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The Hexapod Modernization Process and Its Impact on the Locomotion Efficiency of the Unit

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ABSTRACT: This paper presents the process of retrofitting a six-point-of-freedom walking unit - a hexapod remotely controlled by Bluetooth communication based on a proprietary programme. A comparison is made to show how differences in the design of the walking unit, and in particular the number of freedom points per leg, can affect the efficiency of locomotion. In the first section, the work of other authors related to walking robots is presented. In the next section of the article, the individual components of the robot and the software are analysed and compared with the original unit to show the differences and advantages obtained by the upgrade. The last part of the article summarises the work done and shows further possibilities for the development of the project.

1 INTRODUCTION

Among many types of robots, some move in water, in the air, or on land. The latter group can be divided into two basic types - wheeled and walking - each with its advantages and disadvantages. One of the undisputed advantages of wheeled robots is that they are relatively simple to construct and control since no complex programmes are responsible for their movement. However, their locomotion is severely limited - while moving on flat terrain is not a problem, larger, uneven surfaces can easily reduce their ability to move, even if we consider tracked robots. In such case, solution to the problem is to replace the wheels with legs. With this improvement, the robot can easily cross the obstacle or climb on them. Yet, as the capabilities increase, so do the hardware and software requirements. In order for the robot to move, it must be equipped with sufficiently powerful actuators, and each movement must be programmed so that it does not lose balance and moves in the specified direction.

Despite the difficulties associated with building walking robots, many people are decide to build and further improve them. For example, the authors have built a four-legged walking robot modelled on insects [1,2] or mammals [3,4]. A general review of the development of such machines has been done for four-legged robots [5,6].

Other authors have constructed six-legged robots, called hexapods or 'spiders", to optimize their motion [7,8], track body position [9], or study physical properties [10]. One of the most interesting issues is presented in an article describing the Ball-on-Plate (BoP) problem [11], in which the authors propose a new method of motion designed for robots with six legs installed parallel to each other.

2 MODERNIZATION

The robot presented in this paper is the second version of a walking robot designed by the author. In the original version, the main problems were low tolerance for unevenness of the surface on which the robot was moving, slow tempo of operation, which led to the impression that the design worked sluggishly. To increase the robot's mobility, it was decided to add a servo to each leg, giving the entire design 18 actuators. To meet the new requirements, it was decided to replace the servos with those capable of lifting the structure, which led to necessity of improving the power supply to ensure the stable operation of the robot. To increase the dynamics, it was decided to add commands to the new servos and to make the robot's movement speed depend on the inclination of the joystick.

In new version of the robot, for each leg, two servos are responsible for vertical movement and one for horizontal movement, as shown in the figure 1.:

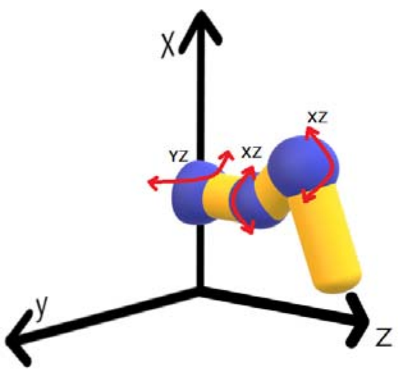

Figure 1. Servo movement

As with the original version, control of the robot is based on wireless communication enabled by Bluetooth modules. The master unit uses an Arduino Nano, while the slave unit uses an Arduino Mega. The robot's limbs are divided into two sections three legs each, which work together to execute most commands. They are chosen to give the robot the greatest possible static stability when walking (when the other limbs take off) by forming a triangle with the longest possible sides. Such arrangement includes the two opposite legs on one side and the middle leg on the other side. The servos included in such groups perform the position change simultaneously [Fig.2.].

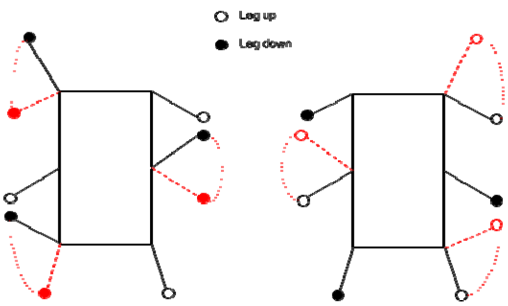

Figure 2. Servo groups and sample motion

To take full advantage of the new servos' capabilities, the master unit's control algorithm was modernised. First, it was a matter of making the robot's speed dependent on the tilt of the joystick. Then, parts of the programme were added to enable the operation of the buttons responsible for the new commands.

3 RESULTS

The first step in the retrofit was to change the entire structure of the robot. Adding new servos required obtaining new parts, which were printed using a 3D printer. Another important step was to modify the software to take full advantage of the new capabilities. The addition of one point of freedom per leg meant that the robot's body could move horizontally as well as vertically [Fig.3.].

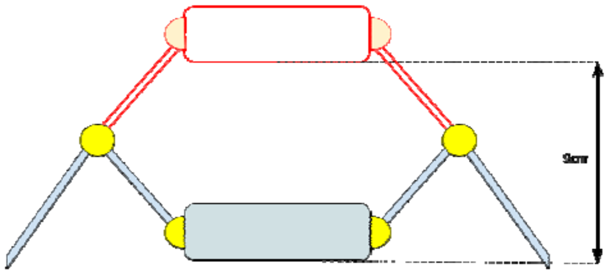

Figure 3. Frontal view

When the robot encounters an obstacle in its path, it can not only avoid it but at the same time move over or under it. In addition, a new command has been programmed that uses the ability to change the height of the torso, allowing the robot to stepping on obstacles up to 4 cm.

By using stronger servos and increasing the number of servos, the robot can not only turn but also move directly to the left or right by changing its centre of gravity and supporting itself with its feet. This has made it possible to reduce the time it takes to avoid obstacles by using a smaller number of commands.

However, this system also has its drawbacks. In the original version, the robot's foot was at a 90° angle most of the time, so the work the servos had to do to stay in place was zero, which could be seen when the power was turned off - the robot stopped. After the upgrade, the servos have to hold the arm at an angle all the time, resulting in constant power consumption, the higher the angle the greater the power usage. Considering this and the increased weight and strength of the servos, the power requirements increased many times over, determinating a power supply change.

A summary of the upgrade is shown in table 1.

The servos used in the second version had metal gears, which added to the weight of the robot. However, this allowed the robot to move faster. Using more commands (from 4 to 7) helps reduce the time it takes to avoid an obstacle and allows it to drive into or over larger obstacles. To increase the precision of the movement, three different speeds are programmed, depending on the inclination of the joystick. The control unit programme itself consists of a main file, a source file and a library.

Table 1. Robot version comparison

	Version I	Version II
Weight [kg]	~1.2	~ 3
Obstacle avoidance [s]	26	9
Distance 30 cm [s]	40	20
Speed control	-	Yes (3 speeds)
Number of programmed commands	4	7
Obstacle climbing [cm]	<=0.5	<=4
Suspension height [cm]	4	0-9

The appearance of the robot after the upgrade is shown in the figure 4.

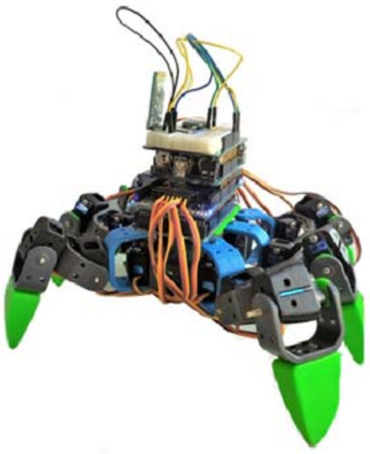

Figure 4. Robot

4 CONCLUSIONS

The article is a prelude to future planned work. The addition of another degree of freedom has greatly improved the robot's locomotion capabilities. It can now climb over obstacles, change the position of its torso, and shift its centre of gravity. For the next work, it is planned to add the possibility of autonomous movement of the robot based on the values measured by the sensors, so that the robot can independently reach hard-to-reach places. Also under consideration is the possibility of modifying the control system so that the robot's steps are controlled by artificial intelligence algorithms in the future.

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