Acta Mechatronica - International Scientific Journal about Mechatronics
Volume: 3 2018 Issue: 4 Pages: 7-10 ISSN 2453-7306

doi:10.22306/am.v3i4.43

Received: 26 Sep. 2018
Accepted: 16 Oct. 2018

SNAKE-LIKE ROBOTS

Ivan Virgala
Technical University of Kosice, Faculty of Mechanical Engineering, Letna 9, Kosice, Slovak Republic,
ivan.virgala@tuke.sk (corresponding author)
Ľubica Miková
Technical University of Kosice, Faculty of Mechanical Engineering, Letna 9, Kosice, Slovak Republic,
lubica.mikova@tuke.sk
Michal Kelemen
Technical University of Kosice, Faculty of Mechanical Engineering, Letna 9, Kosice, Slovak Republic,
michal.kelemen@tuke.sk
Darina Hroncová
Technical University of Kosice, Faculty of Mechanical Engineering, Letna 9, Kosice, Slovak Republic,
darina.hroncova@tuke.sk

Keywords: mechatronics, education, embedded systems
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 degree of freedom and it is complicated to control them.

1 Introduction

Many ground locomotion devices often use endless rotating elements such as wheels or tracks. Endless rotating elements are the fascinating elements in ma-chines. These elements have one big disadvantage. They are not suitable for ex-tremely rough terrain. There is no analogy for wheels and tracks in the nature. In this time, there are a lot of applications with biologically inspired locomotion. Place for biologically inspired locomotion is mainly in cases, where we cannot use wheels or tracks. Living organisms are able to adapt to surround conditions, be-cause of its physiological needs. Consequently, they are able to change own shape and locomotion type.

Biologically inspired snake robots are able to perform the motion in environ-ments where other types of transport mechanisms fail. Snake robots are usually composed of many identical segments. A snake robot's body structure is self-enabling, and offers mechanical transport performance characteristics that are highly desired. However, snake robot body structures are difficult to control.

The most famous research of snake like locomotion comes from Hirose & Yoneda Lab. Their results are summarized in book [1].

They have observed four basic types of snake locomotion. Using of these lo-comotion types depends on environment condition and purpose of locomotion. These locomotion types can be divided into these four modes [1]:

1. serpentine locomotion
2. rectilinear locomotion
3. concertina locomotion
4. sidewinding locomotion

Serpentine locomotion is the locomotion to be seen typically in almost kinds of snake, and is a gliding mode whose characteristic is that each part of body makes similar tracks. From ancient times this has been the mode which has propelled snakes like flowing water between rocks, for instance, and has surprised humans, and of the four modes this can be thought of as the most efficient.

Rectilinear locomotion is the gliding method performed with a special configu-ration by large snake such as boas and vipers when approaching their prey or when gliding over a smooth surface.

Concertina locomotion is gliding method used by snakes confined to a straight path over a narrow straight line, and by snakes placed on floor surfaces, for ex-ample, which are extremely slippery. In particular, the gliding configuration on such a floor surface uses the phenomenon that theoretical terms the coefficient of the static friction is greater than the coefficient of dynamic friction. For this rea-son, propulsion is possible even in a very slippery environment, using this gliding mode. However, the efficiency of such propulsion is extremely low.

Sidewinding locomotion is the gliding method used by snake such as the rattle-snake which live in the desert, and which lift part of their body while gliding and propel themselves like a tumbling spiral coil. In this mode of locomotion, there is no sliding movement between the body and surface glided over, its dynamic characteristic being that the body usually contacts the ground from above. Be-cause of this characteristic, sliding friction resistance is small, and in locomotions in environments which are not firm, such as sandy ground, the locomotive effi-ciency is high [1].

Acta Mechatronica - International Scientific Journal about Mechatronics
Volume: 3 2018 Issue: 4 Pages: 7-10 ISSN 2453-7306

Ivan Virgala; Ľubica Miková; Michal Kelemen; Darina Hroncová

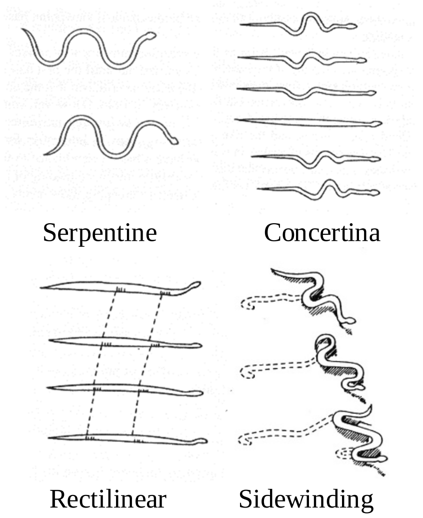

Figure 1 Snake-like locomotion modes [1]

2 Concept of the snake-like robot composed from 1DOF segments

Snake-like robot consist of many joints for obtaining of many degree of freedom to obtain high level of mobility. Many joints means many actuators and complicated controlling. For this reason, it is necessary to make decision. How many joints is necessary for robot. We have to select as least as possible.

Our robot "Hadik" consists of eight articles also called as segments joined with seven plane joints (fig. 2). Every segment has one degree of freedom (DOF). The base of the kinematic principle lies on alternating of vertical and horizontal plane joints. First article (head) and last article (tail) are designed with vertical plane joint, because of their possibility to cross any obstacles (fig. 3). Therefore, every kinematic pair is designed with one degree of freedom.

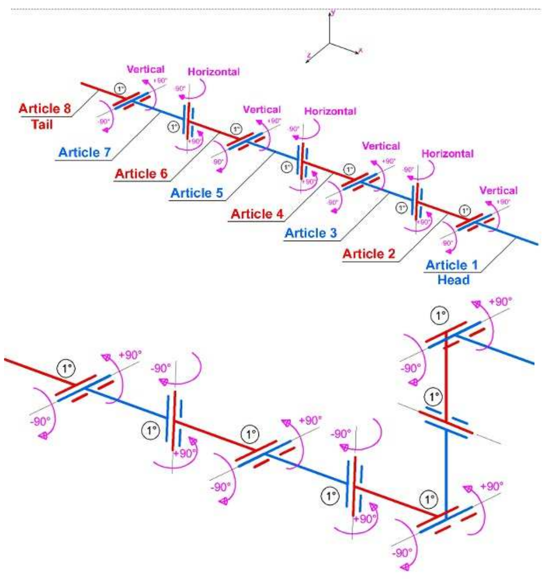

Figure 2 Structure of snake-like robot "Hadik"

Every article has one degree of freedom in regard to neighbour robot article. These plane joints are driven with actuators. As actuator is chosen position servomechanism. General problem for design of locomotion algorithm is timing of sequence. Time of every joint rotation is dependent on its loading and position. Therefore, microcontroller needs information about actual angular position of every joint. Ideal solution is to use information from internal potentiometer as feedback for our microcontroller.

The article of the robot consists of 13 parts. Symmetry and precision of every part has been very important requirement. It has been needed for obtaining of stabile locomotion.

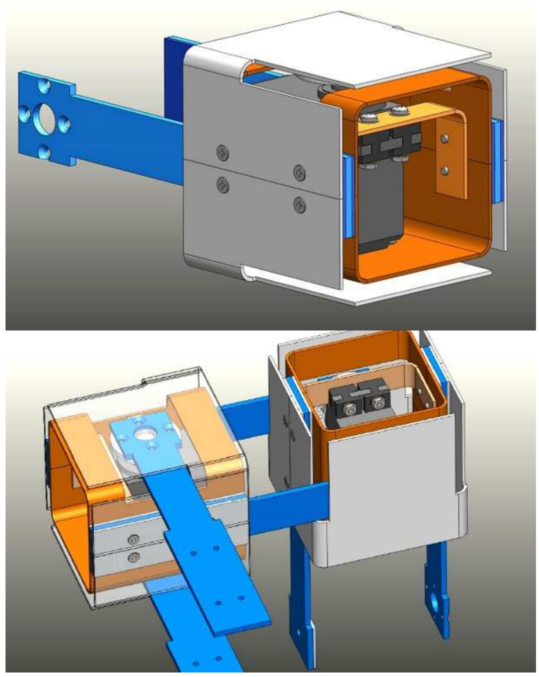
Figure 3 Article (segment) of the snake-like robot

3D model has been created for verification of functionality and possible collisions between parts in locomotion. Realisation of the robot brought several problems. It has been necessary to solve technology process, precision of bending, placement of wires etc. (fig. 4).

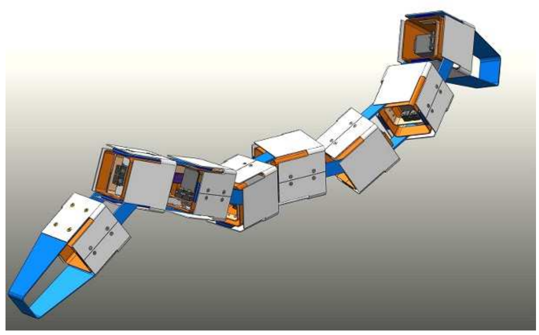

Figure 4 3D model of the snake-like robot

Realisation of the snake-like robot "Hadik" is shown on figure 5.

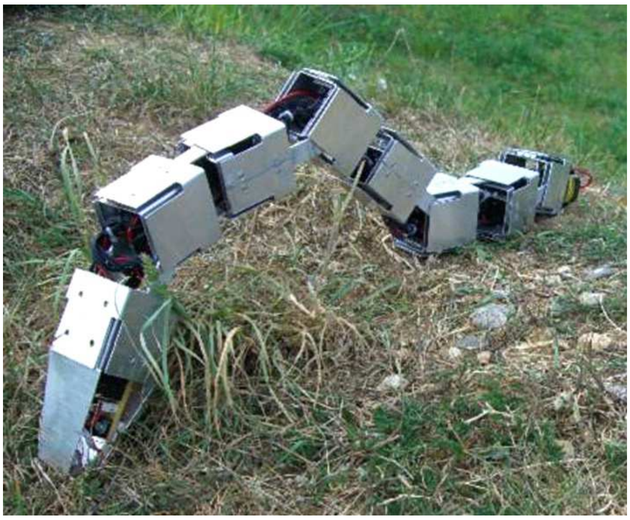

Figure 5 Realisation of the snake-like robot "Hadik"

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

Concept of snake-like robot "Locosnake" consists of segments with 2 degree of freedom (DOF). Figure 6 shows the kinematic structure of it.

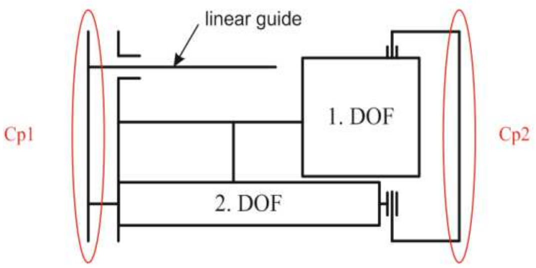

Figure 6 Concept of 2DOF segment for snake-like robot "Locosnake"

LocoSnake is a unique kinematic structure not previously utilized. Each segment of the snake robot possesses two degrees of freedom. Along one degree of freedom, a segment may rotate ± 90° (fig. 7). Along the other, a segment may effect a linear translation up to 50mm (fig. 8). Each segment end is equipped with a clutch which ena-bles the connection of other parts, signal cables, and provides power source cable transportation, see Figure 6.

The kinematic structure of the snake robot was designed using SolidWorks software, see Figure 2 and 3 for models. It was necessary to specify dimensional requirements to ensure the accuracy of the model's configuration. The dimen-sions of the model's action parts were most important.

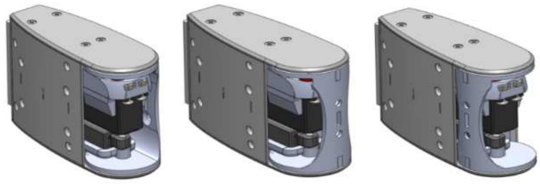

Figure 7 Rotation in segment for snake-like robot "Locosnake"

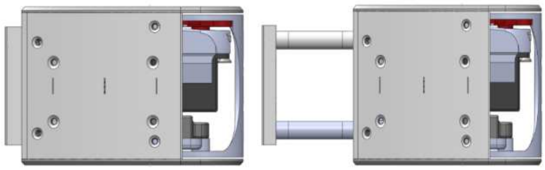

Figure 8 Linear stroke in segment for snake-like robot "Locosnake"

LocoSnake was constructed from parts made by a 3D printer. One link of Lo-coSnake weights 250 g and has a maximum length of 131 mm, width of 80,2 mm, and height of 47 mm. Figure 9 shows the realisation of snake-like robot "Locosnake".

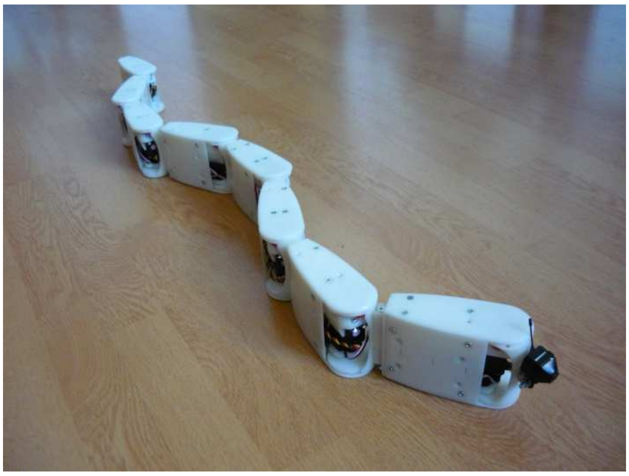

Figure 9 Realisation of snake-like robot "Locosnake"

4 Conclusion

Locomotion is basic of the live of living organisms. They need locomotion for food finding, for avoiding from enemy or another dangerous. Ways of locomotion are very often as inspiration for design of various locomotion devices [2-21].

Snake robots possess the ability to work within a broad range of applications where conventional mechanisms ineffective. These robots, inspired by the nature, provide potential solutions to designers and researches, and they introduce numerous undetermined questions and problems. Pipe inspection is an application snake robots are well suited to, and this area of application has not yet been investigated in detail.

Acta Mechatronica - International Scientific Journal about Mechatronics
Volume: 3 2018 Issue: 4 Pages: 7-10 ISSN 2453-7306

Acknowledgement
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.

References

[1] HIROSE, S.: Biologically Inspired Robots. Snake-like locomotors and manipulators. Ox-ford University Press. New York, 1993. ISBN 0 19 856261 6
[2] ACAR, M., and PARKIN, R.M.: Engineering Education for Mechatronics, *IEEE Trans. on Industrial Electronics*, vol. 43, no. 1, pp. 106-112, Feb. 1996.
[3] CASTLES, R. T., ZEPHIRIN, T., LOHANI, V. K., KACHROO, P.: Design and Implementation of a Mechatronics Learning Module in a Large First-Semester Engineering Course, *IEEE Trans. on Education*, vol. 53, no. 3, pp. 445-454, Aug. 2010.
[4] OSTOJIC, G., STANKOVSKI, S., TARJAN, L., SENK, I. and JOVANOVIC, V.: Development and Implementation of Didactic Sets in Mechatronics and Industrial Engineering Courses, *Int. J. of Eng. Education*, vol. 26, no. 1, Tempus publications, 2010.
[5] BRADLEY, D.: What is Mechatronics and Why Teach It?, *Int. J. of Electrical Eng. Education*, 41, (2004), pp. 275-291, 2004
[6] BRADLEY, D.: Mechatronics - More questions than answers, *Mechatronics*, vol. 20, no. 8, Special Issue on Theories and Methodologies for Mechatronics Design, pp. 827-841, Dec. 2010.
[7] VITKO, A., JURIŠICA, L., BABINEC, A., DUCHOŇ, F., KĽÚČIK, M.: *Some Didactic Problems of Teaching Robotics*, Proceedings of the 1st International Conference Robotics in Education 2010. Bratislava, 16.-17. 9. 2010, Bratislava, Slovak University of Technology in Bratislava, ISBN 978-80-227-3353-3, pp. 27-30, 2010.
[8] KONIAR, D., HARGAS, L., SIMONOVA, A. et al.: *Virtual Instrumentation for Visual Inspection in Mechatronic Applications*, 6th Conference on Modelling of Mechanical and Mechatronic Systems (MMaMS) Location: Vysoke Tatry, SLOVAKIA Date: NOV 25-27, 2014.
[9] van BEEK, T. J., ERDENA M. S., TOMIYAMAA, T.: Modular design of mechatronic systems with function modeling, *Mechatronics*, vol. 20, no. 8, pp. 850-863, Dec. 2010.
[10] WANG, Y., YUA, Y., XIEA, Ch., WANGA, H., FENG, X.: Mechatronics education at CDHAW of Tongji University: Laboratory guidelines, framework, implementations and improvements, *Mechatronics*, vol. 19, no. 8, pp. 1346–1352, Dec. 2009.
[11] KELEMEN, M., KELEMENOVÁ T. and JEZNÝ, J.,: Four legged robot with feedback control of legs motion. In: *Bulletin of Applied Mechanics*. Vol. 4, no. 16 (2008), p. 115-118. - ISSN 1801-1217.
[12] VIRGALA, I., VACKOVÁ, M., KELEMEN, M.: Two-legs walking robot "Wirgil". In: *Medical and treatment*. Vol. 40, no. 2 (2010), p. 32-35. - ISSN 0301-5491.
[13] MIKOVÁ, Ľ., KELEMEN, M., KELEMENOVÁ, T.: Four wheeled inspection robot with differential controlling of wheels. In: Acta Mechanica Slovaca. Vol. 12, č. 3-B (2008), s. 548-558. - ISSN 1335-2393.
[14] DUCHOŇ, F., HUBINSKÝ, P., HANZEL, J., BABINEC, A., TÖLGYESSY, M.: Intelligent Vehicles as the Robotic Applications, *Procedia Engineering*, Volume 48, 2012, Pages 105–114. 2012.
[15] KONIAR, D., HARGAŠ, L., ŠTOFAN, S.: Segmentation of Motion Regions for Biomechanical Systems, *Procedia Engineering*, Volume 48, 2012, Pages 304–311. 2012.
[16] BOŽEK, P., CHMELÍKOVÁ, G.: *Virtual Technology Utilization in Teaching*, Conference ICL2011, September 21 -23, 2011 Piešt'any, Slovakia, pp- 409-413. 2011.
[17] TURYGIN, Y., BOŽEK, P.: Mechatronic systems maintenance and repair management system. *Transfer of innovations*, 26/2013. pp. 3-5. 2013.
[18] HARGAŠ, L, HRIANKA, M, KONIAR, D, IZÁK, P.: *Quality Assessment SMT Technology by Virtual Instrumentation*. Applied Electronics 2007, 2007.
[19] SPANIKOVA, G., SPANIK, P., FRIVALDSKY, M. et al.: Electric model of liver tissue for investigation of electrosurgical impacts, *Electrical Engineering*, Volume: 99, Issue: 4, pp. 1185-1194.
[20] KARAVAEV, Y. L., KILIN, A. A.: Nonholonomic dynamics and control of a spherical robot with an internal omniwheel platform: Theory and experiments, *Proceedings of the Steklov Institute of Mathematics*, Volume 295, Issue 1, 1 November 2016, Pages 158-167.
[21] Kuric, I., Bulej, V., Saga, M., Pokorný, P., *Development of simulation software for mobile robot path planning within multilayer map system based on metric and topological maps*, International Journal of Advanced Robotic Systems, Volume: 14 Issue: 6, pp. 1-14.

Review process
Single-blind peer review process.