Control of mobile walking robot (hexapod)

Bartosz Stańczyk, Dariusz Grzelczyk, Jan Awrejcewicz
Department of Automation and Biomechanics, Lodz University of Technology

Abstract: This paper presents the design and control system of the walking six-feet mobile robot further referred as a hexapod. Hexapod is a robot, i.e. motor vehicle that walks on six legs. Since for the keeping stability of the robot only three legs are sufficient, hexapod possesses the great flexibility in walking. For instance, even if one of its legs would become incapacitated, the robot can still walk. The considered robot is controlled using the software provided through a mobile phone. Communication is realized via a Bluetooth wireless network with a range of about 50 m. Robot is equipped with a wireless camera, the system separating the control signals, and the ATmega162 micro-controller. A choice of the micro-controller has been motivated by a number of the generated PWM (Pulse-Width Modulation) signals. Hexapod drive is realized by means of 18 servos. In addition, it has a gripper, whose movement is performed by three servos. A servo is controlled by a variable signal with a fill factor of 50 Hz. PWM signal with variable duty cycle is divided into eight different servo-controlled signals. ATmega162 micro-controller can control 32 servos. The system dividing the signal is based on a 4-bit binary counter 74LS93N and demultiplexer 74238N.

Keywords: hexapod, control

1. Introduction

Hexapod is a walking robot modelled on the structure of six-feet insects. As the name implies it has six legs, which means that the robot is characterized by a high stability. To maintain a balance of robot only three legs can be used, but to move four ones. For this reason in case of failure of two extremities the robot can still continue his task. The number of different gait realizable by robots of this type according to the McGee formula is equal 11!, which allows to make a broad analysis of different combinations of robot gait. A lot of interesting information on the walking robots can be found in [1–5]. Different types of robot's gait are more fully described in reference [3].

The largest lift capacity and the greatest stability of motion which the robot receives corresponds to the case of walking using one leg and leaning on the other five. The complexity of the system construction allows to obtain such a large number of combinations of gait. Unfortunately, it is related not only with complicated software, but also with a high power energy required to operate the robot. Hexapod has an advantage over riding robots in the event of overcoming obstacles. However, the need for continuous operation of all servos to keep the robot at an upright position requires a lot of battery power. Despite using a 3.5 Ah battery and unit energy expenditure of about 130 A, the developed prototype is able to work only about one hour.

2. Design

Fig. 1 shows the structure of the considered walking six-feet mobile robot (hexapod). Its maximum dimensions (width × length × height) are about 30 cm × 50 cm × 50 cm. The robot has a two-jaw gripper and three pairs of legs, which allows moving at maximum speed 5 km/h. Its total weight with battery is approximately 4 kg. The robot is equipped with a temperature sensor, an ultrasonic distance sensor, a microphone and a colour camera with lighting.

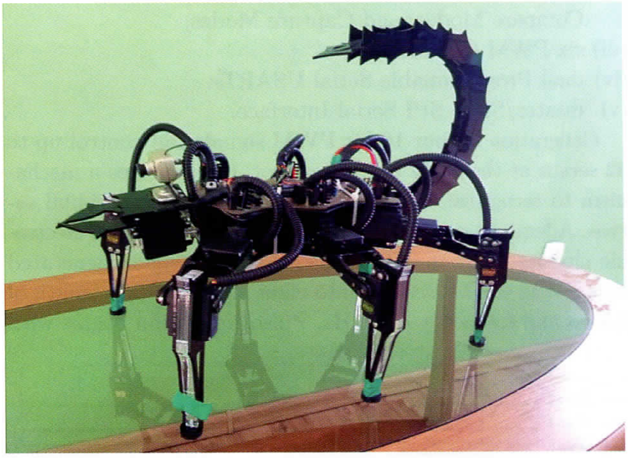

Fig. 1. View of the built walking six-feet mobile robot (hexapod)
Rys. 1. Widok zbudowanego sześcionogiego robota kroczącego – hexapoda

Each limb consists of three identical rotating cells (fig. 2), which allows to simplify the mathematical analysis of its gait. Such construction of the leg is the most optimal system to overcome obstacles. Each node to drive the servo modeling was used to simplify significantly the way of movement and control of the hexapod.

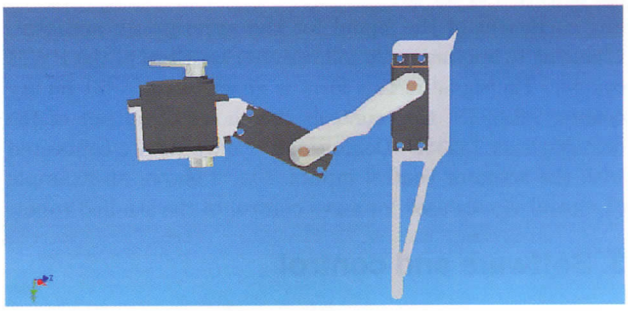

Fig. 2. Design of a robot limb consisting of three rotating cells (servos)
Rys. 2. Projekt nogi robota zawierającej trzy ogniwa obrotowe (serwomechanizmy)

Electric servo actuator is characterized by a gear ratio equal to 273, and the generated torque equal to 0.2 Nm. It has a servo feedback, which based on the reading from the sensor selects the appropriate setting angle of the robot arm. Unfortunately, these mechanisms have not sufficiently high accuracy and require calibration in the control system. To set the appropriate angular position of the servo square-wave signal with a frequency 20 Hz and variable fill factor from 500 µs to 2500 µs is used. It allows the activation of eight actuators (servos) with a single signal PWM. For the generated signal the 8-bit micro-controller Atmega162 was used, possessing the following properties exhibited during the robot movement:

(i) up to 16 MIPS Throughput at 16 MHz;
(ii) on-chip 2-cycle Multiplier;
(iii) 16 kBytes of In-System Self-programmable Flash program memory;
(iv) 512 Bytes EEPROM;
(v) 1 kBytes Internal SRAM.

Peripheral Features:

(i) two 8-bit Timer/Counters with Separate Prescalers and Compare Modes;
(ii) two 16-bit Timer/Counters with Separate Prescalers, Compare Modes, and Capture Modes;
(iii) six PWM Channels;
(iv) dual Programmable Serial USARTs;
(v) master/Slave SPI Serial Interface.

Generation of four 16-bit PWM signals can control up to 32 servos at the same time. However, this requires a mechanism to recognize and divide the signal into individual servos. Adequate system of sharing is based on digital electronic circuits made in TTL technology. The signal generated by a PWM can be divided into eight signals with a length of 2.5 ms and frequency of 20 Hz. Pulse generation begins with

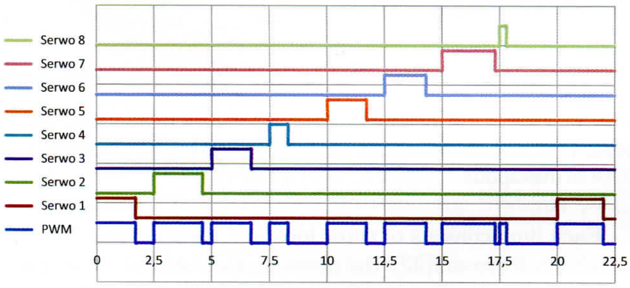

Fig. 3. Control signals used for servo control of the robot
Rys. 3. Sygnały sterujące wykorzystane do sterowanie robotem

the detection of the first servo, then, set the value of the filling coefficient of the signal for the appropriate actuator. Changing to another servo follows after overflow of the PWM counter. The signal in this form is given to the 4-bit binary counter 74LS93N, that controls the choice of output of the demultiplexer 74238N. Demultiplexer outputs are connected with the actuator control inputs. Fig. 3 shows an example of control signals used for servo control of the studied robot.

3. Software and control

The microcontroller was programmed in C++. The signals for the individual movements are sent by Serial USARTs from the control device. Simultaneously, the microprocessor sends the data read from the installed sensors such as temperature or distance from the obstacle. Technology of 18B20 temperature sensor allows for temperature measuring to an accuracy of 0.1 °C, while the results of an ultrasonic measurement system are analyzed by the 10-bit ADC transmitter contained in the micro-controller. Hexapod is equipped with a BTM-222 receiver-transmitter, which allows to send signals even from distance up to 100 m. This technology allows for communication with the robot via any device with a Bluetooth system and appropriate software. In order to control the hexapod appropriate algorithm in Java-me program was developed, which allows to control the robot from any mobile phone. Data sent by the program are responsible for selection of the appropriate sequence of walking or moving of the gripper. The program also receives signals from sensors installed on the robot and displays them on the screen, making it easy for control purposes.

4. Conclusions

In this paper both monitoring and control of walking six-feet mobile robot (hexapod) has been presented. For this reason, an appropriate micro-controller and software installed on mobile phone was used. Control of the robot was realized via Bluetooth wireless signals. The considered robot has been developed both for research studies as well as inspection applications. Its size, ease of overcoming obstacles and compact design, allows reaching the tight and awkward places. In inspection and remote, the control equipped with a wireless system helps transmitting audio and video data.

Acknowledgements

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Sterowanie sześcionogiego robota kroczącego

Streszczenie: Praca przedstawia projekt i układ sterowania sześcionogiego robota kroczącego zwanego hexapodem. Hexapod jest robotem, który chodzi na sześciu nogach. Ponieważ do utrzymania stabilności robota wystarczą mu tylko trzy nogi, hexapod posiada dużą elastyczność w chodzeniu. Dla przykładu, nawet jeśli jedna z jego nóg stanie się niesprawna, robot wciąż może chodzić. Robot sterowany jest za pomocą oprogramowania znajdującego się w telefonie komórkowym. Komunikacja jest zrealizowana za pomocą sieci Bluetooth o zakresie około 50 m. Robot wyposażony jest w kamerę bezprzewodową, system po-

działu sygnałów sterujących oraz mikrokontroler ATmega162. Wybór mikrokontrolera podyktowany został liczbą generowanych sygnałów PWM (Pulse-Width Modulation). Ruch haxapoda realizowany jest za pomocą 18 serwomechanizmów. Ponadto posiada on chwytak, którego ruch jest wykonywany przez trzy siłowniki. Serwomechanizmy sterowane są sygnałami o zmiennym współczynniku wypełnienia i częstotliwości 50 Hz. Sygnał PWM o zmiennym współczynniku wypełnienia podzielony jest na osiem sygnałów sterujących różnymi serwomechanizmami. Mikrokontroler ATmega162 może kontrolować 32 serwomechanizmy jednocześnie. System podziału sygnału sterującego oparty jest o 4-bitowy licznik binarny 74LS93N oraz demultiplekser 74238N.

Słowa kluczowe: sześcionogi robot kroczący (hexapod), sterowanie

Bartosz Stańczyk, BSc Eng.

A graduate of the Faculty of Mechanical Engineering, Mechatronics, of Lodz University of Technology. Interests: electronics, robotics and computer science.

e-mail: bartchez@gmail.com

Dariusz Grzelczyk, PhD

In 2005 he graduated Faculty of the Technical Physics, Computer Science and Applied Mathematics of the Lodz University of Technology and received the MSc degree in a field of Computers Physics. In 2010 he received PhD title in Technical Sciences, Mechanics in the Faculty of Mechanical Engineering of Lodz University of Technology, where he currently works in the Department of Automation and Biomechanics. Interests: Contact phenomena and tribological processes, electronics, mechatronical systems, control of dynamic systems.

e-mail: dariusz.grzelczyk@p.lodz.pl

Prof. Jan Awrejcewicz, DSc, PhD

He graduated from the Faculty of Mechanical Engineering of Lodz Technical University in 1977, where he also completed his PhD in 1981. In 1994 he earned the title of Professor from the President of Poland, Lech Wałęsa, and in 1996 he obtained the Golden Cross of Merit from the next President of Poland, Aleksander Kwaśniewski. He is the author or co-author of over 600 scientific articles and of more than 50 monographs and books. Since 1998 he is the Head of Department of Automatics and Biomechanics, and since 2006 the Head of PhD School on 'Mechanics' associated with the Faculty of Mechanical Engineering of the Technical University of Lodz. He received many awards and honors for achievements of national and international importance. His research interests are focused mainly on mathematics, mechanics, biomechanics, automation and mechatronics.

e-mail: jan.awrejcewicz@p.lodz.pl