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CONGRESO DE INSTRUMENTACION

Septiembre, 1994

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La realización de SOMI IX Congreso de Instrumentación, se llevó a cabo gracias al apoyo de la Coordinación de la Investigación Científica y el Centro de Instrumentos de la Universidad Nacional Autónoma de México, el Consejo Nacional de Ciencia y Tecnología y la Lotería Nacional para la Asistencia Pública.

A New Real-Time Control Method for Free Locomotion in a Walking Robot

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ABSTRACT

This paper present a new real-time control method for free locomotion process in a walking robot. The walking robot named RIMHo has been developed for getting expertness in legged locomotion. A brief description of the robot and its model is shown. A description about the relationship between the machine level and the control station level is presented. The paper shows also a new free locomotion method for forward and turning gaits. The locomotion method shows an interesting phrasing to solve the stability problem in the beginning of locomotion from any initial robot's configuration. The new real-time control method is used to operate the robot by a human operator using a virtual reality representation in the control station machine.

INTRoDUCTIoN

The walking machines presents some advantage over wheeled vehicule in rough terrain, e.g. greater mobility, better isolation from the terrain irre,ularities, less environmelltal demage, and better energy efficiency. These advantages made the free locomotion gaits adecuate for some emerging new potential applications such as planetary exploration, underwater tasks and forestry or industrial agriculture. Up to the present, many researchers on gaits for legged robots have built simulators to understand how locomotions is made in machines and its relationship with animal locomotion. on this sense, this paper shows a new knowledge about free locomotion gaits by using a three dimensional graphic representation of the walking robot.

THE RIMHo WALKING RoBoT

The RIMHo (Fig. 1) is a quadruped walking robot that can be classified as an insect type. This robot has not been developed for any specific application, although we are interested in hostile environments, and at the present it is used as a test bed for different subjects involved in walking vehicles [1].

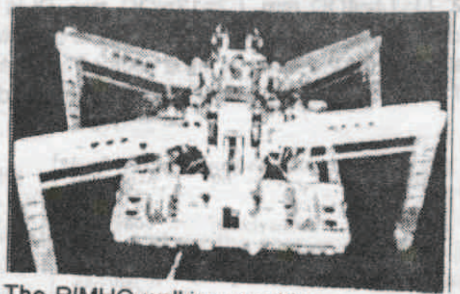

Fig. 1 The RIMHO walking machine.

Its four legs are based on a three dimensional cartesian pantograph mechanism [2], which consists of four links that provides three degrees of freedom. The robot-s body is 73S mm long, 71O mm wide and 344 mm high. The machine's weight is 6S kg, and the robot carry out 2S kg. The leg positions are controlled with a personal computer to obtain the positions in each legs. There are incremental optical encoders of SOO pulses per revolution attached to the motor shaft (12 in all).

KINEMATICS MoDEL

For the solution of the kinematics inverse problem we have placed a reference system fixed on the Geometrical Center of the body, and one auxiliar systems in each leg.

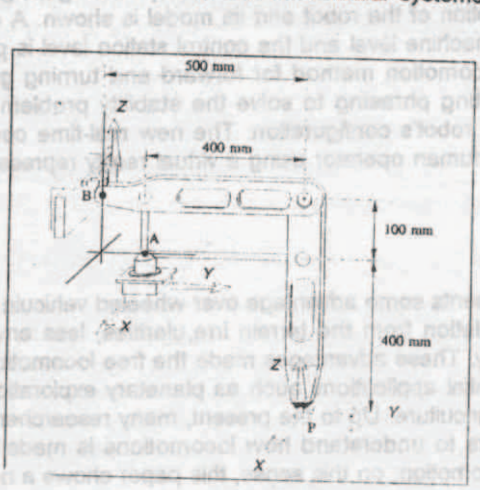

Fig. 2 The three dimensional pantograph mechanism

The geometry of one leg (Fig. 2) permites us to define the A point placed on the joint as produce displacement in the horizontal plane (XY), and the B point on the joint as make movements to going up and down [3]. The reduced equation for the twelve joints (three for each leg) to solve the kinematics inverse problem is expressed in the eq. (1). Where LS=LI+L2=L3+L4, LI=14=4OO mm, L2=13=IOO mm, Pj is a vector from the fixed inertial system to the endpoint of the leg i, i={ 1,2,3,4}; CR is a vector from the fixed inertial system to the geometrical center of the body, V, es a vector from the geometrical center of the body to the origen oj of each leg, ~ define the orientation of the body in the X, Y and Z respectively.

$$\begin{pmatrix} X_A \\ Y_A \\ Z_B \end{pmatrix}_i = \begin{vmatrix} \frac{L2}{L5} & 0 & 0 \\ 0 & \frac{L3}{L5} & 0 \\ 0 & 0 & \frac{L2}{L1} \end{vmatrix} \left\{ \begin{bmatrix} \cos\gamma\cos\psi & -\sin\gamma\cos\theta\cos\psi - \sin\psi\sin\theta & \sin\gamma\sin\theta\cos\psi - \sin\psi\cos\theta \\ \sin\gamma & \cos\gamma\cos\theta & -\cos\gamma\sin\theta \\ \sin\psi\cos\gamma & -\sin\psi\sin\gamma\cos\theta & \sin\theta\sin\gamma\sin\psi - \cos\theta\cos\psi \end{bmatrix} \begin{pmatrix} P_X - CR_X \\ P_Y - CR_Y \\ P_Z - CR_Z \end{pmatrix}_i - \begin{pmatrix} V_X \\ V_Y \\ V_Z \end{pmatrix}_i \right\} \quad (1)$$

The movements for locomotion are designed to small velocity, 25 mm/s to up and down, and I OO mm/s as the highest speed to step forward. Eq. 1 shows three different actions for walking in an instant time: lineal movement in a leg, lineal movements in the body, and turning the body

THE CoNTRoL SYSTEM

The control system consists in two levels: Control Station Level and Machine Level (Fi~. 3). These two levels works in separated computers connected via RS-232. All twelve joints in the machine are driven by DC servomotors. Each motor is controlled by a dedicate microcontroller that provides the interface between motor drivers and processors. An interesting aspect has presents the control station is the posibility to plan a locomotion mission under different terrain by simulation. By this way, new conditions are analized to get new experiences in walking process and improvement the controllers.

These experiences are useful for the locomotion control in real time. The environment control implements the combination of the real and artificial environments with the intention to obtain sensations in the human operator.

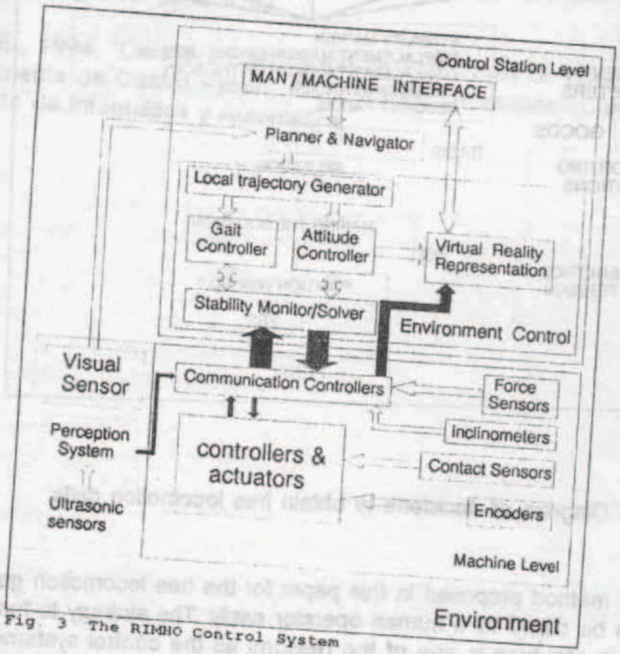

Fig. 3 The RIMHO Control System

A FREE LoCoMoTIoN ALGoRITHM

The problem to select all possible movements and get the sequencial moves for the locomotion process without lose the stability or decrease significantly the robot's mobility has carry us to research the free locomotion problem [4]. The process for walking in this research considers as the robot is moved under static stability viewpoint. So, when the robot walks there are at least three legs supporting the body, and the projection of the Gravity Center of the body (GC) in a horizontal plane is on the supporting polygon. For the stability evaluation we use the stability margin which is define as the minimum distance between the vertical projection of the gravity supporting polygon to evaluate and begin the method since the total displacement of the robot is obtained. The execution of the free gait can be stoped also for the human operator in any time

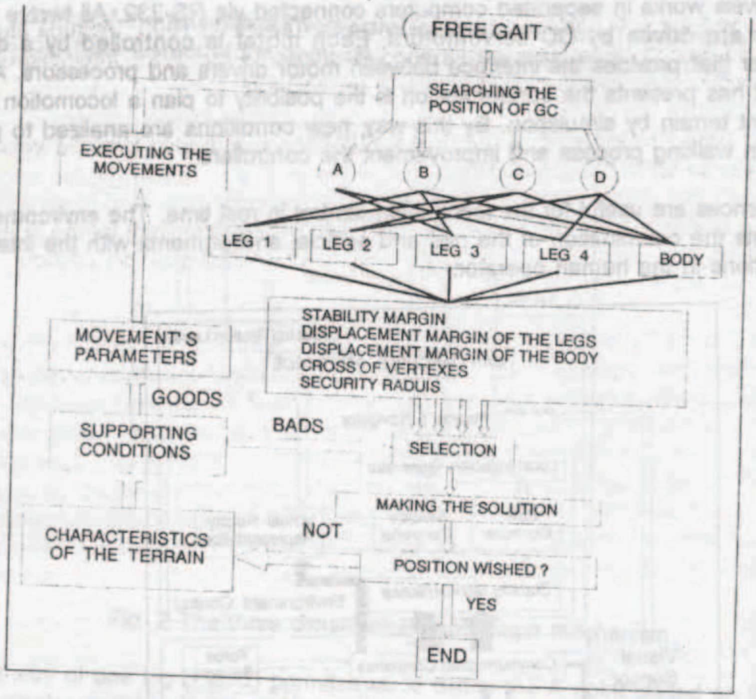

Fig.4 Diagram of decisions to obtain free locomotion gaits.

CoNCLUSIoNS

The real-time control method proposed in this paper for the free locomotion gaits attains walking machine can be drived by a human operator easily. The strategy to form a free locomotion process in real-time is one of the reasons as the control systems works efficiently for practical locomotion. A contribution to the free locomotion theory for walking machines is the definition of a new parameter: Cross of vertexes. This parameter can be extended to walkin,~, robots with more of four legs. An advance in the pharing to solve the stability problem is the innovative treatment of the supporting polygon. We consider as the free locomotion gaits can be characterized with the five parameters: Stability margin, Security radius, Displacement margin of the body, Displacement margin of the legs, and the Cross of vertexes.

ACKNoWLEDGEMENTS

Author want to thanks to the Instituto de Automatica Industrial of the Spanish Council for Scientific Researches the facilities offered in the experiments, and also thanks to the Comisión Tnterministerial de Ciencia y Tecnoligía for the support under the proyect: ROB-90-1044 C20-01

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