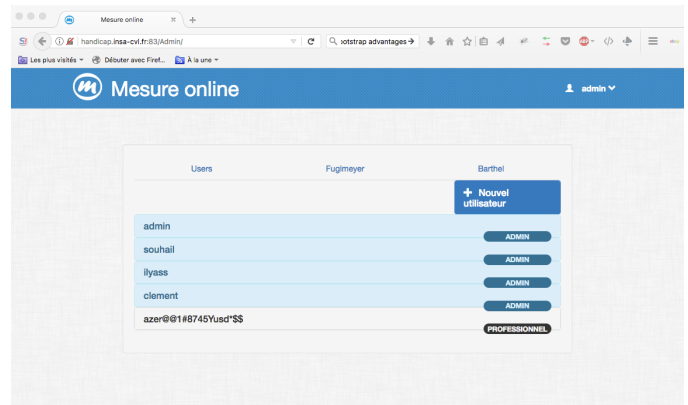


Fig. 12 General administration interface

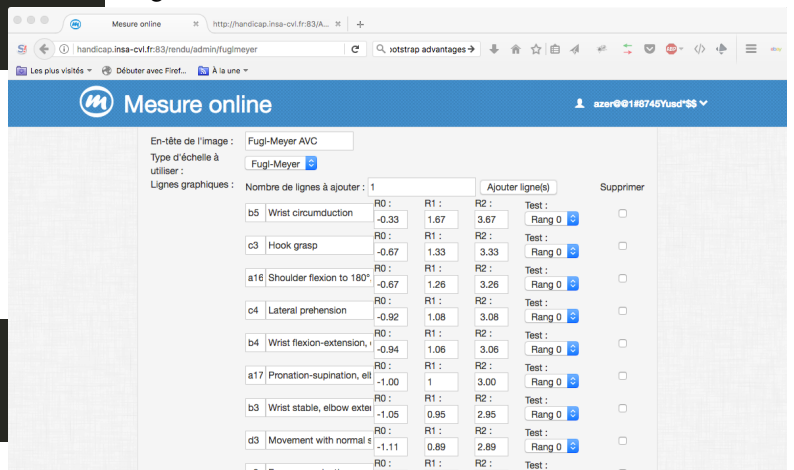


Fig. 13 A rasch configuration available to a clinician

Depending on the role, the user accesses to different interfaces.

Fig. 12 shows the interface for an administrator of the site. Such a role does not authorize to access to the evaluation. The main functionality is the ability to add user and to add evaluations scale. Here, the administrator added Fuglmeyer and Barthel scales.

A regular user has different capabilities. He can for example configure a scale according to his needs. For example, a clinician can have the permission to update a hemiplegia scale. In Fig. 13, a clinician updates the rasch coefficients corresponding to the statistics for his country (e.g. France). Thus, the can improve the scale with statistics that are relevant for his population.

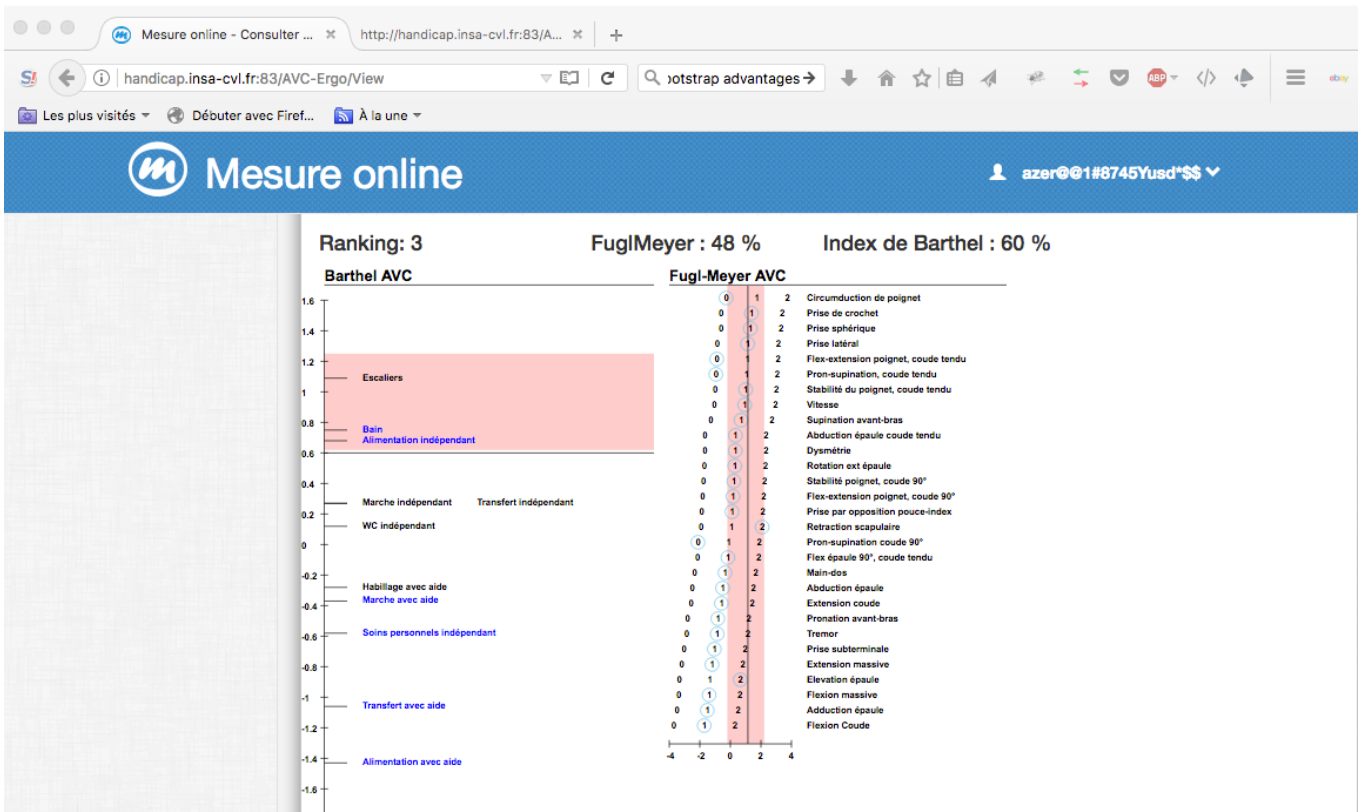


Fig. 14 Correlation between FulgMeyer, Barthel and Ranking.

Fig. 14 shows the graphical results of the correlation between three different scales. Thus, the clinician can verify if the patient satisfies these scales.

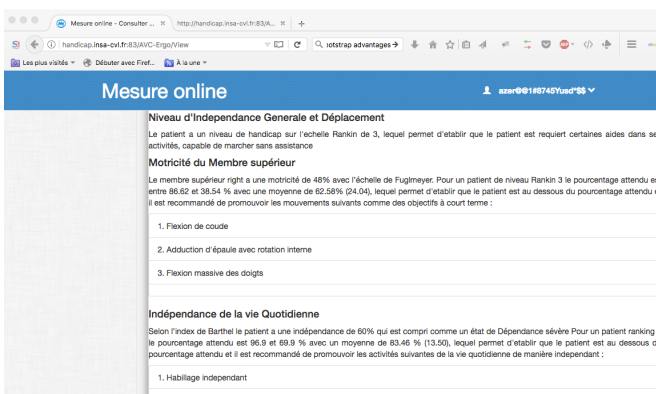


Fig. 15 Consistency between scales and rehabilitation advises

Fig. 15 shows the textual results of an evaluation. The text gives the consistency between the different scales (e.g. FuglMeyer is 48% which is consistent with Rankin 3 since the result must be between 86.62 and 38.54 % with a median at 62.58%).

Fig. 15 also defines the rehabilitation advises for the patient. For example, the rehabilitation must exercise 1) the elbow flexion, 2) the abduction and internal rotation of the elbow and 3) bending for all the fingers.

IV. CONCLUSION

Our paper presents a novel approach to ease the promotion and the improvement of the international disabilities scales. At the best, these scales can be correlated and provide rehabilitation suggestions. Obviously, it is still the work of the clinicians to verify that the suggestions correspond to his global view of the patient.

The E-HandicapScale service improves the standard web services in several directions. First, it enables a better adjustment of the scales through a facility for configuring rasch statistical coefficients. Second, it supports cooperation between different clinicians and their patients. Third, it provides an advanced security where distributed databases prevent the deanonymization of the patient data. Finally, the interface is friendly and supports different roles enabling a clinician to easily share data in a secure manner with other clinicians and patients.

Future works will address different objectives. First, a solution will be developed to support online rasch statistics. Thus, cooperation will be enforced since the clinicians will get better statistics by using anonymous data from other clinicians. Second, big data services could be supported such as providing open statistics and data about a region, a country or a type of disability. Third, the integration of novel scales will be improved through a user interface easing the deployment of new scales.

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