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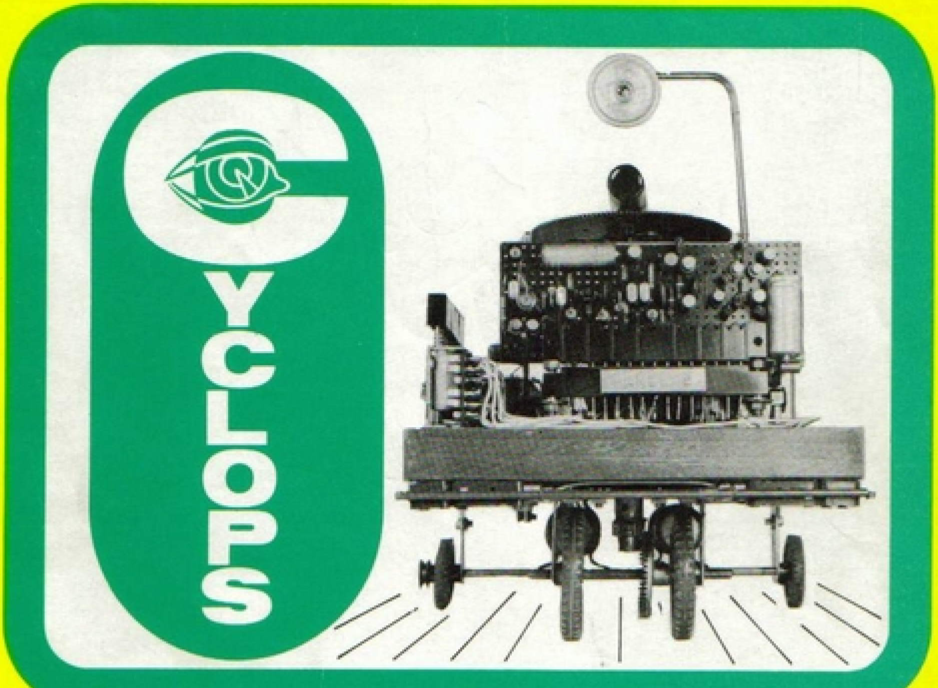

ELECTRONIC ROBOTS—Part 1

Describes various types of robot and introduces CYCLOPS — an electronic robot for home constructors

FEATURED IN THIS ISSUE

- Bedside Reflex Receiver
- Winding Toroidal Coils
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Cover Feature

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PART ONE

EXAMPLES OF THE USE OF CYBERNETICS which is the science of feedback control, have become proliferous in recent years. In general, the wide field of Cybernetics may be divided into two main regions. The first is where a device is built to perform a number of specific pre-determined tasks, and devices of this nature are known as servo-robots. The other region encompasses devices which are built with a much more diversified approach, and have no specific purpose but to exist. They are ususally much less specialised, and are known as auto-robots.

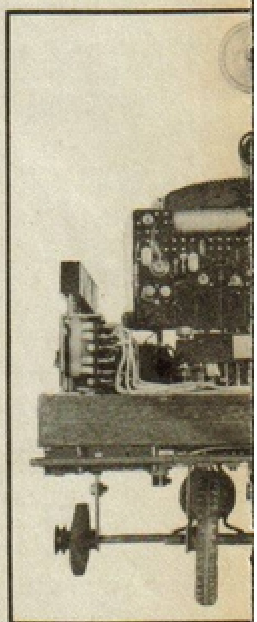
Examples of the former device are to be found everywhere. Computers, industrial control systems, traffic light systems and even common devices such as the motor car, the refrigerator and the washing machine are all servo-robots relying on feedback control.

The most common form of auto-robot is Homo Sapiens, a very generalised machine apparently having no specific purpose but to exist and better his environment. As mentioned in the author's earlier articles concerning 'Cynthia'[1], Man has had for a long time a compulsion to build something emulating himself. At present, his attempts in building various types of auto-robots have been fairly successful, the ultimate development to date having taken place in America with the programme at The Stanford Research Institute for developing a mobile automaton. Details of this device will be appearing in a later article. However, there is at present one limitation to the complexity of the systems that can be built, and that limitation is the finite speed of light.

The reason for this situation is as follows. When one compares the human brain to a computer, the latter, in certain aspects, is far superior. For instance, the rate of transfer of information, storage rate, and reset time of individual elements in a computer are all very much faster than the corresponding rates in the human brain. On the other hand, the human brain excels in storage capacity, and also in the fact that each element in the brain is connected to many more other elements than occurs in a computer. This rich interconnection in the human brain means that it can process information parallel with other information, as opposed to serially. The brain also has a very good filtering capability and, unlike the computer, can receive general information as opposed to pre-digested information. In the event of a component breakdown the brain appears to be 'holographic' in nature, in that it still gives the correct answer to a problem although sometimes to a lesser accuracy. In the event of a computer breakdown, a 'nonsense' answer usually results. Also, the brain can deal with general problems, whilst the computer is rather more limited.

The reason why the computer cannot at present have richer interconnection between elements is that, at the speeds computers operate, light (and therefore electricity) travels but a few feet per computer operation.

[1]L. C. Galitz, 'Cybernetic Cynthia', *The Radio Constructor*, June, July, 1970.



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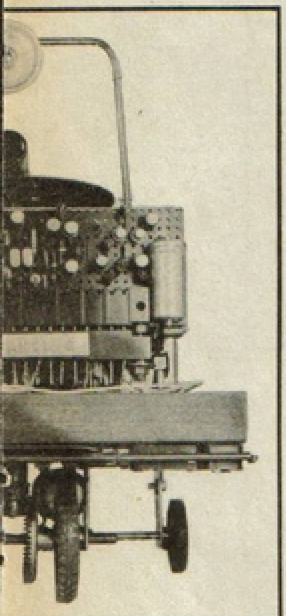

yclops, taken from a low The light bulb and reflector inder immediately below is e housing

by L. C. GALITZ

*

Therefore, in order that computer processing should operate in step, no two units in the central processing unit may be connected by a wire of more than two feet or so, otherwise pulses will arrive too late for any particular operation. At present, it is impossible for a machine to be built with all the relevant electronics in a sphere of radius less than about a foot, and with sufficient complexity to even approach that of the human brain. Nevertheless, we have still come a long way since Babbage's Analytical Engine.

CYCLOPS

One very useful way of finding out about something unknown is to build a model of it, and see how closely it imitates the real thing. In many cases this is the only way, and in some cases, such as solving the mystery of the human brain, it is the most practical way. Many auto-robots nowadays are mechanical equivalents of real animals, and such is the case with Cyclops, which is an approximate electro-mechanical equivalent of an animal in the amoeba family. Although most of Cyclop's behaviour is predetermined in the circuitry, one of the earlier prototypes surprised the author in imitating something which, although beneficial to both animal and machine, had not been intentionally put in!

Cyclops was designed with several criteria in mind. One of the most important of these was that he should explore his environment looking for things to happen, rather than passively wait for them to occur. Cyclops was to be positively tropic[2] towards light, and negatively tropic towards touch and bright lights. In other words, Cyclops is attracted by lights of a moderate intensity, and repelled by lights of dazzling intensity and also by obstacles into which it bumps. An advantage of using light as the sole attractive stimulus is that light, by way of solar cells, can mean food, i.e. electricity. In a perfect machine, the robot would be equipped with a bank of solar cells and, on finding a light, would pause to recharge its batteries. After its 'meal' it would then move off to explore further its environment. Thus, the perfect machine would show internal stability, and by reason of its positive tropism be self-perpetuating. Unfortunately, due to the prohibitive cost of a bank of solar cells providing sufficient power to recharge the machine's batteries within a reasonable length of time, another approach is needed for a practical device. A cheaper alternative would be for every light source to be equipped with a low tension supply, so that the machine would be capable of locating the light, homing into it, and plugging itself into the power source in order to recharge its batteries. Once these were recharged, the machine could move off again.

Returning to Cyclops in particular, other design requirements were that he should be able to recognise his reflection in a mirror, and that he should be able to recognise other members of his species.

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[2] Derived from 'tropism', the response of protoplasm to stimulus.—Editor.

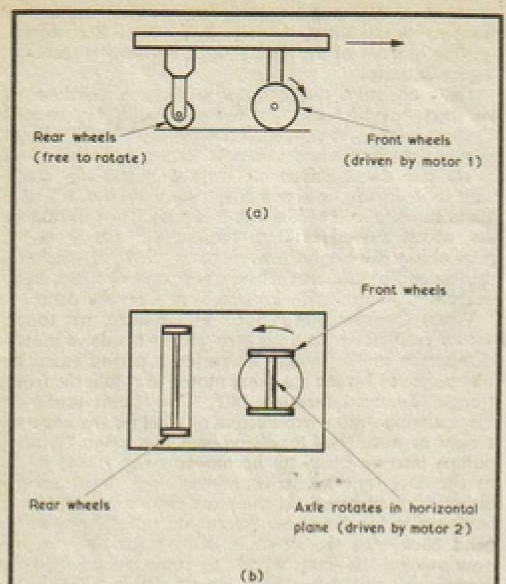


Fig. 1. Side view (a) and bottom view (b), illustrating the drives to the front wheels and their axle

To sum up, Cyclops will explore his terrain looking for light and, upon finding some will approach it and when sufficiently close, stop as if to recharge his batteries. Should he be dazzled, he will move off, and he will also avoid obstacles. This is sufficient to make him self-perpetuating. In order to be more realistic, a learning circuit was introduced, which enables Cyclops to make decisions concerning himself and his actions in relation to his environment.

BASIC DETAILS

The basis by which Cyclops works is by having the electronics control two motors. One motor drives the front wheels round to make Cyclops move. The other motor rotates the front wheels' *axis* through 360° and so changes the direction in which Cyclops moves. The drive from this second motor is in one direction only and cannot be reversed. The arrangement is shown in the side view of Fig. 1 (a) and the bottom view of Fig. 1 (b). The front wheels are caused to rotate by Motor 1, and their axis is rotated by Motor 2. The rear wheels are free to rotate and are not driven. Figs. 2 (a) to (d) illustrate how the rotating front axle changes the direction in which Cyclops moves.

With both motors running, Cyclops follows the path shown in Fig. 3. With the gear ratios incorporated the diameter of this pattern is approximately 6ft. Thus, quite a large area is traced out. The area would be larger if Motor 2 ran more slowly, but if this motor is geared down too much the robot will not home into light sources effectively. Hence, a compromise has to be reached.

Motor 2 not only rotates the front wheel unit but also a unit upon which the 'eye', which senses the presence of light, is mounted. The eye rotates at the same speed and in the same direction as the front wheel and thus always 'looks' in the direction in which Cyclops is moving. This rotation of the eye is referred to as 'scanning'.

When Cyclops sees a faint light, the electronics operate a relay which cuts the power to the scanning motor (i.e. Motor 2), causing Cyclops to move in the direction of the light. It will be appreciated that, unless the eye happens to be pointing straight ahead at the time Cyclops will tend to veer away from the light source, and the scanning motor will cut on. If the scanning stopped at an eye position such that, when the scan restarts, the eye turns in the direction which will bring it to the straight ahead direction sooner, the eye will be brought in line with the light source almost immediately after scanning starts again. Thus Cyclops will once more start heading for the light. He will then veer again for a shorter distance, after which the

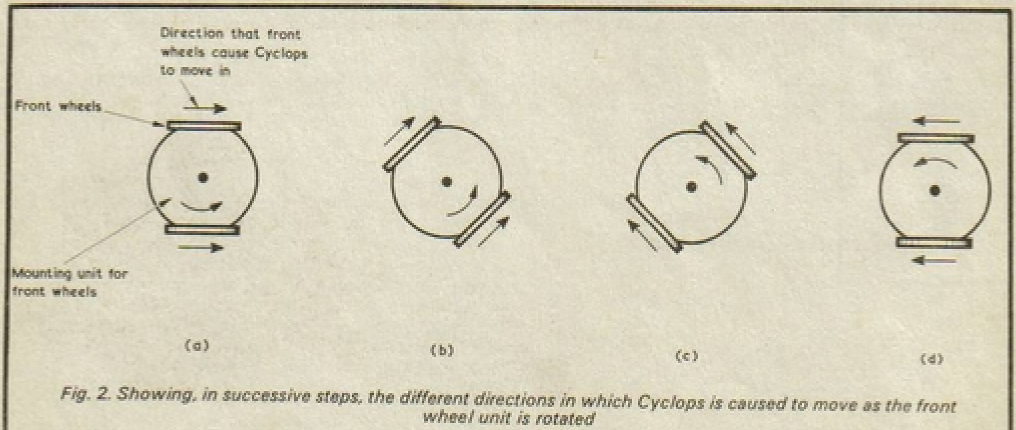


Fig. 2. Showing, in successive steps, the different directions in which Cyclops is caused to move as the front wheel unit is rotated

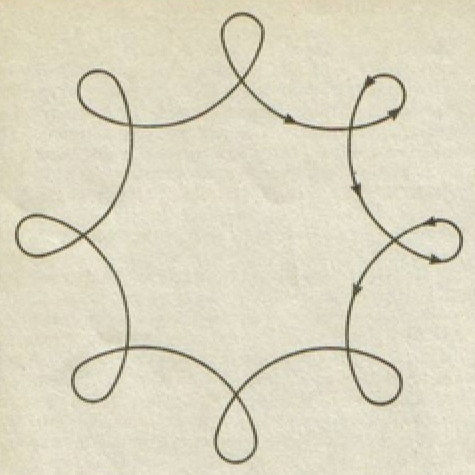


Fig. 3. The pattern traced out by Cyclops when not subjected to external stimuli

.anning motor will once more cut on. This process repeats in quick succession until the eye is pointing straight ahead, and Cyclops will then move straight towards the light. If the eye had stopped rotating in such a position that, on resumption of scanning, it moved in the opposite direction to that just described, then the eye will come to point straight ahead the longer way round. That is to say, it will perform almost a complete rotation before it sees the light again. The process previously described will then take place, ending with Cyclops moving straight towards the light.

When Cyclops is sufficiently close, and the light has reached a sufficiently intense level, the electronics switch both motors off, and the robot waits in front of the light. In the perfect machine, either there would be a bank of solar cells to collect the light and recharge the batteries, or there would be a low tension supply associated with each light source so that the robot could plug itself in to recharge its batteries. Unfortunately, due to the excessively high cost of the former scheme, and due to the mechanical difficulties involved in arranging a reliable form of plug and socket suitable for the latter, it has to be assumed that, whi.st waiting in front of the light source, Cyclops is recharging his batteries.

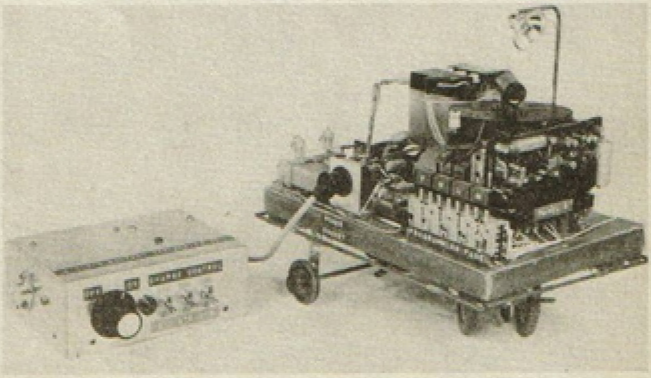
The electronics also arrange an 'ignore' mechanism for very bright lights, or for normal lights should Cyclops happen to approach too closely. Thus Cyclops avoids the 'moth in the candle flame' problem. Due to the fact that Cyclops will only start homing into a light source when he is pointing towards it, he will also avoid the dilemma of Dante's free man, or of Buridan's ass, which starved to death because two exactly equal piles of hay were equidistant from it. If placed precisely the same distance away from two equi-brilliant light sources, Cyclops will visit one, and then the other.

When Cyclops bumps into an obstacle, his touch sensor activates a circuit which causes his drive motor to operate in the reverse mode for a period equal to that required for the scanning motor to rotate the front wheels' direction through 180°. The circuit turns on the scanning motor irrespective of whether the eye sees a light or not. Thus it will be seen that when Cyclops bumps into an obstacle, he moves away from it due to the fact that his drive motor, and therefore his direction, is reversed. At the same time, his scan motor is changing his direction. Then, just as he is about to head back into the obstacle due to the scan motor now causing the front wheels to point in the opposite direction, the drive motor reverts back to normal, reversing the drive again, and therefore causing Cyclops to continue to move away from the obstacle. Due to the fact that the obstacle-avoiding circuitry overrides all the other positively tropic responses, Cyclops will always get himself out of trouble before trying to feed on an otherwise attractive light source. If he were to try and force his way through an immovable object in order to get to a light, it would not be too difficult for him to initially damage his touch sensors, and even for his motors to stall and overheat. Thus touch may also be regarded as being a stimulus of pain, and this fact is used when he is being taught to use his learning circuits.

RECOGNITION

The method by which self- and mutual-recognition is achieved, although apparently difficult, is really very simple to engineer. A lamp with a reflector is fitted to the machine so that it shines in the forward direction.

Cyclops at rest as the batteries are charged



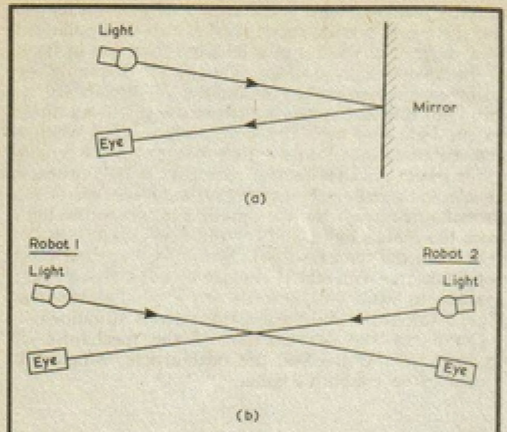


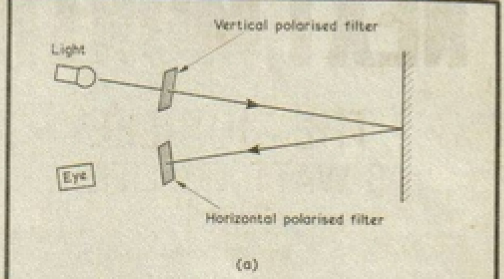
Fig. 4 (a). Cyclops can achieve self-recognition when confronted with a mirror

(b). Mutual recognition between two robots is also possible

t is wired across the main drive motor with the result that, when the machine moves the lamp is illuminated, and when the machine stops the lamp extinguishes. If now a mirror is held up to Cyclops' eye such that he sees the lamp's image through the mirror, he will stop, the light being of sufficient brilliance to activate his 'stop to feed' circuitry. However, the action of this circuit is to cut the power to the motors, and this will extinguish the lamp. As Cyclops can now no longer see the lamp, his 'stop to feed' circuitry will revert to its normal state, and the power to his motors will be restored, and hence the lamp will light up again. This cycle of events will continue for as long as the mirror is held in front of Cyclops' eye, and he will linger in front of the mirror flickering, twittering, and jigging like a clumsy Narcissus. This highly specific behaviour towards his own reflection may be accepted as evidence that Cyclops has some degree of self-awareness. See Fig. 4 (a).

If we consider the result when two 'animals' of the same species as Cyclops encounter one another, we find that they home into one another owing to the attraction of the light. However, as this happens, the lamp and therefore the stimulus is cut off, but the removal of the stimulus restores the light which then becomes a stimulus again. Thus, the two animals dance about one another. See Fig. 4 (b).

With a colony of such creatures, the very fact that each animal extinguishes its own source of attraction in the act of seeking it in others means that the colony, when no other attraction is presented, must stick together. Such a colony will also attract other creatures of the same species due to the fact that the colony is giving off light. Unfortunately, the very gregariousness of creatures of the species of Cyclops is that species' downfall, because even though an external light source will attract several members of the colony, a good many will remain behind. It is not difficult to realise that the light source of the colony (the animals themselves) can never be sufficient to recharge the batteries of the animals therein, and eventually all the animals forming the colony must eventually die unless an external light source is available. An interesting point which arises here is that when an animal is reaching the end of its life its batteries will be low, and therefore the light it



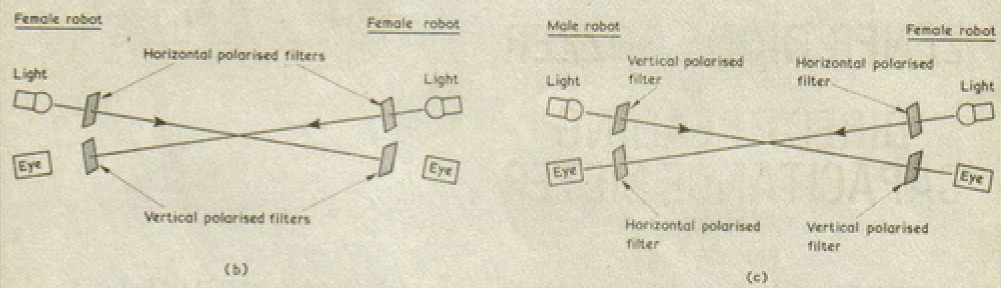


Fig. 5 (a). Although not incorporated in the present model, polaroid filters may be added to modify robot reactions. Here, a male robot is confronted by a mirror but the vertically polarised light cannot pass through the horizontally polarised filter and there is no reaction

(b). The filters ensure that one female robot is not recognised by another female robot

(c). Recognition is only achieved between a male and a female robot

emits will be dim. Therefore, there will be less likelihood of the animal going through the self-recognition response, and also the mutual recognition response, which would certainly be its downfall. The animal would rather look for light to replenish its waning power source than to participate in games with itself or with other animals of its own species.

One can be pedantic about this feature of mutual recognition and, at the expense of the self-recognition feature (which may be regarded as undesirable anyway) one could incorporate polaroid filters in front of the light source on each animal, and in front of the eye. These filters could create arbitrary males and females of the species. With this arrangement, a male will not react to itself or to another male; similarly, a female will not react to her reflection or to another female. However, males and females will react with the mutual recognition response upon encountering one another.

This feature can be accomplished by having a horizontally polarised filter in front of the light of a female and the eye of a male robot; and a vertically polarised filter in front of the eye of a female robot and in front of the light of a male robot. Thus, when encountering a mirror, neither variety of animal is able to see its own light due to the fact that there are opposing filters on the light and eye. The same thing occurs when a male robot meets another male robot, or when a female robot meets another female robot. It is only when a female and a male robot meet that the filters are of the correct orientation for the female eye to see the light from the male's light, and for the male eye to see the light from the female's light. Naturally, the filter does not interfere with the light from unpolarised light sources, to which the animals are normally sensitive. Figs. 5 (a), (b) and (c) show the various situations.

Details of the construction of the mechanics of Cyclops will be given in the next article, which will appear in next month's issue.

(To be continued)