NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONTRACT NO. NAS7-918

TECHNICAL SUPPORT PACKAGE

On

EARTHWORMLIKE EXPLORATORY ROBOTS

for June 98

NASA TECH BRIEF Vol. 22, No. 6, Item #138

from

JPL NEW TECHNOLOGY REPORT NPO-20266

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June 98

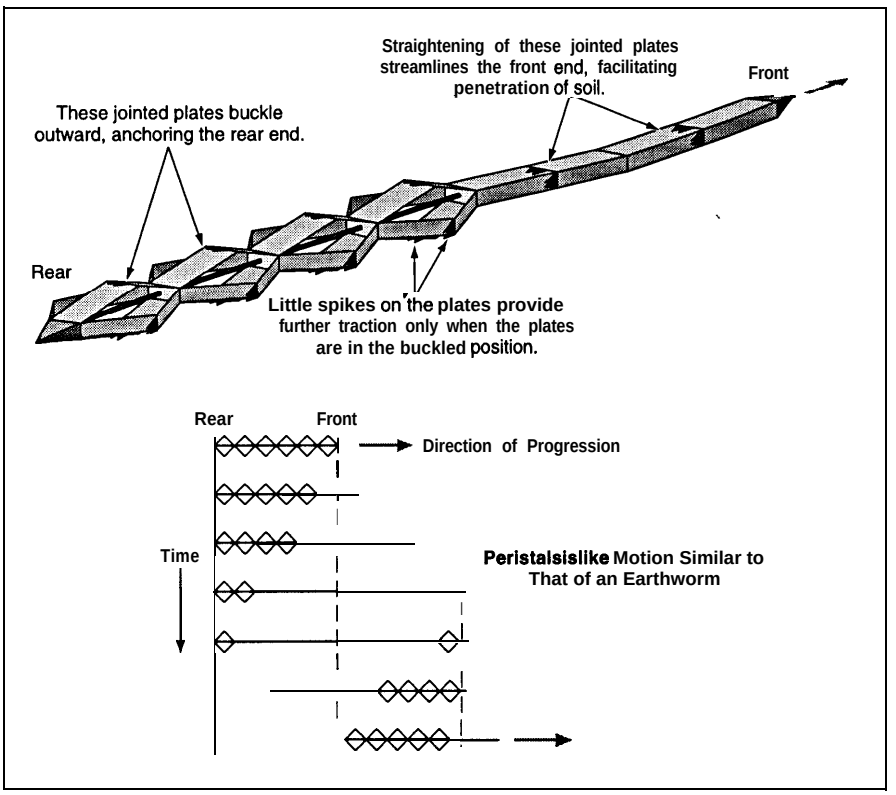
Earthwormlike Exploratory Robots

Mobility would be achieved through coordinated actions resembling peristalsis.

NASA's Jet Propulsion Laboratory, Pasadena, California

Mobile robots that would resemble earthworms have been proposed for use in exploring remote, hostile, or inaccessible terrain surface and subsurface environments. This class of robots would be a special case of the more general class of proposed small, lightweight, relatively inexpensive exploratory robots. To recapitulate: Biomorphic explorers would exploit the emerging technology of biomorphic controls and advanced actuators. They would achieve motion by use of simple electronically or photonically controlled, flexible advanced actuators instead of conventional motors with complex drive trains. The robots would carry advanced microsensors for measuring or detecting specific objects or substances. Animallike combinations of mobility, adaptability, fault tolerance and a limited capability for "learning" would be achieved by integrating the actuators with very-large-scale integrated (VLSI) circuits that would implement neural-network and/or genetic algorithms.

The proposed earthwormlike robots would be flexible in the sense that they would be foldable in segments. The first several segments at one or both end(s) of each robot would generate motion. These segments would be covered with hinged plates connected to interior actuators (see figure). Upon command, the interior actuator in each segment would shorten or lengthen the segment, causing the plates to buckle outward or to move inward to straighten, respectively. A wave of shortening/buckling versus lengthening/straightening, resembling the peristaltic motion of an earthworm, could be generated by sending coordinated, sequential contraction and expansion commands to the actuators in the segments. By this action, the robot could move along the surface or burrow beneath the surface of terrain.



Shortening/Widening and Elongating/Narrowing motions of the segments would be timed to generate an overall peristaltic motion like that of an earthworm.

The direction of travel could be reversed by reversing the sequence of buckling and straightening.

Special-purpose microsensors could be housed in one or more end or middle segment(s). The tips on the end segments could be sharpened to facilitate penetration of soil. Alternatively or in addition, the tips could contain sensors and/or mechanisms to collect samples.

The design of the robot, including the details of the mobility features and the choice of sensors, would be specific to the intended application. For example, an earthwormlike robot might be designed to probe earthquake rubble to find missing persons and animals. The sensors for this application could include a miniature active-pixel-sensor video camera, a temperature sensor, and microspectrometer for detecting carbonates, water, and other chemical signs of life.

This work was done by Sarita Thakoor, Kim Quillin, Alex Fukunaga, John Michael Morookian, and Adrian Stoics of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-20266*

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NTR Inventor's Report

NASA CASE NO.
JPL CASE NO.

Earthworm robot : Implementation of Bio-morphic Explorers- Folding Mechanisms and flexible Multipods.

Sarita Thakoor, Alex Fukunaga, John Michael Morookian, Adrian Stoics JPL and Kim Quillin, UC Berkeley,

1. Novelty:

This describes an earthworm like robot (figure 1) capturing the peristalsis mechanism for mobility. An application specific design of such a robot could offer a good solution for probing through an earthquake rubble. Dedicated sensors such as a miniature active pixel sensor (APS) camera, temperature sensor, or life sensor will form the payload of such an explorer to obtain distributed measurements for scouting the site of interest. Life sensing can be done by looking for carbonates, water etc. Microspectrometers as small as 3cmx3cm x 0.5cm are available from commercial vendors that can be included in the payload to obtain the desired sensing. The front and end segments of the earthworm robot will always perform the mobility function. The center segments can be replaced by the payload as needed.

Novel features of the earthworm robot are:

—- segmented foldable design
—- faul-tolerance, adaptability
–flexibility allowing enhanced spatial access
, reconfigurability allowing adaptability to terrain
–Enhanced spatial access
-Enhanced sample acquisition
- scaleability
- reduced complexity/cost
- surface/subsurface mobility

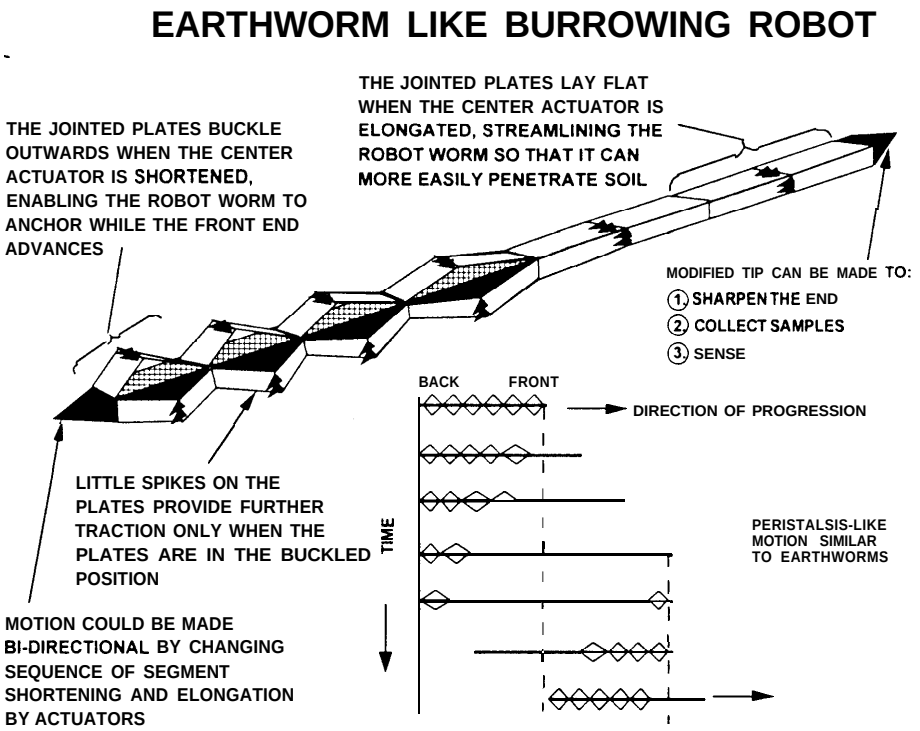

Figure 1: Peristalsis based earthworm-like robot

2. Technical Disclosure

A. Problem

Small low cost, mobile platforms are required for hazardous or scouting activities for a variety of exploration, surveillance, or security need. To obtain mobility, motors are generally used to drive wheels/legs/mobile segments. Reduction of size of motors is a continuing need which is approaching its own limits due to the intricacies involved in designing smaller motors. Assembly of small motors tends to become an intricate and expensive process. Direct driven advanced mobility with features of low mass, low cost, low power in small volume is in great demand for a variety of mobility needs including autonomous miniaturized mobile platforms (as transport mechanisms for a variety of sensors) and medical diagnostic tools for precision minimally invasive treatment.

B. Solution

"Biomorphic Explorers", New technology Report, February 1997, NPO# 20142/9778 hav proposed by Thakoor and Stoics as a solution to the above problem forming a completely new of mobile systems. The earthworm robot described here is a specific implementation of the based on capturing the peristalsis mechanism in biological systems.