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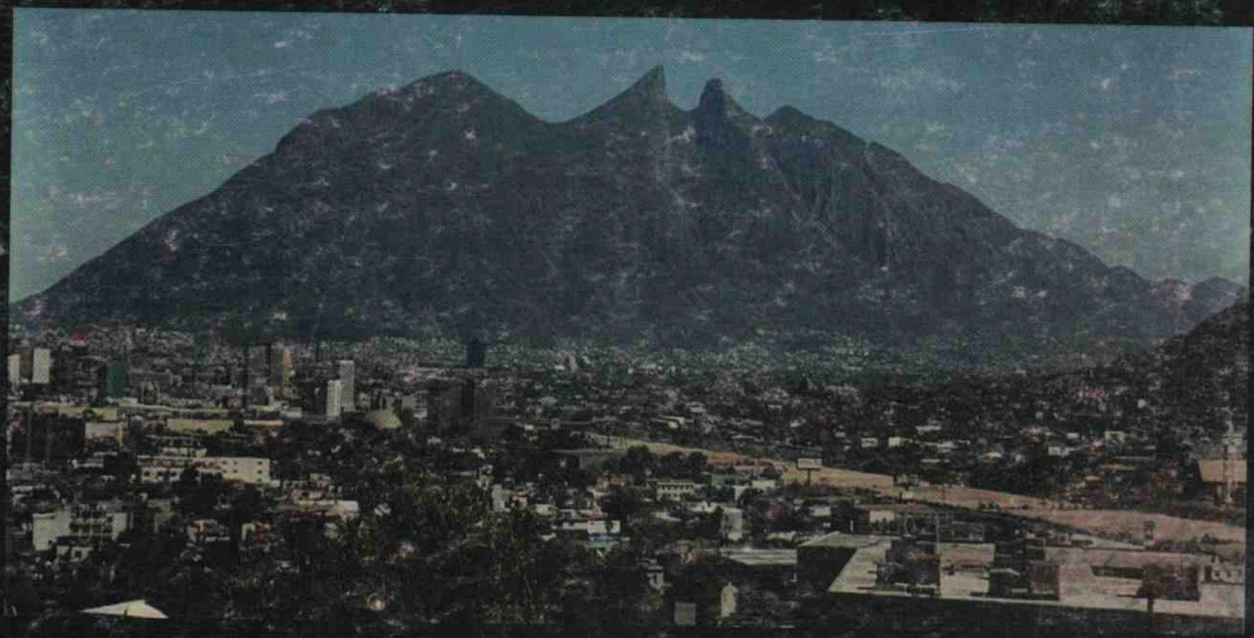

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Designing a Walking Robot of Six Legs

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Abstract

In this article are showed a work related with the design of a walking robot of six legs named: ROSEP-1 (from the Spanish words of RObot de SEis Patas). The design process is described, and also how the configuration of the robot was determined. The paper shows the kinematics model associate with the problem to determine the position of the robot´s body and their legs, and also it is described the architecture of the control system. Finally, a brief description of some locomotion gaits for this type of robot is resumed, as well as a series of proposals of researches that we hoped to carry out with the prototype.

Introduction

Recently the investigations in robotics are focused to develop walking machines, because there are potential new applications for machines with considerable mobility, above all when the necessity of locomotion in irregular terrain is had. The robots with legs permit to coordination with movements in order to isolate the irregularities of the terrain. Furthermore, it get develop machines that require little human intervention or the decrease some restrictions not desired in this kind of legged robots [1].

In some cases the process for the design of a robot, example, longitude of the leg or paw, location of the mass, size and other structural parameters, has been delegated toward the limitation of structures of the natural atmosphere, especially for walking machines where the structures introduce little simplicity but a wide margin of adaptability.

For this reason, some designers of walking robots try to imitate the insects that have multiple legs, with the design, which is proposed to make a better approach to the behavior insects. For example, the ant is an insect with six legs (hexapods). The investigations of this field are oriented to copy the manner of the natural locomotion process. It has generated with better perspectives, interesting and promising results for their imitation in any or some specific points of their natural evolution.

If we can imitate the natural actuation to generate an original walking machine, then we could find practical solutions for environment, where the geometry of the legs is a crucial point of the design and it influence strongly in the efficiency of the robot [2]. By this way, these concepts are fundamentals for the knowledge of a real locomotion.

Some of the most interesting application for the autonomous mobile robots require a high complexity of the kinematics of the robots. Such as the exploration the farthest planets, the inspection of rough terrain, ruined or mined areas, etc. To make possible the applications, that complexity of robots requires methods with specific control technologies.

In this work, the design of ROSEP-1 was done scaling real dimensions of an ant, and also the achieved experiences in the mechanical concepts, and the definition of the architecture for the control system, in such way that motion of robot though eighteen degrees of freedom will allow us the required balance in the machine as well as the motion in its legs.

Each leg has thee degree freedom that are actuated with 12 VDC motors, which led us to design redundant control system for the 18 motors of the robot. The control system has been designed in three command levels:

1) Motions Generator,
2) Trajectory Generator
3) Position control.

All these levels will be communicated by using the parallel port standard.

Robot configuration

There are several systems developed to get automatically the configuration and the locomotion in walking machines. Some of them are inspired from animals and insects. Therefore, many walking robots has been built in last years, they are mainly based in the insects. In the configuration of the six legged robot described in this work, we are looking to imitate some of the characteristics involved in the anatomy of the ants. see Fig.1.

Fig. 1 Top view of the ant

The ant is an insect that have six legs, this distribution is adopted for particular configuration of this insect, it is known that ants walk in environments that present different irregularities and consistencies. The ants also can carry a high load compared with the its weight. [3].

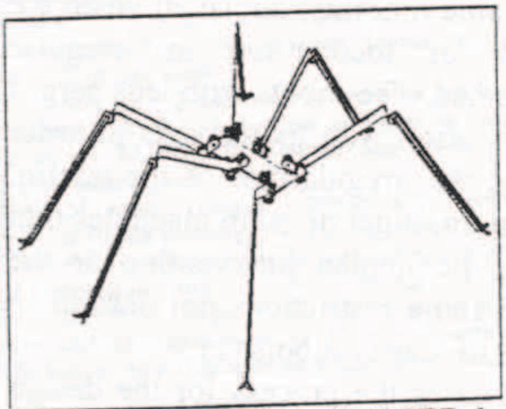

Fig. 2 Configuration of ROSEP-1.

Reproducing the configuration of the ants will lead us to have the security in its reliability that has been showed, thanks to thousand of years in the evolution, of this type of insect. We believe this robot will be more successful to other designing about the load capacity. See Fig. 2

Kinematics Model

The kinematics model for the walking robot is oriented to determine the position and orientation equations for each link of the robot's legs. For that porpoise, the modelation to get the final positions for all legs was built, considering that the robot is walking on irregular terrain, and also the redundancy of the closed kinematics chains formed for the legs. The Fig.3 shows the vectorial relationship of the leg's positions with respect to an auxiliar reference system fixed at the robot's body and also the position of the robot from an inertial coordinate system.

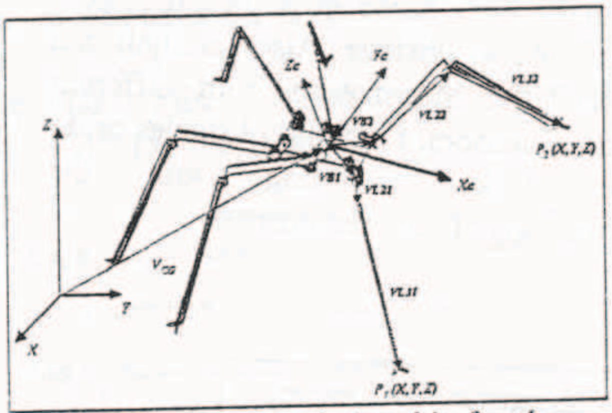

Fig.3 Vectorial relationship for the kinematics

The reduced equation that determine the endpoint of the leg i (i = {1,2,3,4,5,6}) can be expressed as,

$$\bar{V}_{Pi} = \bar{V}_{CG} + \bar{V}_{Bi} + \bar{V}_{L2i} + \bar{V}_{L3i} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{Pi}$$

Where V_{Pi} is the vector of the endpoint of the leg i, V_{CG} is a vector from the fixed inertial system to the gravity center of the body, V_{Bi} is a vector from the gravity center of the body to the base of the leg i, V_{L2i} is a vector from the base of the leg i to the second joint of the leg i, and V_{L3i} is a vector from the second joint of the leg i to the endpoint of the leg i.

Mechanism of the Legs

The kinematics equation is simple if it assumed that each part of the legs is a rigid body, and each leg is supported in a contact point of the terrain. Each leg has three degrees of freedom of rotational type. The design of the leg mechanisms was made taking care to reproduce some characteristics of the ant, by this way we think to validate and understand how ants walk on irregular terrain. The kinematics model of the robot is based in the parameters shown in Fig.4

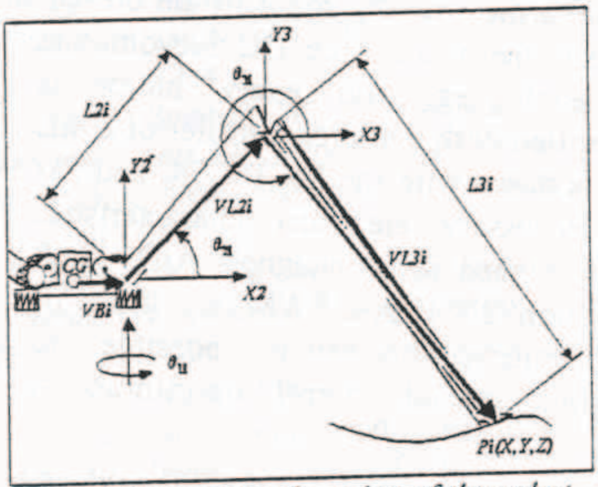

Fig.4 Parameters for a leg of the robot

The position of the leg i, is defined for the next equation:

$$\begin{bmatrix} (L2i\cos\theta 2i + L3i\cos\theta 3i)\cos\theta 1i \\ (L2i\cos\theta 2i + L3i\cos\theta 3i)\sin\theta 1i \\ L2i\sin\theta 2i + L3i\sin\theta 3i \end{bmatrix} = \bar{V}L2i + \bar{V}L3i$$

The robot's body orientation is controlled from the kinematics model and solving the redundancy position problem that define the position of the robot during locomotion on irregular terrain [4]. By this way, the control of the robot's position is done with the coordination moves of all legs that are carry the body, these legs define the supporting polygon and the closed kinematics chains that are essentials to plan the locomotion moves.

The control system

In the development of the motion control system. we research about the ant's control system. The ant has a central unit to control its movement and others function that are essential to survive.

Then the robot has a digital architecture, which can make possible to walk even if it lost a leg. Same as the ants, a centralized architecture control system is proposed in this paper. The microprocessor and micro-controllers allow the control of the legs moves. For to move the walking robot in the present project, there are three DC servomotors for each leg, and every motor is controlled with a microcontroller of 8 bits that is bases with the PIC16C74, and has the necessary electrical characteristics that we need it: 4 channels A/D, clock operation 20MHz. 2 PWM, etc. Inside of this microcontroller is possible to program special control algorithms as, PID. fuzzy logic or neuronal network. using support circuits to make feedback with switches. encoders and current sensors. In this way the robot will have a system that allow position control. velocity, and strength.

The robot's control architecture has a trajectory generator circuit for each leg. capable to generate different kinds of motion trajectories such as the insects of 6 legs. The trajectory generator circuit is made by using the PIC17C44, that has more capability in order to calculate the next trajectory to follow for each leg of the robot , and is the master for each PIC16C74.For the main central unit. other PIC17C44 is used. It gives the instructions to each trajectory generator, and control the moves and the tasks of the robot. To be more specific the architecture is based in a special system master-slave-subslave. Also this unit can process the information from different kinds of sensors, for avoid obstacles or do other tasks according with the instructions of the operator.

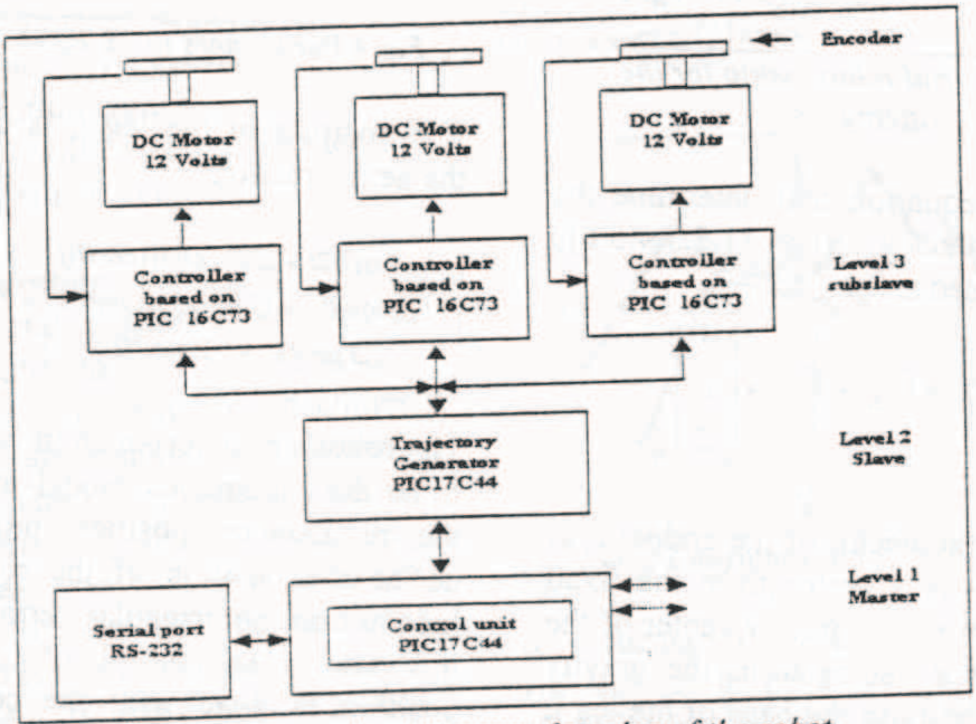

Fig. 5. Control architecture for a leg of the robot

The robot has a RS-232 communication protocol in order to make a flexible system that can be programmed by a computer. By this controllers is possible to make locomotion experiments and evaluate the stability under different conditions. and then improve the design and methods for get a close understanding about the ant´s locomotion.

Locomotion gaits.

It is particularly interesting to control the stability of the robot during locomotion. Different works has been reported from several point of views. Some of them are based in images that shows how the ants make its locomotion by alternating tripods during the walking process. These kind of gaits is periodic and shows a cycle period, its implementation is quite simple, but is not effective when the ant walk on irregular terrain, or when the ant is carry a load [4] y [5]. See Fig. 6.

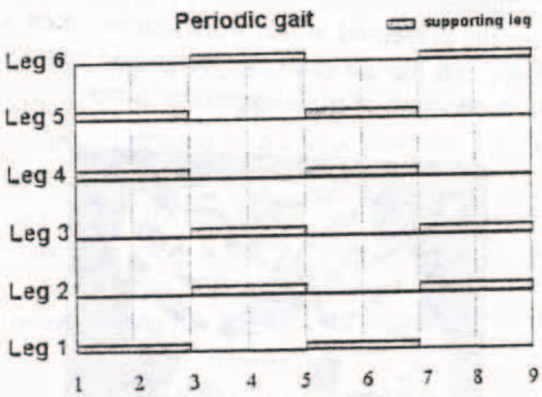

Fig.6 Typical periodic gait for a hexapod robot

Recent researches reports that free locomotion is possible to make a walking plan in real-time, this kind of gait is particular useful for adapt the robot configuration to the irregularities of the terrain [7] y [8]. In this sense, at the time we are designing free locomotion gaits and also a computer program in C language to improve the actual free locomotion algorithms and the kinematics model of the robot [9]. The simulator will permit us to evaluate the interference of the legs and the stability control system.

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References

[1] Kumar V. and Waldron K., ***A Review of Research on Walking Vehicles***, The Robotics Review 1, Ed. Khatib, Craig and T. Lozano-Pérez, The MIT Press, 1989.

[2] Song,Vohnout, Waldron and Kinzel, ***Computer-Aided Design of a Leg for an Energy Efficient Walking Machine.*** Mechanism and Machine Theory Vol. 19, no. 1, pp 17-24, 1984.

[3] Taber, Stephen W., ***The World of the Harvester Ants.*** W.L. moody natural history series:23, College Station, Tx., Texas A. & University, 1998.

[4] Kumar V., Gardner J., ***Kinematics of Redundantly Actuated Closed Chains***, IEEE Transactions on Robotics and Automation, Vol.6, No.2, April 1990.

[5] Raibert M. & Sutherland, ***Máquinas que Caminan***, Investigación y Ciencia, Marzo 1983.

[6] Pugh D., Robble E., Vohnout V., Bihari T., Walliser T., Oetterson M. & Waldron K., ***Technical Description of the Adaptive Suspension Vehicle.*** MIT, Vol 9, No.2, April 1990.

[7] Vargas E., ***A New Real-Time Control Method for Free Locomotion in a Walking Robot***, Int. Journal of Computer Application in Technology, Vol.11, Nos.1/2, 1998.

[8] Arkin R., ***Behavior-Based Robotics***, The MIT Press, 1998.

[9] Vargas E., ***Free Locomotion Gaits for a Four Legged Machine.*** Memorias del 1er.Congreso de Robótica, Torreón, Coahuila, México 1999.