Could a Machine Make Probability Judgments?

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MANY THEORIES OF probability are concerned with degrees or intensities of belief or of rational belief. The notion of a machine that has degrees of belief may sound paradoxical, and this is why I find it interesting to ask whether a machine could make probability judgments. In attempting to answer such a question we may clarify the expression "degree of belief." All the same I shall be deliberately speculative and I am unable to place a machine on the table that actually makes probability judgments. My aim is simply to try to answer the question asked as best I can in a reasonable time.

Our discussion will touch on the topics of learning machines, chess-playing machines, and machines consisting largely of random networks. A certain amount of work has already been done on these topics but I shall not attempt to list all the relevant literature here.[2]

One further warning is necessary. Some of the discussion of machines will seem to be anthropomorphic and teleological. If so, it is because the words "as if" will be frequently taken for granted. If an argument is expressed too rigorously, it is liable to become uninteresting. A completely rigorous argument may go on forever and would be understood by no one.

If I gave ten different definitions of "machine," ten meanings to "probability" and ten definitions of "judgment," I should have 1000 different questions to answer. If I were to talk for fifty minutes, and few people should be allowed to talk for longer, I should have an average of three seconds to deal with each question. Actually I shall of course severely restrict the meaning of the question.

I recall a science fiction story in which the only observable distinction between a human being and an android was that the androids were stamped, inaccessibly, "made in Birmingham" or "fabriquée en Paris." If androids could be manufactured, the question whether they could feel pain would be interesting legally, morally and philosophically, but the question whether they could make probability judgments would reduce to whether human beings could do so. Moreover I find it too speculative to consider whether androids could be constructed. I am more interested in the practical question of whether machines will be making probability judgments in the near future.

The sort of machines I have in mind are general-purpose computers of the types that are likely to be constructed during the next twenty years, and machines consisting largely of random electrical networks,[3] functionally resembling the brain more than most general-purpose computers do. A partially random electrical network is one whose design is left to chance to some extent. Once the design is fixed the behaviour may or may not be deterministic.

It seems likely that the brain consists largely of random neural networks. (Identical twins have different finger-prints so that the development of finger-prints is presumably partially random. The same is likely to be true of the brain since it contains far more components than a finger-print.) Machines consisting largely of random networks would have the advantage of greater speed over brains, but the disadvantage of far less elementary components, if existing techniques are used. It is true that in principle a general-purpose computer can do any logical operation that can be done by a partially random network, but in practice a partially random network may be far more efficient at various classes of jobs. For one thing it may be capable of more parallel working than are most general-purpose computers.

In an article in *Mind*,[4] entitled "Computing machinery and intelligence," Turing argued that a general-purpose computer may be programmed to "think" within the next fifty years. He said that a machine could be said to think if it could fool you into supposing that it was a woman just as well as a man could do so, in five minutes' conversation, the conversation being carried on by teleprinter. Turing's arguments were mainly concerned with the disposal of counter-arguments and he was not constructive in this article. I do not know whether he ever attempted to work out how the program could be organised.

There have also been short published discussions by Popper[5] and by Somenzi[6] on whether scientific induction could be mechanised. If a machine could think or if it could perform scientific induction, than *a fortiori* it could make probability judgments, at any rate if people can. Likewise, if a machine could carry out perfect translation, in the style of a human translator, then it would need to make probability judgments, since most linguistic texts are ambiguous. (But a machine might list all the meanings of an ambiguity instead of selecting the most probable meaning.)

Our question then is relevant to the answers to these other questions, and is also less ambitious. If we can think of examples of a practicable machine that can make probability judgments within a limited field, then our question is answered affirmatively and constructively. It is not necessary that the machine should be able to make probability judgments about everything.

It is worth saying that in principle a machine could certainly think, in Turing's sense, because it could store suitable answers to every possible question. The main trouble with this strategy is that it would be impracticable. Also, thinking is presumably more than the mere use of memory. We see that the only point in asking whether

machines could think is if we are interested in whether such machines are practicable, and the same applies to the question of whether machines could make probability judgments.

Probability Judgments

It is now time to discuss what is meant by a "probability judgment." The meaning naturally depends on our theory of probability. I shall therefore describe briefly the theory of probability that I adopt.[7, 8, 9]

Up to a point the theory has the form of any other scientific theory that has reached a polished form. Judgments are fed into a "black box" and "discernments" are fed out.

Judgments ——→— Black Box ——→— "Discernments"

The black box is the formal apparatus (i.e., the abstract theory or mathematical theory) which depends on the axioms (i.e., the formal postulates) of the theory. Within the black box the word "probability" is not given any particular meaning. There are six or seven axioms, of which the following are typical:

A1. $P(E|F)$ (pronounced "the probability of E given F") is a non-negative number, where E and F are propositions.

A3. $P(E.F|H) = P(E|H)P(F|E.H)$, where E.F means "E and F."

A4. If E and F are logically equivalent, then $P(E|G) = P(F|G)$, and $P(G|E) = P(G|F)$ for any G.

There is the possible modification of A4:

A4′. If "you" have *proved* that E and F are logically equivalent, then $P(E|G) = P(F|G)$, etc.

In order to use the black box we need rules of application. Let $P'(E|F) > P'(G|H)$ be a probability judgment, i.e. a statement that your degree (or intensity) of belief in E given F (i.e., if F is assumed) would exceed your degree of belief in G given H. (Note that the possibility of making such judgments does not depend on the existence of numerical degrees of belief.) Then the main rule of application is that the primes (dashes) can be erased, i.e., in the black box you can write $P(E|F) > P(G|H)$, and conversely. To plug in a judgment is to erase primes; to make a discernment is to insert primes.

The set of judgments is the input body of beliefs. The purpose of the theory of probability is to enlarge your body of beliefs and to detect inconsistencies in it. These may often be patched up by means of more mature consideration.

Theory of Rational Behavior

The theory can be extended into a "theory of rational behaviour" by introducing "utilities," combined with the "principle of rational behaviour." This principle is the recommendation to maximise the mathematical expectation of utility, integrated over the whole future, with a suitable decreasing weighting function.

In addition to the axioms and rules there are "suggestions." These are imprecise, because a precise suggestion would become a rule of application or an axiom. For example:

(i) Numerical probabilities can be introduced by imagining perfect packs of cards perfectly shuffled, or infinite sequences of trials under essentially similar conditions. Both methods are idealizations, and there is very little to choose between them. It is a matter of taste: that is why there is so much argument about it.

(ii) Any theorem of probability theory and anybody's methods of statistical inference may be used to help you to make probability judgments.

(iii) If a body of beliefs is found to be unreasonable after applying the theory, then a good method of patching it up is by being honest (using unemotional judgment). (This suggestion is more difficult to apply to utility judgments because it is more difficult to be unemotional about them.)

(iv) Bayes' postulate, or the principle of indifference, is an example of a suggestion. It would be a rule but it cannot be made quite precise enough.

Justifications of the theory of rational behaviour have been given by F. P. Ramsey,[10] von Neumann and Morgenstern,[11] and by L. J. Savage.[12]

Some people prefer to apply the theory of probability to rational degrees of belief, supposed to be unique and independent of people. They are called "credibilities" by Edgeworth[13] and by Bertrand Russell.[14] Such theories are supported by Jeffreys[15] and by Carnap.[16] A credibility is supposed to exist independently of the existence of human beings, animals, or robots.

Note that the following two statements are equivalent: "I judge that the credibility of E given F exceeds that of G given H," and "$P'(E|F) > P'(G|H)$," although the second statement concerns degrees of belief instead of credibilities. If you believe that credibilities exist, then you can have degrees of belief concerning the magnitude of credibilities.

Apart from degrees of belief and credibilities there are also "physical probabilities," which Popper calls "propensities."[17] These are the limits towards which (with credibility 1) a credibility will tend in an infinite sequence of experiments performed under "essentially the same conditions." Sometimes it is extremely difficult to perform an experiment more than once, as with the throwing of a die composed of a heterogeneous mixture of unbaked clay and mud. Nevertheless the propensity may be assumed to exist. In all cases one can imagine the experiment to be repeated, especially if the universe is assumed to be of infinite extent.

If you are interested in the probability of rain tomorrow, you would like to estimate the physical probability, but in practice you certainly cannot do better than estimate the credibility, and your estimate of the credibility is your degree of belief.

Making Probability Judgments

Now if we fed a body of beliefs into a general-purpose computer, it may very well perform the operations of the black box for us. It does not seem reasonable to say of such a machine that it makes probability judgments (except perhaps where these may be used within pure mathematics): at most it merely deduces "discernments" (in the above technical sense). In fact I should say that the machine made probability judgments only if these were not deducible from the ones fed in by the operator. Also the machine would not be much good if it merely denied what was said by the operator. What seems to be wanted is that the machine should be capable of producing a *consistent* body of beliefs, at least after adequate training and mature consideration.

I shall assume that our machine could make use of the theory of probability, as described; the question that remains is how it is to make its own probability judgments.

On the face of it there is a logical difficulty, because if we specified precisely how the judgments were to be made, then we should not call them judgments, but rather rules of application of the theory of probability. Therefore the specification must be imprecise. The question arises how imprecise specifications can be made for a machine or for a machine program.

Of course a machine could print out probability judgments at random, but then it would soon run into inconsistencies. There must be some principle that tends to make the machine reasonably rational. This principle can perhaps be found in the theory of rational behaviour.

In order to apply this theory the machine must behave as if it could make value (utility) judgments. Any target-seeking machine can be said to behave as if it could estimate utilities. Here again, the utilities may have been entirely determined by human beings. For example, a good chess-playing machine will behave as if it preferred winning to losing. In fact a certain type of chess-playing machine will serve as an adequate example for our main question. Machines that made bets with the operator, or with other machines, would provide another class of examples.

Instructing a Machine to Make Probability Judgments

When we are teaching a machine to play chess it would be inefficient to wait until the end of the game for the post-mortem. It is better to carry out the instruction move by move, or, better still, judgment by judgment. (As I shall indicate later, the play can be largely expressed in terms of probability judgments.)

The instruction can take various forms, of which I shall consider only the following two:

(a) "Telling" the machine that the last judgment was right or wrong; or, almost equivalently, but more efficiently, telling it our own judgments;

(b) "Rewarding" or "punishing" the machine according to its last judgment.

This second form of instruction seems to be more appropriate for a machine constructed largely of partially random networks (a "P.R.N." machine, say). I shall suppose that the P.R.N. machine will consist largely of models of neurons, having synaptic connections between the neurons. Each neuron has a threshold such that when the input voltage is above the threshold then the neuron fires.

The point of using partially random networks is that a systematic arrangement may introduce prejudiced modes of operation not easily overcome by instruction. One of the main problems in the design of a P.R.N. machine would be to decide in what ways it should be systematic and in what ways random. Needless to say the machine must have input and output organs, and it may well be a hybrid machine consisting of a general-purpose computer combined with partially random networks.

When a P.R.N. machine makes a correct judgment it can be rewarded say by pouring some chemical over it, which will permanently lower the thresholds of all the neurons last used, at any rate until the next soaking.[18] Punishment consists in using an antidote that increases the thresholds. Degrees of reward and of punishment would also be possible and could correspond to the amount won or lost in a bet. This type of treatment is especially appropriate for juvenile P.R.N. machines. It should be applied in "hot blood," i.e. before the machine has forgotten what it is being rewarded or punished for. (Otherwise it may need reminding somehow.) The situations presented to the machine should at first be simple ones. The treatment is rather crude and may lead to traumas and to repression, especially if punishment has been given when reward was deserved. If the treatment failed over a long period, and after restarting from scratch a few times, then the machine would be classified as delinquent and it would be redesigned. It is also interesting to speculate on the possibility of treating it by some method analogous to psychoanalysis. Perhaps areas of irrationality could be located by a form of free association. Research along these lines may eventually benefit the study of human psychology as well as robot psychology. (Compare W. R. Ashby.[19])

In the redesigning just mentioned there are a great many parameters that could be changed, such as

(a) the total number of neurons,

(b) the average number of connections to other neurons, and the standard deviation,

(c) the proportion of inhibiting connections,

(d) the time for which each synaptic joint is active if not renewed.

If we hit upon a non-delinquent machine, and if it were very complicated, we could fairly say that it was making its own judgments *because we should not know how they were made.* It is true that we should have brought up the machine ourselves and its judgments would therefore be liable to resemble our own. On the other hand if we were very careful in our instruction and did not instruct when tired or drunk, then the machine's judgment may be as good as ours at its best and much quicker. If we wish the machine really to develop a "mind of its own" then we should at some stage let the machine begin to learn directly from its own experiences of success and failure, instead of continuing indefinitely to insist that our own judgments are better.

These remarks about P.R.N. machines are intentionally speculative. My own guess, however, is that some very striking successes will be obtained with P.R.N. machines during the next twenty years.

Instructing a Machine to Play Chess

I should like to discuss method (a) of instructing the machine, namely by telling it whether its last judgment was right or wrong (without making use of "chemicals"), or by telling it our own judgments. This method would work with a sufficiently adult P.R.N. machine or with an android, if such machines could be constructed, but I should like to indicate that it would be quite practicable as a method of instructing a general-purpose computer to play chess.

Chess exhibits several of the features of theoretical scientific research and at the same time is simple enough to be discussed conveniently. This is presumably a reason why Turing, Shannon, and others have been interested in programming a machine to play chess. It may turn out that chess does not provide a practicable example. But it would be possible to invent some game for which the following general ideas would be effective. Whether a really good chess-playing machine will be constructed within the next twenty years is an open question. (The automatic solution of two-move chess problems, as programmed at Manchester, barely touches the fringe of the problem of chess-playing machines.)

[To Be Continued]

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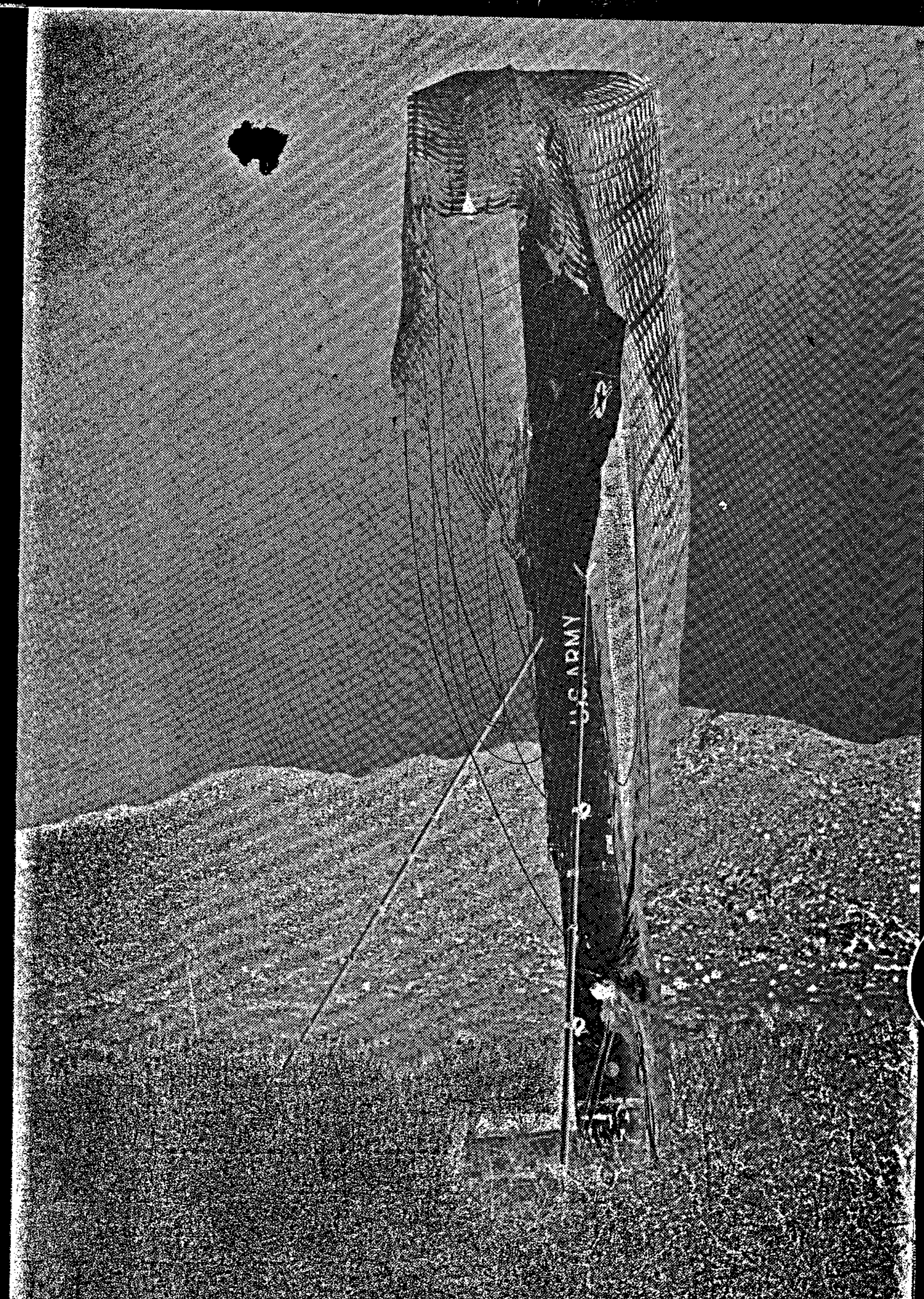

Computers for the Highway Engineering Program

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In the computer field, the advent of Sputnik I in October 1957 caused a significant change. Interest in Russian computer accomplishments, interest in machine translation from Russian to English, has become widespread, perhaps even fashionable. Today we teach Russian in many schools, and over 10,000 Americans have purchased translations of scientific Russian texts. In fact, achievements in the computer field all over the world, both machines and applications, ought to be and are of interest to computer people everywhere.

The epithet "disloyal" is of course not a sound argument against a new idea.

13. "Outside of My Field"

Finally, one of the commonest forms of opposition to new ideas is the argument: "Well, that's outside my field," "I am too busy," "I have no time," "I am not interested," "What's that to me?", etc.

This is one of the biggest sources of opposition to new ideas. Here again, this is an entirely natural and inevitable result of the complexity of the world. In the computer field, already, a single scientist is no longer expected to be a master of all the facets of a computer. Components are one field, applications are another, programming is a third.

But no matter how much specialization inevitably proceeds, we must examine new ideas and keep in touch with them. The computer people who worked on cathode ray tube memory saw nearly all their work go out as junk, when magnetic core memory arrived. At the Eastern Joint Computer Conference in December there was much talk of the "next generation" of computers, with new solid-state devices.

No one can afford to stick consistently to the attitude "not my concern," "not my field." This is the primrose path to becoming extinct. Computer people, like all other people who desire to live and flourish, must give thought to new ideas, especially the new ideas with giant possibilities, such as the intercontinental ballistic missile with the nuclear warhead, which in the world we live in is the unpublicized, central underlying motive for pouring funds into space travel.

14. The Intelligent Treatment of New Ideas

From time to time **Computers and Automation** has put forward the idea that computer people are in reality information engineers, engineers in the information sciences. This thesis is being confirmed more and more, it seems, as the effect of handling information reasonably and in great quantities and at high speeds reaches out to more and more fields, such as translating from one language to another.

Idea: If it is possible to teach a human being something, then it ought to be possible to teach essentially the same thing to a machine.

Idea: If a human being can perform a certain intellectual process, then it ought to be possible to program a machine to perform that process — and the more difficult the process, the more appropriate for the machine.

Idea: It ought to be possible to program machines to handle ideas in discussion, simulating human beings.

Idea: It ought to be possible to educate machines to know what human beings know as the result of the education of human beings.

Idea: It ought to be possible for a human being to treat a new idea tentatively, inquiringly, appraising it to determine objectively its degree of merit — and to teach a machine to do as well or better.

Computer people, as information engineers, as experts in the information sciences, should have a particularly sensible and scientific attitude towards new ideas.

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Part 2 — Concluding Part

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(Continued from the January, 1959, issue, vol. 8, no. 1, p. 16)

Chess is a game played between two players, called White and Black, on an 8 by 8 board, with 16 pieces of each colour, moved alternately. Sometimes a move involves a capture of an opposing piece. There are six types of piece: King, Queen, Rook, Bishop, Knight and Pawn. Each player has a single King and his opponent's aim is to capture it. This is called "winning the game."

In the von Neumann theory of games, chess is trivial since in principle it could be completely worked out. In practice this is impossible, since a complete catalogue of all possibilities would exhaust all the matter in the observable universe. The game is actually played by using a mixture of calculation and judgment, as in all serious games and efforts of the intellect. (Some "end-games" can be completely worked out. Precise subroutines for doing this could be appended to machine programs of the type to be described. Since the game of chess is only incidental to the discussion I shall say no more about end-games.)

Calculation in chess is usually called "tactics." It consists in working out so-called "forced variations." These can be defined as sequences of moves in each of which a piece is captured and its value is at least as great as that of the capturing piece, or when an unprotected piece is captured. Also when the choice of moves on one side is very restricted the variation is to some extent forced. I assume that the machine could be programmed to work out forced variations. The analysis of forced variations beginning at a certain position forms a "logical tree" whose end-points are quiescent positions. The size of the

tree has a very skew distribution:[20] when the tree is very large the original position is said to be "complicated." When it is too complicated a modification of the definition of "forced" is required. Proper chess is played with a two-faced clock, and if the machine got into time-trouble it would automatically change its definition of a forced variation in order to speed up its current move. It might also move faster when its opponent was in time trouble, in order to give him less time to think.[21]

The evaluation of quiescent positions is done by means of "strategic" principles. The probability that a quiescent position is won, drawn or lost should then be estimated. These probabilities depend on the two players. If it is imagined that they are both perfect players, then the probabilities are all 0 or 1, but even in this case we can get probabilities between 0 and 1 by making use of axiom A4′ instead of A4. With real players it would also be desirable to estimate the probabilities that the opponent will make the various selections of moves in almost forced variations. This would be essential for a modified form of chess in which the opponent's moves were selected randomly. I shall consider only the problem of evaluating quiescent positions.

Presumably the probability of winning is a function of the positions of the pieces on all the 64 squares. But for practical play this is not very helpful. In practice a player can estimate his advantage in terms of what pieces are on the board, what squares are controlled (giving more weight to the central squares and to the squares near the Kings), whether there are doubled pawns, outpost Knights, open files, Bishop-pairs, passed pawns and so on. We may assume that the odds of winning rather than losing (the ratio of the probabilities) is some function of all these types of advantage. It is customary to assume that the "material" advantage can be expressed linearly in terms of the pieces (pawn $= 1$, knight $= 3$, queen $= 9\frac{1}{2}$, etc.). It may be adequate to assume that the log-odds are linear in all the types of advantage that are worth listing, with certain coefficients, $\alpha, \beta, \gamma, \ldots$ (The probabilities of winning, drawing, or losing can perhaps be expressed in the form $(p^2, 2pq, q^2)$, and the above log-odds mean $\log(p^2/q^2)$. Judging by some statistics of E.T.O. Slater, p^2/q^2 is approximately 1.4 for the initial position in master chess. I believe that White's advantage is worth half a move or a fifth of a centre pawn, so a pawn is worth a factor of $1.4^5 = 5$, and a queen $5^{9\frac{1}{2}} = 5{,}000{,}000$.)

Now suppose that the machine selects the parameters for itself in some random manner. Then, for each quiescent position the instructor could tell the machine whether it had over- or under-estimated the log-odds of winning, preferably with an associated weight. The machine would thereby be given information from which it could, with the aid of some iterative algorithm, gradually improve its values of the parameters $\alpha, \beta, \gamma, \ldots$ I have not yet worked out the details of the algorithm, but its interest would not be primarily philosophical.

After a time the machine would perhaps arrive at a sensible set of values of the parameters $\alpha, \beta, \gamma, \ldots$ It would then be behaving as if it were making sensible probability judgments concerning the quiescent positions. If we did not know the numerical values of $\alpha, \beta, \gamma, \ldots$ as adopted by the machine, we would not know how the machine was making its judgments.

It is true that it would be possible to find out what these numerical values were by means of certain types of experiment, but it should also be possible by means of psychological experiments to find out how humans make judgments. For all we know even humans may make judgments by means of unconscious calculations. In the distinction, made previously, between calculations and judgments, the "calculations" were supposed to be conscious.

It may be thought that the determination of parameters by a machine is not a convincing example of judgment-making. It would be much more convincing if the machine were also capable of determining a functional form, instead of assuming linearity. Clearly this would also be possible to some extent by means of a suitable program, using the same method of instruction.

It would be still more impressive if the machine were capable of forming new abstractions, such as the idea of doubled pawns. The selection of functional forms is in fact a step in this direction. (For example, the abstraction known as "the advantage of two bishops" could easily be expressed by means of a non-linear function.) If the machine were at all good at forming abstractions it would be well on the way to becoming a first-class scientist. I think it would be wrong to insist on this facility in order to arrive at an affirmative answer to the main question of this talk. There are, after all, only a small proportion of *human* chess players who discover new strategic principles for themselves. It took men as a whole a few hundred years to discover the importance of getting the pieces out quickly during the opening.

This chess example is a little forced because it may well be adequate to evaluate quiescent positions in terms of some score which is not necessarily related to probability. Nevertheless it seems more satisfactory, if possible, to evaluate the position in terms of probabilities. In particular it would facilitate a further improvement of the machine's play, wherein it allowed for the probabilities of its opponent making various moves in a non-quiescent position.

Summary

I may summarise then by saying that general-purpose computers should quite soon be capable of making probability judgments in a reasonable but rather thin sense, i.e., by determining numerical values of parameters and using these for the evaluations of quiescent positions. (The references to chess are introduced in order to make the discussion more concrete, and other games could be invented for which the arguments would be more appropriate.)

More speculatively a P.R.N. machine, or, more likely, a hybrid, may within twenty years be making probability judgments in a very convincing sense, i.e., in a manner that we shall not be able to understand much better than we can understand how humans make probability judgments. (By a "hybrid" is meant here the special case of a P.R.N. machine that consists of a general-purpose computer with random networks appended.)

[1] Based on a talk given on 13th January, 1958 to the Philosophy of Science Group of the British Society for the History of Science and on 14th January to the Gaberbochus Common Room.

[2] Some of the literature may be found in or traced through the section "Behaviour and its mechanism" in *Information Theory* (Third London Symposium), edited by Colin Cherry (London, Butterworths, 1956). See also R. M. Friedberg, IBM Journ. Res. and Dev., 2 (1958), pp. 2-13, which appeared simultaneously with this talk.

[3] Or pseudo-random networks: compare a review of *Symposium on Monte Carlo Methods in Mathematical Tables and Other Aids to Computation,* 11 (1957), 44-46. Discussions of random networks are by now fairly familiar.

[4] Vol. 59 (1950), 433-460.

[5] "Philosophy of science: a personal report," *British Philosophy in the Mid-Century* (Allen and Unwin, 195-), 155-191, esp. pp. 170-1.

[6] "Can induction be mechanised?", *Information Theory* (*loc. cit.*), 226-230 (with discussion by Moles, Good, Fairthorne, Bell, McCulloch, and Hutten).

[7] *Probability and the Weighing of Evidence* (London, Griffin; New York, Hafners, 1950).

[8] "Rational decisions," *J. Roy. Stat. Soc. ser. B,* 14 (1952), 107-114.

[9] "The appropriate mathematical tools for describing and analysing uncertainty," Chapter 3 of *Uncertainty and Business Decisions* (Liverpool, University Press, 1954; 2nd edn. 1957).

[10] *The Foundations of Mathematics* (London, Kegan Paul, 1931).

[11] *The Theory of Games and Economic Behaviour* (2nd edn., Princeton, University Press, 1947), Appendix.

[12] *The Foundations of Statistics* (New York, John Wiley; London, Chapman and Hall, 1954).

[13] "Probability," *Enc. Brit.* 11th edn. 22 (1910), 376-403.

[14] *Human Knowledge* (London, Allen and Unwin, 1948), esp. p. 359.

[15] *Theory of Probability* (Oxford, University Press, 1939).

[16] *Logical Foundations of Probability* (Chicago, University Press, 1950).

[17] "The propensity interpretation of the calculus of probability, and the quantum theory," *Proc. Ninth Symp. of the Colston Res. Soc.* (London, Butterworths, 1957).

[18] It is of course not essential that the effect should be achieved by chemical means, although this may be the method used in the brain.

[19] *Design for a Brain* (London, Chapman and Hall, 1952).

[20] See, for example, "The number of individuals in a cascade process," *Proc. Cam. Phil. Soc.* 45 (1949), 360-3.

[21] *Symposium on Information Theory* (Ministry of Supply, London, 1950; and *Trans. of the I.R.E.,* Feb. 1953), p. 199.

Soviet Union Announces Electronic Computing Centers For Over-all Economic Planning

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The Soviet Union announced recently that in the near future, high-speed computers will be used in the field of planning and statistical reporting of the national economy. Every economic area (the USSR recognizes 105) is to have its own computing center, from which reports will be forwarded to republic computing centers, and finally to an all-union computing center.

The methods of computing, the announcement said, have been worked out. Experimental tables of correlation between various branches of the national economy have been compiled. Questions such as more rational coordination between various economic regions of the USSR and the most efficient transportation of goods are to be solved.

By analyzing steadily increasing quantities of data and using elaborate computing techniques, Soviet economists expect to reach the point where they will be able to determine quickly the effect of individual phenomena on the economy of the country as a whole.

According to Y. Kusmin, Deputy Chairman of the Council of Ministers of the USSR and Chairman of the State Planning Committee, the output of computers in 1965 is to be six times as great as in 1958.

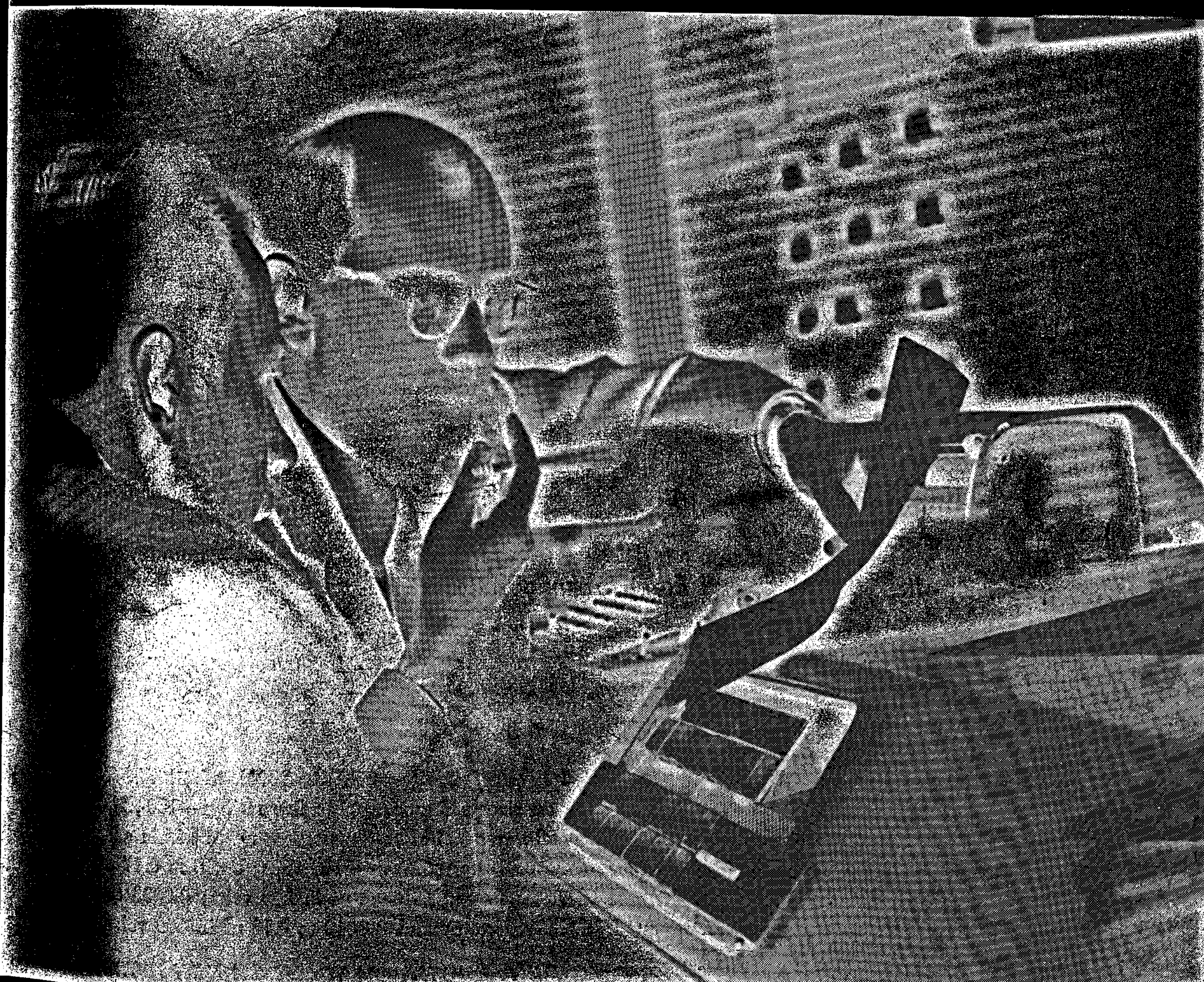
Kusmin also reported that experiments with computers are being carried out in the Soviet Union to make certain production processes fully automatic. He also stated that Soviet engineers had developed an "automatic dispatcher" for electric railroad trains, consisting of a computer and a "memory" with stored data concerning track conditions, time-table, etc.

Traditionally, the main centers for the development of electronic machines and instrumentation were those of the Moscow and Leningrad industrial areas, but since the policy of decentralization of Soviet research was launched in 1957, increasing numbers of problems are being delegated to outlying branches of the USSR Academy of Sciences and the Republican Academies of Sciences. Computing machines for the various research centers and for planning and industry are being developed with a priority. The first Soviet computer was developed by the Institute of Mathematics of the Ukrainian Academy of Sciences. It is one of the two computers installed at the Academy of Sciences in Moscow. Early models of Soviet computers were capable of doing 1,000 operations per second; at present the new types are said, on the authority of Academician Palladin, President of the Academy, to be capable of 10,000 operations per second.

A new universal computer, called the Kiev, is now being assembled at the Ukrainian Academy of Sciences. This machine, the work of Ukrainian scientists Academician Boris Gnedenko and Prof. Victor Glushkov, can be used for solving a wide range of mathematical problems, for controlling production processes at metallurgical works, chemical, oil and other industrial plants. It is reported to be capable of establishing in a matter of a few minutes the optimal method of operation of a blast furnace depending on the quality of the ore, coke, and sinter cake of the charge. By means of automatic devices the machine maintains the mode of operation it had set, and signals when the pig iron is ready for tapping. The Kiev machine is capable of performing 7,000 operations per second and possesses several unique features. All its units, including the arithmetic, storing, and other elements, operate independently, that is on different frequencies which facilitates adjustment. The Kiev computer requires floor space of only 40 square meters for its installation and maintenance. The standard parts of the machine can be used for the assembly of various special purpose computers. Another Kiev computer is being made for the Dubna Nuclear Research Institute.

COMPUTERS *and* AUTOMATION

DATA PROCESSING • CYBERNETICS • ROBOTS



Electronic Computers for Teaching Undergraduates

Survey of Basic Computer Components

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