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Overview of Innovative Walking Robots

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***Abstract**: This overview article discusses latest advances in robotics using example of 2, 4 and 6 finite walking robots applied in various fields. The document provides an overview of main types of walking robots structures, body shapes and types of movers. Thus, on basis of review, classification of main types of walking robots structures, body shapes and types of walking robots movers is given; main parameters and areas of application of walking robots are determined. The paper considers novelties in robotics: bipedal robot, which is most realistic of Ameca's humanoid robots; bipedal robot Kaleid Friends, as well as an innovative robot with 4 limbs Bex (Kawasaki) and 6 – Robotics Six-legged Spider.*

Keywords—frame; engine; design; walking robot

1. INTRODUCTION

One of promising areas was and remains robotics [1]-[6].Various methods and approaches for their construction, modeling and analysis can be used here [7]-[15].

Walking robots (WR) are popular subject of research around world. Such robots can be used in various fields ranging from rescue operations to social services.

The popularity of such robots is largely due to their main advantage over other types of moving robots – ability to overcome surfaces with complex terrain.

Walking robots can solve various classes of tasks, for example, industrial ones to perform heavy, monotonous, harmful and dangerous physical work. Industrial robots are mainly designed to automate all kinds of manual and transport operations in various industries. Or research – search, collection, processing and transmission of information about objects under study. Objects can be underwater and air space, underground cavities, etc.

Some modern WRs are able to independently move in various directions. Some can stand, sit, walk on uneven surfaces, climb up and down various surfaces, and even fall without much harm to themselves. Develop different speeds to move.

Thus, main purpose of article is to review innovative walking robots.

2. BRIEF OVERVIEW OF RELATED WORKS

Development of walking robots is also of great interest.

Walking robots are the second most common type of robot that can move around. Currently, many devices have been created – walking robots, where authors describe designs, characteristics and advantageous areas of application of walking robots.

Design and control of SLIDER: an ultra-lightweight, low-cost bipedal walking robot without knees is described in [16].

In [17], a constructive basis for construction of robot leg is proposed. The general theorem is given to design a mechanism based on template for maximum efficiency. The problem of choosing actuators is being solved.

Numerical analysis of dynamic parameters of mobile walking robot is considered in [18].

Optimization of walking robots parameters and algorithms for their movement is described in [19]. An assessment of walking robots performance was carried out.

The problems of designing walking flying robot are described in [20]. The peculiarity of work is that we are talking about robotic platform with hybrid mobility, which can be used in hazardous industrial environments or emergency power plants, where several types of obstacles cannot be overcome by movement and flight is not always possible.

The area of WRs application is described in [21]-[24]. The use of WR in healthcare, namely in field of information and communication technologies (ICT), namely, robot services, with elements of gamification.

In [25] WR in construction, authors developed an autonomous walking excavator – universal robot on construction sites. The authors described the process of converting finished construction machine into an autonomous robotic system.

The robot is considered in four different real-world applications, such as autonomous trenching, autonomous assembly of dry stone walls, autonomous forestry work, and semi-autonomous remote control.

Humanoid robots in aircraft industry: examples of use of airbuses are presented in [26].

In [27], review of walking in-line robots, which are new class of in-line robots with greater maneuverability, but also more complex control compared to other, more common types of in-line robots. The focus of article is on inverse kinematics of these robots.

A review and prospects for development of mobile walking robotic systems are considered in [28], [29].

3. Features of walking robots use

World market for WR is expanding day by day.

Perfect walking robots imitate movements of insects, crustaceans, and sometimes humans, that is, their distinctive feature is that biological approach is used in design of structure.

WRs are mainly used for: research, rescue operations, entertainment, military and industrial purposes, healthcare, agriculture.

There are different types of walking robots structures, body shapes and types of propulsion systems for WR depending on tasks to be solved (Table 1).

Table 1: Types of walking robots structures, body shapes and types of propulsion units

<table>
<tr><td colspan="4">Characteristic</td><td colspan="3">Description</td></tr>
<tr><td colspan="7">Types of hull designs</td></tr>
<tr><td colspan="5">One piece body</td><td colspan="2" rowspan="3">Articulated body</td></tr>
<tr><td colspan="3">Axisymmetric shape</td><td colspan="2" rowspan="2">Oblong shape</td></tr>
<tr><td>RS</td><td colspan="2">GG</td></tr>
<tr><td colspan="7">Propulsion types</td></tr>
<tr><td colspan="4" rowspan="2">Lever scheme</td><td colspan="2">Single lever</td><td rowspan="2">Multi-link (pantograph)</td></tr>
<tr><td>SS</td><td>MS</td></tr>
<tr><td colspan="4">Telescopic scheme</td><td colspan="3">It is piston with spring, pneumatic or hydraulic drive. Usually piston is fixed on axis of rotation (or two axes) without additional segments.</td></tr>
<tr><td colspan="4">Arc scheme</td><td colspan="3">This is arc made of plastic material, fixed on axis of rotation from one end. The design is cross between wheel and limb.</td></tr>
<tr><td colspan="7">Number of legs</td></tr>
<tr><td colspan="2">2</td><td colspan="2">4</td><td colspan="3">6 and miriapods</td></tr>
</table>

Note* RS – round shape; GG – hexagonal.

Axisymmetric shape – without constructive orientation, which means that robots do not have division of body parts into front / rear and side.

The oblong shape has pronounced orientation, namely, they are structurally more adapted to movement in direction of long axis of symmetry. This is manifested due to change in distance and relative position of attachment points of limbs.

Difference from hexagonal shape is other restriction of rotation angles of “front” and “back” legs, which makes it possible to realize rectilinear movement using limb with two degrees of freedom.

Single-segment (SS) – has rigid configuration and two degrees of freedom (horizontal and vertical). This makes it possible to move in straight line with an elongated body shape, turn on spot and adjust height of robot within small limits. The height adjustment of robot is possible under certain conditions (robot mass, drive power, surface properties), since when height changes, limbs will slip [30].

Multi-segment (MS) – has changeable configuration due to movable segments. The number of freedom degrees in this case is usually one more than number of segments. Each segment is connected to adjacent one (one drive), and first one from body has two drives for horizontal and vertical movement. The number of segments is limited by needs of developer (or customer) and characteristics of equipment used. Most often in six-legged robots there are two-segment limbs with three degrees of freedom. This is enough to perform locomotional actions [30].

Pantograph scheme for controlling supporting part of limb:

– within wide range, you can change height of robot when standing on its limbs, while supporting part of limb will remain in one place;

– control of support segment of limb by means of drive, while drive is located in body-torso, and not on joint. This option can significantly reduce force of gravity acting on limb when lifting, which increases stability.

Telescopic scheme – scheme with following feature – absence of levers, which removes force acting on fasteners and limb drive. The change in the height of raising limb is replaced by level of piston cylinder extension. Forward movement is carried out by changing level of cylinder extension and angle of drive rotation, rotation plane which is perpendicular to direction of movement and crosses surface.

Difference between telescopic system and lever system is also in arc of rotation. If in lever system arc is in plane of surface, then in telescopic plane they are perpendicular.

Arc circuit is movement occurs when actuator rotates in Direction of convex side of arc. The principles of movement and turns are similar to caterpillar tracks. The advantage of scheme is high cross-country ability, and average speed performance. Can be used in robots without top-bottom orientation.

Disadvantages are unidirectional movement (rotation of arc in opposite direction can lead to hooking or jamming), unstable, bouncing nature of movement.

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The bipedal design is attractive for implementation, since it is based on and repeats human motor skills, however, implementation of such robot is rather complicated.

With increasing emergence of bipedal robots in wide range of scientific and diverse industrial fields, especially in extremely hazardous environments, bipedals need lot of attention for scientific research and achieving stable gait control. The basis of bipedal walking is efficient gait planning, and this potentially affects overall performance of bipedal robot as well as stable dynamic balancing.

The quadrupedal design is characterized by presence of sufficient number of legs to hold body in stable position without use of special equipment.

Among all mobile robots, four-legged robot is legged robot that is superior to wheeled and crawler robots due to its ability to explore any terrain like human and an animal.

Most robotic leg designs are either based on biomimetic human or animal leg morphology or mechanically optimized for specific task.

The basic characteristics used in walking robots is:

- design of limbs;
- number of degrees of freedom per 1 leg;
- number of servos;
- orientation in space;
- adaptability;
- possibility of installing additional sensors.

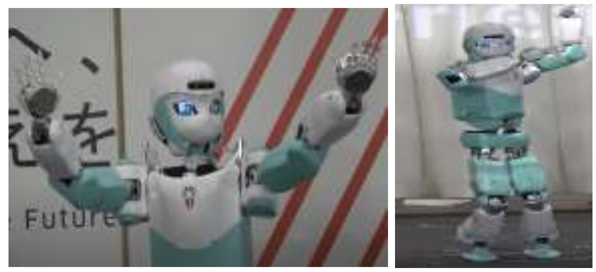
Among main parameters of walking robots, most important is type of walking, which determines other parameters such as: stability, number of limbs, limb configuration and proportions, as well as control method, moment of inertia and torque.

4. Overview of innovative walking robots

One of 2022 novelties is robot with bipedal design from Kawasaki – Kaleid Friends fig. 1 [28], [29]. Kaleid Friends parameters: height 168 centimeters and weight 54 kilograms. The robot is stable not only on straight legs, but also half-bent. The maximum walking speed is 3 km/h. The carrying capacity of Kaleid Friends is up to 10 kilograms. The robot is battery operated. The peculiarity of such robot is that robot can “predict” positions that are unstable for itself and adapt to them in order to maintain stability in real time.

Such robot will be used for entertainment, for example, caring for sick and elderly.

Let's focus on another innovation in field of robotics – bipeadal Ameca robot from Engineered Arts, endowed with artificial intelligence robot, is most realistic humanoid robot in world (fig. 2) [30]. Ameca is considered face of robotics of future.



a) b)

Figure 1: Kaleid Friends Robot

Figure 2: Ameca robot from Engineered Arts

Robot has perfect humanoid body. Which over time will have perfect humanoid artificial intelligence. The body of robot is modular platform. Robot has universal appearance without gender and age. Ameca – robot with live facial expressions

Ameca application: sort data from sensors and encoders, motors, network traffic, video streams, physical conditions and respond to them in time.

At moment, Ameca is equipped only with head and arms.

One of most interesting and unusual novelties in field of WR 2022 is Bex (Kawasaki). The unusual thing is that it is robotic goat capable of moving over rough and mountainous terrain with steep slopes, and when the robot enters plain with smooth road, it transforms and moves on wheels built into its knees (fig. 3) [31].

Bex has: legs, wheels, horns, saddle and handlebars. It is successor to humanoid platform Kawasaki of Kaleid series.

The Bex robot has quadrupedal design and wheels on its knees (fig. 3, b).

Robot is capable of carrying any load up to 100 kg, and it can even be person. At same time, robot can be controlled by person himself or in automatic mode according to programmed program. During transportation of person, small saddle and levers are provided that act as reins.

a)

b)

Figure 3: Robo-goose Bex

The Bex robot can be used at construction site; at industrial enterprises for movement of goods and inspections; in fields for transport of crops; can stream video from its cameras on its head.

Management: direct thanks to steering wheel and remote using remote control.

And as 6-legged robot, Hexapod or Robtics Six-legged Spider robot from Zhizicathy is chosen.

This is a premium class robot (fig. 4) [32].

Figure 4: Robot spider Robtics Six-legged Spider

Device is made of aluminum alloy and fiberglass, which provide it with lightness and strength. There is hole for switch and regulator on case.

It is 18 DOF hexapod, adopts 20 CH servo controller, can control 20 servos at same time.

Device parameters: 31*24*16.5 cm.

Spider robot is controlled by remote control.

5. Conclusion

The paper provides an overview of main types of walking robots structures, body shapes and types of movers, it is determined that body with joints is most often an oblong shape, consisting of movably connected parts.

Such circuit has advantages of one-piece circuit and improved ability to overcome obstacles. At same time, design becomes more complex, which requires additional calculations, and additional articulation elements (mounts, hinges and drives) increase mass and power consumption.

Anthropomorphic bipedal robots are considered most spectacular, but not most practical, sometimes robots are more stable, for example, on 4 legs.

There are many designs of WR, but today they strive to ensure that robots have property of adapting to arbitrary topology of surface on which they move.

Thus, on basis of review, classification of main types of walking robots structures, body shapes and types of propulsion units of WR is given; main parameters and areas of walking robots application are determined.

The paper considers novelties in robotics: bipedal robot, which is most realistic of Ameca's humanoid robots; bipedal robot Kaleid Friends, as well as an innovative robot with 4 limbs Bex (Kawasaki) and 6 – Robtics Six-legged Spider.

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