Robot for Coaching during Gait Training with Lokomat: Preliminary Experiment with a Multiple Sclerosis Patient

Nathalia Céspedes  
Colombian School of Engineering  
Bogotá, Colombia  
nathalia.cespedes@mail.escuelaing.edu.co

Jonathan Casas  
Colombian School of Engineering  
Bogotá, Colombia  
jonathan.casas@escuelaing.edu.co

Betsy Jaramillo Velasquez  
Mobility Rehabilitation Center  
Bogotá, Colombia  
betsy8522@gmail.com

Catalina Gómez  
Clinic Universidad de la Sabana  
Bogotá, Colombia  
macatalina@gmail.com

Marcela Múnera  
Colombian School of Engineering  
Bogotá, Colombia  
marcela.munera@escuelaing.edu.co

Carlos A. Cifuentes  
Colombian School of Engineering  
Bogotá, Colombia  
carlos.cifuentes@escuelaing.edu.co

ABSTRACT

Physical Rehabilitation with Lokomat has been suggested as an important therapy for gait rehabilitation after neurological disorders. Two issues of this approach have been identified: on the one hand, there is a lack of adherence of patients to the programs. On the other hand, there are multiple tasks performed by the therapist such as: monitoring physiological variables and controlling proper gait patterns during sessions. In this context, social robots could be beneficial as a tool to cooperate with therapists to control the patient’s performance and to provide motivation and encouragement during the treatment. This work presents a Human-Robot interface that monitors and provides feedback to the patient according to the cervical and thoracic posture, cardiovascular performance and Borg scale. A preliminary evaluation of this approach with a multiple sclerosis patient is presented. This study shows the potential of robots for coaching in physical rehabilitation in terms of support and accomplishment in Lokomat therapies.

KEYWORDS

Social Assisted Robotics, Physical Rehabilitation, Lokomat

ACM Reference Format:

1 INTRODUCTION

According to the World Health Organization, around 15% of the world’s population has some disability, mostly caused by neurological diseases such as stroke and spinal cord injuries [17]. These pathologies cause limitations in lower and upper limb motor abilities [2] [1]. Physical Rehabilitation (PR) is a continuous process that involves the evaluation, definition, planning and development of different strategies, with the aim of improving the quality of life and self-reliance of patients who have suffered a neurological disease [17].

PR is focused on two main aspects: (1) physiological aspects related to the regulation of biological functioning, (2) cognitive aspects related to cognition processes and the processing of information such as language, memory, attention, motivation and perception [18]; these aspects are important to evaluate the evolution of the patient during the programs. Currently, there are several PR methods based on conventional therapies and robot assisted gait training rehabilitation.

Nowadays, Lokomat (Hocoma, Switzerland) is the gold standard device in these sessions [21]. The Lokomat is a robotic orthotic device that adjusts to the lower limbs of the patient with the general purpose of retraining the gait through repetitive and intensive simulation exercises. It uses sensory stimulation fed by proprioceptive feedback games improving the neuroplasticity for a functional recovery [4] [5]. In different studies the positive effects of Lokomat have been demonstrated, increasing muscular tone, balance, motor control and muscular strength [22], compared with conventional therapies [7].

Two of the most relevant issues presented in PR are: on the one hand, adherence to the programs [10]. Around 42% of the patients abandoned rehabilitation sessions. Although factors that act as a barrier are not clear, it is believed that some of them could be: low aerobic performance during exercises, anxiety, low motivation, depression and other cognitive conditions [10]. On the other hand, multiple task performed by the therapist during a session [6], for example, simultaneous measurements and feedbacks of physiological variables.

In this context, Socially Assistive Robotics (SAR) could be beneficial as a tool to cooperate with therapists to control patient’s performance and to provide motivation and encouragement during the treatment.
2 RELATED WORK
Over the past years, SAR have been introduced in different scenarios. Mataric et al. used SAR for post-stroke rehabilitation, demonstrating the novel use of an autonomous mobile platform with several feedback and monitoring functions, showing potential therapeutic benefits and patient's positive response in achieving different goals [14]. Jung et al. examined the functional utility of an embodied robot agent (uBot-5) as an interactive medium in stroke rehabilitation. The study was performed by one male patient during 8 sessions, the subject demonstrated improvement in the average number of trials accomplished per minute during upper-limb exercises [11]. C. Kidd and C. Breazel in 2008, studied the long-term effects of human-robot interaction in coaching with the aim of reducing the rates of overweight and obesity. In this case, the robot asked patients their diet goals in terms of burning calories during the exercise and data related to the food consumed during the day. The results showed that the participants assisted by the social robot were more interested in knowing the calories consumption and exercise performed than those who used other methods [12]. In 2012 a social robot was designed to engage elderly users in physical exercise. During the session, the robot asked to the user to perform simple seated arm gestures and the user was able to communicate with the robot. The study consisted of two conditions: relational condition, where the robot employed social interaction and personalization approaches, and non-relational condition where the robot only provided instructional exercises. The results of the study show a strong users preference for the relational robot, the exercise system was well received and effective in motivating physical exercises [8]. NAO robot also has been a tool to assist conventional physiotherapy practices, by performing 9 exercises selected since the frequent mistakes or inaccuracies in the execution that patients usually do in the execution of the exercise, for example: abduction of the shoulder. This study shows that patients improve the movement’s technical quality when the robot perform the exercises according to the synchronization speed during the human-robot interaction [19].

This work presents a Human-Robot interface that monitors and provides feedback to the patient according to patient’s performance, which is in order to deal with motivational and engagement issues. Additionally, this interface intends to reduce repetitive therapist’s task during the treatment with Lokomat, such as corrective tasks focus on, both, rectifying patient’s gait pattern, and monitoring cardiovascular performance and Borg scale. The proposed interface integrates: (1) a Heart Rate monitor sensor to continuous monitor cardiac activity, (2) two Inertial Measurement Units (IMU) to estimate cervical and thoracic posture, and (3) a Joystick to choose the Borg Scale (perceived exertion scale). A NAO robot (Aldebaran Robotics, France) is used to give feedback to the user with verbal gestures according to on-line measurements.

3 MATERIALS AND METHODS
This work was developed in two stages: first, a description of the Human-Robot interface, and second, a protocol carried out in the preliminary study where SAR system helps the therapist to assist a patient in order to measure his performance during the session.

3.1 Human-Robot Interface
The proposed Human-Robot interface is based on a previous study developed in [16]. The authors performed a survey on a group therapist and patients, who are undergoing Lokomat therapy at Mobility Rehabilitation Center and Clínica Universidad de la Sabana, which are two institutions involved in this research. This work includes a set of variables relevant to be measured to develop a robot for coaching during gait training in therapy with Lokomat (Fig 1), as it is described below.

Cardiovascular parameters: to monitor heart function during the exercises guided by the Lokomat[3], a heart rate monitor, Zephyr HxM BT (Medtronic, USA) was located with an elastic band in the lower part of the patient’s sternum.

Spinal posture parameters: IMU node (Fig 1) reports the degrees to estimate the spinal posture. Since it is an affected variable during the sessions and is constantly corrected by the therapist [9, 20], two real-time IMUs (Bosch, Germany) were used to measure cervical and thoracic inclination angles at pitch, roll and yaw rotations. One sensor was located in the user’s forehead and the other one between T6-T7 spinal segments adjusted with velcro straps [13].

Cognitive parameters: The borg scale which represents the patient’s perception of the effort during physical activity [15] and it is controlled by a joystick sensor that allows the patient to insert the number related to the scale. Besides, motivational feedback is made by a social robot NAO using randomly verbal phrases. All of these sensors have different transmission rates and sampling frequencies which represent an issue for the on-line system. To solve this issue, the processes of each sensor are made in different nodes, each node is used as a driver to obtain the raw-data of the sensors and perform an initial processing used for the transmission.
As can be observed in Fig 1, this data is acquired by the Index Manager, which performs a downsampling (with a sampling frequency of 1Hz) in order to manage and join all nodes, including the NAO module, graphical user interface and the database.

Currently, the robot interacts with the patient through the feedback of the user’s performance in two ways: (1) in the spinal posture case, NAO gives a verbal advice if the angles do not correspond to an upright posture. (2) NAO provides feedback according to the Borg scale selected by the user. Additionally, the patient has access to a graphical user interface feedback by means of visual reports of the sensors data.

3.2 Preliminary Study Design

An experimental study was designed with the main objective of observing the functionality and usability of the Human-Robot interface. As shown in Fig 2 one patient was randomly chosen to do a therapy assisted by a social robot, a multiple sclerosis male patient (1.83 m, 60 Kg, 62 years old) active in Lokomat therapies. For this protocol the exclusion criteria included cognitive pathologies that could affect the understanding of the protocol.

The Lokomat settings are: treadmill speed at 1.5 m/s, distance of 652.1 m, 29.2% of body weight support, therapy time of 30 minutes, based on the therapist experience. Finally the subject stood in a cool down phase. The measurable parameters were: spinal posture, hear rate and Borg Scale.

4 RESULTS

According to the protocol described in the methods and materials section, the interface was on-line for 30 minutes. Fig 3 and Fig 4 show the evolution of postural behavior. The most relevant inclinations of the body were observed on the sagittal plane corresponding to the pitch axis of the IMU sensor, taking into account the movements in the other planes are controlled by the Lokomat’s features. Bad posture described by a threshold occurs when angles increase in a range of 10-15 degrees (blue and red horizontal line in Fig 3 and Fig 4), over the initial position, in this case 0 degrees.

Comparing spinal postures in pitch axis, cervical posture reached more frequently the threshold than the thoracic posture, due to the characteristics of the Lokomat, which has a support that restricts movements in all the lumbar section and a part of the thoracic section. In this cases the robot interacted with the patient through phrases that encourage the patient to improve the posture, for motivational purposes, three of the main phrases are: "Your head has a bad posture, please tilted it back", "you are doing it right" and "Your torso is bowed, you can improve your posture, please correct it". For cervical posture (see Fig 3), the patient reached the threshold
angle 8 occasions, with evident inclinations at minutes 10 and 17. Similarly, for thoracic posture (see Fig 4) the patient reached the threshold angle 4 times at minutes 4, 6.3, 17.4 and 23. Heart rate and Borg scale were also measured. Fig 5 represents the heart rate data during the session, including the last 10 minutes corresponding to the cool-down phase. The exercises performed during Lokomat sessions weren’t of high intensity, thus in Fig 5 a normal heart rate was observed, keeping in mind intensity of routines with Lokomat.

The borg scale is required during the complete session (Fig 6), the perception of the patient was low and moderate effort, at the 20th minute the hardness perceived level increase due the therapy conditions related to the Lokomat’s treadmill speed. Finally as shown in Fig 7, different events occurred during the therapy, including Borg scale with a request frequency of 3 minutes, NAO motivation interventions and postural feedback.

5 DISCUSSION

The figures in the results section show heart rate, IMU’s and joystick sensors were appropriated to measure physiological and cognitive aspects during the complete therapy. Usability of the system was comfortable for the patient and did not disrupt the physical intervention or the therapist.

The feedback given by NAO allowed the interaction with the patient. During this preliminary session, a positive impact was observed in aspects such as attention, in cases when the robot asks the user to improve the posture and motivation provided by verbal phrases. As shown in Fig 7 the social robot supported different events during the 30 minutes of therapy. As mentioned before there are correctional, motivational and advice feedbacks, where the cervical posture correction and the motivational feedback were the most frequent events. An initial observation was that NAO accompanied the therapy in cases when a poor posture occurred and it was not perceived by the therapist, being an important tool to reduce the number of tasks performed by the therapist. For instance, in different moments of the exercise where the spinal postures were corrected by the robot and kinematic gait parameters were corrected at the same time by the therapist.

This leads towards an interesting research questions about the use and the benefits of social assistive robots in physical rehabilitation with Lokomat. Currently the design of the interface is being updated to include a strong relational robot, through memory and dynamic body gestures, and time-extending studies with Lokomat physical rehabilitation patients.

6 CONCLUSIONS

In the present work, an interface was designed, it combines relevant cognitive and physiological parameters with the aim of assessing user’s performance in PR with Lokomat, using a sensory system composed by a heart rate monitor, inertial measurements units and a joystick obtaining the heart function, cervical posture, thoracic posture and effort perception. These variables can be acquired and presented in real-time to the patients and the medical team, and the
architecture allows data processing, on-line feedback, visualization, and data management. The functionality and usability of the system for this therapy was appropriated, showing reliable measurements. Moreover, the robot gave different feedback corresponding to the variables and motivate the patient with randomly verbal phrases, allowing the interaction with the patient. This study shows the potential of SAR in physical rehabilitation with Lokomat for coaching in terms of supporting the patient and accommodating the therapist’s task. Regarding the observations made in the preliminary pilot study, a well-received behavior and a positive impact by the patient and the therapist were seen during the session.

In the future, it is important to test the social robot impact with a long term study following a greater number of Lokomat patients allowing a complete statistical analysis, finding relevant information about the measurable parameters in different sessions that include a social robot agent. Also, improvements to the Human-Robot interface will be conducted, by adding other relevant clinical variables and a more relational NAO through visual feedback of the postural behavior.

ACKNOWLEDGMENT
This work was supported by the Industry Academia Partnership Programme Colombia UK (IAPP/1516/137 / 2016-2018): Human-Robot Interaction Strategies for Rehabilitation based on Socially Assistive Robotics.

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