PHOTOVORE

Last modified February 4, 2002

Originally Created by Dr. Mark Tilden and adapted for the WCRG by Dave Hrynkiw

OBJECT:

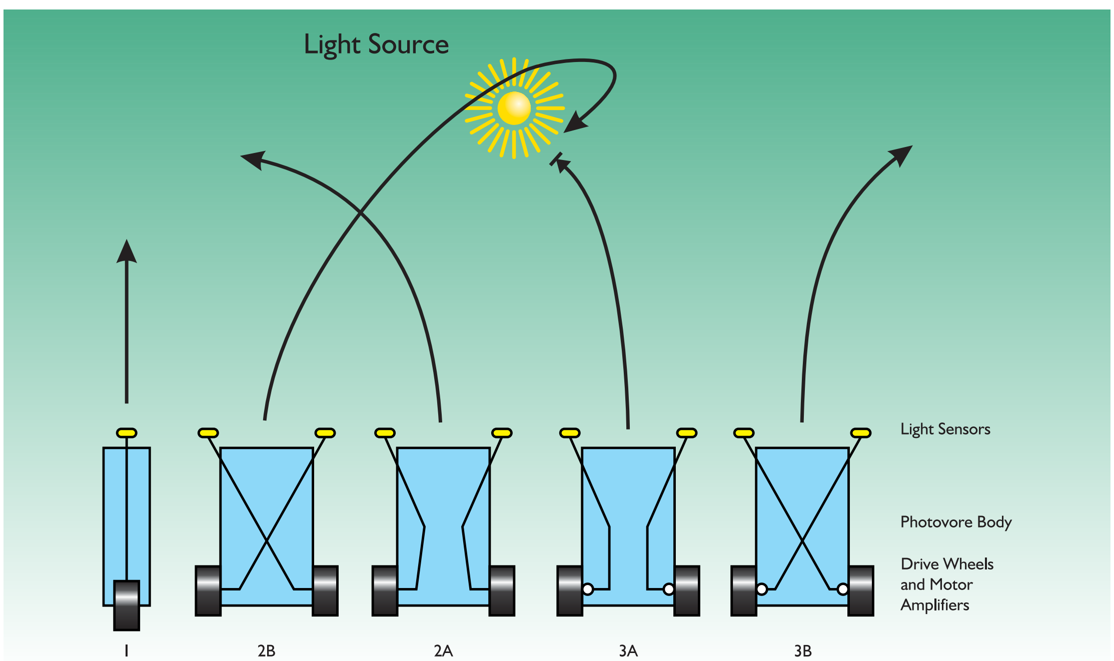
Within a 150mm (6”) cube, build a device that is self contained, solar powered, and goal seeking.

Your only power source is a solarcell with a maximum area of 2442 mm2 (3.79 in2). The robot competitor will have to face off against other devices in a well-lit competition area, having to avoid obstacles and race to the middle. Once there, have your robot dominate the light pool until the end of the 5 minute round. First to the center circle wins a half point, and the one closest to the very center at the end of round wins a full point.

BACKGROUND:

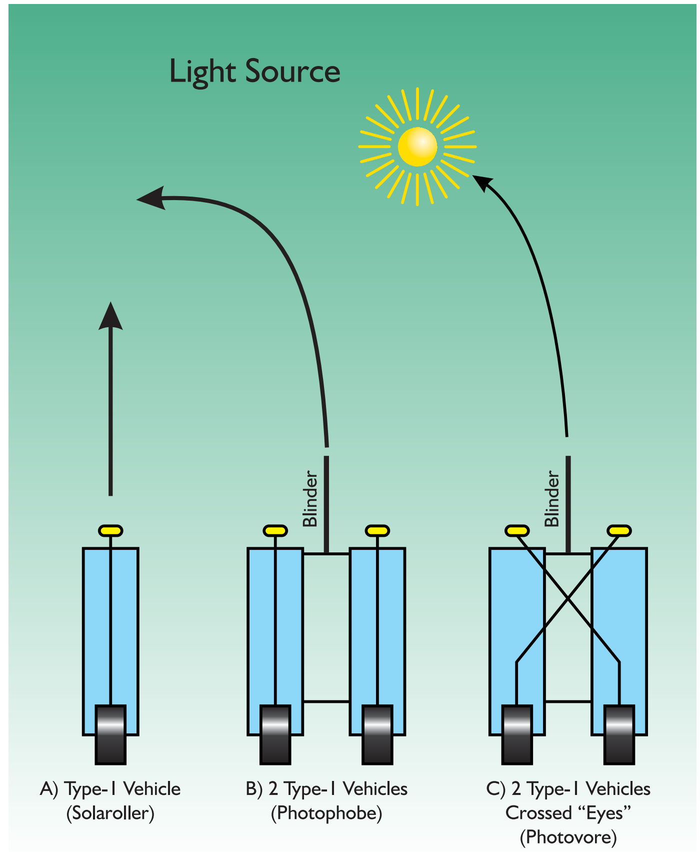
If you tie two Solarollers together and direct their solar cells at different angles, you will notice that your new creature will do one of two things; run away from light sources or run towards them. A similar observation, made by Valentino Braitenberg in his book “Vehicles- Experiments in Synthetic Psychology” (ISBN: 0-262-52112-1), classified a large number of two wheeled devices which existed on a theoretical plane. He noticed that devices that follow light can be thought of as “aggressive” as they charge the light source in an attempt to destroy it, where as devices that run from light slow down in the dark and can be thought of as “submissive”. The first class of devices can technically be called “phototropic” because they mimic plants in their sun-following abilities, and the second as “photophobic”, as they exhibit behavior that shuns light like a mushroom. Braitenberg’s book goes on to describe many classes of such devices, each featuring astonishing behavioral complexity depending on the style and position of sensors, motors and simple internal wiring. An excellent synopsis of the theory was presented in the March 1987 Scientific American in Computer Recreations by A. K. Dewdney should the book “Vehicles” be hard to find (which has been since released in paperback by MIT press).

A “Photovore” (literally, Greek for “light-eater”) absorbs ambient light, converting it directly to electro-mechanical energy; a significant improvement over mother nature who can only do this in living creatures through an intermediary chemical stage. The most basic Photovore is simply two Solarollers joined together, with solarcells swapped over to each other’s side.



A selection of idealized Braitenberg “vehicles” existing on a featureless plain. Imagine the round dot “sensors” at the front of the vehicles to be a solarcell, and you can see how vehicles 1 and 2B resemble a Solaroller and a basic Photovore. In Braitenberg terms, 1 is a Traveller, 2B is Aggressive, 2A is a submissive, 3A is a Lover, and 3B and explorer (note the “o” on the motor amplifier means that the sensor inhibits activity).

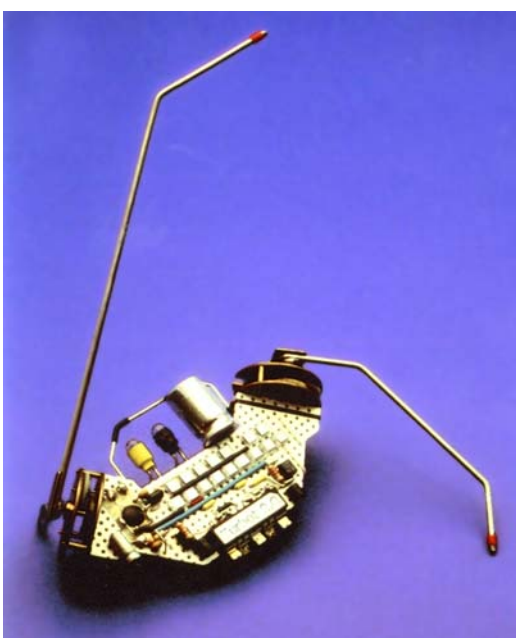
The knowledge of such vehicles is years old, but it has only been recently that work in behavior-based robotics has given such devices more credence. Mr. Mark Tilden (BEAM Founder) took the minimalist approach to robotics that first started with Professor Rodney Brooks of MIT, and built some very capable meso-scale legged robots. His shoebox-sized robots do not have a "world memory" that defines the shapes in the environment the robot lives in. Rather, his devices respond to their environment by direct stimulus-response, That is, these creatures don't have a complex internal world model, but simple reaction sets to changing exterior states. Machines built so far on this principle have proven abilities that match or exceed those using traditional computer and microcontroller approaches. For example, Mr. Tilden's $400 Unibug Walker (about 6" square in size) can easily traverse thick shag carpeting and grass, and negotiate complex terrain without falling or getting trapped, all without the benefit of a microcontroller and programming.



Basic Braitenberg devices as BEAM Robots

The BEAM supposition is that processors may be completely unnecessary, and that simple, symmetric electronics coupled with clever mechanical designs can produce devices that can "survive" in real-world environments, and maybe more. Simulations are unreliable, computers on wheels have difficulty surviving in complex environments, and Artificial Intelligence systems are too large and unwieldy to mount in small robots. Thus BEAM is at least one answer to evolve generations of stimulus based devices that, like the first protozoa on earth, must compete to survive.

The Micromouse HDL 1.0 (see the Micromouse chapter) was the first detailed behavior-based device built by Mark Tilden to support this idea. It can negotiate a complex maze from start to finish without the benefit of a processor. It instead uses seven simple independent electro-mechanical systems working in parallel to achieve its objective. These systems are placed in a hierarchy of behavioral significance so the mouse, without benefit of knowing anything other than its current status, can "figure out" what to do next. It does not do so efficiently, but certainly sufficiently. Total cost of development, $41.00 (Canadian) and less than 100 hours work.



Turbot 2 (Mark Tiltden, 1991)

But the better minimalist BEAM example is the reactive behavior-based device called a "Turbot". Better in that it is not so much smarter, but weirder.

The Turbot is essentially a self-mobile, tumbling, solar- powered paperweight. It uses two legs of unequal length to flip itself over. The heart of Turbot 2 is a heavily modified Hallmark "Happy Birthday Singer" chip from singing greeting cards, which is powered by two strings of photodiode sensors originally intended for reading punch cards.

The Turbot can haphazardly stumble across any terrain which has obstacles less than 2/3 its height. If it bumps into something higher than that, it simply deflects off it and carries on elsewhere, the robot randomly changing directions based on the angle of the flagella legs.

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The surprise is that Turbot, without benefit of exterior sensors, has shown behavior which mimics goal oriented systems and not the random patterns initially expected. It can "find" and move towards light (its sole food source), it can perform standard wall following techniques, it can find its way out of a corner and, given sufficient time, could even solve a micromouse maze in as little as half a year.

It is suspected that it does this because certain program settings cause it to fall towards a common chaotic attractor (a way of describing pseudo-random dynamics like cloud or wave patterns). The turbot is chaotic, but bounded in behavior stimulus. Further research will investigate this assumption, but the main point is that the device does have a series of recognizable behaviors, and at a total assembly cost of $27 (utilizing recycled electronics and oven-timer gearboxes), is probably one of the cheapest experiments in autonomous robotics to date.

There are thousands of others waiting in parts-boxes, surplus shops, and junk drawers everywhere (some assembly required).

On the evolutionary scale, the Turbot is the protozoan of the robot world, but every life form has to start somewhere. It is a valid competitor for the Photovore competition and hopefully will be the first of many. What, then, are the basic design rules to build a Photovore competitor? Well, disregarding older, more esteemed rules of robotics, here are three rules that will give a robot a fighting chance:

BIOMORPHIC LAWS OF ROBOTICS:

1 A robot must protect its existence

2 A robot must be able to acquire more energy than it consumes

3 A robot must continually search for better power sources

OTHERWISE KNOWN AS:

1 Protect thy ass

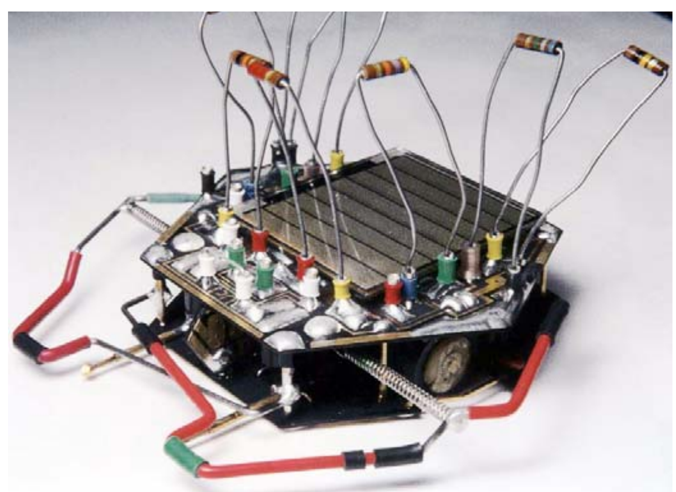
2 Feed thy ass

3 Look for better real-estate

Notice these are vastly different from the classic Asimovian ethical laws for robots (protect humans, obey humans, then look after yourself), which make for good fiction, but alas, lousy robots. An autonomous robot may have to be able to break those laws, if only accidentally, in order to be truly autonomous. A kind of robotic "freedom of choice".

We are not saying that a Photovore has to be a modified tank in order to compete. It is simply that the above rules are very easy to incorporate into robotic structure and control systems. It is through the exploration of unconventional ideas that more interesting discoveries will be made in this new science. (Besides, what kind of damage could a 300 gram robot do if it does decide to go berserk?) As well, there is something to be said for making a device without an off-switch. Such creations can be observed over a long time without fear of tether-influence or wearing batteries.

To begin, it is recommended that you build a Solaroller first, and then expand into building a Photovore or turbot-variant when the mechanical difficulties become familiar. The variations and varieties of Photovore creatures are next to infinite, but if you use common sense and experimentation, it is possible to build something that will surprise you with its "smarts".

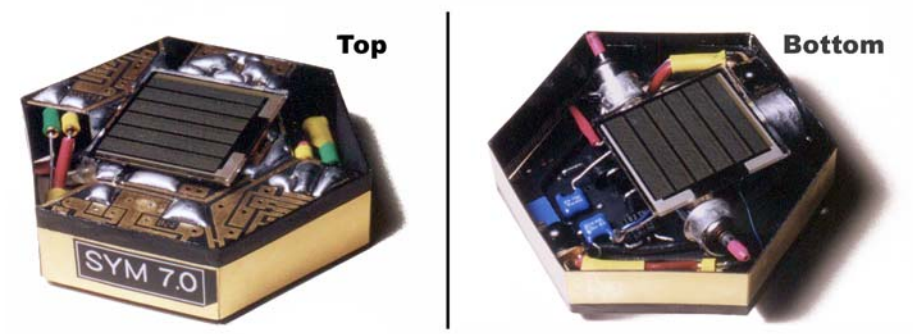


Unicore Photovore (Mark Tilden, 1998)

Being the quickest to the goal does not guarantee the win - your robot must be able to protect the bright arena goal from it's opponent. A slower, but more powerful Photovore can be last to the goal, push the other robot out, and still win the round! This behavior mimics what is frequently seen in nature - a seagull may be first to find the donut, but the stronger seagull will pursue him and rough him up until he gets the prize.

COMPETITOR DESIGN PARAMETERS: PHOTOVORE

1 The competing device must initially fit within the boundaries of a 150mm (6") cube. During competition, robot devices may vary their geometry as necessary but cannot deliberately leave any part of themselves behind. Competing devices must finish with all that they started with, although they may add to their mass if able.



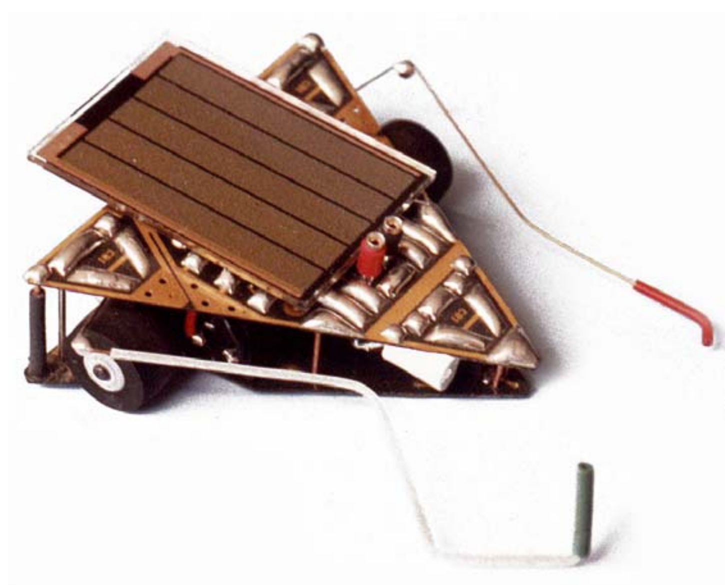
A Symet Photovore (Mark Tilden, 1996) that is able to live on overhead projectors as well as in the competition ring.

2 The maximum allowable solar cell surface area cannot exceed 2442 mm2 (3.79 in2). A 37x66mm, 5.5 volt Panasonic Sunceram BP3766 will be considered the norm. Any solar-cell configuration will be considered valid so long as the effective cell area does not exceed the maximum allowable. Any solarcell found to be in violation of the maximum area rule must be replaced, or the device will not be allowed to compete. There is no minimum solar cell size restriction.

3 No batteries (rechargeable or otherwise) are be allowed on the Photovore competitor, only verifiable electrical capacitors. Batteries (even nicads) have an inherent residual charge left in them, even after they've been run down. This residual charge would be an unfair advantage on the field of competition. No other form of power source (chemical, mechanical, animal, etc.) is allowed. Spring energy may be utilized only if the spring is energized only by the means of the energy produced via the solar cell after the start of competition. The competitor must extract all the energy it uses from solar cells on its chassis.

4 Devices are forbidden to exhibit deliberately destructive behavior (saw blades, cutters, electro-shock devices, etc.) towards other robotic competitors. All interactions between devices should be on the order of a pushing/grappling match.

5 Although devices are allowed to touch or follow internal walls and hazards, they are forbidden to intentionally damage the "world" in any way (beyond expected norms). Any device exhibiting such behavior will be disqualified and removed from play.



Micro BEAMAnt Unicore (Mark Tilden, 1999) - The above Photovore is a light-seeking, obstacle avoiding robot with visual & tactile sensors, and built-in backup ability all on one highly utilized 74HCT240 "Bicore" Logic Chip. Miniature gear-motors driving cassette-tape capstan wheels make this robot move almost continuously in direct sunlight, negating the need for batteries. The whole device is powered from th e24x33mm 2.7 volt solarcell mounted on top.

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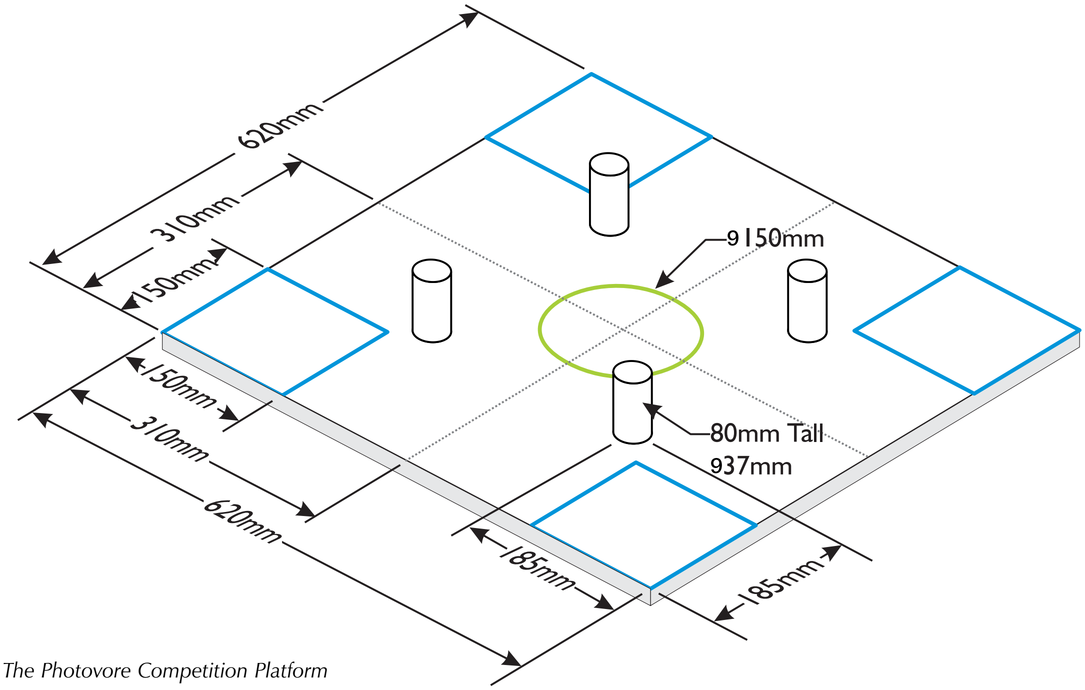
PLATFORM DETAILS: THE PHOTOVORE "WORLD"

The arena will be a level surface constructed of 5/8″ white Melamine or light-brown MDF construction particle-board. It will have dimensions of approximately 620mm (24.4″) square, with 80mm (3.15″) tall, 37mm (1.5″) diameter wooden dowel posts painted black fixed in four equidistant locations in the arena.



The Photovore Competition Platform

In addition to ambient lighting, the arena will be illuminated by a single 250 watt halogen lamp mounted in a standard Luxo-Lamp style fixture (the Satco Halogen double-envelope clear Bulb S3475 considered the norm). This fixture will be located and aimed directly down towards the center of the goal circle from an elevation of 300mm to the bulb tip. The goal circle is 150mm in diameter with a dot indicating middle, located in the center of the arena.

Each of the competitor robots can start from any of the four 150mm corner squares. The competitor must fit fully within the starting square, and a method must be made to ensure the device is at zero stored-energy potential at the time of event start. The initial orientation of the robot is to be entirely determined by the competitor at the start of the event.

The robots will have to contend with the four black posts mounted on the arena, and the shadows they cast. The posts will be mounted so tactile sensors will not have any cracks to be lodged in.

The goal circle and starting squares are marked with a 1mm black ink "Sharpie" marker. Photovore Competition Procedure:

At the time of competition, the robots will be placed in competitor-selected starting squares, and the energy "kill" mechanisms put in place. At the judge's indication, the kill mechanisms are disabled and the timer started.

The first robot to cover the dot in the middle of the goal circle with a part of it's body will be awarded a fi point. Passing a sensor flagella or sensor stalk over the dot does not constitute covering the dot, nor considered part of the robot geometry when it comes to finding the geometric center of the robot. If neither robot successfully covers the goal circle dot, the fi point will not be awarded.

At the end of the 5 minute round, the light source will be turned off, and the energy "kill" mechanisms put back in place to arrest any further movement. The robot nearest to the goal circle dot will be awarded a full point. Distance will be measured from the geometric center of the robot (as determined by the judge) to the goal circle dot.

The robots cannot be interfered with in any way until the round finishes at the end of the 5 minutes, unless if the judge rules that the round has come to a definite conclusion. This covers contingencies such as both robots stalling, or a robot failing in the starting square. ✯