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Estimating the patient's contribution during robot-assisted therapy

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Abstract—Robot-assisted therapy has become increasingly common in neurorehabilitation. Sophisticated controllers have been developed for robots to assist and cooperate with the patient. It is difficult for the patient to judge to what extent the robot contributes to the execution of a movement. Therefore, methods to comprehensively quantify the patient's contribution and provide feedback are of key importance. We developed a method comprehensively to estimate the patient's contribution by combining kinematic measures and the motor assistance applied. Inverse dynamic models of the robot and the passive human arm calculate the required torques to move the robot and the arm and build, together with the recorded motor torque, a metric (in percentage) that represents the patient's contribution to the movement. To evaluate the developed metric, 12 nondisabled subjects and 7 patients with neurological problems simulated instructed movement contributions. The results are compared with a common performance metric. The estimation shows very satisfying results for both groups, even though the arm model used was strongly simplified. Displaying this metric to patients during therapy can potentially motivate them to actively participate in the training.

Key words: cooperative control, dynamics, feedback, modeling, performance metric, rehabilitation, robot-aided therapy, robotics, stroke, upper limb.

INTRODUCTION

To promote effective neurorehabilitation, active participation of the patient is a key factor [1–3]. In conventional therapy, the therapist tries to motivate the patient with an attractive therapy concept. The therapist often touches the patient's limbs to assist him or her and estimates effort based on therapeutic experience. During robot-assisted therapy, the robot supports the patient's limb; the therapist is usually not in direct contact and, therefore, less able to assess effort. Many robots automatically adapt their support to the needs of the patient with a patient-cooperative control strategy [4–5]. The goal of these controllers is to assist as needed and ensure that the patient can perform the demanded movement. The disadvantage of these strategies is that the patient might find it convenient to rely too much on the robotic support, leading to decreased voluntary effort. Because the robot adapts its assistance levels to the needs of the patient, the therapist would not observe the decreased patient contribution to the movement. To account for this human lacking in the control loop, Wolbrecht et al. proposed a forgetting factor for the adaptation of assistance [6]. Another solution would be to put the patient in charge of

Abbreviations: CAD = computer-aided design, DOF = degree of freedom, FM = Fugl-Meyer, RMS = root-mean-square, SD = standard deviation.

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