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AMPHIBIOUS-LIKE MINIROBOT

ABSTRACT *A subject of presented work ware design and building a prototype of microrobot, which can imitate behavior of an amphibian, (e.g. salamander). Robot, which has been built, generates both types of the amphibian movement: walk on four legs and imitation of the swimming gait. Modular structure is one of its features, and constructed modules are fully interchangeable. The commercial DC servos controlled by microprocessor unit were used as actuators (for leg and thorax movement). The master software is installed in PC microcomputer. Operator controls main parameters of the movement (straight on or turn) and sequences of commands for servos are generated automatically.*

Keywords: *education, microrobot, biomechanics*

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1. INTRODUCTION

In mobile robotics engineers prefer objects on wheal or caterpillars. There are some advantages of such solutions: easiness of control (adaptation of "large scale" automotive solutions), typical electrical rotary machines as drives, possible relatively high speed of the movement etc.). Those robots have a number of very serious applications: in military forces, in police services, for inspections of dangerous areas and objects, as well as in Space technique – for planet exploration (e.g. Mars Pathfinder Mission). Mobile robotics also is a popular subject in didactics of technical universities all around the World – both in design and control teaching.

But maintained forms of movement "on wheals" do not exist in the Nature. Walk, crawl or swim are typical form of animals. Some of them connect two forms of the movement (e.g. amphibians have possibility of walk on legs or swim). A movement of animals is studying by biologists, biomechanics and now – specialists in robotics.

The wide problematic of walking machines (systematic, fundamentals, control) presents book [7]. Systematic connects issues of stability (walking robots are static-stabile, quasi-stabile or dynamic-stabile) with control algorithms and number of legs. From point of view of number of the legs walking robot can be realized as a one leg (jumping), two-legs (biped, sometimes humanoid-type, but often equipped in non realistic big foot for stabilization), four-legs, six-legs (like insects), eight-legs (spider-like) and (generally) "many legs".

Bodies and structure of the legs could be realistic (directly inspired by Nature), but often the structure of the joints and number of legs segments are not existing in a real life of animals.

2. IDEA OF THE SALAMANDER-LIKE MICROROBOT

There was idea of simulation of the algorithms of real motion of small animal – characterised by various kind of movement in two habitats – in water and on the ground – salamander (Type**:** *Chordata* - Phylum: *Amphibia* - Family: *Salamandridae* [6]. The works of *BIRG (Biologically Inspired Robotics Group,* Ijspeert at team*)* [8], especially those concern to mechanisms of motion of

amphibians, simulation of neural signals in natural control algorithms were the directly inspiration. Mathematical description directly used for preparation of the control procedures of our microrobot is presented in papers [1, 3-5].
There were following assumptions:

- Modular structure (with use of a number of similar elements) – ready for modifications, and design with techniques characteristic for unitary manufacturing;
- Popular in modeling-works DC servodrives as actuators with using of their microcontroller as a first level of control;
- Battery supply as a option (in first stage – application of supply unit and cable connector);
- PC computer as a platform for control software.

Finally – the structure of the microrobot and its “general motion” shall imitate body and behavior of the salamander, but inner structure of the segments (actuator systems) is not similar as muscles (natural actuators) of such animal. Also readiness for swimming is (in this phase of prototype) only symbolic – on level of algorithms of control and structure of the body, without waterproof body and active draught.

3. REALIZATION OF THE MODULAR STRUCTURE

The modular structure of the robot was assumed. There are used only two kinds of modules. The first (called by us: A-type) is the basic element of the body, with characteristic details: symmetric design, coupling element, rotary servodrive (integrated with gear and position sensor) – for realization rotating movement between module and the following one with use of the lever mechanisms. The second one is more complicated and in fact realize the shoulders joints of animal and is equipped with additional two leg units; each leg unit is driven by next two servodrives with gears. This B-type module is built on basis of the A-type. In effect - in the modular structure of the robot the three parts of the body: head, thorax and tail are build from only two kinds of modules. This solution was effective and profitable from point of view of costs of the project.

The block diagram of all structure of microrobot is presented on Fig 1. The mechanical design of the both kinds of module has special space for two AA type batteries (but prototype is supplied from outside source).

"Muscles system" of the microrobot is build by set of 18 servodrives (hobby-type) with dedicated SK18 controller are used. Transmission from PC "master unit" is realized by RS232 with typical transmission protocol (transmission: 9600 B/s; no of bits: 8) via conventional cable connector. Servodrives are control by PWM (*Pulse Width Modification*) signals. For each servo 4 Bites data frame is used. For SK 18 unit are send information about number of active servo, position of the servos actuators (different 1000 is possible) and speed of the action. The structure of the modules enables battery supply, but prototype is supplied from outside source (6 V).

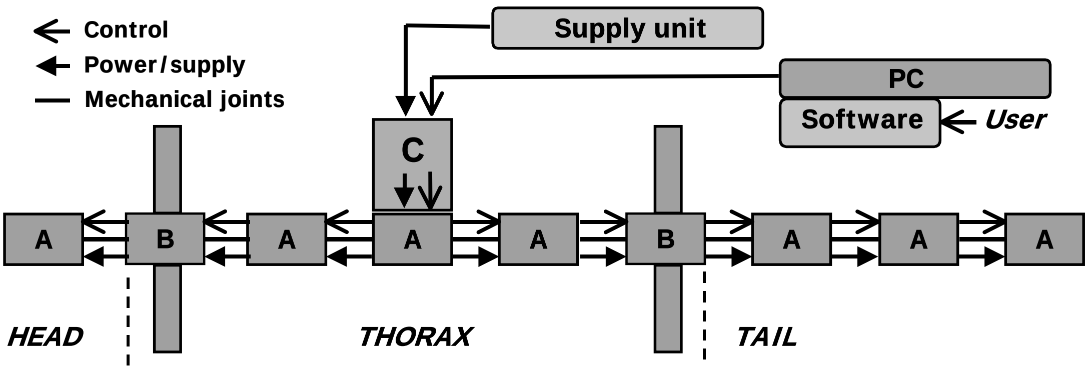


Fig. 1. The scheme of the lizard-robot

A – basic module of a body (head, thorax, tail), B – legs module; C – controller

The equations of the position/motion of the body of salamander during walk and swim are taken from the basic works of A.J. Ijspeert [3, 4] – and fundamentally is description like wave of the neural activity of the animal generates wave of motions of the body - which is going from the head to tail according to formulas (1), (2) – during swimming and (3) – during walk:

$$A_i = i \cdot \sin(\omega t - \lambda_i) \tag{1}$$

$$\lambda_i = i \cdot 2\pi / n \tag{2}$$

$$A_i = a \cdot \sin(\omega t - \lambda_i) \tag{3}$$

where:

A_i – input of „i" segment of the body (interpreting as angle of bow-shape twist of such segment),

a – amplitude,
ω – circular velocity,
t – time,
C – phase angle for „i” segment of the body in walk (for swim values are constant – thorax: $\lambda_I = 0$ and for head as well as tail: $\lambda_I = \pi$),
n – number of segments.

For control of the speed of walk the ω parameter could be taken into consideration, as well as change of amplitude (a). In the second variant collision between legs or leg with body.

The turn of the microrobot could be realized on way of asymmetric body motions (the amplitude depends on side of the turn – both during walk and swim). There is also the second method, useable only for walk – with change of a length of different phases of leg motion.

4. CONTROL SOFTWARE

The control software is an integrated part of the robot. In presented phase of the works operator of PC microcomputer realizes all control options. The block diagrams of the main algorithms is presented in paper [2].

The main window of the program implemented on PC gives the operator possibility to control all function of the robot. There are nine basic fields on this window (see Fig. 2).

The field no 1 has three overlaps for choice of form of the motion – “walk”, “advanced walk” and “swim”. The 2 field makes possible to set fit a length of motion cycle and amplitude of a bow of the body (in effect to assume a speed of the motion – both walk and swim). The role of the field no 3 is visualization of the robot. There are plan view from above and position of the legs from behind presented. Window no 3 is in fact a animation of the movement in certain conditions. This field is usually also for initiating software’s self test.

The running time of the cycle of the motion is shown in window no 4. Option of the control with use of arrows button from the keyboard is switch on/off by field no 5. The control by main window is realized via buttons (fields) no 6. The 7 button initializes the motion. For a switching of the variant walk/swim. the button 8 is used. Initialization of the button 8 starts the special procedure, which begins change of the legs position after full cycle of the motion. The amplitude of the bow of the body is automatically and fluently minimized to zero and than returns to nominal value.

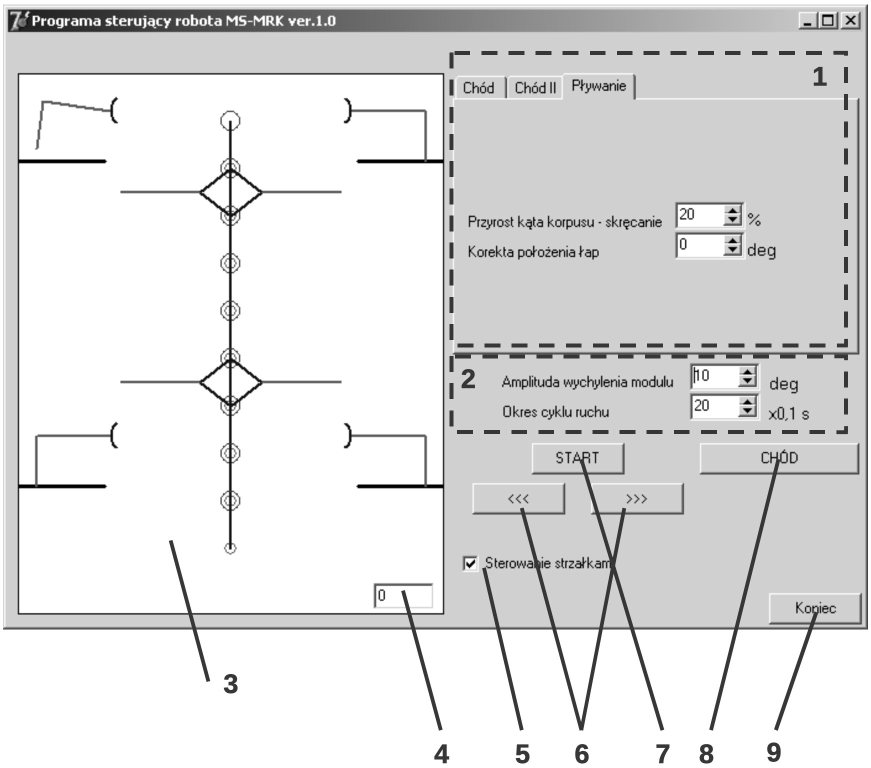


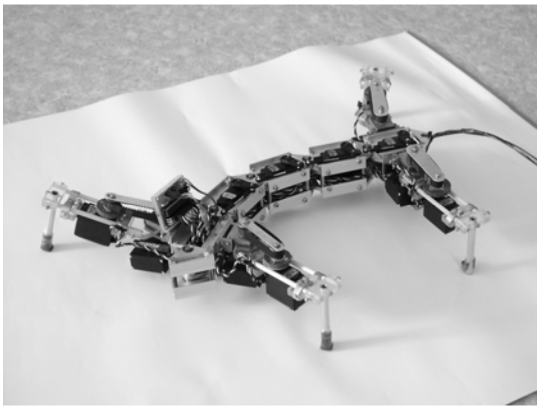
Fig. 2. The main window of the control software (description in the text)

5. DESIGN OF PROTOTYPE

There were design the 3D computer models of electromechanical structure. On the Fig. 3 are presented examples of two phases of the walk.

Fig. 3. Phases of the walk – 3D visualization of the microrobot

Photos of the real prototype are presented on Fig. 3. There are indicate characteristic positions of the legs in various forms of motion.



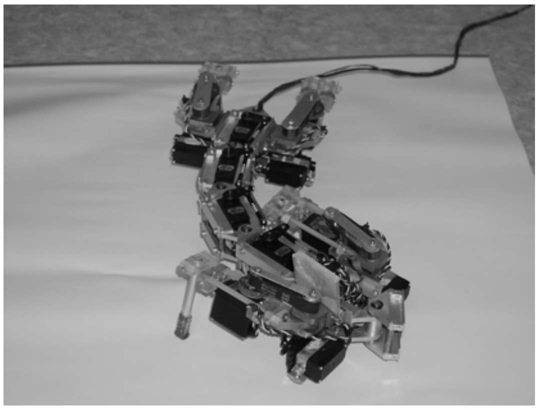


Fig. 4. Photos of prototype (left – in walk, right – ready for swim)

6. REMARKS AND CONCLUSION

The works realized in Institute of Micromechanics and Photonics, Warsaw University of Technology had following stages: design of electromechanical components, adaptation of control algorithms and implementation of them on PC and test of work of prototype. The building and activating of the microrobot was successful. Tests confirm correctness of algorithms and their implementation. Now the next stages are realized with following goals. In mechanical part: reduction of the weight and design of waterproof casing (for tests in water), as well as design of full section-mechanisms for the legs are necessary. There is also plan to build the head module with microcameras. In electronic part an independent control (instead of central control unit) is planned. The improvements in control are going to implementation of the algorithms of dynamic movement, with use of signals from sensors. There is plan to build-in miniature accelerometers into modules of the body and force (pressure on ground) sensors in each leg.

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MINIROBOT NAŚLADUJĄCY PŁAZA ZIEMNOWODNEGO

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STRESZCZENIE *Większość praktycznie wykorzystywanych robotów mobilnych porusza się na kołach lub gąsienicach. Rozwijany jest jednak także wątek mikrorobotów naśladujących naturalne (występujące w przyrodzie) formy ruchu – chód, pełzanie lub pływanie na wzór zwierząt żyjących w środowisku wodnym. Praca [7] przedstawia szeroko problematykę robotów kroczących, w tym bezpośrednio inspirowanych przez organizmy żywe.*

Bezpośrednią inspiracja autorów były prace grupy badawczej BIRG [8], w szczególności przedstawiające analizę mechanizmów ruchu płazów ziemnowodnych (rodzina salamandrowate) i opis matematyczny sposobu generacji chodu i pływania [1, 3-5]. Z wyżej wymienionych prac zaczerpnięto wzory (1-3), zaimplementowane następnie w opracowanym urządzeniu.

Opracowany minirobot ma strukturę modułową. Jego ciało składa się z głowy, korpusu i ogona oraz czterech łap. Struktura całego systemu jest przedstawiona na rysunku 1. Konstrukcja mechaniczna składa się z dwóch typów modułów. Modułem bazowym jest tzw. segment A będący elementem korpusu urządzenia. Moduł ten może

skręcać się względem elementu poprzedzającego (następującego) – rys. 1. Na bazie tego rozwiązania skonstruowano moduł osadzenia łap (moduł B), którego kinematyka umożliwia dodatkowo unoszenie łap oraz ich składanie przy zmianie trybu ruchu od chodu do pływania (przy czym konstrukcja prototypu nie jest jednak przystosowana do pracy w środowisku wodnym). Siłownikami są popularne modelarskie serwomechanizmy prądu stałego, sterowane za pośrednictwem specjalizowanego układu SK18 (z wykorzystaniem techniki PWM) z mikrokomputera PC – poprzez złącze RS232. Nadrzędny program sterujący jest zaimplementowany w mikrokomputerze PC. Panel główny programu przedstawiono na rysunku 2. Poszczególne przyciski panelu umożliwiają zmianę trybu ruchu, zmianę parametrów chodu lub „pływania" (np. szybkości lub promienia skrętu). Prowadzona jest również bieżąca wizualizacja układu ciała „salamandry". Główne algorytmy pracy urządzenia podano w pozycji literaturowej [2]. Robot może być zasilany z akumulatorów wbudowanych w poszczególne modułu, jednak w bieżącej fazie prac zdecydowano się na zmniejszenie masy (i autonomiczności) poprzez zastosowanie zasilania za pośrednictwem przewodów.

Projektowanie struktury wykonawczej rozpoczęto od opracowania modeli trójwymiarowych (rys. 3). Umożliwiły one analizę zachowania robota w różnych warunkach oraz wygenerowanie dokumentacji konstrukcyjnej prototypu. Zbudowano następnie dwie wersje prototypu (różniące się wielkością i momentem serwomechanizmów. Zdjęcia prototypu przedstawia rysunku 4. Urządzenie zostało uruchomione i przetestowane. Obecnie trwają prace związane z zabudową sieci czujników (w tym mikrokamery wideo).