
VOLUME 57' 2018
https://mc04.manuscriptcentral.com/jtug
2018
JOURNAL
of the Technical University
of Gabrovo
Editor-in-Chief: Jordan Maximov
Mechanical Engineering
Electrical Engineering, Electronics and Automation
ISSN 1310 - 6686

Journal of the Technical University of Gabrovo

https://mc04.manuscriptcentral.com/jtug

EXAMINATION ON BIPEDAL ROBOTS STRUCTURES AND MOTION CONTROL METHODS

Hilmi Kuscu[1*], Eray Yilmazlar[2], Taskin Tez[3]
[1]*Trakya University, Mechanical Engineering Department, Edirne, Turkey*
[2]*Kırklareli University, Technical Sciences Vocational School, Kırklareli, Turkey*
[3]*Edirne Sultan Murat I State Hospital, Edirne, Turkey*

ARTICLE INFO

Article history:
Received 3 September 2018
Accepted 22 November 2018

Keywords:
Bipedal Robot, Zero Moment Point, Movement Control

ABSTRACT

In this study, it is aimed to determine the equipment to be used in bipedal robots, walking motion structures, balance control systems and the points to be considered in the balance motion algorithm of the robot. In bipedal robots, the main purpose is to imitate human movement and to stay in balance. There are many studies in this field about bipedal robots, humanoid robots. Bipedal robots are an integrated system in which many mechanical, electronic equipment, control algorithms are integrated into the body. It is important to determine the mechanical, electromechanical structures, equilibrium, motion algorithms and control method used in such systems. The properties of the units used in this study and the control methods are explained. The effect of the work on the movement of the joints and the factors to be considered in the control of the center of gravity according to this change are explained.

INTRODUCTION

Bipedal robots, humanoid robots are being investigated and developed in today's world for more than 50 years. Starting with basic stepping and walking exercises, bipedal robots nowadays have become intelligent, capable of interacting with people, being able to perceive objects and learnable structures. With this transformation, the human being has become able to meet the needs of daily life, to support in industrial production processes and even to provide health services.

The structure of bipedal robots, humanoid robots are evolving as time goes by. Increased skills in mobility, high-level human interaction is advancing with the development of present-day technology. The structure of these designs has changed from mechanical designs to mechatronic designs in which software and motion controls are made. The bipedal robots have problems that can not be resolved even though their work has improved. For example, high-speed mobility, flexible mobility, self-balancing against external factors. For this reason, many universities, institutes, and organizations are now working on the mechanics and control algorithms for the development of bipedal robots.

LITERATURE

WABOT-1, the first humanoid robot in the world, started its work in 1970 at the Waseda University Science and Engineering High School in 1970 with the WABOT project. The Wabot-1 mechanical limb structure incorporates the vision system and speech systems. Has the ability to walk, hold and carry objects [1].

In 1986, the first work of the Asimo-named humanoid robot, which was produced by Honda company, started. The movement structure of the robot named E0 was realized by the design of a bipedal robot which resembles human walk [2].

In 2008, Giorgio Metta and his colleagues created a two-legged humanoid robot design that can perceive and grasp the color of the objects interacting with the icub named human [3].

In 2011, E. Taşkıran and his colleagues realized the bipedal robot study which forms orbits with the zero moment point called SURALP by Sabancı University Department of Mechatronics Engineering [4].

In 2017, R. Luxman and his colleagues conducted a two-step walkable robot design study with biped robots controlled by an inverse dynamic model according to the zero moment point [5].

In 2018, Ko Yamamoto conducted a two-legged humanoid robot with a weight of 54 cm and a weight of 6.7 kg. In his work, he has worked on the dynamic structure of the viscoelasticity equilibrium structure which will improve the walking performance with the gravity center solution [6].

These studies are aimed at developing the abilities of bipedal, humanoid robots and perfect movement and control ability.

[*] Corresponding author. E-mail: hilmi@trakya.edu.tr

MECHANICAL CONSTRUCTION AND CONTROL METHODS OF BIPEDAL ROBOTS

The bipedal robot is a robot type that consists of parts of waist and leg limbs of humanoid robots that can walk like a human, can take steps and balance, can turn. In the design of bipedal walking robots, the human walking structure is taken as an example and it is aimed to realize the perfect movement and balance structure of most of the studies. For this reason, as in the examples shown in Fig.1., the designs are made with reference to the physical structure of the human shape of the mechanical shape.

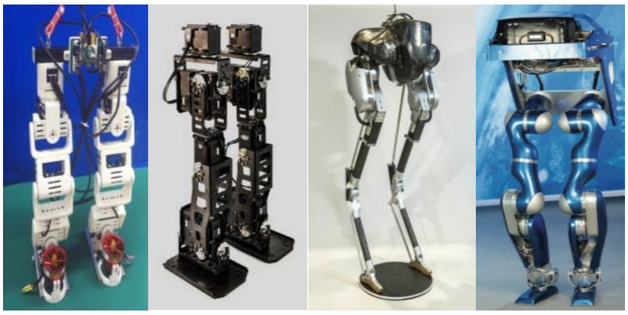

Fig. 1. Examples of bipedal robot design

The structures that make up bipedal robots and the units within them can be listed as shown in Fig.2. below. The equipment consists of mechanical, electromechanical and electronic parts.

MECHANICAL BODY STRUCTURE

The body and leg structure of bipedal robots are similar to the structure of human legs. As shown in the example in Figure 1, the foot base consists of ankle joint, knee joint, hip joint and limbs connecting these joints. The size proportions of these limbs are similar to those of the golden body in the human body. The type of material used for body and leg construction can be composed of metal and plastic alloys to provide the necessary strength.

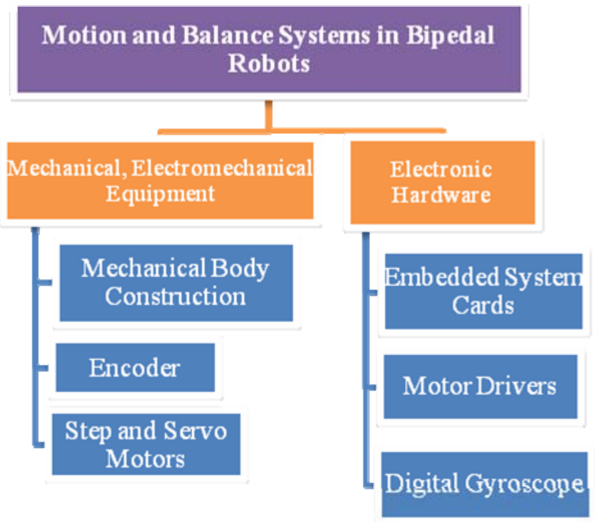

Fig. 2. Units forming bipedal robot designs

Servo-motor, transmitted coded signals are the motors that can rotate the shafts in a special angular position. The servomotor maintains the angular position of the shaft as long as the coded signal is applied to the servo motor input. If the coded signal is changed, the angular position of the shaft also changes. According to the control method of the coded signal servo motor, the pwm signal can be controlled with microcontroller cards as angle information. In Fig.3. (b), variants of servo motors produced by different brands appear.

Step motors are brushless DC motors that are used in machines, robots, automation systems to turn electrical pulse signals into circular movements and to move them into liner movements. The stepper motor must be controlled by a stepper motor drive circuit in order to rotate by angular steps. Today, there are many driver cards and kits that perform this control process. Similarly, pulse signals can be generated by many units such as PLC, FPGA, Arduino, Raspberry pi. In Fig.3. (c), stepper motor variants appear [7].

Encoder, in response to the movement of the shaft, it is an electromechanical device that produces a digital electrical signal. The encoders are shown in Fig.3. (a). Shaft encoders operating in rotation and Linear encoders operating linearly. Angular displacement is used to measure magnitudes such as linear and circular motion, rotation speed, and acceleration. The encoders are divided according to the output type.

Fig. 3. Types of Encoders, Servo Motors and Step Motors

Absolute type encoders give position information instead of pulse information. This information can be in different formations, but the most commonly used type is the binary output type based on the binary system method.

Incremental encoders produce serial output pulses with respect to this type of encoder shaft rotation angle. No output signal when the spindle is not turning. A separate counter is needed to count the number of output signals. The encoder detects the rotational position with the number of signals counted.

ELECTRONIC HARDWARE

Raspberry Pi, the ease of use of embedded system cards, low cost, accessible and practical, has increased the use of single card computers in the industry and academies since an operating system can be installed on them. The Raspberry Pi 3 model shown in Figure 4 is the 3rd version of the raspberry cards sold in 2016. On ARMv8 CPUs are single-card computers with a 1.2GHz 64-bit quad-core processor. On the Raspberry 3 card used in the work, there are 1GB Ram, 40 GPIO, 4 USB port, Full HDMI port, Ethernet port, 3.5mm audio jack, camera and display interface, micro SD card slot, 3D graphics kernel [8].

Arduino, an open-source embedded system card with an Atmel ATmega microcontroller with electrical input and output units. It can read data from many sensor units and control actuators according to control algorithms. In the Arduino uno model shown in Figure 4, the ATMega328 microcontroller has 14 digital input/output pins, 6 PWM outputs, and 6 ADC inputs. It has 32 Kb flash memories.

Motor driver cards are used where control and software cards are insufficient due to factors such as supply voltage, control current. The characteristics of the motor control cards vary according to the motor type, power, control type to be used.

Step motors are the cards that adapt the signals required for the desired operation to stepper motor windings. The stepper motor driver cards have different characteristics according to the number of phases and torque. Servo motor driver cards are used for acceleration and speed control of the signals generated by the control unit.

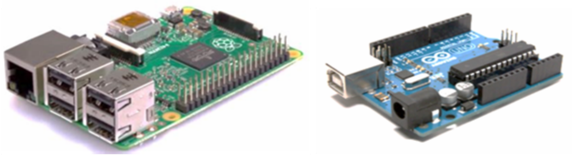

Fig. 4. Raspberry pi and Arduino control cards

Digital gyroscopes are electromechanical elements used to measure acceleration sensors, acceleration, vibration and mechanical shock values. shown in figure 5. The acceleration sensors, also referred to as the G sensor, operate as 2 axes 3 axes (x, y, z) according to their axes. The output type of the acceleration sensors may be analoge to digital output type [9].

Fig. 5. Step motor driver cards

BALANCE CONTROL METHODS USED IN BIPEDAL ROBOTS

It is created with the aim of keeping the bipedal robots flat on the floor of the controlled foot base by zero point control method. The ZMP concept was first described by Vukobratovic in 1969 for use in the control of humanoid robots. In Figure 6, the force distribution example under a foot is given. These forces can be simplified to R resultant force provided that all forces acting under the foot are in the same direction, so that they are at a point within the foot boundaries. Thus, the resultant force acting on the foot is denoted as R-point zero-point or ZMP [10].

Mass center (COM) is the point of gravity sum. Robot connection forces are applied. Figure 6 shows the mass center of gravity.

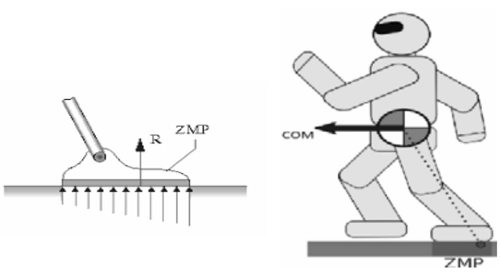

Fig. 6. Zero moment point and mass center of gravity

In bipedal robots, whose main purpose is to remain in a stable walking state, the angle of the hip, knee, and wrist joints changes in order to maintain the equilibrium. These angle changes appear in figure 7 below.

These varying angle values are measured by the acceleration sensor on the encoder and it is necessary to continuously control the control of the servo motors by removing the change of the external factors against the external factors such as ground fault, wind effect, external force, etc. according to the measured values.

PID, one of closed-loop control methods, consists of proportional, integral and derivative controls. Due to its simple structure, the industry is widely used. Pid accepts the difference between the desired value and the actual value in the process as an error. It controls the process input to minimize the error value.

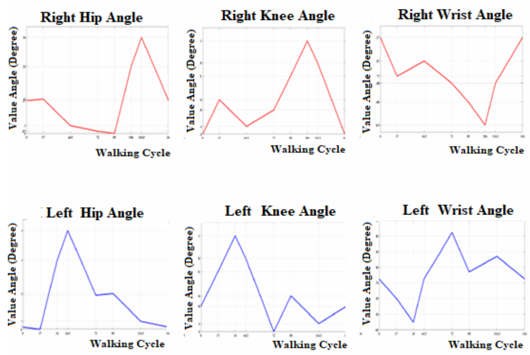

Fig. 7. Angle changes in right and left leg joints

The proportional, integral and derivative ratios appearing in the PID reference input shown in figure 8 and the block diagram for transmitting the output to the system appear [11].

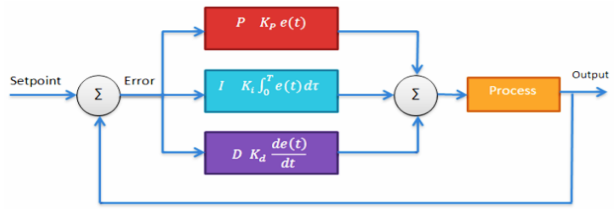

Fig. 8. PID control system block diagram

CONCLUSION

The most common difficulty to be considered in the design of bipedal robots is the balance system. The balance system, robot motion, stepping motion, speed of motion, rotation movements can be caused by the control and mechanical structure of the robot, and also due to external factors such as ground fault, ground gradient, external balance disturbance factors. For this reason, bipedal robots balance control structures include both a theoretical and a practical integrated system. For this reason, the motors in the joints must be continuously controlled in order to move the robot without tipping with the zero point control method used. The robot should be controlled in the closed loop to measure the angle changes in the knee, wrist and hip joints and to keep the robot in balance during the walking motion release. In particular, ground disturbances can cause balance and moment relationships to deteriorate even at low gradient slopes.

Another thing to note is that the robot should stay in the two leg area of the center of gravity. If the center of gravity goes out of range, the robot will be overturned. For this reason, it should be ensured that the center of gravity remains in the moving orbit of the center of gravity, except for the external factors.

In the control process performed, the walking swing, the stepping sequence, the movement processes in the right and left legs have to be a certain periodic adjustment. As shown in the figure, the knee and knee joints should be moved periodically for the step movements.

As a result, the bipedal robots should be created and controlled by choosing the equipment to be used for the above mentioned factors, taking care of the control structure.

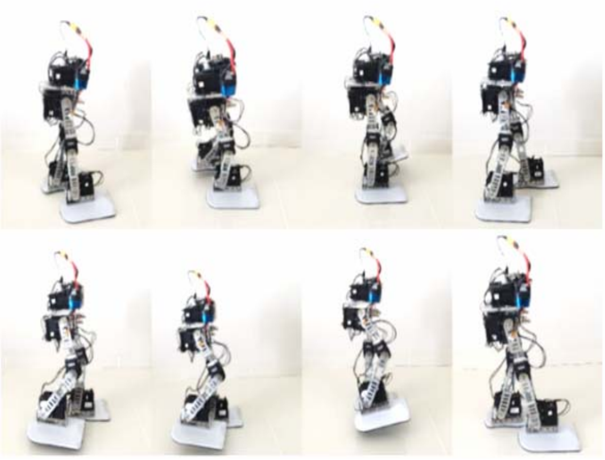

Fig. 9. Step swing of bipedal robot

REFERENCES

[1] Kato I. (1985b). Development of Waseda Robots-The Study of Biomechanisms at Kato Laboratory, Tokyo, Waseda University publication dedicated to I. Kato 60th anniversary jubilee.

[2] Kato I. (1985a) Development of Waseda Robot. 1985. Retrieved from http://asimo.honda.com/asimo-history/ It was taken on August 3, 2018.

[3] Tikhanoff V., Cangelosi, A., Fitzpatrick, P., Metta, G., Natale, L., & Nori, F. (2008). An open-source simulator for cognitive robotics research: the prototype of the iCub humanoid robot simulator. Paper presented at the Proceedings of the 8th workshop on performance metrics for intelligent systems.

[4] Erbatur K., Seven, U., TAŞKIRAN, E., Koca, Ö., Yilmaz, M., Ünel, M., Onat, A. (2011). Design and control of the humanoid robot SURALP. Turkish Journal of Electrical Engineering & Computer Sciences, 19(5), 725-731.

[5] Luxman R., & Zielinska, T. (2017). Robot motion synthesis using ground reaction forces pattern: Analysis of walking posture. International Journal of Advanced Robotic Systems, 14(4), 1729881417720873.

[6] Yamamoto K. (2018). Resolved Multiple Viscoelasticity Control for a Humanoid. IEEE Robotics and Automation Letters, 3(1), 44-51.

[7] Fa-Qun Q., Xue-Dong, J., & Shi-qing, Z. (2011). Design of stepping motor control system based on AT89C51 microcontroller. Procedia Engineering, 15, 2276-2280.

[8] Solak S., Yakut Ö., & Bolat E.D. (2017). Yaygın Kullanılan ARM Tabanlı Tek Kart Bilgisayar Sistemleri ve Kullanım Alanları. El-Cezeri Journal of Science and Engineering, 4(1).

[9] Kadıoğlu T., Dinçer H. (2008). İvme sensörü uygulaması, ELECO'2008 Elektrik-Elektronik ve Bilgisayar Mühendisliği Sempozyumu.Vukobratovic, M. and D. Juricic. (1969). Contribution to the synthesis of biped gait. IEEE Transactions on Biomedical Engineering, p. 1-6.

[10] Åström K. J., Hägglund T. (2001). The future of PID control. Control engineering practice, 9(11), 1163-1175.