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AUTHOR	Kochen, Manfred
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ABSTRACT

This paper is an extension of "Referential Consulting Networks" which explicated the concept of a network of referential consultants each of whom could "field" questions by: (a) answering them on the basis of his own expertise; (b) answer them with the help of library resources at his command; (c) refer the question to a colleague he judges to be more skilled than he in (a), (b), and (c). The querist, who originates a question of concern to him, is part of this network too. The question of primary concern in this paper is the trade-off between turn-around time (response time) and quality of the response. Small response time and high quality of the response both contribute to total benefit; also to total cost. A key factor determining both response time and quality is the quality of the directories available to the various referential consultants in the organization that services queries. A directory, exemplified by the "Yellow Pages", or a library catalog, points its user to the optional library resources and colleagues among which he makes choices. To design a referential consulting network is to; (1) select the number and kinds of referential consultants; (2) specify the directories which characterize each unit; (3) specify the way these units interconnected. (Other papers from this conference are available as LI 003360 - 003370 and LI 003372 through LI 003390) (Author/NH)

SWITCHING CENTERS FOR INQUIRY REFERRAL

Manfred Kochen

Mental Health Research Institute
University of Michigan

1. Introduction.

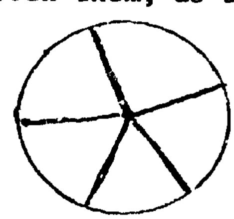
This paper is an extension of "Referential Consulting Networks"[19], in which we explicated the concept of a network of referential consultants each of whom could "field" questions by: (a) answering them on the basis of his own expertise; (b) answer them with the help of library resources at his command; (c) refer the question to a colleague he judges to be more skilled than he in (a), (b), and (c). The querist, who originates a question of concern to him, is part of this network too. He need not, however, know how his request is processed between the time he submits it and the time he gets a response—even if it is only the first pass in a multi-pass query negotiation "dialogue". If his request leads to extensive but productive library searches or to quality-improving "buck-passing", he will notice this only as increased turn-around time.

The question of primary concern in this paper is the trade-off between turn-around time (response time) and quality of the response. Small response time and high quality of the response both contribute to total benefit; also to total cost. A key factor determining both response time and quality is the quality of the directories available to the various referential consultants in the organization that services queries. A directory, exemplified by the "Yellow Pages", or a library catalog, points its user to the optional library resources and colleagues among which he makes choices (b) and (c). It might also jog his own memory in choice (a), but we will ignore that in this paper. The directory serves both to prompt and to teach, but again we confine our study to only the prompting function.

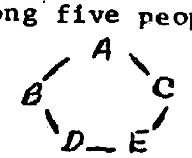
To design a referential consulting network is to[1] (1) select the number and kinds of referential consultants -- each of whom is thus a potential switching point, with the possibility that some units in the organization are exclusively switching centers; (2) specify the directories which characterize each unit; (3) specify the way these units are interconnected. We then ask how the choice of a consulting network affects benefit-cost ratio, and we attempt to search for that organization, or its properties, which maximize it.

2. Review of the Literature: Evaluation of Trends.

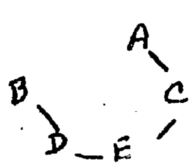
Interest in communication networks as objects of mathematical and experimental study began in 1948[6,7] with Bavelas' work on task-oriented groups. A team of people -- paid experimental subjects -- were seated around a round table with, say five radial partitions between them, as shown. There were slots such as in mail boxes, into which each subject could drop a message, which would be delivered to one or more specified people according to a particular network scheme. The entire team was given a task which required cooperation and communication. The aim was to investigate the effect of different networks on performance.



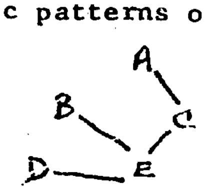
Leavitt, in 1951[26], examined four basic patterns of communication among five people:



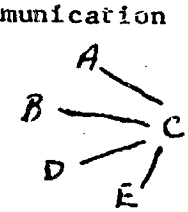
Circle



Chain



Fork



Wheel

He found that leaders emerged in the "fork" and "wheel" structures (positions C and E); also, that the wheel is administratively most efficient at information processing. In the chain, A and B were never perceived as leaders.

In 1954, we[20] began a mathematical investigation of such networks, with the aim of relating the flow of information to the performance of the organization. We believed, at the time, as did Rothstein[36], Brillouin[8], and Watanabe* . to mention but a few investigators, that a measure of the "degree of organization", analogous to Shannon's[37] measure of the "amount of information" could perhaps be created and used to prove theorems about the "emergent" properties of organized assemblies of numerous parts.

It was not until von Neumann[39] introduced the beautiful idea that an assembly of unreliable parts, suitable organize could in its entirety function like one of the parts but with arbitrarily high reliabilty, that a major conceptual advance took place. At the same time, the economist Marschak began to develop a theory of teams[30] which led later to profound insights into the economics of information. In 1958, we connected some of these notions[18]. In 1960, Shannon and Moore[38] made a significant advance on how to make a reliable switch with less reliable components, and in 1964, Winograd and Cowan crowned this line of investigation with definitive results about the reliability of networks, analogous to the coding theorems of information theory[40]. In a sense, this provided a satisfactory answer to what switching networks can do that could, in principle, not be done without them.

At a less profound level, switching networks have been extensively studied since the days of the first computers.[3] Since at least the

*In private communication.

pioneering work of McCulloch-Pitts[31] it was understood that logic could be performed by switching networks. Of course, computers are built of switching networks, and there exists an enormous literature on how to find the cheapest and most effective networks to act as a specified switching function[34].

At an even more practical level, the proliferation of computers and terminals -- over 50,000 installations exist in the U.S. --telephones, copying machines, etc. -- led both "sociological engineers" and computer scientists to concern themselves with "switching networks". The early experiments with time-sharing at MIT and SDC led to the exciting concept of an "on-line intellectual community." IBM began to concern itself with total systems approaches as early as 1956. Far-sighted engineers[15] began to investigate computer networks. Experiments like DICO[25] and SASIDS[21], which extended the notion of SDI to that of a network in which each member acts both as a source of recommended literature and as a recipient of information selectively disseminated to him, showed the value of such exchange nets.

And, at a commercial level, airline and hotel reservation systems proved to be extremely cost-effective. Though they required the surmounting of such technological hurdles as the development of a reliable magnetic disk, the conceptual problems were simple, primarily because only a very specialized demand -- just two or three stereotyped questions or requests -- had to be serviced. The service does, however, require a switching net involving thousands of switching centers, and response time in seconds is as important as up-to-the-minute updating of rather large files.

The notion of networks in library and information science arose at several levels. It may well have been inspired by the various attempts to use graph theory in thesaurus design[1,2,9,13,33]. Interlibrary communication nets are, of course, not new, though the use of communication channels, such as the one between N.Y.C. and Albany is fairly recent. Systematic studies gathered momentum at the 1967 Educom conference. A careful study of regional networks was made in 1968 by Meise[32]. In 1969, Duggan[10] analyzed communication networks of libararies, raising such questions as: How can configurations be evaluated? and What is the best type of network configuration? We shall see how the model we present later can help answer these questions.

In "Referential Consulting Networks"[19] we argued for a new, expanded role for the reference librarian[41], as precisely the kind of switching point in a network such as we are discussing here. We noted the work of Grogan[16], indicating some typical questions that reference librarians are requested to service, the viewpoints of Lorenz[28] Freiser[12] and Rees[35] on the division of responsibilities among libraries and information centers in this regard, and such experiments in the use of libraries as community information centers[4,17]. Aspens[5] has argued that contemporary reference librarians already have a status comparable to that of doctors, engineers, lawyers. Shera and Egan[11] proposed an important revision to the classical definition of librarianship (a collection of books organized for use) by asserting its function to be "to maximize the effective social utilization of the graphic records of civilization". In "Referential Consulting Networks" we proposed a further revision of this to read: "to maximize the greatest potentially attainable effective and efficient social utilization of documented knowledge". And that is where networks come in.

If the literature shows any trends, it is perhaps an increasing concern with the benefits of networks. Professionals at well-endowed, large libraries -- and computing centers -- are hard-pressed to find uses for communication to or from other institutions if a better network were available. Many investigators and enterpreneurs and managers seem to favor centralized facilities: small, stand-alone facilities (minicomputers, personal or departmental libraries) for those who can afford them and and large centers to be shared by all the others.

But this trend may not last. In a series of papers aiming at building a theory of decentralization K.W. Deutsch and I[22,23,24] have shown that historical trends favor decentralization: networks with distributed switching centers. This is primarily due to the increase in the volume of requests to be serviced. For an organization to remain responsive, and minimi otal cost, the number of dispersed service facilities should increase predominantly as the square root of the load. I believe there will be a trend toward larger centers and satellites organized into a decentralized network, but this trend is not yet evident in practice. This paper is a contribution to develop the theoretical basis.

3. Directory Design Parameters.

Imagine an organization of n+1 active units or potential switching points labeled 0, 1, 2, ..., i, ..., n. Interpret 0 to designate the querist. Let D_i designate the directory at i's disposal, for i = 0, 1, ..., n, and picture D_i to be represented as a table like that of Figure 1. Alternately, picture it as a black box with one of N_i acceptable inputs and as many corresponding outputs. The set of inputs or entries resemble the entries to a library or parts catalog, a classified directory like the Yellow Pages, or an encyclopedia: they are a mixture of subject-headings and proper names, in terms of which any query is to be represented. The output corresponding to each input is a list of surrogates for either documents or colleagues in the organization or both.

Let M_i be the average number of document-surrogates per entry and let L_i be the number of "colleague"-surrogates per entry. Thus, M_i+L_i is the average total number of surrogates from which the directory user can pick one when he enters the directory with a term that matches. If m_i is the average number of bits per document-surrogate and l_i that for a colleague-surrogate and b_i is the average number of bits per entry, then the entire directory takes $N_i(b_i+M_im_i+L_il_i)$ bits to store. If it takes T seconds to check if a given term matches some entry in the directory and the entries are kept in order, it takes approximately T log N_i seconds to locate a row in the directory if the input term matches some entry. To this should be added the time, T' seconds, it takes the directory user to read the output and make a choice terminating in a new input registered in the system.

Basically, i will have used the directory in response to a query. He must judge, for relevance to the query, document or colleague surrogates which are the outputs of the directory. His relevance judgment can be faulty for two reasons: (1) the surrogate, which is all he has on which to base his judgment does not accurately reflect the relevance judgment he would have made had he encountered the document or colleague directly; (2) his relevance judgment does not correspond to the requirements of the query.

For example, suppose that 0 requests of 1 the combination to his bank safe, which he lost, giving 1 his name. Now 1 consults his directory, locates 0's name and finds listed surrogates of two documents and three colleagues, say the "List of all active Savings Accounts" and "2, Vice President in charge of Safe Deposits", etc. 1 should pick the third surrogate. It is possible that 2 does not have in his directory a direct surrogate for the book of combinations either, but only something like, "3 officer in charge of customer access". Then 1 should refer the query to 2 who refers it on to 3 who, hopefully, is pointed by his directory to the document containing 0's combination. Of course, if 0 could see the union of the entries in all the directories of 1, 2, and 3, he could have contacted 3 rather than 1 in the first place. Even better, if 0 had the document of all combinations himself he would not have had to bother anyone.

Let Q be the set of all possible queries -- assumed to be characterized by a single term suitable as input for matching a directory entry -- with which 0 might ever enter the system. Let $Dom(D_o)$ be the set of entries in his directory. We shall assume, for purposes of analysis, that he does not rely on his own memory at all, only on this directory. Clearly: $N_o = |Dom(D_o)|$.

Assumption 1: $N_o < |Q|$, and if, for some $q \in Q$, $q \notin Dom(D_o)$, this query is switched to 1.

Assumption 2: $Q \subseteq \bigcup_{i=1}^{n} Dom(D_i)$ and if $q \notin Dom(D_i)$, this query is switched to i+1, i = 1, ..., n.

Theorem 1: Every query in Q will match an entry in some directory, and it will take at most $T \log \prod_{i=1}^{n} N_i$ seconds to effect this match

Assumption 3: Surrogation is perfect and i makes no errors in judging relevance, i = 0, 1, 2, ..., n.

The reason that a directory in which q matches an entry would fail to produce the desired response to 0 for q, even though the output is relevant, is that the output is not yet direct. It may be indirect, pointing correctly to another place where the search can be narrowed down. Will it always be narrowed down, or could it get more diffused? Could it go in non-ending cycles?

If i refers a query q to j who has in his directory pointers which lead q back to i, then i has erred in referring to j. If i can neither, through his directory, find an answer to q, nor find some j who can either find an answer or find some k who can either ..., then the question cannot be answered, and i should so inform O.

4. A Computer Program for Analyzing Referential Consulting Nets.

We present in this section an operational FORTRAN program, created by A. Breveleri, R. Chlopan, W. Everett and A. Tars for this paper. It can be used by anyone to simulate a great variety of proposed configurations of networks of switching centers with directories. We shall show how to use it and one result of its use. The program resembles simulators like that of Gordon[14] and SIMSCRIPT[29], but it is not a programming language.

To conform to FORTRAN notation and to simplify exposition, we relabel the following key variables:

LP: number of people (referential consultants, switching centers) - was n.

LQ: number of questions a directory can match, was $N_i = |Q|$ all i

LD: total number of documents containing answers.

A particular configuration of switching centers to be analyzed is specified by four input arrays. The first array, called MANS, consists of LP answer-directories, one for each person. Each directory is in the form of an LQ x ADEPTH matrix, in which an entry is any integer from 0,1,2, ... to LD + LP. We denote the people by the integers 1,2, ..., LP and the documents by LP + 1, LP + 2, ..., LP + LD. Each row denotes one of the LQ questions; the entry in each row is the set of people or documents each of which is <u>known</u>, by the directory user, to contain the answer. Zeroes are used simply to fill out the matrix, the columns denoting nothing. Thus, if there are LQ = 4 questions, LP = 2 people (labeled 1, 2) and LD = 3 documents (labeled 3, 4, 5) an answer-directory for person R_1 may

be: $D_1 = \text{MANS} = \begin{array}{|c|c|c|}\hline 2 & 4 & 5 \\ \hline 3 & 0 & 0 \\ \hline 0 & 0 & 0 \\ \hline 2 & 3 & 5 \\ \hline\end{array}$. ADEPTH (here = 3) is $\max_i (L_i + M_i)$ in the notation

of section three. We read this as: If R_1 gets question 1 (first row), he can get the answer by asking R_2 or looking in documents four or five. If he gets question 2 (row 2), he can get the answer <u>only</u> from document three. He can't get an answer to question three at all, and he can get the answer to question four by asking R_2 or looking in documents three or five.

The second array, called MREF, consists of LP "buck-passing" directories, one for each person. Each is given as an LQ x RDEPTH matrix, with entries 0, 1, ..., LP. Each row again denotes one of the LQ questions. Posted next to each entry are not more than RDEPTH other people, each of whom the directory user <u>thinks</u> can obtain an answer to that question. Thus, for R_1, as above, we

might have $\text{MREF} = \begin{array}{|c|}\hline 2 \\ \hline 0 \\ \hline 2 \\ \hline 2 \\ \hline\end{array}$ with RDEPTH = 1 (it couldn't be greater here).

Here, R_1 thinks that <u>if</u> he referred any question but 2 (row 2) to R_2, R_2

could either answer it or refer it more appropriately than could R_1.

The third array, called MACOST, consists of LP answering-cost-matrices one for each person. Each matrix, for R_i, has LQ rows and LP + LD columns. An entry in row j, column k is any positive real number, representing the cost to R_i of getting the answer to question j from source k. (Recall that k = 1, ..., LP is a person, and k = LP + 1, ..., LP + LD are documents.)

The last array, called MRCOST, consists of LP reference-cost-matrices each being LQ by LP. An entry in row j, column k of this matrix for R_i denotes the cost to R_i of referring question j to person k.

The four arrays are entered as input parameters. The program consists of five parts, as shown in the rectangular boxes of Figure 2. The top box causes all inputs to be read in, all variables to be set initially. The second part, "Question", reads in a question and the person to whom it is originally directed. This can be input or generated randomly by a program. We can think of the programmer as being the querist who refers his question to one of the persons in the network by his input, or we can think of the querist as being the first person in the network who is faced with the question. The basic logic of the next part "Action" is shown in Figure 3. "Action" assumes that a given person cannot be asked the same question twice (in this version of the program), which rules out bureaucratic cycles. The "Pricing" box forms the cost-estimates used in "Action". An adaptive feature is built in which makes the choices converge to the lowest cost per query.

The results printed by the first version of the operating program ("BUCKPASS") are, for each input question and starting consultant,

(1) the total cost and

(2) the chain of referential consultants to whom the "buck" was passed, ending with a person or document.

Example: for LP = 5, LQ = 5, LD = 10, ADEPTH = 10, RDEPTH = 15

Question Input: Question 5 to Person 1.

Output: Cost = \$10; chain = $1 \rightarrow 2 \rightarrow 5 \rightarrow 13$ (a document).

It should be emphasized that the last link in the chain is not a referral, even though the last item in the chain might be a person in the network. We distinguish between person i obtaining the answer to a question directly from person j (by use of MANS) and person i referring a question - passing the buck - to person j (by use of MREF).

A variety of refinements in the program are underway. One important improvement is hierarchization of queries. The input question is first classified into gross and high-level categories, with the first consultant receiving it doing the coarse screening and sending it to one of several other generalists, one for each gross category. A second, closely related new feature is the decomposition of the question into parts, and sending, in turn, (or copies, in parallel) to specialists on the parts. Thirdly, as in [19], measures of quality are introduced. In place of the MANS matrix, we have:

$p(i,j,k)$ = Probability (i knows k has answer to j and finds it)

$r(i,j,k)$ = Probability (i judges k relevant to j | k relevant to j)

$q(i,j,k)$ = Probability (i judges k relevant to j | k irrelevant to j)

(j,k) = Probability (k is relevant to j and provides correct answer)

Now the output is:

(1) the total cost per query, obtained by adding the consultant costs to the lookup costs.

(2) The turn-around time, add the times for referral, the times for each question part that is delivered and the lookup times.

(3) The quality of a response is the probability that the answer is correct.

This permits us to study a trade-off between quality of responses and turn-around time. We can estimate benefits by the expected utility of a high quality response. We can now investigate now different configurations and directory designs affect benefit-cost ratio.

5. Use of BUCKPASS

In this section we present an example of the use of BUCKPASS to analyze a particular network model, a wheel configuration with [illegible] persons. Assumptions in this model render the analysis toosimplistic for practical use; more realistic assumptions, however, would complicate our illustration and would direct attention to the model rather than to the use of BUCKPASS.

In the wheel (fig. 4) the central person, R_1, can refer questions to any of the persons on the periphery. The peripheral persons, $R_2, \ldots, R_5$, can only refer questions to R_1. We consider ten questions, $q_1, q_2, \ldots, q_{10}$, which can be answered by consulting source documents $s_6, s_7, \ldots, s_{15}$ respectively. (In other models, a person in the network might also be a source of answers, e.g. $R_1 = s_1$.) We assume that if one person in the network knows that the answer to q_i can be obtained from s_j, then no other person in the network knows (assumption of disjoint answer directories). We assume that persons R_2, R_3, and R_4 can answer exactly one question, and R_5 can answer N_5 questions. It follows that R_1 in the center can answer $N_1 = 7-N_5$ questions. For example, if $N_5 = 4$, we have MANS and MREF in fig. 5.

If we think of ourselves as the querist, we might ask which person in the network, R_1, R_2, or R_5, we should address our questions to. We might also wish to know the effect of N_5 on the average cost of answering a question if the questions are randomly directed to different persons in the network, under the following assumptions about costs:

1. When a person can answer less than two questions, there is no answer directory look-up.
2. Answer directory look-up proceeds linearly and costs $1.00 for each item examined.
3. The cost of obtaining the answer from the source document is $1.00.
4. The referral directory is consulted only after failure to match in answer directory; hence referral cost includes $\$N_i$ when $N_i \geq 2$.
5. Referral directory look-up proceeds linearly and costs $1.00 for each item examined.
6. Communication costs $1.00 for each question referred.

These assumptions determine the costs in MACOST and MRCOST. In fig. 6, these matrices are flattened in the third dimension since there is in this model only one source to answer each question, and referral of an unanswered question is likewise unique. It should be clear that we have optimal directory design under our assumptions (e.g. the fourth item in R_1's referral directory is the first item in R_5's answer directory).

Example: Suppose we direct question q_6 to person R_5.

1. R_5 consults his answer directory and fails to match each of the four items. He does not consult a referral directory since he refers all unanswered questions to R_1. Referral cost is $4 + 0 + 1 = 5$.
2. R_1 consults his answer directory and fails to match each of the three items. He consults his referral directory and finds a match after examining the sixth item. Referral cost is $3 + 6 + 1 = 10$, and the question is referred to R_3.
3. R_3 does not consult an answer directory since there is only one question he can answer. He obtains the answer from source document s_{11}. Answer cost is $0 + 1 = 1$.

4. To obtain the answer to question q_6 by asking R_5, the chain is $5 \rightarrow 1 \rightarrow 3 \rightarrow 11$ and the total cost is \$16.00.

In table 1 are shown the average costs for asking all ten questions of R_1, R_2, and R_5 as well as the average cost for directing questions randomly to any of the five persons in the network. This information is given for each of the values of N_5. For $N_5 = 7$, R_1 acts only as a switching center and can answer no questions. The case $N_5 = 0$ is of no interest since we would be dealing with a four person network with the option of sending a question directly to R_1 or indirectly through a \$1.00 communication channel R_5. The effect of cost assumption 1 is apparent for $N_5 = 6$. With that exception, the cost decreases as the expertise of R_1 increases. Except when $N_5 = 7$, R_2 is the best entry point to the network under these assumptions.

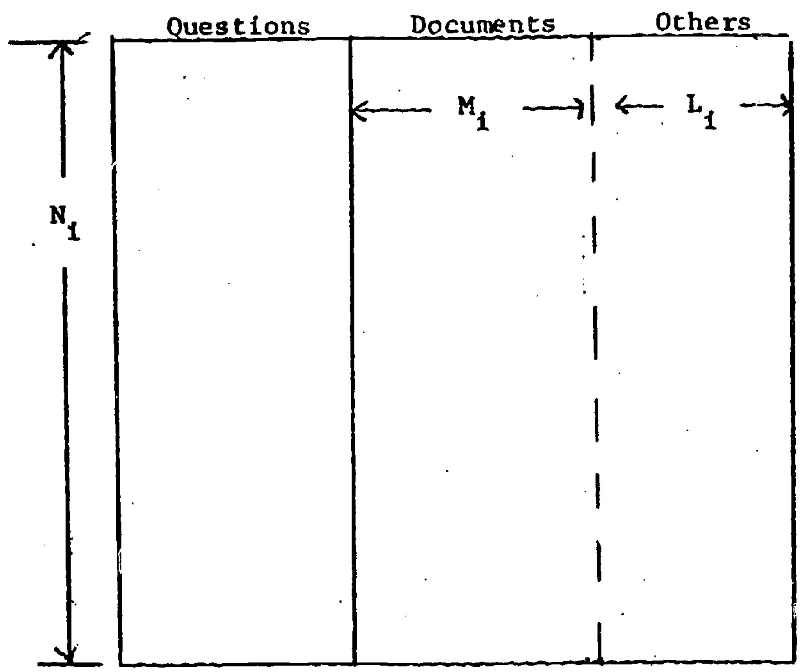
We can modify our cost assumptions and observe the resulting effect on the cost of the network. If we replace cost assumption 5 by

5'. Referral directory look-up is categorical, proceeds linearly, and costs \$1.00 for each category examined,

we have MRCOST as in fig.7 (with $N_5 = 4$). Questions q_1, q_2, q_3, and q_5 match the first item in R_1's referral directory, that item being the category of questions referred to R_5. In table 2 we see the results of this model. The reduction in referral costs has made R_1 the optimal entry point to the network. However, if we never use R_5 as an entry point, the minimum cost is obtained when R_1 can answer four or five questions, rather than six. This contrasts with the first model in which the lowest cost was obtained when R_1 had maximum expertise.

A more interesting use of BUCKPASS would be to allow referral of any question to any of the other persons in the network and to determine what distribution of question-answering capabilities and what cost assumptions cause the model to converge to a wheel configuration of preferred communication links. In the example described above there were no alternative paths and consequently no opportunity for convergence.

A refinement incorporated in BUCKPASS II allows the user to specify implicit cost functions, eliminating the need to provide the cost matrices as input data. With the additional output statistics mentioned in the preceeding section, we have a powerful tool for readily determining cost-benefit ratios of referential consulting networks under different directory designs, distributions of question answering capability, and cost assumptions.



Directory D_i for i^{th} Referential Consultant

FIGURE 1.

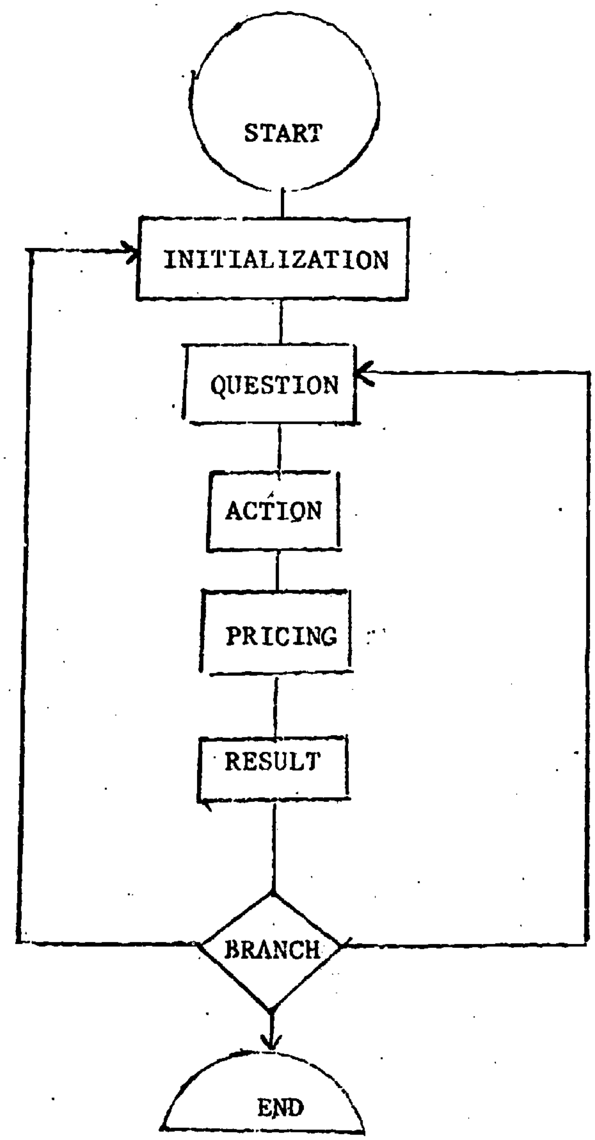

START
INITIALIZATION
QUESTION
ACTION
PRICING
RESULT
BRANCH
END

FIGURE 2

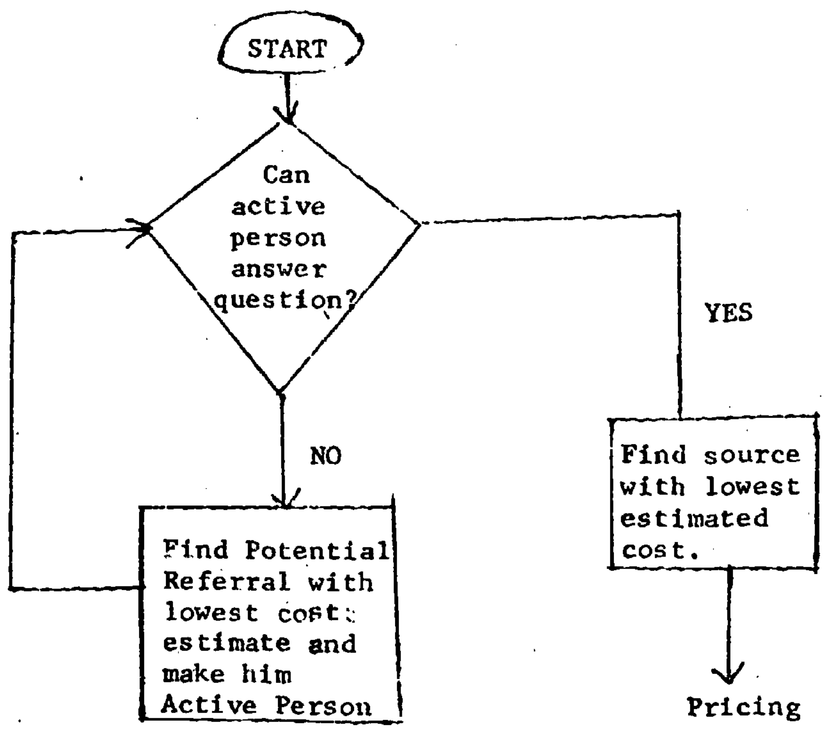

START
Can active person answer question?
YES
NO
Find source with lowest estimated cost.
Find Potential Referral with lowest cost estimate and make him Active Person
Pricing

FIGURE 3.

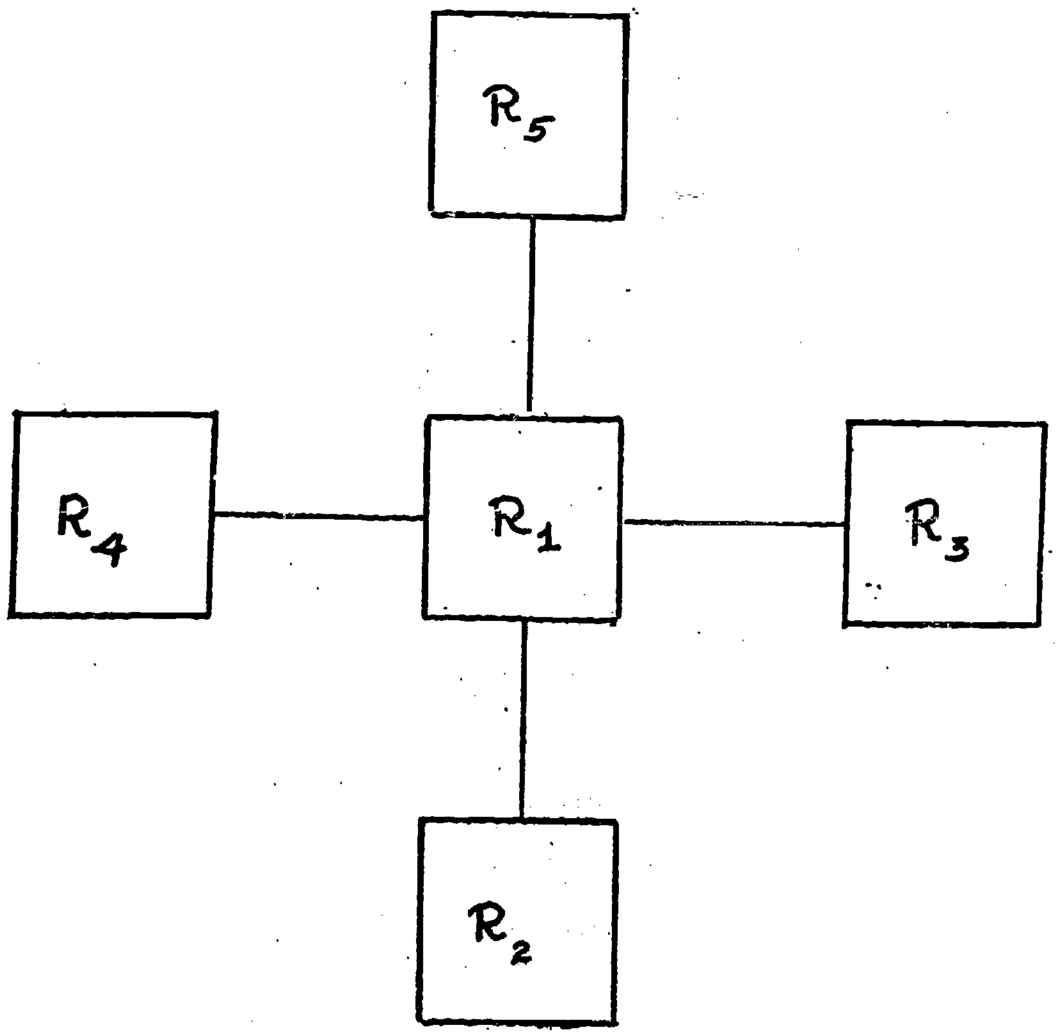


FIGURE 4

	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}
R_1	0	0	0	0	0	0	0	13	14	15
R_2	0	0	0	0	0	0	12	0	0	0
R_3	0	0	0	0	0	11	0	0	0	0
R_4	0	0	0	0	10	0	0	0	0	0
R_5	6	7	8	9	0	0	0	0	0	0

MANS

(ADEPTH = 1)

	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}
R_1	5	5	5	5	4	3	2	0	0	0
R_2	1	1	1	1	1	1	0	1	1	1
R_3	1	1	1	1	1	0	1	1	1	1
R_4	1	1	1	1	0	1	1	1	1	1
R_5	0	0	0	0	1	1	1	1	1	1

MREF

(RDEPTH = 1)

FIGURE 5.

	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}
R_1	0	0	0	0	0	0	0	2	3	4
R_2	0	0	0	0	0	0	1	0	0	0
R_3	0	0	0	0	0	1	0	0	0	0
R_4	0	0	0	0	1	0	0	0	0	0
R_5	5	4	3	2	0	0	0	0	0	0

MACOST

	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}
R_1	5	6	7	8	9	10	11	0	0	0
R_2	1	1	1	1	1	1	0	1	1	1
R_3	1	1	1	1	1	0	1	1	1	1
R_4	1	1	1	1	0	1	1	1	1	1
R_5	0	0	0	0	5	5	5	5	5	5

MRCOST

FIGURE 6.

	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}
R_1	5	5	5	5	7	8	9	0	0	0
R_2	1	1	1	1	1	1	0	1	1	1
R_3	1	1	1	1	1	0	1	1	1	1
R_4	1	1	1	1	0	1	1	1	1	1
R_5	0	0	0	0	5	5	5	5	5	5

MRCOST

FIGURE 7.

		Network Entry Point		
N_5	R_1	R_2	R_5	Random
7	10.30	10.10	9.20	10.02
6	8.50	8.40	8.60	8.52
5	8.80	8.60	8.80	8.74
4	8.20	8.00	8.60	8.22
3	7.70	7.50	8.40	7.78
2	7.30	7.10	8.20	7.42
1	6.90	6.70	7.00	6.86

Average Cost in Dollars for Model I.

TABLE 1.

		Network Entry Point		
N_5	R_1	R_2	R_5	Random
7	6.40	6.80	7.40	6.90
6	5.50	5.90	7.10	6.12
5	5.00	5.40	7.00	5.70
4	4.60	5.00	6.80	5.34
3	4.40	4.80	6.60	5.14
2	4.40	4.80	6.40	5.10
1	4.50	4.90	5.20	4.94

Average Cost in Dollars for Model II

TABLE 2.

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