DODEKAPOD AS UNIVERSAL INTELLIGENT STRUCTURE FOR ADAPTIVE PARALLEL SPATIAL SELF-MOVING MODULAR ROBOTS

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Summary This paper presents a novel concept of a parallel spatial mechanism with twelve degrees of freedom, called Dodekapod robot, as universal intelligent structure for adaptive parallel spatial self-moving modular robots. We aim at merging technologies from information technology, special requirements in various branches industry, e.g. rehabilitation medicine, space engineering, methods of transportation, spatial active vibration protection systems and robotics in order to design adaptive and intelligent robots.

INTRODUCTION

There are numerous examples of applications of parallel spatial robots (PSR) with 6 degrees of freedom (d.o.f.) (so-called hexapods) in most various fields [1]-[2]. Such robots versus classical robots (so-called serial robots) have the following main advantages: much higher accuracy and rigidity, higher productivity and reliability, much less sensitive to scaling effect, and ability to manipulate large loads [2]. Compared to the serial robots, the main drawback of hexapods is the smaller workspace [2]. Therefore, some novel designs of PSR with the larger workspace are needed. Dodekapod robots with 12 d.o.f. is modern stage of development in the field of PSR [3]-[4]. Such robot versus hexapod has the larger workspace. Each of its sides can clamp (unclamp) things with a closed loop surface of various form. Reference [3] shows kinematics analyses of dodekapod manipulator. Currently, many modern multifunctional concepts are needed to expand functional capabilities of Dodecapod robots. Reference [4] shows novel functional capabilities of dodekapod robot, such as the self-movement, the diagnostics of contact surfaces, and other ones. New functionality of Dodekapod robots is represented below.

DESCRIPTION OF DODEKAPOD ROBOT

We present novel concept of the adaptive parallel spatial self-moving modular robot, called Dodekapod robot, where we aim at merging technologies from information technology, special requirements in various branches industry, e.g. rehabilitation medicine, space engineering, methods of transportation, spatial active vibration protection systems and robotics in order to design adaptive and intelligent robots. Dodekapod robot is an octahedral parallel spatial mechanism. Every one of its triangular faces is formed by linear drives that are connected with vertices of octahedron by spherical joints (link balls). This feature opens new functionality of Dodekapod robot versus a hexapod and others parallel spatial robots. The schematic view of the monomodule Dodekapod robot (a) and the simplified structural scheme of the control system (b) are shown in Fig. 1. The structural scheme includes maximal number of sensors, radial stops and grippers. This number is dependent on the applications and it may be decreased. Dodekapod robot is executed as the octahedral module 1. All ribs of the octahedron are executed as the rods with the linear drives 2 each of which have the axial force sensor 3, the medial force sensor 4, the relative linear movement sensor 5, and the relative velocity sensor 6. The ends of the adjacent ribs are connected by the spherical joints in the vertices 7 of the octahedral module 1. The vertices 7 contain the radial stops and the middles of the rods contain the grippers (on Fig. 1 were not shown) each of which have the temperature sensor 8. The octahedral module 1 has 12 d.o.f., which is a spatial farm as soon as all linear drives 2 are turned off. All vertices 7 have the spatial position sensors 9 which are integrated with the three-axial accelerometers 10. The control system (CS) 11 includes: the computer 12, the software 13 and the digital-to-analog converter (DAC) 14. The inputs of CS 11 are connected to outputs of the analog-to-digital converter (ADC) 15 for the force sensors 3 and 4, ADC 16 for the relative linear movement sensors 5, ADC 17 for the spatial position sensors 9 with the three-axial accelerometers 10, ADC 18 for the relative velocity sensors 6, and ADC 19 for the temperature sensors 8. Outputs of CS 11 are connected to inpets of the software 13 and DAC 14. The outputs DAC 14 are connected to the power amplifier 20 which is connected to each of the linear drives 2.

The octahedral module 1 may be used as a base element not only at the monomodule Dodekapod robots, but also at the multimodule ones. The radial stops and the grippers (on Fig. 1 were not shown) provide the transmission of the efforts from linear drives toward the internal and external contact surfaces. The force sensors 3, 4 and temperature sensors 8 provide the operative control of these efforts and temperature in the contact places. The spatial position sensors 9 with three-axial accelerometers 10 provide the operative control of the spatial position of vertices 7 and of vibration along each of axes of rods with linear drives 2. The relative linear movement sensors 5 and the relative velocity sensors 6 of the linear drives 2 register their relative movements and velocities. Before using it we will have to place the octahedral module 1 in inside or outside of the closed surface and then carry out the necessary movements depending on tasks. The linear drives 2 and the CS 11 fulfill the coordinated changes of the lengths of the ribs of the octahedral module herewith. As a result the vertices 7 have got spatial movement concerning a base system of coordinates. A geometrical

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invariability of the octahedral module 1 allows to define the spatial coordinates of all tops 7 as a result of the measurement of the lengths of all rods and to control their spatial movements like as in Stewart's platform [1]. The sensors of the spatial position 9 allow elevating a precision of these measurements herewith. The computer 12 and the software 13 provide the control of real time.

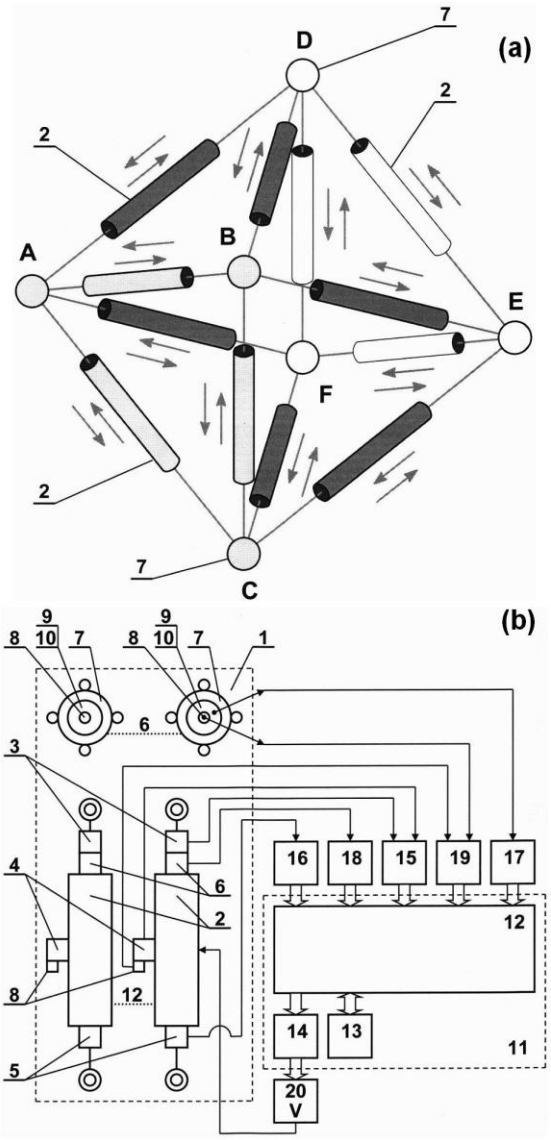

Fig. 1. The schematic view of the octahedral module of Dodecapod robot (a) and the simplified structural scheme of the control system (b).

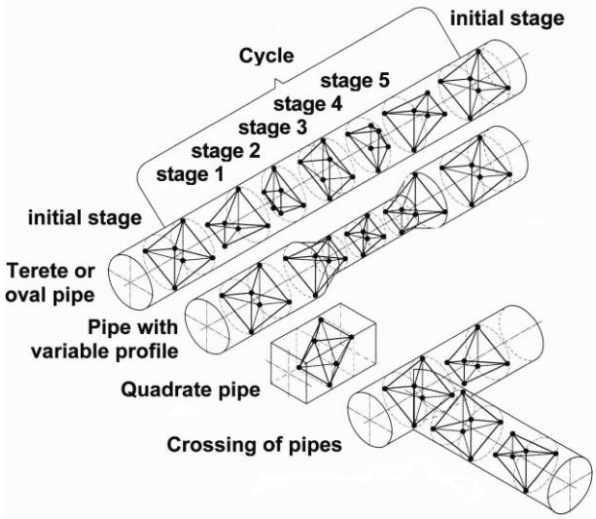

Fig. 2. The self-movement of the octahedral module of Dodecapod robot in the pipes.

A placement of the octahedral module of Dodecapod robot inside the pipes of a various profile with a cycle of its self-movements is shown in Fig. 2. This concept may be used in some miniature robotics, for example for the self-movement Dodecapod robot inside the highly branched vessels or inside the divided manifolds with the various profile pipes.

CONCLUSIONS

Currently, there are numerous examples of applications hexapods in most various fields. Hexapods versus serial robots have the following main advantages: much higher accuracy and rigidity, higher productivity and reliability, much less sensitive to scaling effect, and ability to manipulate large loads. Compared to the serial robots, the main drawback of hexapods is the smaller workspace.
Dodekapod robots with 12 d.o.f. is modern stage of development in the field of PSR. Such robot versus hexapod has the larger workspace. Each of its sides can clamp (unclamp) things with a closed loop surface of various form.
The novel concept of the parallel spatial mechanism with 12 d.o.f., called Dodekapod robot, as universal intelligent structure for adaptive parallel spatial self-moving modular robots, is shown.
Dodekapod robots can connect together, forming some novel mobile structures for various applications.
The concept of Dodekapod robot may be used in various branches industry, e.g. rehabilitation medicine, space engineering, methods of transportation, spatial active vibration protection systems and robotics in order to design adaptive and intelligent robots.

References

[1] Stewart D.: A platform with six degrees of freedom. *J. Proc. Inst. Mech. Eng.*, vol. 180, Part 1, no. 15, pp. 371-386, 1965-1966.

[2] Merlet J.-P.: Parallel Robots, 2nd ed. Dordrecht, The Netherlands: Sringer, 2006.

[3] Bande P., Seibt M., Uhlmann E., Saha S. K., Pao P. V. M.: Kinematics analyses of dodekapod. *J. Mechanism and Machine Theory.*, vol. 40, no.6, pp. 740-756, 2005.

[4] Sayapin S. N., Siniov A. V.: Adaptive mobile 3D manipulator and method of organizing displacements and control over physical-mechanical properties, geometrical share of contact surface and displacement trajectory hereby. Invention with a patent of Russian Federation No. 2424893, 2011.