Pilot Study of a Performance-Based Adaptive Assistance Controller for Stroke Survivors

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Abstract. Robotic gait training is a promising tool to improve walking ability after neurological disorders. Despite its benefits, its therapeutic effects might depend on the customization of the robotic training to the patient's capabilities. In the last years, various approaches focused on the assist-as-needed (AAN) paradigm, have been proposed to improve the effectiveness of robotic rehabilitation. However, in most of these cases the amount of robotic assistance is chosen by a therapist, and therefore, subjective decisions could affect the adaptation of the therapy to the patient's needs. This contribution presents the implementation of a novel performance-based adaptive controller, which automatically adjusts robotic assistance for diverse subtasks of gait based on the user's performance during training. A pilot study testing this controller in one stroke survivor, shows the potential of the proposed tool to be included in future robot-based gait training protocols.

1 Introduction

Robot-assisted gait training (RAGT) has received increased attention in the last decades to complement traditional physical rehabilitation of people with neurological disorders. Several robotic gait trainers have been developed and implemented with positive results in different motor disorders resulting from cerebral palsy [1, 2], complete paraplegia [3], or stroke [4]. So far, determinants for successful gait training have been focused on intensity [5], self-initiative [6] and task-specificity [7]. However, RAGT should be further improved by helping physiotherapists to objectively customize training according to patient's needs and progression.

This contribution presents a pilot study of a novel controller that automatically regulates the provided robotic assistance separately for diverse subtasks of gait. The algorithm was previously tested in ten healthy participants to evaluate its feasibility at various amounts of gait speed and partial body-weight support (PBWS) [8]. Based on

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the conclusions derived from this previous analysis, here we expose a first pilot study of the controller behaviour with one stroke survivor.

2 Materials and Methods

2.1 Robotic Device

The LOPES II gait trainer was used to develop and test the controller [9]. It is a treadmill-based rehabilitation exoskeleton with eight actuated degrees of freedom for the hips, knees and pelvis to control the motion and guide the lower limbs following prescribed gait patterns. The robotic assistance provided by the device can be classified into several subtasks of walking (i.e. step length, step height, stability during stance, prepositioning and weight shift). For each of those subtasks, the support is scaled from 0% (no support) to 100% of assistance in steps of 20%.

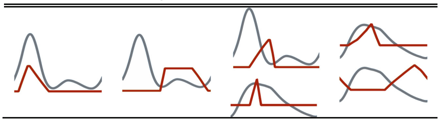
2.2 Adaptive Controller

The new performance-based adaptive controller presented in [8] was adjusted to be implemented in a pilot study with one stroke survivor. The algorithm determined patient's performances by evaluating the deviations of the measured joint angles from the reference pattern ($\theta_{ref} - \theta_{real}$) at specific key points of the gait cycle. Each key point corresponded to one particular subtask of walking, and all of these subtasks were evaluated separately for each leg.

The controller assessed patient's performances per subtask during the exercise by evaluating the walking pattern after a specific *time of evaluation*, which can be understood as a concrete number of previous steps [8]. The LOPES II increased or decreased the robotic assistance based on the comparison of these performances with a selected threshold. Finally, the subtask-specific control was completed by using different assistance profiles per subtask (see Table 1). Any combination of assistance profiles was possible, resulting in a total robotic assistance that was the sum of all the different assistance profiles.

Table 1. Subtask-based profiles (red) & joint angles for knee and hip (grey)

Step height	Stability during stance	Prepositioning	Step length



2.3 Patient and Pilot Experiment

A female stroke survivor participated in this pilot study (44 years-old, hemiparesis of the right side). The experiment consisted of walking in the LOPES II at 0.4 m/s and 0% of PBWS for 3.5 min. The participant started receiving 100% of robotic assistance for all the subtasks, and subsequently, the support was automatically subtask-based adapted every five steps based on her performance.

3 Results

As an example of the obtained results, we focus on the step height subtask here. For other subtasks, the controller was also able to adjust the robotic assistance based on the participant's performance.

Figure 1 shows the effect of the robotic assistance for step height (red) on the patient's walking pattern (blue). When 40% of assistance was applied (see windows W1 and W3), the patient (blue) walked with more knee flexion during swing (closer to the reference (grey)) compared to 20% of robotic assistance represented in window W2.

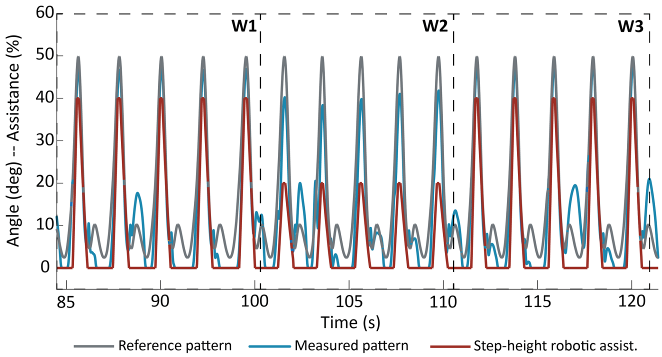


Fig. 1. Reference (grey) and measured (blue) joint angles of right knee (paretic), and robotic assistance (red) provided for step height subtask. The support changed every 5 steps (windows W1, W2 and W3).

Comparing the paretic and non-paretic leg (right and left side respectively), as we expected, the patient received less assistance for the non-paretic (see Fig. 2). The robotic assistance started in 100% and automatically decreased after intervals of five steps, until it reached the proper assistance level for each leg (0% for the non-paretic, and fluctuations of 20–40% for the paretic side).

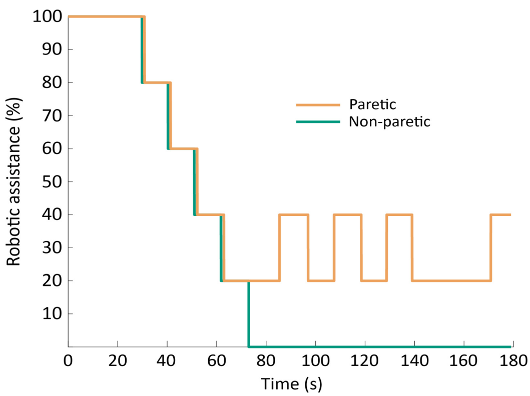


Fig. 2. Assistance levels for the step height subtask (paretic and non-paretic leg). Both started at 100% of robotic assistance and decreased until appropriate assistance levels were achieved for each leg.

4 Conclusions

The controller can be used to selectively assist stroke survivors with specific subtasks of walking. Further experiments with stroke survivors are currently performed. They will give more information about the feasibility of the controller to be used in future clinical rehabilitation protocols to improve walking ability after stroke.

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