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„The WalkTrainer™: A Robotic System for Walking Rehabilitation“

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The WalkTrainer™: A Robotic System for Walking Rehabilitation

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INTRODUCTION

Standard reeducation methods for paraplegic people rely on manual or robotic mobilization on a treadmill [Reikensmeyer2004]. However in both cases the motion is generated by an exterior force, the training is thus called passive. In this context the Swiss Fondation for Cyberthoses (FSC) has decided to combine the advantages of robotics (precise and repeatable motion, unlimited training) with closed-loop muscle stimulation. Thus the motion is provided by the muscle of the patients and the robot assists the subject [Fitzwater2002].

MATERIAL

The WalkTrainer (Figure 1) is the second step of the Cyberthosis project [Bouri2006]. Its precursor, the MotionMaker has been successfully tested on paraplegic subjects [Metrailler2006] and is now being commercialized by Swortec. The MotionMaker is built to perform "only" closed-loop muscle stimulation on a subject that is seated. On the other hand the WalkTrainer is equipped with:

- two leg orthoses to control and measure the force/position of the hip/knee/ankle articulations
- a 6 degree of freedom pelvic orthosis to enable a perfect reproduction of the motion of the pelvis during deambulation
- a twenty channel real time muscle stimulator to enable closed-loop muscle stimulation
- an active bodyweight support
- a motorized deambulator that will enable true overground deambulation

This device allows overground deambulation combined with leg and pelvis mobilization. Furthermore closed-loop muscle stimulation enables an active participation of the subject.

METHODS AND RESULTS

Trajectories:
Correct robotic trajectories are a key issue in the rehabilitation process. For the pelvis the available data was not satisfactory. The WalkTrainer was thus converted in order to be able to measure the motion of the pelvis of a subject.

To do this only the mobile frame of the WalkTrainer was used and two potentiometers were added in order to measure the distance/speed of the subject and a 6 degree of freedom (DOF) optical device (EasyTrack) was used to record the motion of the subject's pelvis (the 6 DOFs are recorded). A measurement campaign was then performed on about 20 subjects to obtain representative database [Stauffer2007].

Figure 1: WalkTrainer with valid subject.

We then made an attempt to find a model that predicts the amplitude of each DOF as a function of height/weight/speed of the subject. It turned out that the most reliable variable was the speed. This model was then used to adapt the amplitudes of the motion of the pelvic orthosis (the leg orthosis was not available at that time). The subject was then asked to walk in front of the WalkTrainer with his pelvis mobilized by the orthosis. The synchronization information was provided by a footswitch. During the experiment the RMS forces applied by the orthosis were measured. The subject was then requested to walk at different speeds and the amplitude correction was switched on and off every 50 steps. And every 200 steps the walking speed was increased (starting at 1km/h, 1km/h is added at each increment). As expected the measured forces decreased when the amplitude was adapted to the speed of the subject. Furthermore the applied force also increases with speed, this comes mainly from the fact that the used trajectory profile was recorded at low walking speed. This result can be viewed in figure 2.

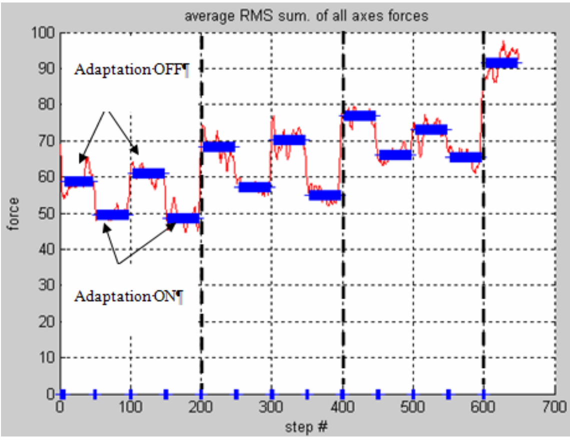

Figure 2: RMS force measured by the pelvic orthosis vs steps (every 200 steps the walking speed is increased and every 50 steps the adaptation algorithm is turned from OFF to ON).

Muscle:

The previously used muscle model was a function of segment position and stimulation intensity only. By using a knee orthosis speed dependent parameters were identified. Now the model also takes into account passive damping and force-velocity in the muscle contraction. The identification time required is however not negligible, the use of an iterative algorithm for the muscle stimulation is thus thinkable.

DISCUSSION

While these lines are written the last pieces of the leg orthoses are being assembled. Complete tests of the system on valid subjects and later on paraplegic subjects are planned for September 2007. So far the method of closed-loop muscle stimulation and robotic assistance has been proven to give promising results while using the MotionMaker, it is thus believed that the results provided by the WalkTrainer should even be better. Indeed the subjects motivation will be maximal since overground deambulation will be performed. Furthermore precise movements of the lower limbs but also the pelvis will be performed.

Up to now muscle stimulation as well as trajectory generation for the pelvis have been on focus. Both have provided useful results.

CONCLUSION

The WalkTrainer project is challenging a complex domain in which predictions are very hard to make. It is almost impossible to predict what improvement a paraplegic subject will get. However the results of the MotionMaker comfort us in our research and we are looking forward to the clinical trials that will be held in at the CRR (Sion, Switzerland).

THANKS

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