1 Introduction

The central point in the rehabilitative treatment of hemiplegic patients is 'exercise', which represents the significant unit for any therapeutic regimen. The therapeutic programme should be considered as a set of different tasks oriented to recover as much as possible the characteristics of lost motor capabilities (Perfetti, 1987). From another point of view, the therapeutic exercise could be an experiment in which the therapist can reflect on several questions: about the nature of the pathological state, or whether the treatment is correct. It is therefore important to study a training strategy taking into account the difficulties of the specific task and the behavioural and psychological aspects of the patient.

From a general point of view three sequential steps have been identified in the development of motor learning:

(a) cognitive phase
(b) fixation phase
(c) automation phase.

In the cognitive phase the subject drafts a sort of prototype of the motor skill to be learned (Marteniuk, 1979) in order to create new cinesthetic channels to control motor activities. In the fixation phase a period of continuous reorganisation of motor behaviour can be observed. Finally, in the automation phase the motor skill is progressively improved to become more co-ordinated. Obviously this step comes necessarily after the previous two.

Some review articles herald biofeedback as a promising tool for neuromuscular re-education when incorporated into a comprehensive treatment programme (Fernando and Basmajian, 1978; Basmajian, 1981). However, several significant factors exist in determining if a patient is a suitable candidate for biofeedback-based treatment. The major factor is that the potential for voluntary control must exist before training is begun (Binder-Macleod, 1983; Bracale et al., 1982; 1983; Pepino et al., 1983). On these bases several criteria could be suggested as guidelines to the therapeutic planning (although, especially for neurological patients, no standard rule should be set (Perfetti, 1987)).

(i) The patient should pay attention to the spatial parameters of the movement.
(ii) The patient should pay attention to the intensity of variables related to the movement.
(iii) The patient should pay attention to the effects of external stretching.
(iv) The patient should train voluntary capabilities through a set of simple voluntary tasks.
(v) The patient should pay attention to the wrong schemes of global movements through a set of more complex therapeutic exercises (Perfetti, 1987).

In what follows we present a therapeutic tool, which aims to be a help in the cognitive-based rehabilitative treatment of hemiplegic patients. The system provides visual biofeedback patterns and could be used starting from an early stage of the treatment when no voluntary control is available.

2 PERM: electropneumatic platform for motor rehabilitation

The PERM electropneumatic platform is able to:

(a) provide mechanical information to be recognised by the patient
(b) record the voluntary movements
(c) provide visual biofeedback patterns.

It consists of a basculant plane moved by four pneumatic pistons, driven through a microprocessor-based device. The platform is provided with pressure and position sensors for closed-loop control and permits, via a video monitor, several visual biofeedback outputs. Some I/O interfaces are available for other control needs (Figs. 1 and 2).

The active parts consist of a 40 cm square plate which can move in any direction under force or position control. The fullscale pressure inside the pistons ranges between 2 and 6 atmospheres, and can be changed manually or automatically or both. The maximum inclination of the moving plate is 12°.
Usually the patient sits or stands with the plegic side over the moving plane. Two working modes are allowed; active mode and passive mode. In the active mode the operator can control through a command console the position of the platform and the pressure distribution inside the pistons, in order to provide the patient with mechanical stimuli. (In this first prototype it is not possible to control the speed, either in force or position control.) In the passive mode the pistons under the platform are first charged to a reference pressure level. The patient then performs voluntary actions on the platform receiving visual biofeedback patterns from the display.

2.1 Mechanical architecture

The mechanical structure of the PERM platform consists simply of two metal plates, connected through a cardanic joint (Fig. 3); a piston is placed at each corner of the lower plate of the platform, the centre of which coincides with the centre of the joint. The desired movement is transmitted to the platform through the synergism of the opposite pistons. The upper plate receives the resulting moment from the simultaneous action of the four pistons. An iron sphere is placed on the tube to reduce the friction between the piston and the lower side of the upper plate.

Two position transducers (P) are connected to the upper plate and four pressure transducers are used for monitoring the pressure inside the pistons. The pistons are supplied with fluid (air) coming from a compressor which acts as a constant-pressure source (Fig. 4).

The charging fluid passes through a unidirectional airflow regulator $R_c$ (manual control) and an electrovalve $E_c$ excited by DCC (from the microprocessor). The discharging fluid, coming from the pistons, passes through another valve $E_s$ excited by DCS and another unidirectional airflow regulator $R_s$ (manual control as well). The pressure transducer $T_p$ picks up a measure of the pressure inside the pistons when both valves are closed. The force transmitted to the upper plate can be controlled by regulating the pressure inside the pistons.

The pistons are charged or discharged by activation of DCC and DCS, depending on the difference between the desired pressure (from the joystick) and the measured pressure. The airflow regulators $R_c$ and $R_s$ permit damping of the system. The algorithm used to control the pressure is reported in Section 2.3.

The position of the platform can be controlled by changing the distribution of the pressure inside the four pistons; the position transducers provide the feedback signals.

2.2 Electronic architecture

The electronic system consists of a central unit and a command console unit. The central unit has four PC boards connected through a bus backplane.