Project No. 231724

HUman behavioral Modeling for enhancing learning by Optimizing hUman-Robot interaction

HUMOUR

THEME 2: Cognitive Systems, Interaction, Robotics

Deliverable 3.3

Methods for assessment of the performance of the learned skills

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Lead beneficiary for this deliverable: **AAU**

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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Service)	
RE	Restricted to a group specified by the consortium (including the Commission Service)	
CO	Confidential, only for members of the consortium (including the Commission Service)	√

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1 Objectives

The tasks of the WP3 directly related to this deliverable are related to the establishment of methods for the assessment of the performance of the learned skills. Partners that mostly contributed to this deliverable are AAU, IIT and FSM. The plan was to use the sensors developed in Task 3.2 within the passive robot (A2D, A3D, W3D, H and their combinations depending on the specific motor task) as the assessment tool for the skills acquired during the training of the non-skilled arm/hand. The assessment methods are being considered with the view of possible future use in the tele-rehabilitation systems.

2 Introductory remarks

In the original plan of the WP3 we suggested that we will build the sensors system that will output data that is similar to the output of the biological sensors (e.g., Golgi tendon organs, muscle spindles, joint receptors). However, the works in the project indicated that this activity does not contribute to the project. Due to this finding we decided to use conventional sensors for the action representation, and even more to test the use of some sensors system that are part of games (Wii games, Nintendo; Kinect, Microsoft Xbox; etc.) since it became evident that the gaming would play important role in the future rehabilitation robots as the motivation for increased load of exercising. The research led to several results.

3 The Drawing Test: Assessment of coordination

We introduced the Drawing Test (DT) as a measure of coordination of the elbow and shoulder joints during a functional task in tetraplegic and hemiplegic patients [1]. This DT required that a subject tracked by his paretic hand the sides of a square drawn on the digitizing tablet. The digitizing tablet was used to acquire the absolute position of a wireless magnetic mouse held in- or attached to the hand. The score of the DT was the ratio between the areas of the drawn square and the target square (200 mm x 200 mm). In the same studies we used the Modified Ashworth Scale (MAS) as a clinical measure of impairment. The results showed that the trend lines in the changes of the DT scores and MAS scores were correlated [2]; thereby, we hypothesized that the DT score could be used as a measure of recovery after the motor impairment. We validated the reproducibility of the DT in able-bodied humans: the analysis of electromyography (EMG) signals showed highly variable muscle activity during transitions between radial and tangential movement from subject to subject. In addition, we found that the score was not an adequate measure of the ability to control the hand trajectory because the task to track the drawing was cognitively demanding.
In order to overcome this deficiency we modified the DT. The new DT is simple; it requires that a subject make self-paced radial point-to-point movements within his/her horizontal working space. This new test eliminates the changes in the direction of the movement, and it does not present cognitive overload. The score of the new DT relates only to the kinematics of simple movements, and assesses the coordination of the shoulder and elbow joints.
Here we describe a quantitative metrics for assessing the movement quality. Subject should be seating in a chair so that her arm rests on a digitizing tablet positioned horizontally within the workspace. A line, in front of the acromion, long 20 cm is shown on the tablet (Drawing Board III™, by GTCO Calcomp, Inc. 14555 N. 82nd street Scottsdale, AZ 85260, Arizona, U.S.A.). The trajectories are recorded with a precision of ±0.25 mm, and sampled at 100 samples per second.

Subject needs to be instructed to perform a self-paced movement by moving the mouse from start to end position of the line (point to point movement) or track the line (tracking movement) as shown in Fig. 1. In the case that the subject can not hold on mouse, the mouse should be attached to the hand by Velcro™ tape. In this case the hand needs to be positioned in a pronated position to allow the mouse to slide without tendency to tilt and without additional friction along the surface of the tablet.
The movements need to be repeated at least 5 times. We define a 'trial' as a single movement, and consequently 'number of trial' as the number of movement – performed by a single subject.
The hand trajectory data needs to be graphically inspected. The hand velocity is calculated for each trial by first differentiating, and then filtering the velocity data. The maximum hand velocity is then computed. The movement duration, T, is calculated as the time between the beginning and end of the movement. The beginning and end of a trial are computed at 15% of maximum hand velocity. This threshold was chosen arbitrarily high in order to provide a robust standard for comparison of movement duration between subjects. Three geometric outcome measures were defined: Fig. 1 illustrates the geometric outcome measures for movements from starting to the target position. The directional and perpendicular to direction distances of the movement end points from the target corner (Xm,Ym) and the standard deviation e(x) of the point to point tracking movement are chosen as geometric measures representing drawing skill. Xm and Ym were obtained by subtracting the coordinates of the movement end point (x,y) from the desired target end-point. The measure e(x) is the standard deviation of the data points in perpendicular to the direction of movement line.

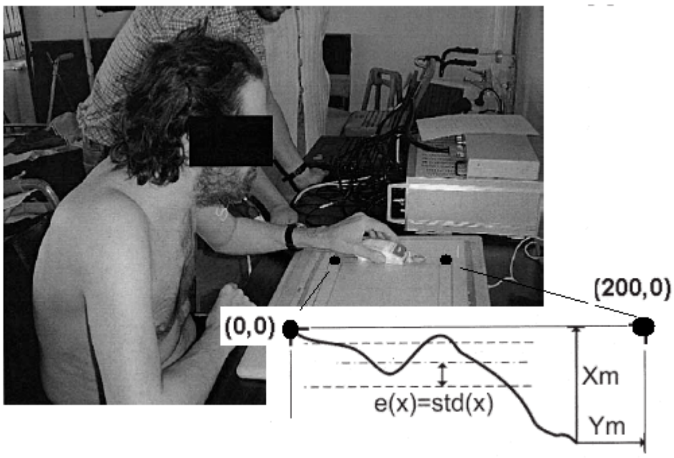

Figure 1: A stroke patient during the assessment of the abilities to make 20 cm long point to point movement. The drawing test shows the errors (Xm, Ym and e(x)) which are correlated with the level of disability. This assessment is effective for the follow up of the recovery of the function. See text for details.

Statistical evaluation. The outcome measures T, X_m, Y_m and e(x) for each trial and each subject are computed in Matlab and saved in spreadsheet format for further statistical analysis.
Average values of consecutive trials are submitted to a factorial Analysis of Variance (ANOVA) in order to study the main effects and interactions of the between-subject factors and within-subject factors on each dependent variable separately. In addition, the outcome of all statistical tests were declared significant if $p<0.05$. A Neuman-Keuls post-hoc test was computed for each dependent variable to compare the five levels of the factor AS score.

References:

1. Popović DB, Popović MB, Sinkjaer T. "Neurorehabilitation of Upper Extremities in Humans With Sensory-Motor Impairment." *Neuromod* 2002;5(1):54-67.

2. Eder C, Popović MB, Popović DB, Stefanović A, Schwirtlich L, Jović S. The Drawing Test: Assessment of coordination abilities and correlation with the clinical measure of spasticity. *Arch Phys Med Rehabil* 86:289-295, 2005.

4 The modified Bender Gestalt test for the assessment of motor skills

The modified Bender-Gestalt (BG) psychological test in preschool children was modified to assess movement performance. Many techniques for the assessment measure terminal accuracy of the movement. For scoring purposes different measurement techniques were derived: root-mean-square error, accuracy index, linearity index. In our work subjects were asked to draw complex shapes so more refine technique of scoring had to be used. Therefore we decided to base this experiment on standard psychological test.
The BG test was used as visual-motor test, for studying personality and psychopatology, and prediction of academic achievements . Test's importance lies in its potential as a quick screening device that could be administered by paraprofessionals. Survey on the psychological tests in the USA show that BG is among the most frequently used clinical instruments. An interesting modifications of the BG test was designed to examine children's perceptuo-motor organization of the space, and it is called Graphical Test of Perceptive Organization (GTPO), having two versions for the children age 4 to 6 (GTPO I), and for age 6 to 14 (GTPO II). The test requires that children copy five distinctive drawings that are presented to them in forms of paper cards. Each of the drawings is valued by scoring three categories: 1) the orientation of an element; 3) the angles between elements and lines; and 3) the mutual position of the elements.

Testing of the system: We formed a group of five right handed healthy subjects (62±3 years of age) with known ortopedic or neurological deficit. We formed a group of five right handed stroke subjects with the similar Fugl-Mayer score for upper extremities (23±3). All subjects signed the informed consent form approved by the local institution. The measurement was conducted in familiar environment for all subjects. None of the subjects used digitizing drawing board before, but they all had some computer experience and used the mouse at some point of their lives.

Procedure: Patients are seating on the chair in front of the desk on which various computer inputs can be positioned (e.g., digitizing board, haptic robot, computer mouse). In this case the Calcomp digitizing board was used. In front, at the height of eyes a computer monitor is providing the task to be drawn, but also can be used for visual feedback of the performance. The tasks for the test are from the modified objects selected from the Bender Gestalt test. Patients have to repeat the movement at least five times. The position of the mouse is recorded at 100 samples per second with the precision of 0.5 mm. The time to perform the movement is assessed form the recordings. Before the test patients were given the opportunity to practice movement with various computer interfaces, and various visual feedback. The tasks that we used for the test are shown in Fig. 2.

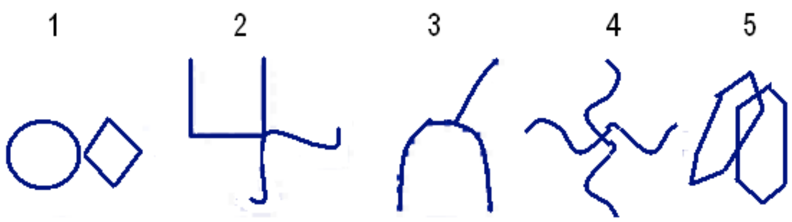

Figure 2: Five Bender Gestalt test shapes selected ro the assessmen of motor skills

We also tested this performance in healthy subjects, but in this case we used a large neck collar to prevent subjects from seeing their arm. We also used various type of modified visual feedback by transforming the position in space by rotating coordinate frame or other transformations (horizontal and vertical component condensed or expanded up to 50%). This test was used to estimate if the visual feedback provided from the vertical monitor is actually being a difficult cognitive task. The tests with healthy subjects (average age 62) demonstrated that the performance drops for about 5% compared for the “normal” visual feedback. The modified feedback decreased the performance for more than 30% in average. This finding (in 10 subjects) suggests that the cognitive load when moving the hand watching the position on the screen is a cognitive task, but with almost identical effect on all subjects and small influence on the motor performance. Fig. 3 shows the testing in a healthy subject.

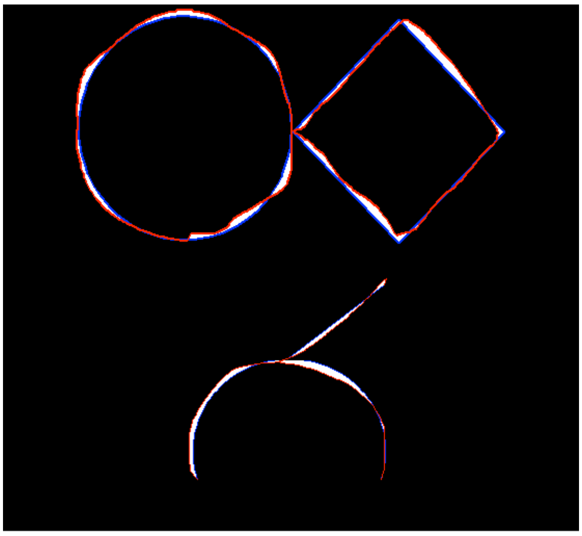

Figure 3 : A representative result for the testing. The white zone is the diffrence between the task and the figure drawn by the healthy subject.

The summary of the testing is in tables. Details of the results are being part of the publication that is in process of preparation, therefore there are not presented in this report.

Table 1. Healthy and patients groups’ score for all five tasks.

	CT		DIF	MAX.	
	healthy	patients		healthy	patients
TASK 1	47	57	29	11%	38%
TASK 2	40	29	36	24%	10%
TASK 3	54	38	38	44%	30%
TASK 4	51	13	47	70%	8%
TASK 5	49	43	27	23%	45%
TOTAL	241	180	177	33%	27%

Table 2. Groups' score by categories.

	CT		DIF.	MAX.	
	healthy	patients		healthy	patients
ANGLES	58	42	36	33%	38%

ORIENTATION	74	61	66	18%	11%
MUT. POSITION	71	45	48	45%	32%
TOTAL	203	180	150	33%	26%

The ANOVA test was run to see statistical significance on each of the categories to the mean of the patients group, and the p=0.008, 0.021 and 0.011 values were obtained respectively for angles, orientation and mutual position.

5 MIMATE: A wireless mechatronic platform for teaching the design of assistive and rehabilitative devices

The ageing population and the wish to improve quality of life, as well as the economic pressure to work longer, call for intuitive and efficient assistive and rehabilitation devices. Although much research has been devoted to the development of such devices, little attention has been paid to formal teaching of the core skills required for their design and construction. This work establishes a prototyping platform for the education of mechatronic design skills appropriate for the development of rehabilitative/assistive technologies. Through the use of this platform as a foundation for the design of simple rehabilitative/assistive devices it is proposed that these skills may be taught quickly and effectively to students with little previous experience. This research introduces the MIMATE module, a miniature wireless sensing and feedback generation system for application in human centred devices. It describes the requirements for this device, its resultant specification as well as the educational opportunities this system created in a novel project-based course on rehabilitation technology (details are in the paper N Roach, A Hussain and E Burdet, 2011, submitted, Imperial).

6 A robust and sensitive metric for quantifying movement smoothness

The need for movement smoothness quantification to assess motor learning and recovery, has resulted in various measures that look at different aspects of a movement's profile. It was shown that most of the previously published smoothness measures lack validity, consistency, sensitivity or robustness. The research introduces and evaluates the spectral arc length metric, which uses a movement speed profile's Fourier magnitude spectrum to quantify movement smoothness. This new metric is systematically tested and compared to other smoothness metrics, using experimental data from stroke and healthy subjects as well as simulated movement data. The results indicate that the spectral arc length metric is a valid and consistent measure of movement smoothness, which is both sensitive to modifications in motor behavior and robust to measurement noise. We hope that the systematic analysis of this paper is a step towards the standardization of the quantitative assessment of movement smoothness.
Details are in the paper S. Balasubramanian, A. Melendez-Calderon and E. Burdet. “A robust and sensitive metric for quantifying movement smoothness” IEEE Trans Biomed Eng, accepted (Imperial)

7 Papers relevant to Deliverable 3.3

7.1 Journal papers

1. Iftime Nielsen SD, Došen S, Popović MB, Popović DB. „Learning Arm/Hand Coordination with an Altered Visual Input.“ *Comp Intel Neurosci*, 2010, Doi:10.1155/2010/520781, Hindawi Publishing Corporation, ID 520781, 12 pages
2. Balasubramanian S, Melendez-Calderon A, Burdet E. “A robust and sensitive metric for quantifying movement smoothness” *IEEE Trans Biomed Eng*, 2011, accepted
3. Roach N, Hussain A, Burdet E. “MIMATE: A wireless mechatronic platform for teaching the design of assistive and rehabilitative devices”, 2011 (submitted)

7.2 Conference papers

1. Kostić M, Popovic DB. “Action Representation for Wii Bowling: Classification.” *Proc of the 10th Symp Neural Network Applications in Electric Engineering - NEUREL 2010*, September 23-25, 2010, Belgrade, Serbia, pp. 23-26, ISBN 3-900928-09-5.

2. Došen S, Andersen A.H, Kannik K.E, Klausen C.S, Nielsen L, Wojtowicz J, Popović DB. “Assistive" Forces for the Acquisition of a Motor Skill: Assistance or Disturbance?” *Proc. of the 1st International Conference on Applied Bionics and Biomechanics ICABB-2010*, October 14-16 2010, Venice, Italy, CD

3. Kostić MD, Kovačević PS, Popović DB. “Is the Haptic Tunnel Effective Tool for Motor Learning?” In Ákos Jobbágy (Ed.), *Proc 5th European Conf Intern Fed Med Biol Eng*, IFMBE Proceedings Vol. 37, ISSN 1680-0737, ISBN 978-3-642-23507-8, e-ISBN 978-3-642-23508-5, DOI 10.1007/978-3-642-23508-5, pp. 761-764, 2011, September14 - 18 2011, Budapest, Hungary.