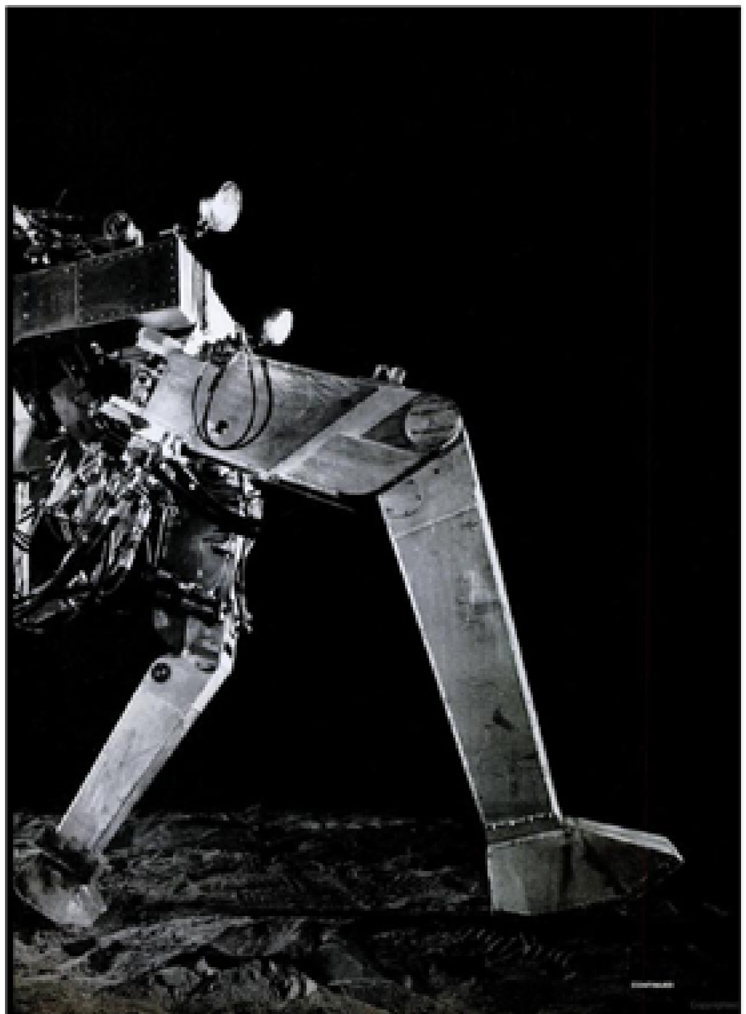


WALKING MACHINES

The history of machines that walk is long and varied.

Cybernetic Zoo is an online resource that contains an exhaustive survey of historical ephemera related to robots that reference to biological designs. Many of the photos here are from this fantastic repository, and it is highly recommended as a virtual zoo.

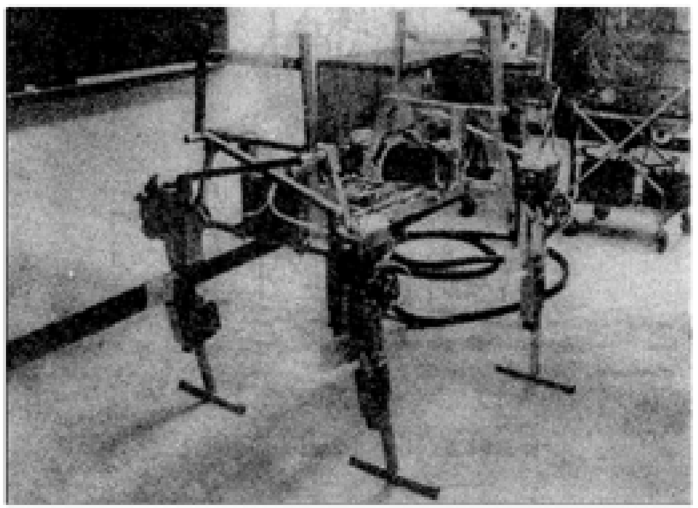
Most of the robots built prior to the dynamic machines of Raibert were considered “static crawlers”. The Trojan Cockroach as well as the machines see here are statically balance systems, which was the standard approach to legged locomotion for many years. This concept centers on the “polygon of support” provided by the feet, which allows the system to prevent tipping because the “polygon of support” is always underneath the center of mass.

Raibert summarizes the problems faced in order to build successful walking machines:

“Legged vehicles need systems that

- control joint motions
- sequence the use of legs
- monitor and manipulate balance
- generate motions to use known footholds
- sense the terrain to find good footholds
- calculate negotiable foothold sequences”

The common approach for many years was to design linkages that would generate motions forward and backward when driven by a source of power. Early designs incorporated these linkages and gears, but machines tended to have fixed patterns of motion, and could not predict or accommodate variations in terrain very well.



THE PHONY PONY Date: 1966-8

Origin: Andrew Frank, Bob McGhee and Rajko Tomovic, at the University of Southern California

Contribution: The first legged vehicle to walk autonomously under full computer control.

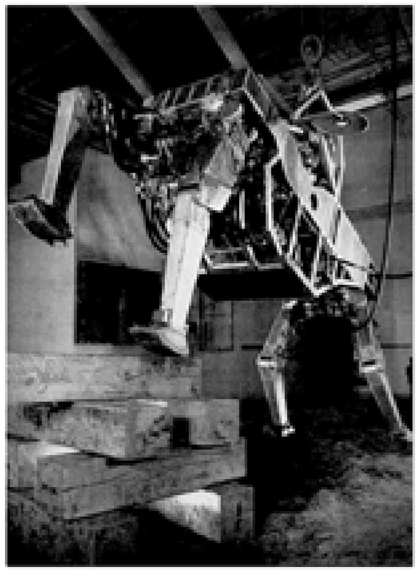
Degrees of Freedom: Two degrees of freedom, and joint coordination performed by a computer.

Design: Composed of two links and two single-degree-of-freedom joints.

Power: Powered externally by a cable.

Details: The four legs each had two joints, and each was identical to one another. The front and back pair were mounted and controlled in the same way.

It had a highly non-biological structure, since the architecture of the front and back legs of animals have distinct support structures, quite unlike the symmetry of this robots design.



THE G.E. QUADRUPED Date: 1968

Design: A 3,000 pound quadruped Origin: General Electric and Ralph Mosher

Contribution: A human operator was connected directly to the mechanism on the inside, individually actuating each joint.

They would walk inside the big machine and the 12-foot legs would mirror the steps taken by the operator.

The arms of the machine would also follow the movements of the operator's arms!

Degrees of Freedom: Three degrees of freedom for each leg.

Power: The operator controls the four legs with his hands and feet through a bi-lateral, force reflecting, hydraulic servo system.

Details: Impressive ability to climb obstacles and good mobility in difficult terrain.

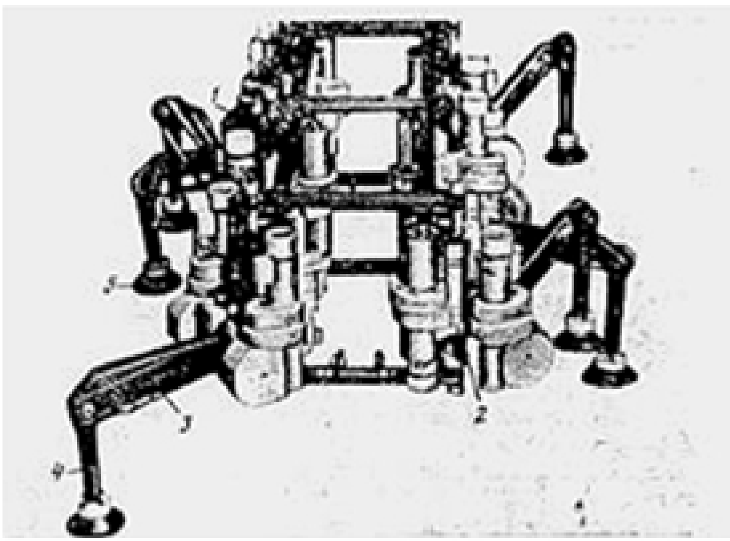
It could touch its foot down onto an egg without cracking it.

See also GE PEDIPULATOR

(also by Ralph Mosher):

The human operator, who would be coupled directly to the mechanism, would walk inside the big machine and the 12-foot legs would take the same steps. The arms of the machine would follow the movements of the operator's arms.

The body of the pedipulator would be big enough to hold, besides the operator, electronic circuits, servo units and power drives.



MASHA HEXAPOD

Date: 1976

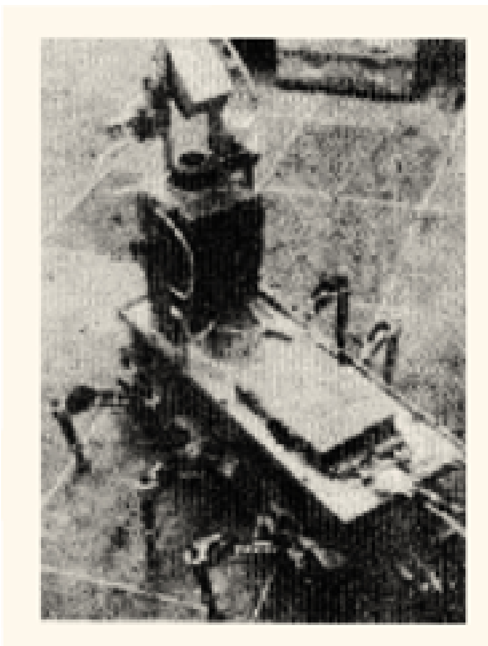
Origin: Soviet scientists at the Moscow State University, E.V. Garfinkel, , A. Yu. Shneider, and more.

Design: Hexapod

Size: 18 kg, payload of 10 kg. moved at 4 meters per minute.

Degrees of Freedom: articulated legs with three degrees of freedom

Details: Objects that could not be traversed directly were bypassed by its seniors!



PV II

Origin: Russia, Moscow Physico- Technical Institute

Design: A medium sized hexapod

Power: It was controlled from an analog computer and powered externally.

Details: Each leg has three degrees of freedom. The joint is actuated by motors and gears. The foot pad is attached on the lower link with a gimbal joint.

Date: 1978- 1980

Origin: Shigeo Hirose at the Tokyo

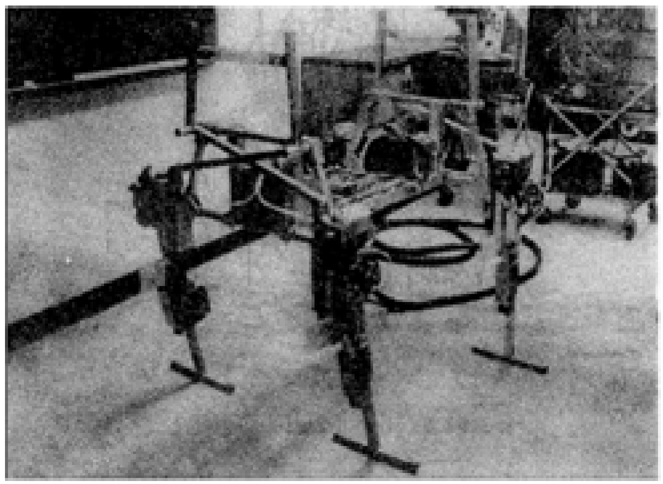
Institute of Technology

Design: Quadruped. The legs were 3D pantograph mechanisms. It also had a passive ankle system.

Size: 22 lbs. Average speed 0.8 in/ sec.

Contribution: The PV II is the first robot to climb stairs using tactile sensors on the ends of the legs. Degrees of Freedom: Each leg had a driving motor/clutch

Details: It had contact sensors on each foot, and was skilled at detecting obstacles. The PV II was special in that it had a light weight and slow speed.



OSU HEXAPOD Date: 1977

Origin: Bob McGhee and his associates at the Ohio State University

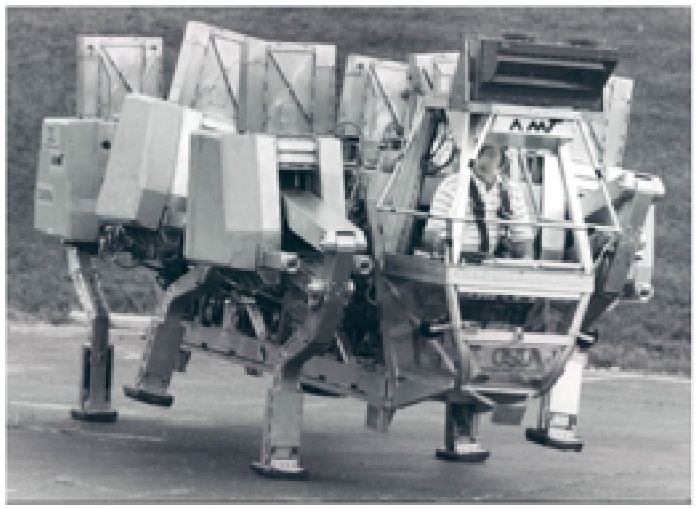
Design: force sensors, gyroscopes, proximity sensors and a camera system. It weighed approx. 300 pounds.

Contribution: This machine was built primarily to study control algorithms for a walking machine.

Degrees of Freedom: Each leg had three degrees of freedom and was made of two links connected by joints.

Power: fully controlled by a PDP 11/70 computer via an umbilical cord and was powered externally through a cable.

Details: This insect-like hexapod could walk with a number of standard gaits, turn, walk sideways, and negotiate simple obstacles.



ASV (ADAPTIVE SUSPENSION VEHICLE) Date: 1982 - 1990

Origin: Dr. K. J. Waldron

Size: 5-9fthigh,15ft.wide,15ft long

Contribution: The ASV had an advanced terrain sensing system that scanned its environment to develop a map for foothold placement.

Degrees of Freedom: 6 passive, 18 active

Power: Hydraulic engine

AMBLER (AUTONOMOUS MOBILE EXPLORATION ROBOT) Date: Jan. 1988 - Dec. 1992

Origin: Planetary Rover Group, School of Computer Science, Carnegie Mellon

William Red Whittaker, Dr. Simmons, Dr. Krotkov

Design: 6 legs. This behemoth stands about 16 ft tall, was roughly 23 ft wide, and weighed 5512 lb.

Degrees of Freedom: 18

Power: batteries, propane generator,

permanent magnet DC motors

Details: It moves at a blistering 13.8 inches per minute. Just sitting still, it consumes 1400 W of power. When walking it consumes in excess of 4000 W!

DANTE

Date: 1990- 1994

Origin: Field Robotics Center, Carnegie Mellon University, John E. Bares & William Red Whittaker

Design: 120 in long, 85 in wide, 120 in. high

weighs 1700 lbs. Moved 1 meter per min.

Power: 3A at 1000VAC (peak) and 2 KW (nominal)

Details: Developed to withstand treacherous conditions, Dante was a tethered walking robot that explored the Mt. Spur volcano in Alaska in July 1994.

The purpose was to attain high temperature fumarole gas samples for volcanic science research that are too dangerous for humans to retrieve.

Dante rappelled down the craters of the volcano and was able to successfully analyze high temperature gases on the crater floor.