ZagHexa: Design, Construction and Control of a Hexapod Walking Robot

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***Abstract*—This paper presents design, construction and control of a hexapod robot named ZagHexa which is a six-legged walking robot. As walking robots in general and hexapod robots in particular attract considerable attention for several decades. Thus, many studies are carried out in research and industry. We provide an overview of the state of the art on walking robots. In addition, an account of the basic characteristics of legged robots will be given with description of some of existing robots and their pros and cons.**

Our main goal is to produce an efficient walking machines that is designed and built with performances suitable for as many as possible applications. Therefore, careful attention is given to the main design issues and constraints that influence the technical feasibility and operation performance. A design procedure is outlined to systematically design a hexapod walking robot. In particular, the proposed design procedure considers the main features, such as mechanical structure and leg configuration, actuating and driving systems, payload, motion conditions, and walking gait.

The result of this project is the legged robot ZagHexa, which can walk using tripod, wave and ripple gait and is equipped with a couple of sensors. The robot is controlled and monitored from a user interface program based on the Robotic Operating System (ROS). It can display data from the sensors and the positions of robot legs. The robot can be used to test and verify algorithms, gaits and features of walking machines.

***Index Terms*—Hexapod, Legged chassis, Walking robot, Hexapod gaits, design procedure.**

I. Introduction

Robots can be found everywhere. One of the most important part of a robot is its chassis. There are several basic chassis types: wheeled, tracked and legged chassis. Wheeled chassis are fast, but not suitable for rough terrain. Tracked chassis are slower, but more suitable to rugged terrain. Legged chassis are quite slow and more difficult to control, but extremely robust in rough terrain. Legged chassis are capable to cross large holes and can operate even after losing a leg. [1] Many researches were performed in this field in past few years, because of its large potential. Legged chassis are especially ideal for space missions [2,3]. There are also several projects in military research [4, 5, 6].

A hexapod robot is a mechanical vehicle that walks on six legs. Since a robot can be statically stable on three or more legs, a hexapod robot has a great deal of flexibility in how it can move. If legs become disabled, the robot may still be able to walk. Furthermore, not all of the robot's legs are needed for stability; other legs are free to reach new foot placements or manipulate a payload.

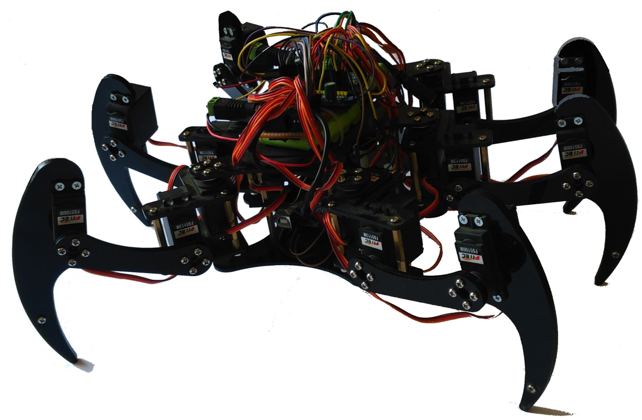

Fig. 1. ZagHexa Robot.

As technology developed, so did the potential uses for the robots. With six legs, the hexapod has a remarkable degree of stability. It can balance its weight on a combination of its legs using an alternating tripod gait, and can engage in complex activities like climbing stairs relatively easily.

Development of hexapods is increasingly robust in the military sector. Armies all over the world are exploring ways of using hexapods to detect land mines, traverse rocky, unstable terrain, and carry out simple delivery missions in danger zones.

We aim to create a cheap legged platform, which would allow research and testing of walking patterns. Create a system with many sensors that allows the robot any movement or behavior. The robot should be driven from wirelessly connected computer and should send all available data from sensors, which will be displayed on the computer in the user interface program. Figure 1 shows the 3D CAD design of the robot.

II. Hardware and software architectures

There are many ways how to classify walking robots by a body shape [7], number of legs, number of degrees of freedom per leg or locomotion technique. Various options can be combined to achieve many different configurations. At least two degrees of freedom are needed to construct a walking robot the first for lifting the leg, second for rotating it. Nevertheless, there should be three degrees of freedom for a good functioning chassis, because the legs move along a circle and the forward movement of the body causes slipping between the foot and the terrain, which can be compensated by third joint [8, 9]. Walking chassis movement can be divided into statically stable and dynamically stable [1, 9]. Static stability represents the ability of the chassis to remain in a stable position in every moment of movement. Static stability is typical for hexapod, which is always stable during its movement. Dynamically stable chastises are sometimes out of balance balancing or falling. This is common for two-legged robots.

ZagHexa is a hexapod robot with 18 DOFs (3 DOFs each leg), it can walk in any direction (translation), or turn in place (rotation), or any combination of the two. The leg lift and ride height is adjustable as well. It is an integrated multi-legged walking robot based on de fecto standard robotic platforms and operating system (ROS) that employs novel and different walking patterns. We have an interactive website for robot inspection and online control in addition to leaning materials such as robot building and implementation walkthroughs and as well as step-by-setup tutorials.

The hexapod is controlled remotely using hand-held devices such as: a mobile application or a joystick. Furthermore, it has its own navigation system and a camera for instant video recording and streaming.

The power to the entire system is supplied through two 5 volts NiMH batteries, which can supply sufficient power required for basic movement. There is an additional power bank to power up the Raspberry Pi and other electronic components.

A. Hardware

ZagHexa is equipped with all necessary resources to interact with his world. The system is supplied with an embedded computing system which is Raspberry Pi 3 Model B that use Ubuntu Xilinx. Raspberry Pi is a miniature computer the size of a credit card, to which a standard monitor, a keyboard and a mouse can be connected. It has extremely low power consumption (max. 3.5 W) and can run ROS based on Ubuntu operating system. There are several models, which differ in RAM, the number of USB ports or GPIO pins and the connation methods. Raspberry Pi is equipped with a USB Wi-Fi dongle, which is connected to a wireless network, and runs Qt [11] client program, which is able to find the IP address of the server and gets connected to it. Sensor data are sent to a computer after successful connection. Client is also capable of reconnect after disconnection.

Fig. 2. Front view of the leg

ZagHexa can use all the sensors form any mobile phone thanks to its own mobile application that communicate through Bluetooth, which able it to sense the environment and deal with it.

All servomotors are connected and driven by an external controller PCA9685 that take the walking pattern from the raspberry through I2C pins controlling the sequence of order and keep the position in the last order it was in (see Fig.2).

B. Software

The highlevel functionality and control of the robot are implemented in ROS packages. The Robot Operating System (ROS) is a standard and opensource operating system for robot control [10]. ROS is not an operating system in the traditional sense of process management and scheduling; rather, it provides a structured communication layer above the host operating systems of a heterogeneous compute cluster. Our software ROS packages interact with each of the subsystems in C++ and Python for direct system control. The system described uses a Linux based software framework as an operating system (OS) for providing the advantages of using an OS which supports developing additional modules that can be easily implemented and integrated. ROS provides operating system like service for the robot. It is a meta-operating system which loads on top of an operating system to provide a standardized set of software framework and APIs. These facilities cannot only help robots but also other embedded systems with a rich set of tools to successfully manage the complexity. With ROS handling the basic communications and data exchange.

III. Mechanical Design

We, firstly, developed our hexapod robot design using the well-known solid design software called SOLIDWORKS, then we have our model into real world using a laser cutter.

This hexapod has rectangular body type it has two groups of legs, three on each side. Each leg has three degrees of freedom and is powered by hobby servomotors with different torque rating (FS5113M on coxa and femur and FS5106M on tibia joints

Servomotors must be sufficiently powerful, depending on the desired behavior. If tripod gait is required, then each motor on the middle legs must be powerful enough to hold half of the weight of the robot. It is important to choose a suitable material for the body. It must be solid enough, but not too heavy. Therefore, aluminum profiles were chosen for the body construction. They are quite light-weighted and solid enough. In addition, they are available in various sizes and shapes and are easy to handle. The project is made of a double layer profile of thickness equals 3 mm each.

IV. Conclusion

This paper presents a system description and the main aspects related to the design, construction, and implementation of six leg robot ”ZagHexa”, a legged robot for search and rescue mission. The robot benefits form the reliability of the legged robot with the exibility and versatility required to operate in different types of surface.

These features are mainly achieved due to its original movement that make it deal with different surfaces. Additionally, its shape and weight give it more stability, and its ability to continue with its moving and sensing capabilities after collisions or even small falls. However, more tests and experiments to improve and validate the design and sensor performance are to be carried out in order to optimize the system performance.

Finally, some issues have to be addressed in order to fulll fully autonomous operation and integration into a heterogeneous system. in order to make the integration of ZagHexa into different missions easier, an effort is being carried out so as to provide it with a standard connectivity by using the common robot operating system (ROS) framework. This task becomes easier since it natively works using Ubuntu as its operating system and encapsulate its functionality in ROS packages.

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V. CONCLUSION

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The authors would like to thank...

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[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.