Servo-actuated Stylus for Post Stroke Arm and Fore Arm Rehabilitation

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Abstract. This paper describes the design and implementation of a 1-DOF servo-actuated stylus, which is used as an end effector in a desktop haptic device. The desktop haptic device is part of a multimodal system aimed for the assessment, training and rehabilitation of the arm, forearm and hand while the user perform several tasks. Patients will use the haptic device which carries out the servo-actuated stylus in order to draw simple and complex sketches, in this way, the patient is able to feel the virtual sketch by using the haptic device, which acts as a virtual guide taking advantages of its force feedback capabilities. The therapist is able to control the 1-DOF-stylus rotation according to the requirements of the patient.

Keywords: Haptic Guidance, Sketching task, Stroke patient, Multimodal system.

1 Introduction

Rehabilitation after a stroke is a long process and usually the therapist guides the patient verbally as well as physically. For example, if the patient needs to perform a 2D rectangular sketch motion, the therapist will say now, lets draw a rectangle as she or he begins guiding the patients hand. A sketch is a rapidly executed freehand drawing that is not intended as a finished work. Sketching is one of the most important and complex human activities in which the hand movements are controlled by the central nervous system, which regulates the activity of the hand and arm muscles to act in synergy. The central nervous system receives dynamic feedback information from visual sensors and from other body sensors located on the skin, muscles and joints while regulating the motor output. In case of rehabilitation after a stroke, one important factor is motivation [1]. The guidance haptic device concept has been described in [2], while the multimodal system has been described in [3] which consisting in a combination of visual, haptic and sound technologies, aims to be a step forward in the field of multimodal devices for supporting unskilled people to improve their skills and in the assessment of manual activities. Sketching, hatching and cutting tasks are assisted through the haptic guidance device. The drawn shape can also be physically produced as a piece of polystyrene foam as shown in Figure 1.

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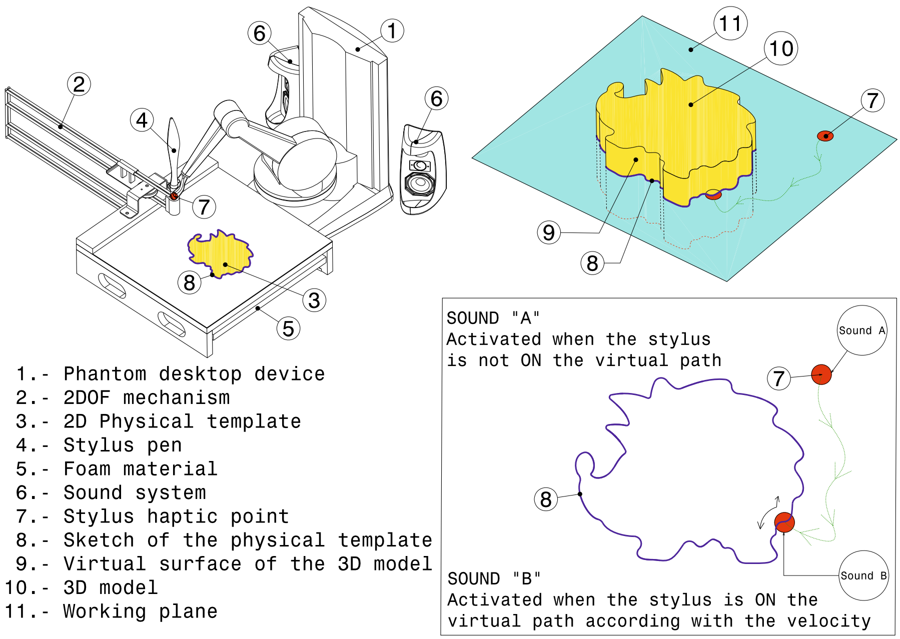

Fig. 1. Concept of the Multimodal System

The user is sitting in front of the haptic guidance device in a comfortable way, and then by handling the stylus (4) tries to follow the sketch (8) from the physical template (3) in order to perform the 2D tasks. These tasks are driven by the operators movement and assisted by the Magnetic Geometry Effect (MGE). The MGE constraint is linked to the external surface (9) of the virtual object that has been previously created by using a CAD software and the stylus haptic point (7). When this option is activated, a spring force tries to pull the sphere of the stylus (7) of the haptic device towards the virtual surface (9) of the 3D model (10). In fact, this effect is used to assist the users hand movements. In the cutting modality, while user follows the 2D template (8) by using the MGS, the wire tool, which is carried out by the 2DOF mechanism (2) cuts the polystyrene foam (5). The polystyrene foam is an interchangeable element. Note that in the intersection between the external surface (9) and the stylus haptic point (7), there is a working plane (11). In fact, this working plane is a physical constraint created by the 2DOF mechanism linked to the Phantom device (1). Figure 1 also shows in detail the sound strategy that has been adopted. In the multimodal system, the stylus (4) can freely rotate according to the hand movement.

2 Servo-controlled Stylus

According to preliminary test with stroke patients using our system, in which the therapist was involved in order to run a therapy session, we have noted the necessity to provide an additional degree of freedom to the stylus (4). Figure 2-a shows the patient's hand while tries to grasp the stylus. Figures 2-b and Figure 2-c show the therapist hand while guiding the patients hand in order to perform the sketching test. Figures 2-d and Figure 2-e show the patient performing the test without the therapist help. The patient is not able to control the radial deviation, flexion and extension of the hand as a result of the stroke and is not able to correct positioning the stylus in order to perform the sketching test.

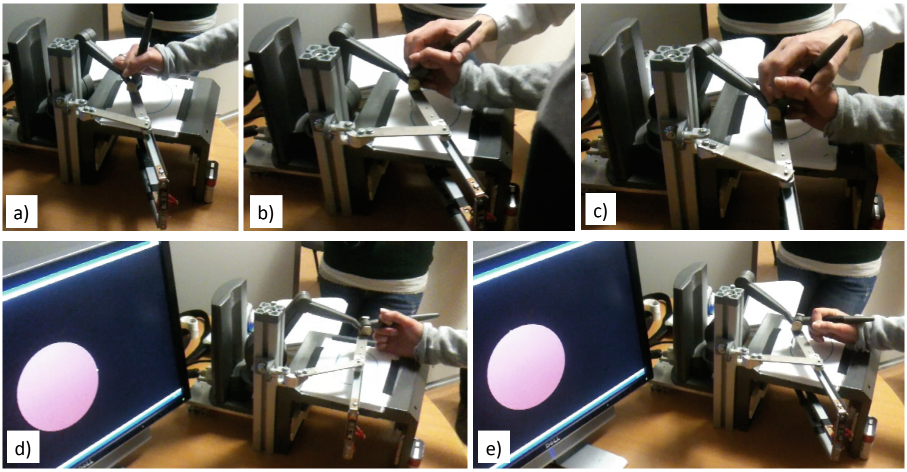

Fig. 2. Therapist guiding the user's hand

2.1 Biomechanics of Human Arm

The human arm has seven degrees of freedom: Abduction/adduction and flexion/extension of the shoulder; rotation of the upper arm; flexion/extension of the elbow; rotation of the forearm; and radial/ulnar deviation and flexion/extension of the wrist.

This paper presents the design and implementation of a 1-DOF servo-actuated stylus, which is driven by the therapist in order to allow the patient to correct handle the stylus according to the rehabilitation task. Figure 3-a shows the ideal position for the users hand while Figures 3-b and Figure 3-c show several problems in reaching the stylus. Figure 3-d shows the concept of our approach in which the stylus is driven by a servo-actuator. This servo-actuator is driven by the therapist in order to rotate the stylus according to the specific needs required in the rehabilitation task. In this way, once the user is able to correct handle the stylus, then is able to perform the sketch operation by using the multimodal system.

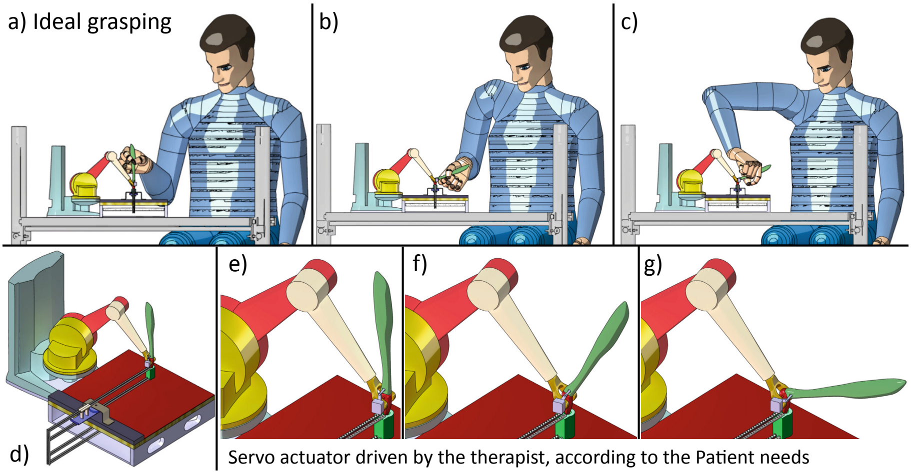

Fig. 3. Postural position problems

3 The Prototype

The main structure used for the Multimodal Guidance System has been designed taking into account some important considerations related to the use of sheet metal and aluminum components that implies: low inertia, light weight parts and low friction. Regarding the static and dynamic modeling, the links and components are considered to be rigid. However, the haptic guidance device is not a rigid structure. To provide this stiffness, the links have been designed as beams or shell structures. Also, the mounting arrangement of the main structure has been designed to accommodate manufacturing tolerances. Figure 4-a shows the prototype of the device and Figures 4-b and Figure 4-c show two different positions on the stylus while the user sketching a circle in a therapy session. A force and torque analysis have been performed in Visual Nastran 4D.The results of these analysis have been used to select the actuators. In fact, the servo drives have been selected so as to guarantee high reliability: the servo motor with titanium gears provides up to 2.35 Nm of continuous torque. The servo drives are HS-5955TG manufactured by HITEC [4]. This allows us to get high stiffness and load capacity.

The therapist is able to control the rotation of the stylus from -75 to 0 degrees through a computer interface which allow the signal communication between the computer and the DMX Servo-12 controller board.

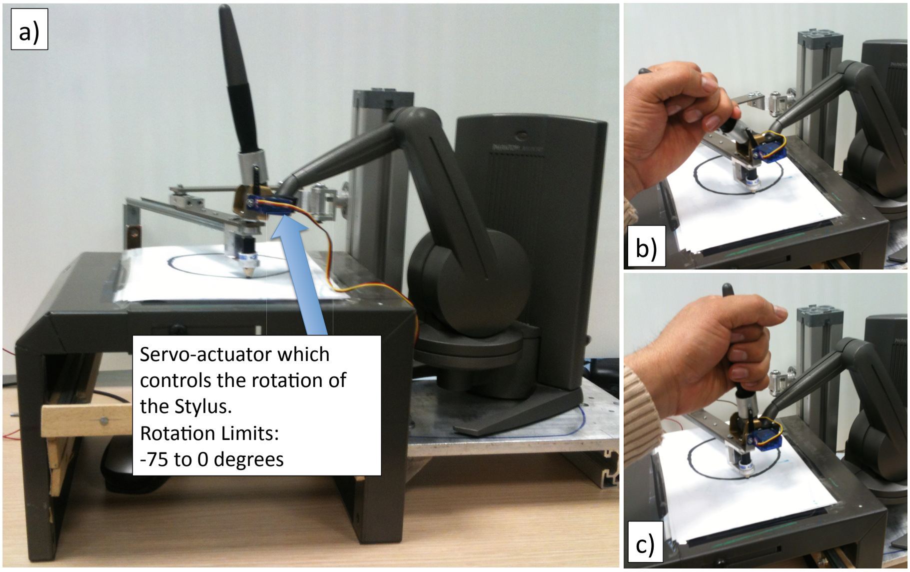

Fig. 4. The prototype

References

1. Mihelj, M., Novak, D., Milavec, M., Ziherl, J., Olenšek, A., Munih, M.: Virtual rehabilitation environment using principles of intrinsic motivation and game design. Presence: Teleoperators and Virtual Environments 21(1), 1–15 (2012) ISBN 1054-7460, `http://www.mitpressjournals.org/doi/abs/10.1162/PRES_a_00078` (April 05, 2013)
2. Covarrubias, M., Bordegoni, M., Cugini, U.: Sketching haptic system based on point-based approach for assisting people with down syndrome. In: Stephanidis, C. (ed.) Posters, Part I, HCII 2011. CCIS, vol. 173, pp. 378–382. Springer, Heidelberg (2011)
3. Covarrubias, M., Gatti, E., Mansutti, A., Bordegoni, M., Cugini, U.: Multimodal guidance system for improving manual skills in disabled people. In: Miesenberger, K., Karshmer, A., Penaz, P., Zagler, W. (eds.) ICCHP 2012, Part I. LNCS, vol. 7382, pp. 227–234. Springer, Heidelberg (2012)
4. HITEC servos, `http://www.hitecrcd.com/` (accessed January 25, 2013)