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ACTIVE ARM ORTHOSIS AND EXPERIENCE WITH ITS PRACTICAL USE

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A b s t r a c t

The Active Arm Orthosis was conceived in the form of an arm-transfering manipulator with three active degrees of freedom , mounted in practical way to the wheelchair of the dysthrophic patient. It is being controlled by means of an electronic control system, realized around an INTEL 8085 microprocessor.The control system is activated via a three-axes "joy-stick", manipulated by the patient's other hand. The plastic-metallic structure of the orthosis is driven by means of three electric servomotors. The trials with the orthosis, in the Mihailo Pupin Institute at the beginning, and now, at the time of the presentation of this lecture, already more than one and half years at the patient's home (interrupted by an operation for correction of the spine of the patient during four months) have confirmed the practical value of the Active Arm Orthosis for improving the quality of the patient's everyday life. One set of the orthosis has been delivered to the TIRR Texas Institute for Rehabilitation and Research in Houston, USA.

Introduction

The Robotics Department (formerly Department for Biotechnics) of the "Mihailo Pupin" Institute in Beograd, has been engaged during the period of the last fifteen years with the study, modelling, control synthesis and practical development of ARTIFICIAL MOTION SYSTEMS. These have been predominantly used for the realization of ACTIVE MECHANISMS for application in the rehabilitation of handicapped persons of the paralyzed or dysthrophic type,(1, 2, 3, 4, 5, 6, 7). The latter patients were found to be quite numerous, the majority ofthem being of the proximal type.

From the experience of the Institute for Neuro-muscular diseases of Youth in Beograd with people attacked by this type of disorders, it was learnt that nobody of them likes any kind of orthopaedic aid. It is well known, that these people prefer to use even their weakest muscles, finding special "tricks" than to use the most perfect and expensive aid. Thus, only extremely handicapped patients, who became practically completely dependent on other persons in all their life activities, are interested in some aid, but which if possible will not be hung on them, will not be on them or around them, that will be also comfortable enough to employ and easy to handle by themselves, and that will give them as much independence as possible.

The Active Arm Orthosis for neuromuscular patients was designed to help the most handicapped persons with proximal weakness. Inquiry carried out on more than 300 patients with proximal distribution of muscle atrophies and weakness (patients with Duchenne's muscular dystrophy, Becker's muscular dystrophy, facio-scapulo-humeral dystrophy, congenital myopaties, spinal muscular atrophies of Kugelber-Welander and adult types, chronical polymyosistis and difficult cases od Myastenia gravis, complicated with myasthenic myopathy) showed that they were all interested in these types of orthosis, considering that it was designed to:

1) improve the comfort of their everyday activities: washing, combing, tooth brushing, eating, drinking, applying make-up, writing, drawing, typing on electrical typewriter, etc.

2) eventually enable professional rehabilitation, according to previous educational capacities, as well as to the progressivity of the disease. There are various possibilities for the most handicapped patients if they accept the orthosis, to mention but a few:

- various occupations, where the basis of the job is writing, e.g. administrative jobs, lecturer, proof reader, etc.;
- telephone operators, telegrahers and teletype operators;
- controllers of final and semi-final products in various branches of industry (small cast meatl parts, in electromechanical, chemical and food industry, laboratory work, photography;
- help compulsory physical self-treatment of the "activated" arm of the patient - prevention of contractures.

<u>Solution</u>

In Fig.1 is presented the kinematical scheme of the orthosis. The three active degrees of freedom are in the form of three rotation angles: one around the transverse axis of the shoulder joint, second around same axis of the elbow joint and the third

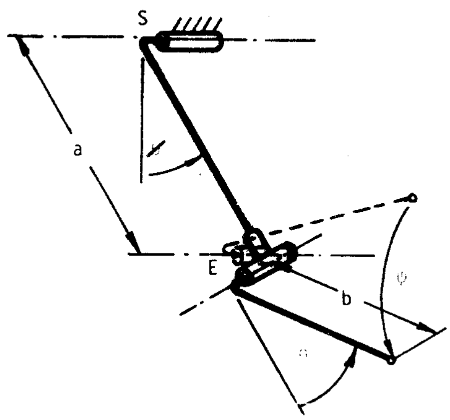

Fig.1 Kinematical scheme of orthosis

one around the longitudinal axis of the upperarm. By that arrangement a working space of the arm is formed, which is in front of the patient, enabling to reach his head (hair, face) and to lower the arm with the hand to the working surface (table, typewriter or similar).

For the control of the orthosis itself, a special version of velocity control was employed. According to experience and knowledge with human living control, this type of the same is most adapted to such problems. The joy-stick possesses three degrees of freedom: fore - aft, left - right, turn knob ccw: up - turn cw: down. These three degrees are in a quasi-cartesian coordinate system, and must be transformed in real-time into the coordinate system of the anthropomorphic arm. Fig.2 shows the transformation matrix of the joy-stick system into the system of the arm (orthosis) which can be satisfactorily processed by means of a microcomputer with a frequence of 40 c.p.s. For the first trials the PDP 11-03 minicomputer was applied and in the present version a home-developed and built microcomputer, based on the INTEL 8085 micrprocessor was adopted as standard solution, packed in a standard 19" rack.

$$\begin{Bmatrix} \Delta\psi \\ \Delta\theta \\ \Delta\phi \end{Bmatrix} = \begin{bmatrix} b\sin\theta\cos\psi & b\cos\theta\sin\psi & 0 \\ -b\sin\theta\sin\psi\sin\phi & b[\cos(\phi+\theta) + \cos\theta\cos\psi\cos\phi] & a\cos\phi+b[\cos(\phi+\theta) + \sin\theta\cos\psi\cos\phi] \\ b\sin\theta\cos\psi\sin\phi & b[\sin(\phi+\theta) + \cos\theta\sin\psi\sin\phi] & -b[\sin(\phi+\theta) + \sin\theta\sin\psi\cos\phi] \end{bmatrix}^{-1} \begin{Bmatrix} \Delta y \\ \Delta x \\ \Delta z \end{Bmatrix}$$

Fig.2 Transformation matrix

The Active Arm Orthisis follows the following vector commands: direction and sense are determined by the corresponding deplacement of the joy-stick, but the velocity of the componental movements is proportional to the deplacement amplitude; it means, that the orthosis moves faster when the joy-stick is more moved out from its neutral position. When the joy-stick is released, it returns by springforce into its neutral position, or better, neutral zone, and the orthosis rests still in the attained position. Now the patient is enabled to perform some task with his hand and fingers in this zone. For the time being, the velocities of motion are modest, about 0,15-0,20 m/s maximum, but this can be augmented substantially, although it seems from the experience gathered, that such velocities are satisfying. It must be kept in mind, that the patient generally has the time.

Trials, results and experience

In Fig.3 the mechanical part of the orthosis is illustrated mounted on a simple standard wheelchair. The three described artificial joints: in the shoulder one, and two in the elbow can be recognized together with their driving units in the form of electrical servomotors-reducers. For motion stability reasons, the shoulder joint is equiped with a tachogenerator, too, beside the servopotentiometers, which are in all joints. The miniature joy-stick, mounted on a small box at the armrest (left) can also be depicted. The photo shows the prototype of the orthosis, the second example is slightly cosmetically improved and is mounted on the electric wheelchair of the patient. It can be easily mounted an dismounted by operating four butterfly nuts.

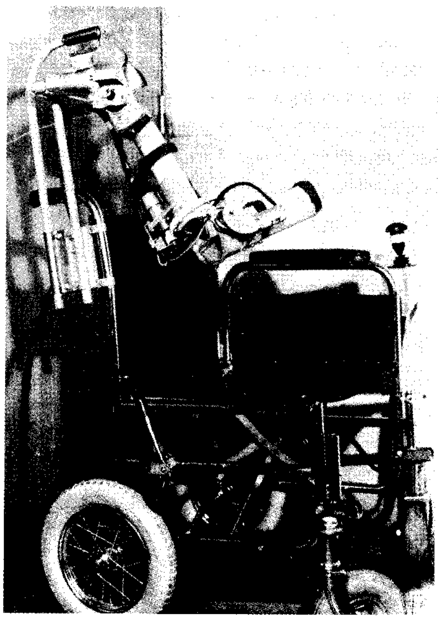

Fig.3 Orthosis prototype

The plastic semi-tubes of the basic arm structure are covered by thin soft rubber sponge and soft leather for comfort and the arm can be fastened in place by "Velcro"-strips, but this has been found not to be indispensable. The arm rests stably in the orthosis due to gravity.

Our patient is illustrated in Fig.4. O.J. from Beograd,45, dyagnosis:
amyotrophia spinalis progressiva Kugelberg-Wellander, now in the VIII stade according to the Zellweger-Hansen scale, which means, that she can sit in upright position when properly supported, which holds for the head, too. The only active parts of her body are the hands and fingers of hands, with a power rating of 1-2 according to the international scale. The patient is a very intelligent, sufficiently educated person, very willing and motivated for cooperation. She was, in the course of the initial trials very handicapped by the high scoliosis of the spine, which caused fast fatigue with obstructed breathing and also heart troubles. Nevertheless, by extraordinary willpower she mastered almost all basic performances of the orthosis, both during the initial trials at the Institute and later at her home, when the orthosis was transfered there. In the middle of 1983 she was able to organize a trip to the USA, where

she was subdued to a spine-corrective operation, which prooved to be quite successful. After post-operative rehabilitation and readaption, it was found that her height has augmented by some 8-9 cm (more than 3"), which caused no troubles with the orthosis and its adaptation to the new measures of the patient.

Fig.4 Patient O.J.,45

In the time of writing this paper, the patient mastered to a quite high degree the following basic tasks from her every-day life and activities:

- face washing with wet cloth
- make up donning
- hair combing
- teeth brushing
- self-feeding with spoon and/or fork
- writing and drawing on special desk, mounted onto the wheelchair
- typing on an electric typewriter.

The patient is very satisfied with the orthosis, which contributes substantially to the quality of her everyday life. She is using it as frequently, as can be organized. It must be pointed out, that somebody must place the patient into the wheelchair and place her right arm into the shell of the orthosis and her left hand on the joy-stick. If she has the necessary items (pencil, comb, make up, food, etc.) at the reach of her right arm and hand, she can swith herself the orthosis on, by means of a miniature single-throw switch in the vicinity of the joy-stick, which she operates with her thumb.

A series of photographs are given to illustrate the mentioned activities of the patient:

Fig.5 illustrates the process of eating with a fork,
Fig.6 shows donning of the eyeglasses,
Fig.7 presents the process of lifting a glass with liquid,
Fig.8 shows drinking from same glass,
Fig.9 shows again donning eyeglasses from another angle,
Fig.10 illustrates play with the patient's small parrot.

It should be noted, that the small bird is not afraid of the orthosis, which prooves soft motion and acceptable sound.

Another interesting thing is the very clear illustration of the patient operating the joy-stick, which can be seen in all photos. Let us also indicate, that Figs.7, 8, 9 and 10 were taken in the patient's home.

Fig.5 Patient eating with fork

Fig.6 Patient donning the eyeglasses

Conclusion

It has been proven, that an active arm orthosis can successfully help heavy cases of patients attacked by some forms of neuro-muscular deseases of proximal type, which were found to be quite numerous. The typical patient mastered the control of the orthosis with the fingers of the other (unactivated) hand via a miniature three-degrees-of freedom joy-stick, in the course of less than 20 hours' training duration. The technical and technological level of the present version of the Active Arm Orthosis can be regarded as satisfying. The security and controllability of the orthosis, performing smooth trajectories in space proove the high level of the solution of the control and actuator part of the orthosis. Further development could follows the following main directions: cosmetic improvement, weight reduction, price reduction, motor sound reduction, evaluation with a larger number of patients and production of a preseries of the orthoses.

At the time of this paper presentation it is hoped, that some experience will be available with the example of the orthosis delivered to the Texas Rehabilitation Institute.

At last it should be pointed out, that the development of this successful prosthetic aid would not be possible without the financial support of the Republican and Belgrade Science Supporting Funds and the Health Care Association of Belgrade. It is hoped, that the up to now lacking financial means will be found for the mentioned preseries production of the orthosis. In that sense the Dystrophy Association of Yugoslavia, Serbia and Belgrade are making coordinated efforts. It is also hoped, that the successful cooperation with the Institute for Neuro-Muscular Diseases of Youth from Beograd will be continued in the future.

Fig.7 Patient lifting glass　　Fig.8 Patient drinking

Fig.9 Patient donning glasses   Fig.10 Patient with pet

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