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by Peter Starke and Dr. Thiele

- East Germany -

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/Following is a translation of an article by Peter Starke and Dr. Thiele of the Institute for Mathematical Logic, Humboldt University, Berlin, published in the German-language newspaper Leipziger Volkszeitung (Peoples Journal of Leipzig), 2 February 1963, page 8./

A new word is appearing in news media and is creating widely different impressions and associations in those who read it. This is the term "cybernetics." Some see rockets lift into the sky or automatic factories devoid of human beings or an automatic kitchen. Others have frightening visions of a world of electronic machines which can do everything quicker and better. Which of these concepts are correct, which are anticipations and which are wrong?

Liberation from Routine: Cybernetics as a science was created some 15 years ago and its birth date is generally regarded as the publication by Norbert Wiener of the book "Cybernetics" in 1948. In this short space of time, this science has received an impetus, the most impressive manifestation of which is the beginning of the conquest of space by man. The explanation for this impetus lies in the fact that science and techniques in our times are practically forced toward cybernetics. With the development of electronics, manual control is more and more replaced by automatic control and regulation. Cybernetics creates the prerequisites for solving one of the basic problems of our times, the liberation of man from routine.

It is generally difficult to delineate the subject of a particular science, especially when the latter is still in the first stage of its development. Norbert Wiener defines cybernetics as the science of the processes of transmission, control and regulation in living organisms and machines. In his book "Cybernetics and Philosophy," Georg Klaus extends the definition further and regards cybernetics as the science of the different possible ways of behavior of possible dynamic structures. We do not intend to examine here which of these definitions is the more pertinent but merely want to illustrate some important problems of cybernetics.

Cybernetic Systems: Cybernetics considers dynamic structures or, in simpler words, certain well defined areas of reality, also called systems, within which certain processes take place as a function of time and which are related to other systems around them (interaction). However, the essential factor in cybernetics is not the transformation of energy but the processing of information. Considered from this viewpoint, the systems are called cybernetic systems. For example, a motor vehicle with its driver is a cybernetic system. Here cybernetics is not interested in how the motor vehicle is propelled but in how it is controlled. What occurs here is a conversion of information taking place approximately as follows: the driver receives optic and acoustic information on the traffic conditions, the condition of the road, the direction and the speed of his motor vehicle. These data are converted into corresponding motions of hand and foot (steering wheel, accelerator) with which he controls the vehicle.

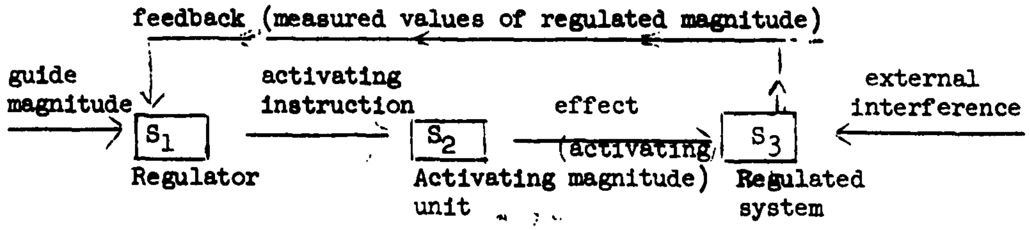
From this example, we see that a system can be decomposed into components, in our example, motor vehicle and driver, and that data (information) can be exchanged between the components or partial systems. For example, the driver obtains information from the speedometer (the speed of the vehicle) in response to which he depresses the accelerator and so transmits information on the required engine speed to the partial system "motor vehicle." This is the flow and processing of information with which cybernetics is concerned.

Let us now consider a second and somewhat more complicated example, in which our system consists of a human being and an automatic device engaged in a game of chess. The whole system consists first in two partial systems for exchanging information which are the human being and the machine. The exchange of information can here be effected by inscribing moves in the game into the machine by a keyboard and by receiving an answer from the machine by some printing device (typewriter). However, it is also possible to conceive of a machine as consisting of partial systems with different functions and exchanging information among each other. There is first the inscribing device (keyboard) which translates the input signal (the move of the human opponent) into electrical impulses. These impulses are accumulated in a further partial system, a memory or "storage" device. Here all of the moves made up to this point have been inscribed so that the content of the storage reflects the course and status of the game (the human opponent utilizes paper and pencil for this purpose). The storage device now delivers the information (in the language of electrical impulses) to two further units, i.e. a computing unit which calculates a series of possible future moves on the basis of the status of the game and an evaluation unit which analyzes and evaluates the future situations created by every one of these possible moves, in order to determine the most favorable move. The answer or "output" device now selects, from the moves offered by the computing unit, the one with the highest value as selected by the evaluation unit and then transmits it. Since it is generally not possible for technical reasons to calculate and evaluate all possible moves, a "random" selection is made which is the function of other special units. We now see how large and complicated the flow of information is within complex cybernetic systems.

Control and Regulation: In the interaction between two or more systems and their respective flow of information, particular stress is given to two types, i.e. control and regulation.

This is expressed by saying that system I controls system II if information is transmitted from system I to system II and causes changes in the latter. For example, in dial telephoning, the impulses transmitted by the dial control the relays of the automatic exchange and establish the desired connection. The called station retransmits information whether the line is open (ringing tone) or busy (busy tone). Depending on the nature of the information received, we then react either by waiting until the called subscriber answers when we hear the ringing tone or by hanging up when we hear the busy tone. If we hear no tone whatever after dialing, we then intercept this as information that "something" in the automatic exchange mechanism is not functioning. We then react by hanging up and then dialing once more. Such retransmission of information from the controlled to the controlling system, i.e. feedback, on the effect (result, success) of the information transmitted to the controlled system is exactly what characterizes the type of regulation (control loop) which frequently occurs in daily life. The best known example of a control loop is undoubtedly the thermostat.

Let us consider the basic diagram of a control loop. In a certain system S_3, a certain parameter (the regulated magnitude) is to assume certain values (determined by the guide magnitude) as a function of time. For example, the temperature in an aquarium is to drop uniformly ("linearly") by 5 degrees in the course of 24 hours. In the simplest case, the guide magnitude is a constant (e.g. a thermostat is intended to keep the temperature constant). The regulated magnitude is subject to external interference. It is continuously measured and compared with the guide magnitude in a system S_1 (the regulating device or regulator), e.g. a thermometer in which the mercury column closes and/or opens electric contacts and so converts the measured value into an electric impulse or signal. These impulses are transmitted to the switching unit. If regulated and guide magnitudes differ, the regulator transmits an activating instruction to a system S_2 (the activating unit), e.g., closing and/or opening of a heating and/or cooling circuit. The activating unit must be designed so that it is able to adequately influence the regulated magnitude. In our example, this means that so much heat is absorbed by cooling that the temperature drop specified can be obtained within the time specified. The flow of information in a regulatory circuit therefore is constituted by the diagram shown below.



Such principles as the control loop are utilized not only in technics but are also found in organic systems. An example of this is the automatism of the pupil of the human eye. Here the regulatory parameter is the amount of light which strikes the retina. The central nervous system acts as regulator and issues activating instructions (corresponding to the incidence of light) to the activating unit (the muscles of the iris), which enlarge or contract the pupil correspondingly.

If the regulatory parameters are changed abruptly, so-called control oscillation may occur in the control loop, i.e. the regulated parameter does not immediately adjust to the value of the guide magnitude but oscillates repeatedly around the value of the guide magnitude until the oscillations become gradually damped out. This process can also be observed in the automatism of the pupil when light suddenly strikes the eye. Since the transmission of information as well as the action of the activating unit on the regulated magnitude do not take place without inertia but at a finite speed, processes may be involved in the control loop which are in direct contradiction to its purpose. If the regulated magnitude changes periodically, then the effect produced by the activating unit will also change periodically when the guide magnitude remains constant. If light and dark alternate periodically, the pupil will enlarge and contract correspondingly if the intervals are long enough so that automatism is able to follow. With "rapidly alternating intensity of light on the retina" ("Netzwechselstromlicht"), for instance, this is not the case and the effect of regulation is retarded (the pupil contracts only when a certain interval has elapsed after increase of intensity) and the reaction undergoes a phase shift. At a certain frequency of oscillation of the regulated magnitude, the latter is then displaced in relation to the oscillation of the activator so that the exact opposite occurs of what the automatism of the eye is intended to achieve. In our example, this means that the pupil contracts only after the intensity has already decreased and enlarges only when the intensity has again increased. For technical application, it is therefore of great importance to fully understand such processes theoretically. The means for this are furnished by the theory of regulation which is a part of cybernetics.

Algorithmic Description: We distinguish basically between continuous and intermittent regulation, i.e. regulation in which the regulated magnitude is changed continuously and/or intermittently. For example, the heating current can be continuously regulated by a thermostat through a sliding rheostat but regulation may be simply restricted to opening and/or closing thr heating circuit. Regulation processes are frequently described by means of differential equations (mainly when we are concerned with continuous regulation) but a description by algorithms is also possible as in all data-processing methods. The theory of algorithmies therefore occupies a central position in cybernetics.

What is an algorithm and what is an information-processing method? By a process, we understand in general the progression in time of certain occurrences. For example, a process is the burning of a candle, the switching-on of a machine, the baking of a cake, the repair of a radio instrument, the multiplication of two figures, the sorting of file cards according to certain viewpoints, the preparation of a financial statement, or the composition of a piece of music. In cybernetics, we are less interested in chemical or physical processes, i.e. processes in which the transformation of substances or energy are the essential factor, than in the processing of information in which the conversion of information is the essential factor. Examples of information-processing are, for instance, the sorting of file cards, the multiplication of two figures or the preparation of a financial statement. The input information here, in our first example, are the viewpoints according to which the cards are to be sorted and the information inscribed on the cards. The output information is represented by the sorted piles of cards. In the second example, we have two figures as input information and obtain their product as output information.

An algorithm is a finite system of rules (this term should here not be understood in the sense of "regulation,") together with instructions for application of these rules which serve for the solution of a certain amount of tasks or, more correctly, for the description of the process of solution. A process described by an algorithm is an algorithmic process. Here we may regard the input information for this process as the input data of a task where the algorithm describes the solution of the latter. Accordingly, the output information of the process is then the solution of the task.

However, this does not yet give an exact (mathematical) definition of the concept "algorithm" because such terms as "rule" or "instructions for application" have here not been defined. The concept of algorithmics and the closely related concept of the algorithmic (effective) process has been defined repeatedly in several ways which always result again in the same class of algorithmic processes described by the respective but externally rather different algorithmic concepts. It would lead us too far afield to explain here even only one of these definitions.

The above explanation of the algorithm does highlight its essential character as a pattern (of rules). To regard a process as an algorithmic process therefore means finding a model (an algorithm) describing it. For example, "make as many vertical lines as the figure a indicates and make as many vertical lines as the figure b indicates and then count the lines made" is an algorithm for the determination of the sum of two positive whole numbers (1, 2, 3, . . .). There are also algorithms for all other arithmetical operations. Calculation is therefore an algorithmic process which can be automated by designing a machine which embodies the respective algorithm.

The above remarks contain the significance of the theory of algorithmics for automation. If a given process is to be automated, we must first find an algorithm which describes it. Such an algorithm may be as simple as in the above example but may also be very complicated, e.g. if the further progression of the process depends on the results already obtained from the starting parameters by application of some rules.

Such decisions on further progression occur, for instance, in iteration calculations. One example may make this clearer. We know that multiplication is the iteraction of addition, i.e. instead of multiplying a by b, we can also add a exactly b times. An algorithm which applies multiplication even to counting can be described as follows:

Rule 1: Make a vertical line in the square A.

Rule 2: Make one vertical line in the square B.

Rule 3: Examine whether b vertical lines are entered in field B; if so, count the lines in square A. This number is the result; if not, start over and apply Rule 1, subsequently Rule 2 and finally Rule 3.

Automated Repair . . . : Another example may make it clear that algorithms are not necessarily related to calculation. For example, certain repair activities can be automated, i.e. algorithms are known according to which these repair processes progress. If a radio instrument becomes defective, the procedure in general is to test first, in their order, the most short-lived components, the tubes of the instrument. After this (logical) decisions are taken, i.e. the further progression of repair is decided on the basis of the results of tube testing. In some cases, the repair is effected by simply replacing a tube. If there is no defective tube, tension and current will be measured at certain points of the circuits and compared with those indicated in the wiring diagram. Deviations from normal values so determined furnish information on the type of the defect and lead to further decisions on the further progression of the repair.

On a similar basis, any given sufficiently adequate instruction for application of some object is an algorithm, for example, a recipe for baking. Such a recipe consists after all only of a series of rules which must be applied in a certain sequence and produce as a result a cake. However, we should here not overlook the fact that there are many inexactitudes in the customary recipes (a "pinch" of salt, "medium" heat, etc.) which are the bane of inexperienced housewives.

. . . and Mental Effort: In addition to the processes of production, special efforts have been directed recently also to automating phases of mental activity, i.e. to analyze the algorithms which are at the base of such activity. Among these problematics is, for example, automatic programming. Electronic computors require for their operation a detailed program which prescribes each individual step (of calculation). This program must be formulated for the automat in "its language," the language of this automatic machine, and must be set up in it. The algorithm describing the calculations to be carried out must therefore be formulated in a special manner which depends not only on the problem but also on the automat utilized. This reformulation, the last part of programming, can be automated if the algorithm is described in a suitable form, i.e. in a language which is not that of general speech but is similar to it (only more formalized). However, automation in this field at the present time is just at the beginning of its development. Especially important today are problems of automation in production or, more correctly, in technics.

Obviously, it is not possible in this article, to treat all fields of cybernetics. We have therefore restricted ourselves to some remarks on the theory of control and the theory of algorithmics because we believe them to be especially important in practice.

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