

The Automatic Digital Computer as an Aid in Medical Diagnosis

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INTRODUCTION

THE IDEA to be presented here is that an automatic digital computer can provide great assistance to the medical diagnostician by rapid calculation, based upon symptoms and physical findings, of the relative probability that a certain disorder fits that set of findings. In a given diagnostic problem, the physician is practically always able to select the correct category of disorders which will include the disorder which constitutes the correct diagnosis. But it is also true that in many such categories the distinction between the different disorders included is quite difficult.

This paper proposes that the incidence of correct diagnosis in such difficult cases may be very greatly increased by the use of systematic statistical correlation technique. Basically, the idea is that for each category of disorders, the computer remembers a large number of cases, each with the correct diagnosis and the complete pattern of associated symptoms and physical findings. From these, it forms correlation constants between symptoms and disorders, and is able when confronted with a new set of symptoms to bring to bear all of the case history evidence in selection of the disorder most likely to be the correct diagnosis for the particular case.

The need for the development of this technique is demonstrated by three conditions which apply to present day diagnostic procedures. The most important of these is the fact that up to this time medical diagnosis has remained, to a marked degree, an art. Although some scientific methods are utilized, the necessary practical limitations of laboratory and clinical procedures, plus the great complexity of many diagnostic problems have thus far prevented the full development of a *science* of medical diagnosis. This plan of statistical diagnosis with calculating machine aid should enable the medical doctors to move much closer to the "science" objective, and achieve a markedly increased incidence of correct diagnosis.

The other two justifications hinge on the cost of present day medical services. The computer technique should greatly increase the speed of reaching a decision in diagnosis, and thus should very significantly reduce the total diagnosis cost. Furthermore,

in many instances, it may be that a clear cut differentiation reported by the digital calculator would make unnecessary further expensive and time consuming clinical and laboratory procedures which might now be employed to verify an initial diagnosis. The second area of cost saving would be avoidance of expensive hospitalization which might be rendered unnecessary by quick and accurate diagnosis.

There is a by-product virtue in this technique which should not be overlooked. This is that in order to use the technique, it is necessary first to record all symptoms and manifestations concerning the particular disorder in a systematic and uniform fashion. This is fed into the machine for the calculation of appropriate probabilities. That same information also becomes a part of the machine memory and of the foundation for correlation constants. Thus, the record on a particular case is not only made fully and recorded permanently, but quickly added to the body of statistical data upon which future diagnoses of cases in that category will be based. This represents a very marked improvement over present day case history recording, filing and utilization.

TECHNIQUE PROPOSED

Here we will use the term "symptom" in the broad sense to include all pertinent forms of evidence, — patient's reports of symptoms, doctor's examination, laboratory test results, etc.

Assume a table of disorders D_a, D_b, D_c , etc., and symptoms S_1, S_2, S_3 , etc.; let's say we can derive a correlation constant C expressing the probability of association of each symptom with each disorder. Then, we will have a table like Table I.

TABLE I
FORM OF THE TABLE OF CORRELATION CONSTANTS

Disorders	D_a	D_b	D_c	D_d
Symptoms				
S_1	C_{1a}	C_{1b}	C_{1c}	C_{1d}
S_2	C_{2a}	C_{2b}	C_{2c}	C_{2d}
S_3	C_{3a}	C_{3b}	C_{3c}	C_{3d}
S_4	C_{4a}	C_{4b}	C_{4c}	C_{4d}
S_5	C_{5a}	C_{5b}	C_{5c}	C_{5d}
S_6	C_{6a}	C_{6b}	C_{6c}	C_{6d}
S_7	C_{7a}	C_{7b}	C_{7c}	C_{7d}
S_8	C_{8a}	C_{8b}	C_{8c}	C_{8d}

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Now the simplest imaginable approach to the task is to note a set of observed and reported symptoms such as $S_2, S_3, S_5,$ and S_8 applying to the case at hand; and for each disorder in the table obtain the total of the corresponding correlation constants.

TABLE II

PROCESS OF OBTAINING RELATIVE PROBABILITY INDEX NUMBERS

Disorders	D_a	D_b	D_c	D_d
Symptoms				
S_2	C_{2a}	C_{2b}	C_{2c}	C_{2d}
S_3	C_{3a}	C_{3b}	C_{3c}	C_{3d}
S_5	C_{5a}	C_{5b}	C_{5c}	C_{5d}
S_8	C_{8a}	C_{8b}	C_{8c}	C_{8d}
	N_a	N_b	N_c	N_d

This process is illustrated in Table II, which is Table I with the not-observed symptoms and corresponding constants deleted, and the totals indicated. The largest total N should be the correct diagnosis, or the one with highest correctness probability. We call the totals N the relative probability index numbers; they don't represent quantitative probability, but rather they rank the diseases in the group from "most likely" to "least likely" to be the true diagnosis for the particular case. Fig. 1 is the actual set of correlation constants used in our experimental work.

In the very limited testing of the idea which has been done thus far, this straightforward simple summation scheme has been tried and yielded the encouraging results shown in Figs. 2 through 7. It is clear that some more sophisticated approach may have to be used for fullest effectiveness of the technique. For example, it appears that in some instances the correlation constant C must contain not only the occurrence correlation but also a factor representing the importance of the symptom in indicating the particular disorder, that is, whether or not it is a primary symptom having a clear cut relation to the disorder. It also appears that the intensity of certain symptoms should be noted in the preparation of the summation equations yielding the relative probability figures. For example, a mild abdominal pain might be considered a generally inconclusive evidence; while an intense abdominal pain localized in a certain area would be much more telling.

There may also be some more decidedly non-linear factors in this technique such as the existence of a symptom which positively eliminates one or more of the disorders in the appropriate category. Another possibility is that a certain combination of two or more symptoms may positively eliminate or positively identify a certain disorder within the appropriate category. A further example is the importance of history of symptoms in the preparation of the input to the computer. Thus the time rate of change of certain conditions occurring among the symptoms may be highly significant in the determination of the diagnosis.

In spite of all of the above possible changes, we feel strongly that the fundamental technique of summation of an appropriate set of correlation constants, modified or unmodified, will be very effective in indicating the most likely correct diagnosis.

MEDICAL FOUNDATIONS

The history of medicine shows a well established parallel of the strides in therapeutics and diagnostic methods. When the practice of medicine was confined largely to the relief of symptoms it often mattered little, except academically, whether or not the precise diagnosis was made so long as the resulting symptoms could be managed. In the current era, on the other hand, remarkable strides in specific treatments for diseases have greatly increased the need for improved precision in diagnosis.

Present day diagnosis is largely an intuitive and subjective process which is not easily described. Essentially it consists of the collection of data and interpretation leading to the synthesis of a diagnosis. The data collected by the patient's recounting of symptoms and the doctor's examination are interpreted in the light of the physician's training, experience, interest, and knowledge of published statistics.

COMPUTED DIAGNOSIS TEST	Case Number						
	Symptoms Reported	Stomach Cancer	Cholli-thiasis	Gas-tritis	Hiatus Hernia	Peptic Ulcer	Pyloro-spasm
PAIN LOCATION:							
Epigastrium	1	55	45		60	94	85
Right upper quadrant	2	15	76		52	40	10
Radiation to scapula	3	5	43		0	28	0
Radiation to back	4	15	28		7	28	5
PAIN RELIEF BY FOOD	5	0	0		20	75	12
PAIN AGGRAVATED BY FOOD	6	57	42		50	10	45
PAIN AGGRAVATED BY LYING DOWN	7	0	0		78	0	5
PAIN TIMING:							
Worse in a.m.	8	10	3		70	0	18
Odd infrequent interval attacks	9	10	62		20	0	86
Under 1 hour post prandial	10	65	22		80	5	68
Over 1 hour post prandial	11	47	32		20	95	10
FOOD INTOLERANCE:							
Spices	12	20	7		0	15	33
Cabbage family	13	10	28		0	5	37
Gravy	14	25	57		0	10	28
Fried Foods	15	40	60		0	10	30
Other Symptoms:							
Belching	16	14	25		50	65	50
Flatus	17	17	8		70	50	23
Jaundice	18	3	27		0	0	0
Fever	19	5	37		0	0	0
Constipation	20	28	10		0	50	32
Diarrhea	21	4	20		0	2	35
Pellet stools	22	0	10		0	20	10
Nausea	23	65	75		60	35	70
Vomiting	24	53	67		57	68	30
Anorexia	25	22	20		70	50	78
Multiple children	26	0	37		0	0	0
Obesity	27	0	25		39	5	15
Sex: Male	28	78	40		40	75	47
Female	29	22	68		60	25	62
Alcoholism—Under 4 oz. per day	30	0	62		0	0	62
AGE GROUP: Under 20	31	2	7		1	15	13
20 - 40	32	10	21		7	62	62
40 - 65	33	80	56		84	20	30
Over 65	34	5	13		8	3	10
Emotional stress related to Sx	35	0	0		0	30	80
PHYSICAL EXAM:							
Tender epigastrium	36	55	32		15	75	40
Hyperesthesia epigastrium	37	0	20		10	35	10
Tender right upper quadrant	38	0	70		5	40	15
Abdominal mass	39	28	18		0	0	3
Laboratory: Anemia	40	30	7		10	0	7
Leucocytosis	41	5	55		0	0	0
B.D.	42	0	62		0	0	0
Hyperacidity	43	0	10		10	90	18
Hypoacidity	44	84	8		0	0	8
X-RAY: Chest	45	0	0		15	0	0
Gallbladder	46	0	94		25	0	10
Stomach	47	91	15		81	95	50
COEFFICIENT TOTAL							

Fig. 1—Actual table of constants

While the data collection process may be fairly uniform among various doctors, the interpretation in some areas of medicine is highly variable. These areas are the rare and unusual disorders.

Past efforts to attack that problem of variability in interpretation of symptoms have led to the evolution of the practice called differential diagnosis. This is the technique of listing all the possible disease processes which might account for the patient's symptoms and physical findings. Each of these possibilities is individually related to the pattern of symptoms, and the diagnosis selected by an elimination process. The big weakness of this technique lies in the fact that the disease list *must* contain the correct diagnosis. If it is not there, the further study of the patient is not oriented toward the discovery of the proper diagnosis unless the various laboratory examinations happen to overlap the areas between the differential diagnosis and the correct diagnosis.

From this standpoint, then, the physician as a diagnostician, which he must be if he is to choose precise therapy, is the repository of data from his training, his reading of the current literature, and his day-to-day experience. This body of knowledge to be applied at the bedside in deriving a diagnosis from symptoms and signs suffers a few obvious disadvantages. First, the individual physician's practice may or may not have contained experience with the unknown disease at hand. Second, the individual physician's memory, not only of past experience but of past training and current efforts to keep abreast of his field, may not be adequate to the task. Finally and much less frequently, the individual physician's own interest in one area of disease may focus attention in this direction effectively raising blinders to his diagnostic acumen — this in contrast to blind spots in his diagnostic acumen that may always have been blank because of rarity of disease or absence of experience.

In choosing a group of diseases to test the proposition of the use of simple statistical procedures in making diagnoses, it was felt that a group of diseases diagnosable with certainty by some objective method was the first requirement. The second requirement for the test group of diseases was that they have enough overlapping symptomatology that diagnosis by history and physical examination presented some difficulties. The next problem was that of converting the subjective and intuitive information given by the patient to the physician to black, white, and reasonable shades of gray. Finally, and most difficult, is the construction of the statistical pattern of the disease to serve as a template with which to compare the individual patient's data. This particular difficulty serves to focus attention upon the need for the collection and collation of dependable statistics about the occurrence of major and minor manifestations of a given disease.

The diseases chosen are those involving the upper gastrointestinal tract and its appendages and all causing intermittent upper abdominal pain. The validity of the proposal was then ready for examination in the trial here reported. The construction of the statistical templates and the collection of the data from the individual patients for the trial pointed up additional problems such as the relative importance of individual symptoms and combinations of symptoms which bore greater weight in the consideration of one diagnosis versus others in the group. In this respect the attempts to objectify and "to mechanize" the subjective process will serve to further objectify diagnostic methods and procedures.

STEPS IN DEVELOPMENT OF THE TECHNIQUE

The following is considered to be a logical sequence of steps toward evolving a technique and testing the idea.

(1) *Test Area Selection*

This is selection of a group of diseases or disorders which are symptomatically similar and difficult to diagnose; and for which a sizable body of data in the form of actual case histories exists.

(2) *Test Data Compilation*

A statistical number of cases from the literature on the selected category must be reviewed. The symptom data must be extracted in sufficiently uniform format to permit derivation of correlation constants.

(3) *Derivation of Constants*

This is the "dog work" of actually counting up the incidence of each manifestation as associated with each disorder within the selected category.

(4) *Test Computations and Evaluation*

First trials of the method should be made using the cases upon which the table was based. This enables development of the technique, as described in the following steps, without introduction of new variables.

(5) *Development of the Correlation Technique*

Here the so called nonlinearities or irregularities in the preparation and use of the correlation constant table will be tried and introduced as they are found to be effective in improving the resolution of the technique.

(6) *Establishment of Data Format and Computer Programs*

This is the adaptation of the process to high-speed machine use. The two major tasks are selection of an appropriate form for input information, and programming.

(7) *Parallel Use With Conventional Diagnosis in New Cases*

With no change in technique, doctors will make diagnoses as they are now being routinely made, while in parallel with that the computed diagnosis technique would be utilized and the effectiveness compared.

PROGRESS TO DATE

For the first trial of this idea, the authors selected a set of five abdominal disorders, — cholelithiasis (gall stones), cancer of the stomach, peptic ulcer, hiatus hernia, and pylorospasm. In the hope of making an inexpensive first trial, we elected to derive the initial set of correlation constants by asking several specialists in internal medicine to report their estimates of the various constants. Each was given a blank table with the five disorders, each heading a column; and 48 rows for the 48 symptoms of significance in this set of disorders. The correlation constants which they reported were averaged to obtain a trial set of constants. These were then tested with a few case histories. The results were correct; but the difference between the correct and the incorrect probability index numbers was very little. Furthermore, in some of the manifestations, the doctors reported rather markedly different estimates of the appropriate correlation; and this cast doubt on the validity of the particular trial. It was evident that the rather laborious formulation of a true statistical basis would have to be performed.

This has been done, utilizing a statistical number of case histories for each of the five disorders. With the resulting table of constants, Fig. 1, the technique is now being tested on the same case histories. This puts us in Step 4 of the development sequence described in the last section. The first results are shown in Figs. 2 through 7.

Fig. 2 shows the result for 23 cases of hiatus hernia and 22 of peptic ulcer, in all of which the actual disorder was determined by X-ray. Each case is represented by a vertical column of the five different symbols. The vertical position of a symbol indicates N , the relative probability index number. The horizontal position for each column has no significance except that within each group the cases were plotted arbitrarily in descending order of highest N for the case. This places at the left the cases in which many symptoms were noted, proceeding to those with fewer symptoms at the right.

If the method were perfectly effective the flagged symbols would all be at the top of the mass in both sets. This is fairly closely approached in the peptic ulcer set; but with hiatus hernia the results are less encouraging. It is interesting to note that in about one-sixth of all the cases, the total for hiatus hernia was closely approximated by that of cholelithiasis.

FLAGGED SYMBOL INDICATES CORRECT DIAGNOSIS

- STOMACH CANCER
- CHOLELITHIASIS
- HIATUS HERNIA
- ▲ PEPTIC ULCER
- △ PYLOROSPASM

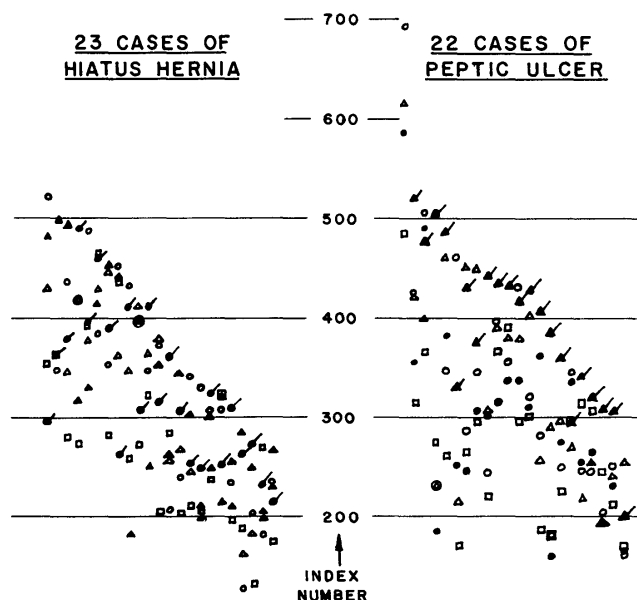


Fig. 2—Probability index numbers for 45 cases.

In all of these there was a history of gall bladder surgery or an established diagnosis of gall stones in addition to the hiatus hernia.

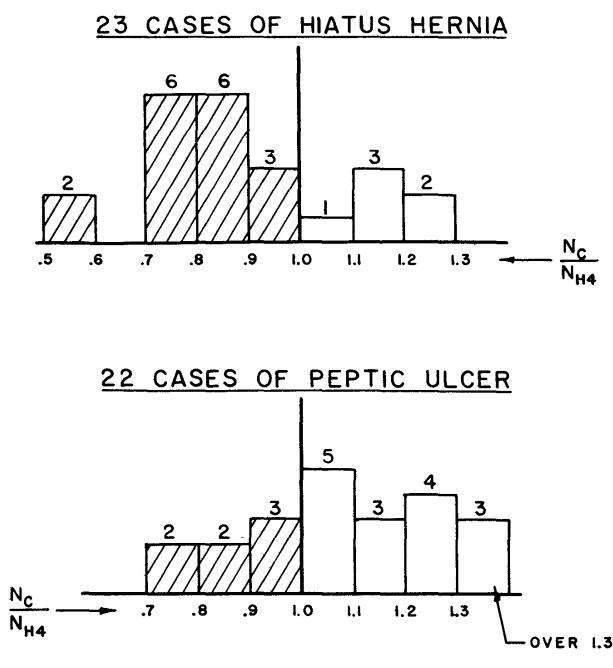


Fig. 3—Distribution of $\frac{N_c}{N_{H4}}$

Fig. 3 is an effort to summarize the most significant data of Fig. 2. For each case the ratio of N for the correct diagnosis to the highest of the other four N values was computed; and the distribution of these ratio values is represented by Fig. 3. Where this ratio $N_C : N_{H4}$ is greater than one, the correct diagnosis has been defined by the technique. The cross-hatched bars represent groups of cases where the ratio value is less than one and the technique has failed.

Figs. 4, 5, and 6 are like Fig. 3; they show the test results for the other three diseases in our test group. They are made up of somewhat smaller numbers of cases, but the results are very good, only 4 failures in 35 cases.

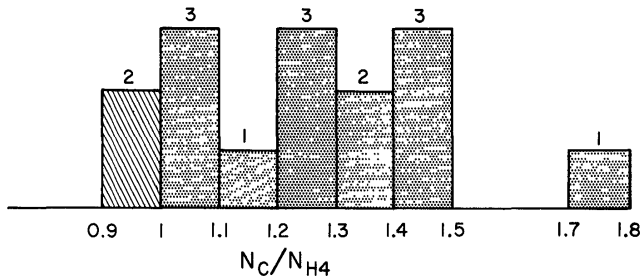


Fig. 4—Pylorospasm.

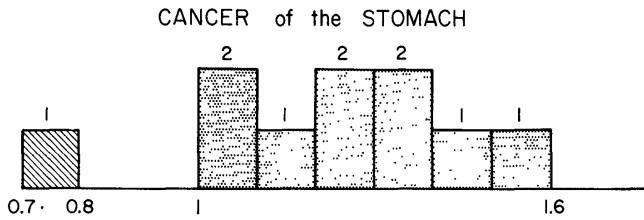


Fig. 5—Cancer of the stomach.

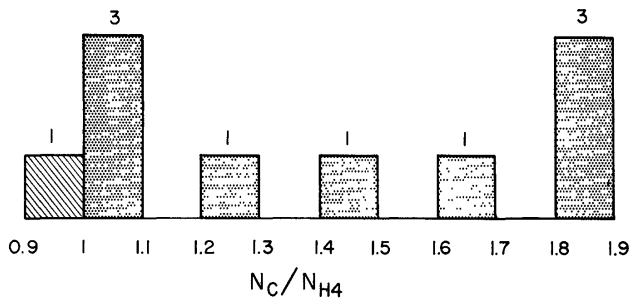


Fig. 6—Cholelithiasis.

Fig. 7 is a summary chart, like Figs. 3 through 6 but representing the whole test group of five diseases. It shows that in the test mass of 80 cases, there were 52 correct diagnoses and 28 failures for this initial trial technique. Nearly two-thirds of the failures were in cases of hiatus hernia, a disorder difficult to diagnose and often complicated by the coexistence or history of other abdominal troubles.

These figures, based on very few cases, still make it pretty clear that refinements of the method,

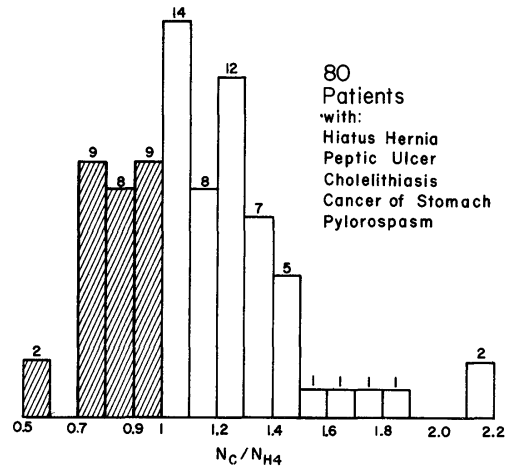


Fig. 7—Summary of test results.

suggested in the section on technique, will indeed be essential.

COMPUTER CONSIDERATIONS

The block diagram, Fig. 8, shows the organization of a digital calculator considered suitable to this problem. Assuming for the moment that the machine would be used for the analysis of individual cases, one at a time, then the determination of the diagnosis probability index numbers would involve the following steps:

- (1) Place in the working storage of the computer the input information which consists of the disorder category, selected by the physician, and the manifestations noted and reported by him.
- (2) According to the disorder category, search the bulk storage for the appropriate table of correlation constants and transfer it to the working storage.
- (3) Modify any of the constants in the table according to any of the various nonlinear effects which were noted in the section on technique.
- (4) Extract the appropriate correlation constants under the heading of each of the disorders in the category, and accumulate the sum for each of the disorders.
- (5) Report the appropriate sum for each disorder.

The bulk storage requirement shown in the diagram might be satisfied by a magnetic tape unit, a large capacity magnetic drum, or a large capacity random access memory unit such as the I. B. M. Ramac. A typical table of correlation constants is expected to require perhaps one thousand decimal digits. Thus, a moderate capacity magnetic drum as working storage could easily accept one such table of correlation constants and a fairly detailed program.

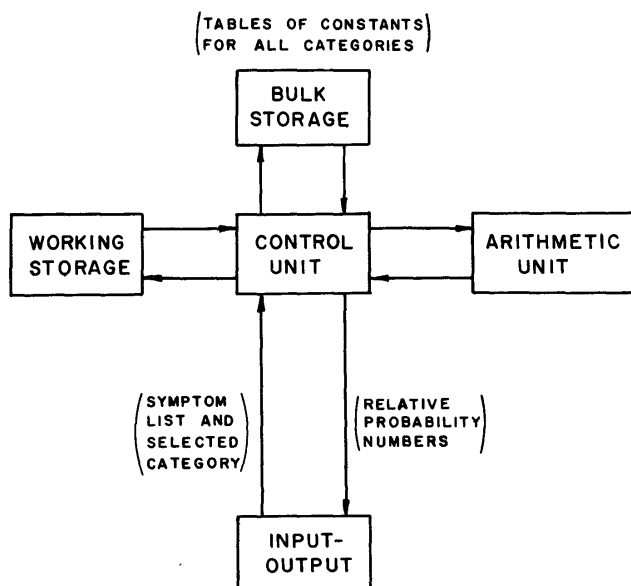


Fig. 8—Machine organization.

If we look at the diagnosis operation as a whole, it becomes evident that the time requirement for manual preparation of the input information for the individual diagnosis is going to be of the order of several minutes. Thus, it would seem that allowance of two minutes for the total computer operation would not be excessive. On that scale, the actual arithmetic operations time becomes practically insignificant; and the most of the time can be allotted to the extraction of the appropriate correlation constants table and placing it in the working storage. If something like one minute and a half is allotted to this, then a magnetic tape servo should be sufficiently fast.

This line of thought leads to the conclusion that an inexpensive medium size general purpose machine with magnetic tape facility, such as the Bendix G-15, would be entirely appropriate.

It may turn out to be desirable to treat diagnosis problems in groups, by accumulation of a number of cases, prepared for machine input, and all to be handled in a continuous machine run. In this method, the machine time requirement per case may become much more important, and faster bulk storage, working storage, and arithmetic unit may be called for.

With such a small machine time requirement per case, the use of a single machine serving many hospitals, clinics, and independent doctors is a leading possibility. This scheme substitutes a communications requirement for the local machine requirement. By intelligent selection of coding and format, the information content of these messages will be kept low enough such that existing communications media such as teletype will be adequate. Thus it appears almost certain that the central computer service will

be the most practical way of applying the technique.

You may note that the real problem in this project is not the computer, nor the program, but rather the development of statistical correlation procedures. That is true; and we admit that we haven't yet made use of an electronic calculator in the experimental work. From these facts one might conclude that high speed machine use is only incidental to the idea. Of course, that isn't so.

The statistical procedure proposed cannot be applied practically unless it can be performed rapidly. Thus in a sense we have a classic computer application, one in which the machine is not just a convenience nor a luxury, but rather an essential requirement. The job simply can't be done without it.

CONCLUSIONS

No doubt it is quite evident from the limited progress which we reported above, that we are hardly in a position to state many conclusions on the effectiveness of this scheme. There are two statements which we can make in which we feel very confident. One is that, qualitatively at least, the scheme is definitely effective although some doubt still remains about the capability of the idea, as it is now visualized, to make a sharp and unmistakable differentiation of the correct from the incorrect diagnosis.

Our second conclusion is in a sense a by-product one arising from the observations during the first preparation of correlation constants. This is that the opportunity for improving the doctor's basis for diagnosis is greater than we expected. Present day diagnosis ideally is based upon all the information to which the diagnostician has been exposed, — his total textbook and classroom content plus all the data from his daily practice. This ideal is not realized because of the limitations of the human memory, and the differences in constants reported by several internists suggested that the natural distillation of memory yields quite variable results in various men.

On the other hand, the digital computing machine can remember and utilize all the data it is given; and that fact is the foundation for our strong confidence in the need for and effectiveness of the proposed technique.

This is the real essence of our notion that here is another way that automatic computers can contribute to the good of mankind.

BIBLIOGRAPHY

- [1] Dr. K. Brodman, Dr. A. J. van Woerkom, Dr. A. J. Erdmann, Jr., and Dr. L. S. Goldstein, "Interpretation of Symptoms with a Data-Processing Machine," Reprinted from the *A. M. A. Archives of Internal Medicine*, May 1959, Vol. 103 pp. 776-782.
- [2] R. S. Ledley and L. B. Lusted, "Reasoning Foundations of Medical Diagnosis," *Science*, Vol. 130, No. 3366, pp. 9-21, July 3, 1959.

- [3] D. M. Cleary "The Role of Automation in Diagnostics," *Current Medical Digest*, April 1959, pp. 57-63.
- [4] "Dr. Automation," *Time*, Vol. 74, No. 6, p. 48, August 10, 1959, on work at System Development Corporation under C. J. Roach.
- [5] M. Lipkin and J. D. Hardy, "Mechanical Correlation of Data in Differential Diagnosis of Hematological Diseases," *Journal of American Medical Association*, Vol. 166, No. 2, pp. 113-125, Jan. 11, 1958.
- [6] C. L. Chiang, J. L. Hodges, Jr., and J. Yerushalmy, "Statistical Problems in Medical Diagnosis," Third Berkeley Symposium on Mathematical Statistics and Probability, 1954-1955, Vol. 4, pp. 121-123, University of California Press, Berkeley 1956.
- [7] "Dr. Robot," *Time*, Vol. 68, p. 44, August 20, 1956. Punched card machine diagnosis of diseases of cornea, by Dr. Francois Paycha
- [8] Charbonnier, Cyffers, Schwartz, and Vessereau, "Discrimination entre icteres médicaux et chirurgicaux a partir des résultats de l'analyse électrophorétique des protéines du sérum," *Revue Internationale d'Hépatologie*, Vol. 5, No. 7, 1955.
- [9] C. F. Paycha, "Memoire diagnostique," *Montpellier Med.*, Vol' 47, p. 588, 1955.

DISCUSSION

N. Shapiro (Nat'l. Institute of Health): One should distinguish between the use of computers as a research tool, say in developing diagnostic techniques, and its other use as a diagnostic tool. Please comment.

Mr. Crumb: I understand the distinction and also understand the probable origin of the question. I did not bring up the subject because I don't know enough about it. There are several related projects in some of which the computers are used as tools, and some are pure research. The particular project we are working on is toward use of the computer as a diagnostic tool; I think this would be called a non-research application. However, the aim at present is the technique itself; we have not utilized any large scale machine.

R. Tevonian (Western Electric): How does the likelihood of an incorrect diagnosis by the computer in each case compare with the likelihood of error by a doctor in the same case?

Mr. Crumb: In order to answer that I would have to know what the doctor's performance on diagnosis is. I don't know that. I don't know the status of statistics on incorrect diagnosis by doctors. When I talk to doctors considered objective, they admit that there is lots of room for improvement.

C. Kagan (Western Electric): Did you have anything to do with the three-year-old, excellent TV science fiction show "Dr. Robot," which presented the story of a medical diagnostic computer, incidentally a Bendix G15?

Mr. Crumb: No, I regret to say I had nothing to do with that. I am glad to see those things. There are lots of people working on the job, and I had no part in that.

T. E. Digan (IBM): Do plans exist for recording many case histories in punched card form to improve statistical data for computer usage?

Mr. Crumb: There are several projects dealing with machine handling of medical data per se for more than one application of the data. These are projects that have more general objectives than the one we are working on. This means the answer is "yes." There are in various places jobs going on to improve the character and availability of statistical medical data by machine handling.

J. Rothstein (Edgerton, Germeshausen & Grier): Have you considered that logical constraints — for example, the necessity or impossibility of associating some symptoms with certain diseases — might occasionally yield sharper discriminations than the lumping of probabilities which might blur them?

Mr. Crumb: Yes, we have. We have not tested any of these procedures, but we do have in preliminary form plans for things like that. We consider that they will be modifications, and we will test them to try to increase the computer technique effectiveness. We very fortunately have had comments and suggestions made by some very expert people to improve the discriminatory ability of the technique.

Dr. B. R. Hutcheson (Dept. Mental Health): Have you determined that these physicians can call the same symptom by the same name; for example, rate symptoms?

Mr. Crumb: Well, we have determined that making data uniform is very greatly aided by providing the framework for case history reporting which is uniform in detail and would have to be done for such a project as this. Fortunately there have been efforts in previous years without this kind of an objective but with the objective of attempting to uniformize reports of what they call case histories for medical records. It has been demonstrated that this can make the histories much more utilizable by machine methods.

T. J. Kobb (IBM): The Soviet doctors claim a great success in employing computers for medical diagnosis. Are you familiar with their techniques and results?

Mr. Crumb: No, all I know is what I saw in the newspapers. I have not observed any source of detailed information.

R. S. Ledley (Na't. Bureau of Standards): How do you take into account the important seasonal, social, local, epidemiological, and so forth effects on making a diagnosis?

Mr. Crumb: This technique does not yet do that at all. I recognize that other projects, including Dr. Ledley's, are aimed at actually accounting for those influences on the parameters used in preparation of the input to the machine. This method as yet does not do that.

F. Reilly (Veterans Administration): Do you foresee a national standard of correlation constants being established? If so, by whom?

Mr. Crumb: I would expect that would be the logical result if this technique were found to be the best one of the various techniques that are now being worked on.

M. Sendrow (RCA): How much of an increase in computing time do you estimate if the number of symptoms and diseases is increased greatly; for instance, to 200 symptoms and 2000 diseases?

Mr. Crumb: We visualize no such table of correlation constants, because we feel certain that diseases will be treated in logical groups which are much smaller than 2000. Even though there may be many more ailments to which humans are subject, the method will deal only with difficult diagnostic problems for which data actually exists to compute dependable correlation constants. In general, we expect the groups to be fairly small in number of disease per group and the number of symptoms to be typified by the slide I showed with 47.

E. H. Cabaniss (GE): Have you considered learning procedures for optimizing your C's automatically? That is increase those that help and reduce those that hinder each diagnosis?

Mr. Crumb: We have considered that, in the ideal application of the method, each case, when its true diagnosis was verified, would be immediately added to the data of the table of correlation constants on which its diagnosis was based; but this is an ideal which I think would be only approximated for some time after the introduction of the procedure.