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THE CONCEPT OF MOBILE SYSTEM OF ANALYSIS AND VISUALIZATION OF HUMAN GAIT PARAMETERS

A. Muraszkowski*, J. Szrek**

Abstract: *The article presents briefly the current state of knowledge concerning methods of rehabilitation using Nordic Walking poles. The concept of mechatronic poles that allow to measure the human gait parameters is presented. They will be used to determine the correctness of exercise performance, progress in rehabilitation and planning further methods to restore the patient health, as well as gait techniques improvement in sports. Mechatronic poles enclose inertial sensors, which generate measurement data, so that it will be possible to exercise in any area, indoors and outdoors. Examples of data obtained from the inertial sensor are also presented. The possible use of mechatronic Nordic Walking poles are described.*

Keywords: Human gait kinematic, Gait parameters registration, Nordic Walking poles.

1. Introduction

Analysis of human movement has had its place among the issues that are the interest of researchers for a long time. Especially nowadays, when the quality of life value is increasing.

For a thorough analysis of human movement, computer musculo-skeletal models are created, in order to perform kinematic and dynamic simulations (Pandy, 2001). They contain a number of parameters, which are determined on the basis of statistical data. Some are easy to determine, such as the length of individual body segments, or their mass. Others are more complex to define the values, such as the length of the muscle, contraction range, the exact position of the points of attachment of the muscle to the skeletal system. Torques loading joints or forces in muscle can be concluded on the basis of such created models. The models created on the basis of statistical data are often used in medicine to define disease, their classification and to develop general methods for the rehabilitation (Perry, 2010). There is a tendency to create individual models in order to obtain results which are closer to the actual for individual person. This method is used especially in sport disciplines where gait technique are optimized for each athlete taking into account his differences in physique (Nakashima, 2014). The method is being increasingly used in rehabilitation noting, that each patient suffers from a given physical dysfunction in varying degrees.

When the dynamic model of the human is already given, there is need for data on the kinematics. To determine the trajectory of human move, there are various methods used. Currently, the most commonly used method for measuring kinematic parameters is optical method. The person wear many markers, the movement of which is recorded by a camera system (infrared or visible light range). This calls for the deployment of cameras with high accuracy in a specific area and can be used in principle only indoors. In addition, the deployment of markers on human body is difficult. Placement of markers results from the protocol. In medicine, the most commonly used is Davis protocol (Davis, 1991).

Today, there are other methods to obtain information on the location and orientation of objects in space, including those that do not require the use of external stationery devices in the form of transmitter or receiver stations. One of them involves the use of inertial sensors to measure linear accelerations and

* MSc. Artur Muraszkowski: Faculty of Mechanical Engineering, Department of Biomedical Engineering, Mechatronics and Theory of Mechanisms, Wrocław University of Science and Technology, ul. Ignacego Łukasiewicza 7/9, 50-371 Wrocław; PL, artur.muraszkowski@pwr.edu.pl

** PhD. Jarosław Szrek: Faculty of Mechanical Engineering, Department of Biomedical Engineering, Mechatronics and Theory of Mechanisms, Wrocław University of Science and Technology, ul. Ignacego Łukasiewicza 7/9, 50-371 Wrocław; PL, jaroslaw.szrek@pwr.edu.pl

angular velocity. Currently, there is a whole range of measuring systems integrating various inertial sensors. They are called inertial measurement unit (IMU). They include accelerometers, gyroscopes, magnetometers and sometimes barometers. The use of inertial sensors has the advantage over the above described optical method. They do not need fixed installations for movement recording so there is no need of predefined workspaces, limited by number of cameras. Moreover, they are not sensitive to variable, changing lighting. This makes it well suited for applications involving the study of human movement during the course of everyday tasks or exercises performed in the field, both by athletes and patients during rehabilitation.

Another phenomenon contributing to the development of computer technology in the field of physiotherapy is the effect of significantly increase in the rehabilitation progress through the use of methods of biological feedback (biofeedback). It consists in the fact that the patient gets information about the parameters of their body, for example the angle of knee joint, gait length, data from devices such as ECG (electrocardiography), EEG (electroencephalography), EMG (electromyography). It turns out that the person who receives such information can better control the behavior of his body, and even learn to control the reactions of the body, even those which normally are not controlled consciously, such as breathing, heartbeat, brain waves. As a result, properly selected, to match the rehabilitation method, biofeedback signal significantly accelerates recovery and increases the effects of performed exercise (Tate, 2010). Successfully it is used for people with impaired posture caused by diseases of the musculoskeletal system, nervous system, or as a result of internal diseases (Allum, 2005).

One of the newer methods of rehabilitation is the commissioning exercises with the use of Nordic Walking (NW) poles with appropriately technique. This technique increases the activity of the muscles of the upper body, increasing oxygen consumption by 20 %, energy expenditure and at the same time reduces the load on individual muscles and joints (Schena, 2009) (Hagen, 2011). It is used with the rehabilitation of patients after heart attacks and other diseases of the cardio-respiratory system (Morgulec-Adamowicz, 2011). It increases the mobility of people with Parkinson's disease (Van Eikeren, 2008), It is also used to improve the physical condition and overall development and strengthening of muscles (Kocur, 2009).

Currently, diagnosis of this kind of rehabilitation methods is performed in appropriately equipped rooms with an optical measurement system that uses a set of cameras installed permanently, and strain mats to determine forces on feet. This test method is good for determining disease conditions and periodic improvement during rehabilitation. But it is not suitable for everyday use because of the sophisticated equipment usage under specific conditions. It has little in common with the actual conditions in which a major part of rehabilitation is performed - walking in the open field without the direct supervision of a physiotherapist. As a result, the patient for the better part of rehabilitation is left alone without feedback about how well does exercise and what is the effectiveness of health improvement. Physiotherapist after a longer time can identify these factors but only during short, relatively to period of rehabilitation, meetings with the patient, during which conditions are far different from the natural.

2. The Concept

Taking into account the information presented in the previous section, a device were developed that can be used to analyze human gait during exercise in the field with NW poles. There is proposed mechatronisation of typical poles, which can be purchased at sport stores. It involves equipment of the poles with multi-axis inertial sensors - for example nine-axis unit consisting of a three-axis gyroscope, accelerometer and magnetometer. In addition, the force sensor is mounted for measuring the force along the axis of the pole and a contact sensor in the handle (Fig. 1, left).

Considering the expansion of the device with additional force sensors placed in such points that the bending torque of pole can be determined. The occurrence of torque would mean an incorrect method of gait, requiring correction, and the read value would serve to identify and parameterization of algorithms for improve gait technique. Signals from the sensors are read, stored and processed by a control unit placed on a pole. Processed data will be transmitted to the device, which acts as the user interface (ex. Tablet, smartphone, SmartWatch) to visualize them and to inform the person exercising about the

progress, mistakes and methods for improving technique. The data will also be stored on the device for

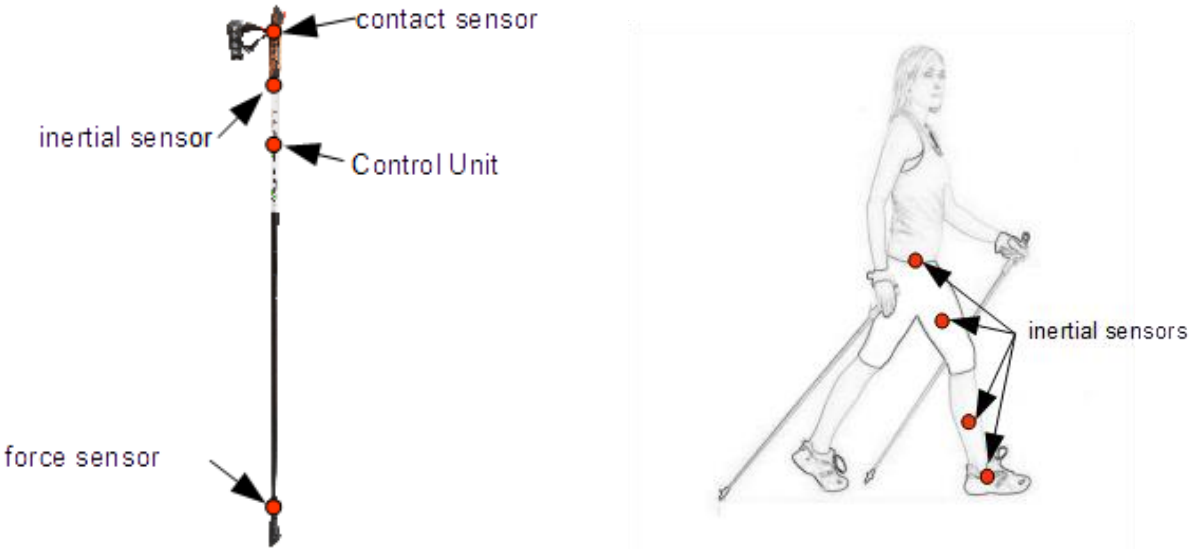

Fig. 1: Concept of mechatronic Nordic Walking pole – left.
Sensors locations on human body for kinematic data acquisition – right.

later analysis by specialists, physiotherapists, doctors, or sent in real time to an immediate confrontation with the recommendations of the person that leads rehabilitation process.

In order to obtain the additional data needed to determine the gait technique, together with an indication of disability and motor dysfunction of a subject, proposed a set of sensors mounted on the human body. This would be the inertial sensors, such as those mounted on NW poles. They would be placed on the individual segments of the body (Fig. 1, right) to determine their position and orientation in space. For each lower limb 3 sensors are mounted, one sensor would provide further information on the movement of the pelvis. These sensors would be connected to an additional control unit placed on the person or could be connected to the unit placed on the NW pole.

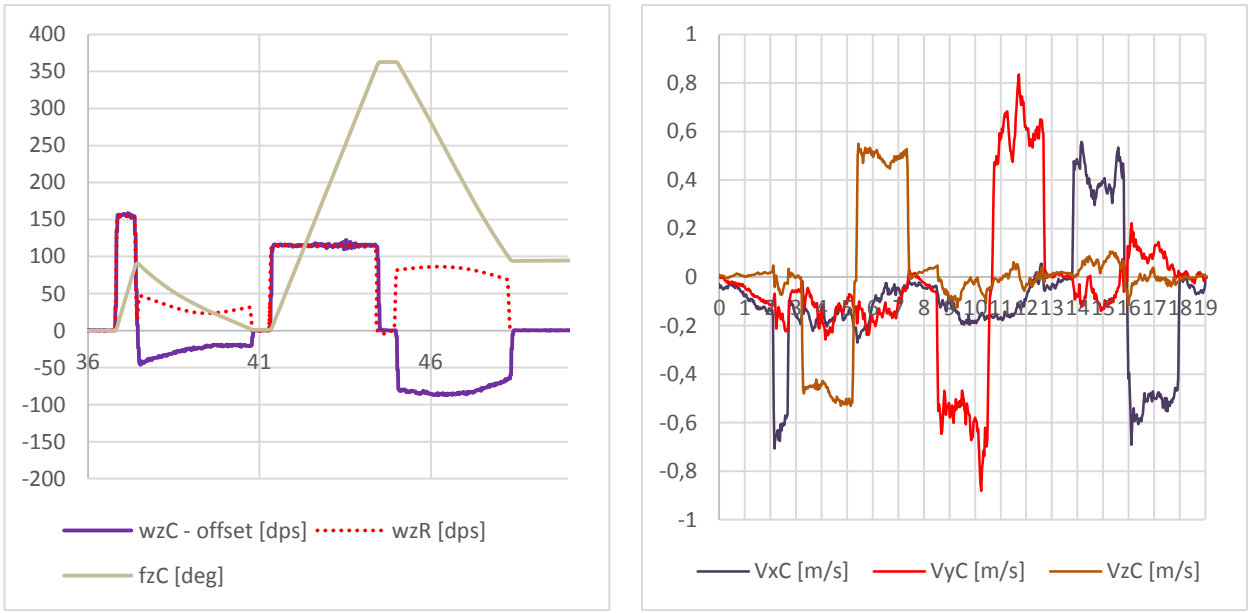

Fig. 2: Characteristic of IMU. wzC – angular velocity along Z axis of sensor, wzR – theoretical angular velocity along sensor Z axis, fzC – angular displacement along Z axis (integrated wzC signal), VxC,VyC,VzC – linear velocity along sensor axis respectively X, Y, Z.

In order to implement the concept, in the first place, tests of signals from the inertial sensors were performed. There was selected relatively cheap sensor, which was dictated by economic considerations of endpoint device, which is expected to have the widest possible audience. The data shown in Fig. 2 were obtained from the inertial sensor. The results and analysis (Kiwała, 2016) have been presented here in

order to show that an inexpensive IMU gives very good results with gyroscopic data and worse for the accelerometer. However, appropriate processing such as filtering, averaging can reduce the size of the error acceleration. In addition to these applications, the key element is the orientation of the various parts of the body and NW poles obtained mainly from gyroscopes.

3. Conclusions

Computer technology, including dynamic modeling is increasingly used both in sports and in medicine. They are used to improve performance of athletes but also for the analysis of locomotor system diseases and development of new techniques of rehabilitation. The paper presents a new concept of mechatronic Nordic Walking poles, which will help collect data in both laboratory and real conditions during daily exercise. At the beginning, Mechatronic Nordic Walking poles (MNW) will be used for the rehabilitation of people with various disabilities. Patients will use it in the initial phase under the control of physiotherapists. Then patients will rent equipment for home and practice on their own, coming to periodic checks, where a specialist will be able to assess the progress of rehabilitation on the basis of the data contained in the poles and suggest the next set of exercises. Different area of application is the use of MNW to sports training, for the purpose of improving health, techniques, and creation of new habits through biofeedback. Commercialization of MNW will require such configuration of the device to make it user friendly, characterizing by ease of calibration, operation, had a simply interface, generating messages understandable for people who does not have knowledge of biology, mechanics and computer science and the price range must be appropriate for the target audience.

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