The assessment of gait features according to the data of a portable acceleration sensor in an intelligent monitoring system

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Abstract. The article is devoted to assessing the possibility of identifying individual characteristics of a person’s gait according to the data of one accelerometric sensor, as well as the possibility of assessing impaired functioning of the musculoskeletal system with subsequent use in intelligent expert systems based on neural network algorithms. The article notes the prospects of using dynamic measurements to improve the effectiveness of orthopedic diagnostics. The prospects of using accelerometry along with complex medical motion capture systems are noted. The results of distinguishing characteristic gait indicators among a group of subjects according to one accelerometer sensor, as well as an assessment of the distribution structure of the articular angle when walking, are described. As subjects, people with impaired functioning of the musculoskeletal system and people without disorders are involved. The results obtained are in good agreement with the data of goniometric control systems built on the basis of several sensors. Thus, the results of the research show the possibility of obtaining a detailed picture of gait. The results obtained will allow us to form a preliminary structure of the neural network and evaluate its coefficients with the further development of automated control and monitoring systems based on existing portable wearable devices (phone, watch).

Keywords: registration, monitoring, geotechnical system, technical and economic analysis

1. Introduction
In the field of orthopedics modern scientists and researchers have found that disorders of the musculoskeletal system are best manifested in the process of performing motor actions [1-3]. So, for example, when performing multiple locomotion, the maximum value of the articular angle can be significantly larger than with a single bending of the joint. This is explained not only by the physicomechanical properties of biological tissues that make up the joint compound, but also by the stimulation of biochemical processes in the body (blood flow, volume dynamics of synovial fluid, etc.) [4-6]. However, most diagnostic techniques rely on data obtained by examining a person in a static position [7, 8]. This leads to a decrease in the reliability of the diagnosis of the real clinical picture of the disease, errors in the diagnosis and the wrong choice of rehabilitation procedures.

In a dynamic state diagnosis of diseases of the musculoskeletal system of a person is based on the allocation of motion parameters and is a difficult task in medical orthopedics, requiring the use of specialized measuring instruments and algorithms for processing recorded data. This task is complicated by factors, the main of which are:
• movement parameters of each person are individual;
• movement consists of a set of monosyllabic locomotion, in the process of which dozens of articular joints can be involved;
• when registering movement parameters, it is necessary to compensate for the biomechanics of muscle tissue, skin and fat;
• the need to isolate and classify movements in complex waveforms;
• dynamic time range characterizing the performance of the same movement;
• the need to compensate for the result of free mounting of sensors and their possible movement during movements.

Currently, motion capture systems are used to measure the dynamics of motion parameters in medical practice. Such systems use an optical channel for recording motion parameters and are characterized by the high complexity of processing the data provided and are quite expensive for mass implementation in medical institutions.

In the field of manufacturing microelectronic wearable devices the development of technologies allows us to create systems that can eliminate shortcomings and expand the functionality of traditional motion capture systems. The use of accelerometric sensors in micromechanical design has special prospects in solving the problem of recording motion parameters. These devices are technological and allow high-precision fixation of the acceleration of biokinematic links.

In the works of a number of scientists [9–13] the trends are traced in the use of accelerometers in solving problems of recording motion parameters, in which the effectiveness of this approach was confirmed. However, the effectiveness of the diagnosis of violations is largely determined by the data processing algorithms using the accelerometric control method [14-17], methods for identifying and classifying motion parameters [18, 19], and the number of attributes taken into account [20]. Currently, in portable wearable devices (telephones, watches, smart tags, etc.) the presence of accelerometric sensors provides an opportunity to assess individual characteristics of a person, his identification. However, researches have not been conducted enough to identify the features of movements based on a wearable acceleration sensor and the application of this approach in intelligent systems of medical monitoring, tracking and identification.

Thus, the aim of the research is to assess the possibility of identifying individual characteristics of a person’s gait according to one accelerometer sensor, as well as the possibility of assessing impaired functioning of the musculoskeletal system.

2. The method and approaches
When evaluating gait parameters, studies were conducted involving 10 students of 3 and 4 courses at the age of 19 to 21 years. When forming the group, the similarity of the anthropometric profile was taken into account - height, weight, length of the lower extremities. Two out of 10 students had impaired motor function of the left leg due to recent knee surgery. During the week, gait was recorded and analyzed based on accelerometer data.

When walking measurement of the angle of deviation of the thigh was carried out on the basis of an external accelerometer and an accelerometer of a mobile phone. Both devices were in the pocket of the researcher closely fitting to the body. Data obtained from both devices correlate with each other.

The data processing algorithm includes: preliminary low-pass filtering at a frequency of 50 Hz; determination of medium-term and inter-quartile differences to assess the differences in the angle of movement. The data were processed both for each committed movement and for the daily interval.

3. Results
The objective of the research was to highlight the characteristic indicators of gait among a group of subjects, as well as to assess the distribution structure of the articular angle when walking. Initially, an assessment of the manifestation of a knee joint injury in gait parameters was made. figures 1-3 show the data for one step of the student with surgery on the knee joint (right leg - figure 1a) and the step of the student without violations (left leg - figure 1b).
Figure 1. The change in the parameter of the articular angle over time in a test subject with a knee joint injury (left). The change in the articular angle parameter over time is normal (right).

In the course of studies of the step parameter of a healthy person, three phases of movement can be distinguished:

- The phase of the beginning of movement - a period of time with a sharp increase in the parameters of the articular angle lasts from 50 to 60% of the total step time. During this period, an increase in the speed of limb movement to the maximum value at the end of the period is recorded.
- The mid-motion phase is the time interval between the legs being brought together and the moment the tibia moves to the vertical position, begins immediately after the first phase and lasts within 10–13% of the total step execution time. There is a decrease in the speed of movement until a minimum peak is reached at the end of the period.
- The phase of the end of the movement is the time interval between the moment of the vertical leg of the leg and contact with the surface of the earth, begins immediately after the phase of mid-movement and lasts from 27 to 30% of the total step time. An increase in the speed of movement is recorded until the second maximum peak is reached at the end of the step.

In the case of analysis of the step of a person who suffered a knee joint injury, three phases of movement can also be distinguished. However, the steps of a person with a knee joint injury will differ in duration, as well as in the parameters of speed and amplitude of movement, which is reflected in the graphs (Figure 1 a and b).

To increase the reliability of experimental studies, daily observations were made of the dynamics of the articular angle of the subjects. Deviation of the angle of the hip joint during walking per day for the left (Figure 2) and right (Figure 3) legs of the subject from operations on the knee joint have pronounced surges and fluctuations, which is not observed in the gait of a healthy person (Figure 4). It should be noted about deviations in the movement of the injured leg, which is also seen from the presented diagrams.

For completeness of the analysis, Figures 5, 6 present diagrams showing the structure of the distribution of the angle when walking for 24 seconds for several days in a student who underwent surgery on the knee joint.
Figure 2. Daily deviation of the angle of the hip joint of the left leg when walking per day of the subject who underwent surgery on the knee joint

Figure 3. Daily deviation of the angle of the hip joint of the right leg when walking per day of the subject who underwent surgery on the knee joint

Figure 4. Daily deviation of the angle of the femoral joint when walking a healthy subject per day
4. Conclusion
As a result of the research, the structure of the distribution of the angular parameters of the gait of a person was built, the events of the gait cycle were revealed, the significance of which was confirmed by similar studies in this area [21-25].
It should be noted that the above graphs were obtained in the course of studies of gait parameters using one accelerometer sensor. As can be seen from the presented results, the analysis of the data as a result of such an accelerometric research already allows you to get a fairly detailed picture of the gait (change in angle, walking speed, deviations in the functioning of the musculoskeletal system). However, the prospects for further research are aimed at finalizing data analysis algorithms using mining methods. The results obtained will allow us to form a preliminary structure of the neural network and evaluate its coefficients.

Using the approaches of accelerometry of the parameters of human movements will allow to register joint pathologies and evaluate the numerical characteristics of biomechanics in a dynamic mode. In the course of medical diagnostics, it is possible to assess the degree of joint damage and prescribe rehabilitation techniques using the provided graphic information.

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