

Cybernetics

or Control and Communication in the Animal and the Machine

Norbert Wiener

forewords by Doug Hill and Sanjoy K. Mitter

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the various threads of research together as we had made at home in the States.

In France, the meeting at Nancy on harmonic analysis contained a number of papers uniting statistical ideas and ideas from communication engineering in a manner wholly in conformity with the point of view of cybernetics. Here I must mention especially the names of M. Blanc-Lapierre and M. Loève. I found also a considerable interest in the subject on the part of mathematicians, physiologists, and physical chemists, particularly with regard to its thermodynamic aspects in so far as they touch the more general problem of the nature of life itself. Indeed, I had discussed that subject in Boston, before my departure, with Professor Szent-Györgyi, the Hungarian biochemist, and had found his ideas concordant with my own.

One event during my French visit is particularly worthwhile noting here. My colleague, Professor G. de Santillana of M.I.T., introduced me to M. Freymann, of the firm of Hermann et Cie, and he requested of me the present book. I am particularly glad to receive his invitation, as M. Freymann is a Mexican, and the writing of the present book, as well as a good deal of the research leading up to it, has been done in Mexico.

As I have already hinted, one of the directions of work which the realm of ideas of the Macy meetings has suggested concerns the importance of the notion and the technique of communication in the social system. It is certainly true that the social system is an organization like the individual, that it is bound together by a system of communication, and that it has a dynamics in which circular processes of a feedback nature play an important part. This is true, both in the general fields of anthropology and of sociology and in the more specific field of economics; and the very important work, which we have already mentioned, of

Re. viability of applying cybernetics (in general, numerical methods, ML, PR, neural nets, LLM etc.) to analyze communication in human societies:

von Neumann and Morgenstern on the theory of games enters into this range of ideas. On this basis, Drs. Gregory Bateson and Margaret Mead have urged me, in view of the intensely pressing nature of the sociological and economic problems of the present age of confusion, to devote a large part of my energies to the discussion of this side of cybernetics.

do not share] Much as I sympathize with their sense of the urgency of the situation, and much as I hope that they and other competent workers will take up problems of this sort, which I shall discuss in a later chapter of this book, I can share neither their feeling that this field has the first claim on my attention, nor their hopefulness that sufficient progress can be registered in this direction to have an appreciable therapeutic effect in the present diseases of society. To begin with, the main quantities affecting society are not only statistical, but the runs of statistics on which they are based are excessively short. There is no great use in lumping under one head the economics of steel industry before and after the introduction of the Bessemer process, nor in comparing the statistics of rubber production before and after the burgeoning of the automobile industry and the cultivation of *Hevea* in Malaya. Neither is there any important point in running statistics of the incidence of venereal disease in a single table which covers both the period before and that after the introduction of salvarsan, unless for the specific purpose of studying the effectiveness of this drug. For a good statistic of society, we need long runs *under essentially constant conditions*, just as for a good resolution of light we need a lens with a large aperture. The effective aperture of a lens is not appreciably increased by augmenting its nominal aperture, *unless the lens is made of a material so homogeneous that the delay of light in different parts of the lens conforms to the proper designed amount by less than a small part of*

a wavelength. Similarly, the advantage of long runs of statistics under widely varying conditions is specious and spurious. Thus the human sciences are very poor testing-grounds for a new mathematical technique: as poor as the statistical mechanics of a gas would be to a being of the order of size of a molecule, to whom the fluctuations which we ignore from a larger standpoint would be precisely the matters of greatest interest. Moreover, in the absence of reasonably safe routine numerical techniques, the element of the judgment of the expert in determining the estimates to be made of sociological, anthropological, and economic quantities is so great that it is no field for a newcomer who has not yet had the bulk of experience which goes to make up the expert. I may remark parenthetically that the modern apparatus of the theory of small samples, once it goes beyond the determination of its own specially defined parameters and becomes a method for positive statistical inference in new cases, does not inspire me with any confidence unless it is applied by a statistician by whom the main elements of the dynamics of the situation are either explicitly known or implicitly felt.

I have just spoken of a field in which my expectations of cybernetics are definitely tempered by an understanding of the limitations of the data which we may hope to obtain. There are two other fields where I ultimately hope to accomplish something practical with the aid of cybernetic ideas, but in which this hope must wait on further developments. One of these is the matter of prostheses for lost or paralyzed limbs. As we have seen in the discussion of *Gestalt*, the ideas of communication engineering have already been applied by McCulloch to the problem of the replacement of lost senses, in the construction of an instrument to enable the blind to read print by hearing. Here the instrument suggested by McCulloch takes over quite explicitly

some of the functions not only of the eye but of the visual cortex. There is a manifest possibility of doing something similar in the case of artificial limbs. The loss of a segment of limb implies not only the loss of the purely passive support of the missing segment or its value as mechanical extension of the stump, and the loss of the contractile power of its muscles, but implies as well the loss of all cutaneous and kinesthetic sensations originating in it. The first two losses are what the artificial-limbmaker now tries to replace. The third has so far been beyond his scope. In the case of a simple peg leg, this is not important: the rod that replaces the missing limb has no degrees of freedom of its own, and the kinesthetic mechanism of the stump is fully adequate to report its own position and velocity. This is not the case with the articulated limb with a mobile knee and ankle, thrown ahead by the patient with the aid of his remaining musculature. He has no adequate report of their position and motion, and this interferes with his sureness of step on an irregular terrain. There does not seem to be any insuperable difficulty in equipping the artificial joints and the sole of the artificial foot with strain or pressure gauges, which are to register electrically or otherwise, say through vibrators, on intact areas of skin. The present artificial limb removes some of the paralysis caused by the amputation but leaves the ataxia. With the use of proper receptors, much of this ataxia should disappear as well, and the patient should be able to learn reflexes, such as those we all use in driving a car, which should enable him to step out with a much surer gait. What we have said about the leg should apply with even *more* force to the arm, where the figure of the manikin familiar to all readers of books of neurology shows that the sensory loss in an amputation of the thumb alone is considerably greater than the sensory loss even in a hip-joint amputation.

I have made an attempt to report these considerations to the proper authorities, but up to now I have not been able to accomplish much. I do not know whether the same ideas have already emanated from other sources, nor whether they have been tried out and found technically impracticable. In case they have not yet received a thorough practical consideration, they should receive one in the immediate future.

Let me now come to another point which I believe to merit attention. **It has long been clear to me that the modern ultra-rapid computing machine was in principle an ideal central nervous system to an apparatus for automatic control; and that its input and output need not be in the form of numbers or diagrams but might very well be, respectively, the readings of artificial sense organs, such as photoelectric cells or thermometers, and the performance of motors or solenoids.** With the aid of strain gauges or similar agencies to read the performance of these motor organs and to report, to “feed back,” to the central control system as an artificial kinesthetic sense, we are already in a position to construct artificial machines of almost any degree of elaborateness of performance. Long before Nagasaki and the public awareness of the atomic bomb, it had occurred to me that we were here in the presence of another social potentiality of unheard-of importance for good and for evil. The automatic factory and the assembly line without human agents are only so far ahead of us as is limited by our willingness to put such a degree of effort into their engineering as was spent, for example, in the development of the technique of radar in the Second World War.¹³

I have said that this new development has unbounded possibilities for good and for evil. For one thing, it makes the metaphorical dominance of the machines, as imagined by Samuel

Butler, a most immediate and non-metaphorical problem. It gives the human race a new and most effective collection of mechanical slaves to perform its labor. Such mechanical labor has most of the economic properties of slave labor, although, unlike slave labor, it does not involve the direct demoralizing effects of human cruelty. However, any labor that accepts the conditions of competition with slave labor accepts the conditions of slave labor, and is essentially slave labor. The key word of this statement is *competition*. It may very well be a good thing for humanity to have the machine remove from it the need of menial and disagreeable tasks, or it may not. I do not know. It cannot be good for these new potentialities to be assessed in the terms of the market, of the money they save; and it is precisely the terms of the open market, the "fifth freedom," that have become the shibboleth of the sector of American opinion represented by the National Association of Manufacturers and the Saturday Evening Post. I say American opinion, for as an American, I know it best, but the hucksters recognize no national boundary.

Perhaps I may clarify the historical background of the present situation if I say that the first industrial revolution, the revolution of the "dark satanic mills," was the devaluation of the human arm by the competition of machinery. There is no rate of pay at which a United States pick-and-shovel laborer can live which is low enough to compete with the work of a steam shovel as an excavator. The modern industrial revolution is similarly bound to devalue the human brain, at least in its simpler and more routine decisions. Of course, just as the skilled carpenter, the skilled mechanic, the skilled dressmaker have in some degree survived the first industrial revolution, so the skilled scientist and the skilled administrator may survive the second. However,

taking the second revolution as accomplished, **the average human being of mediocre attainments or less has nothing to sell that it is worth anyone's money to buy.**

The answer, of course, is to have a society based on human values other than buying or selling. To arrive at this society, we need a good deal of planning and a good deal of struggle, which, if the best comes to the best, may be on the plane of ideas, and otherwise—who knows? I thus felt it my duty to pass on my information and understanding of the position to those who have an active interest in the conditions and the future of labor, that is, to the labor unions. I did manage to make contact with one or two persons high up in the C.I.O., and from them I received a very intelligent and sympathetic hearing. Further than these individuals, neither I nor any of them was able to go. It was their opinion, as it had been my previous observation and information, both in the United States and in England, that the **labor unions and the labor movement are** in the hands of a highly limited personnel, thoroughly well trained in the specialized problems of shop stewardship and disputes concerning wages and conditions of work, and **totally unprepared to enter into the larger political, technical, sociological, and economic questions which concern the very existence of labor.** The reasons for this are easy enough to see: the labor union official generally comes from the exacting life of a workman into the exacting life of an administrator without any opportunity for a broader training; and for those who have this training, a union career is not generally inviting; nor, quite naturally, are the unions receptive to such people.

Those of us who have contributed to the new science of cybernetics thus stand in a moral position which is, to say the least, not very comfortable. We have contributed to the initiation of a

new science which, as I have said, embraces technical developments with great possibilities for good and for evil. We can only hand it over into the world that exists about us, and this is the world of Belsen and Hiroshima. We do not even have the choice of suppressing these new technical developments. They belong to the age, and the most any of us can do by suppression is to put the development of the subject into the hands of the most irresponsible and most venal of our engineers. The best we can do is to see that a large public understands the trend and the bearing of the present work, and to confine our personal efforts to those fields, such as physiology and psychology, most remote from war and exploitation. As we have seen, there are those who hope that the good of a better understanding of man and society which is offered by this new field of work may anticipate and outweigh the incidental contribution we are making to the concentration of power (which is always concentrated, by its very conditions of existence, in the hands of the most unscrupulous). I write in 1947, and I am compelled to say that it is a very slight hope.

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