The analysis of gait patterns using a color camera and computer vision

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Abstract

Objective of the study was to validate the approach for determining human walking metrics through the application of neural networks and computer vision techniques.

Methods and structure of the study. The scientific research involved the following steps:

1. Capturing video footage using a single RGB camera.
2. Calculating the coordinates of key points using the OpenPose neural network and creating a data set.
3. Removing any artifacts from the resulting data set using the Hodrick-Prescott filter.
4. Identifying the walking cycle.
5. Calculating the walking parameters.

The walking parameters of the subject were recorded and evaluated using the Zebris Rehawalk system (system configuration from h/p/cosmos) at the Scientific and Practical Center for Pediatric Neurology of the Moscow Department of Health. The video was captured using a Panasonic HC-VX1 camera. The Body_25 model was employed to determine the spatial positions of the subject's body parts. The parameters were calculated for the sagittal projection using the Edinburgh Scale for Visual Assessment of human walking.

Results and conclusions. According to the calculations, the following values were obtained: the duration of a walking cycle is 1,58 ± 0,92 seconds, the time taken to complete a step is 0,78 ± 0,03 seconds, the length of a step is 41,33 ± 1,92 centimeters, and the speed of walking is 1,91 ± 0,09 kilometers per hour. The movement parameters of the subject's hips, knees, and feet were calculated. When comparing the obtained values with the normative ones, slight deviations from the standard were observed in the subject's walking. The accuracy of the calculations was 0,95. The results demonstrate that computer vision can accurately assess the biomechanics of human movement and can serve as an objective monitoring tool in various fields, including sports, medical diagnostics, and rehabilitation. This approach does not require specialized training, equipment, or facilities, making it easier to monitor human movement indicators in any environment.

Keywords: *gait analysis, Edinburgh Visual Gait Scale, computer vision, OpenPose.*

Introduction. Walking is one of the most common ways of human movement in everyday life and provides vital information about its functional state and physical fitness [1, 2]. Also, by analyzing a person's gait, sports injuries can be diagnosed, as well as diseases associated with the musculoskeletal system, such as sprains, osteoarthritis, etc. [3, 4]. The active development of computer vision systems contributes to the introduction of contactless methods of human movement analysis into motor activity monitoring systems, including the use of RGB cameras, which are currently built into cell phones [5].

As shown by bibliometric analysis[1], most of the research in the field of computer vision and artificial intelligence application in assessing biomechanical parameters of human movement, including in the field of sports training, is currently being conducted in the USA, Canada and China. This is confirmed by the research results described in the source [5]. In Russia, such technologies are just beginning to develop and be implemented in the practice of monitoring human movements and, therefore, in this area they are frag-

[1] Ispolzovana biblioteka Bibliometrix yazyka programmirovaniya R. Available at: https://www.bibliometrix.org/home/.

mentary, there are no fundamental publications in this area. In order to substantiate the computer vision tools used in assessing human motor activity, including in sports training processes, we are testing an innovative method for assessing walking parameters, which is based on a combination of neural networks and deep learning. The conducted study makes it possible to integrate computer vision methods into the practice of contactless monitoring of the biomechanics of human movements, thereby increasing the objectivity of assessment in sports, rehabilitation, and medical diagnostics.

Objective of the study was to validate the approach for determining human walking metrics through the application of neural networks and computer vision techniques.

Methods and structure of the study. The assessment of walking parameters was carried out in a healthy person using the Zebris Rehawalk system (system configuration from h/p/cosmos) based on the Scientific and Practical Center for Pediatric Neurology of the Moscow Department of Health. The research methodology includes the following stages: 1) video recording on one RGB camera in the sagittal projection; 2) calculation of point coordinates using the OpenPose neural network and formation of a data array; 3) cleaning the resulting array from artifacts using the Hodrick-Prescott filter, which allows removing the cyclic component from the time series; 4) identification of the walking cycle; 5) calculation of walking parameters. To calculate the coordinates of the location of the test subject's body elements in two-dimensional space, the Body_25 model was used (Figure 1). Video recording was carried out on a Panasonic HC-VX1 video camera with the following parameters: 4K recording format at a speed of 50 frames per second, with a maximum bitrate of 500 Mbps. The MPEG-4 AVC/H.264 compression algorithm was used during recording in HD resolutions (1920 × 1080).The distances between points were calculated using the formula:

$d_{ij} = \sqrt{} (x_i - x_j)2 + (y_i - y_j)^2$

where x_i, x_j, y_i y_j – coordinates of the analyzed points in two-dimensional space.

The angular distances were determined using the cosine theorem. The parameters were calculated for the sagittal projection using the Edinburgh Visual Gait Scale (EVGS), which includes an analysis of the spatial positions of the main body elements involved in movement in all phases of its cycle [6]. The EVGS method includes the calculation of 34 walking parameters in the sagittal and frontal projections.

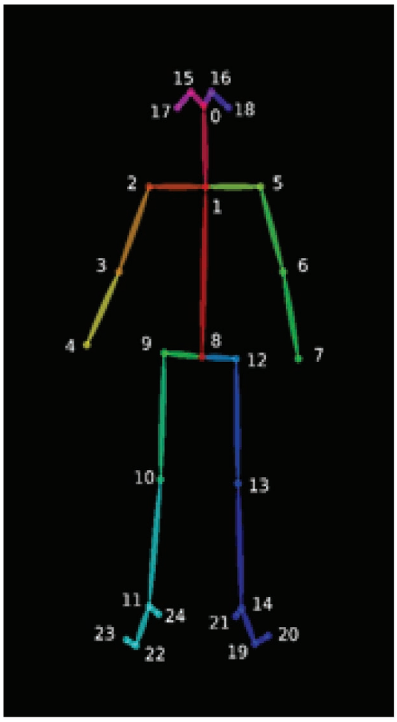

Figure 1. Location of points in the Body_25 model

In the study, after identifying the walking cycles, the calculation of the main indicators was performed, such as the walking cycle time, step execution time, step length, walking speed. The values of the angles of movement of the hips, knees, feet during the walking of the subject were also calculated using the EVGS method for the sagittal projection. A comparison of the obtained values with the normative ones, which are given in the method used in the study, was performed. The accuracy of the calculations was 0,95.

Results of the study and discussion. The complete human gait cycle consists of two main phases – the support phase and the swing phase, including stance and turn. The gait cycle is calculated for one leg [6]. The events of the subject's foot strike and toe-off were determined using the method given in the source [7]. Figure 2 shows the identification of the gait cycle events on the timeline 1-128 frames. Points 19 and 22 of the Body_25 model (determine the toes) were used in the calculation. The gait cycle time is 1,58±0,92 s, the step execution time is 0,78±0,03 s, the step length is 41,33±1,92 cm, the walking speed is 1,91±0,09– km/h. The subject completes about 76 gait cycles per minute.

Walking indicators, calculation methods, estimated and standard values

Indicator	Designation (Figure 3)	Calculation method	The value obtained using the author's algorithm	Norm values
Maximum hip flexion during walking, degrees	1	The angle formed by points 1, 8, 13 (10).	160,60 *19,40**	25,00-45,00
Maximum knee extension during walking, degrees	2	The angle formed by points 12 (9), 13 (10), 14 (11).	176,94 *3,06**	5,00-15,00
Angle of foot rise from horizontal plane, degrees	3	The angle formed by points 21 (11), 19 (22) and the horizontal plane of the floor (treadmill).	19,04	No, according to literary data no more than 20
Maximum deviation of the torso from the vertical axis (in the middle pose), degrees	4	It is defined as the angle between points 1, 8 and the vertical line drawn from point 8, determined in the middle pose.	3,99	0-5
Maximum hip extension in mid-stance, degrees	1	The angle formed by points 1, 8, 13 (10). Determined in the middle pose.	188,48* 8,48	0-20
Maximum knee extension in mid-stance, degrees	2	The angle formed by points 12 (9), 13 (10), 14 (11). Determined in the middle pose.	180,8 0,8	0-15
Maximum angle of ankle flexion in the middle position, degrees	5	The angle formed by points 13 (10), 14 (11), 19 (22). Determined in the middle pose.	86,88 3,12**	No more than 5
Maximum angle of ankle flexion during walking, degrees	5	The angle formed by points 13 (10), 14 (11), 19 (22). Determined while walking.	82,77	Not specified

* – Defined as the difference between 180 and the obtained angle value. Used to convert the values of the indicators to the Edinburgh scale standards. ** – Defined as the difference between 90 and the obtained angle value. Used to convert the values of the indicators to the Edinburgh scale standards.

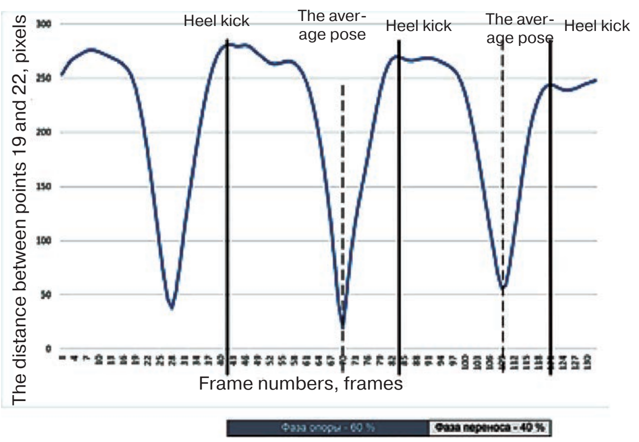

Figure 2. Identification of human gait cycle events

Figure 3 shows the calculated values of angles according to EVGS. The table shows the values of the calculated indicators, a brief description of the calculation method, and the standard values according to the EVGS method. Indicators whose values deviate from the standard values are highlighted in italics (see table). Based on the calculations performed, the following conclusions can be made. The subject's walking indicators differ slightly from the standard values (maximum hip flexion during walking, degrees; maximum knee extension during walking) (see table), which may require additional research.

Conclusions. The study tested the method for calculating human walking parameters using neural networks and parametric geometry. The results showed that computer vision has sufficient accuracy in assessing the biomechanics of human movement, in the study this indicator was 0.95, and can be used as a tool for objective monitoring in various sports, medical diagnostics, and rehabilitation. The use of

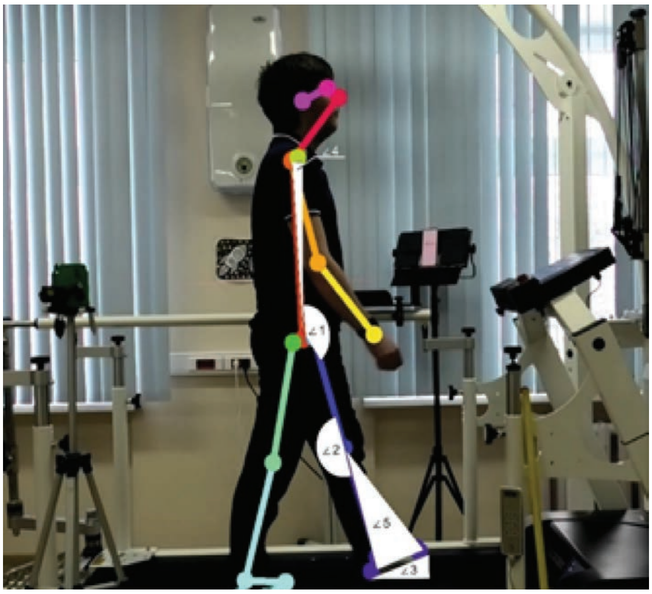

Figure 3. Estimated angles according to the Edinburgh Visual Gait Scale

this approach does not require special training, equipment, or premises, which facilitates monitoring human movement parameters in any conditions.

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