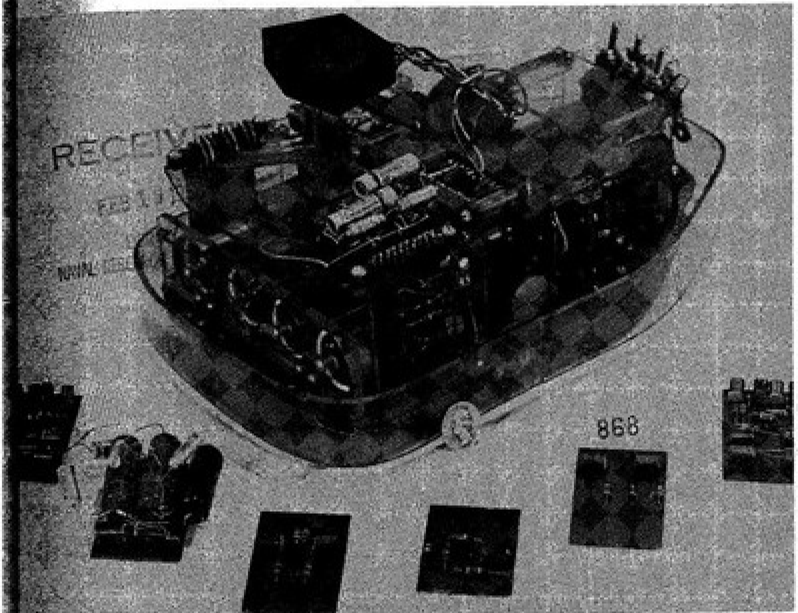

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An Electro-Mechanical Model of Simple Animals

Comparing Digital Computing Systems

Automatic Programming for Business Applications

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An Electro-Mechanical Model of Simple Animals

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Scarsdale and Troy, N.Y.

(Based in part on a thesis submitted by W. R. Sutherland and M. G. Mugglin to the Department of Electrical Engineering, Rensselaer Polytechnic Institute, Troy, N.Y.)

OUR SUBJECT lies in a novel and relatively unexplored field to make a machine that mimics some of the characteristics of living things. To do this requires a combination of electronics and biology, yet it is difficult to bridge the gap between two fields so far apart. However, we have constructed and studied some electro-mechanical models of simple animal life, and the purpose of this article is to report on what we have studied and constructed and to discuss some of the implications.

We should like to acknowledge our indebtedness to W. Grey Walter, Claude Shannon, W. R. Ashby, and other scientists who have examined automata and robots, either theoretically or with working models. For example, W. Ross Ashby in England has built a device which he calls a homeostat. It behaves like a sleeping cat which when poked finds a comfortable position and goes back to sleep. It has a very large number of possible stable states so that whenever it is disturbed it methodically searches until a new stable state results.

W. Grey Walter has published an account of the "life and habits" of an electro-mechanical creature which he built and named mock-biologically "Machina Speculatrix." When placed in a room or other suitable environment it would immediately *begin to explore* following a cycloidal pattern. Speculatrix would turn from its wanderings to investigate lights. It was attracted to light of medium intensity and repelled from strong light. When it bumped into an obstacle it would back and turn until it had freed itself. During the time it was escaping from an obstacle, Speculatrix had no interest for lights. This singleness of purpose is necessary for it to avoid becoming caught on the horns of a dilemma. Neither could it be caught between two lights of equal intensity but would go first to one and then to the other. It was also capable of recognizing itself in a mirror because of a pilot light on the creature itself. Last but by no means least, when its battery began to run down it would seek out its "hut" and go there to be recharged. A later attachment was added to the animal so that it could learn. This involved the analogy of a conditioned reflex so that it could be taught that "sound means light" and hence would come into the room on hearing a whistle.

It is becoming increasingly apparent today that there are similarities between the behavior of electronically controlled machines and that of certain animals. Since we design computing machines to carry out operations that seem logical to us, we should not be so surp when they show some of the same tendencies and ceptibilities that animals do, nevertheless we are s how we find it difficult to admit that machines ma have in a life-like manner.

An electro-mechanical model has many advan over the animal it imitates. Parts are interchang closer control and measurement are possible, a better understanding of the mechanisms involved be afforded.

Desirable Characteristics

Some of the characteristics that are inherent in an are difficult to accomplish in machines. The probl learning and forgetting is one of these. Comp machines learn instantly and retain the informatio tact until cleared, whereupon they forget instan well. This is a desirable characteristic in a comp machine but is not a characteristic of life, which slowly and forgets slowly. The same objection m raised in the case of Claude Shannon's mech mouse which fidgets its way through a maze bu into the walls until it eventually reaches its goal second time it goes through the maze it rememb way perfectly making no mistakes. It does not unless the machine is turned off, clearing the me A more life-like model should learn gradually th repeated trials and forget slowly if the experience repeated.

Another problem is that of getting some sort predictable or experimental behavior. This is a knotty problem, and in the machines we have structed it is solved in only a limited fashion, b way not inconsistent with the machine's low intelli The machine has a set of alternatives to choose when it encounters a given situation. Which alte it chooses is tied in with the problem of learning shall see presently. However, it should be obvio if the model is to have any interest for most gators, it must be somewhat unpredictable.

Another important characteristic to put in a machine is curiosity. When placed in a strange en ment, an animal will begin to explore, encou many varied situations. This was lacking in one earlier models. The lazy thing just couldn't be b to look for some fun but preferred to sit idly unti thing stimulating it came along.

A model of an animal should also have a mo sing interest in its surroundings It should actively ek some goal such as a light as a moth does Curios y plus goal seeking provides a basis on which more plex behavior can be built

It is of course inevitable that such a model will run o many obstacles during its explorations Some means f escaping from these 'stumbling blocks' must be pro ided

A group or small society of these mechanical animals ld also have some way of communicating in a very ple *fashion* Without this characteristic there would e little chance of getting any cooperation or analogous oup behavior

Finally, it is important to point out that there is a fference between models that imitate the *appearance* f life and those that imitate the *behavior* of living ganisms There was at one time a toy beetle on the arket that illustrates this point quite well It had two ar driving wheels and a front transverse driving wheel was so constructed that a feeler was in contact with e table top where it rested and the feeler was long ough and positioned so that it prevented the trans erse driving wheel from resting on the table The etle would run forward until its feeler ran off the edge e transverse driving wheel then would fall on the ble and turn the beetle away from the edge The same pe of mechanism has also been mounted in a toy car e important thing is not whether it looks like a beetle r an automobile, but rather that we have here a mech ism with a built in instinct for self preservation in hostile environment

These are some of the desirable characteristics of a odel of animal life, however it is sometimes a problem o mean proportions to design a working mechanism ing these characteristics

Power for Electro-Mechanical Animals

All life depends on energy obtained from some kind food A model of life must likewise obtain energy d should be able to store it for future use However, e choice of a power supply for a model animal is some at limited The power supply must be portable and erefore reasonably light, it must be independent of environment except for "meal times", and it must t be too difficult to construct

A gasoline or steam engine would be light and easily but, besides being difficult to connect to the driv wheels, a convenient size is not available Further ore, the fumes are a problem

Compressed air would be a better source of power We have experimented with an air tank and a wind ld wiper motor and found that, although this sys m worked, it was too hard to control Then too, high ssure air is not easily available

A storage battery seems to be the most practical It s some disadvantages, namely a low energy storage, h weight, and a long recharging time, but these are weighed by its availability and ease of connection evious experience that we had with the electro me anical squirrel Squee of E C Berkeley, which used a volt Willard wet battery, showed that a higher ltage source was definitely desirable A higher voltage em would have less current drain, simplifying the rol problem and extending the operating time be en chargings A surplus 28 volt Willard battery of reasonable size was available and was the supply of the June 1957 models In addition, some small but powerful 28 volt, DC series wound motors were cannibalized from surplus fans and became the driving motors

But subsequently we transistorized and lightened the whole model animal The September 1957 model (see Figure 1) contains three sets of dry batteries about ten size D flashlight batteries, about six penlite batteries (for the transistors), and 2 Burgess 67½ volt batteries

Steering and Driving

For steering, both Walter's Turtle and Berkeley's Squee made use of a single front wheel for both steering and driving There were two rear wheels for support, free running, much like a child's tricycle This method has at least one serious drawback it is mechanically difficult to construct The driving motor must be mounted on the steering column, making it bulky and requiring brushes and slip rings Therefore, we decided to use two independent front driving wheels and one free rolling rear caster Driving one wheel or the other provides a method of steering somewhat analogous to that of a caterpillar tractor

Our first model animal (Spring, 1956) showed the advantages of these basic changes As expected, the driving and steering systems worked well, and the higher voltage was a definite asset Nevertheless this animal still left much to be desired Its bumpers were unsatisfactory, and the battery needed to be mounted so as to be accessible without dismantling the machine In addition the dynamotor, which was the plate supply for the vacuum tubes, drew too much current We decided to switch to transistors and get rid of the vacuum tubes Doing this had double effect, it eliminated not only the dynamotor but the filament current as well

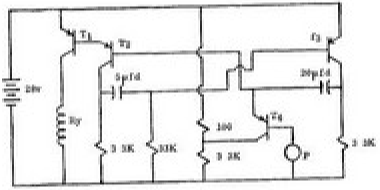
During the summer and fall of 1956 we started constructing a second model, which included desirable features lacking in the first model The second model had a cast aluminum body, and its battery could be removed through the bottom The battery was covered by a plastic case which supported the bumpers and many of the components The bumpers themselves were bent out of plastic and hung from the battery case by four spring wires

Permanent Senses and Active Responses

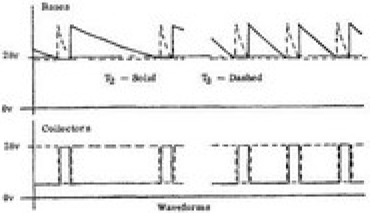
Once the power supply and the basic mechanics of the model were decided upon and worked out, our next problem was making the permanent senses These senses are sight, hearing, and touch and the responses are moving, squealing, and lighting up

To control the motors, we need relays, but instead of a simple on off control, each relay was run by a multivibrator, which pulsed it periodically (see Figure 2) Varying the repetition rate of the pulses provided a variable motor speed This system proved to be quite satisfactory The only drawback is sparking at the relay contacts Each motor had an additional relay to control its direction (see Figure 3)

The model's eyes directly controlled the repetition rate of the multivibrator The motor relays receive a pulse every two to five seconds when the model is in complete darkness When the eye sees light, its resistance decreases, the pulses become more frequent, and the motor speed increases



Circuit



Waveforms

Figure 2. Multivibrator Motor Control. Note how T_4 provides a variable time constant which changes the spacing of the short on-pulses. T_1, T_2, T_3 — Clevite 1032. Ry — Motor relay. T_4 — Raytheon CK 722, low leakage. P — Photocell, Clairex CL 3.

Each eye consists of a cadmium selenide "retina" (photo cell) mounted in an eye socket. The socket limits the field of vision to a 30° cone. The eyes are mounted on a circular "head" so that the animal may be made to look in any direction. If the eyes are set at a slightly diverging angle, a light directly ahead will be seen by both eyes while a light moving to one side will pass out of one eye's field of vision before the other's. Connecting each eye to the opposite motor enables the model to follow a light. A light illuminating only one eye will drive the opposite motor, turning the machine until both eyes see equally well. If the head is pointed forward, lights are attractive. If the head is positioned sideways, a wary circling results. If made to look "over its shoulder," the model slinks away from the light like some forlorn nocturnal creature.

The plastic bumpers provide the model animal's sense of touch, enabling him to detect obstacles. The circuit adopted for obstacle evasion is shown in Figure 4. Each motor's direction is controlled by a neon tube oscillator and oscillates between forward and reverse. The two oscillators are independent of each other, making the resulting motion a random jigging that will eventually take the animal clear of the obstacle. The rest of the circuit is a delay which continues the jigging for about three seconds after the bump signal ceases.

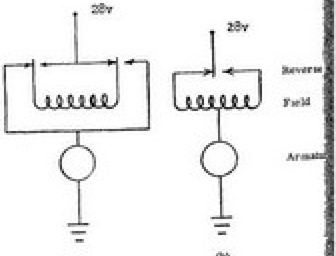
Communication

The one construction problem we did not finish to our satisfaction was communication between animals. Making a voice was easy, but the model's ear was an inherently difficult problem. The motors are noisy ear must reject this noise but yet pick up sounds the other animals. This means either using a very "voice" in each animal or else filtering out the noise. Several attempts at filtering were made, successful. So it seemed best to bypass the proble moving the frequency into the rf range. 425 cycles provides a reasonable antenna size (¼ length is 7 inches) and we had a small transmitte that frequency. The receiver for each animal, ho has not yet been built. The use of this "hearing transmitter to rebroadcast audible sound should no change in the external behavior of the model fact an observer could not tell the difference.

The last response included is a light mounted on animal and controlled by a relay (see Figure 3). present the light is connected so that it is on whe animal is moving slowly and goes out when motio comes rapid.

To make the models versatile the componen mounted in interchangeable printed circuits. The ing is made from a copper clad formica board by tecting the desired layout with tape, and then e away the undesired copper.

The animal's brain, where the senses are connect the responses, is also easily changed. It is mount a small chassis which plugs into the animal. Th changing brains a cowardly animal may be made a ferocious beast.



(a) (b)

Figure 3. Motor Direction Control

Characteristics of a Brain

The most basic type of behavior is instinctiv stinct is possessed by all animals. In fact, the forms of life operate purely as a result of it. If w to consider the brain of an animal as a "black instinct would dictate that the inputs and out directly connected. That is, the same stimulus always produce the same response.

As we progress up the ladder toward highe of life, we find what might be called a "capa learning." This implies that there is a physic vision for switching between stimuli and re whether this provision is ever used or not. It is

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An Electro-Mechanical Model of Simple Animals

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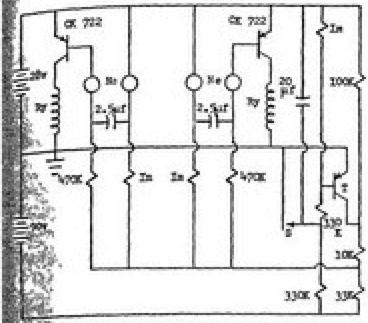

Figure 4. Improved Obstacle Evasion Circuit. T—Raytheon CK 722. Ry — Reverse relays. S — Bump contact.

[illegible] physically possible for the animal to change its behavior to meet the circumstances of the moment.

Obviously, two other characteristics are necessary before learning can take place. These are memory and association. One must not only recall but correlate past experiences before they become significant.

The highest function of a brain might be termed "intelligent behavior." This consists in making choices which are shaped by the learning process. Whether a [illegible] is "intelligent" or not depends on whether the [illegible] is beneficial or not.

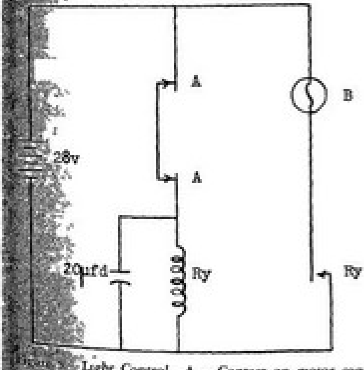

Figure 5. Light Control. A — Contact on motor control relay. B — Light Bulb.

The problem is to design circuits possessing these characteristics. Instinct is easy to imitate. Any behavior of a machine where a given input always produces the same output may be said to operate by "instinct." A capacity for learning is also easy to provide. All that is necessary is to design the model in such a way that there are many possible connections between the inputs and outputs of the "black box." Both of these characteristics were incorporated into our model.

As was previously mentioned, however, the problem of designing a memory that would learn and forget slowly seemed to be difficult. Walter's *Machina Docilis* had a memory that consisted of a slowly dying oscillation in its conditioned reflex circuit. This type of a memory has a tendency to be unstable and somewhat complicated. Obviously what is needed is a physical phenomenon which has a long time constant and is electrically detectable (see Figure 6). After consideration of many highly impractical schemes, the answer turned out to be ridiculously easy. A thermistor potted in plaster of paris and mounted inside a hollow, ceramic resistor has exactly the desired characteristics. The phenomenon that has the slowly decaying characteristic is the temperature of the unit. Electrical energy is put into the ceramic resistor and is changed into heat. The thermistor has a high negative temperature co-efficient of resistivity and functions as a detector. The rate of "learning" is controlled by the resistance of the heater while the rate of "forgetting" is determined by the amount of surrounding thermal insulation. This system has some advantages. One of these is that thermistors are available in many different shapes and sizes. Another is that the method is extremely simple.

The problem of association is the problem of designing a conditioned reflex. Here again the reader is

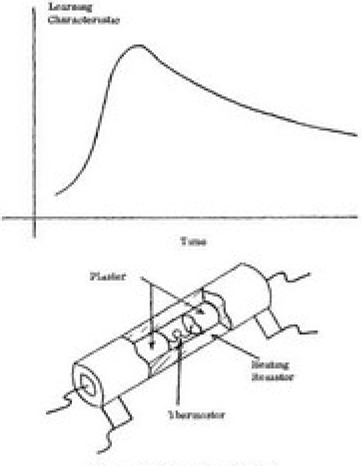

Figure 6 Learning Method

referred to W. Grey Walter's "The Living Brain." The chapter on the seven steps from chance to meaning gives an excellent discussion of the processes that are necessary for association. Dr. Walter has also built a circuit which embodies these processes. We therefore decided that rather than simply duplicate work so well done, it would be more profitable to investigate the intelligence aspect.

An intelligent being must first of all possess the power of choice. When faced with a set of properly defined alternatives, this hypothetical person must choose one alternative even if that one is to do absolutely nothing. To be properly defined, such a set of alternatives should be mutually exclusive and exhaustive. This is not really difficult to do. Cases where two alternatives overlap may be defined as new and independent alternatives, preserving the exclusive requirement. To make the set exhaustive, a "catch all" alternative may be introduced to include everything that the model animal might do that is not one of the defined alternatives.

Each alternative has an associated probability of being chosen. The value of this probability is dependent upon many factors such as a person's previous experience, his emotional state at the time, or what he had for breakfast, perhaps. Certainly what he has learned from previous experience is not the least factor that shapes the probability distribution.

If the set of alternatives is mutually exclusive and exhaustive, then the sum of the probabilities is always unity. The effect of the learning process is to cause a redistribution or "flow" of probability between the various choices. Consider the following example. If we have a maze built in the shape of a capital T and we send a number of hungry rats through the maze, each one will be forced to choose whether to go right or to go left. If retracing is not allowed and we place food *always* on the right but *never* on the left, we should find that, on the first trial, about half will go right and half left. In other words, the probability of a particular rat going right should be about 0.5. However, after a number of trials, the probability of a rat going right should be considerably enhanced. In any given trial, we would never be able to predict which way the rat would go, but we would have a good idea of the probabilities involved. Learning, characterized by such a flow of probability may be said to complete whenever the flow ceases and the probabilities become stable. If the training is now stopped the rats should slowly but surely forget and the probabilities be correspondingly changed.

The ability of man to choose his course of action is often called free will. From a strictly external and objective point of view, it may be argued that free will means simply that the behavior of the organism is unpredictable in any given instance. The problem now facing us is to find a circuit possessing these three characteristics: learning and forgetting, its associated probability flow, and unpredictability.

In our search to find a circuit that would appear to choose quite randomly from a set of alternatives, we considered using a neon tube relaxation oscillator (see Figure 7). The operation of this circuit is such that the

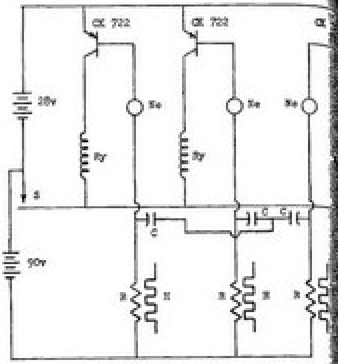

Figure 7. Probability Learning Circuit. H & R —
ing Resistor and Thermistor. C — Chosen with
mistor for desired time constant. S — Choice c
closed momentarily.

neon tubes flash in sequence. At any given time o
only one tube is on. When the voltage across one
others builds up enough to fire that tube, the
change in potential shuts off the tube that is on. L
three tubes represent three alternative responses to a
stimulus and let whichever tube is on, at the inst
stimulus is applied, be the response that is chosen
provides the desired unpredictability. It can easily b
that the ratio of the time a particular tube is on
total time for a cycle is the probability of that re
being chosen.

All that is necessary to make this circuit poss
probability flow characteristic and the slow learn
getting characteristic is to vary the size of one of
sistors. The means of accomplishing this lies right
finger tips. The thermistor-heater combination hol
key. The thermistor is substituted for one of the re
and the heater is connected in such a way that the s
causes a brief heating current to flow. Applying he
creases the resistance of the thermistor and increa
length of time that its associated tube is on in prop
to the others, so that the probabilities will change
is more, they will change gradually as the thermisto
and return even more gradually as it cools.

Our model now possesses a number of the desire
acteristics under discussion.

1. Instinct — The model follows lights.

2. Capacity for Learning — The behavior of the
is flexible: there are many possible connections b
inputs and outputs.

3. Memory — Thermistor and heater circuit.

4. Experimental and Unpredictable Behavior —
tube circuit.

5. Probability Flow — Combination of 3 and 4

Actual Behavior of the Model

We come now to a discussion of the actual behavior of the model which we have constructed and which we have named Machina Versatilis.

The model is capable of following lights and is able to escape from obstacles. When the battery is placed in [illegible] and the switch is turned on, Versatilis begins to move. His curiosity causes him to begin to search immediately. How curious he is depends on the light level in the room. As the light gets brighter, he moves faster and faster. When a light source such as a bulb is presented to him, he turns and makes his way to it, always increasing his speed and interest as the distance grows smaller. Finally he literally comes roaring down on the light until he either runs into or passes under it.

If presented with an ordinary flashlight beam, he [illegible] down it, sometimes wandering to one side or the other until one eye passes out of the beam, whereupon he turns back into it. In this situation, he behaves for all the world like some ungainly prototype of a guided missile. However he loses all interest for a lowly flashlight beam if the window shade is raised.

When two members of this species are turned loose together their behavior depends largely on the position of their heads. If one animal is looking forward while the other is looking backward, each will see the other's light and the one will chase the other. If both heads are turned sideways, the two will circle as if they were wary of each other. When both heads are turned forward, however, they run together at full tilt and bump, scrape and fight at a great rate.

One other interesting thing ought to be mentioned. We built a toy for the animals to play with. It consists of a light mounted on a rolling platform. The animals are of course attracted to the light and appear to have a good time pushing it around. The more of them that can get at it at once, the merrier is the occasion.

The obstacle evasion circuit provides a good example of the model's big advantage over some animals. Initially the neon tube reversing circuits were so adjusted that the forward and reverse times were about equal. Unfortunately, this did not allow the model to escape from anything. To avoid frustrating the poor thing, it was necessary to unbalance the forward and reverse times. The model now reverses for about three times as long as it goes forward and thus manages an eventual escape from almost any situation. Changing two resistors did the trick for the model, but what can you change in a phototropic bug or moth?

Model Versus Animal

In any attempt to imitate something in the world about us, it is important to consider the success or failure of the model. How well does such a model as ours fit the biological facts of life? What characteristics does the model have in common with animals and where do they differ?

The reader may recall that the goal-seeking mechanism has a symmetrical construction with the two eyes cross connected to the two motors. Practically speaking, it is simply a symmetry machine controlled entirely by the light stimulus. Is this characteristic of animals? The answer is emphatically yes! One might then ask quite legitimately, How so? Under what conditions may we treat an animal as a mere symmetry machine? To answer this question, the following excerpts from Loeb's *Forced Movements, Tropisms, and Animal Conduct* are presented.

> If the velocity of the chemical reactions in one eye of an insect is increased by illumination the muscles connected with the more strongly illuminated eye are thrown into stronger tension and if now impulses for locomotion appear in the central nervous system, they will not produce equal responses in the symmetrical muscles but a stronger one in the muscles turning the head and body to the light. The animal will thus be compelled to change the direction of his motion and to turn to the source of light until both sides again receive equal illumination. As soon as the plane of symmetry once more goes through the source of light, both eyes again receive an equal amount of light the tension in the symmetrical muscles becomes equal and the animal proceeds to the source of light until some other asymmetrical disturbance is introduced.

Sounds familiar, doesn't it?

> If we bring about a permanent difference in illumination of the eyes e.g. by blackening one eye in certain insects, we can also bring about permanent circular motions.

This is also true of the model. If one eye is blinded, it will run in circles. The motor connected with the blinded eye will still run, but it will be greatly hampered in so doing.

Loeb then goes on to point out the fact that a shark's eyes always move in the opposite direction from his tail so that he always looks in the direction in which he is swimming. He also points out that changing the position of a dog's head automatically changes the tension of the leg muscles. Furthermore, operating on a dog's brain produces many strange effects. If one side is damaged circular motions result. If the occipital lobes are damaged, forward movements are difficult and if the back halves of the cerebral hemisphere are damaged, the dog shows a tendency to run madly forward without stopping.

One further example in the biological world ought to be presented because it shows the usefulness of one particular animal's attraction to light. The caterpillar is attracted very strongly to lights, but *only* when he is hungry. This attraction induces him to climb the stems of plants to get at the leaves which are his food. When he has gorged himself however, he loses this attraction almost completely, showing very little further interest in light. This is fortunate from the caterpillar's point of view because it allows him to climb back down instead of starving to death at the top when he has eaten all the leaves.

Walter's *Speculatrix* has a somewhat similar attraction. When it returns to its charging hut, if the batteries are run down and it is "hungry," it will enter and be "fed." If the batteries are well charged however, the light is too strong and is repellent to the creature.

The ability of our model to feel its way around obstacles is somewhat similar to the methods an ant might use to get past a book placed in its path. Both have a way of bumping and feeling their way until they are free to continue on. It is interesting to note that, in the case of the model, an encounter sometimes causes it to forget what it was looking for. If it is following a light when it bumps the obstacle, it sometimes takes off in a com-

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Readers' and Editor's Forum

[Continued from page 13]

tunity to participate in the conference Would you be so kind as to publish the following notice in COMPUTERS *and* AUTOMATION?

The International Conference on Scientific Information, planned for Washington, D.C., November 16 21 1958, is sponsored by four societies the National Academy of Science, the National Research Council, the National Science Foundation, and the American Documentation Institute

The conference will be concerned with problems of scientific information emphasizing in particular the storage and retrieval of information for all groups of users — from the individual scientist to the large scale mechanized documentation centers

The program committee is considering proposals for papers relevant to the subject matter of the conference as defined in the following seven areas which comprise the program agenda They are

1 Requirements of scientists for scientific literature and reference services knowledge now available and methods of ascertaining their requirements

2 The function and effectiveness of abstracting and indexing services for storage and retrieval of scientific information

3 Effectiveness of scientific monographs compendia, and specialized information centers in meeting the needs of scientists present trends and new and proposed techniques and types of services

4 Organization of information for storage and search comparative characteristics of existing systems

5 Organization of knowledge for storage and retrospective search intellectual problems and equipment considerations in the design of new systems

6 Organization of information for storage and retrospective search possibility for a general theory of storage and search

7 Responsibilities of governmental bodies professional societies universities and research and industrial organizations to provide improved information services and to promote research in documentation

All proposals for papers are being evaluated in terms of the following criteria

1 Papers will deal with work that has not been published or presented at any open meeting Work will be considered to have been published if it has been reproduced for general distribution in any form or if copies have been deposited in libraries where they are available to the public

2 Papers will be directed to specialists in the field covered Only sufficient background information will be included to serve as an adequate framework for new work described in the papers More general background material will be indicated by references

3 Papers dealing with systems and methods will describe these at length only when they have not been described previously If new methods or systems are involved these will be described in sufficient detail to enable other qualified workers to duplicate the procedures and the results There will be sufficient information to enable qualified readers to judge the validity of results in objective terms

4 Theoretical papers will clearly explain the factual basis from which theoretical conclusions have been drawn and will point the way to experimental methods of verifying predictions which follow from such theoretical conclusions

Final drafts of proposed papers must be submitted by February 3, 1958 These will be reviewed by competent specialists in the various areas, accepted papers will be preprinted and distributed in advance to registrants The plan of the conference provides that no papers will be presented orally, instead, their content will be discussed area by area by the authors and other participants at plenary sessions led by panels of scientists and information specialists Observers will be welcome by registration in advance and will receive the preprints of accepted papers

In keeping with the goal to have the conference include reports of all current research in the storage and retrieval of information the Program Committee will be pleased to accept additional suggestions for papers It is requested that detailed outlines be submitted as soon as possible Inquiries as to details of the program and the established criteria for papers should be addressed to the Secretariat International Conference on Scientific Information, National Academy of Sciences, Washington 25, D.C

An Electro-Mechanical Model of Simple Animals

[Continued from page 25]

pletely new direction, apparently feeling that the necessary to attain the goal was too great

What the Future Holds

What can be done in the future with electro me cal animals seems limited only by the time and one could devote to the problem If a single voice system is interesting, imagine what coul done with two or three voice channels on differe quencies?

Another rather obvious improvement would make Machina Versatilis able to move his own and look about him He could then decide, as the moved him, to chase lights or circle them or stan and size up the situation

Versatilis could also easily be made to charge h battery but there is one thing to keep in mind battery should be charged slowly over a period of twelve hours Faster charges are possible but ve for the battery We wondered if the behavior charging would be worth the price of havin machine idle for so long a time

Considering the possibilities for behavior, we th of many interesting, and perhaps wild, schemes ever, they are all realizable and might possibly b able Who can say?

Most practical of all and not in the least bit w neon probability learning circuit should actually stalled in some electro mechanical animals and make them learn

In addition, the animals could play a simple g tag They already can chase each other All needed is a new brain that can think about be and not it It would be interesting to see what degrees of crippling of one animal would do proportion of the time that it would be it

If the animals could be given a sense of d (simple gyroscope), they could have quite a socce with the toy Two opposing teams could scrimm the ball

It would also be fairly easy to make the machi for something with steel coins, which they wou on the floor They might hoard their money it when they wished to buy a charge or perha a simple juke box

A most fascinating experiment would be t duce into the mechanical animal society a crimi would steal the others coins Would the mach learn that crime does not pay?

We believe that the study of behavior and in mechanical models of animals has a very pr future After all, to the Greeks, electronics much more than the static electricity in a cat's f