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Constructive solution of the robotic chassis AnyWalker

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Abstract. Presented constructive solution of the robotic system effectively solves the problem of movement in human-adapted not pre-prepared environment. AnyWalker stabilization system consists of three flywheels, implemented in the form of motor-wheels or driven with the help of transfer mechanisms each from its motor, in orthogonal planes, and the centers of mass flywheels are the same. It is proposed to formalize the functionality of the movement in the human-adapted environment in the form of a standard architecture for robotic chassis with the possibility of hardware and software extension.

1 Introduction

There are many applications of robotic systems in which robots must be able to effectively locomote in the human-adapted, not specifically prepared for the machines environment, for example, service robotics, work in rugged terrain, multistorey buildings, weightlessness. Right now there are no robotic systems, including those with anthropomorphic design, satisfying this criteria.

The external forces compensation and stabilization plays a key role during the movement of the robotic systems. At the same time there are no mathematical models of anthropomorphic robots, which have analytically solvable locomotion equations systems, provided that movement and stabilization are carried out using the same actuators [1].

It is proposed to formalize the functionality of the movement in the human-adapted environment in the form of a standard architecture for robotic chassis with the possibility of hardware and software extension.

2 Kinematic schemes

Robotic system was developed, that can move in the human-adapted environments, with the stabilization and motion being controlled by different cyber-physical systems.

The scheme of arrangement non-anthropomorphic bipedal chassis is proposed, where each leg has three links and a foot, and the center of mass of the whole structure is located on the second level from the surface of the support joint, which provides simplicity of balancing this platform, and also increases the area available to make a step or manipulate the objects, in comparison with anthropomorphic linkage (Fig. 1).

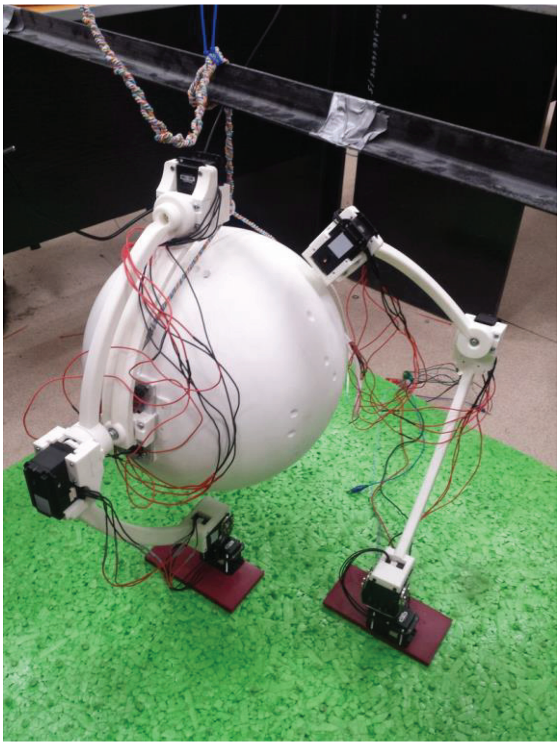

Figure 1. General view of the prototype

Kinematic scheme is shown on the Fig. 2, where 1 – body of the robot, 2 – control unit, 4 – power supply, 5 – corrective center of mass displacement unit, 6 – surface, 7 – axis of the first and second hinges rotation, 8 – axis of gravity passing through the center of mass, 9 – obstacle, 11 – first part of the upper robot leg, 12 – second part of the upper robot leg, 13 – lower robot leg, 14 – foot, 21 – first hinge, 22 – second hinge, 23 – third hinge, 24 – fourth hinge.

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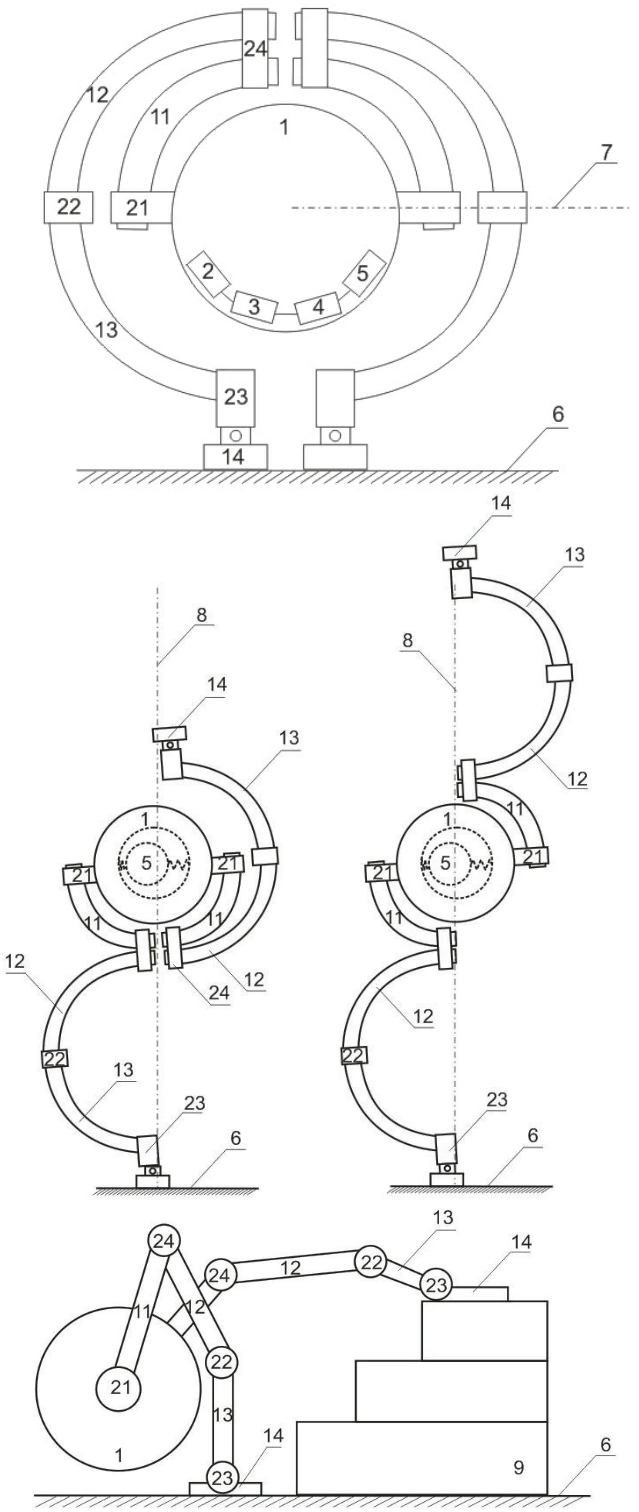

Figure 2. Kinematic scheme

The phase space of allowed manipulator states ω is specified with a Boolean function $P(\theta)$ which returns 1 if the vector displacements of the joints θ is valid. The movement θ of the kinematic scheme is a curve $\xi \subset \omega$ with initial point θ_1 and endpoint θ_2. Here θ_i $(i=\overline{1,12})$ — vector specifying the position of manipulators of the robot relative to the housing. In Fig. 2 under the numbers shown 21, 22, 24 joints are shown with one rotational degree of freedom, number 23 — joint with three rotational degrees of freedom. The endpoint of each step θ_2 is computed by solving the inverse kinematic problem for a given control algorithm coordinates in three-dimensional space relative to the robot body. Curve ξ must satisfy the following conditions:

$$\forall\theta \subset \xi P(\theta)=1;$$
$$S(\theta_1,\gamma_1)=1, S(\theta_2,\gamma_2)=1.$$

Function $S(\theta,\gamma)$ here determines whether the static state is subject to the vector of the readings of the auxiliary sensors γ.

The speed of movement of joints ν_i $(i=\overline{1,12})$ are determined by the control algorithm depending on the received commands and sensor readings at each given time.

AnyWalker stabilization system consists of three flywheels, implemented in the form of motor-wheels or driven with the help of transfer mechanisms each from its motor, in orthogonal planes, and the centers of mass flywheels are the same. One flywheel is perpendicular to the ground and the direction of motion, the second perpendicular to the ground and parallel to the direction of motion, the third parallel to the ground. This stabilization system allows to compensate external influences, without altering the kinematics of walking, and moments of inertia that occur when you move the manipulators. This stabilization system is an evolution of the design presented in [2-4].

3 Hardware and software architecture of the control system

Hardware and software architecture of the control system AnyWalker consists of the following levels:

1. Reactive layer is based on a microcontroller STM32F100RB. This level is responsible for:
   - Direct control of the actuators and flywheel joints, and getting the status information;
   - Filtering of raw data from accelerometers, gyroscopes, magnetometers, pressure, distance and other sensors.
2. The Executive level is based on the controller TRIK. This level is responsible for:
   - Localization of the robot in space by using vision systems and sensors;
   - The planning of movements based on the type of surface and dimensions of obstacles;
   - Processing of the sensor readings are in the “joints”, “feet” and the housing;
   - Stabilization system flywheels and stabilization of manipulators;
   - Ancillary functions, such as specialized sensors and reactive behavior.
3. Algorithmic level represents the application software installed on a personal computer or smartphone, completely or partially in the cloud. This level is responsible for:

- The user interface. Directly integrated into the chassis: bluetooth, wifi, USB. Controlled via Internet;
- Machine learning: conducting complex calculations on powerful external computing platform that communicates the sensor readings and control commands from the chassis;
- Making decisions on application behavior that is not part of the basic functionality of the chassis;
- Multi-agent interaction, robotic platforms, built on the chassis.

It is proposed to use the control algorithmic support as an information service that will allow you to give third-party API researchers to solve applied problems. The levels of the software architecture provides an API to the next level according to their functionality:

1. Reactive level: the RPC API;
2. Executive level: C++ API, API QtSrcipt;
3. Algorithmic level: the SOAP API.

AnyWalker chassis is a standardised platform for robot applications. Standards extensions:

- Hardware level: the addition of various sensors, modernization of manipulators, resize, etc. Provides the ability for third-party developers to produce and sell their own hardware that is compatible with AnyWalker architecture;
- Control level for the robotic system: programming new movements, specialization under specific conditions of external environment, etc. Provides the ability for third-party developers to create and implement their own algorithms of movements through the app store;
- Intelligent systems level: programming groups of robots or chassis in specific conditions, competitive programming, artificial intellect systems on the basis of the chassis, debugging in the simulation environment. Provides the ability for developers to create and implement their own application scenarios robots, such as competitions and performances.

4 Conclusion

Proposed robotic system is able to move in the human-adapted environment, with non-anthropomorphic kinematic scheme. In this case, movement and stabilization are attributed to different cyber-physical system, which allowed the development of a mathematical model of the controlled motion with the analytically solvable system of equations.

Proposed scheme of standardization of software and hardware architecture of the chassis provides a third party service to create hardware and software extensions and build robotic systems based on this chassis, solving different applied tasks according to their specifications and conditions of the operation.

Presented constructive solution and the hardware-software description of the robotic system effectively solves the problem of movement in human-adapted not pre-prepared environment. Provided the description of the chassis architecture for robotic systems with the aim of providing to third-party developers mechanisms to increase the functionality and specialization robots, built on hardware and software solutions for this platform.

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