LA-UR- 95-841

Conf-9505197--1

TITLE:

BIOMORPHIC ROBOTS AS A PERSISTENT MEANS FOR REMOVING EXPLOSIVE MINES

AUTHORS:

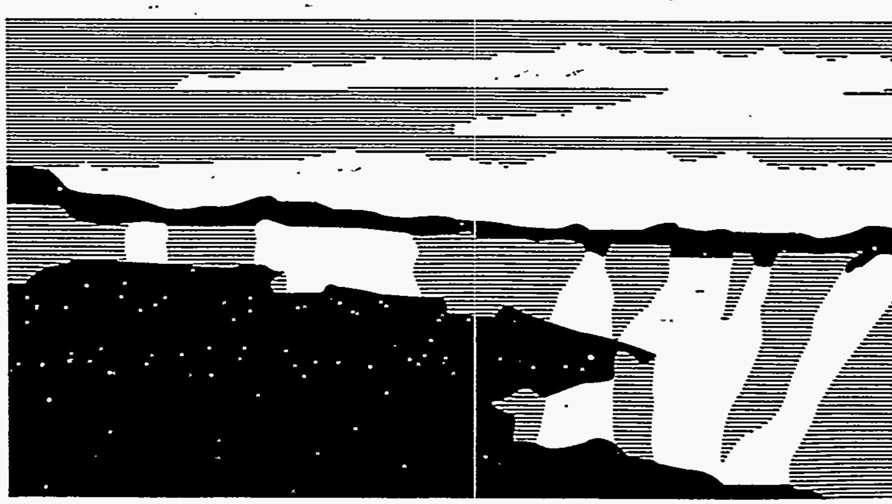
M. W. TILDEN

SUBMITTED TO:

Autonomous Vehicles in Mine Countermeasures Symposium
Naval Post Graduate School
Monterey, CA
April 5, 1995

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.



Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

Form No. 836 R5
ST 2629 10/91

MASTER

DT

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Biomorphic Robots as a Persistent Means for Removing Explosive Mines:

Figure A: "Bug of the Badlands"

Mark W. Tilden
Biophysics Division
Los Alamos National Laboratory
Los Alamos, NM 87545, USA
<mwtilden@lanl.gov>
P: 505/667-2902
F: 505/665-5103

LANL Paper ID: LA-UR

Biomorphic Robots as a Persistent Means for Removing Explosive Mines:

Mark W. Tilden
P3, Los Alamos National Labs, MSD449
Los Alamos, NM 87545
505/667-2902, Fax: 505/665-5103
<mwtilden@lanl.gov>

ABSTRACT:

The current variety and dispersion of explosive mines is a daunting technological problem for current sensory techniques. The bottom line is that the only way to insure a mine has been found and removed is to step on it. As this is an upsetting proposition for biological organisms like animals or children, this paper details a proposed non-biological method that may have validity following additional research into the new science of Biomorphic Machines.

A Robobiologist at LANL has invented and developed a variety of "living" robots that are solar powered, legged, autonomous, adaptive to massive damage and terrain, and very inexpensive. This technology, called Nervous Net (Nv) design, allows for the creation of capable walking mechanisms (known as "Biomorphic Robots") which rather than run on a "work" ethic, use "survivalist" design principles. These principles allow Nv based machines to continue doing work even after multiple limbs have been removed or damaged, and to dynamically negotiate complex terrains as an emergent property of their operation. They are not programmed, and indeed, the 12 transistor controller used keeps their electronic cost well below that of most pocket radios. It is suspected that in finding and removing randomly placed explosive mines, they may be an interesting, capable solution.

INTRODUCTION:

Nervous Net (Nv) technology is a non-linear analog control system that solves real time control problems normally thought to be intractable, or at least quite difficult to handle by digital methods. Nervous nets are to Neural nets the same way the peripheral spinal system is to the brain. This work has concentrated on the development of Nv based robot mechanisms with electronic approximations of biologic autonomic and somatic systems. It has been demonstrated that these systems, when fed back onto themselves rather than through a computer-based pattern generator, can successfully mimic many of the attributes normally ascribed to lower biological organisms. Using Nv nets, highly successful legged robot mechanisms have been made which can negotiate terrains of inordinate difficulty for conventional wheeled or tracked designs. That non-linear systems can provide this degree of control is not so surprising as the part counts for successful Nv designs. A fully adept insect-walker, for example, can be fully controlled and operated with as little as 12 standard transistor elements. A picture of a solar-powered, field negotiating prototype is detailed in Figure 1.

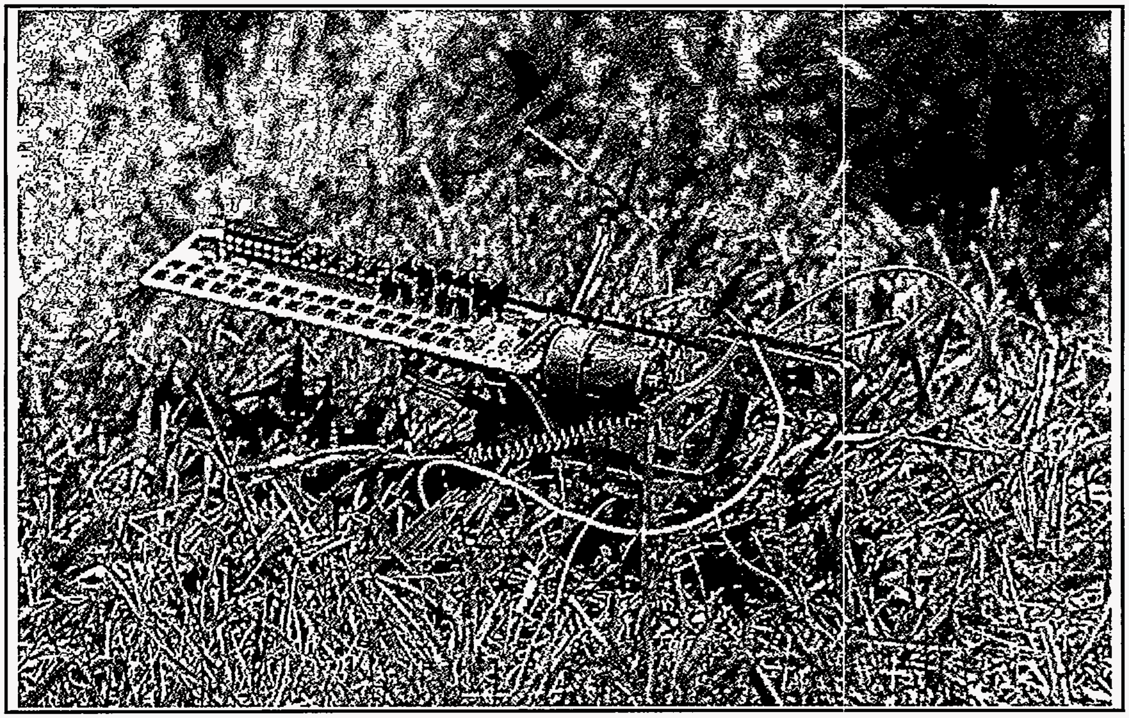


Figure 1: An experimental "minebot" device just over a cubic foot in size (Named "Walkman Solar 1.0). The forward sensor array is to the right, and the back of the device sports the solar cells and analog "Nervous Net" controller.

The idea is to produce an array of cheap, disposable robots that will systematically stomp over minefields blowing up all they encounter. As mines are designed to inflict damage to humans and vehicles, these robots will be designed to trigger the mines with the greatest chance of continued survival. They will be solar powered, easily repaired (or salvageable with interchangeable components), long lasting, and simple enough even for uneducated third world farmers to use effectively. Design details follow:

Physically, using suspension systems, lightweight materials, and cheap motors, we design the devices to deliberately and dynamically survive explosions from underfoot (unlike broad-footed wheeled or tracked designs). For example, we make the robots' legs out of slim carbon steel (or titanium if cost effective). When a mine is detonated under foot, the blast then has only a very small, and tough, surface area to react upon, directing the mines blast up rather than out. This serves to minimize damage to the local area and the robot itself. The robots' legs are suspended so if the robot is of a certain size, only one of four things will happen:

1 - the robot will flex its leg to the blast and carry on,
2 - the robot will flip over and carry on walking on its knees.
3 - the robot will loose a bit of leg, but still carry on.
4 - the robot will be shattered by the force of the blast.

If 1, 2, or 3, these conditions will still allow the machine to hunt for another mine. If 4, then robots must be designed which are themselves cheaper to produce than the average cost of the mines they remove (nominally $27 per). Recent work shows that this may be feasible given the discounts possible with mass-production.

The advantage of walking mine sweepers compared to wheeled sensory devices are:

1 - Legged machines can negotiate much more varied terrains than wheeled devices. Where walking is not practical, slithering is (robot snake mechanisms are proposed for mined jungle environments. As yet, the prototypes are awaiting further work). As in nature, there is no one universal walker that can negotiate all terrains, but as these devices have an infinite reconfiguration space, they can be customized easily to everything from desert to snow-tundra environments. Design of these machines is directly related to the limit complexity of the environment to be traversed. Eventually, a robots' design will be as simple as getting detailed environment specifications

2 - A legged machine alternately puts over twice its weight on each leg every forward step it takes. This means that a 40 pound robot (for example. Prototypes under development) can put down better than 80 pound steps, more than enough to trigger a standard mine. The advantage is that when the mine explodes, the robot being only 40 pounds will not suffer the inertial damage otherwise delivered to a larger, heavier body. The robot can be designed so it could "roll" with the blast. This damage can be further reduced with flexible materials and suspensive designs, and the placing of the main motor/control/power components a reasonable distance from the blast. Figure 2 details some of these ideas.

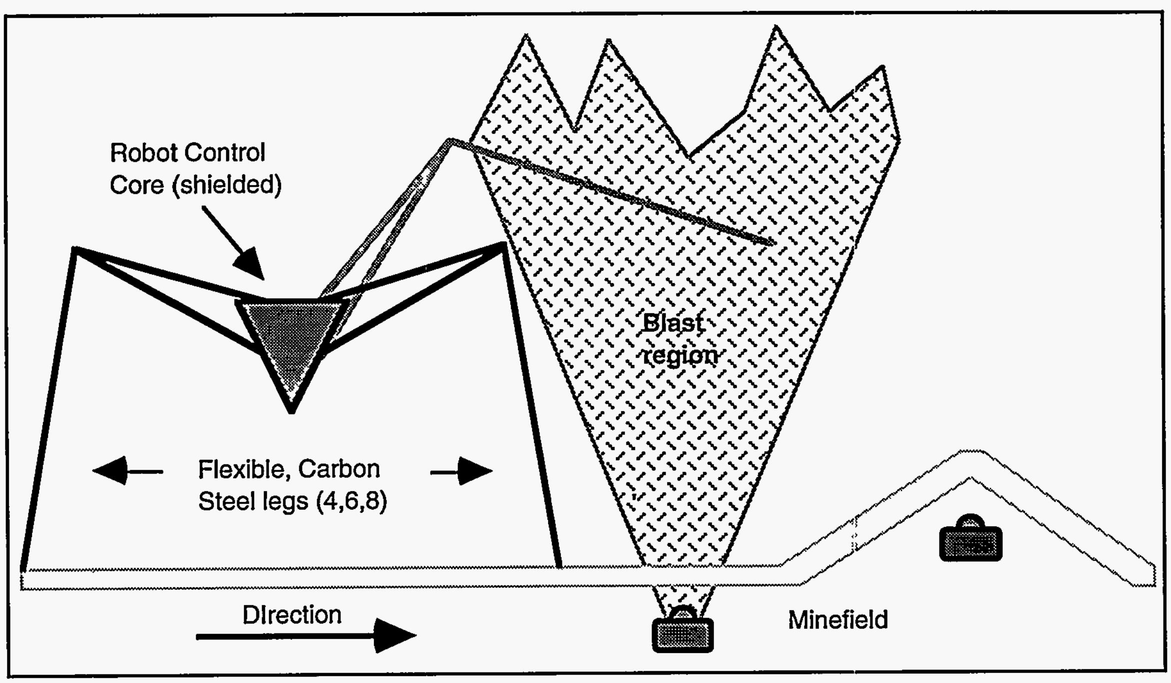


Figure 2: A biomorphic robot with its control apparatus and solar cells in a contained, blast-resistant cone, responding to an explosion underfoot.

The previous figure shows a "high-stepper" design that would be necessary for environments where bushes, rocks or grasses may hinder progress. For more level terrain like fields, deserts, or sand, a lower-wider robot would do better at avoiding blast-shock. These are examples of where the machine must be adjusted to fit the environmental constraints first. Mine removing robots are of little use if they cannot handle the complexities of a particular terrain.

3 - Mathematically, these mechanisms can be considered "alive" in the same way that ants are "alive": they cannot reproduce themselves but they fight to sustain their survival at a local level. This means that although these robots will react to a mine explosion, they are not intelligent enough to "understand" that they are in a minefield, wishing they were somewhere else. They can be thus controlled by simple "domestication" methods like tethers, fences, or beacons.

4 - This technology is too slow for military purposes (biomorph designs cannot yet walk as fast as a man), but more than adequate for civilian purposes where time is not of an essence (some mines have waited 70 years for cleanup, so slow removal is not much of an issue). Consequently these machines will hopefully remain in-field and not in-storehouse.

5 - Legged devices can be made with any number of legs (over the necessary minimum of three). This means that a walker covers its path thoroughly as legs rarely step on the same patch of ground twice. Furthermore, a robot can cover an area twice with the front legs, and then with the back. For security of effort, an 8 or 10 legged device, although costly, would have the best possible path-sweep ability, as well as having redundancy on the number of legs it could use and loose. For most applications, however, cheap, two-motor, 4 legged devices should be adequate. Only experimentation will tell.

6 - Unlike other methods, Biomorphs will not require continuous human monitoring for the task at hand, thus saving not a few nerve-endings.

7 - Biomorphs will not mistake battlefield debris for mines. That which does not explode is just part of the environment.

APPLICATION:

There are many ways of applying these devices for mine sweeping purposes, but viable deployment suggestions are:

1- Have large numbers of these devices walk freely over minefields for as long as they are able under solar power (uninterrupted lifetime: 10 years based upon decay efficiency of solar cells). Data is not available at this time as the technology is still in a fledgling stage, but it is suspected a 40 pound, solar powered device could systematically sweep an acre field in as little as a month of sunny weather to a 99% accuracy (based upon scaled abilities of current walking prototypes)

2 - As before but with "herds" of these devices deployed, controlled, and maintained by trained professionals to systematically and efficiently clear vast areas while the human operators work from safe, quiet distances. Telepresence abilities (i.e., robots with cameras broadcasting to a remote user) would allow these machines to handle situations where precise or intelligent action is necessary.

3- Have these devices carry low power sensory platforms for the detection and deliberate removal of mines (Note: expensive and difficult as these sensors would take up valuable weight and power resources from the robot, but perhaps necessary in complex situations like the inside of burning buildings).

4- Issue (sell? deploy?) said sweepers to 3rd-world farmers who want to clear out arable land for agriculture. Show them that they are not useful for anything else than mine sweeping and that they respond just like a steel beast of burden. Urge them to set up "Bug Cooperatives" as what one mine sweeper can do in a month, a hundred can do in a day to a 99.9% clearance accuracy. Farmers will be able to measure success by the number of detonations heard, the footprint patterns on the area, and the degree of damage on the machines. Proof of effectiveness will keep said farmers from selling the devices for their metal, and if properly designed, machines will have obvious interchangeable parts so that farmers can repair them with ease and without training.

BOTTOM LINE:

This proposal offers a proposed solution that no other mine sweeping solution known currently provides: long term, unattended, easily deployable mine removal at a low cost and high media visibility. It must be noted that though the principle investigator has working prototypes he is willing to demonstrate on request, his research is more concerned with developing the basic principles of Biomorph robots capable of handling real world environments. Mine sweeping is not *the* application, just *an* application, but one that would be an excellent proof of the technology, and possibly save some lives in the process. This paper was written and submitted to generate discussion, speculation, and application on the topic.

The principle investigator will gladly demonstrate his robots on request.

Is all.

Mark W. Tilden
Feb. 20, 1995