Acta Mechanica Slovaca
ISSN 1335-2393
www.actamechanica.sk

Robotic snakes

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Abstract: The paper deals with snake-like robots. There are several types of snake-like locomotions. Biological example – snake always select the best type of locomotion in accordance with terrain. Big manoeuvrability leads many teams to develop snake-like robots. These structures have many degrees of freedom and it is complicated to control them. Articulated bodies of these snake-like robots consist of segments. The paper deals with segment with one and two degree of freedom.

Keywords: *snake, robot, servomechanism, motion, mechatronics.*

1. Introduction

There are many areas where is a need for robot application as moving inside break down building, pipe inspection, pipeline repairing, cable installation into unused pipes, moving in narrow spaces. Robots can be used for rescue tasks after disasters caused by natural forces.

Big area is application in environment dangerous for human as radioactive irradiation, fire exposition, dangerous gases exposition, chemical contamination etc. Special case is a finding of explosives and bombs and also mine detection what is dangerous for human. Special task forces and police use robots in fighting against the terrorists.

Nowadays many robotic applications are as service robots for works as cleaning, vacuum cleaning, cutting the grass. Mobility of the robot is thanks to mobile undercarriage. Wheeled robotic platform is the most frequently used type of motion (fig. 1). Also tracked type is often used for the mobility of the robot (fig. 2). Wheeled and tracked type has the problem with overcoming through the obstacles as stairs and inclined planes. There are several types with improved mobility through the rough terrain [1-9].

Fig. 1: *Wheeled mobile robots for inspection tasks.*

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Tracked robots have better mobility than wheeled type, but there is a bigger friction between the belts and terrain. Also energy consumption is bigger.

Design of the mobile robots comes from inspiration by animal examples as cockroach, spider, snake etc. Animal examples show superlative properties of animal motions (fig. 3).

The articulated body motion robots have been developed and also legged type is used as good form of mobility through the rough terrain. Animal examples obtain the fast mobility and for this reason there is the effort to imitate the animal form of motion. Snake like robots seems to be as good representative of platform with high mobility and manoeuvrability in rough terrain.

Special category of robots is a humanoid robot, which take inspiration from human motion. Humanoid robot seems to as the most complicated robotic type. The humanoid robot should be used as personal robot for home using as servant. There are robot competitions as robot-soccer similar to human soccer (fig. 4). The vision is to build the full size humanoid robot able to play football against the human champions. Humanoid robots will be as future top form of the robots.

Fig. 2: *Tracked mobile robots for inspection tasks.*

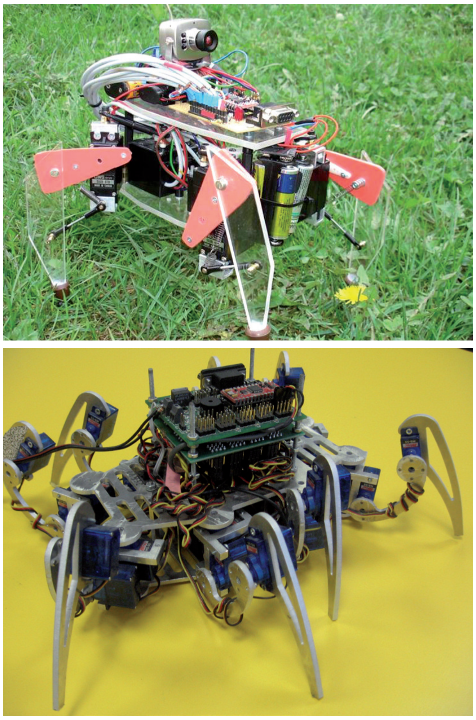


Fig. 3: *Legged mobile robots.*

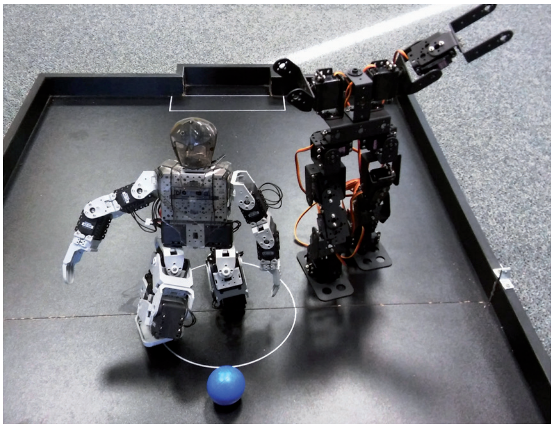


Fig. 4: *Humanoid robot-soccers.*

2. Snake like motion strategy

Snakes are perfect example for inspiration in design process of service robots for narrow spaces. The body of these robots has articulated character because of high degree of mobility.

The famous study of snake-like motion has been made by Hirose and Yoneda Labs [4]. These studies show that snake uses several types of motion in according with terrain where they passes through the obstacles. Snakes are able to uses obstacles as aid to better mobility. They adapt to environment and select the most suitable type of motion from the view of overcoming the terrain and from the viewpoint of energy consumption. The body of snakes consists from segments and also design of robotic snakes takes this inspiration. Complicated structure of snake consists from many degrees of freedom and many joints and actuators. Consequently the controlling of this structure is very difficult. There is a need for many sensors of robot joints and pose of the robot and contact forces.

Normally, snakes use of four types of motion as serpentine motion, rectilinear motion, concertina motion and sidewinding motion. Every type has own specific properties and usability for specific type of terrain.

Selection of motion type needs information about environment and robot pose. Many sensors information is hard for data processing. On the base of this information analyses the suitable strategy of motion selection should be used with aim of effective fast motion with minimum energy consumption.

3. Proposal of individual fuel map

This concept comes from using segments which includes only one actuator for realisation of one rotary joint. The final mobility depends on number of these segments and their arrangements. Small number of segments will cause the low mobility of snake robot, but high number causes the larger overall weight and complicated control strategy. Also high number of actuators causes high energy consumption. Finally the compromise has to be made and select suitable number of segments and suitable arrangement.

The eight segments articulated body snake robot has been developed (fig. 5). The concept is based on alternating of rotation axis position between the neighbour segments. It helps to better mobility and overcoming through the obstacles.

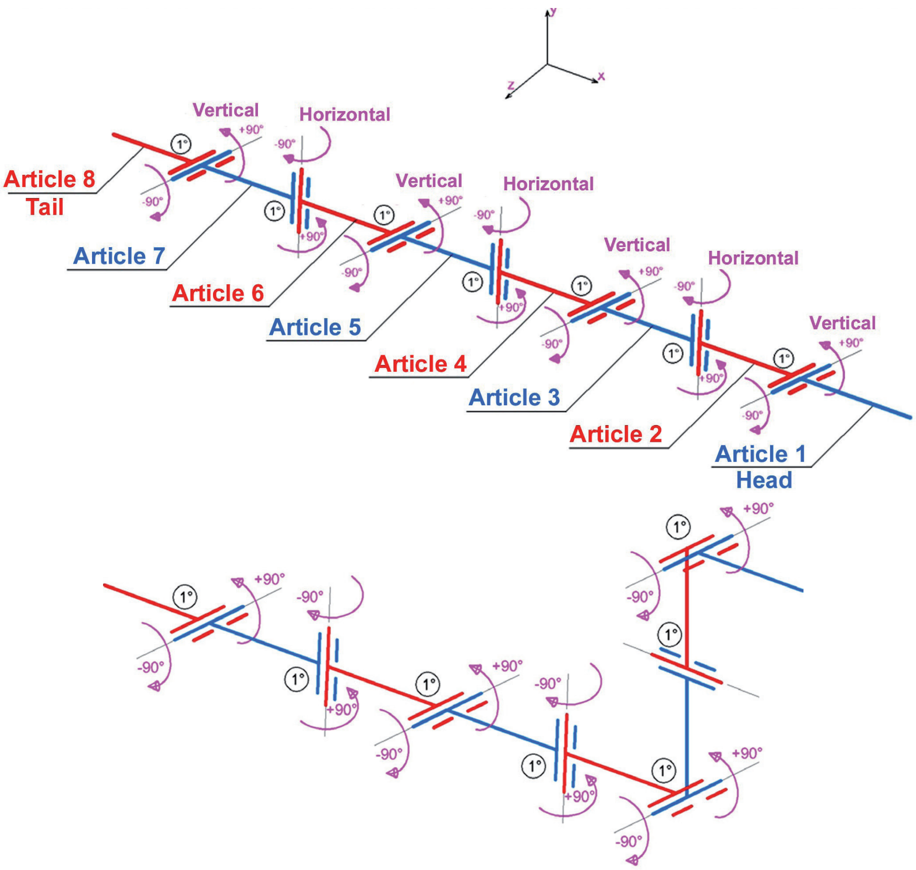


Fig. 5: *Arrangement of segment in snake robot with one degree of freedom per segment.*

RC servo actuator is used for realisation of rotation in every segment. Every segment has cube geometry (fig. 6). Sensor of angle rotation is placed in every joint for the robot pose identification and motion planning. Algorithm is selected on the base of identified pose. This concept is able to execute concertina type and sidewinding type of motion.

Design process has been supported via using the CAD model and also simulation with CAD model has been executed for testing of collision inside the robot structure (fig. 7).

Building of this robot required the technology of precise cutting and bending of metal plates. Wiring inside the robot structure was also complicated during the robot realisation (fig. 7).

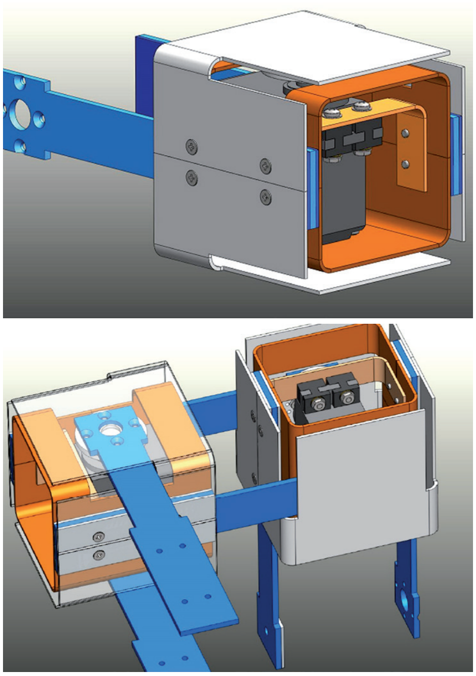
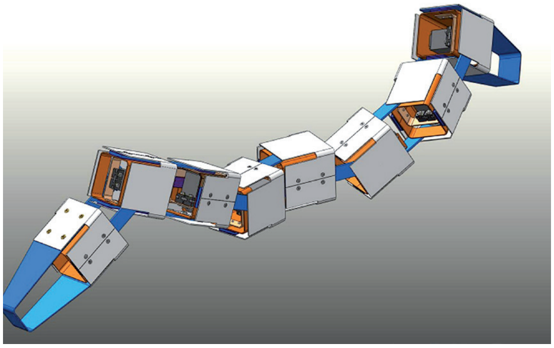


Fig. 6: *Geometry and arrangement of the robot segment.*



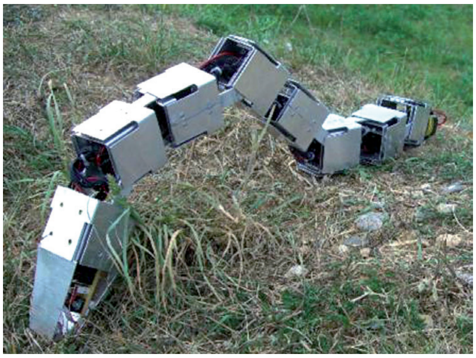


Fig. 7: *CAD model of the snake robot and final prototype of snake robot with one degree of freedom in every segment.*

4. Concept of the snake-like robot composed from 2DOF segments

Next snake robot concept (fig. 8) is based on segments with two degree of freedom. It means that every segment includes two movable couplings. It includes one rotary joint and one linear translation link. Rotary joint has range 180° angle and linear translation has range 50 mm.

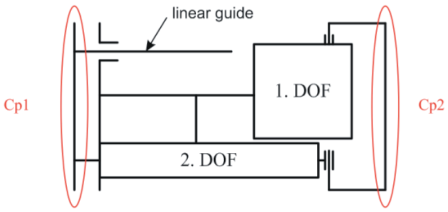


Fig. 8: *Concept of segment with two degree of freedom – rotary and translation.*

On the base of this concept the new segment has been designed (fig. 9). Maximal distance is 130 mm and width 50 mm. The weight of segment is 250 grams. All parts have been made on 3D printer from ABS plastic.

This segment is as building unit for snake robot. Coupling cp1 is translation and coupling cp2 is rotary.

Final robot can be composed from various numbers of these segments depending on used application (fig. 10). Also segment can be arranged in different way. For example coupling can be mixed as it shown on fig. 10. Prototype (fig. 11) of snake robot consists of eight segments. It is able to move via using of all types of snake motion.

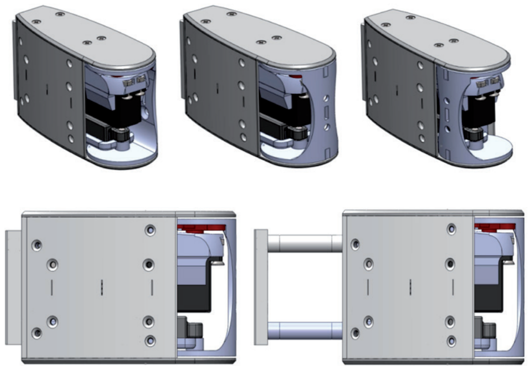


Fig. 9: *Rotation and linear translation in segment with 2 DOF.*

Fig. 10: *Examples of various segment combinations.*

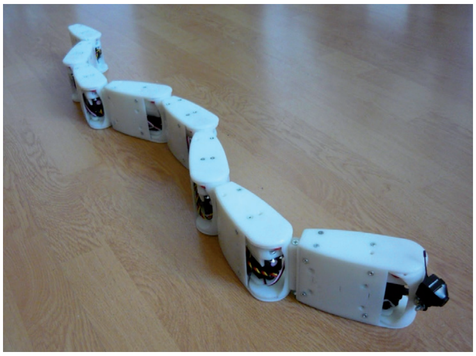


Fig. 11: *Prototype of snake robot from segments with 2 DOF.*

5. Conclusions

The aim of this methodology is clear communication between experts in design process of mechatronic products. Design process of mechatronic products requires the experts from various areas and they use the different approach in design process. This uniform approach makes the design process more simple and clear.

The main goal is to achieve fast design process as soon as possible. The short design process is important for achieving of good position on market [10-23].

Acknowledgments

The authors would like to thank to Slovak Grant Agency – project KEGA 018TUKE-4/2018, VEGA 1/0389/18, VEGA 1/0872/16 and FGV/2016 supported by Faculty of Mech. Eng. at Technical University of Kosice.

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