

# The Current State of Human Gait Simulator Development

V. Musalimov, I. Stepanov, Y. Monahov, A. Safonov

**Abstract**—This report examines the current state of human gait simulator development based on the human hip joint model. This unit will create a database of human gait types, useful for setting up and calibrating Mechano devices, as well as the creation of new systems of rehabilitation, exoskeletons and walking robots. The system has many opportunities to configure the dimensions and stiffness, while maintaining relative simplicity.

**Keywords**—Hip joint, human gait, physiotherapy, simulation.

## I. INTRODUCTION

**W**ALKING - automated motor act, carried out as a result of a complex coordinated activity of trunk skeletal muscles extremities. Starting from the ground, the foot causes the body in motion - forward and slightly upward, and again performs swing in the air [1].

Human gait is directly related to the operation of the skeletal and muscular systems, central and peripheral nervous systems. Disturbances in the functioning of the central nervous system may cause different movement disorders: shuffling, mincing gait, jerky movements [2].

Physiotherapy is an important area of modern rehabilitation medicine. It uses a set of devices of varying degrees of complexity, which are intended to restore the normal functioning of the skeletal and muscular systems of man. In particular, the gait analysis is a method of diagnosing and assessing the severity of Parkinson's disease types. Assessment is made on the length of the step, and a portable reference phase, singly and doubly periods. Including an extensive range of devices designed to restore mobility of the hip joint.

Fig. 1 shows the trajectory of the human pelvis joint points, obtained using motion capture systems. Based on the data it is planned to build a management system [3]. In view of this was considered the possibility of creating the human gait simulator model, through which it was possible to improve the programs of motion of such systems. Based on it is possible to create a database of species of human gait and attendant data.

Human gait simulator is designed to simulate the movements of the person in the development of Physiotherapy rehabilitation devices. The proposed simulator is the development of Gustav Zander gait physiotherapy methods. He's in the middle of the 19th century developed several special apparatus, which made for accurately dose movement and resistance on the joints.

Ivan Stepanov is with the IFMO University, Russian Federation (e-mail: gn0ll@mail.ru).

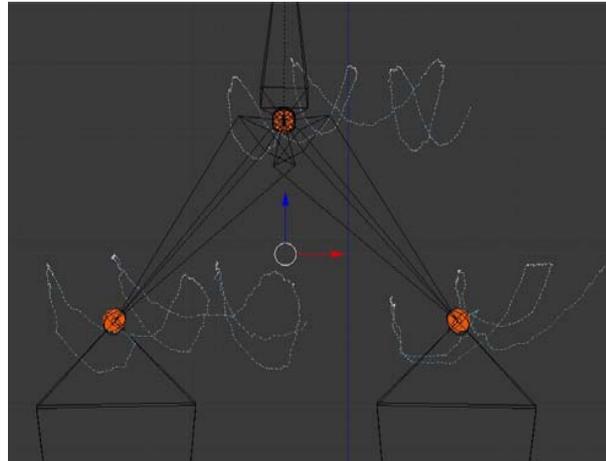


Fig. 1 Human pelvis trajectories

## II. GENERAL ARRANGEMENT

At this stage of development of gait simulator is designed to simulate the motion of the human hips and pelvis using for base motion trajectory of knees. The device mechanism involves consideration of the scheme moving, like the human gait, what is structure close to the hip joint. Retrieving data from sensors installed on the system, will provide the laws of motion, most similar to leg walking movements. Patented analogs of this device have not been revealed, but there are several articles describing the design of devices that are similar to our main goal.

On scheme of the mechanism (Fig. 2), the movement is organized by pairs of horizontal and vertical drives. The horizontal movement is carried out by means of a belt drive (6), since it was the most appropriate design allows horizontal displacement of the joint at a desired rate and at a relatively large distance. Vertical movement, due to less need for speed is accomplished by a pair of screw-nut (5).

Structurally, the primary construction is a mechanism that simulates the vertical projections of the forces acting during human gait. On its scheme presented blocks, simulating pelvic bone (1), simulating hip joint blocks (2), fixed elements, showing the femur (4) and a rack construction (3), which provides a fixed center of mass of the pelvic bone and allows only oscillate around this point. The other ends of these elements are connected to the actuator system. This system consists of pairs of nodes carrying, respectively, movement on the vertical and horizontal axes. Horizontal movement is carried out by means of a belt drive (6). The advantages of this transmission include simplicity of design, the ability to

transmit over long distances, and rather high speed of forward movement of freight. The main disadvantage of belt drive is a belt tension and consequently its sagging. To resolve this problem, the belt tension mechanism was developed (7). Vertical movement is performed by a pair of screw-nut (5). System of vertical movement is mounted on a special carriage moving along the horizontal guide. The entire system is mounted on a common base (7), made of cast-iron stoves, which allows to extinguish unwanted vibrations. The overall design of the mechanism is shown on Fig. 3.

One of the main advantages of the system sees its modular structure. The whole structure consists of three constructive blocks (modules): the drive on axes x and y, the hip simulator and the femur simulator linking them. Important is the presence of pins, making it easy to customize the basic dimensions of the mechanism. Thus, moving apart the blocks imitating hipbone or blocks imitating femur can vary the width of the pelvis within 280-320 mm and the length of the thigh within 370-470 mm, which corresponds to a normal spread of these parameters in people of different heights. In addition, thanks to the modularity in the future will be much easier to refine and restructure the system using the new blocks and restrictions \ assumptions. Many of the elements are standard products, to increase maintainability and reduce cost. In addition to the customization in size is extremely important system settings stiffness provided in the block that simulates the hip joint. This system allows to partially simulating the displacement occurring in the joint during movement. It is planned to carry out by means of concentrically arranged springs (1) fixed on one side of the ring (2) and on the other a screw (3). By increasing or decreasing the spring, tension with the screw (3) and the nut (4) may receive the necessary rigidity. The part of a screw head is cut off, and the cut off side abuts against the housing of the joint, thus the screw is fixed and change the spring tension is achieved by rotating the nut. Screws are installed in special crown (5) which is screwed to the housing. In the center of the suspension is spherical joint (6), which allows the system to perform additional rotational movement partially mimicking the joint. The block simulates the hip joint is shown on Fig. 4.

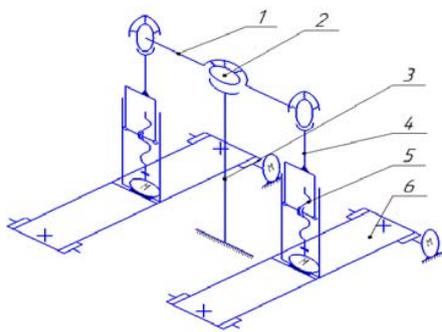


Fig. 2 The kinematic scheme of the device where: 1. Unit that simulates the hip bone; 2. Unit that simulates the hip joint; 3. Stand design; 4. Unit that simulates the femur. 5-6. Axis actuators

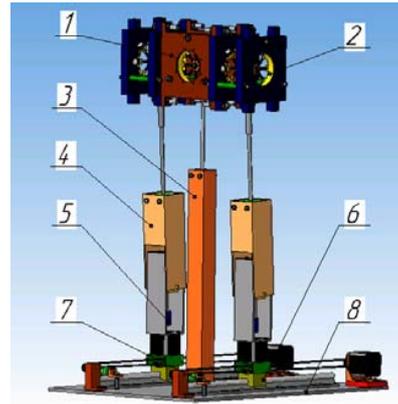


Fig. 3 The overall design of the mechanism device where: 1. Unit that simulates the hip bone; 2. Unit that simulates the hip joint; 3. Stand design; 4. Unit that simulates the femur. 5-6. Axis actuators. 7. Belt tension mechanism; 8. Overall base

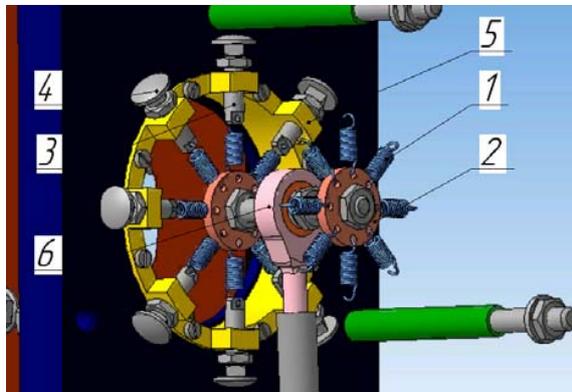


Fig. 4 The block simulates the hip joint where: 1. Springs; 2. Connection ring; 3. Calibrating screw; 4. Nut; 5. Crown-shaped body block; 6. Bearing

### III. DATA OUTPUT AND PROCESSING

Motion capture data is recorded using the program 3ds Max as a time-lapse animation. On the one person from who the movement is recorded, were put a few markers that track movement by multiple cameras simultaneously. Then, the coordinates of the markers are recorded frame by frame and applied to the skeleton model created beforehand.

After removing the necessary motions, animation is saved, in the format of FBX as a scene in 3ds Max. In that animation for gait simulator important, only the nodes that are in the lap of the model, but the recorded motion can also be used in other projects. [4] Motion capture was carried out with the support of the St. Petersburg State University of Film and Television.

The output format of the animation FBH As mentioned above, the animation in FBX represented as a set of node coordinates with the transition functions between them. Accordingly, an animation can be obtained as a set of coordinates. Coordinates are derived directly from the scene in 3DS MAX, using a scripting language specifically for this package - MaxScript.

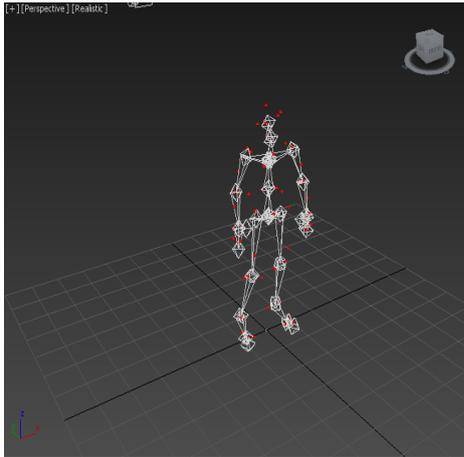


Fig. 5 The model, resulting in a motion capture

Algorithm works as follows:

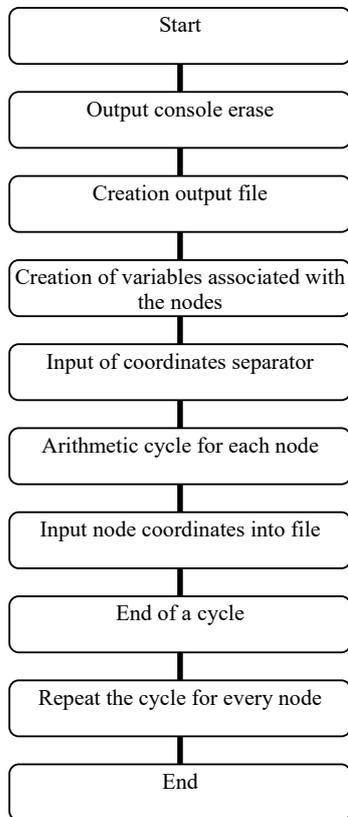


Fig. 6 Coordinate output script scheme

The algorithm searches the model names with the necessary components (in this case RKNE and LKNE, for the right and left feet, respectively), copies of their location in each frame, and outputs them to the output file. This procedure is repeated for each reporting unit. [5] The result of the script is a text file of the following form:

```

"Right knee"
[-3.83981,-0.43103,18.4024]
[-3.84007,-0.424826,18.4021]
[-3.8441,-0.418571,18.4008]
[-3.84877,-0.413661,18.4003]
[-3.85094,-0.411481,18.4014]
[-3.85402,-0.412525,18.4012]
[-3.85722,-0.413811,18.4005]
[-3.85971,-0.415274,18.3992]
[-3.86138,-0.41797,18.3986]
[-3.86324,-0.422676,18.3992]...
"Left knee"
[10.3388,-0.472636,19.2166]
[10.3352,-0.470187,19.2155]
[10.3317,-0.468999,19.2144]
[10.3276,-0.466827,19.2157]
[10.3227,-0.464925,19.2177]
[10.3229,-0.471962,19.2125]
[10.3177,-0.489728,19.2111]
[10.3143,-0.503024,19.2077]
[10.3118,-0.516342,19.2067]
[10.3102,-0.528087,19.2066]
    
```

File is a set of coordinates for each node (respectively along the axes X, Y, and Z), sequentially from the first frame of the animation to the end.

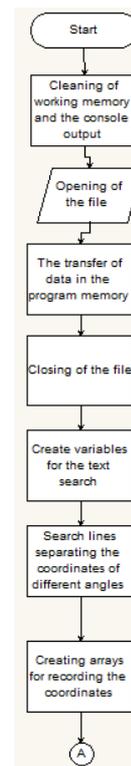


Fig. 7 Flowchart of processing a coordinate file, Pt1

For development, testing, and debugging an algorithm that will handle the coordinates and display them in easy-to-control signal to the microcontroller was chosen software package «MATLAB». This choice is because the package contains a convenient way to debug code and control

variables. In addition, to verify the correctness of the algorithm, from the source animation displays the coordinates of another site that will act as a pillar of the simulator. This measure is necessary for the proper display of leg movement simulator. Therefore, the algorithm was developed and implemented by means of language MATLAB. Its block diagram is shown in Figs. 6, 7 and 9.

The program is based on the algorithm reads a text from the source file. Immediately after the reading of the data provide an array of text itself without division into separate lines:

```
"Right knee"
[-3.83981,-0.43103,18.4024]
[-3.84007,-0.424826,18.4021]
[-3.8441,-0.418571,18.4008]
[-3.84877,-0.413661,18.4003]
[-3.85094,-0.411481,18.4014]
[-3.85402,-0.412525,18.4012]
[-3.85722,-0.413811,18.4005]
[-3.85971,-0.415274,18.3992]
[-3.86138,-0.41797,18.3986]
[-3.86324,-0.422676,18.3992]...
```

These data are a variable of type string, which does not use it directly in the management or modeling. Therefore, the string must be converted to a numeric view and this function is performed by the algorithm. At first, in the file are searched labels that were printed in the derivation coordinates of animation. These tags separated blocks coordinates for different nodes. Then, each block separately detected coordinates, and results are stored, each in a separate array of one hundred three (three coordinate axes X, Y and Z, respectively, for each one hundred frames).

The results of work recognizing line is partially shown in Table I.

Frame number	Axis X	Axis Y	Axis Z
1	-3.83981	-0.43103	18.4024
2	-3.84007	0.424826	18.4021
3	-3.8441	-0.418571	18.4008
4	-3.84877	-0.413661	18.4003
5	-3.85094	-0.411481	18.4014
6	-3.85402	-0.412525	18.4012
7	-3.85722	-0.413811	18.4005
8	-3.85971	-0.415274	18.3992
9	-3.86138	-0.41797	18.3986
10	-3.86324	-0.422676	18.3992

Such wise, the coordinates are transmitted in numeric form. Next, the coordinates are converted to a median point to display the graph displayed moving part of the simulator. Also in this program is calculated variation of the coordinates in each frame of the starting point, which will be necessary in the future.

Fig. 8 was built on the results of the algorithm that shows the movement of parts of the installation.

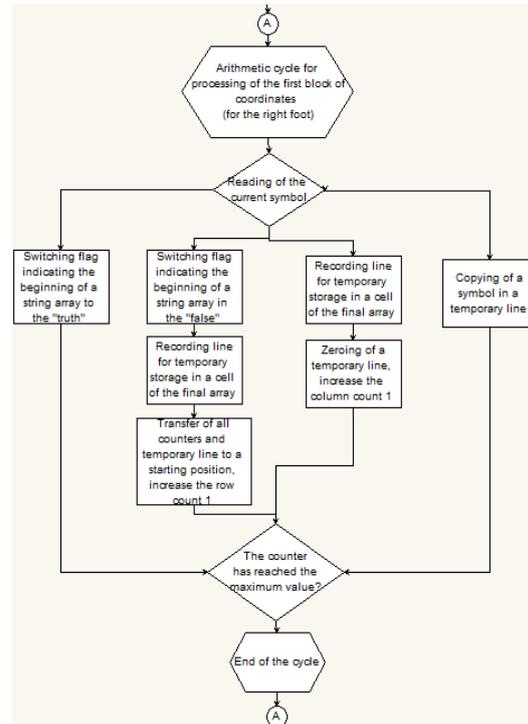


Fig. 8 Flowchart of processing a coordinate file, Pt. 2

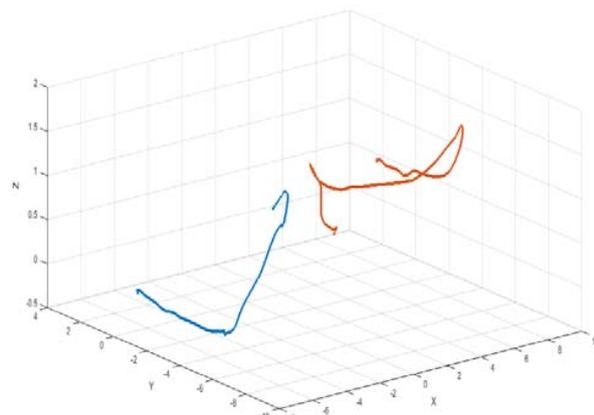


Fig. 9 Moving limbs simulator with respect to the rack

#### IV. CONCLUSION

In the future, the entire complex will be equipped with a system of sensors. They will provide data of human body movements and the most comprehensive analysis of the forces, velocities and accelerations. They will be mounted in various units of the robot and to achieve the greatest approximation of the laws of motion similar mechanisms to the human gait. In addition, active feedback can correct errors of position to be as human-like as possible the most comprehensive analysis of the forces, velocities and accelerations, active in various units of the robot and, as a consequence, to achieve the greatest approximation of the laws of motion similar mechanisms to the human gait.

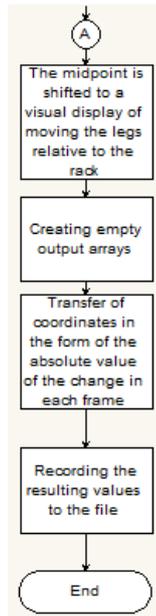


Fig. 10 Flowchart of processing a coordinate file, Pt3

#### REFERENCES

- [1] Dubrovskiy V., Fedorova V. Biomechanics. Moscow; Vldos-press, 2003.
- [2] Inertial Measurement System for Human Gait Analysis // Korotkin D., Kuznetcov A. Proceedings of the 8th International Conference on Body Area Networks 2013/ Boston USA, p.414-419.
- [3] Zhigailov, S., Kuznetcov, A., Musalimov, V., Aryassov, G. Measurement and Analysis of Human Lower Limbs Movement Parameters during Walking. Solid State Phenomena 220-221. Mechatronics Systems and Materials YI, 2015, p. 538-543. ISSN 1662-9779
- [4] What is Autodesk FBX Technology? Autodesk Knowledge Network. 2015.
- [5] MaxScript Help: MAXScript Introduction. Autodesk. 2015.