Development of robotic mobile platform with the universal chassis system

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Abstract. The problem of stabilizing the position of mobile devices is extremely relevant at the modern level of technology development. This includes the problem of stabilizing aircraft and stabilizing the pitching of ships. In the laboratory of robotics and mechatronics of the Kuban State University, a robot is developed. The robot has additional internal degrees of freedom, responsible for compensating for deflections - the dynamic stabilization system.

1. Introduction

The problem of stabilizing the position of mobile devices is extremely relevant at the modern level of technology development. This includes the problem of stabilizing aircraft and stabilizing the pitching of ships, stabilizing and improving the safety of motor vehicles.

Particular attention is paid to the problem of stabilization in the construction of robotic mobile means and exoskeletons for people with disabilities [1]. At the moment, there are no exoskeletons that would allow people with inactive legs to maintain a dynamic balance without using additional means of support.

Also, the problem of moving by step is not solved for a wide class of off-road devices using the principle of walking for moving. According to the leading US universities and companies, expressed in the report "A Roadmap for US Robotics 2016": "In order to optimize the automation of the logistics chain processes in the world, robots must have the mobility that corresponds to the human level. Robots should be able to overcome stairs, escalators, doorways, curbs, concrete fragments, unpredictable environments, and move just like people. This type of extended mobility is possible for robots equipped with legs. Then the logistics will be 24/7 and inexpensive." From the same analysis: "Service robots that contain multiple mobility mechanisms, such as legs, caterpillars and high-speed wheels, will be able to provide collision-free and mobile manipulation in completely unstructured environments." According to this analysis, the market of mobile robots in need of stabilization will amount to 16 billion dollars by 2025. Jun Ho Oh, professor of engineering mechanics at the Korea Institute of Advanced Technology (KAIST, winner of the DARPA Robotics Challenge): "There is no right (for a walking robot) even for one mistake. The problem of stabilization of walking robots is not solved "[2]. Seth Teller of the Massachusetts Institute of Technology (MIT) team argues that the most difficult tasks for robots are in a rapidly changing environment. To solve these problems, it is necessary to search for the optimal configuration of mechanics [3].

The next problem is the movement in a highly rugged terrain in conditions of low or absent gravity. Existing rovers working on Mars and on the Moon cannot overcome a highly crossed, stony, rocky and hilly terrain, now an astronaut is required for such tasks [4]. Also, for work on the ISS, manipulators are attached to the station itself, access to the elements of the construction is limited to the zone of their operation. Currently, the task is to create mobile robotic systems capable of performing various operations inside and around the ISS [4].

The most relevant, based on the analyzed sources, is the creation of a platform for service robots with the characteristics described in the Terms of Reference for this project, namely:

The calculated speed of the platform moving with the dimensions of the body, fitting in the sphere of 40 cm, along the horizontal, on the average surface, in the step mode will be 5 km / h, and in the rolling mode on the body with the manipulators up to 15 km / h, it can autonomously function for 24 hours in the video broadcast mode, under active control and moving through the terrain medium cross-over, able to carry 3.8 kg payload.

As a result of the analysis of performance indicators, power-torque characteristics, market availability and prices, it was revealed that there is an actual problem with the selection of servo drives for walking structures with a carrying capacity of up to 5 kg, the weight of the structure up to 20 kg, and the battery life of up to 2 hours.

Thus, there is a wide class of devices that need more and more advanced stabilization technologies.

A two-legged walking robot can be developed by a specialist in practice and, when developed, ensures the realization of the claimed destination. The possibility of development in practice follows from the fact that for each feature included in the utility model formula on the basis of the description, the material equivalent is known, which makes it possible to conclude that it follows the criterion "industrial applicability" for the utility model and the "completeness of disclosure" criterion for the utility model.

In accordance with the proposed utility model, the applicant made a prototype of the Bipedal Walking Robot. The experimental operation of the proposed device showed that the static stability zones look very simple and account for up to 250% of the horizontal dimensions of the robot body and up to 100% of the length of the horizontally elongated support. In this case, the robot can overcome obstacles that exceed its own dimensions.

All this, in the final analysis, ensures the fulfillment of the achieved technical result – increasing the patency and overcoming obstacles.
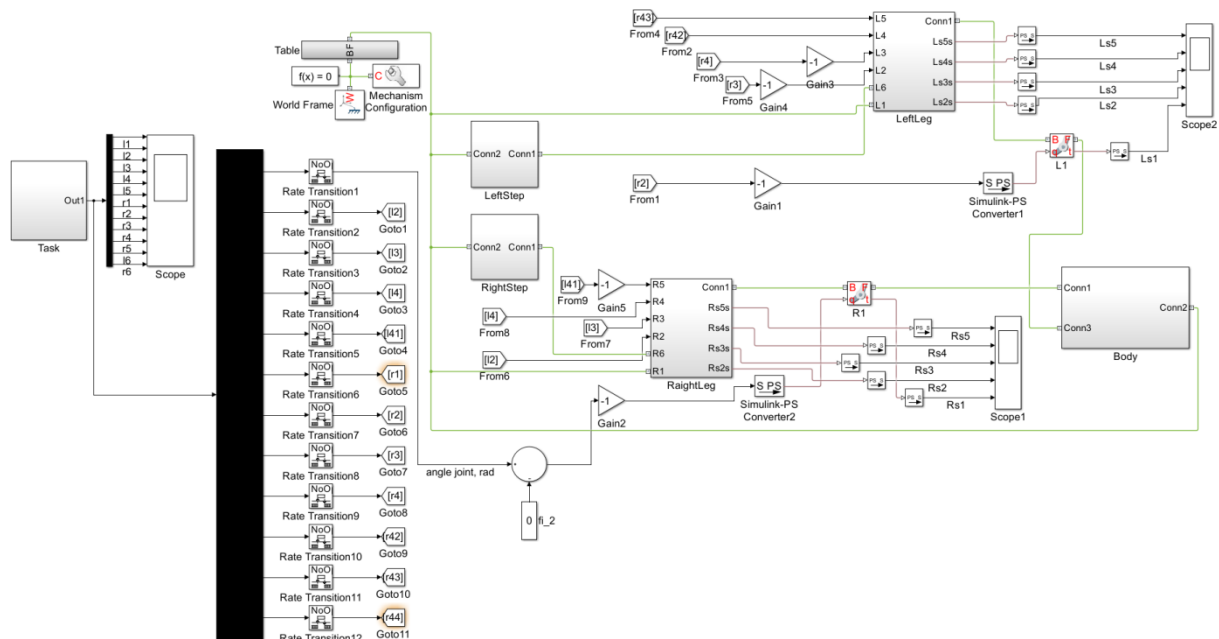
The proposed device can be used as a walking robot:
- for educational purposes to study the appropriate modes of displacement;
- in robotics for moving devices;
- as an independent vehicle that allows you to move on a complex surface, for example, over the mountains, as well as on the surface of other planets.

The two-legged walking robot works as follows. (An example of use that does not limit the use of the utility model is given) [5, 6].

2. Mathematical modeling of the walking platform in development with the kinematic scheme

Mathematical modeling of the developing stepping platform with a kinematic scheme was performed to determine the force-moment characteristics of the drives used to ensure the movement of the joints of the robot's extremities. The mathematical modeling of the dynamic stabilization system was performed separately. Modeling was performed in the MATLAB matrix laboratory using the Simulink extension and specialized utility packages, such as the Control Toolbox, Simscape and CONTACT FORCES Library, to calculate the contact forces of interaction with the underlying surface. The general view of the model is shown in Figure 1. The Task subsystem translates the motion pattern, which is an array of specified angles of moving servo drives from the MATLAB data space. The displacement array is formed by the motion planner, and at the moment consists of empirically selected angles and angular velocities of the servo drives, allowing for a steady motion in increments.

Figure 1. General diagram of the mathematical model in the MATULAB/Simulink package

3. Selection of servo drives of the robot propulsor
In the process of analyzing the kinematic scheme of the robot and numerical modeling of the walking process, the necessary servo drive parameters were identified, which are listed in Table 1.

Table 1. Found parameters of the required servo

Torque, Nm	Speed, rad / s	Weight, g	Feedback
30	1,5	300	Availability

In the process of analyzing the servo drives on the market, according to the resources http://www.servodatabase.com/, http://www.robotshop.com/, https://www.pololu.com/, http://www.trossenrobotics .com, https://www.servocity.com/, www.robodrive.com, http://www.maxonmotor.com, http://hitecrcd.com, http://www.oc-servo.com, http://harmonicdrive.de servo drives were selected, suitable for any parameter.

The servo drive HS-1100WP Ultra-Heavy Duty, Giant, Waterproof Servo was chosen (Fig. 2).

Figure 2. Servo Drive HS-1100WP

This servo drive has a waterproof, extremely rugged body and high torque, which allows the drive to be used on an industrial scale and in bad weather conditions. At the same time, the HS-1100WP is very compact and light, just 0.363 kg. However, the big drawback of this drive is the lack of feedback.

4. Conclusion

The proposed robotic system is able to move in an environment adapted to humans, having a non-anthropomorphic kinematic scheme. In this case, for the movement and stabilization, there are different cyberphysical systems, which made it possible to develop a mathematical model of controlled motion with an analytically solvable system of equations.

Advantages of the kinematic scheme AnyWalker over anthropomorphic constructions (for example, solutions from Boston Dynamics):

- low center of gravity and many zones of static stability;
- large surgical field with small dimensions (the robot in height of 70 sm can reach to a 2-meter obstacle);
- energy efficiency and low value of the Cost of Motion parameter;
- scalability;
- possibility to climb on obstacles, 2.7 times exceeding the dimensions of the platform.

The principles of independence of kinematic walking and stabilization are supposed to be used in developing a solution for stabilizing exoskeletons, which will allow the pilot to accelerate movement and get rid of crutches.

In the future, the system of dynamic stabilization consisting of three flywheels realized in the form of motor-wheels or driven by gears each from its motor located in orthogonal planes will be developed (while the mass centers of flywheels coincide). One flywheel is perpendicular to the ground and the direction of motion, the second is perpendicular to the ground and is parallel to the direction of motion, and the third is parallel to the ground. This stabilization system allows compensating for external influences without changing the kinematics of walking, as well as the moments of inertia that arise when moving the manipulators.

Acknowledgments

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