MEASUREMENTS AND EVALUATION OF HUMAN GRASPING

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Abstract:

In the paper methods and devices for measurement and evaluation of grasping in the rehabilitation environment are proposed. Investigation of grasping was divided into three phases: reaching to grasp an object, exerting force on the object, and changing the orientation of the grasped object. The original methods are computer based and provide quantitative evaluation of grasping. Reference pattern of grasping was obtained by measurements performed in healthy persons. Assessment of grasping force and training of grasping was performed in groups of patients with various etiologies.

INTRODUCTION

Grasping is such an everyday activity that it is difficult to imagine, why grasping would be an interesting object of research. Nevertheless, we can state that grasping is the most important human motor ability. Grasping food and bringing it close to the mouth certainly is a proof for this statement (1, 2). Another question arises, why grasping is of interest in engineering environment. The answer lies in development of ever more complex man-machine interfaces, multifingered robotic hands, and prosthetic or orthotic devices. Our aim is, however, to design devices and methods enabling assessment and quantitative evaluation of grasping abilities before and after various rehabilitative interventions in people with special needs.

Our studies of grasping are divided into three phases. In the first phase the fingers are approaching the object to be grasped. In the second phase the fingers are exerting forces onto the object, while in the last phase the position and orientation of the grasped object is changed by appropriate finger movements.

HAND APPROACHI NG PHASE

Preshaping of the fingers according to the shape of the object is characteristic for the approaching phase. Three objects were selected in experiments: thin plate, block, and cylinder. The objects were by the use of magnetic contact attached to the endpoint of a robotic manipulator. The task of the robot was to place the objects in different positions and orientations in the subject's workspace. Robot also randomly introduced perturbations of the object position or orientation. Five infrared markers were placed on the fingertips together with additional three markers attached to the dorsum of the hand. The preshaping of the fingers was evaluated by defining a pentagon connecting the five fingertips (3). Reaching and pointing hand movements were also studied by the help of haptic robot and virtual environment (4). In virtual environment, a labyrinth was created at the start of each test. By moving the end point of the haptic robot, the subject was able to move the pointer through the labyrinth and to feel the reactive forces of the wall. The subject's primary task was to pass the labyrinth as quickly as possible, with a few collisions with the walls as possible. The test was applied to subjects with various neurological diseases and also to subjects after amputation.

Figure 1: *A compact assessment system with two force measuring units in the shape of a cup and thin plate can be connected to a personal computer to accurately measure the dynamic grip force in cylindrical and lateral grip.*

GRASPING PHASE

An original tracking system for the assessment and training of grip force control was developed (5). The system consists of two measuring objects enabling assessment of power and precision grip (Figure 1). It can be connected to a personal computer for visual feedback and data acquisition. The task requires the patient to track the target signal on screen by applying appropriate force to the grip-measuring device (Figure 2). The target signal is presented with blue ring moving vertically in the centre of the screen. The applied force is indicated with a red spot. When the grip force is applied, the red spot moves upwards. The aim of the task is to continuously track the position of the blue ring by dynamically adapting the grip force to the measuring unit. The complexity of the task is adjusted by selecting the shape of the target signal, e.g. ramp, sinus, rectangular shape, setting the level of the target force, and changing the dynamic parameters, e.g. frequency, force-rate. The results in healthy subjects showed significant differences in grip force control among different age groups. In a patient after Botulinum-Toxin treatment the method revealed noticeable effects of the therapy on patient's tracking performance. Training with the tracking system showed considerable improvements in the grip force control in 8 out of 10 stroke patients. The systems was tested also in a group of users of orthoses.

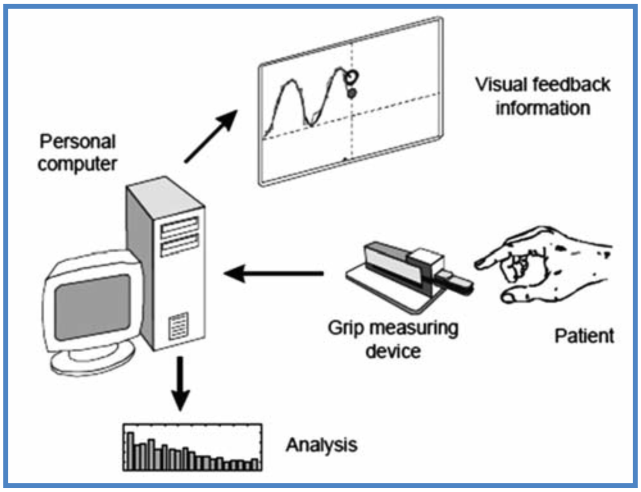

Figure 2: *Grip force control was assessed using the force tracking task where the patient applied the grip force according to the visual feedback from the computer screen.*

HAND DEXTERITY PHASE

An original assessment approach was developed with the aim to evaluate the grip dexterity (6). In this case the subject holds an object with the fingertips and changes its orientation. The movements of the fingers, wrist, and forearm were observed. The subject was sitting in front of computer screen, while holding a block with his fingertips. Six infrared markers were attached to the block. The position and orientation of the block was assessed by six OPTOTRAK cameras. The block was then displayed in the virtual environment within the same orientation as in the real world. In the same time a reference semi-transparent object was displayed on the screen in another orientation. The task of the subject was to align both objects. In further studies of hand dexterity a new isometric device for multi-fingered grasping in virtual environments was designed (7). The device was aimed to simultaneously assess forces applied by the thumb, index, and middle finger. A mathematical model of grasping, adopted from the analysis of multi-fingered robot hands, was applied to achieve interaction with virtual objects. The movements of virtual object corresponded dynamically to the forces and torques applied by the three fingers. The training tasks were designed to train patient's grip force coordination and dexterity through repetitive exercises.

CONCLUSION

Three original approaches to measure and evaluate human hand functionality are described in the paper. The simple device enabling assessment of forces during power and precision grasping was extremely well accepted in clinical environment, both from the side of patients and therapists. Several prototype devices were, therefore, built and distributed for further clinical evaluation to rehabilitation centres in Slovenia and also Australia and Romania. Slovenian producer of medical equipment is interested into production of the grasping force tracking system providing evaluation and training of grasping in patients with various etiologies.

In all three approaches computer measurements were introduced enabling quantitative estimation of human hand functionality. With some of the approaches described virtual reality was used. Virtual reality is a powerful tool providing the patients with repetitive practice, feedback information, and motivation to endure practice. Another advantage of virtual reality rehabilitative systems is the possibility of the adaptation of the training task to the capabilities of individual patient. In this way training in virtual environment can start at an earlier stage than training in real environment. Execution of skilled tasks rather than simple movements induces improved results of the training process.

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