Mechatronic solution of components cooperation in the device for gait reeducation

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Abstract
A dynamic development of biomechatronics led to the intensification of scientific research and to the implementation of projects aimed at designing robotic equipment for rehabilitation purposes. One of the examples of modern rehabilitation equipment is a mechatronic device designed at the Department of Theoretical and Applied Mechanics, which supports the process of walking reeducation. The inability to walk properly is a result of a disease or a traffic accident. This device, as opposed to the ones designed so far, follows the moving patient in the area limited only by the range of the drive systems (fig. 5), offering at the same time relief to the lower limbs [1].
The device was designed due to a cross-functional cooperation of a team of mechanics, automation specialists, biomechanics and employees of rehabilitation centers. The concept of the device together with selecting proper drives, was developed based on the research on moving the center of gravity in patients with various types of walking abnormalities.
The device is a MIMO (Multiple-Input Multiple-Output) system. Control system processes the measuring signal from the sensors: relief force, rope deviation angle, a sensor detecting the pressure with which the foot touches the floor and encoders recording the position of the relief system. Acquisition of all recorded signals, both digital and analogue, is done in a specially designed interface for signal conditioning. Drive motors work by adjusting the rotation speed.

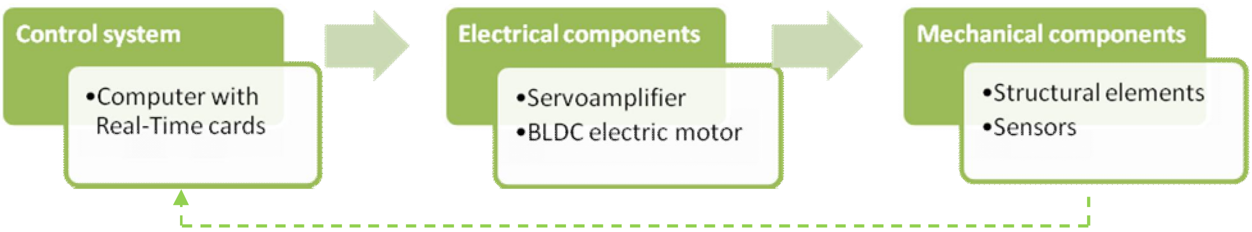

Figure 1: Diagram of subassembly connections of the mechatronic device used in the process of walking reeducation

The device operations are controlled by a computer equipped with the RT-DAC4/PCI card for real-time operations. The computer is directly connected to the signal conditioning [2].

MATLAB/Simulink software is used to program the device controlling system. Due to a big amount of measurement signals to be integrated in one controlling system, separate subsystems have been developed, which cooperate with each other in a dependent manner:

- Algorithm for detecting the falls and other dangerous situations – working with the use of pressure sensors situated in the insole,
- Algorithm responsible for the crane following the patient,
- Algorithm responsible for controlling the work of a system compensating the patient's weight.

If the system does not detect any dangerous situations (including improper position of individual actuator systems of the device), it is possible to continue with other algorithms. The recommended structure allows for implementing various methods of controlling individual actions. Furthermore, the device may operate in different modes – depending on the rehabilitation activity.

Algorithms implemented in the control system of the drives use the PID controller. The values of setpoints for drive controllers responsible for the movement of an individual device axis were set based on the optimization of the timeline. Response of the drive system to the requested forces with the use of a device numeric model was investigated. During the optimization of parameters of the algorithm responsible for the following movement, a rope deviation angle and for the weight compensation system a deviation of the relief force from the requested value were minimized [3,4].

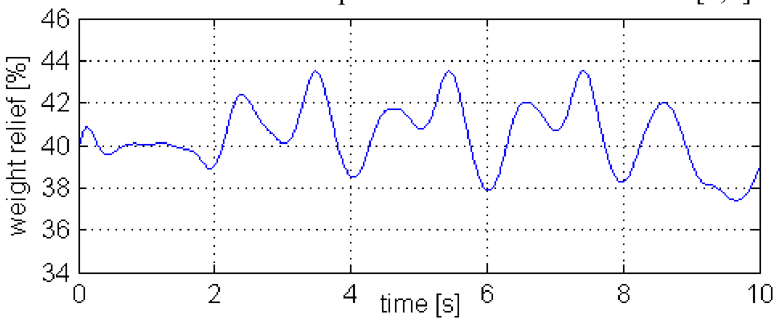

Figure 2: Change of the percentage body weight relief as a function of time

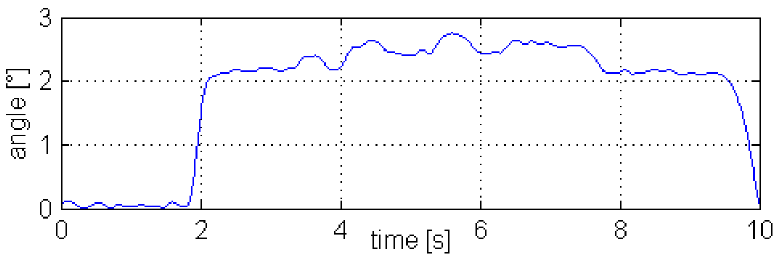

Figure 3: Change of the value of the rope angle deviation of crane slings in the sagittal plane while walking

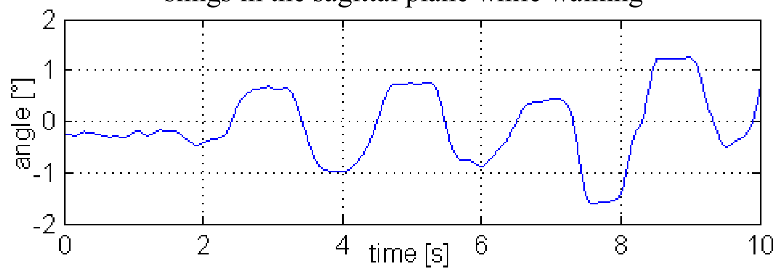

Figure 4: Change of the value of the rope angle deviation of crane slings in the coronal plane while walking

Figure 5: Illustration from experimental research

The adjusted controllers in the controlling algorithms allowed to obtain results due to which rehabilitations may be more effective and comfortable for the patient. The value of the relief force was kept at a constant level with deviations +/– 3% of the body weight, while the rope deviation angle did not exceed 3°(fig. 3,4).

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