Machinery/Automation

Controlling Herds of Cooperative Robots

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A document poses, and suggests a program of research for answering, questions of how to achieve autonomous operation of herds of cooperative robots to be used in exploration and/or colonization of remote planets. In a typical scenario, a flock of mobile sensory robots would be deployed in a previously unexplored region, one of the robots would be designated the leader, and the leader would issue commands to move the robots to different locations or aim sensors at different targets to maximize scientific return. It would be necessary to provide for this hierarchical, cooperative behavior even in the face of such unpredictable factors as terrain obstacles. A potential-fields approach is proposed as a theoretical basis for developing methods of autonomous command and guidance of a herd. A survival-of-the-fittest approach is suggested as a theoretical basis for selection, mutation, and adaptation of a description of (1) the body, joints, sensors, actuators, and control computer of each robot, and (2) the connectivity of each robot with the rest of the herd, such that the herd could be regarded as consisting of a set of artificial creatures that evolve to adapt to a previously unknown environment. A distributed simulation environment has been developed to test the proposed approaches in the Titan environment. One blimp guides three surface sondes via a potential field approach. The results of the simulation demonstrate that the method used for control is feasible, even if significant uncertainty exists in the dynamics and environmental models, and that the control architecture provides the autonomy needed to enable surface science data collection.

This work was done by Marco B. Quadrelli of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.techbriefs.com/tsp*** *under the Software category.*

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-40723.

Modification of a Limbed Robot to Favor Climbing

A kinematically simplified design affords several benefits.

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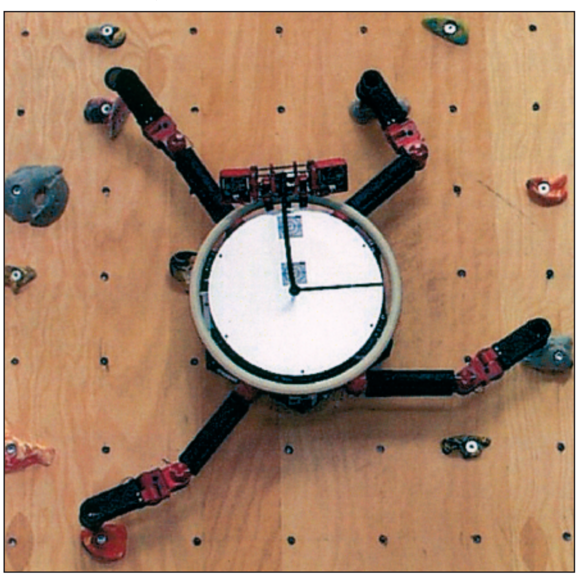
The figure shows the LEMUR IIb, which is a modified version of the LEMUR II — the second generation of the Limbed Excursion Mechanical Utility Robot (LEMUR). Except as described below, the LEMUR IIb hardware is mostly the same as that of the LEMUR II. The IIb and II versions differ in their kinematic configurations and characteristics associated with their kinematic configurations. The differences are such that relative to the LEMUR II, the LEMUR IIb is simpler and is better suited to climbing on inclined surfaces.



The **LEMUR IIb Walking Robot** is simpler and less massive, yet a better climber, relative to its predecessor, the LEMUR II.

The first-generation LEMUR, now denoted the LEMUR I, was described in "Six-Legged Experimental Robot" (NPO-20897), *NASA Tech Briefs*, Vol. 25, No. 12 (December 2001), page 58. The LEMUR II was described in "Second-Generation Six-Limbed Experimental Robot" (NPO-35140) *NASA Tech Briefs*, Vol. 28, No. 11 (November 2004), page 55. To recapitulate: the LEMUR I and LEMUR II were six-legged or six-limbed robots for demonstrating robotic capabilities for assembly, maintenance, and inspection. They were designed to be capable of walking autonomously along a truss structure toward a mechanical assembly at a prescribed location. They were equipped with stereoscopic video cameras and image-data-processing circuitry for navigation and mechanical operations. They were also equipped with wireless modems, through which they could be commanded remotely. Upon arrival at a mechanical assembly, the LEMUR I would perform simple mechanical operations by use of one or both of its front legs (or in the case of the LEMUR II, any of its limbs could be used to perform mechanical operations). Either LEMUR could also transmit images to a host computer. The differences between the LEMUR IIb and the LEMUR II are the following:

- Whereas the LEMUR II had six limbs, the LEMUR IIb has four limbs. This change has reduced both the complexity and mass of the legs and of the overall robot.

- Whereas each limb of the LEMUR II had four degrees of freedom (DOFs), each limb of the LEMUR IIb has three DOFs. This change has also reduced both complexity and mass. Notwithstanding the decrease in the number of DOFs, the three remaining DOFs are configured to provide greater dexterity for motion along a surface.
- To extend reach, the limbs of the LEMUR IIb are 25 percent longer than those of the LEMUR II.
- Additional benefits stemming from the modifications are that the robot body supported by the limbs is now less massive and its center of gravity is now closer to the surface along which the robot is to move.

These benefits have been obtained without sacrificing load-carrying capacity. Hence, overall, the LEMUR IIb is a more adept climber.

This work was done by Avi Okon, Brett Kennedy, Michael Garrett, and Lee Magnone of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1). NPO-40354*