

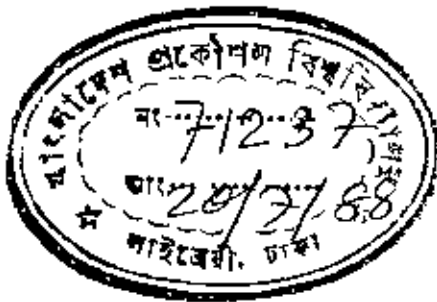
DESIGN OF AN EXPERT MANUFACTURING SYSTEM:
THE CASE OF SELECTION OF A SUITABLE LATHE
FROM A MACHINE PARK

A Thesis

By

MD. AL-AMIN HOSSAIN

Submitted to the Department of Industrial and Production
Engineering, Bangladesh University of Engineering and
Technology, Dhaka in partial fulfilment of the requirement
for the degree of M.Sc. Engg. (IP) from the DEPARTMENT OF
INDUSTRIAL AND PRODUCTION ENGINEERING



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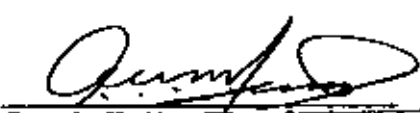

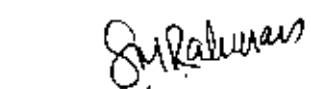
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Author

S U M M A R Y

Production facilities such as machine tools are costly. Thus one of the goals of PPC is to maximize the total utilization which includes time as well as technological utilization. Sometimes, it is very difficult and costly enough to attain this goal by human expert. To avoid the shortcomings of human factors, an artificial expert namely Expert Manufacturing System (EMS) has been developed.

The EMS consists of mainly three parts i.e. (1) Knowledge Base (KB) 2) Data Base (DB) & 3) Inference Engine (IE). KB is the collection and representation of knowledge and the knowledge is represented by Rules. Similarly, DB is the collection and representation of data and the data is represented in DB by array. The IE is the control and inference strategy of the system. For inference strategy modus ponens is used and for control strategy Branching method. Generate-and-Test method, etc., are used. The reasoning are governed here by forward chaining. The relationship among this three parts are shown in fig. 1.3.

For the development of the system it is assumed that the machine to be selected is lathe of different types for a simple rotary job and it is capable of selecting blank, fixture and lathe and identifying operations. A suitable one is selected among the available blanks, on the basis of minimum material removal. The operation identification is on the basis of minimum number of machining (i.e. operation) and here only some simple operation considered. The selection of fixture is on the basis of minimum

job deflection and here only some job holding and extra supporting devices of lathe are considered. And finally, the lathe selection is on the basis of minimum machining cost.

To develop EMS, BASIC is chosen as a language and it runs on an IBM PC XT with a MS DOS operating system.

To implement it, no special computer knowledge is necessary, only some physical and mechanical job characteristic should be typed into the system through man-machine interaction.

The results as obtained by EMS is more logical and the interaction procedure is friendly.

LIST OF SYMBOLS

- AI - Artificial intelligence
- A_T - Set of input variables for machine selection
where $T = (1, 2, 3, \dots, g)$
- AC_m - Minimum grades of dimensional accuracy as obtained by machine m
- AC_r - Average grades of dimensional accuracy as obtained by rough turning
- AC_f - Average grades of dimensional accuracy as obtained by finish turning
- AC_1 - Grades of accuracy of Blank
- AC_2 - Grades of accuracy of finished job
- A_1 - Lower tolerance limit of Blank (in.)
- A_2 - Lower value of tolerance limit of job (in.)
- a_{cd} - Input table for fixture selection
where $c = (1, 2, \dots, W)$, $d = (1, 2, \dots, S, \dots, b)$

- dc - depth of cut, (in.)
- dc_m - Minimum value of depth of cut for machine m
- dc' - Minimum depth of cut needed for a job
- D_1 - Nominal dia. of Blank
- D_2 - Nominal dia. of finished job (in.)

- ES - Expert system
- EMS - Expert Manufacturing System
- F_S - Selected fixture(s)
- F_x - Output variables for fixture selection
where $x = (1, 2, 3, \dots, z)$
- f_e - Cutting feed in ipr
- f_{em} - Cutting feed available in machine m (ipr)
- f_1 - Surface roughness of Blank (in.)

LIST OF SYMBOLS (Contd.)

f_2	-	Surface roughness of finished job (in.)
f_r	-	Average surface roughness as obtained by rough turning
F_m	-	Fixture available in machine m.
f_m	-	Minimum surface roughness as obtained by machine m in inch
f_f	-	Average surface roughness as obtained by finish turning
HR	-	Machine hourly rate (Tk./hr.)
h_T	-	No. of elements in the T-th set of input variables for machine selection
J_1	-	Upper value of tolerance limit of Blank (in.)
J_2	-	Upper value of tolerance limit of finished job (in.)
JM_m	-	Job material usually processed by machine m.
JM	-	Job material
K	-	No. of NUM variables
L_1	-	Blank length
L_2	-	Finished job length
L_m	-	Maximum centre distance of the machine m
LS	-	Lot size of the job
MO	-	Inference operator for Blank selection
M_j	-	Inference operator for operation type identification
M_s	-	Selected machine
M_Q	-	The output variables for machine selection where $Q = (1, 2, \dots q)$
N_c	-	Cutting speed in rpm
N_m	-	Cutting speed in rpm available in machine m
NAM	-	Name of the machine
n	-	Number of cuts during rough turning
O_j	-	Output variables for total operation identification where $j = (1, 2, \dots m_1)$
O_s	-	Identified operation

LIST OF SYMBOLS (Contd.)

O_m	- Operations to be done by machine m
P_e	- Input variables for fixture selection where e = (1, 2, 3, ... y)
P_a	- Scheduled load of machine during a plan period (hr.)
P_o	- Maximum hp needed to process the job (hp)
P_{om}	- Power capacity of machine m (HP)
q	- Total no. of available machine
R	- Total no. of available Blank
r	- No. of NONNUM variables
SB	- Swing over bed (in.)
SC	- Swing over cross slide (in.)
T_{tu}	- Time utilization factor of machine
T_A	- Available time of the machine (hr.)
T	- Total operation time for the job (hr.)
t_{su}	- Setup time (standards) etc. for the job (min.)
TC	- Total operation cost (Tk.)
t_c	- Actual machining time (min.)
u_i	- Input variables for Blank selection where i =(1, 2, ... n)
V_s	- Selected Blank
V_c	- Surface cutting speed (fpm)
η	- Workplace efficiency

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INTRODUCTION

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CHAPTER - 1

INTRODUCTION

1.1 Expert System

Since the dawn of the civilization the man is inventing tools and devices to free him from the burden of manual work. As a consequence, there is a chain effect in this process of invention. At one stage of this evolution of civilization the man felt the need of such a machine which can serve the mankind by doing all laborious and repetative works of calculation very quickly. Computer is the outcome of that thought. New generations of computers having more and more capacities are being continuously marketed. Recently computer scientists are working to develop techniques that would allow computer to act more like human being. This the starting point of Artificial Intelligence (AI). The entire research effort, including decision making system, robotic devices, and various approaches to computer speech, is usually called AI. The AI spreads into three major areas, such as -

- 1) Expert System
- 2) Robotics
- 3) Natural Language Understanding

One of the important areas where AI is currently being exploited is in the field of Expert System (ES), many of which can do as well (or even better) than human experts, e.g. in case of weather forecasting, ES is nothing but the collection of expertise knowledge in a software package.

Professor Edward Feigenbaum of Stanford University defines as:

" an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. The knowledge of an ES consists of facts and heuristics. The facts constitute a body of information that is widely shared, publicly available, and generally agreed upon by experts in a field. The 'heuristics' are mostly private, little discussed rules of good judgement (rules of good guessing) that characterize expert-level decision in the field "

An expert system (ES) is designed to function like a human expert. It takes information from the current task and then compares this with the information stored in database and searches for a match. Finally it gives a report based on whether or not a match has been found.

Some of the important characteristics of ES are given below:

- 1) The ability to add rules and modify reasoning.
- 2) The ability to explain the reasoning.
- 3) The ability to interact easily with the users.
- 4) It should be able to perform difficult tasks at expert level.

The application of ES is widening day by day. In the case of medical diagnosis, identification, measuring, scientific analysis, etc. the concept of ES is being used successfully. The popularity of this concept is increasing as the application of specialized knowledge is increasing. In fact, there is a shortage of qualified human expert in developing countries and naturally the cost of using them in problem solution is higher.

In addition, human decision processes are slow, less reliable and time bounded. So people are going for creation of artificial expert - the ES. In many countries of the world such as UK, USA, Hungary, China, Canada, etc. tremendous research work on ES is being carried out for its application in newer field. In manufacturing system, a very few expert package are available for example TOPIS-II. and it is a production planning and control software package. Unfortunately none of the ES, included the case of m/c (lathe) selection process. So there is a wide scope of using ES in this field.

In case of business, ES may play a vital role. The impact of ES come in at least two waves. (Fig. 1.1). The small wave grew upto 1986 and then level off. The second, much larger wave will not peak until the early 1992s and has a large impact on business and industry when it arrives.

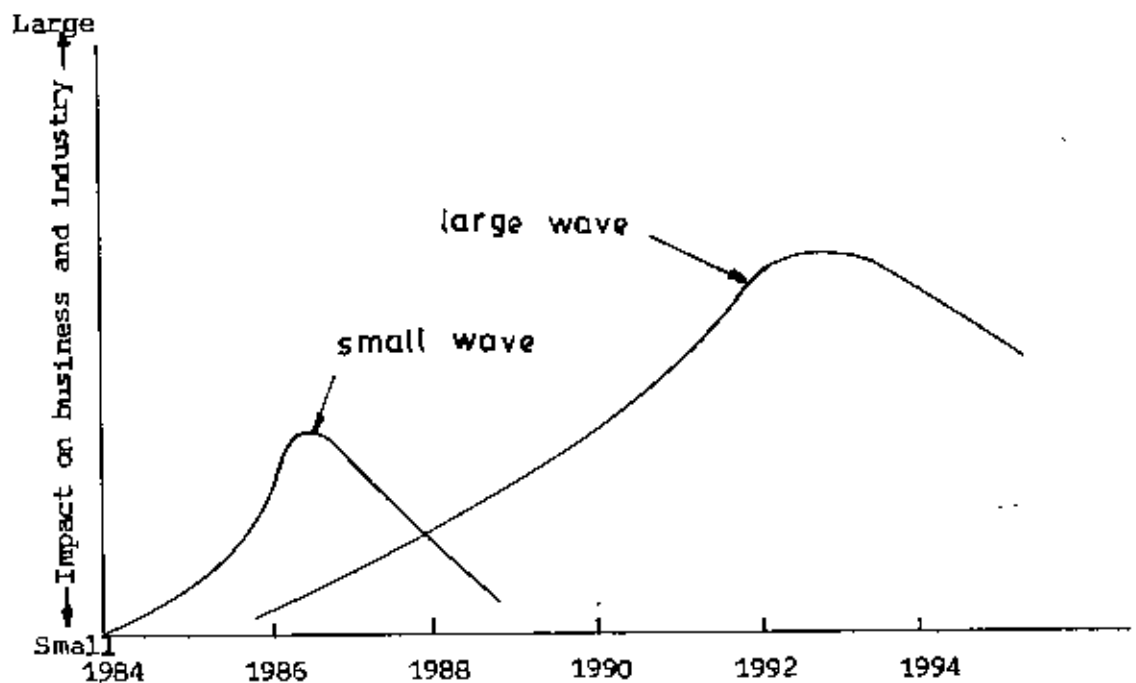


Fig. 1.1 : Impact on business and industry due to ES⁽¹⁾

1.2 Problem definition

Production facilities such as machine tools are costly. Thus one of the goals of PPC is to maximise the total utilization which includes time as well as technological utilization. This complicates the production planning to a great extent. The traditional process of machine tool selection does not guarantee this. Because that is mainly experience based and almost no systematic and logical steps are followed to attain these objectives. The problem of production planning for a job order can be seen in fig. 1.2. When a job order is received by PPC, it needs to select at first raw materials, then the identification of operation, in sequence the selection of jigs and fixture and that of machine tools. When a machine tool is selected, the selection of cutting tools and cutting variables are imperative to process the job order.

But a traditional planner can not consider all the influencing factors, in their complex relation, this may result in inappropriate selection of machine tools, machining process, etc. This problem may be solved in two ways. Firstly, by using human expert to include the variables. Secondly, an artificial expert can replace a human expert. In a developing country like Bangladesh there is acute shortage of human experts. Thus the artificial expert may be more easily available and will be cheaper, faster and more reliable. Hence it is proposed in the work to design an artificial expert.

1.3 Objectives of the research:

The present research is to improve the traditional selection procedure of a machine from a machine park. The goal will also be to make the procedure more

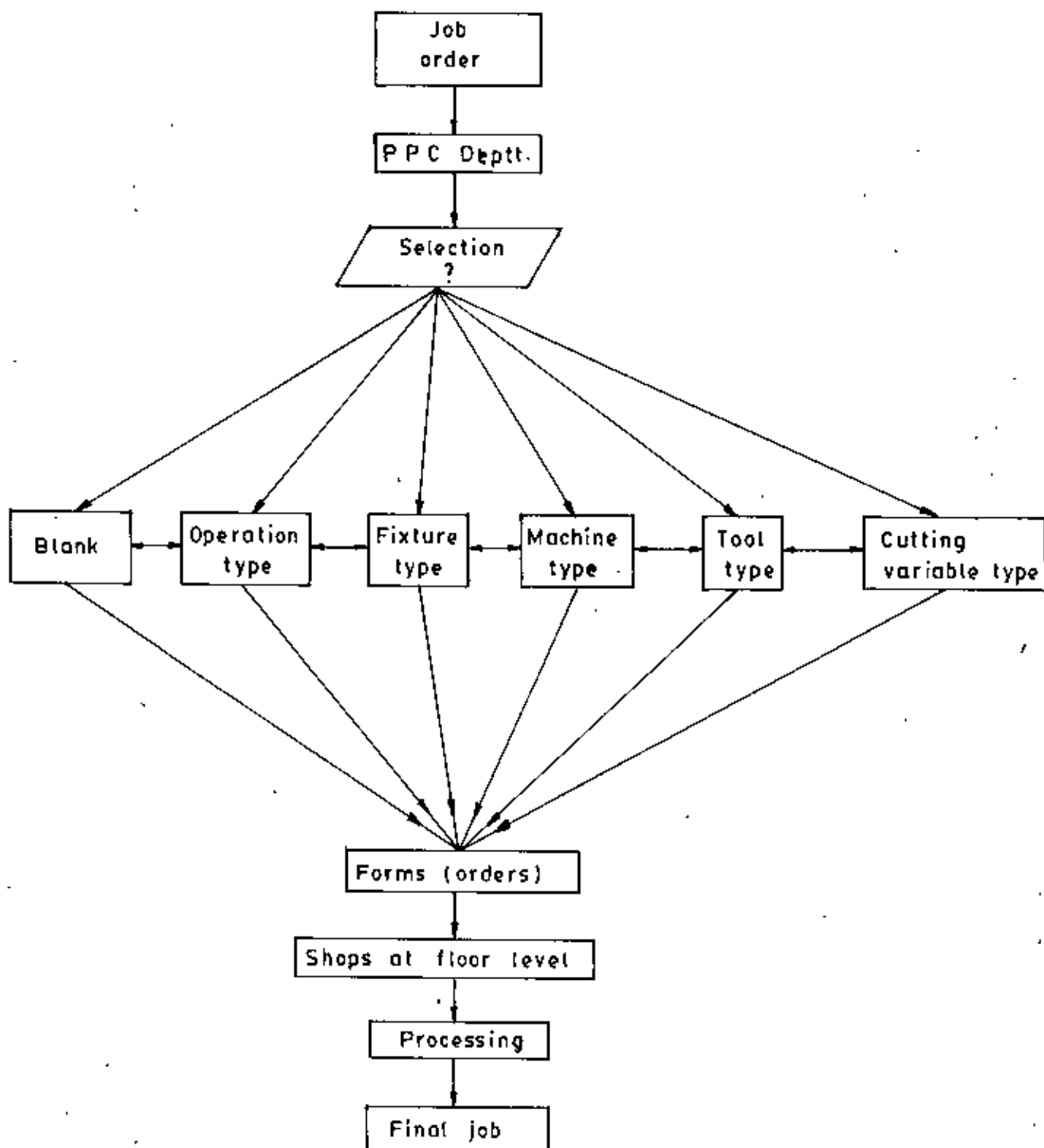


Fig. 1.2 A typical problem of manufacturing system

reliable, faster and cheaper. An expert system capable of tackling this types of problems is to be designed. The objectives of the study are:

1. To collect the expert knowledge and data from both theoretical and practical viewpoints, and develop a knowledge base and a database for the selection of a suitable lathe.
2. To formulate the mathematical statements of the sequential logic of the selection hierarchy.
3. To design an inference engine used to draw inferences and control the reasoning process.
4. To develop that part of an EMS, which deals with the selection of raw material, fixture(s), identification of operation(s) types and selection of the machine tools (lathe).

1.4 Research Methodology:

The prime objective of this study is to design a part of an Expert Manufacturing System (EMS), which deals with the selection of raw material, identification of operations, and selection of fixture and machine (lathe). The EMS consists of mainly three parts i.e.

- 1) Knowledge base (KB)
- 2) Data base (DB)
- 3) Inference Engine (IE)

KB and DB are the collection and representation of knowledge and data respectively. IE is the control and inference strategy of the system. Their relationship may be shown as in Fig. 1.3

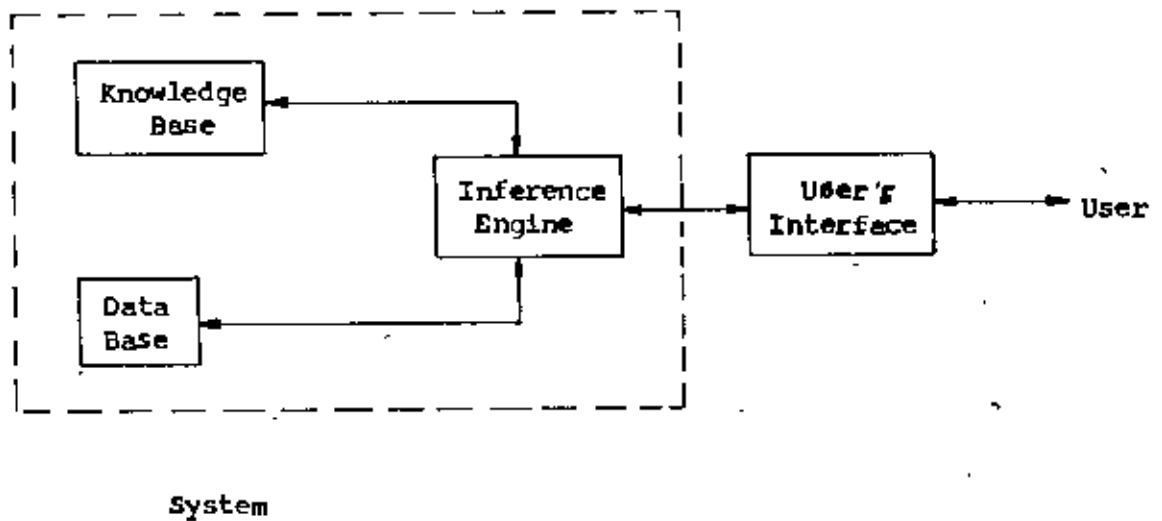


Fig. 1.3 : Structure of the System

In order to attain the objective the following steps and procedures were followed as seen in Fig. 1.4.

All these data and knowledges are collected, keeping theoretical and practical aspects in view.

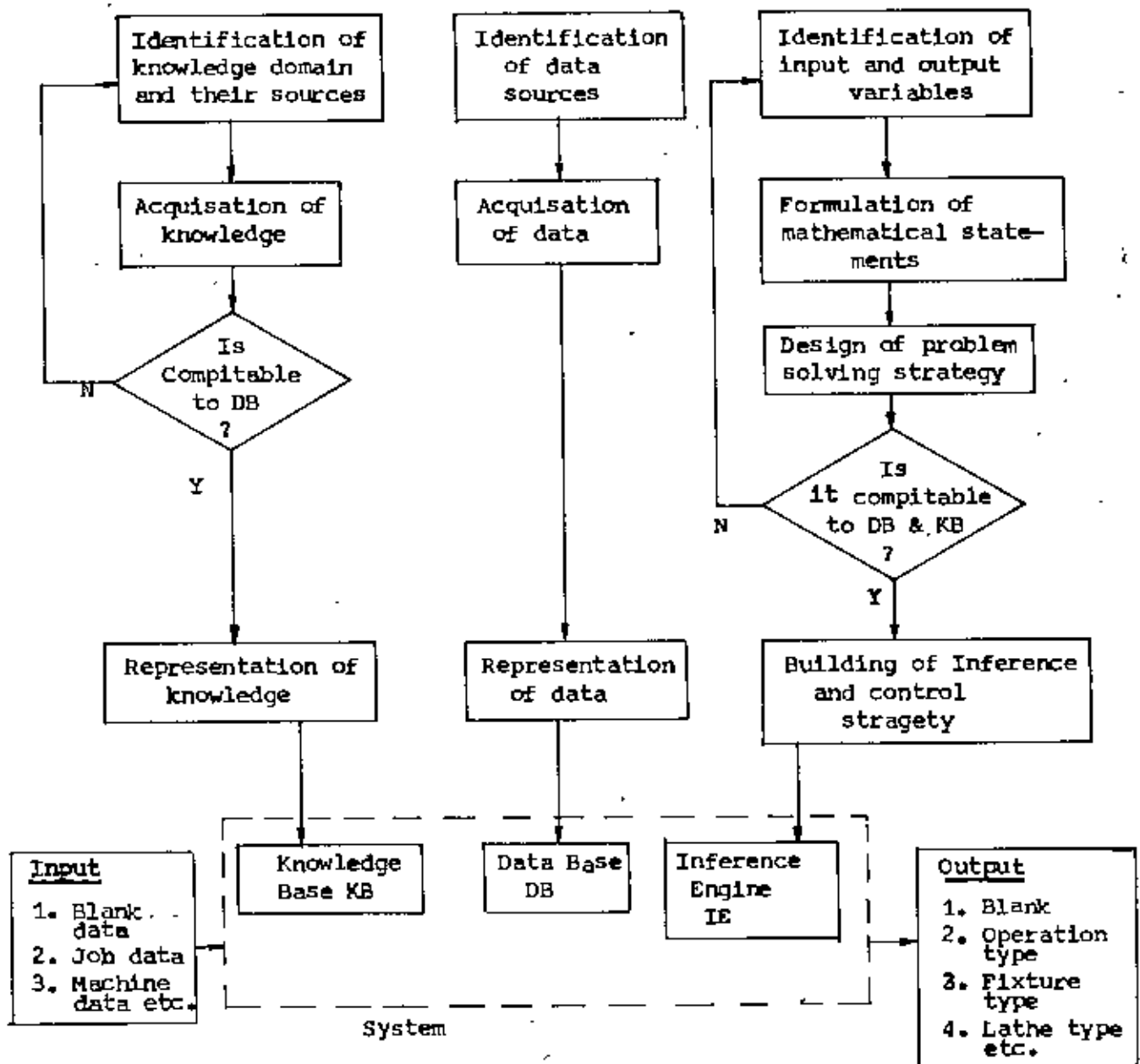


Fig. 1.4 : Methodology of the system

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CHAPTER - 2

LITERATURE REVIEW

2.1 Background Study of Expert System

Ever since its birth, approximately 25 years ago, in the academic world, the AI community has been a heterogeneous group, consisting of psychologists, computer scientists and an occasional engineer. Therefore, it should not be a big surprise that over the years A.I. researchers have not agreed on much; not even on a common terminology or a common approach. Some of the researchers originally held rather simplistic views about human thinking and learning and soon claimed that "any time now computers will out think human beings". Their failure to live up to such promises eventually brought A.I. in to disrepute, at least among practising computer experts and engineers.

About 15 years ago a number of corporations thought that some of the research coming out of the A.I. Laboratories would prove useful in business. Several companies set up AI groups to develop practical applications. By and large, these efforts failed because AI programs were too costly to develop, were too slow, and didn't produce sufficiently practical results. However, AI researchers continued to work in the universities and made steady theoretical progress. Meanwhile, the development of microelectronics technology resulted in a new generation of faster, more powerful, and relatively inexpensive computers.

AI can be subdivided into three relatively independent research areas⁽¹⁾ as shown in fig. 2.1. One group of A.I. researchers is concerned primarily with developing computer programs that can read, speak or understand

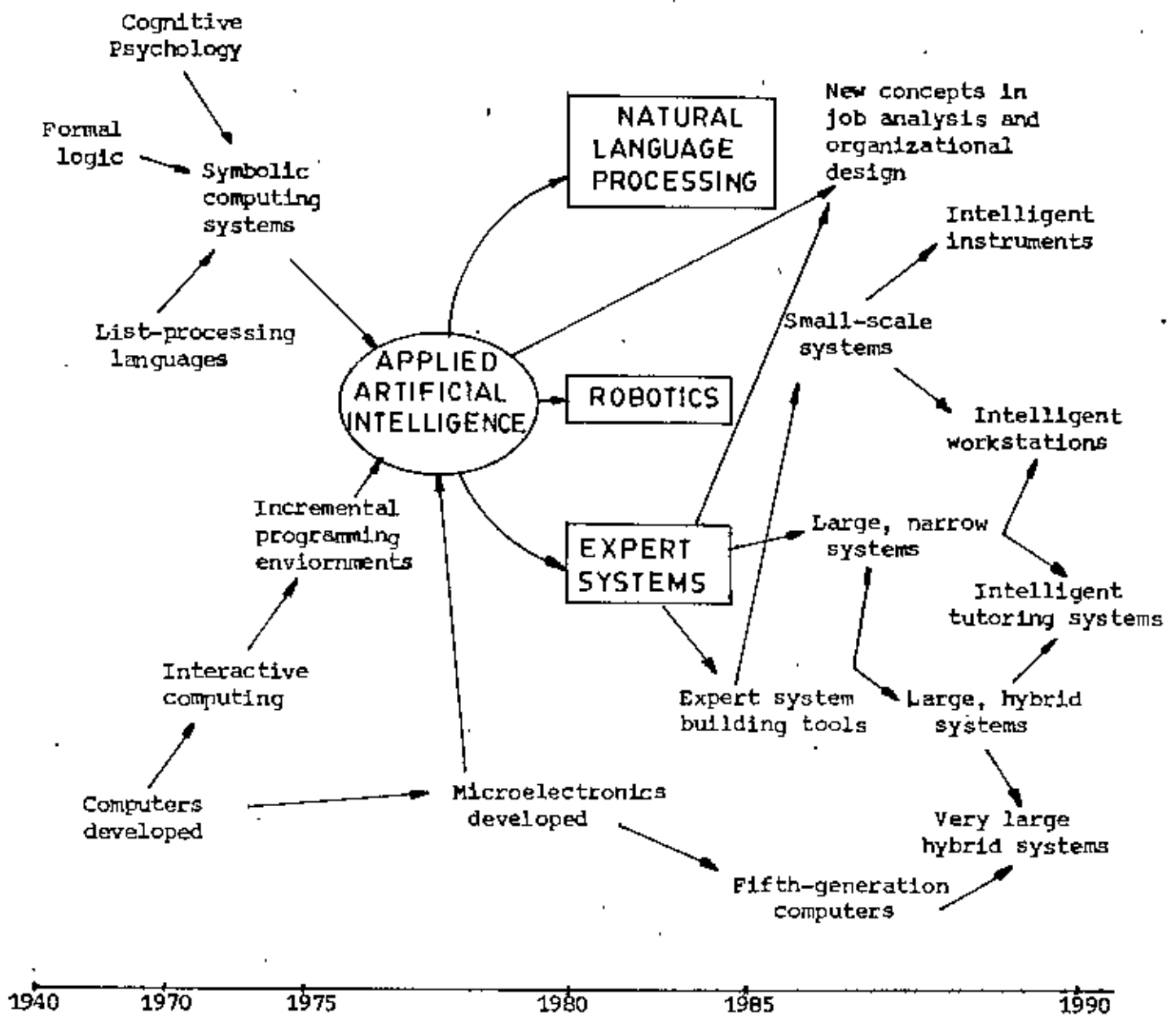


Fig. 2.1 : The evolution of expert system⁽¹⁾

language as people use it in every day conversation. This type of programming is commonly referred to as natural language processing. Another group of AI scientists is concerned with developing smart robots. They are especially concerned with how to develop visual and tactical programs that will allow robots to observe the ongoing changes that take place as they move around in an environment. A third branch of AI research is concerned with developing programs that use symbolic knowledge to simulate the behavior of human experts. Table 2.1 gives a brief overview of the key developments in AI.

2.2 Problem Solving Method

It is a process in which one starts from an initial state and proceeds to search through a problem solving space in order to identify the sequence of operations or actions that will lead to a desired goal. Some of the problem solving methods are presented in the following:

2.2.1 Generate and Test

The generate-and-test strategy is the simplest of all the approaches and it consists of the following steps:

1. Generate a possible solution. For some problems, this means generating a particular point in the problem space. For others it means generating a path from an initial state.
2. Test to see if this is actually a solution by comparing the chosen point or the endpoint of the chosen path to the set of acceptable goal states.

Period	Key Events
Pre-World War II roots	Formal logic Cognitive psychology
The postwar years, 1945-1954	Computers developed H. Simon, Administrative Behavior N. Wiener, Cybernetics
Pre-AI	A.M. Turing, "Computing Machinery and Intelligence" Macy Conferences on Cybernetics
The formative years, 1955-60	Growing availability of computers Information Processing Language I (IPL-I)
The initiation of AI research	The Dartmouth Summer Seminar on AI, 1956 General Problem Solver (GPS) Information processing psychology
The years of development and redirection 1961-1970	A. Newell and H. Simon, Human Problem Solving LISP Heuristics Satisficing Robotics Chess programs DENDRAL (Stanford)
The years of specializa- tion and success, 1971- 1980	MYCIN (Stanford) HEARSAY II (Carnegie-Mellon) MACSYMA (MIT)
The discovery of know- ledge based systems	Knowledge engineering EMYCIN (Stanford) GUIDON (Stanford) PROLOG Herbert Simon-Nobel Prize
The rush to applications, 1981 -	PROSPECTOR (SRI) Japan's Fifth-Generation Project E. Feigenbaum and P. Mc Corduck, The Fifth Generation
International competition and commercial ventures	U.S.'s Microelectronics & Computer Technology Corp. (MCC) INTELLECT (A.I.C.) Various corporate and entrepreneurial AI companies

Table : 2.1 An Overview of the Key Events in the History of Artificial Intelligence⁽¹⁾

If the generation of possible solutions is done systematically, then this procedure will find a solution eventually, if one exists.

Unfortunately, if the problem space is very large, it eventually may take a very long time to find a solution.

The generate-and-test algorithm is a depth-first search procedure, since complete solutions must be generated before they can be tested. In its most systematic form, it is simply an exhaustive search of the problem space. Generate-and-test can, of course, also operate by generating solutions randomly, but then there is no guarantee that a solution will ever be found.

For hard problem, it is not a very effective technique but when combined with other techniques to restrict the space in which to search even further, the technique can be very effective.

2.2.2 Hill Climbing

Hill climbing is a variant of generate-and-test in which feedback from the test procedure is used to help the generator decide which direction to move in the search space. In a pure generate-and-test procedure, the test function responds with only a yes or no. But if the test function is augmented with a heuristic function that provides an estimate of how close a given state is to a goal state, the generate procedure can exploit it as shown in the procedure below. This is particularly nice because often the computation of the heuristic function can be done at almost no cost at the same time that the test for a solution is being performed.

1. Generate the first proposed solution in the same way as would be done in the generate-and-test procedure. See if it is a solution. If so, quite. Else continue.
2. From this solution, apply some number of applicable rules to generate a new set of proposed solutions.
3. For each element of the set do the following:
 1. Send it to the test function. If it is a solution, quit .
 11. If not, see if it is the closest to a solution of any of the elements tested so far. If it is remember it. If it is not, forget it.
4. Take the best element found above and use it as the next proposed solution. This step corresponds to a move through the problem space in the direction that appears to be leading the most quickly toward a goal.
5. Go back to step 2.

Hill climbing is not always very effective, it is particularly unsuited to problems where the value of the heuristic function drops off suddenly as you move away from a solution. This is often the case, whenever any sort of threshold effect is present. It is a local method. It shares with other local methods, such as the nearest neighbour algorithm, the advantage of being less combinatorially explosive than comparable global methods. But it also shares with other local methods a lack of a guarantee that it will be effective. Hill climbing can be very inefficient in a large, rough problem space. But it is often useful when combined with other methods that get is started in the right general neighborhood.

2.2.3 Breadth-First Search

A breadth-first search procedure is guaranteed to find a solution if one exists, provided that there are a finite number of branches of the tree. This is easy to prove. If there exists a solution, then there exists a path of finite length, say N , from a start state to a goal state. The breadth first search will explore all paths of length 1, of which there are a finite number. It will then look at all paths of length 2, of which there are also a finite number.

It will continue until it has explored all paths of length N , by which time it will have found a solution. By this same argument, it can be shown that this procedure is guaranteed to find not just any solution, but the one with the shortest path from the goal.

But this procedure requires a lot of memory of a lot of work and it is not suitable in situation where there are many paths that lead to solutions but each of them is quite long.

2.2.4 Best-first Search

Best-first search is a way of combining the advantages of both depth-first and breadth-first search into a single method. At each step of the best-first search process, select the most promising of the nodes that is generated so far. This is done by applying an appropriate heuristic function to each of them. Then expand the chosen node by using the rules to generate its successors. If one of them is a solution, then quit. If not, all those new nodes are added to the set of nodes generated so far. Again the most promising node is selected

and the process continues. Usually what happens is that a bit of depth-first searching occurs as the most promising branch is explored. But eventually, if a solution is not found, that branch will start to look less promising than one of the top-level branches that had been ignored. At that point, the now more promising, previously ignored branch will be explored. But the old branch is not forgotten. Its last node remains in the set of generated but unexpected nodes. The search can return to it whenever all the others get bad enough that it is again the most promising path.

Fig. 2.2 shows the beginning of a best-first search procedure. Initially there is only one node, so it will be expanded. Doint so generates three new nodes. The heuristic function, which in this example, is an estimate of the cost of getting to a solution from a given node, is applied to each of these new nodes. Since node D is the most promising, it is expanded next, producing two successor nodes E and F. But then the heuristic function is applied to them. Now another path, that going through node B looks more promising, so it is pursued, generating nodes G and H. But again when these new nodes are evaluated they look less promising than another path so attention is returned to the path through D to E. E is then expanded yielding nodes I and J. At the next step, J will be expanded, since it is the most promising. This process can continue until a solution is found.

Although this example illustrates a best-first search of a tree, it is sometimes important to search a graph instead so that duplicate paths will not be pursued. The A* algorithm, first described in (Hart, 1968, Hart, 1972) is a way to implement best-first search of a problem graph. It is an extremely useful algorithm. Its operation is described below.

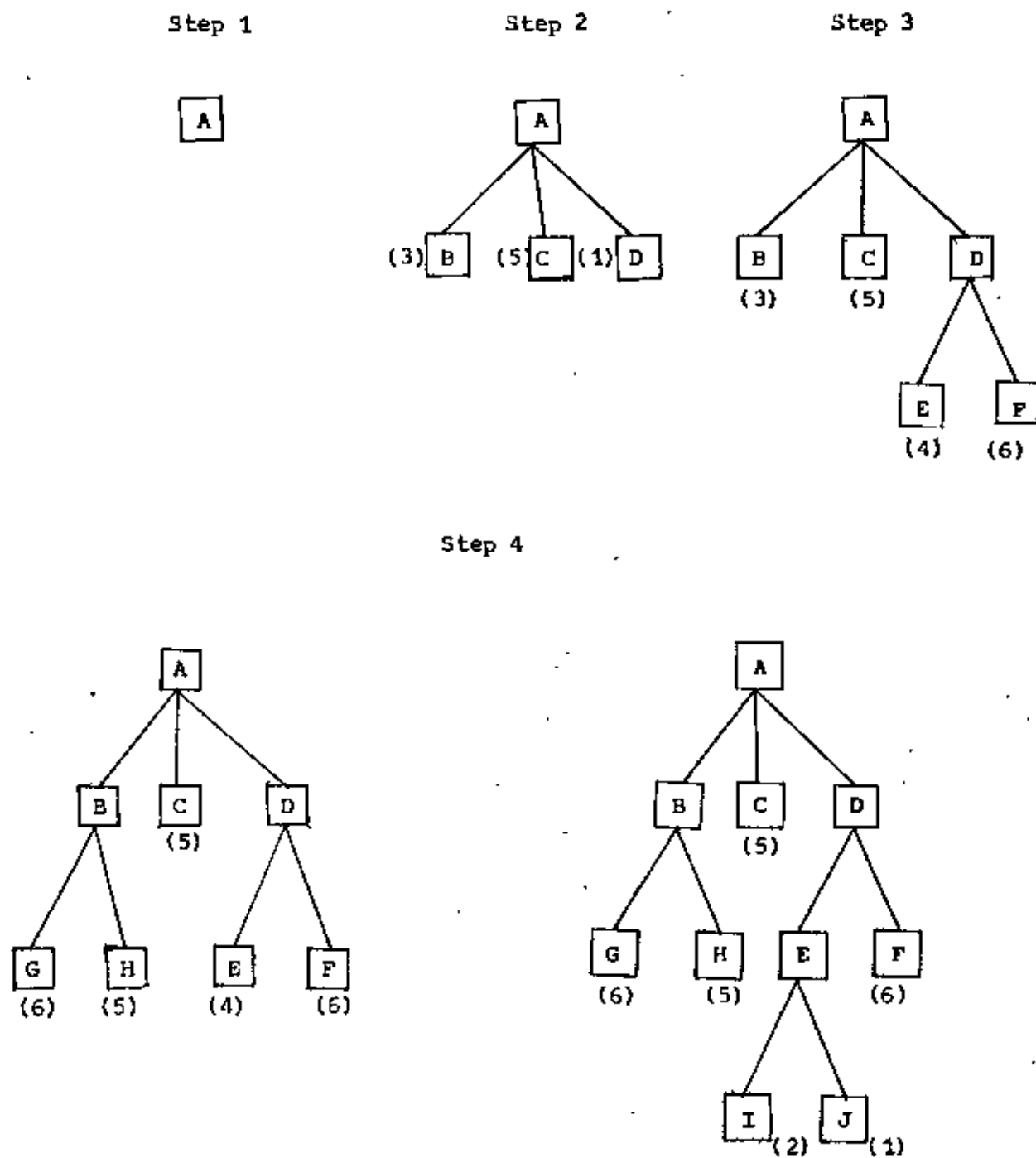


Fig. 2.2 : Operation of a best first search procedure (2)

The algorithm will operate by searching a directed graph in which each node represents a point in the problem space. Each node will contain, in addition to a description of the problem state if represents an indication of how promising it is, a parent link that points back to the best node from which it came, and a list of the nodes that were generated from it. The parent link will make it possible to recover the path to the goal once the goal is found. The list of successors will make it possible, if a better path is found to an already existing node, to propagate the improvement down to its successors.

It will need to use two lists of nodes.

- OPEN - nodes that have been generated and have had the heuristic function applied to them, but which have not yet been examined
- CLOSED - nodes that have already been examined.

It will also need a heuristic function that estimates the merits of each node that is generated. This will enable the algorithm to search more promising paths first. Call this function f' (to indicate that it is an approximation to a function f that gives the true evaluation of the node). For many applications, it is convenient to define this function as the sum of two components, that is g and h' . The function g is a measure of the cost of getting from the initial state to the current node. Note that g is not an estimate of anything, it is known exactly to be the sum of the costs of applying each of the rules that were applied along the best path to the node. The function h' is an estimate of the additional cost of

getting from the current node to a goal state. The combined function f' then represents an estimate of the cost of getting from the initial state to a goal state along the path that generated the current node. If more than one path is found, the algorithm will record the best one. Note that because g and h' must be added it is important that h' be a measure of the cost of getting from the node to a solution (i.e. good nodes get low values, bad nodes get high values), rather than a measure of the goodness of a node (i.e. good nodes get high values). The actual operation of the algorithm is described in detail below.

The A* Algorithm⁽²⁾

1. Start with OPEN containing only the initial node. Set that node's g value to 0, its h' value to whatever it is, and its f' value to $h' + 0$, or h' . Set CLOSED to the empty list.
2. Until a goal node is found, repeat the following procedure. If there are no nodes on OPEN, report failure. Otherwise, pick the node on OPEN with the lowest f' value. Call it BESTNODE. Remove it from OPEN. Place it on CLOSED. See if BESTNODE is a goal node. If so, exit and report a solution. Otherwise, generate the successors of BESTNODE, but don't set BESTNODE to point to them yet. For each such SUCCESSOR, do the following:
 - a) Set SUCCESSOR to point back to BESTNODE. These back links will make it possible to recover the path once a solution is found.
 - b) Compute $g(\text{SUCCESSOR}) = g(\text{BESTNODE}) + \text{Cost of getting from BESTNODE to SUCCESSOR}$.

- c) See if SUCCESSOR is the same as any node on OPEN (i.e. it has already been generated but not processed). If so, call that node OLD. Since this node already exists in the graph, SUCCESSOR can be thrown away and add OLD to the list of BESTNODE's successors. Now it must be decided whether OLD's parent link should be reset to point to BESTNODE. It should be if the path that have been just found to SUCCESSOR is cheaper than the current best path to OLD.

So see whether it is cheaper to get to OLD via its current parent or to SUCCESSOR via BESTNODE, by comparing their g values. If OLD is cheaper (or just as cheap), then we need do nothing. If SUCCESSOR is cheaper, then reset OLD's parent link to point to BESTNODE, record the new cheaper path in g (OLD), and update $f'(OLD)$.

- d) If SUCCESSOR was not on OPEN, see if it is on CLOSED. If so, call the node on CLOSED OLD' and add OLD to the list of BESTNODE's successors. Check to see if the new path or the old path is better just as in step 2.a, and set the parent link and g and f' values appropriately. If a better path to OLD is just found. Propagate the improvement to OLD's successors. OLD points to its successors. Each successor in turn points to its successors, and so forth, until each branch terminates with a node that either is still on OPEN or has no successors. So to propagate the new cost downward, do a depth-first traversal of the tree starting at OLD, changing each node's g value, terminating each branch when you reach either a node with no successors or a node to which an equivalent or better path has already been found. This condition is easy to check for. Each node's parent link points back to its best known parent. As it is propagated down to a node, see if its parent points to the node that are coming from. If so, continue the propagation. If not, then its g value already reflects the better path of which it is part. So the propagation may stop here. But it is possible that with the new value of g being propagated downward, the path we are following may become better than the path through the current parent. So compare the two. If the path through the current parent is still better, stop the propagation. If the path that are being propagat

being propagated through is now better reset the parent and continue propagation.

- e) If SUCCESSOR was not already on either OPEN or CLOSED, then put it on OPEN, and add it to the list of BESTNODE's successors. Compute $f'(SUCCESSOR) = g(SUCCESSOR) + h'(SUCCESSOR)$.

2.2.5 Problem Reduction⁽²⁾

The AND-OR graph (or tree), is useful for representing the solution of problems that can be solved by decomposing them into a set of smaller problems, all of which must then be solved. This decomposition or reduction, generates arcs that we will call AND arcs. One AND arc may point to any number of successor nodes, all of which must be solved in order for the arc to point to a solution. Just as in an OR graph, several arcs may emerge from a single node, indicating a variety of ways in which the original problem might be solved. This is why the structure is called not simply an AND graph but rather an AND-OR graph. In order to find solutions in an AND-OR graph, an algorithm similar to A* is needed, but with the ability to handle the AND arcs appropriately. This algorithm should find a path from the starting node of the graph to a set of nodes representing solution states. Notice that it may be necessary to get to more than one solution state since each arm of an AND arc must lead to its own solution node.

The process of searching an implicit AND-OR graph, is illustrated in fig. 2.3. At step 1, A is the only node, so it is at the end of the current best path.

In step 2, node D is chosen for expansion. This process produces one new arc, the AND arc to E and F, with a combined cost estimate of 10. So the f' value of D is updated to 10. Going back one more level, it is seen that this makes the AND arc B-C better than the arc to D, so it is marked as the current best path.

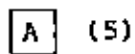
At step 3, it is traversed that arc from A and discover the unexpanded nodes B and C. To find a solution along this path, it will have to be expanded both B and C eventually, so lets choose to explore B first. This generates two new arcs, the ones to G and to H. Propagating their f' values backward f' of B is updated to 6. This requires updating the cost of the AND arc B-C to 12 ($6 + 4 + 2$). After doing that, the arc to D is again the better path from A, so it is recorded that as the current best path and either node E or node F will be chosen for expansion at step 4. This process continues until either a solution is found or all paths have led to deadends, indicating that there is no solution. The actual operation of the algorithm is described as bellow:

The AO* Algorithm: ⁽²⁾

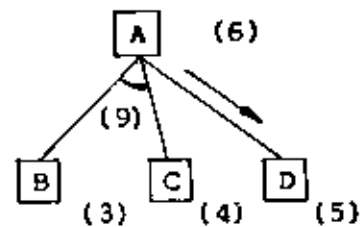
1. Let G consist only of the node representing the initial state.
(Call this node INIT.). Compute h' (INIT).
2. Until INIT is labeled SOLVED or until INIT's h' value becomes greater than FUTILITY, repeat the following procedure:
 - a) Trace the marked arcs from INIT and select for expansion one of the as yet unexpanded node that occurs on this path. Call the selected node NODE.

It is expanded, yielding nodes B, C and D. The arc to D is marked as the most promising one emerging from A, since the one to B and C costs 9 compared to its 6.

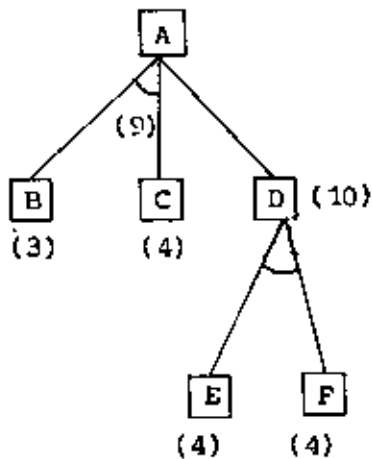
Before step 1



Before step 2



Before step 3



Before step 4

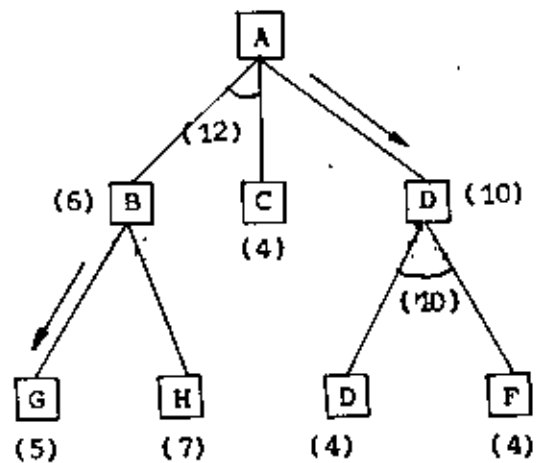


Fig. 2.3 : The operation of the AO* Algorithm⁽²⁾

- b) Generate the successors of NODE. If there are none, then assign FUTILITY as the h' value of NODE. This is equivalent to saying that NODE is not solvable. If there are successors, then for each one (called SUCCESSOR) that is not also an ancestor of NODE do the following:

1. Add SUCCESSOR to the graph G.
2. If SUCCESSOR is a terminal node, Label it SOLVED and assign it an h' value of 0.
3. If SUCCESSOR is not a terminal node compute its h' value.

- c) Propagate the newly discovered information up the graph by doing the following:

Let S be a set of nodes that have been marked SOLVED or whose h' values have been changed and so need to have values propagated back to their parents. Initialize S to NODE. Until S is empty, repeat the following procedure:

1. Select from S a node none of whose descendants in G occurs in S. Call this node CURRENT, and remove it from S.
2. Compute the cost of each of the arcs emerging from CURRENT. The cost of each arc is equal to the sum of the h' values of each of the nodes at the end of the arc plus whatever the cost of the arc itself is. Assign as CURRENT's new h' value the minimum of the costs just computed for the arcs emerging from it.
3. Mark the best path out of CURRENT by marking the arc that had the minimum cost as computed in the previous step.
4. Mark CURRENT SOLVED if all of the nodes connected to it through the new marked arc have been Labeled SOLVED.

- 5) If CURRENT has been marked SOLVED or if the cost of CURRENT was just changed, then its new status must be propagated back up the graph. So add to S all of the ancestors of CURRENT.

2.2.6 Delta-Min. Method: ⁽²⁾

Consider the problem of accepting a series of inputs, one at a time, and processing them sequentially to construct a single, consistent interpretation of them. This problem arises in domains such as speech recognition and natural language understanding. The Δ -MIN approach to the solution of such problems is to let an individual knowledge source (KS) to be triggered whenever it is appropriate and for it then to generate all of the hypothesis it thinks are likely and to assign to each a rating. From these ratings, values, representing the difference between one hypothesis's rating and that of the best competing hypothesis, can be computed. Only the best of the competing hypothesis will then be considered further by the other experts. If however, that hypothesis eventually leads to an inconsistency, one of the competing hypothesis may be considered. The Δ values provide a way of choosing the most promising competing hypothesis if the need for such backtracking does occur.

Figure 2.4 illustrates how the procedure works. Node A represents the initial state before any KS's have been activated. When the first input is read, KS1 fires and generates the hypotheses shown as nodes B, C and D. Node D is the most promising. The difference between its rating and itself is, of course, 0, so it has a Δ value of 0. The difference between its rating

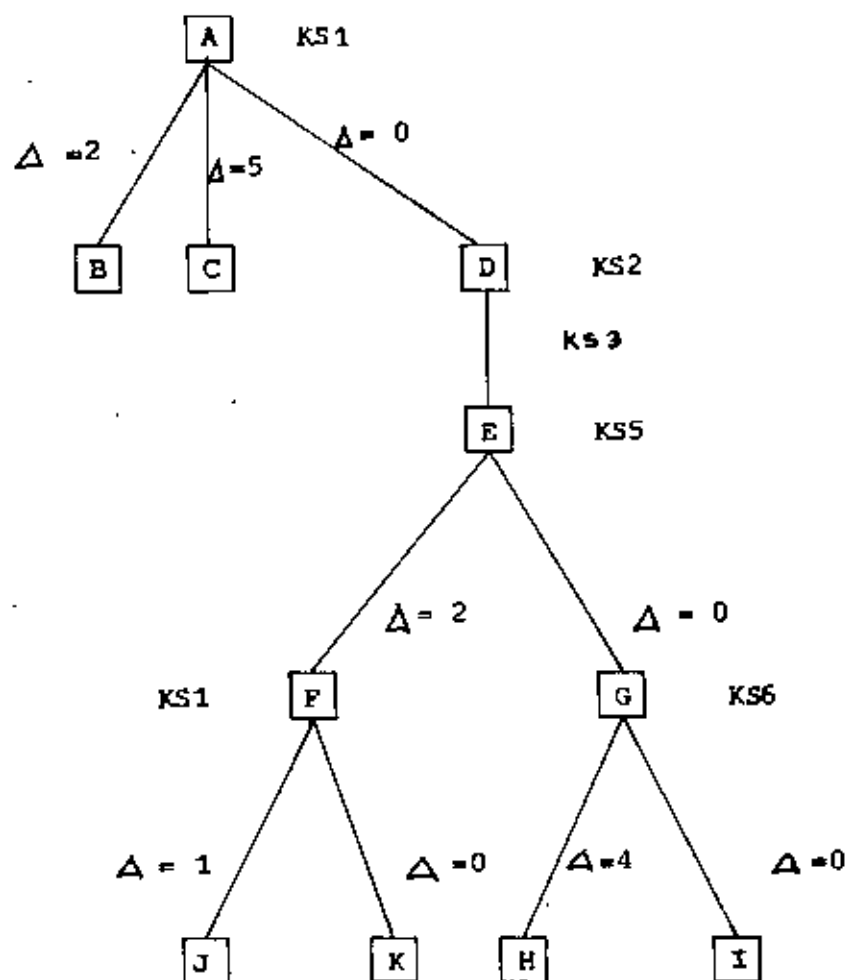


Fig. 2.4 : A Δ -MIN search Tree⁽²⁾

and that of node B is 2, and between it and node C is 5, as reflected in the Δ ratings of those two nodes. For now, only the state represented by node D will be further explored by the other KS's. KS2 fires but is unable to do anything. Then KS3 is activated, but only one hypothesis is generated,

represented by node E. Then KS5 is activated. It generates two possibilities, shown as nodes F and G. Node G is the most promising, so it is explored further, using KS6. It generates two possible next states, shown as nodes H and I, where node I appears the most promising. So far, it has been illustrated a straightforward depth-first search process. But now suppose that information that was unavailable to KS6 leads to a contradiction with the hypothesis of node I. This information could come from a global system constraint or from another independent KS. At this point, backtracking is required.

The role of the Δ values can now be illustrated. To what node should the search procedure return? The most straightforward answer is node H. In other words, simply return to the last decision point. But notice that the expert that generated node H rated it well below ($\Delta = 4$) its other guess (i.e. node I). In contrast, if look back up the tree, it is seen that KS5, at node E, was much less sure that its best hypothesis node G, was really the best, since its next best guess, node F, had a Δ value of only 2. This suggests that the best strategy is to explore node F, which it will be done. Using the Δ -MIN search procedure, the backtracking process will always return to the node that appears overall to be the next most promising.

Continuing with the example, it is seen that KS1 generates two hypothesis nodes J and K. K appears the most promising to KS1, but suppose that again external constraints eliminate it. Then backtracking is again necessary. This time the smallest Δ value is that of node J ($\Delta = 1$). But notice that node J is a descendant of node F, which was itself a second choice. The total uncertainty about the correctness of node J should be a function both of its own uncertainty and that of its ancestors. So it may be a total uncertainty to node J of 3, which is the sum of its Δ value and those of all of its ancestors. This

makes node B, with an uncertainty of 2 (its own Δ value), appear to be the most promising path, so it should be explored next. There are several points that can be made about this control procedure.

- i) It eliminates the need to compare ratings generated by one KS to ratings generated by another. But rating differences (Δ values) must be compared. So there must be some standard interpretation of them. For example, $\Delta(\text{NODE}) = 2$ could mean that the best hypothesis had a rating twice as high as NODE did.
- ii) When backtracking is not required a simple depth-first search is performed. This means that processing will stop when one complete answer is found. Other possible answers will not be considered.
- iii) Just as with other probabilistic reasoning schemes, such as that used in MYCIN, it is important in this procedure to consider not just individual ratings, but also to have a way of combining ratings to get a measure of the overall uncertainty of a given hypothesis.

2.2.7 Branching Method: ⁽⁹⁾

This method is generally used for E.S. development. Here a logical branching out of the knowledge is adopted to reach a goal state from a problem state. This method may be divided into two submethods:

2.2.7.1 Simple Branching: ⁽⁹⁾

This is a simple technique to form an E.S of any problem, which uses 'matching' concept. In reality everybody need to be able to deal with more difficult problems, where the answer can not be found without asking a whole series of questions. This technique may be described clearly with a fault diagnosis problem.

For example, what should an expert do if he put the key in the ignition switch of his car and turned it, but nothing happened ? There could be a number of reasons for this:

- i. FLAT BATTERY
- ii. BAD CONNECTIONS
- iii. SWITCH BROKEN
- iv. STARTER JAMMED
- v. STARTER BROKEN
- vi. SOLENOID BROKEN

To find the cause, he should follow a logical path and make a number of checks. The first thing to do is to check wheather it is only the starter motor which is not working:

IS IGNITION LIGHT ON ? (Y/N)

If the answer to this is 'N' then there is no power at the switch so the cause must be one of the first three possibilities listed above. The things can be now narrow down by finding out if the lights work:

DO LIGHTS WORK CORRECTLY ? (Y/N)

If the answer is yes, then the battery can not be flat and it must be connected to the light switch correctly. So presumably the switch is broken and a suggestion can be made that you replace it.

REPLACE IGNITION SWITCH.

If the lights do not work, then the connections should be checked.

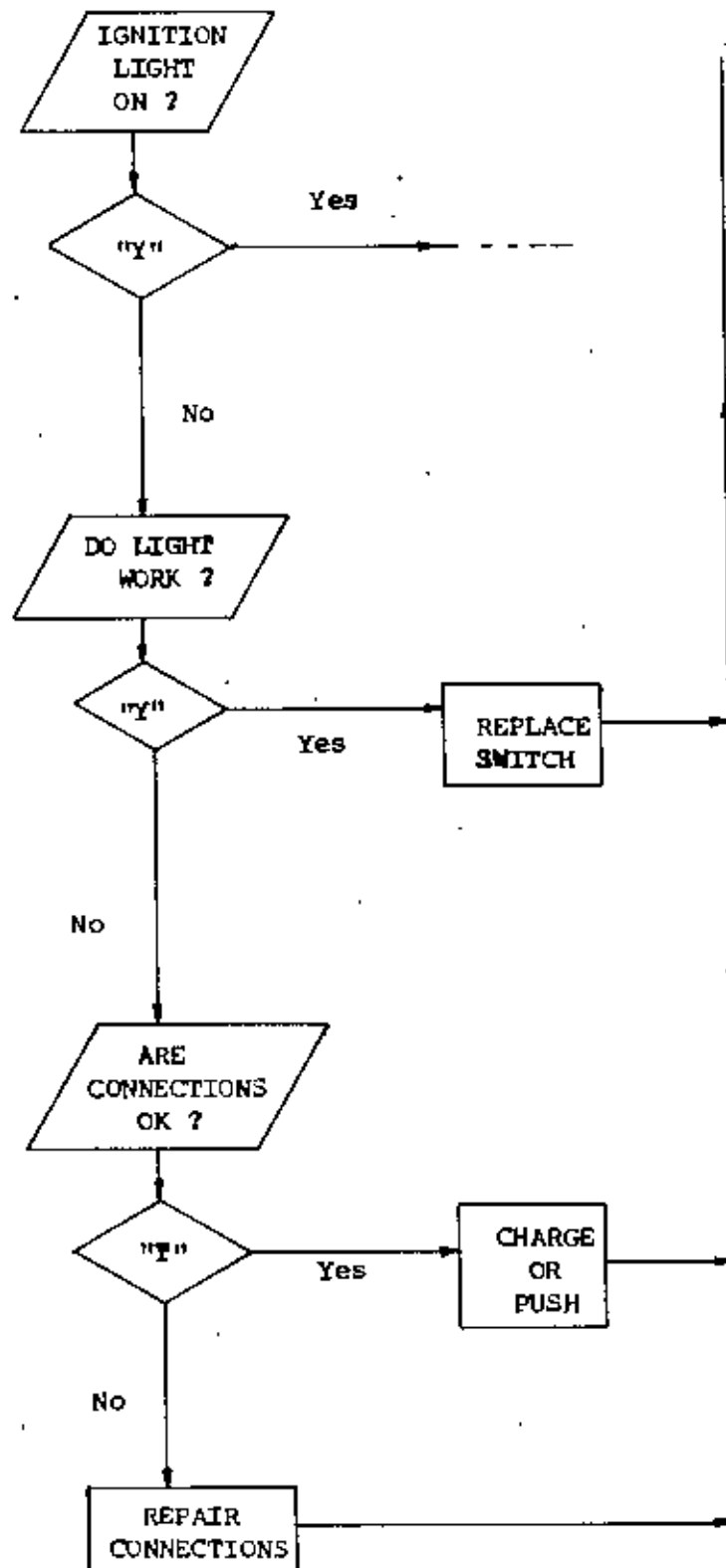


Fig. 2.5 : A Branching 'Expert' (9)

ARE BATTERY CONNECTIONS OK ? (Y/N)

If the answer is yes, then the battery is flat so it must be charged (or push).

CHARGE BATTERY OR PUSH CAR.

In the same way, a sequence of checks could be made to deal with a situation where there is power but the starter mechanism itself does not work (the last three possibilities).

The simplest way to program this branching structure is by a series of IF-THEN tests (Fig. 2.5). This sort of program is easy to write, but as usual is inefficient as it becomes longer and more complicated.

2.2.7.2 Branching with pointer:⁽⁹⁾

A more efficient way to deal with the situation is to put the text into arrays and have pointers which direct user to the next question or reply, according to wheather user answer yes or no to the current question (Fig.2.6). The format for entering the DATA for each branch point is, then:

(TEXT), (Pointer for 'YES'), (Pointer for 'No')

This technique may be described by using the same fault diagnosis example as used in simple branching method:

The first question was:

IS IGNITION LIGHT ON ? (Y/N) ... 1

If the answer was 'N' then it is needed to ask the second question:

DO LIGHTS WORK CORRECTLY ? (Y/N) ... 2

Otherwise it is needed to continue with the other part of the diagnosis (which have not been included but which would be point 7).

It is needed to set up three arrays:

Op\$(n) contains the output (text), Y(n) the pointer for 'yes' and N(n) the pointer for 'no'

A pointer CP is used to indicate the current position in the array: to begin with this is set to 1 and the first text printed. If this is an end point $Y(cp) = 0$, then CP is reset to 1 so that the sequence starts again. On the other hand, if a real pointer is present then an INPUT is requested. If the input is 'Y', then CP is set to the value contained in the appropriate element of the Y(n) array, otherwise it is set to the value contained in the N(n) array.

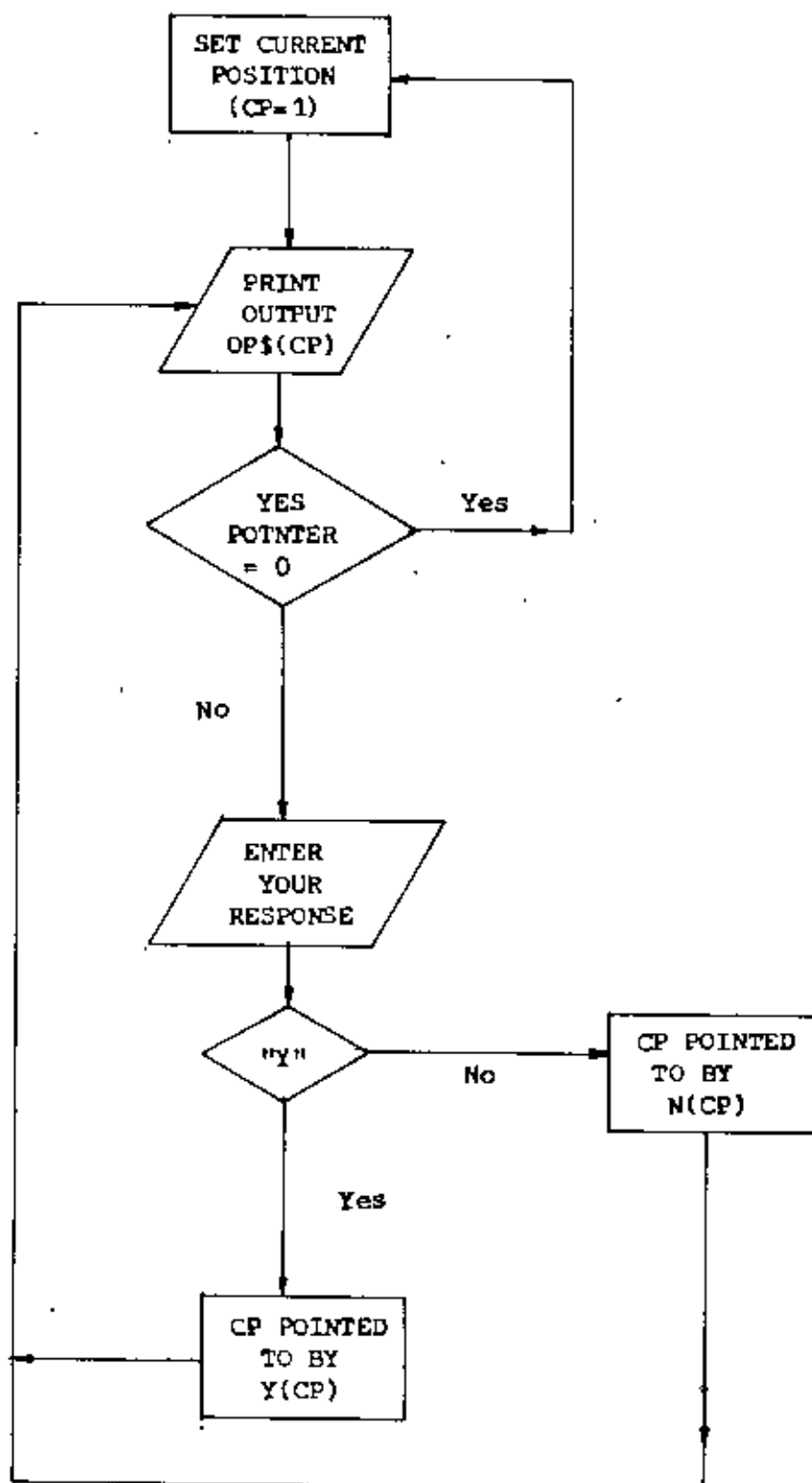


Fig. 2.6 : A branching Expert⁽⁹⁾

2.2.8 Inferential Method: (13)

This method involves the process of inference, the procedure for going from a sample (data) and structural knowledge (model) to a statement. Before taking any decision, the following steps are considered:

1. Draw up a list of possible statements or hypotheses.
2. Specify all possible samples.
3. For each hypothesis specify the expected and the unusual samples.
4. If the actual sample is on the unusual list, the corresponding hypotheses is rejected.
5. By a process of elimination the hypotheses are rejected one by one. If one hypothesis remains which cannot be rejected, this hypothesis is affirmed.

This can be explained clearly by an example as shown below. The Great Detective Studies the knife wound in the murder Victim's back and announces: "The murderer is left-handed". The GD has not seen the murderer with a knife clutched in his left hand. Yet he has to conclude and the basis of this conclusion was the logical structure of the intuitive inference. Let us suppose that the GD has just arrived on the scene of the crime, notes various clues and set up a list of alternative statements (hypotheses):

H_o : The murder weapon was held in the right hand.

H_a : The murder weapon was held in the left hand.

The GD now draws on his prodigious knowledge and past experience. He is well acquainted with the pattern of behavior of a killer who holds a knife in his right hand (i.e. the detective can set up a model for human behavior),

and this information leads him to deduce (i.e. derive from the addition of H_0 to the model) that a specific type or class of knife wound would result. The GD therefore considers all possible types of knife wounds (samples) and under the hypothesis that the murderer used his right hand, the criminologist can divide the set of all possible knife wounds into two classes, say likely and unlikely.

In the same manner, the GD can take the hypothesis H_a , and under this hypothesis he can again divide the set of all possible knife wounds into those which are likely and those which are unlikely. This classifies the set of possible wounds into four categories: (1) wounds which would be expected if the killer were right-handed but would be unusual otherwise, (2) wounds which would be expected if the killer were left-handed but which would be unusual otherwise, (3) wounds which might be expected if the thrust were either right-handed or left-handed, and (4) wounds which would be unlikely to have been made by a thrust (i.e. might be made by a thrown knife). Notice that this entire classification process does not involve the actual wound yet, and could be performed before the victim is seen.

The GD in his examination of the actual wound is trying to classify it into one of the four determined categories. He concludes that the nature of the wound is such that it falls in category number two - that this wound is one of the types of wounds which would be expected from a left-handed knife thrust but which would be unusual, or even impossible, if the killer used his right hand. In view of this the GD rejects H_0 and affirms H_a . He announces: "The murderer is left-handed".

2.3 State of research in the present area of the present study:

Expert system is undoubtedly an increasingly important area of research and its importance is increasing day by day. Despite the emergence of ES, the technology is very young and a number of development are needed. The fields at which ES technology is being used are for example,

- i) in Engineering
- ii) in Military Science
- iii) in Medicine
- iv) in Psychology
- v) in Mathematics
- vi) in Science
- vii) in Space technology, etc.

ES may be classified into two types on the period of their origin such as 1) Early system - which were generally developed prior to 1980 and 2) Recent system - which were generally developed after 1980. Some of the examples along with their developer and domain are given in Table 2.3.1. Apart from the ES, some commercial tools are available in the market, which may be exploited easily to build an ES.

The example of some knowledge engineering tools along with their manufacturer, introduction period and cost are given below as in Table 2.3.1.

Table 2.3.1 : Some examples of ES⁽¹⁾

<u>Type</u>	<u>System</u>	<u>Developer</u>	<u>Domain</u>
Early system	DENDRAL	Stanford	Organic chemistry
"	MACSYMA	MIT	Mathematic
"	HEARSAY II	Carnegie- Mellon University	Speech understanding
"	PROSPECTOR	SRI international	Geology
Recent System	XCON(R-1) XSEL	Carnegie-Mellon university and digital equipt. corp.	Configure computer hardware
"	GENESIS	Intelli Corp.	Genetic Engg.
"	DRILLING ADVISOR	Teknowledge Inc. and Elf - Aquitaine	Advise oil drilling crews about problems
"	DELTA	General Electric	Diesel-Electric Locomotive Troubleshooting Aid (DELTA)

Table 2.3.2 : Some ES tools⁽¹⁾

<u>Name</u>	<u>Manufacturer</u>	<u>Introduction period</u>	<u>Cost</u>
AL/X	J. Reiter, S. Barth, & A Paterson Univ. of Edinburgh	-	-
ES/P ADVISOR	Expert system Inter- national	1984	\$ 1,895
Expert/Ease	Expert software International Ltd.	1983	\$ 2,000
M.1	Teknowledge Inc.	1984	\$12,500
EXPERT	Weiss & Kulikowski Rutgers University	1981	-
OPSS	Carnegie - Mellon Univ.	1980	-
Knowledge Engg. System (KES)	Software A&E Arlington	1983	-
S.1	Teknowledge Inc.	1984	\$50,000
TIMM	General Research Co. CA 93160	1983	\$ 9,500 (IBM PCXT)

In the field of manufacturing system, ES has been playing a significant role to enhance the productivity of a production system. It has come into the processing industry following the path of automation and robotics. There are some ES package in this field but most of them have been designed to solve the scheduling problem in a production shop. For example, TOPIS II is an expert package, which deals with inventory management, quality planning and control, maintenance planning and control, manufacturing information and production planning, tool planning and control, etc. one more example is PTRANS, which deals with production planning and shipment.

In many countries of the world, such as, UK, USA, Japan, China, Hungary, etc. tremendous research work is being carried out in this field. But in the context of Bangladesh, ES is very new and no research is being carried out for the use of ES in the production system.

CHAPTER - 3

GENERALIZED MODEL FOR MACHINE SELECTION

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CHAPTER - 3

GENERALIZED MODEL FOR MACHINE SELECTION

The machine selection problem is an assignment problem. Here it may be assumed that M machines are available for J jobs and the jobs are assigned to the machines on the basis of maximum machine utilization. The problem may be shown as in fig. 3.1

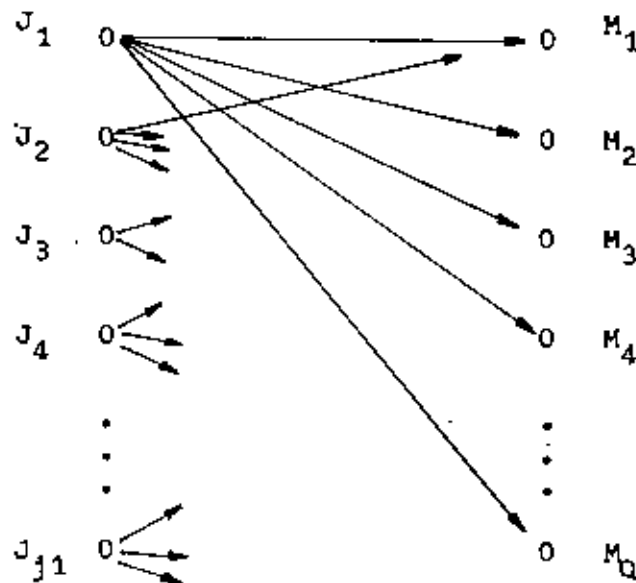


Fig. 3.1 : Assignment problem of multi-job and multi-machine

In this multisource and multisink assignment problem, an edge (J_{j1}, M_Q) exists mean Job J_{j1} , is assigned to machine M_Q if and only if no other machine is more utilized by Job J_{j1} than M_Q . The plan period existence of the edge (J_{j1}, M_Q) is ascertained by the test using job characteristics and machine facilities. The test procedures are described below in the form of mathematical model. To develop mathematical model of the system, different direct or indirect influencing factor of the manufacturing system is to be identified and correlated. The relation matrix of the total machine selection system is presented below as in fig. 3.2

The mathematical model of the whole system may be divided into four main module:

1. Blank selection
2. Operation type identification
3. Fixture selection
4. Machine selection

These will be discussed in the following.

To From	Job	Blank	Operation	Fixture	Machine	Tool	Cutting condition
Job	0	1	1	1	1	1	1
Blank	0	0	1	1	1	1	1
Operation	0	0	0	1	1	1	1
Fixture	0	0	0	0	1	1	1
Machine	0	0	1	1	0	1	1
Tool	0	0	0	1	0	0	1
Cutting condition	0	0	0	1	0	1	0

1 - relationship exists

0 - no relationship exists

Fig. 3.2 : Relation matrix for machine selection

3.1 Mathematical Model for Blank Selection

To select a Blank for a particular job as specified in the drawing, a inference operator is to be designed. The inference operator MO acts on a set of input characteristics of a job and select a Blank along with its characteristics. The input characteristics may be related to material, dimension, surface finish, etc. and are expressed as a set of n elements such as

$\{u_i\}$; $i = 1, 2, 3, \dots \dots \dots, n$. The output characteristics of a selected Blank (v_s) are also related to the same parameters as stated for the case of input characteristics and symbolized as

$$\{v_{si}\} ; i = 1, 2, 3, \dots \dots \dots, n.$$

$$MO \{1, 2, \dots i, \dots n\} = v_s \dots \dots (3.1)$$

$$\text{But } v_s = \{v_{s(1, 2, \dots i, \dots n)}\}$$

So it may be concluded that the inference operator MO operates on the set of input characteristics to obtain a set of output characteristics, i.e.

$$MO \{1, 2, \dots i, \dots n\} = \{v_{s(1, 2, \dots i, \dots n)}\} \dots (3.2)$$

3.2 Mathematical Model for Identification of Operators

This model is designed to identify the operations that will be needed to completely manufacture a job (in a part). To identify different operation needed for a job, a set of input variables is needed and the input variables include both raw material characteristics and final job characteristics. The relationship among the variables are shown in fig. 3.3

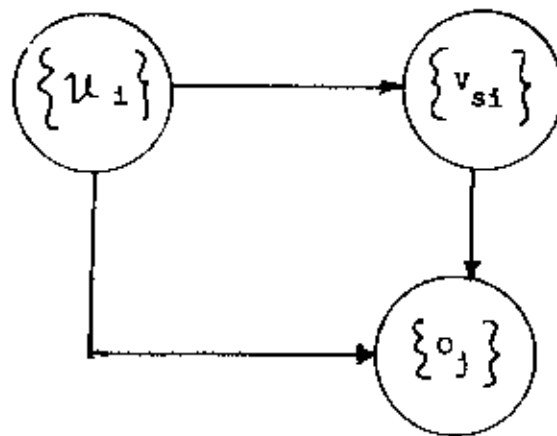


Fig. 3.3 : The process of operation identification

The output variables is the total operation types are also expressed as a set of m elements and symbolized as $\{o_j\}$; $j = 1, 2, 3, \dots \dots m$.

A inference operator M_j is to be designed such that it operates on the set of input variables to obtain an operation o_j .

$$M_j \{u_{1, 2, \dots i, \dots n} ; v_{1, 2, 3, \dots 1, n}\} = o_j \quad \dots \quad (3.3)$$

Now another inference operator M' is to be designed to associate all operation in a single unit i.e.

$$\begin{aligned} \text{Total operation} &= M' (o_j) \\ &= \{ o_j \}. \end{aligned}$$

3.3 Mathematical Model for Fixture Selection

The input and the output variables related to the process of fixture selection are identified to formulate the mathematical model. The input variables may be some mechanical or physical job characteristics, type machine, operation type, tec. They are expressed as a single set of elements y and symbolized as $\{p_e\}$; $e = 1, 2, \dots \dots y$.

The output variables i.e. the different types of fixtures are also expressed as a single set of elements Z and symbolized as $\{q_r\}$; $r = 1, 2, \dots \dots Z$. Now an input table $\{a_{cd}\}$; $c = 1, 2, \dots W$; $d = 1, 2, \dots S, \dots b$, may be defined such that each elements of the table is the coded values of the input variables. For coding purpose, the input variables may be classified into two groups such as 1) Input variables ($1 \leq d \leq s$) which have continuous values such as, L/D ratio, and 2) Input variables ($s < d \leq b$) which have discrete or qualitative values such as operation type, etc. The coding procedure are shown below.

1) For continuous input variables:

$$\text{Let } P_1 = a_{c1} \quad \text{where } C_{c1} < P_1 \leq C_{(c+1)1}$$

$$\text{where } 1 \leq c \leq (c + 1)$$

$$P_2 = a_{c2} \quad \text{where } C_{c2} < P_2 \leq C_{(c+1)2}$$

$$\text{where } 1 \leq c \leq (c + 1)$$

$$P_3 = a_{c3} \quad \text{where } C_{c3} < P_3 \leq C_{(c+1)3}$$

$$\vdots$$

$$P_s = a_{cs} \quad \text{where } C_{cs} < P_s \leq C_{(c+1)s}$$

$$\text{where } 1 \leq c \leq (c + 1)$$

Here all C 's are constant and the value limits are set by the experts.

2) For discrete or qualitative input variables:

$$\text{Let } P_{(s+1)} = a_{(s+1)} \quad \text{where } P_{(s+1)} = C'_{(s+1)}$$

$$P_{(s+2)} = a_{(s+2)} \quad \text{where } P_{(s+2)} = C'_{(s+2)}$$

$$\vdots$$

$$\vdots$$

$$P_b = a_b \quad \text{where } P_b = C'_b$$

Here all C 's are alpha-numeric constant.

For any incoming job, the input table $\{a_{cd}\}$ would be a set of input variable of number x , which is called index set (IS).

Now the selection equation of fixture may be defined as follows:

$$F_s = \begin{cases} \{q_1\} & \text{where } IS = \{a_{cd}^{(1)}\} \\ \{q_2\} & \text{where } IS = \{a_{cd}^{(2)}\} \\ \{q_3\} & \text{where } IS = \{a_{cd}^{(3)}\} \\ \vdots & \vdots \\ \{q_z\} & \text{where } IS = \{a_{cd}^{(z)}\} \end{cases} \quad \dots \quad (3.4)$$

where

F_s = A set of fixture for total operation of the job

$\{a_{cd}^{(z)}\}$ = A set of x elements of input table, which corresponds to set of fixture q_z .

3.4 Mathematical Model for Machine Selection

Production facilities such as machine tools are very costly. If these highly capital-intensive machines have a poor time as well as technological utilization, the cost of products become high and consequently they become less competitive in the market. The management has thus to plan the production program and the investment in production facilities in keeping these in view.

There is a general misconception that it is sufficient to engage the production facilities for the maximum possible duration. But it has serious drawbacks. For example, if a seven feet lathe is used all the time without interruption, one may say, it has the highest possible utilization. But if the jobs machined are, say less than one foot, then the lathe has not been utilized to the maximum possible capacity. A much smaller lathe could as well have served the purpose and would have been more economic.

Thus the selection of a lathe from a machine park should be on the basis of both the factors of utilization, namely

- a) time utilization
- and b) technological capability

- a) Time utilization: Time utilization of a machine tool may be defined as percent of its total available time, when it is directly or indirectly engaged in production. In case of a machine selection, it is difficult to know the time spent for processing a particular job and hence to find out the time utilization. So the time to be estimated or forecast prior to operation, for the purpose of estimating time utilization indirectly.

If the total operation time of a machine M_Q for a lot of job type J, is $T(M_Q J)$, then the utilization factor $T_{tu}(M_Q)$ is as follows:

$$T_{tu}(M_Q) = \frac{T(M_Q J) + P_a(M_Q)}{T_A(M_Q)} \quad \dots \quad (3.5)$$

where

$P_a(M_Q)$ - Scheduled load of machine M_Q in a plan period

$T_A(M_Q)$ - Available time of machine M_Q in a plan period

The total operation time $T(M_Q J)$ may be calculated by the following equation:

$$T(M_Q J) = \left[t_c(M_Q J) \right] \left[LS(J) \right] + \left[t_{su}(M_Q J) \right] \quad \dots \quad (3.6)$$

where

$LS(J)$ - lot size of the order for job J

$t_{su}(M_Q J)$ - set up time ^{fatigue time, etc.} of machine M_Q for job J

$t_c(M_Q J)$ - machining time of machine M_Q for job J

- b) Technological Capability: Technological capability of a machine tool may be ascertained with a number of factors such as power capacity, accuracy capacity, physical capacity (length, dia.) etc. Let all the influencing factors may form a set of V elements i.e.

$$\{ A'_1, A'_2, A'_3, \dots \dots A'_V \}$$

From the above V factors, g different groups are formed

such that each group contains the functions of close nature i.e. almost same implication to the machine selection. They are shown below:

$$\begin{aligned}
 A_1 &= \left\{ A_{11}, A_{12}, A_{13}, \dots \dots A_{1x}^{(1)} \right\} \\
 A_2 &= \left\{ A_{21}, A_{22}, A_{23}, \dots \dots A_{2x}^{(2)} \right\} \\
 &\vdots \\
 &\vdots \\
 &\vdots \\
 A_g &= \left\{ A_{g1}, A_{g2}, A_{g3}, \dots \dots A_{gx}^{(g)} \right\}
 \end{aligned}$$

where

$$\sum_{i=1}^g x^{(i)} = v \quad \dots \quad \dots \quad (3.7)$$

Now the above A variables of g different groups may be shown in form of matrix as below:

$$A = \begin{bmatrix} A_{11} & A_{12} & A_{13} & \dots & \dots & A_{1x}^{(1)} \\ A_{21} & A_{22} & A_{23} & \dots & \dots & A_{2x}^{(2)} \\ \vdots & & & & & \vdots \\ \vdots & & & & & \vdots \\ \vdots & & & & & \vdots \\ A_{g1} & A_{g2} & A_{g3} & \dots & \dots & A_{gx}^{(g)} \end{bmatrix} \quad \dots \quad (3.8)$$

To measure the technological capability of a machine, another sets of variables, (X) is defined below:

"The utilization of certain facility of a machine tool is 100%" - It may be defined heuristically such that capacity of machine regarding that facility is exactly equal to the capacity requirement for the job. To take into care this, a set of selector variables are defined based on the following formula.

Variable = (capacity of machine - capacity requirement for job) -
margin factor.

Here margin factor means a safer value of each input variable set by the experts. Its value may be greater than or equal to zero. According to formula the selector variables are as follows:

$$x_{1h_1} = (A_{1h_1})_{ma} - (A_{1h_1})_{jb} - s_{1h_1} \quad ; \quad h_1 = 1, 2, \dots \quad x^{(1)}$$

$$x_{2h_2} = (A_{2h_2})_{ma} - (A_{2h_2})_{jb} - s_{2h_2} \quad ; \quad h_2 = 1, 2, \dots \quad x^{(2)}$$

$$x_{3h_3} = (A_{3h_3})_{ma} - (A_{3h_3})_{jb} - s_{3h_3} \quad ; \quad h_3 = 1, 2, \dots \quad x^{(3)}$$

⋮

$$x_{gh_g} = (A_{gh_g})_{ma} - (A_{gh_g})_{jb} - s_{gh_g} \quad ; \quad h_g = 1, 2, \dots \quad x^{(g)}$$

The above g variables may be divided into two groups on the basis of their characteristics, such as 1) NUM variables 2) NONNUM variables.

- 1) NUM variables: They are a set of variables which are always present in a machine but their capacities or value generally varies with machine such as swing over bed of a lathe, Motor power capacity, etc. The set of variables are shown below:

$$\{x_{1h_1}, x_{2h_2}, x_{3h_3}, \dots \dots x_{kh_k}\}$$

- 2) NONNUM variables: They are a set of variables which are generally additional facilities of a machine and those may or may not be present in a machine and only their presence is treated as facility, for example, steady rest, follower rest, etc. The set of $(g - k)$ NONNUM variables are as follows:

$$\left\{ x_{(K+1)h_{(K+1)}} , x_{(K+2)h_{(K+2)}} \dots \dots x_{gh_g} \right\}$$

The above X variables now may be exploited to measure the technological capability of a machine tools in the following manner.

A set of conditional equations corresponds to each X variables now may be written as below and in the following equations, 1 represents that the machine is technologically capable and C represents that it does not and it has any values except one.

$B_{1h_1} = 1$	where $x_{1h_1} \geq 0$
$= C_{1h_1}$	otherwise.
$B_{2h_2} = 1$	where $x_{2h_2} \geq 0$
$= C_{2h_2}$	otherwise.
$B_{3h_3} = 1$	where $x_{3h_3} \geq 0$
$= C_{3h_3}$	otherwise.
\vdots	\vdots
\vdots	\vdots
\vdots	\vdots
$B_{gh_g} = 1$	where $x_{gh_g} \geq 0$
$= C_{gh_g}$	otherwise.

Another dependent variables on the basis of this B variables may be defined.

1) For NUM variables:

$$B_1 = \prod_{h_1=1}^{x^{(1)}} B_{1h_1} = 1 \quad \text{where } x_1 = \prod_{h_1=1}^{x^{(1)}} x_{1h_1} \geq 0$$

$$= C_1 \quad \text{otherwise.}$$

$$\text{where } C_1 = \prod_{h_1=1}^{x^{(1)}} C_{1h_1}$$

$$B_2 = \prod_{h_2=1}^{x^{(2)}} B_{2h_2} = 1 \quad \text{where } x_2 = \prod_{h_2=1}^{x^{(2)}} x_{2h_2} \geq 0$$

$$= C_2 \quad \text{otherwise.}$$

$$\text{where } C_2 = \prod_{h_2=1}^{x^{(2)}} C_{2h_2}$$

•
•
•

$$B_k = \prod_{h_k=1}^{x^{(k)}} B_{kh_k} = 1 \quad \text{where } x_k = \prod_{h_k=1}^{x^{(k)}} x_{kh_k} \geq 0$$

$$= C_k \quad \text{otherwise.}$$

$$\text{where } C_k = \prod_{h_k=1}^{x^{(k)}} C_{kh_k}$$

A single variable may now represent the condition of all NUM variables.

It is given below:

$$B_N = \prod_{T=1}^k B_T = 1 \quad \text{where } x_N = \prod_{T=1}^k x_T \geq 0$$

$$= C_N \quad \text{otherwise}$$

$$\text{where } C_N = \prod_{T=1}^k C_T$$

\prod : indicates the multiplication sign

2) For NONNUM variables:

$$B_{(k+1)} = \prod_{h_{(k+1)}=1}^{x^{(k+1)}} B_{(k+1)h_{(k+1)}} = 1 \text{ where } x_{(k+1)} = \prod_{h_{(k+1)}=1}^{x^{(k+1)}} x_{(k+1)h_{(k+1)}} \geq 0$$

$$= C_{(k+1)} \text{ otherwise.}$$

$$\text{where } C_{(k+1)} = \prod_{h_{(k+1)}=1}^{x^{(k+1)}} C_{(k+1)h_{(k+1)}}$$

$$B_{(k+2)} = \prod_{h_{(k+2)}=1}^{x^{(k+2)}} B_{(k+2)h_{(k+2)}} = 1 \text{ where } x_{(k+2)} = \prod_{h_{(k+2)}=1}^{x^{(k+2)}} x_{(k+2)h_{(k+2)}} \geq 0$$

$$= C_{(k+2)} \text{ otherwise.}$$

$$\text{where } C_{(k+2)} = \prod_{h_{(k+2)}=1}^{x^{(k+2)}} C_{(k+2)h_{(k+2)}}$$

...

$$B_g = \prod_{h_g=1}^{x^{(g)}} B_{gh_g} = 1 \text{ where } x_g = \prod_{h_g=1}^{x^{(g)}} x_{gh_g} \geq 0$$

$$= C_g \text{ otherwise.}$$

$$\text{where } C_g = \prod_{h_g=1}^{x^{(g)}} C_{gh_g}$$

A single variable may now represents the condition of all NONNUM variables and it is given below:

$$B_{NN} = \prod_{T=k+1}^g B_T = 1 \quad \text{where } x_{NN} = \prod_{T=k+1}^g x_T \geq 0$$

$$= C_{NN} \quad \text{otherwise } \dots \dots (3.9)$$

where

$$C_{NN} = \prod_{T=k+1}^g C_T$$

A capability equation now may be written on the basis of two variables of two types.

$$B_D = \begin{bmatrix} B_N \\ B_{NN} \end{bmatrix} = 1 \quad \text{where } x_D = \begin{bmatrix} x_N \\ x_{NN} \end{bmatrix} \geq 0 \quad \dots (3.10)$$

$$= C_D \quad \text{otherwise}$$

where

$$C_D = \begin{bmatrix} C_N \\ C_{NN} \end{bmatrix}$$

So far a particular machine M_Q and for a particular job j the above equation may be as follows

$$B_D(M_Q J) = \begin{bmatrix} B_N \cdot (M_Q J) \\ B_{NN} \cdot (M_Q J) \end{bmatrix} \quad \dots (3.11)$$

When some of the machines are both time and technologically capable, then there is a question of selecting suitable one among them and for this a selector variable is to be defined. Total operation cost may be one of the selector and it is influenced by so many factors such as, over head cost

labour cost, type of machine, type of job, type of operation, set up time, operation time, etc. So the total operational cost (TC) of a machine M_Q for a lot of job J is defined as:

$$TC(M_Q J) = f \left\{ \begin{array}{l} \text{Type of machine, job characteristics, operation type,} \\ \text{OH cost of machine, labour cost, set up time, operation} \\ \text{time, etc.} \end{array} \right\}$$

where f - represents the function

Now the total formulation may be written as:

Minimize

$$TC(M_Q J)$$

subject to

$$B_D(M_Q J) = 1$$

$$T_{tu}(M_Q) < 1$$

If the minimum value of $TC(M_Q J)$ as obtained from the above formulation is for $M_Q = q$ then

the selected machine;

$$M_S = NAM(q)$$

where NAM is the name of a machine.

CHAPTER - 4

MATHEMATICAL STATEMENT OF THE SYSTEM

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CHAPTER - 4

MATHEMATICAL STATEMENT OF THE SYSTEM

The mathematical statements for the selection of suitable lathe to turn a particular job will be developed in this chapter. For simplification of the system, it is assumed that the machine to be selected is a lathe and the job a simple cylinder. The system will be divided into four main modules:

1. Blank selection
2. Operation identification
3. Fixture selection, and finally
4. Lathe selection

These will be discussed in the following :

4.1 Statement for Blank selection

The blank selection may be an important decision because over size blank is needed large extra machining, extra time etc. and thus cost is increased. To select the suitable one of available blank, a mathematical statement has been developed and described below. Here it is assumed that the blank is of uniform diameter i.e. no blow holes and irregularities are present. The input characteristics of blank selection as used in EMS are as follows:

1. Final job nominal diameter in inch (D_2)
2. Final job tolerance limit in inch ($+J_2, -A_2$)
3. Final job surface roughness in inch (f_2)

The output characteristics of blanks are as follows

1. Nominal dia in inch (D_1)
2. Tolerance limit in inch ($+J_1, -A_1$)
3. Surface roughness in inch (f_1)

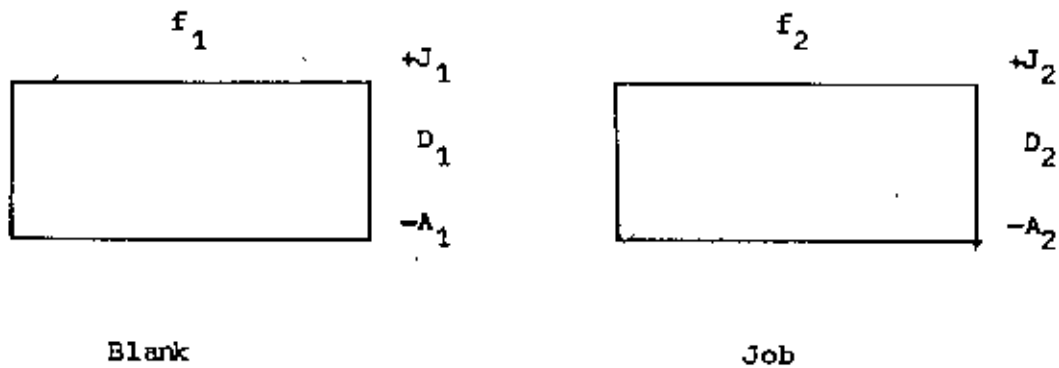


Fig. 4.1 : Blank and job with their characteristics

If the number of available blank is t , then a parameter ϕ_t for each t may be defined as follows and on the basis of this parameter the blank is to be selected.

$$\phi_t = (D_{1t} - A_{1t}) - (D_2 - A_2) \quad \dots \quad \dots, \quad (4.1)$$

$$\psi_t = (D_{1t} + J_{1t}) - (D_2 + J_2) \quad \dots \quad \dots \quad (4.2)$$

The formulation, which may be called very often the inference operator is as follows.

$$\begin{aligned} &\text{Minimize } \psi_t \\ &\text{subject to } \phi_t \gg 0. \end{aligned}$$

If the minimum value of ψ_t as obtained from above formulation is ϕ_{tm} and it is for $t = t_m$ then the selection blank -

$$V_s = \left\{ D_{1t_m}, A_{1t_m}, J_{1t_m}, f_{1t_m} \right\}$$

By omitting the suffix t_m it may be

$$V_s = \left\{ D_1, A_1, J_1, f_1 \right\}$$

Due to the time limitation, the length of the job will not be considered.

4.2 Statement for Operation Identification

This module will work upon to identify the operations which will convert the job of a chosen blank into the finished job. The input and output variables as used in this statements are as follows.

1. Input variables

- i. Blank characteristics = $\left\{ D_1, A_1, J_1, f_1 \right\}$
- ii. Job characteristics = $\left\{ D_2, A_2, J_2, f_2 \right\}$

2. Output variables

- i. No operation
- ii. Surface finishing
- iii. Finish turning
- iv. Rough turning

The variable, ϕ & ψ now may be defined for selected blanks are as -

$$\phi_s = (D_1 - A_1) - (D_2 - A_2) \quad \dots \quad (4.3)$$

$$\psi_s = (D_1 + J_1) - (D_2 + J_2) \quad \dots \quad (4.4)$$

On the basis of ψ value, two cases may be drawn.

- a) where $\Psi_s \leq 0$:
- Operation, $O_s = \begin{cases} = \text{no operation where } f_1 \leq f_2 \\ = \text{surface finishing where } 2(f_1 - f_2) \leq \phi_s \text{ and } (f_1 > f_2) \end{cases}$
- b) where $\Psi_s > 0$:
- Operation $O_s = \begin{cases} = \text{finish turning where } \Psi_s \leq 0.1'' \\ = \text{rough turning otherwise.} \end{cases}$

Now the sequence of operations may be shown below -

1. $O_s =$ Rough turning and Finish turning and Surface finishing where $\Psi_s > 0$ and $(f_r > f_2 \text{ OR } AC_r > AC_2)$ and $(f_f > f_2 \text{ OR } AC_f > AC_2)$
2. $O_s =$ Finish turning and Surface finishing where $(\Psi_s > 0 \text{ and } \Psi_s \leq 0.1'')$ and $(f_f > f_2 \text{ OR } AC_f > AC_2)$
3. $O_s =$ Rough turning and Finish turning where $\Psi_s > 0$ and $(f_r > f_2 \text{ OR } AC_r > AC_2)$ and $(f_f \leq f_2 \text{ and } AC_f \leq AC_2)$
4. $O_s =$ Rough turning only where $\Psi_s > 0.1''$ and $(f_r \leq f_2 \text{ and } AC_r \leq AC_2)$
5. $O_s =$ Finish turning only where $\Psi_s > 0$ and $\Psi_s \leq 0.1''$ and $(f_f \leq f_2 \text{ and } AC_f \leq AC_2)$
6. $O_s =$ Surface finishing only where $(\Psi_s \leq 0)$ and $(f_1 > f_2)$

4.3 Statement for fixture selection

The fixture as used on a lathe are the work holding devices as well as the extra supporting devices. These are:

1. Work holding devices
 - a. Face plate
 - b. Dog clutch
 - c. Tail stock
 - d. Four jaw chuck
 - e. Three jaw chuck
2. Extra supporting devices
 - a. Steady rest
 - b. Follower rest

As the operation is turning and the machine to be selected is lathe, so the input variables $\{P_e\}$ to select fixtures are as follows.

$$P_e = \left\{ L/D, P_3 \right\}$$

L/D : It is the length to diameter ratio i.e.

$L/D = L_1/D_2$. As a thumb-rule, the following values of L/D ratio as shown in fig. 4.2 are taken for different types of fixtures.

P_3 = It is the length difference i.e.

$P_3 = L_1 - L_2$. As a thumb-rule it is assumed that if $P_3 \gg 2"$ then the job may be clamped directly into chuck. Here the 2" includes the length of chucking, right side facing, parting etc. if needed.

For coding the input variables some statistical data⁽⁸⁾ are used and for each input variable a coding table is generated. The coding procedures are shown in fig. 4.2. Coding table of all the input variables together form a table called input table. For a job of particular dimension the input table will be a set of input variables of number same as the no. of input variable, which is called index set. All possible index sets are identified and for each index set assign a set of fixtures. For example -

$$F_s = \left[\begin{array}{l} \text{Clamping in} \\ \text{chuck} \end{array} \right]$$

where Index = 12

$$= \left[\begin{array}{l} \text{Clamping between} \\ \text{centres by face} \\ \text{plate \& dog clutch} \end{array} \right]$$

where Index = 11 OR
Index = 21, 22.

$$= \left[\begin{array}{l} \text{Clamping between} \\ \text{centres and use} \\ \text{Rest} \end{array} \right]$$

where Index = 31 OR 32

L/D coding

Code	Mark
1	$0 \leq L/D < 4$
2	$4 < L/D < 10$
3	$L/D \geq 10$

P₃ coding

Code	Mark
1	$P_3 < 2''$
2	$P_3 \geq 2''$

Input Table

L/D	P ₃
1	1
2	2
3	-

Fig. 4.2 : Coding of input variables

4.4 Statement for machine selection

The machine selection depends upon the job characteristics as well as on the availability of machine. Here the machine selection is limited only to lathe selection for a simple cylindrical job, as stated earlier. The lathe characteristics i.e. the output variables which have been considered here as follows:

1. Swing over bed in inch (SB)
2. Swing over cross slide in inch (SC)
3. Maximum distance between centres in inch (L_m)
4. Grades of dimensional accuracy (tolerance limit) capacity (AC_m)
5. Maximum surface finish capacity in inch, (f_m)
6. Minimum allowable depth of cut of machine in in. (dc_m)
7. Maximum power capacity in hp (P_{om})
8. The job materials generally processed (JM_m)
9. The operations that can be done (O_m)
10. The available fixture in machine (F_m)
11. The hourly rate of machine in Tk. (HR)
12. Min. allowable depth of cut in inch (dc_m)

To obtain a selected lathe i.e. the above output variables, a set of input variables is needed. They are blank or job characteristics, previous engage time in working of machine, identified operation, selected fixture, etc. As the machine is very costly, so the selection of a lathe for the purpose of processing the job should be such that the total utilization of that lathe should be the maximum. The total utilization can be divided into two groups, such as

- A) Time utilization
- B) Technological capability

These will be discussed as in the following. :

- A) Time utilization: It may be defined as that percent of its total available time, when it is directly or indirectly engaged in production. Total available time (TA) may be defined from different aspects. For example it can be 8 hours in a shift or approx. 2000 hours per shift per annum. Direct or indirect engage time (T) in production includes actual machining time, set up time, job and/or tool replacement time, time for quality checking, allowance, etc.

In case of machine selection, it is not possible to know earlier the actual operation time (T), because the selection is done prior to operation. It may however, be estimated by using the equation as below.

$$T = (t_c \cdot LS + t_{su}) / \eta \quad \dots \quad (4.5)$$

where,

LS = lot size (of the job order)

t_c = Machining time in hour of the machine

t_{su} = Set-up time^{etc.} of the machine in hour

T = Actual operation time in hour

η = Work place efficiency

The machining time, t_c may calculated by the following equation

$$t_c = \frac{(L_2 + \frac{1}{8}) \cdot n}{(f_e \cdot N) 60} \quad \dots \quad (4.6)$$

where

n = no. of cuts during rough turning

f_e = economic feed in ipr

N = economic cutting speed in (rpm).

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The set up time, t_{su} is available as standards.

The time utilization factor (T_{tu}) now may be defined as below:

$$T_{tu} = \frac{P_a + T}{T_A} \quad \dots \quad (4.7)$$

where

P_a = Scheduled load in hour of machine during a plan period

T = as defined in equation (4.5)

T_A = Available time of the machine during a plan period

Because the availability of a machine Q , for a lot during a plan period has binomial characteristics, which can be expressed by a variable, $B(Q)$ as shown in equation (4.6).

$$\begin{aligned} B(Q) &= 1 && \text{where } 0 \leq T_{tu} \leq 1 \\ &= 0 && \text{otherwise} \end{aligned}$$

where

1 indicates that the machine has enough free time to be loaded with the job under consideration

0 indicates that the machine is not available

B) Technological Capability:

A machine tool is utilized whenever it is directly or indirectly engaged in production. But during this time a machine tool may not be utilized to its maximum capacity. The factors, which influence the measurement of technological capability in this case (which have been stated in chapter 3.4 b as V elements for a general case) are as follows:

- a) Blank / job characteristics(*)
1. Length in inch (L_1/L_2)
 2. Diameter in inch (D_1/D_2)
 3. Grades of dimensional accuracy (AC_1/AC_2)
(tolerance limit)
 4. Surface finish in inch (f_1/f_2)
 5. Material (JM)
 6. Minimum depth of cut needed for a job for a particular operation (dc')
 7. Maximum power required to process the job in HP (P_o)
- b) Identified operation type (O_g)
- c) Selected fixture type (F_g)

The above input variables should be mapped into the available machine characteristics. The machine having maximum technological utilization should be allotted for the lot under consideration. During mapping from input to output variables, all the elements of problem space need not to be searched. The searching space is rather less and it has been shown in fig. 4.3.

To represent the mapping procedure mathematically a set of conditional equation has been designed as follows.

* Suffix 1 indicates blank
Suffix 2 indicates job.

In the following set of equations, 1 indicates that the machine is technologically capable and 0 indicates that the machine is not technologically capable.

$$\begin{aligned} A_1 &= 1 && \text{where } \{O_s\} \subseteq \{O_m\} && \dots && (4.8) \\ &= 0 && \text{otherwise} \end{aligned}$$

where

O_s = set of identified operations

O_m = set of operations that can be done by machine

$$\begin{aligned} A_2 &= 1 && \text{where } \{F_s\} \subseteq \{F_m\} && \dots && (4.9) \\ &= 0 && \text{otherwise} \end{aligned}$$

F_s = Set of selected fixtures

F_m = Set of fixtures available in machine

$$\begin{aligned} A_3 &= 1 && \text{where } SC > D_1 \text{ AND } L_m > L_1 && \dots && (4.10) \\ &= 1 && \text{where } SC > D_1 \text{ AND } F_s = \text{chuck clamping AND } L_m > L_2 \\ &= 1 && \text{where } O_s = \text{facing AND } SB > D_1 \text{ AND } L_{m-12^\circ} > L_2 \\ &= 0 && \text{otherwise} \end{aligned}$$

SC = Swing over cross slide in inch

D_1 = Blank diameter in inch

L_m = Maximum distance between centres of lathe in inch

L_1 = length in inch

L_2 = Job length in inch

SB = Swing over bed

$$\begin{aligned} A_4 &= 1 && \text{where } AC_m \leq AC_2 && \dots && (4.11) \\ &= 0 && \text{otherwise} \end{aligned}$$

AC_m - Grades of accuracy as obtained by machine

AC_2 - Grades of accuracy of job

$$A_5 = 1 \quad \text{where } f_m \leq f_2 \quad \dots \quad (4.12)$$

$$= 0 \quad \text{otherwise}$$

f_m - Minimum surface roughness as obtained by machine in inch

f_2 - surface roughness of job.

$$A_6 = 1 \quad \text{where } dc' \geq dc_m \quad \dots \quad (4.13)$$

$$= 0 \quad \text{otherwise}$$

dc' - Minimum depth of cut needed for a job for a particular operation in inch

dc_m - Minimum allowable depth of cut of machine in inch

$$A_7 = 1 \quad \text{where } JM \in \{JM_m\} \quad \dots \quad (4.14)$$

$$= 0 \quad \text{otherwise}$$

JM - Job materials

JM_m - Job materials generally processed by machine

$$A_8 = 1 \quad \text{where } P_{om} \geq P_o \quad \dots \quad (4.15)$$

$$= 0 \quad \text{otherwise}$$

P_{om} - Power capacity of machine in HP

P_o - Maximum hp needed to process the job

* Here it is assumed that generally 12" of the bed length is covered by carriage

The above equations may be associated into a single one, which will show the acceptability of a particular machine @

$$A(Q) = \prod_{i=1}^8 A_i \quad \dots \quad (4.16)$$

Evidently, the values of $A(Q)$ are 1 and 0.

After checking the feasibility of both time and technological capability of a machine tool, total machining cost (TC) has been taken as a factor for machine selection. Because heuristically it is assumed that if a machine has low technological facilities then consequently it's hourly rate will be low compared to others and vice versa. So machine selection on the basis of minimum cost implies that this machine is more technologically utilized than others.

The total machining cost is

$$TC = (HR) [T] \quad \dots \quad (4.17)$$

where

HR = Machine hourly rate in Tk.

T = as defined in equation 4.5

Here the machining time t_c has three components for three operations such as rough turning, finish turning and surface finishing. So,

$$t_c = C_r(t_{cr}) + C_f(t_{cf}) + C_s(t_{cs}) \quad \dots \quad (4.18)$$

Where C_r , C_f and C_s are the coefficients of rough turning, finish turning and surface finish respectively, and the values are either 0 or 1. (1 for present and 0 for absent).

t_{cr} , t_{cf} and t_{sf} are the cutting time for rough turning, finish turning and surface finish respectively and they are calculated by

$$t_{cr} = \frac{(L_2 + \frac{1}{8})n}{f_{mr} \cdot N_{mr}} \quad \dots \quad (4.19)$$

$$t_{cf} = \frac{(L_2 + \frac{1}{8})}{f_{mf} \cdot N_{mf}} \quad \dots \quad (4.20)$$

$$t_{sf} = \frac{(L_2 + \frac{1}{8})}{f_{ms} \cdot N_{ms}} \quad \dots \quad (4.21)$$

where

$L_2 + \frac{1}{8}$ = final job length in inch + approach length in inch

f_{mr} = Actual rough cutting feed in ipr which is the most nearest one of economic rough cutting feed (f_{er})

N_{mr} = Actual rough cutting speed in rpm which is the most nearest one of economic rough cutting speed

f_{mf} = Actual finish cutting feed in ipr which is the nearest one of economic finish cutting feed

N_{mf} = Actual finish cutting speed in rpm which is the nearest one of economic finish cutting speed

f_{ms} = Actual surface finishing feed in ipr which is the nearest one of economic cutting feed

N_{ms} = Actual surface finishing speed in rpm which is the nearest one of economic cutting speed.

So the total machining cost for a particular machine Q is

$$TC(Q) = HR(Q) \cdot T(Q) \quad \dots \quad (4.22)$$

Now this cost is to be minimized among those machine which have both time and technological feasibility and the machine which costs the minimum, is the selected one. This may be shown mathematically in the form of formulation as follows.

Minimize

$$TC(Q) = [T(Q) \cdot HR(Q)] [A(Q) \cdot B(Q)]$$

subject to

$$A(Q) > 0$$

$$B(Q) > 0$$

If the minimum value of $TC(Q)$ as obtained from above formulation is for $Q = q$, then the selected machine is

$$M_s = NAM(q)$$

where NAM is the name of the lathe

If $TC(Q)$ is minimum but it does not differ so much (which is estimated by the users in EMS) with the cost of some other machines say number q_1 then the selection criteria is shifted into another formulation as follows.

$$\text{Minimize } T_{tu}(q_1) = \left[\frac{T(q_1) + P_a(q_1)}{T_A(q_1)} \right]$$

If the minimum value of $T_{tu}(q_1)$ is for $q_1 = w_1$ then the selected lathe is

$$M_s = NAM(w_1)$$

	SB	SC	L_m	AC_m	f_m	dc_m	P_{om}	JM_m	O_m	F_m	HR
L_1											
L_2											
D_1											
D_2											
AC_2											
f_2											
dc'											
JM_1											
P_o											
O_s											
F_s											


 : Search space

Fig. 4.3 : The input-output relationship matrix for lathe selection

CHAPTER - 5

DESIGN OF INFERENCE ENGINE

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CHAPTER - 5

DESIGN OF INFERENCE ENGINE

Inference Engine is the portion of a knowledge system that contains the inference and control strategies. More broadly, the inference engine also includes various knowledge acquisition, explanation, and user interface sub-systems. Inference engines are characterized by the inference and control strategies they use. Some of the most common strategies for inference & control are described below.

5.1 Inference:

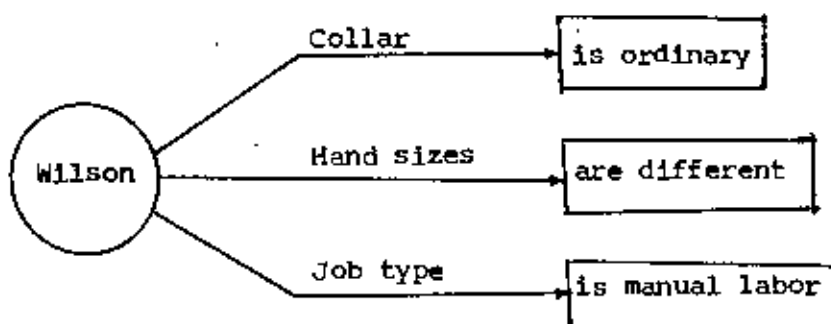
The process by which new facts or conclusions are derived from known facts. A rule (e.g. If the sky is black, then the time is night), combined with a rule of inference (e.g. modus ponens) and a known fact (e.g., The sky is black) results in a new fact (e.g. The time is night). The most common strategies for inferences are as follows:

5.1.1 Modus Ponens:

The most common inference strategy used in knowledge systems is the application of logical rule called modus ponens. This rule says, as it is done by all without thinking about it, that when A is known to be true and if a rule states, "If A, then B," it is valid to conclude that B is true. Stated differently when it is discovered that the premises of a rule are true, it is being entitled to believe the conclusions.

Fig. 5.1 shows two rules and some facts from the detective's knowledge base. For example, Wilson has an attribute called hand sizes, which has the value

different. Rule X states that if a person's hand sizes are different, then a person's job type has been manual labor. Because the antecedent of Rule X is true, modus ponens allows to conclude that Wilson's job type has been manual labor. If the second rule is tested, it will not succeed. Since Wilson's tested, it will not succeed. Since Wilson's collar is not a clerical collar, the rule does not support the conclusion that his job is religious.



Rule X : If a person's hand sizes are different, then a person's job type has been manual laborer.

Rule Y : If a person's collar is clerical then a person's job type is religious.

Fig. 5.1 : Some facts and rules⁽¹⁾

5.1.2 Reasoning about uncertainty

In conventional programming all required information is provided before computation takes place. In knowledge programming, this is not necessarily the case. Just as consultants and advisors must typically deal with cases for which some information is missing or unknown, an inference engine must be able to handle incomplete information. Rules can also be included in a knowledge base to provide knowledge about incomplete information explicitly.

Experts are usually familiar with providing advice without complete information. In fact, part of their expertise is knowing when to ignore missing information and when to stop and get it. It may be imagined Holmes asking, "Has that revolver been fired lately ?" and Dr. Watson answering "I don't know". At this point, Holmes may ask another question: "Does the barrel smell of sulphur ?" Such selective probing is represented by means of a rule like this:

If "Revolver recently fired ?" is unknown, and smell of sulphur is strong.

Then "Revolver recently fired ?" is "Yes".

5.2 Control:

The method used by the inference engine to regulate the order in which reasoning occurs. The most common strategies for control are as follows:

5.2.1 Strategy for Problem Solving

Problem solving is a process in which one starts from an initial state and proceeds to search through a problem space in order to identify the sequence of operations or actions that will lead to a desired goal. Successful problem solving depends upon knowing the initial state, knowing what an acceptable outcome would be, and knowing the elements and operators that define the problem space. If the elements or operators are very large in number or if they are poorly defined, one is faced with a huge or unbounded problem space and an exhaustive search can become impossible. Different problem solving techniques have been described earlier as in chapter 2.

5.2.2 Reasoning Process:

The process of drawing inferences or conclusions is called reasoning.

In another words, it is to discover a path through a problem space from an initial configuration to a goal state or to discover a particular point in a problem space. There are two directions in which such a could proceed.

- a) Forward reasoning
- b) Backward reasoning

For each type of reasoning, a set of rules have to be established. The same rules may be used both to reason forward from the initial state and to reason backward from the goal state. To reason forward, the left sides (the preconditions) are matched against the current state and the right sides (the results) are used to generate new nodes until the goal is reached. To reason backward, the right sides are matched against the current node and the left sides are used to generate new nodes representing new goal states to be achieved. This continues until one of these goal states is matched by an initial state.

5.3 Inference Engine of EMS:

Inference engine is a part of EMS that contains the inference and control strategies, which are described as follows:

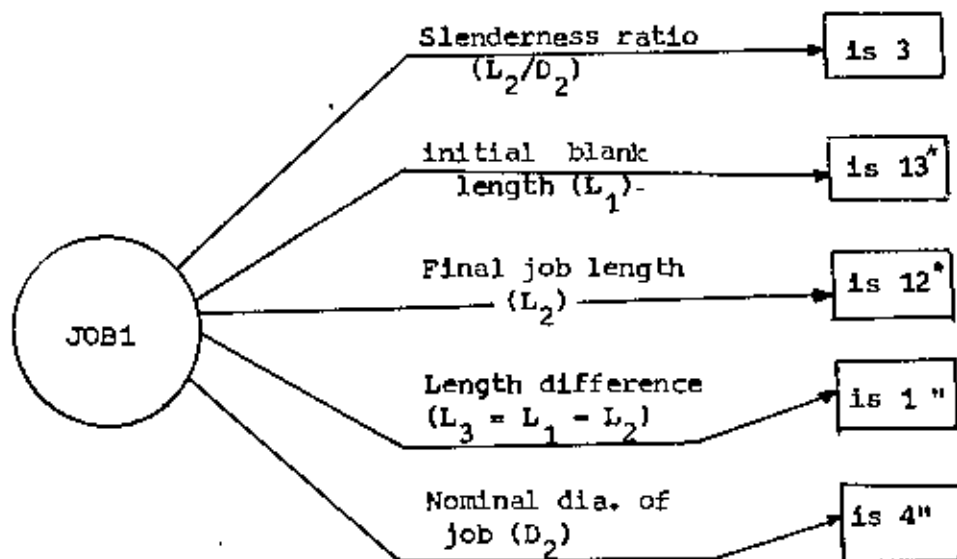
5.3.1 Inference of EMS:

The strategies used in the design of the inferences for EMS are as follows:

5.3.1.1 Modus Ponens:

This type of inference procedure is used in the design of the EMS. Because it is a simple, intuitively appealing way to conduct reasoning. The rules have been designed such a way that during reasoning, this type is used. The way how actually modus ponens are used, may be explained by an example given below as in figure 5.2.

Fig. 5.2 shows two rules and some facts of a job. For example, JOB1 has some attribute called slenderness ratio, initial blank length, final job length, length difference, nominal dia. of job, etc. which have the values 3, 13", 12", 1", 4" respectively. Rule 9 (which will be defined in Chapter 6.1) states that if the slenderness ratio of the job is less than or equal to 4, then the clamping of blank will be directly in the chuck. Because the antecedent of Rule 9 is true, modus ponens allows to conclude that blank of JOB1 should be clamped directly in chuck. In Rule 14 (Chapter 6.3) ($L_3 = L_1 - L_2$) is also an attribute. Here modus ponens allows to conclude that JOB1 place between centres.



Rule 9 : If the length of blank (L_1) is unknown and the slenderness ratio ($L_2/D_2 \leq 4$) of the job is less than or equal to 4. Then the clamping of blank will be directly in chuck.

Rule 14: If the slenderness ratio of the job is less than or equal to 4 i.e. ($L_1/D_2 \leq 4$) and the length difference is less than two inch, i.e. $L_3 < 2"$

Then place blank between centres.

Fig. 5.2 : Some facts and rules

5.3.1.2 Reasoning about uncertainty:

If some values of attributes are not known or available then it may estimate those values. The possible uncertain attributes used are -

1. Blank length
2. Maximum power required for job processing
3. Maximum cutting force

These are described in rules, R9, R10, R30 and R 31 respectively as shown in chapter 6.3.

5.3.2 Control of EMS:

The strategies used in EMS, for control are described as follows:

5.3.2.1 Strategy for Problem Solving:

To solve the problem of machine selection, it has been divided into

Four module. The strategies for each module are written separately in

the following section. The main control structure of the system are shown in figure 5.3

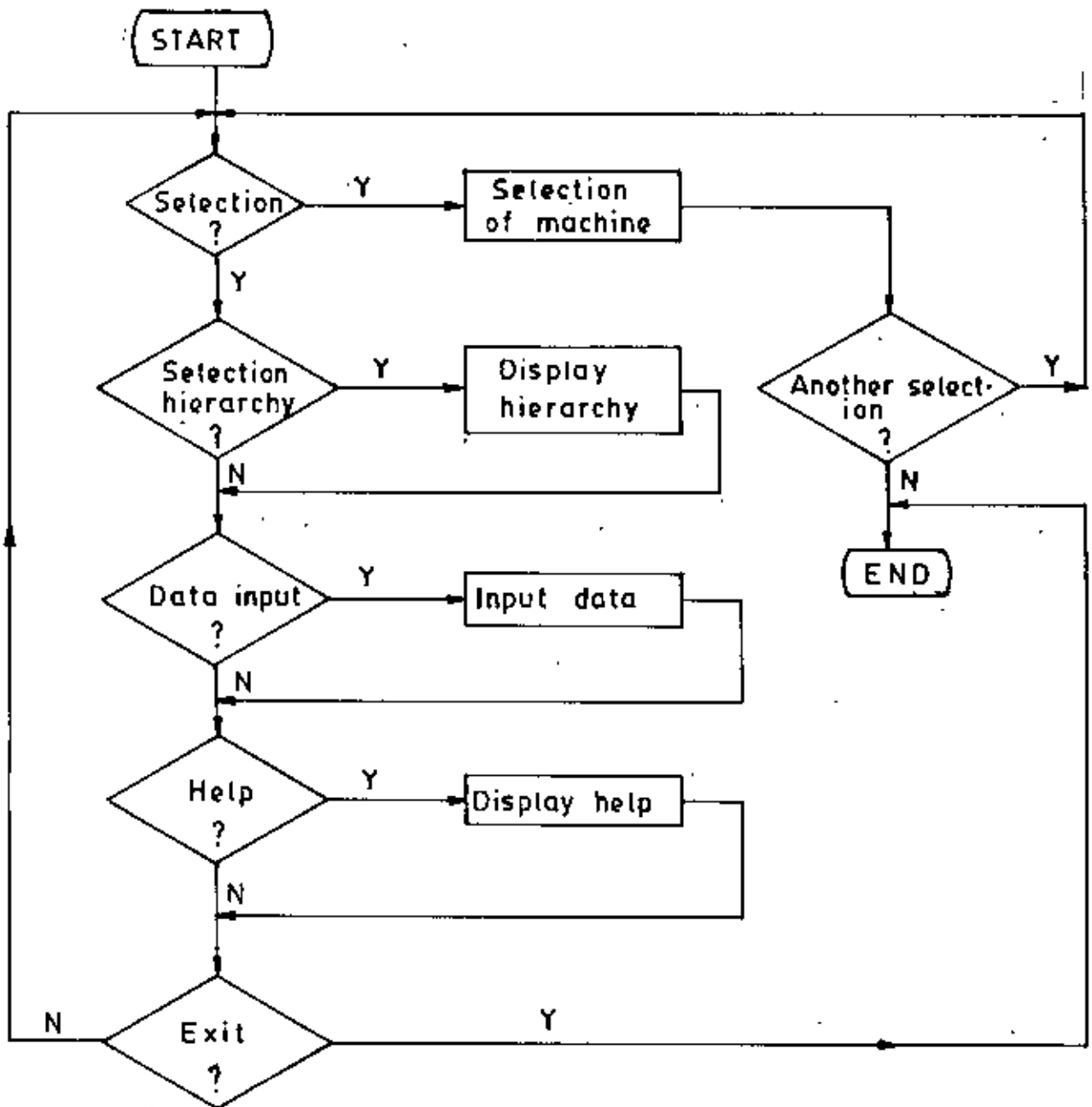


Fig. 5.3 The main control structure of EMS

5.3.2.1.1 Strategy for blank selection:

To select the most suitable one among all available blank by seeing the job specification as on the drawing, a simple branching method is being used. In the developed strategy as in fig. 5.4, these are some intermediate questions, which are asked by the system and also answered by the system. For example, one such question is "Is $\phi_s \geq 0$?" (where $\phi_s = (D_1 - A_1) - (D_2 - A_2)$). Here the value of ϕ_s is calculated by it and reply to that question.

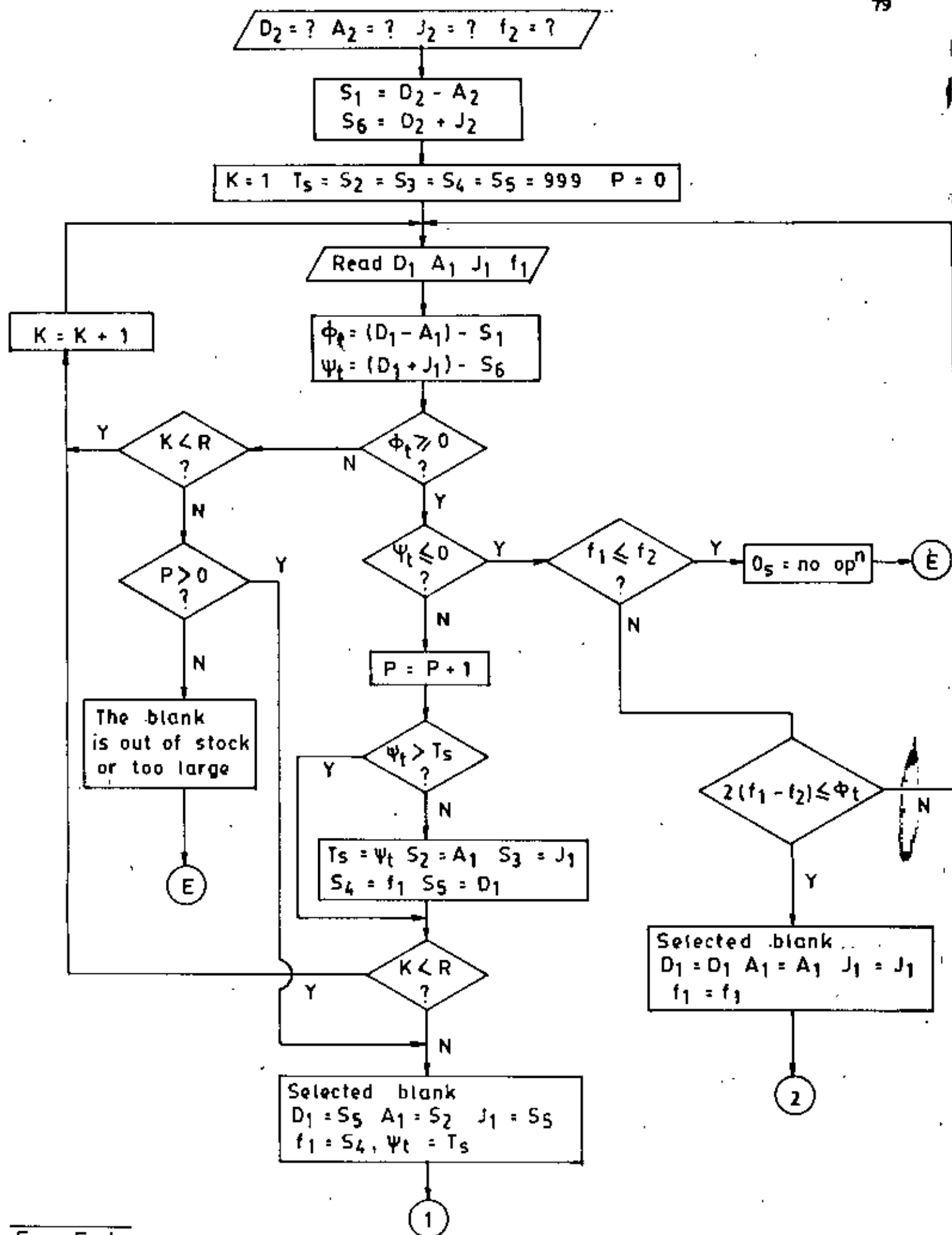
5.3.2.1.2 Strategy for operation identifications:

It was already stated that in this work a simple job has been considered. Accordingly, only outside turning operating are involved. To identify these operations by considering both the selected blank and the job specifications a simple branching method is being used. The strategy in the form of logic diagram can be shown in fig. 5.4.

5.3.2.1.3 Strategy for fixture selection:

For fixture selection the input variables of blank are coded and for each set of code number, a set of fixtures is assigned. The input variables of a job under consideration lead a code number which search for a match with the stored one. When there is a match then the corresponding set of fixtures are selected.

For searching and decoding of set of code numbers (Index), a method namely branching with pointer is used. An example, as used in the EMS is given below (fig. 5.5). The strategy may be shown as in Fig. 5.6 in the form of flow chart.



E - End

contd.

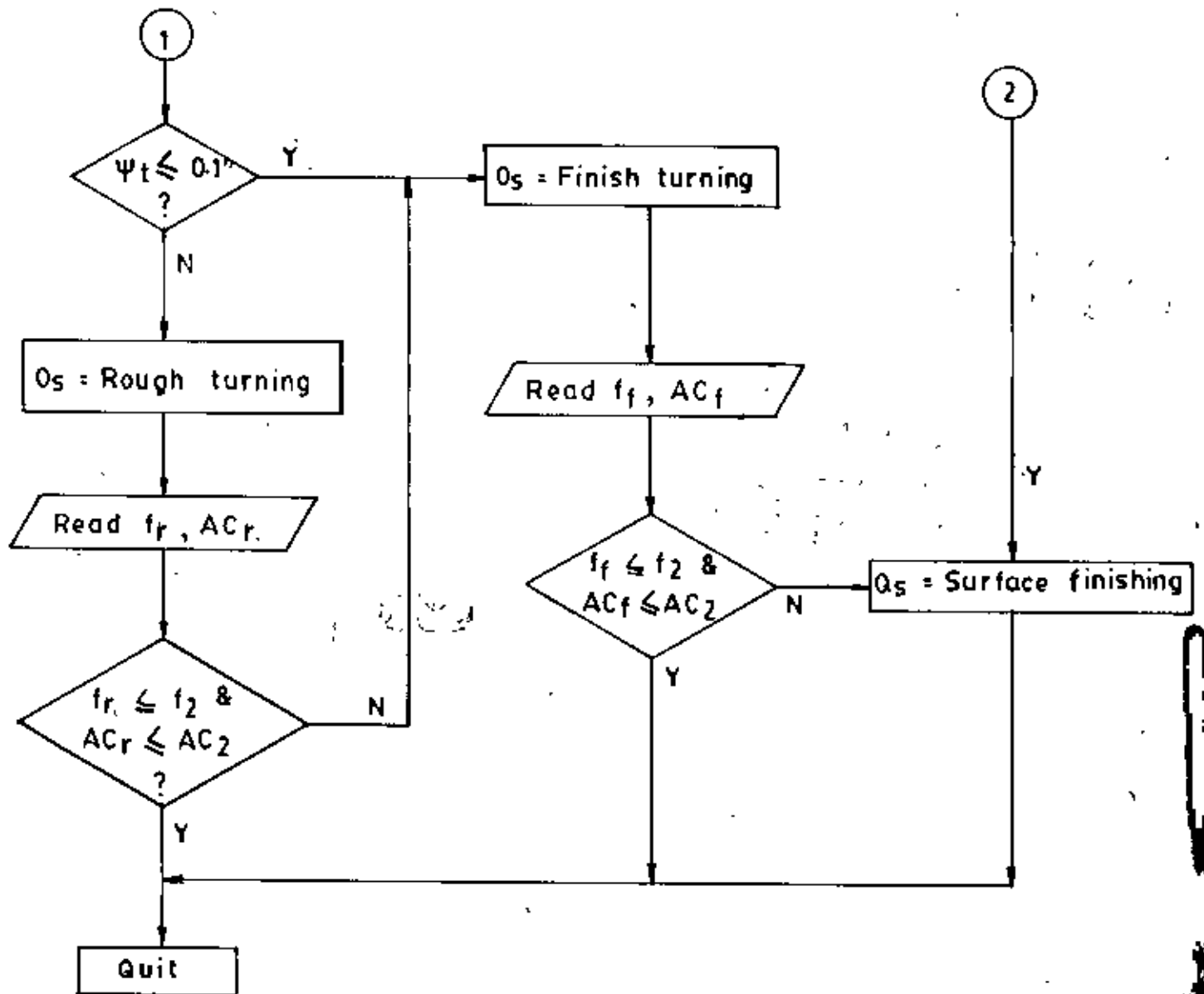


Fig. 5.4. Strategy for blank selection and op^n identification

```

100 DATA "IS Index = 12",7,2
200 DATA "IS Index = 11",8,3
300 DATA "IS Index = 21",8,4
400 DATA "IS Index = 22",8,5
500 DATA "IS Index = 31",9,6
600 DATA "IS Index = 32",9,10
700 DATA "   Clamping in chuck" 0,0
800 DATA "Clamping between centres", 0,0
900 DATA "Clamping between centres and use Rest!", 0,0
1000 DATA "End of program", 0,0

10 CP = 1
20 PRINT OP$(CP)
30 IF Y(CP) = 0 THEN 80
40 INPUT IN$
50 IF IN$ = "Y" THEN CP = Y(CP):GOTO 20
60 CP = N(CP)
70 GOTO 30
80 PRINT "Is another selection needed";
90 INPUT A$
100 IF A$ = "N" THEN "Quit".
110 IF A$ = "Y" THEN 10

```

Fig. 5.5 An example of branching with pointer

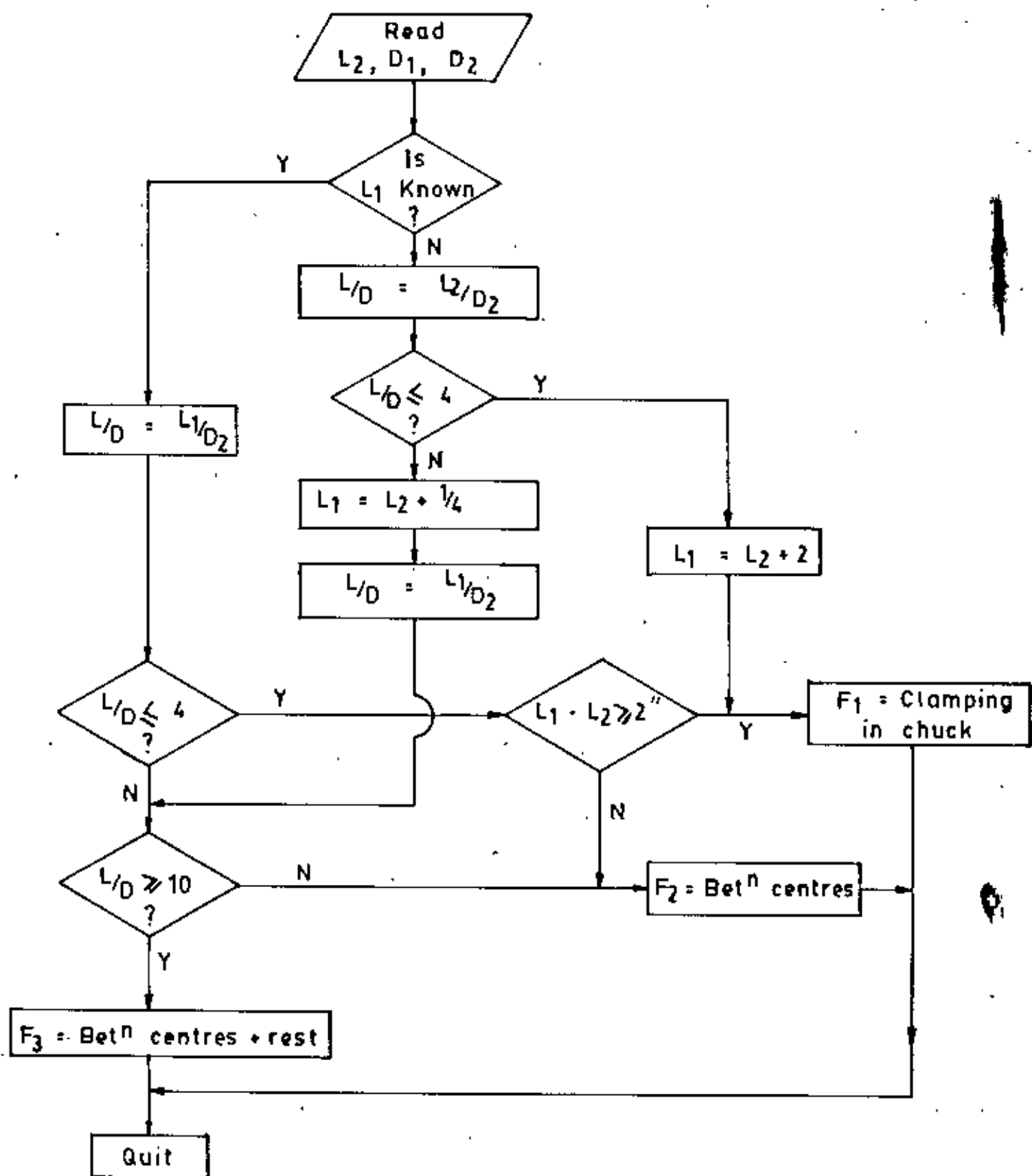


Fig. 5.6 Strategy for fixture selection.

5.3.2.1.3 Strategy for lathe selection:

To select the most suitable lathe on the basis of maximum machine utilization (ref. chapter 4), a simple AI technique namely Generate and Test is used. Here there are two types of testing such as -

- 1) Technological feasibility testing
- 2) Time feasibility testing

After carrying out the above two tests, the criterion for the machine selection has been completed with the machining cost. The strategy in the form of logic diagram may be given in fig. 5.7. The detail strategy for lathe selection have been shown in Appendix - II.

5.3.2.2 Reasoning process:

EMS adopt the process of forward reasoning. The left sides of the rules (described in chapter 6) are match against the facts and the right sides are used to generate new nodes until the goal is reached. The reasoning flow of the system have been shown as in figure 5.8 with the help of rules, as designed for EMS.

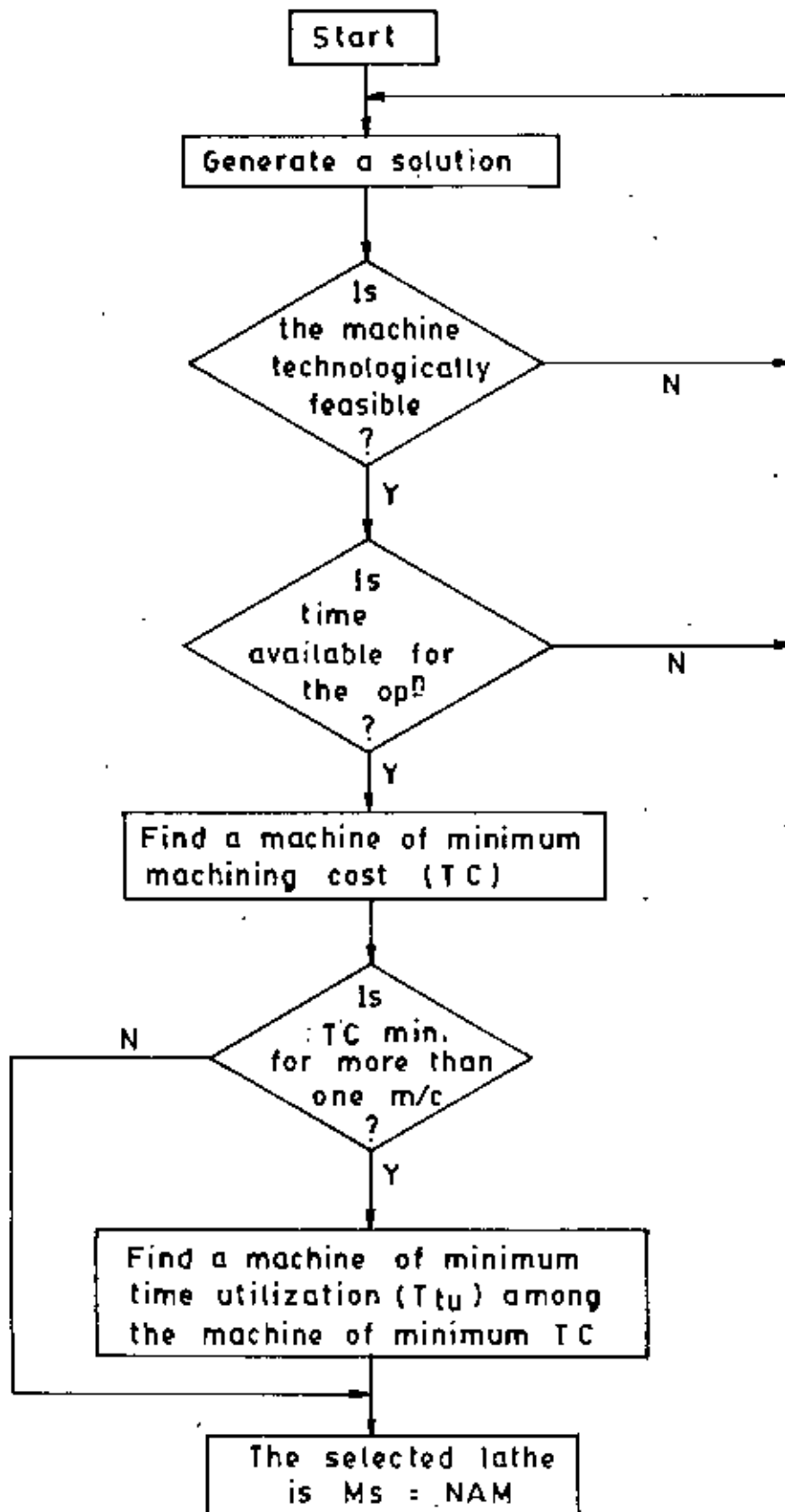
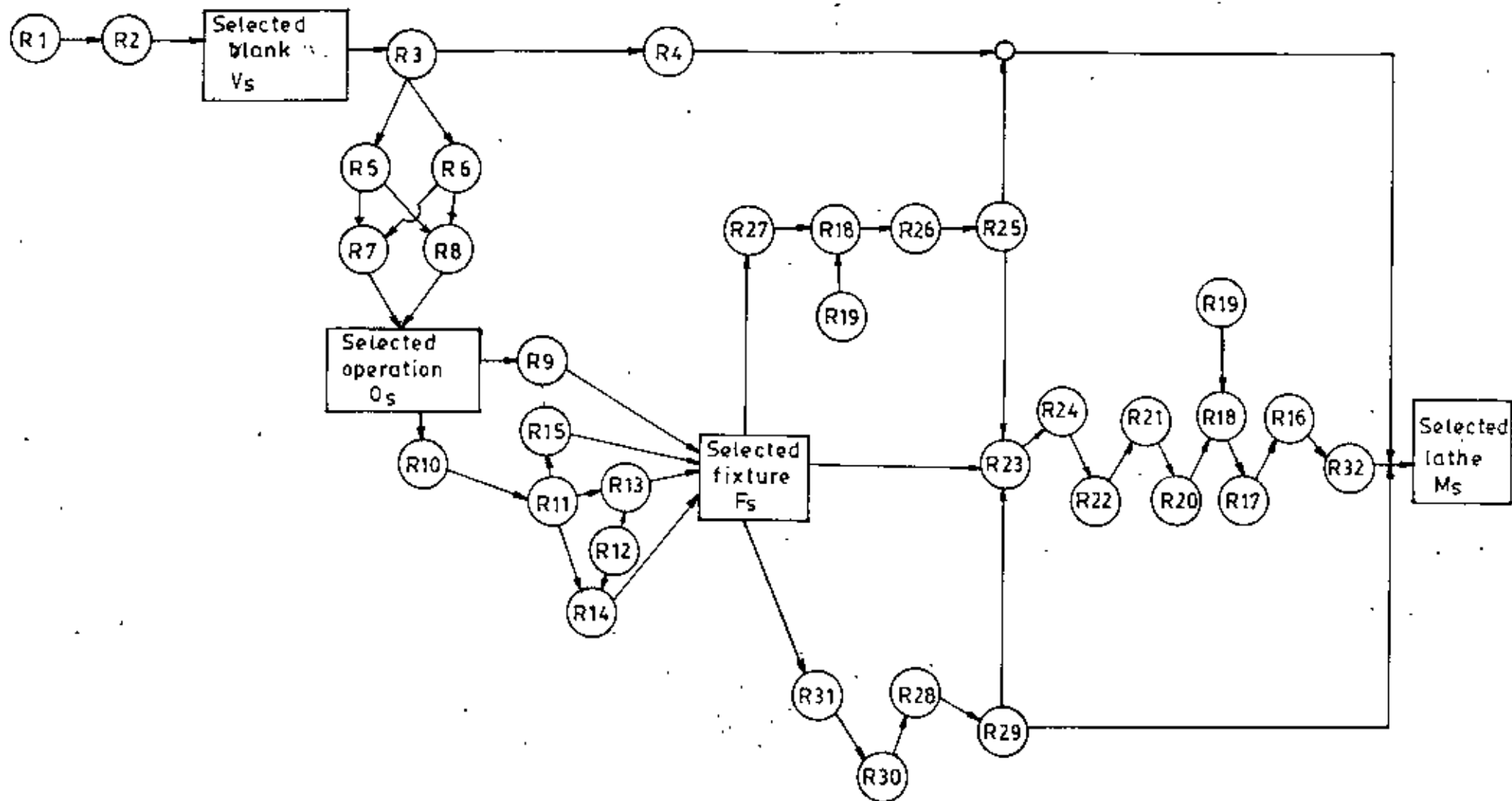


Fig. 5.7 Strategy for machine selection



Note - R indicates the rule

Fig. 5.8 Reasoning flow network .

CHAPTER - 6

REPRESENTATION OF KNOWLEDGE AND DATA

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CHAPTER - 6

REPRESENTATION OF KNOWLEDGE AND DATA

6.1 Representation of Knowledge:

Knowledge representation is the method used to encode and store facts and relationships in a knowledge base. There are many approaches to represent knowledge in a system, some of them are as follows :

6.1.1 Semantic Networks:

The most general representational scheme, and also one of the oldest in AI, is the semantic network (or semantic net). A semantic network is a collection of objects called nodes. The nodes are connected together by arcs or links. Ordinarily, both the links and the nodes are labeled. For example, a portion of "detective knowledge base" by S.Holmes is shown in fig. 6.1.

There are no absolute constraints as to how nodes and links are named.

However, some typical conventions are the following:

- 1) Nodes are used to represent objects and descriptors
- 2) Links relate objects and descriptors. A link may represent any relationship.

6.2 Object-attribute-value Triplets:

Another common way to represent factual information is as object-attribute-value (O-A-V) triplets. In this schma, objects may be physical entities such as a door or a job, or they may be conceptual entities such as a logic gate, a bank loan, etc. Attributes are general characteristics or

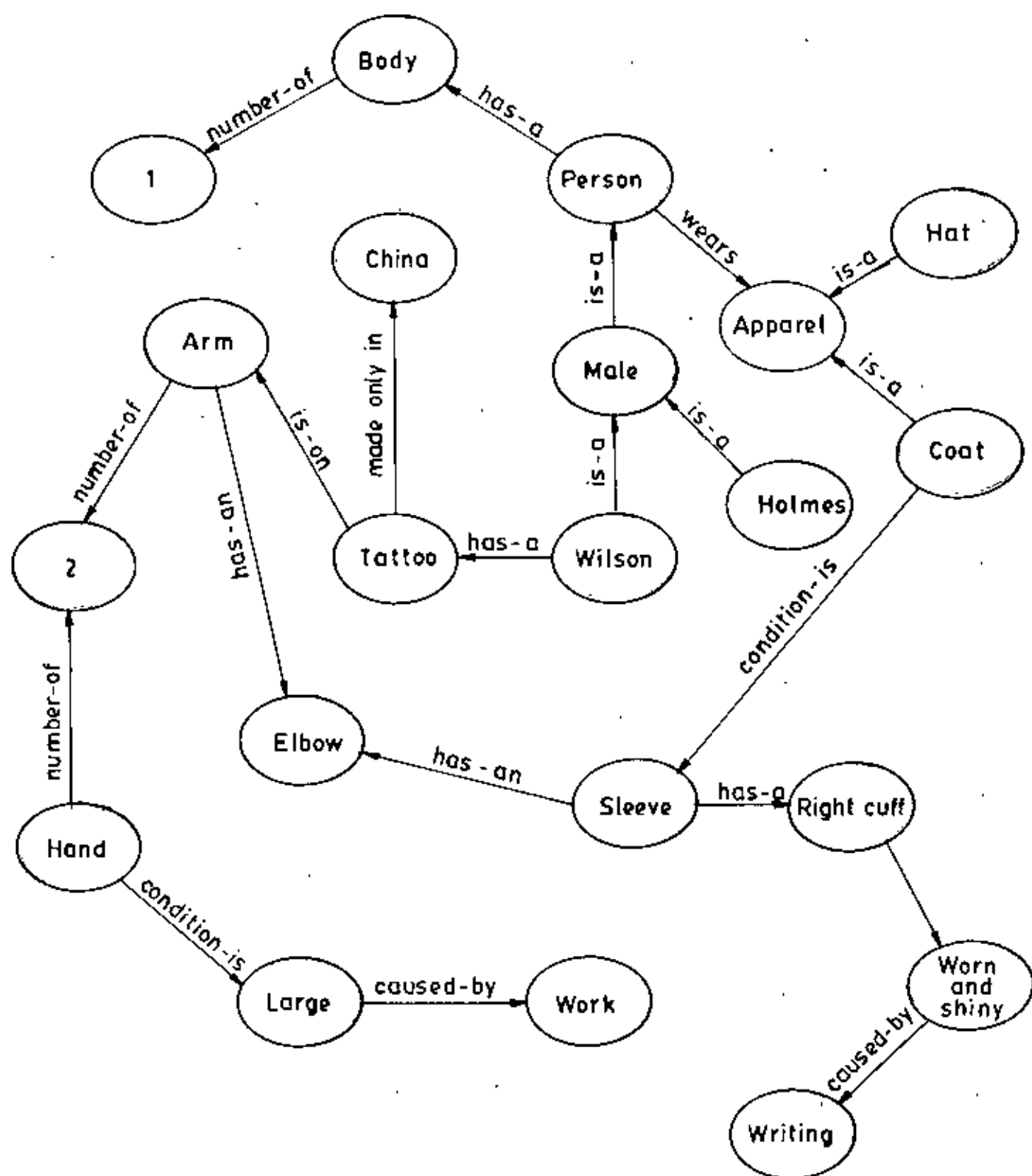


Fig. 6.1 A detective's knowledge base (1)

properties associated with objects. Size, shape and color are typical attributes for physical objects. Interest rate is the attribute for a bank loan. The final member of the triplet is the value of an attribute. The value specifies the specific nature of an attribute in a particular situation. Some examples are shown in fig. 6.2.

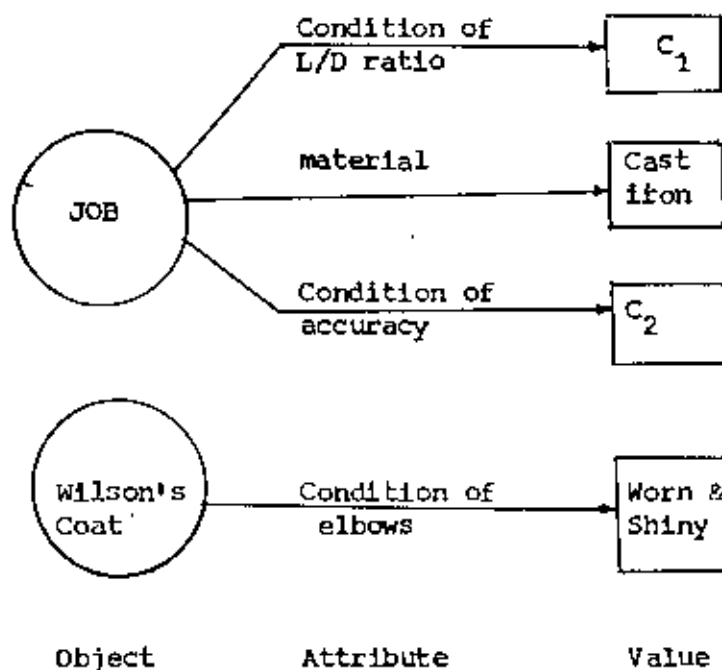


Fig. 6.2 : O-A-V triplets

6.1.3 Rules:

A conditional statement of two parts. The first part, comprised of one or more if clauses, establishes conditions that must apply if a second part, comprised of one or more then clauses is to be acted upon. The clauses of rules are usually O-A-V triplets. The general form of IF-THEN rules are -

If : <Conditions> , then : <Conclusion>

The examples of rules are as follows:

Rule : If Cheque complete and payee known and finds covered

Then Cash cheque

6.1.4 Frames:

It provides another method for representing facts and relationship. A frame is a description of an object that contain slots for all of the information associated with the object. Slots, like attributes, may store values. Slots, may also contain default values pointer to other frames, set of rules, or procedures by which values may be obtained. A frame of the "detective knowledge base" is shown in Table 6.1. The frame representation is of two types, one is declarative and another one is procedural representation. Declarative representation of a fact is simply an assertion that the fact is true. Procedural representation of a fact is a set of instructions that, when carried out, arrive at a result consistent with the fact.

Table 6.1 : Frame of Wilson's Coat⁽¹⁾

C O A T	
Slots	Entries
Owner	Wilson
Condition	Rumpled
Condition of cuffs	Worn, shiny
Condition of elbow	Worn, shiny
Number of arms	Default : 2
Fabric	Default : Wool
Pockets ?	Default : Yes
Size	If needed, find owner, height and weight and compare to Table X
Style	If needed, findout collar: pockets; and length; the look in Table Y

6.1.5 Logical Expressions:

Logic provides another way to represent knowledge. There are several logical notations. The two most common forms are described as follows:

6.1.5.1 Propositional logic:

It is a common logical system. Propositions are statements that are either true or false. Propositions that are linked together with connectives, such AND, OR, NOT, IMPLIES and EQUIVALENT, are called compound statements. Propositional logic is concerned with the truthfulness of compound statements. There are rules for propagating the truthfulness of statements, depending on the connectives. For example, if one proposition X is true and another proposition Y is false, then the compound statement "X AND Y" is false, whereas the compound statement "X OR Y" is true. Other rules allow for inferences. If X is known to be true, and if X IMPLIES Y, then we can conclude that Y is true.

6.1.5.2 Predicate Calculus:

It is an extension to propositional logic. The elementary unit in predicate logic is an object. Statements about objects are called predicates. For example, "is-red (ball)" is an assertion that says that a ball is red. This assertion is either true or false. Predicates can address more than one object. The statement that "daughter-of (Mimi, Susan)" is an example of a two-place predicate. This statement asserts that Mimi is the daughter of Susan.

6.2 Representation of Data:

Data is the raw and basic information of fact. If the data is stored more-or less permanently in a computer, then it is called a database. The structure of data may be of different types, such as -

1. Array type
2. Record structure
3. Linked lists
4. Tree structure.

Some data values may constitute a data file. The organization of data file may be also different types, such as,

1. Sequential
2. Index sequential
3. Direct access
4. Partitioned file

6.3 Representation of Knowledge and Data in EMS

Representation of knowledge and representation of data are very important to conceive the problem easily. They are discussed as follows.

6.3.1 Representation of Knowledge:

The method used to encode and store facts and relationships in a knowledge base. There are many ways to represent the knowledge. Among them 'Rules' method is chosen in EMS because of its simplicity. It is also termed as 'If-then' rules and some of them (including meta rules, which belong to the

inference engine) used in EMS are given as below in the translated form of English Language.

R.1 If the specifications of blank $(D_{1t}, A_{1t}, J_{1t}, f_{1t})$ and job (D_2, A_2, J_2, f_2) are known

then $\Phi_t = (D_{1t} - A_{1t}) - (D_2 - A_2)$

R.2 If Ψ_1 is the minimum among all Ψ_t , where $\Phi_t \gg 0$.

then the selected blank is V_s i.e.

$$V_s = (D_1, A_1, J_1, f_1)$$

R.3 If the specifications of selected blank (D_1, A_1, J_1, f_1) and job (D_2, A_2, J_2, f_2) are known

then $\Psi_s = (D_1 + J_1) - (D_2 + J_2)$ and

$$\Phi_s = (D_1 - A_1) - (D_2 - A_2)$$

R.4 If $\Psi_s \leq 0$ and $\Phi_s \gg 0$ and the surface roughness of blank is smaller than or equal to that of job ($f_1 \leq f_2$)

then no operation is needed on the selected blank to obtain the job and end of selection;

R.5 If $\Phi_s \gg 0$ and $(\Psi_s \leq 0)$ and $(f_1 > f_2)$ and $2(f_f - f_2) \leq \Phi_s$

then O_s = surface finishing

R 6.1 If $\Psi_s > 0$ and $\Psi_s \leq 0.1''$

then O_s = Finish turning

2 If $\Phi_s \gg 0$ and $\Psi_s > 0.1''$

then O_s = Rough turning.

R 7.1 If O_s = Rough turning and

$(f_r \leq f_2)$ and $(AC_r \leq AC_2)$

then O_s = Rough turning only

2. If $O_s = \text{Finish turning}$ and

$$(f_f \leq f_2) \text{ and } (AC_f \leq AC_2)$$

then $O_s = \text{Finish turning only}$

3. If $O_s \neq (\text{Rough turning or Finish turning})$ and $2(f_1 - f_2) \leq \phi_s$

then $O_s = \text{Surface finishing.}$

R 8.1 If $O_s = \text{Rough turning and}$
 Finish turning and
 $(f_r > f_2 \text{ OR } AC_r > AC_2)$ and
 $(f_f \leq f_2 \text{ AND } AC_f \leq AC_2)$

Then $O_s = \text{Rough turning and}$
 Finish turning

2. If $O_s = \text{Rough turning and Finish turning}$ and

$$(f_r > f_2 \text{ OR } AC_r > AC_2) \text{ and}$$

$$(f_f > f_2 \text{ OR } AC_f > AC_2)$$

Then $O_s = \text{Rough turning and}$
 Finish turning and
 Surface finishing.

3. If $O_s = \text{Finish turning}$ and

$$(f_f > f_2 \text{ OR } AC_f > AC_2)$$

Then $O_s = \text{Finish turning and}$
 Surface finishing.

R.9 If the length of blank is unknown and

$$LD (= L_2/D_2) \leq 4$$

Then $L_1 = L_2 + 2$ and

clamp blank directly in chuck.

R.10 If the length of raw material is unknown and

$$LD (= L_2/D_2) > 4$$

Then $L_1 = L_2 + 4$

R.11 If the specifications of the selected raw material and the job are known

$$\text{Then } L/D = L_1/L_2$$

R.12 If L_1 and L_2 are known

$$\text{Then } L_3 = L_1 - L_2$$

R.13 If $L/D \leq 4$ and $L_3 \geq 2''$

Then clamp blank directly in chuck

R.14 If $\left\{ \begin{array}{l} L/D \leq 4 \text{ and } L_3 < 2'' \\ 4 < L/D < 10 \end{array} \right\}$ OR

Then place blank between centres.

R.15 If $L/D \geq 10$

Then place blank between centres and use Rest

R.16 If $TC(q)$ is the minimum total machining cost by machine q for a particular job order

Then the selected machine is $NAM(q)$

R.17 If the hourly rate of machine Q is $HR(Q)$ and the approximately engage time of machine Q is $T(Q)$

Then total machining cost by machine Q for the order is $TC(Q) = HR(Q) \cdot T(Q)$.

R.18 If the cutting time is t_c and the setup time is t_{su} and the lot size of the order is LS

Then total engage time of machine Q is

$$T(Q) = (t_c) LS + t_{su}$$

R.19 If set up time of previous 5 standards are respectively C_1, C_2, C_3, C_4 and C_5

$$\text{Then set up time is } t_{su} = \frac{C_1 + C_2 + C_3 + C_4 + C_5}{5}$$

- R.20 If machining time due to rough turning, finish turning and surface finishing are respectively t_r , t_f and t_s

Then total machining time is

$$t_c = C_r(t_r) + C_f(t_f) + C_s(t_s)$$

- R.21.1 If the operation is not rough turning

Then coefficient for rough turning, $C_r = 0$ else $C_r = .1$

- 2 If the operation is not finish turning

Then coefficient for finish turning, $C_f = 0$ else $C_f = 1$

- 3 If the operation is not surface finishing

Then coefficient for surface finishing

$$C_s = 0 \text{ else } C_s = 1$$

- R 22.1 If $O_s =$ Rough turning and
 N_{mr} and f_{mr} are the actual rough cutting speed and feed
 which is the most nearest one of economic rough cutting
 speed and feed respectively

Then cutting time for rough turning is

$$t_c = \frac{(L_2 + 1/8) \cdot n}{N_{mr} \cdot f_{mr}}$$

2. If $O_s =$ finish turning and

N_{mf} and f_{mf} are the actual finish cutting speed and feed
 which is the most nearest one of economic finish cutting
 speed and feed respectively

Then cutting time for finish turning is

$$t_c = \frac{(L_2 + 1/8)}{N_{mf} \cdot f_{mf}}$$

3. If O_s = surface finishing and N_{ms} and f_{ms} are the actual surface finishing speed and feed which is the most nearest one economic surface finishing speed and feed respectively

Then cutting time for surface finishing is

$$t_{ts} = \frac{(L_2 + 1/B)}{N_{ms} \cdot f_{ms}}$$

- R 23.1 If job material is Aluminium or cast iron or mild steel and

O_R = Rough turning

Then the economic cutting speed, feed and depth of cut are V_R , fe_R and dc_R respectively.

2. If job material is Aluminium or cast iron or mild steel and

O_s = Finish turning

Then the economic cutting speed, feed and depth of cut are V_f , fe_f and dc_f respectively.

3. If job material is Aluminium, or cast iron or mild steel and

O_s = Surface finishing

Then the economic cutting speed feed and depth of cut are V_s , fe_s and dc_s respectively.

- R 24 If the cutting speed is V_R or V_f or V_s and the dia. of raw material is D_1

Then the rpm are

$$N_R = \frac{12V_R}{\pi D_1} \quad \text{or} \quad N_f = \frac{12V_f}{\pi D_1} \quad \text{or} \quad N_s = \frac{12V_s}{\pi D_1}$$

- R 25 If time utilization, $T_{tu} > 1$ for machine Q

Then machine Q is unable and go back to search for machine (Q+1) else continue.

- R.26 If time needed to process the job is T and scheduled load time of machine for a plan period is P_a and available time in a plan period to work with the machine is T_A

$$\text{Then time utilization is } T_{tu} = \frac{T + P_a}{T_A}$$

- R.27 If O_s = Rough turning and N_r and fe_r are the economic cutting speed and feed respectively

$$\text{Then cutting time is } t_t = \frac{(L_2 + 1/8) \cdot n}{N_r \cdot fe_r}$$

- R.28.1 If the identified operation is available in machine Q i.e.

$$\{O_s\} \subseteq \{O_m\}$$

$$\text{Then } A_1 = 1 \text{ else } A_1 = 0$$

- 2.If the selected fixture is available in machine Q i.e. $\{F_s\} \subseteq \{F_m\}$

$$\text{Then } A_2 = 1 \text{ else } A_2 = 0$$

3. If $(SC > D_1 \text{ AND } L_m > L_1) \text{ OR}$
 $(SC > D_1 \text{ AND } F_s = \text{Chuck clamping}$
 $\text{AND } L_m > L_2) \text{ OR}$
 $(O_s = \text{facing AND } SB > D_1)$
 $\text{AND } (L_m - 12) > L_2$

$$\text{Then } A_3 = 1 \text{ else } A_3 = 0.$$

4. If $AC_m \leq AC_2$ and

$$f_m \leq f_2 \text{ and}$$

$$dc' \geq dc_m \text{ and}$$

$$JM \in \{JM_m\} \text{ and}$$

$$P_{om} \geq P_o$$

$$\text{Then } A_4 = 1 \text{ else } A_4 = 0.$$

$$R.29 \text{ If } A(Q) = \prod_{i=1}^4 A_i = 0$$

Then machine Q is unable and go back to search for machine
(Q + 1) else continue.

R.30 If power needed for processing a job is unknown and cutting speed
is V_r and cutting force is FT .

Then the power needed is

$$HPM = \left[\frac{1}{0.8} \left\{ \frac{FT \cdot V_r}{33000} \right\} + 0.5 \right]$$

[Note: Here 0.5 is the t horse power and 0.8 is the mechanical
efficiency of machine]

R.31 If the cutting force is unknown and the depth of cut is dc_r
and the feed is fe_r and the coefficient is C_y

Then the cutting force is

$$FT = C_y \left\{ (dc)^{0.77} \cdot (fe)^{0.95} \right\}$$

[Note: Though some variation of cutting force with respect to changes
in speed may occur at low cutting speeds, the cutting force can
be considered to be independent of cutting speed within the
practical ranges of cutting speeds normally used.]

R.32 If $TC(Q)$ is the minimum cost for more than one machine say q_1 and
 $T_{tu}(w_1)$ is the minimum among q_1

Then the selected lathe is $NAH(w_1)$

6.3.2 Representation of Data:

The structure of data as used in EMS, is of array type and the elements arrays are as follows.

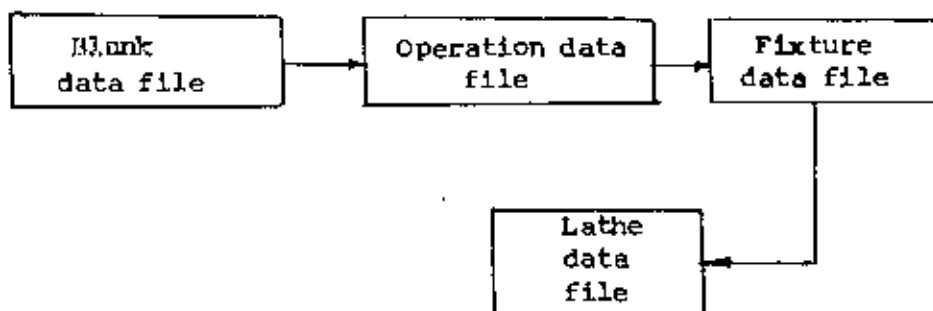
a. For blank data:

1. serial no.
2. Nominal dia.
3. Upper tolerance limit
4. Lower tolerance limit
5. Surface finish

b. For operation data

1. serial no.
2. Name of operation

The organization of these data files are sequential and may be shown as below.



The data flow diagram of the system are shown in fig. 6.3

c. For fixture data

1. serial no.
2. Name of fixture

d. For lathe data:

1. Serial no.
2. Name of lathe
3. Swing over bed

4. Swing over cross slide
5. Max. distance between centres
6. Max. motor power capacity
7. Max attainable grades of accuracy
8. Max surface finish capacity
9. Minimum allowable depth of cut of machine
10. Job material may be processed
11. Operations to be done
12. Available fixtures
13. Hourly rate
14. Setup time etc. for processing a simple rotary job of previous 5 standards
15. Available speeds in rpm
16. Available feeds in in./rev.

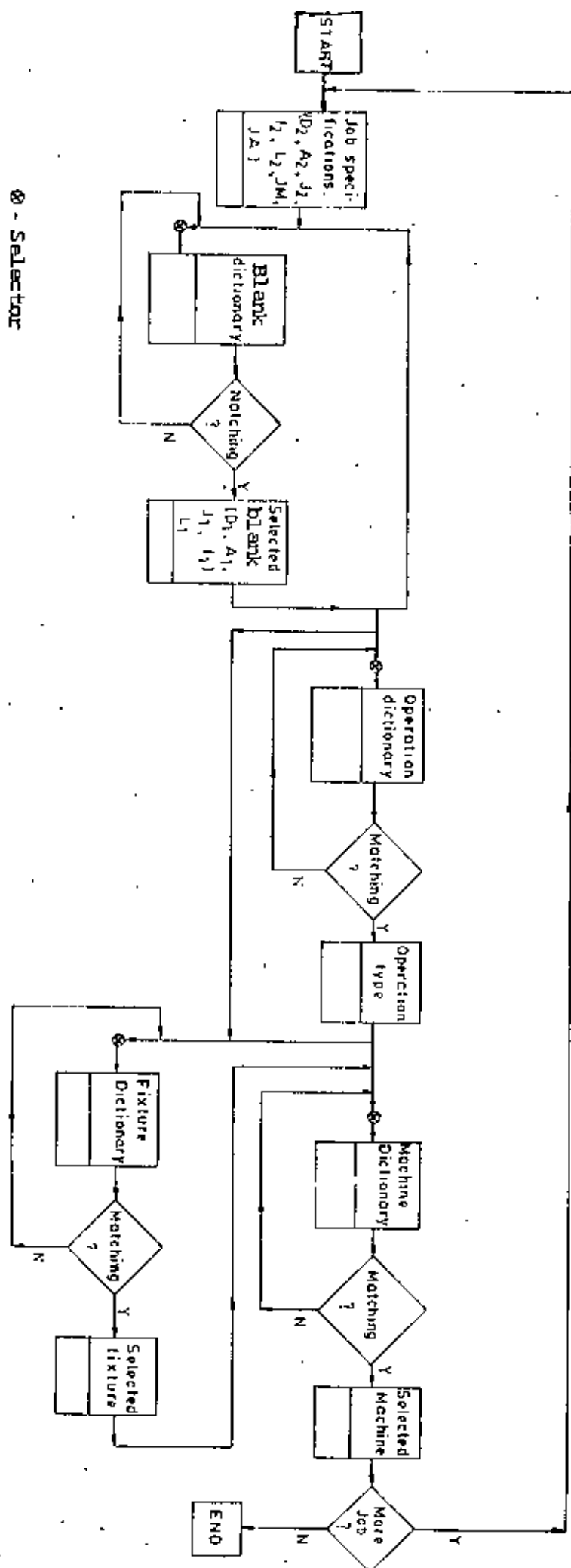


Fig. 6.3: Data flow diagram

CHAPTER - 7

SYSTEM CONSTRUCTION

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CHAPTER - 7

SYSTEM CONSTRUCTION

7.1 Structure of the System

A part of an EMS, which deals with the selection of the machine tools (lathe) has been designed. The structure of the working principle of the system have been shown in figure 1.3. It consists of two main parts such as

- a) User interface
- b) Original or core system

User interface is the link between a computer program and the outside world. User interface features include explanation facilities, display devices or sensors.

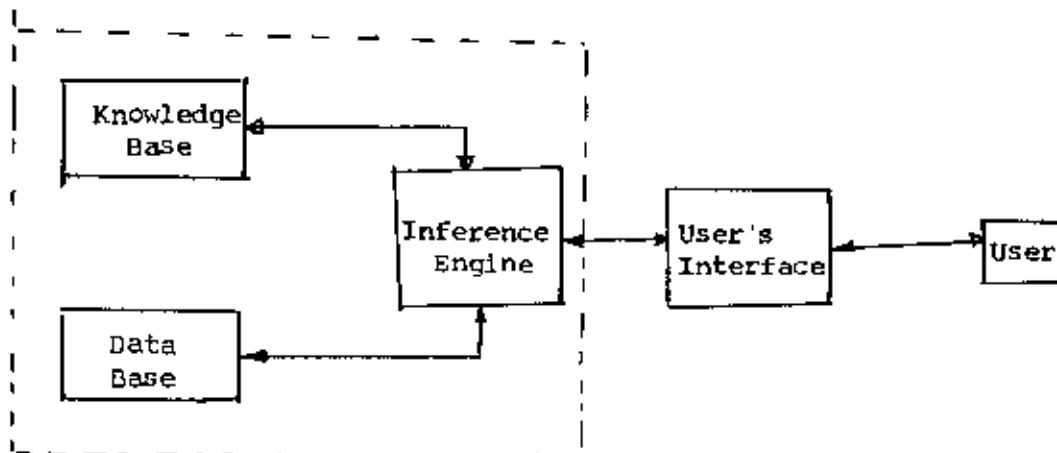


Fig. 1.3 : Structure of the System

The core system consists of three elements namely, 1) Knowledge Base (KB) 2) Data Base (DB) 3) Inference Engine.

The knowledge Base of the system consists of facts and rules related to parameters of job, fixture, machine, etc. and it provides data related information for a selection. The inference engine consists of inference and

control strategies, which guide both the KB and DB of the system, to reach a conclusion.

During man-machine interaction, the system works in a simple, friendly way - asking questions, understanding answers - so that no special computer knowledge is necessary to use it, only the answers should be typed in through keyboard.

7.2 General Block Diagram

The general block diagram of the system is shown in fig. 7.1. The main functions of each block are as follows:

- a) **INPUTS**: Input some physical and mechanical characteristics of a cylindrical job.
- b) **INFORM**: Produce data such that it may be easy useable and make it capable to handle uncertainties

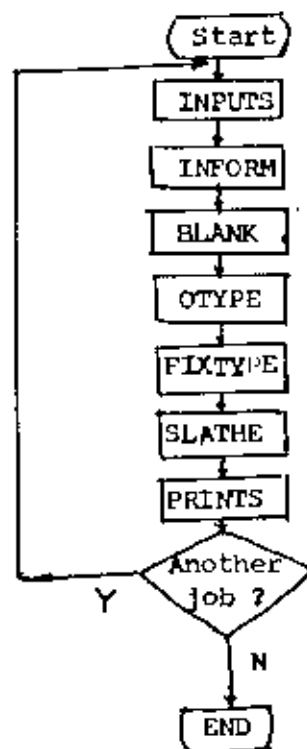


Fig. 7.1 : General block diagram of the system

- c) BLANK : Selection of blank on the basis of job specifications and available blank.
- d) OTYPE: Identify some operation needed for a particular rotary job.
- e) FIXTYPE: Estimate the type of fixture needed to process a particular job. To estimate this, the type of operation and input job data is needed.
- f) SLATHE: Select the lathe of suitable type for a particular job. To select the suitable one, the job information, type of operation, and type of fixture is needed.
- g) PRINTS: Print the final result of the selection.
- h) END: The selection system operates on the basis of each individual job. It assigns job to a machine and the operation comes to an end when all the job are assigned.

7.3 Philosophy of the System

The philosophy of the selection process is same as a human expert. It follows the following steps.

- 1) It takes in information on the current task.
- 2) It compares this with information stored in his brain and looks for a match.
- 3) Finally it reports wheather or not a match has been found.

The process may be shown in fig. 7.2 in the form of flowcharts.

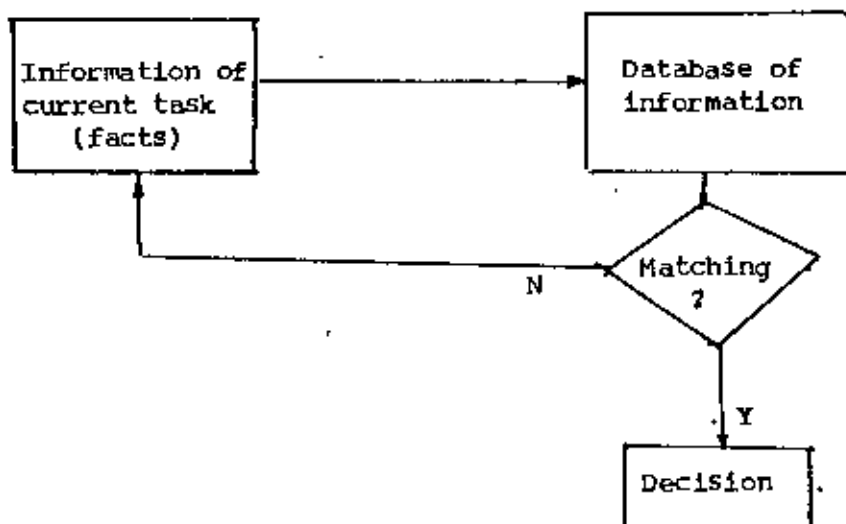


Fig. 7.2 : Philosophy of the selection (9)

7.4 Interacting with the System

In order for an expert system to be an effective tool, people must be able to interact with it easily. To facilitate this interaction it is important that an expert system have the following two capabilities.

- 1) Explain its reasoning
- 2) Acquire new knowledge and modification of old knowledge

The EMS is not a solitary problem rather than a conversational problem, in which there will be intermediate communication between a person and the computer, either to provide additional assistance to the computer or to provide additional information to the user or both. A user can halt the processing at any time and ask why a particular line of questioning is being pursued or how a particular conclusion was reached. The system is highly interactive. It asks questions to the user and by understanding questions give the answers accordingly. If it asks question like this -

"Do you need some help 'Yes/No' ?" and if the user reply like this-

"Yes" then the help literature will be listed in the interface

And if the user reply like this -

"No" then it asks another question.

Sometimes, it uses 'menu' form to ask question like this -

- 1) Selection for another job,
- 2) Main control structure
- 3) Exit the system.

If the user's choice is 1 then it will be ready to select lathe for another job and accordingly.

7.5 Language of the System

Most programming is done in one of a number of high-level language. High level language may be classified into two types, namely, 1) conventional language, 2) AI programming language. Generally, conventional programming languages include BASIC, COBOL, FORTRAN, PASCAL, C AND AI programming language include LISP, PROLOG, etc. But LISP and PROLOG are less well known than FORTRAN and PASCAL. Implementations of conventional programming language are available for almost all computer hardware. Until recently, implemnetations of LISP and PROLOG were not available for mainframe computers. To make it easy to run ES on a wide variety of existing computers, some system developers have coded their system in conventional language⁽¹⁾. The examples of such system package may be shown in table 7.5.

Among conventional programming language, all types of problems are not suitable for all language.

For the development of EMS, BASIC is chosen as a language.

<u>Package</u>	<u>Machine type</u>	<u>Knowledge representation</u>	<u>Pre-decessor</u>	<u>Base language</u>
EXTRAN-77	Various	Rule	Edinburgh	FORTRAN
Expert-Ease	Micro	Tree	Edinburgh	PASCAL
RULEMASTER	UNIX	Rule	Edinburgh	C
KES	Various	Rule	None	C
TIMM	Various	Rule	None	FORTRAN
TESS	Micro	Rule	None	C
Micro-Expert	Micro	Network	Prospector	PASCAL
ADVISER	ICL	Network	SAGE	PASCAL

Table 7.5 : Various Expert System Package⁽¹¹⁾

7.6 Expertise in EMS:

One of the puzzles in learning about Expert Systems is deciding exactly where the expertise lies. The inference schemes are simple and it forward-chains through the knowledge base attempting to apply the modusponen rule. So where exactly is the expertise in EMS ?

The expertise lies in two places: First, although the scheme for representing knowledge are simple, the factoring and acquisition of the knowledge are difficult. So it needs expertise.

The second source of expertise is found in the wisdom compiled into the heuristic rules.

In case of designing rules the logical duplication is avoided, so that the system may be really an expert. In the following figure (7.3, 7.4, 7.5) some examples have been shown and the shaded area represent the redundant condition or knowledge.

	$(D_1+J_1) \leq (D_2+J_2)$	$f_1 \leq f_2$	Minimization of $\psi = (D_1-A_1) - (D_2-A_2)$	$\phi_s = (D_1-A_1) - (D_2-A_2) \leq 0.1$	$E_R \leq E_2$ AND $AC_R \leq AC_2$	$f_f \leq f_2$ AND $AC_f \leq AC_2$
$(D_1-A_1) \geq (D_2-A_2)$						
$(D_1+J_1) \leq (D_2+J_2)$						
$(D_1+J_1) > (D_2+J_2)$						


 : Redundent space

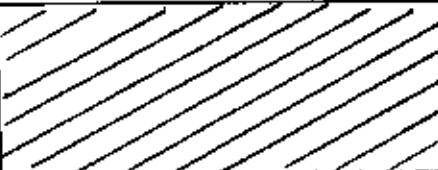
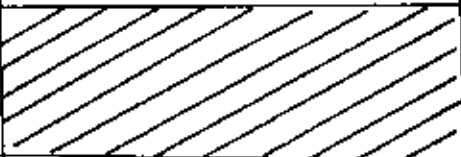
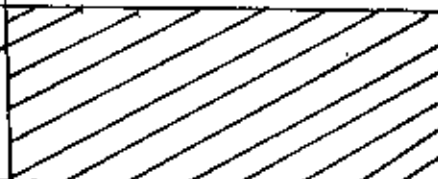
Fig. 7.3 : Reduction of search space by avoiding logical duplication (in case of raw material selection and operation identification)

	$L/D \approx \frac{L_1}{D_2}$	$L/D \approx \frac{L_2}{D_2}$	$L/D \leq 4$	$L_3 \geq 2$	$L/D \geq 10$	$L_1 = L_2 + 2$	$L_1 = L_2 + 4$
L_1 known							
L_1 Unknown							
$L/D \leq 4$							
$L/D > 4$							

Fig. 7.4 : Reduction of search space by avoiding logical duplication (in case of fixture selection)

	$SC > D_1$	$SB > D_1$	$L_m > L_1$	$F_{\text{chuck-}}^{\text{ing}}$	$O_{\text{facing}}^{\text{ing}}$	$L_m > L_2$	$L_m - 12 > L_2$
$SC > D_1$							
$SC \leq D_2$							
$SB > D_1$							
$L_m > L_1$							
$L_m \leq L_1$							

 : Redundant space

	Machine specifications (SB, SC,)	Economic (calculated) (fe, N, dc,)
Technological feasibility		
Time feasibility		
Cost minimization		


 : Redundent space

Fig. 7.5 : Reduction of search space by avoiding logical duplication (In case of machine selection)

CHAPTER - 8

IMPLEMENTATION OF EMS

CHAPTER - 8

IMPLEMENTATION OF EMS

The designed EMS is an expert system capable of selecting raw material, fixtures, suitable lathe and identifying some operations, for a simple cylindrical job to be processed. The system runs on an IBM PC with a MS DOS operating system.

It May be used in any production shop, specially in job order type production shop, to select a suitable lathe. By having statistics of incoming job into the shop, it may be helpfull to forecast the proper types of lathe to be purchased for the shop.

To implement it, no special computer knowledge is necessary only some physical and mechanical job characteristics should be typed into the system through man-machine interaction.

For the simple rotary job, the selection of raw materials, the identification of operation, the selection of fixture and the selection of lathes are shown below.

Fig. 8.1, Fig. 8.2, fig. 8.3 and fig. 8.4 represent the drawing of job 1, job2, job3 and job 4 respectively.

For job 1:

Table 8.1 represents the input and output towards selection of blank

Table 8.2 represents the input and output towards identifications of operation type

Table 8.3 represents the input & output towards selection of fixtures

Table 8.4 represents the input & output towards selection of lathe.

For job 2

Table 8.5 represents the input & output towards selection of blank

Table 8.6 represents the input and output towards identification of operation type

Table 8.7 represents the input and output towards selection of fixtures

Table 8.8 represents the input and output towards selection of lathe

For job 3

Table 8.9 represents the input and output towards selection of blank

Table 8.10 represents the input and output towards identification of operation

Table 8.11 represents the input and output towards selection of fixtures

Table 8.12 represents the input and output towards selection of lathe

For job 4

Table 8.13 represents the input & output towards selection of blank

Table 8.14 represent the input and output towards identification of operation

Table 8.15 represents the specifications of available lathe - 1

Table 8.16 represents the specification of available lathe - 2

Table 8.17 represents the specification of available lathe - 3

Table 8.18 represents the specification of available lathe - 4

Table 8.19 represents the specification of available lathe - 5

Table 8.20 represents the specification of available lathe - 6

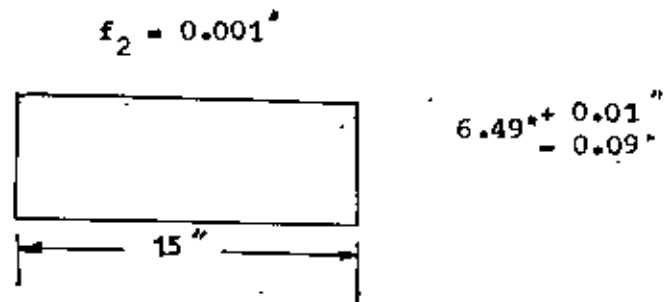


Fig. 8.1 : The drawing of job 1 .

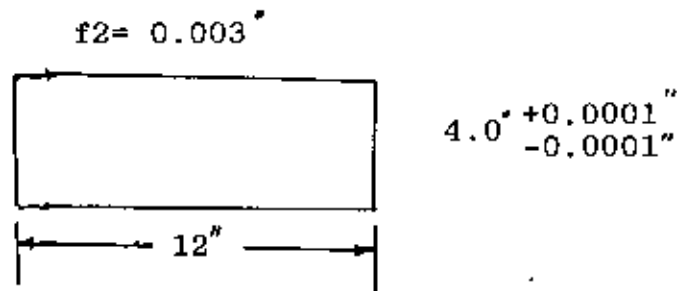


Fig. 8.2 : The drawing of job 2

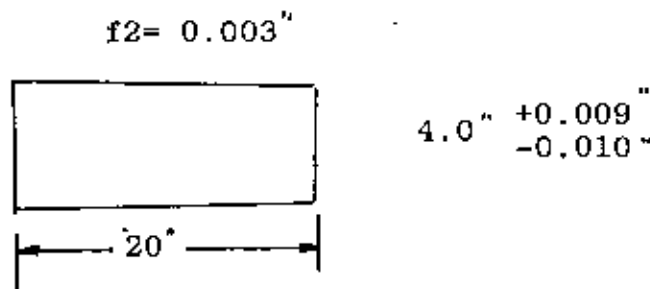


Fig. 8.3 : The drawing of job 3

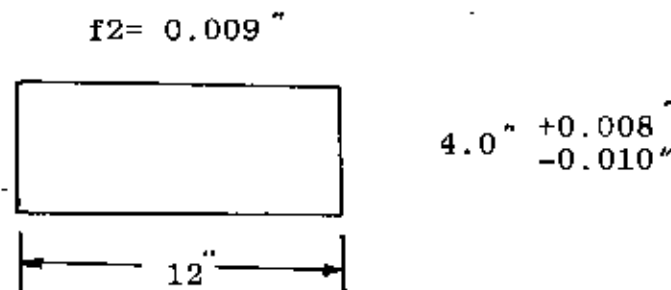


Fig. 8.4 : The drawing of job 4

INPUT TOWARDS EMS

The job specifications are--

Final job nominal diameter	=6.49 in.
Final job upper tolerance limit	=0.01 in.
Final job lower tolerance limit	=0.09 in.
Final job surface finish	=0.001 in.

The available blank specifications are--

Nominal diameter	= 1, 3, 4, 5.00, 6.50, 7.00 (in.)
upper tolerance limit	= .05, .02, .008, 0.02, 0.04, 0.03 (in.)
lower tolerance limit	= .02, .01, .009, 0.01, 0.03, 0.02 (in.)
surface finish	= .008, .009, .008, 0.009, .007, 0.009 (in.)

OUTPUT OF EMS

The selected blank is .

serial no.	= 5
Nominal diameter	= 6.5 in.
upper tolerance limit	= 0.04 in.
lower tolerance limit	= 0.03 in.
surface finish	= 0.007 in.

Comments : The results are satisfactory. (Job 1)

Table:8.1: The job specifications and the selected blank

INPUT TOWARDS EMS

		+0.01	
Final job diameter	= 6.49		(in.)
		-0.09	
Final job surface finish	=0.001 in.		
		+0.04	
Selected blank dia.	= 6.5		(in.)
		-0.03	
Selected blank surface finish	=0.007 in.		

OUTPUT OF EMS

The operations to be done are--

Osl = Finish Turning only.

Comments : The results are satisfactory. (Job 1)

Table:B.2 : The job specifications and the operations.

 INPUT TOWARDS EMS

Selected blank length.	=	17 in.
Selected blank dia.	=	6.50 ^{+0.04} -0.03
Final job length	=	15 in.
Final job diameter	=	6.49 ^{+0.01} -0.09
Operations to done are	=	Finish Turning only.

 OUTPUT OF EMS

The selected fixtures are---

Fs = { Chuck clamping only & No other extra
 { supporting devices are needed.

Comments : The results are satisfactory. (Job 1)

Table:8.3:The job requirements and the fixture needed.

INPUT TOWARDS RMS

Initial blank length	= 17 in.
	+0.04
Initial blank dia.	= 6.5 in.
	-0.03
Initial blank surface finish	= 0.007 in.

Finished job length	= 15 in.
	+0.01
Finished job diameter	= 6.49 in.
	-0.09
Finished job surface finish	= 0.001 in.
Lot size of the job	= 10
Material of the job	= MS (Mild Steel)

Scheduled load in hours for the plan]	
period of 6 Lathes are respectively]	= 11,0,0,12,15,0
Available working hour for the plan]	
period of 6 Lathes are respectively]	= 111,100,90,90,100,90

The intermediate inputs(Dynamic data base)--

Identified operations are	= Finish Turning
Selected Fixture are	= Chuck only
Grades of accuracy of job	= 13
Cutting power in HP	= 3.68

Total machining cost of available 6]	
Lathes are respectively in TK.]	= -,14.34, 14.14, 14.80, 18.31, 30.26
Time utilization of available 6]	
Lathes are respectively]	= -, .034, .037, .1712, .184, .038

OUTPUT OF RMS:

The selected Lathe is-

Serial number	= 2	**
Name of the Lathe	= Bench Lathe-002	

** Note:For detail information please see Table 8.15 to 8.20.

Comments : The results are satisfactory. (Job 1)

Table: 8.4 : The detail job specifications and the selected lathe

INPUT TOWARDS EMS

The job specifications are--

Final job nominal diameter = 4.00 in.
 Final job upper tolerance limit = 0.0001 in.
 Final job lower tolerance limit = 0.0001 in.
 Final job surface finish = 0.001 in.

The available blank specifications are--

Nominal diameter = 1, 3, 4, 5.00, 6.50, 7.00 (in.)
 upper tolerance limit = .05, .02, .008, 0.02, 0.04, 0.03 (in.)
 lower tolerance limit = .02, .01, .009, 0.01, 0.03, 0.02 (in.)
 surface finish = .008, .009, .008, 0.009, .007, 0.009 (in.)

OUTPUT OF EMS .

The selected blank :

serial no. = 4
 Nominal diameter = 5.0 in.
 upper tolerance limit = 0.02 in.
 lower tolerance limit = 0.01 in.
 surface finish = 0.009 in.

Comments : The results are satisfactory. (Job 2)

Table:8.5: The job specifications and the selected blank

INPUT TOWARDS EMS

		+0.0001	
Final job diameter	= 4.00		(in.)
		-0.0001	
Final job surface finish	=0.003 in.		
		+0.02	
Selected blank dia	=5.0		(in.)
		-0.01	
Selected blank surface finish	=0.009 in.		

OUTPUT OF EMS

The operations to be done are--

[Rough Turning &
 Osl = [Finish Turning &
 [Surface Finishing.

Comments : The results are satisfactory. (Job 2)

Table: 8.6 : The job specifications and the operations.

 INPUT TOWARDS EMS

Selected blank length	= unknown
Selected blank dia.	= 5.00 $\begin{matrix} +0.02 \\ -0.01 \end{matrix}$
Final job length	= 12 in.
Final job diameter	= 4.00 $\begin{matrix} +0.0001 \\ -0.0001 \end{matrix}$
Operations to done are	= Rough turning & Finish turning & surface finishing.

 OUTPUT OF EMS

The selected fixtures are---

Fs = [Chuck clamping only & No other extra
[supporting devices are needed.

Comments : The results are satisfactory. (Job 2)

Table:8.7: The job requirements and the fixture needed.

INPUT TOWARDS EMS

Initial	blank	length	=	unknown	
				+0.02	
Initial	blank	diameter	=	5.0	in.
				-0.01	
Initial	blank	surface finish	=	0.009	in.

Finished job length	= 12 in.
Finished job diameter	= 4.00 in. +0.0001 -0.0001
Finished job surface finish	= 0.003 in.
Lot size of the job	= 15
Material of the job	= CI (Cast Iron)

Scheduled load in hours for the plan]
period of 6 Lathes are respectively] = 11,0,0,12,15,0
Available working hour for the plan]
period of 6 Lathes are respectively] = 111,100,90,90,100,100

The intermediate inputs(Dynamic data base)--

Identified operations are	=	Rough Turning & Finish Turning & Surface finishing.
Selected fixtures are	=	Chuck only
Grades of accuracy of job	=	4
Cutting hp.	=	1.22
Total machining cost of available 6]		
Lathes are respectively	=	-,--,--,--,--, 2793.1
Time utilization of available 6		
Lathes are respectively	=	-,--,--,--,--, 0.5156

OUTPUT OF EMS:

```

The selected Lathe is-
Serial number          = 6          **
Name of the Lathe      = Engine Lathe-006

```

**** Note: For detail information please see Table 8.15 to 8.20.**

Comments : The results are satisfactory. (Job 2)

Table: 8.8 : The detail job specifications and the selected lathe

INPUT TOWARDS EMS

The job specifications are--

Final job nominal diameter	=4.00 in.
Final job upper tolerance limit	=0.009 in.
Final job lower tolerance limit	=0.01 in.
Final job surface finish	=0.003 in.

The available blank specifications are--

Nominal diameter	= 1, 3, 4, 5.00, 6.50, 7.00 (in.)
upper tolerance limit	= .05, .02, .008, 0.02, 0.04, 0.03 (in.)
lower tolerance limit	= .02, .01, .009, 0.01, 0.03, 0.02 (in.)
surface finish	= .008, .009, .008, 0.009, .007, 0.009 (in.)

OUTPUT OF EMS

The selected blank is

serial no.	= 4
Nominal diameter	= 5.0 in.
upper tolerance limit	= 0.02 in.
lower tolerance limit	= 0.01 in.
surface finish	= 0.009 in.

Comments : The results are satisfactory. (Job 3)

Table:8.9: The job specifications and the selected blank

INPUT TOWARDS EMS

		+0.009	
Final job diameter	= 4.00	(in.)	
		-0.01	
Final job surface finish	=0.003 in.		
		+0.02	
Selected blank dia.	=5.0	(in.)	
		-0.01	
Selected blank surface finish	=0.009 in.		

OUTPUT OF EMS

The operations to be done are--

Osl = Rough turning only.

Comments : The results are satisfactory. (Job 3)

Table: 8.10 :The job specifications and the operations.

 INPUT TOWARDS EMS

Selected blank length	= unknown
Selected blank dia	= 5.00 $\begin{matrix} +0.02 \\ -0.01 \end{matrix}$
Final job length	= 20 in.
Final job diameter	= 4.00 $\begin{matrix} +0.009 \\ -0.01 \end{matrix}$
Operations to done are	= Rough turning only

 OUTPUT OF EMS

The selected fixtures are---

Fs = [Clamping between centres by --
 [1. Face plate
 [2. Dog clutch
 [3. Tail stock

Comments : The results are satisfactory. (Job 3)

Table:8.11: The job requirements and the fixture needed.

INPUT TOWARDS EMS

Initial blank length	=	unknown	
		+0.02	
Initial blank dia.	=	5.0	in.
		-0.01	
Initial blank surface finish	=	0.009	in.
Finished job length	=	20	in.
		+0.009	
Finished job diameter	=	4.00	in.
		-0.01	
Finished job surface finish	=	0.003	in.
Lot size of the job	=	15	
Material of the job	=	MS (Mild Steel)	
Scheduled load in hours for the plan]			
period of 6 Lathes are respectively]	=	11,0,11,0,0,0	
Available working hour for the plan]			
period of 6 Lathes are respectively]	=	111,90,100,100,90,100	

The intermediate inputs(Dynamic data base)--

Identified operations are	=	Rough turning
Selected Fixture are	=	Face plate ,Dog clutch & Tail stock.
Grades of accuracy of job	=	13
Cutting hp.	=	3.68
Total machining cost of available 6]		
Lathes are respectively]	=	-, 204.32, 235.55, 155.97, 113.24, 429.45
Time utilization of available 6]		
Lathes are respectively]	=	-, .5924, .6438, .534, .593, .534

OUTPUT OF EMS:

The selected Lathe is-

Serial number	=	2	**
Name of the Lathe	=	Engine Lathe - 005	

** Note:For detail information please see Table 8.15 to 8.20.

Comments : The results are satisfactory. (Job 3)

Table: 8.12 : The detail job specifications and the selected lathe

INPUT TOWARDS EMS

The job specifications are--

Final job nominal diameter	=4.00 in.
Final job upper tolerance limit	=0.009 in.
Final job lower tolerance limit	=0.01 in.
Final job surface finish	=0.009 in.

The available blank specifications are--

Nominal diameter	= 1, 3, 4, 5.00, 6.50, 7.00 (in.)
upper tolerance limit	= .05, .02, .008, 0.02, 0.04, 0.03 (in.)
lower tolerance limit	= .02, .01, .009, 0.01, 0.03, 0.02 (in.)
surface finish	= .008, .009, .008, 0.009, .007, 0.009(in.)

OUTPUT OF EMS

The selected blank ;

serial no.	= 3
Nominal diameter	= 4.0 in.
upper tolerance limit	= 0.008 in.
lower tolerance limit	= 0.009 in.
surface finish	= 0.008 in.

Comments : The results are satisfactory. (Job 4)

Table:8.13: The job specifications and the selected

 INPUT TOWARDS EMS

		+0.009	
Final job diameter	= 4.00		(in.)
		-0.01	
Final job surface finish	=0.009 in.		
		+0.008	
Selected blank	=4.0		(in.)
		-0.009	
Selected blank surface finish	=0.008 in.		

 OUTPUT OF EMS

NO OPERATIONS ARE NEEDED.

Comments : The results are satisfactory. (Job 4)

Table: 8.14 : The job specifications and the operations.

The specifications of lathe-001

Serial number	= 1
Name of the lathe	= Bench Lathe-001
Swing over bed in in.	= 12
Swing over cross slide in in.	= 10
Max.distance between centres (in.)	= 100
Max.motor power in HP.	= 5
Max.attainable grades of accuracy	= 10
Max.surface finish capacity (in.)	= 0.005
Min.allowable depth of cut in inch	= 0.01
Job material generally process	= CI,MS,AL
Operations to be done	= Rough Turning, Finish Turning & Surface Finishing
Fixtures available	= Chuck, Face plate, Dog clutch, Tail stock & Rest.
Hourly rate in TK.	= 1.00
Setup time in min. for processing a simple rotary job such as job1 or job2 or job3 or job4 of previ- ous 5 standards	= 2, 3, 2.5, 4, 6
Available speeds in rpm.	= 20, 30, 45, 63, 88, 115, 138, 165, 198, 238, 285, 343, 411, 535, 855.
Available feeds in in./rev.	= 0.0005, .001, .009, .02, .06, .1

Table:8.15 : The specifications of lathe -001

The specifications of lathe-002

Serial number	=	2
Name of the lathe	=	Bench Lathe-002
Swing over bed in in.	=	15
Swing over cross slide in in.	=	12
Max.distance between centres (in.)	=	110
Max.motor power in HP.	=	6
Max.attainable grades of accuracy	=	9
Max.surface finish capacity (in.)	=	0.001
M/n.allowable depth of cut in inch	=	0.005
Job material generally process	=	CI,MS,AL
Operations to be done	=	Rough Turning,Finish Turning & Surface Finishing
Fixtures available	=	Chuck,Face plate,Dog clutch, Tail stock & Rest.
Hourly rate in TK.	=	2.00
Setup time in min. for processing}		
a simple rotary job such as job1 }	=	3,3,2.5,4,6
or job2 or job3 or job4 of previ- }		
ous 5 standards }		
Available speeds in rpm.	=	25,35,45,63,83,108,130,155,186, 224,291,378,491,639,958.
Available feeds in in./rev.	=	0.0006,.001,.009,.01,.08,.15

Table:B.16: The specifications of lathe -002

The specifications of lathe-003

Serial number	=	3
Name of the lathe	=	Engine Lathe-003
Swing over bed in in.	=	20
Swing over cross slide in in.	=	15
Max.distance between centres (in.)	=	120
Max.motor power in HP.	=	7
Max.attainable grades of accuracy	=	B
Max.surface finish capacity (in.)	=	0.0005
Min.allowable depth of cut in inch	=	0.001
Job material generally process	=	CI,MS,AL
Operations to be done	=	Rough Turning,Finish Turning & Surface Finishing
Fixtures available	=	Chuck,Face plate,Dog clutch, Tail stock & Rest.
Hourly rate in TK.	=	2.00
Setup time in min. for processing] a simple rotary job such as job1] or job2 or job3 or job4 of previ-] ous 5 standards]	=	3,4,5,7,6
Available speeds in rpm.	=	38,60,72,95,118,130,185,260,375, 455,590,740,815,1155,1600
Available feeds in in./rev.	=	0.0009,.002,.008,.01,.09,.20

Table:8.17: The specifications of lathe -003

The specifications of lathe-004

Serial number	=	4
Name of the lathe	=	Engine Lathe-004
Swing over bed in in.	=	24
Swing over cross slide in in.	=	20
Max.distance between centres (in.)	=	130
Max.motor power in HP.	=	8
Max.attainable grades of accuracy	=	5
Max.surface finish capacity (in.)	=	0.0001
Min.allowable depth of cut in inch	=	0.0009
Job material generally process	=	CI,MS,AL
Operations to be done	=	Rough Turning,Finish Turning & Surface Finishing
Fixtures available	=	Chuck,Face plate,Dog clutch, Tail stock & Rest.
Hourly rate in TK.	=	2.50
Setup time in min. for processing] a simple rotary job such as job1] or job2 or job3 or job4 of previ-] ous 5 standards]	=	5,3,4,5,7
Available speeds in rpm.	=	25,30,45,68,101,152,228,342,479, 670,870,1040,1254,1505,1956
Available feeds in in./rev.	=	0.001 ,.005,.009,.02,.10,.30

Table:8.18: The specifications of lathe -004

The specifications of lathe-005

Serial number	=	5
Name of the lathe	=	Engine Lathe-005
Swing over bed in in.	=	24
Swing over cross slide in in.	=	20
Max.distance between centres (in.)	=	130
Max.motor power in HP.	=	9
Max.attainable grades of accuracy	=	5
Max.surface finish capacity (in.)	=	0.00009
Min.allowable depth of cut in inch	=	0.0005
Job material generally process	=	CI,MS,AL
Operations to be done	=	Rough Turning, Finish Turning & Surface Finishing
Fixtures available	=	Chuck, Face plate, Dog clutch, Tail stock & Rest.
Hourly rate in TK.	=	3.0
Setup time in min. for processing]		
a simple rotary job such as job1]	=	5,4,4,5,7
or job2 or job3 or job4 of previ-]		
ous 5 standards]		
Available speeds in rpm.	=	30,40,52,62,75,98,146,219,329,427, 555,777,1088,1414,1839
Available feeds in in./rev.	=	0.001 ,.006,.009,.03,.15,.40

Table:8.19: The specifications of lathe -005

The specifications of lathe-006

Serial number	= 6
Name of the lathe	= Engine Lathe-006
Swing over bed in in.	= 24
Swing over cross slide in in.	= 20
Max.distance between centres (in.)	= 130
Max.motor power in HP.	= 10
Max.attainable grades of accuracy	= 4
Max.surface finish capacity (in.)	= 0.00001
Min.allowable depth of cut in inch	= 0.0001
Job material generally process	= CI,MS,AL
Operations to be done	= Rough Turning, Finish Turning & Surface Finishing
Fixtures available	= Chuck, Face plate, Dog clutch, Tail stock & Rest.
Hourly rate in TK.	= 4.0
Setup time in min. for processing]	
a simple rotary job such as job1]	= 5,4,8,5,7
or job2 or job3 or job4 of previ-]	
ous 5 standards]	
Available speeds in rpm.	= 35,52,79,118,177,266,399,598,897,1300,1884,2637,3828,4428,5794
Available feeds in in./rev.	= 0.002 ,.009,.01 ,.09,.20,.60

Table:B.20: The specifications of lathe -006

CHAPTER - 9

CONCLUSION AND SCOPE OF FUTURE WORK

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CHAPTER - 9

CONCLUSION

9.1 Conclusion

The complete EMS is an expert system capable of identifying all operation for a job, blank, fixtures, machines, tools, cutting conditions, etc. Specifications of blank and production facilities etc. are used as input to the system. Thus the EMS will take over the function of FPC.

But the designed EMS is actually a part of complete EMS and it is able to select blank, fixtures, lathes, and to identify some operations for a simple rotary job. The input output of the system may be shown as in fig. 9.1.

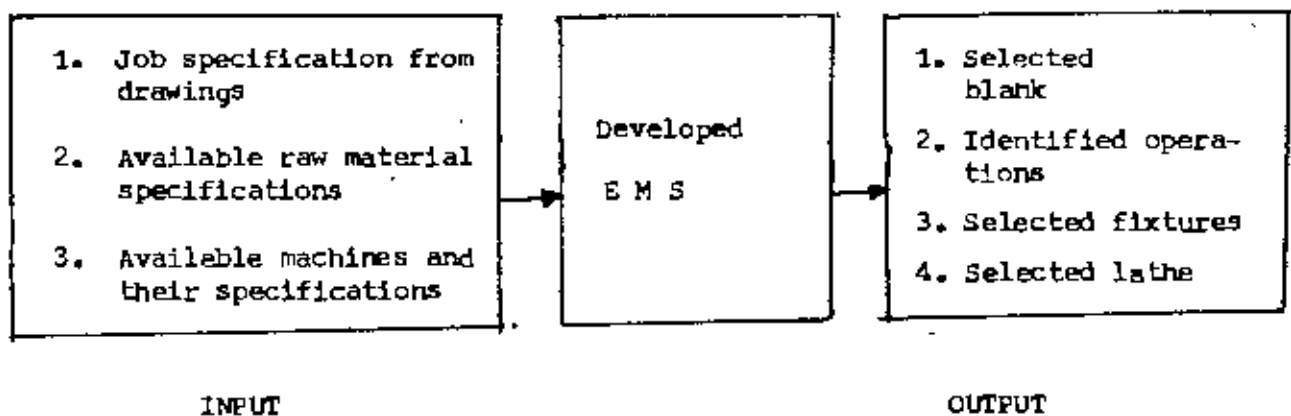


Fig. 9.1 : Expert Manufacturing System

The features of designed EMS are as follows:

- | | | |
|-----------------------------|---|------------------|
| 1. Language | - | BASIC |
| 2. Operating system | - | MS DOS |
| 3. Machine type | - | IBM PC.XT |
| 4. Knowledge representation | - | by Rules |
| 5. Data representation | - | by array |
| 6. Control system | - | Forward chaining |

The criterion for selection of the output variables of EMS are as follows:

1. Selection of blank - The blank is selected from the point of view of minimum machining
2. Identification of operation - It is on the basis of minimum no. of machining
3. Selection of fixture - It is on the basis of slenderness ratio and minimum deflection
4. Selection of lathe - It is on the basis of minimum machining cost.

It has not been possible to develop EMS as a complete expert system, because of some limitations, among them the followings possess top the list.

1. Non availability of Expert System Tool
- & 2. Time

9.2 Scope of Future Work

In the present study only a part of EMS has been developed, on the basis of some simplifications or assumptions, such as -

- 1) Rotary job
- 2) Turning operation
- 3) Lathe
- 4) Independent of manufacturing process of blank

Due to the simplifications the applicability of developed EMS is being limited. Because only lathe selection is not sufficient to assist management unless the following parameters are included.

- 1) Cutting conditions
- 2) Tools and its characteristics

There is much more still left to be done in this regard. Future work may be identified and sequentially described as follows.

- 1) To add the capacity of selecting cutting conditions, tools and its characteristics with present EMS and to feed back for their effects on lathe selection.
- ii) To implement all lathe related operations in to EMS, so that fixture, lathe and its cutting conditions, tools & its characteristics may be selected.
- iii) To inserts all others operations in to EMS so that for each set of operations of rotary job, fixtures, any rotary job processing machine and its cutting conditions, tools and its characteristics may be selected.
- iv) To add the capacity for non rotary job, so that for any operations of any job, fixtures, the machine and its cutting conditions, tools and its characteristics may be selected.
- v) To introduce the capacity of process sequences, so that it may select the sequences of operations to be done along with other capacities.

The development procedure of complete EMS may be shown as in fig. 9.2

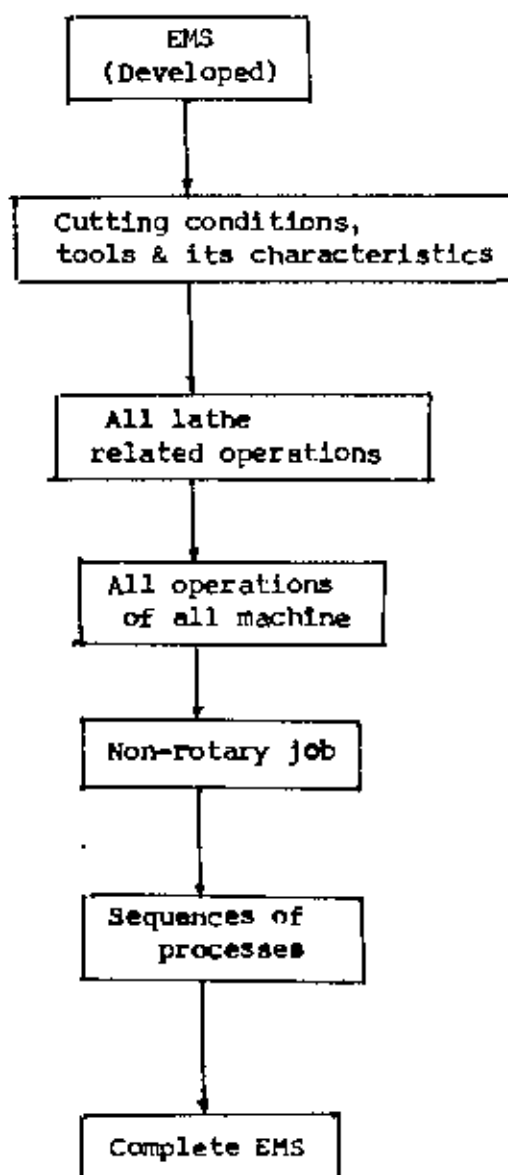


Fig. 9.2 : Development hierarchy of EMS

After developing the complete EMS, it would be used for a practical problem. Then compares the situation in all respect before and after the introduction of EMS.

BIBLIOGRAPHY

1. Harmon, Paul and David King, "Artificial Intelligence in Business - EXPERT SYSTEM", Copy right (c) 1985 by John Wiley & Sons, Inc.
2. Rich, Elaine, "Artificial Intelligence"
Copy right (c) 1983 by McGraw Hill Book Co.
3. Gotfried, Byron S, Schaum's outline series, Programming with BASIC.
Copyright(c) 1985 by McGraw-Hill Book Co.
4. Ullman, Jeffrey D. "Principles of Database System"
Published by Suncel Galgotia for Galgotia for Galgotia publications,
New Delhi, India, 1987
5. August 20-22, 1985. Beijing, China "Preprints of the IFAC/IFORS conference on control science and Technology for Development" Volume II & III
6. "International Journal of PRODUCTION RESEARCH" VOL 20 No 3, May/June 1982"
7. Deo, Narsingh, "GRAPH THEORY with applications to engineering and computer science" Prentice-Hall of India Private Limited New Delhi-110001, 1980
B.Grinberg, S. Kantenik, V. Zhadan, D. Vasilyev
8. Polukhin, P.A. "Metal Process Engineering", Translated from the Russian by N. Weinstein. PEACE PUBLISHER, MOSCOW
9. Keith and Steven Brain, "Artificial Intelligence on the BBC"- make your micro think "Published in India by arrangement with SURSHINE BOOKS, ENGLAND. FIRST INDIAN EDITION 1986
10. Gupta, R.B., "Production Technology" Satya Prakashan, Tech. India Publications, 1982.
11. O'Keefe, Robert M., "Experiences with using Expert Systems in O.R." Society. Vol. 37. No-7, 1986
12. Azim, M.A. "Utilization of machine tools in Bangladesh" Presented in the second Annual Bangladesh Science Conference held at Mymensingh from January 23-26, 1977
13. Bross, Irwin D.J. "Design for decision" The free Press, New York. Collier-Macmillan Limited, London
14. Pollack Herman, W. "Tool Design" Published by arrangement with RESTON PUBLISHING COMPANY, INC.
15. Hawkes, Barey and Raw Abinett "The Engg. design process" Pitman publishers ltd.
16. "Computer applications in production and engineering - CAPE'86":
Edited by K.B , L.ESTENSEN, P.FALSTER, E.A.WARMAN.
17. Wilson, Frank W. "Fundamentals of Tool design", American Society of Tool and Manufacturing Engineers. Prentice Hall of India Private Limited, New Delhi, 1983.

APPENDIX - I
DIALOGUING WITH EMS

The dialogue between EMS and the user is given below, with the user's responses underlined:

FOR JOB2 :

Well Come into EMS:

1. Do you want to go for selection (y/n): Y

2. Nominal dia.of final job in inch. : 4.00

3. Upper limit of tolerances in inch. : 0.0001

4. Lower limit of tolerances in inch. : 0.0001

5. Surface finish of final job in inch. : 0.003

The selected blank is ---

+0.02

Diameter in inch. : 5.0

-0.01

Surface finish in in. : 0.009

(Press any key to continue)

6. Do you want to see the reason of selection (y/n): Y

The blank is selected as it ensures the minimum material removal and the material to be removed for each blank are---

----,----,----, 1.02, 2.54, 3.1

(Press any key to continue)

7. Do you want to see the the operation needed (y/n): Y

The identified operations are----

Rough Turning, Finish Turning & Surface Finishing.

(Press any key to continue)

8. Do you want to see the reason of selection (y/n) : Y

It is selected on the basis of the following rules---

1. If the difference of lower limit of dia. betn. blank & job, $DD1 \geq 0$ & the difference of higher limit of dia. betn. the same $DD2 \leq 0$ & the surface finishing of raw mat. is greater than that of a job ($f1 < f2$) and $2(f1 - f2) \leq DD1$: ----Then the operation is surface finishing.
2. If ($0 < DD1 \leq 0.1$ & $DD2 > 0$) & ($ff \leq f2$ & $ACf \leq AC2$)--Then Opn. is Finish Turning only,

Else Finish Turning plus Surface finishing. 3. If (DD1>.1 & DD2>0)
 And (fr<=f2 & ACr<=AC2) ---Then Opn.is Rough Turning only,Else
 Rough Turning Plus Finish Turning OR Surface finishing.

(Press any key to continue)

9. What is the length of final job in inch. : 12

10. Is the length of raw material known (y/n) : n

11. Index = 12

Is the Index 11 (y/n) : n

Is the Index 12 (y/n) : y

Press enter key unless the two index are equal.

When equal,Type 'Y' and Press enter key.

12. The selected fixing are--clamping in chuck.

(Press any key to continue)

13. Do you want to know the reason of selection (y/n): Y

The selection is on the basis of following rules---

1. If (L1-unknown & $L2/D2 \leq 4$) OR (L1-known & $L1/D2 \leq 4$ & $L3 = (L1 - L2) \geq 2$) --Then clamping in chuck. 2. If ($L2/D2 \leq 4$ & $L3 < 2$) OR ($L2/D2 < 10$) --Then place blank betn centres. 3. If $L2/D2 \geq 10$ --Then place blank betn.centres and use rest.

(Press any key to continue)

14. Is cutting power known (y/n) : N

15. Choose any one of the following :

1) Mild steel (MS)

2) Cast iron (CI)

3) Alluminium (AL)

Choice: 2

16. What is the total no.of lathe available : 6

17. What is the lot size of the job : 15

18. Scheduled load in hour of lathe-001 for the plan period: 11

19. Available working hour of the lathe-001 for the plan period: 111

20. Scheduled load in hours of lathe-002 for the plan period: 0

21. Available working hours of lathe-002 for the plan period: 100

22. Scheduled load in hours of lathe-003 for the plan period: 0

23. Available working hour of lathe-003 for the plan period: 90

24. Scheduled load in hours of lathe-004 for the plan period: 12

25. Available working hour of lathe-004 for the plan period: 90

26. Scheduled load in hours of lathe-005 for the plan period: 15

27. Available working hour of lathe-005 for the plan period: 100

28. Scheduled load in hours of lathe-006 for the plan period: 0

29. Available working hour of lathe -006 for the plan period: 100

30. The cost of all lathes are--
---, ---, ---, ---, ---, 2793.10

The time utilization of all lathes are----

---, ---, ---, ---, ---, 0.5166

Is the cost same for more than one machine (y/n): N

31. The cost of all lathes are---

---, ---, ---, ---, ---, 2793.10

The time utilization of all lathes are--

---, ---, ---, ---, ---, 0.5166

Is the cost for lathe-001 minimum (non-zero) (y/n): n

Is the cost for lathe-002 minimum (non zero) (y/n) : n

Is the cost for lathe-003 minimum (non zero) (y/n) : n

Is the cost for lathe-004 minimum (non zero) (y/n) : n

Is the cost for lathe-005 minimum (non zero) (y/n) : n

Is the cost for lathe-006 minimum (non zero) (y/n) : y

Press enter key unless the machine & the display value are
matched,when match,Type 'Y' & press enter key.

32. The selected lathe is ENGINE LATHE-006

(Press any key to continue)

33. Do you want to see the reason of this selection (y/n): n

34. Do you want to see the technological specifications-
of selected lathe: (y/n) : n

35. Choose any one of the following:

1. Selection for another job
2. Main control structure
3. Exit

Your choice: 3

GOOD BYE !!

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The dialogue between EMS and the user is given below, with the user's responses underlined:

FOR JOB1 :

Well Come into EMS:

1. Do you want to go for selection (y/n): Y

2. Nominal dia.of final job in inch. : 6.49

3. Upper limit of tolerances in inch. : 0.01

4. Lower limit of tolerances in inch. : 0.09

5. Surface finish of final job in inch. : 0.001

The selected blank is ---

+0.04

Diameter in inch. : 6.5

-0.03

Surface finish in in. : 0.007

(Press any key to continue)

6. Do you want to see the reason of selection (y/n): Y

The blank is selected as it ensures the minimum material removal and the material to be removed for each blank are---

----, ----, ----, ----, 0.0039, 0.53

(Press any key to continue)

7. Do you want to see the the operation needed (y/n): Y

The identified operations are----

Finish Turning

(Press any key to continue)

8. Do you want to see the reason of selection (y/n) : Y

It is selected on the basis of the following rules---

1. If the difference of lower limit of dia.betn.blank & job, $DD1 \geq 0$ & the difference of higher limit of dia.betn.the same $DD2 \leq 0$ & the surface finishing of blank is greater than that of job ($f1 < f2$) & $2(f1 - f2) \leq DD1$ ---- Then the operation is Surface Finishing.
2. If ($0 < DD1 \leq 0.1$ & $DD2 > 0$) & ($ff \leq f2$ & $ACf \leq AC2$) ---- Then opn is Finish Turning only, Else Finish Turning plus Surface Finishing.

3. If (DD1>.1 & DD2>0) and

(fr<=f2 & ACr<=AC2) ---Then Opn.is Rough Turning only,Else
Rough Turning Plus Finish Turning OR Surface finishing.

(Press any key to continue)

9. What is the length of final job in inch. : 15

10. Is the length of blank known (y/n) : y

11. What is the length of blank : 17

12. Index= 12

Is the Index 11 (y/n) : n

Is the Index 12 (y/n) : y

Press enter key unless the two index are equal.

When equal,Type 'Y' and Press enter key.

13. The selected fixing are--clamping in chuck.

(Press any key to continue)

14. Do you want to know the reason of selection (y/n): Y

The selection is on the basis of following rules---

1. If (L1-unknown & $L2/D2 \leq 4$) OR (L1-known & $L1/D2 \leq 4$ &
 $L3 = (L1 - L2) \geq 2$) --Then clamping in chuck. 2. If ($L2/D2 \leq 4$ & $L3 < 2$)
 OR ($L2/D2 < 10$) --Then place blank betn centres. 3. If $L2/D2 \geq 10$
 --Then place blank betn.centres and use rest.

(Press any key to continue)

15. Is cutting power known (y/n) : N

16. Choose any one of the following :

1) Mild steel (MS)

2) Cast iron (CI)

3) Aluminium (AL)

Choice: 1

17. What is the total no.of lathe available : 6

18. What is the lot size of the job : 10

19. Scheduled load in hour of lathe-001 for the plan period: 11

20. Available working hour of the lathe-001 for the plan period: 111

21. Scheduled load in hours of lathe-002 for the plan period: 0

22. Available working hours of lathe-002 for the plan period: 100

23. Scheduled load in hours of lathe-003 for the plan period: 0

24. Available working hour of lathe-003 for the plan period: 90

25. Scheduled load in hours of lathe-004 for the plan period: 12

26. Available working hour of lathe-004 for the plan period: 90

27. Scheduled load in hours of lathe-005 for the plan period: 15

28. Available working hour of lathe-005 for the plan period: 100

29. Scheduled load in hours of lathe-006 for the plan period: 0

30. Available working hour of lathe -006 for the plan period: 90

31. The machining cost by all lathes are--
-- , 14.34, 14.14, 14.80, 18.31, 30.26

The time utilization of all lothes are----

--, .0340, .0370, .1712, .1840, .0380

Is the cost same for more than one machine (y/n): y

32. The cost of all lathes are---

--, 14.34, 14.14, 14.80, 18.31, 30.26

The time utilization of all lathes are--

--, .0340, .0370, .1712, .1840, .0380

Is the time utilization for lathe-001 minimum (non-zero)
among those of similar cost (y/n): n

Is the time utilization for lathe-002 minimum (non-zero)
among those of similar cost (y/n): y

Press enter key unless the machine & the display value are
matched,when match,Type 'Y' & press enter key.

33. The selected lathe is BENCH LATHE-002

(Press any key to continue)

34. Do you want to see the reason of this selection (y/n): y

The machine is selected as it ensures the minimum machining cost and/or minimum time utilization.

The cost of all machine are--

--,14.34, 14.14, 14.80, 18.31, 30.26

The time utilization of all machine are--

--, .0340, .0370, .1712, .1840, .0380

(Press any key to continue)

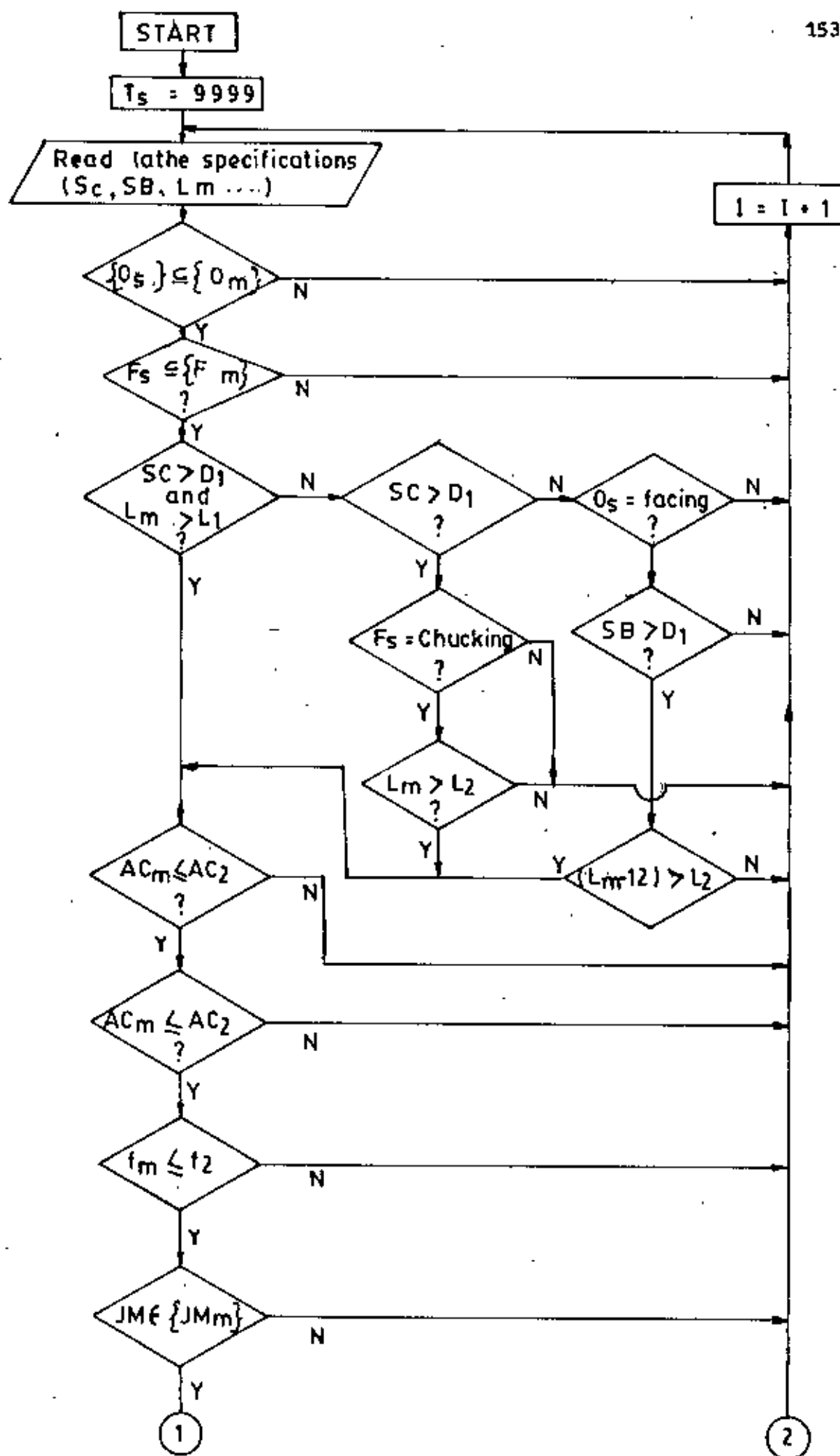
35. Do you want to see the technological specifications of lathe (y/n): n

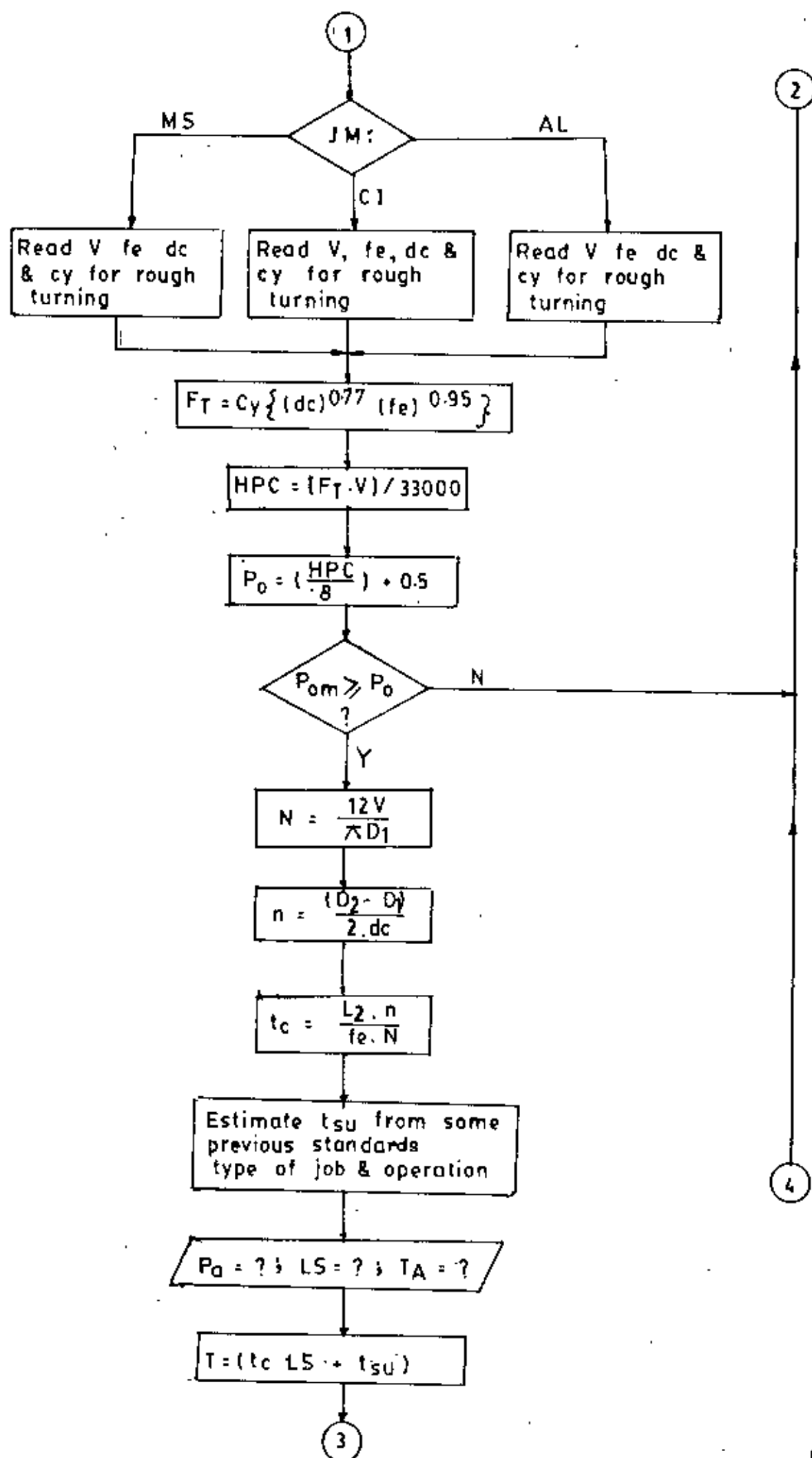
36. Choose any one of the following:

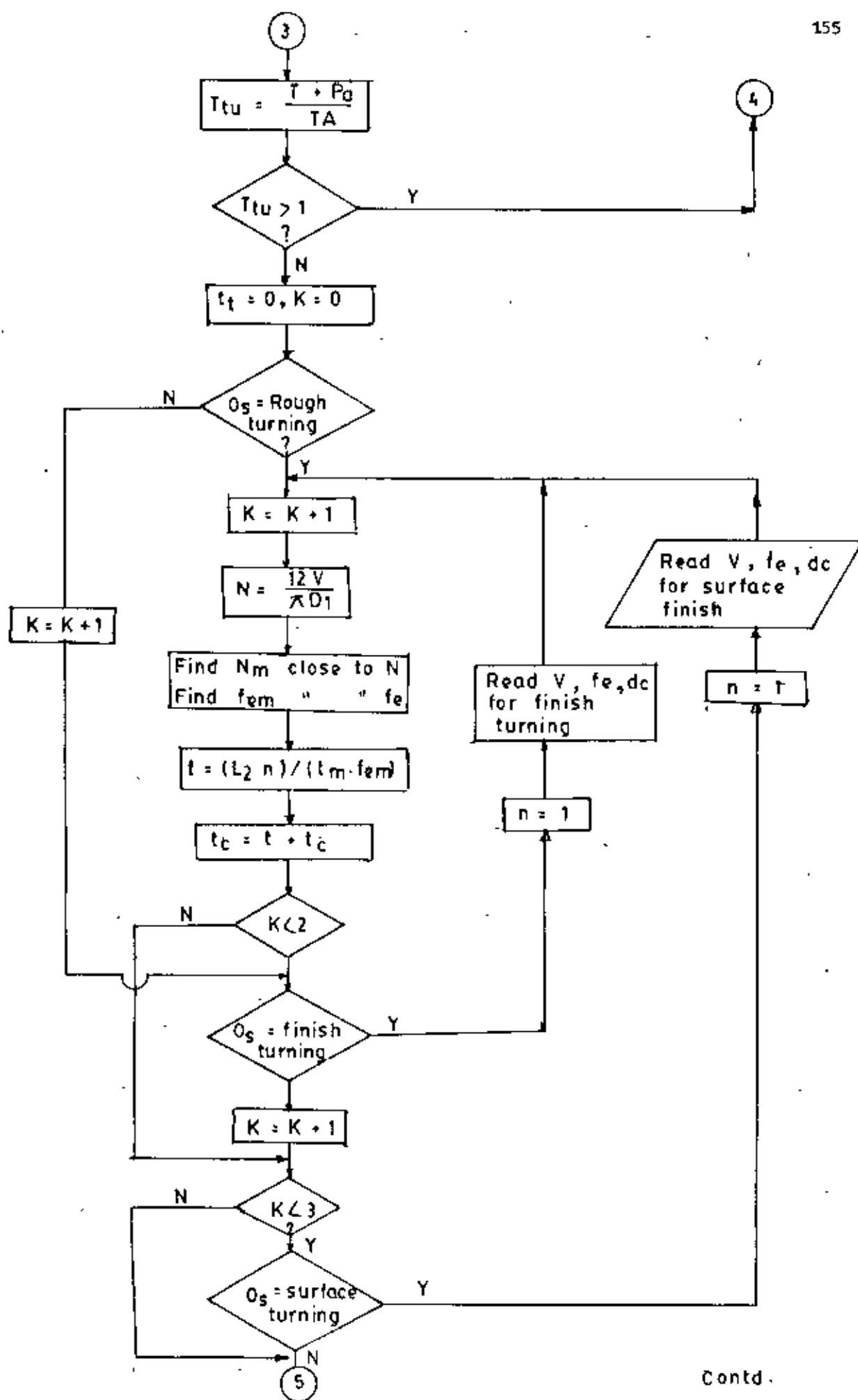
1. Selection for another job
2. Main control structure
3. Exit

Your Choice: 3

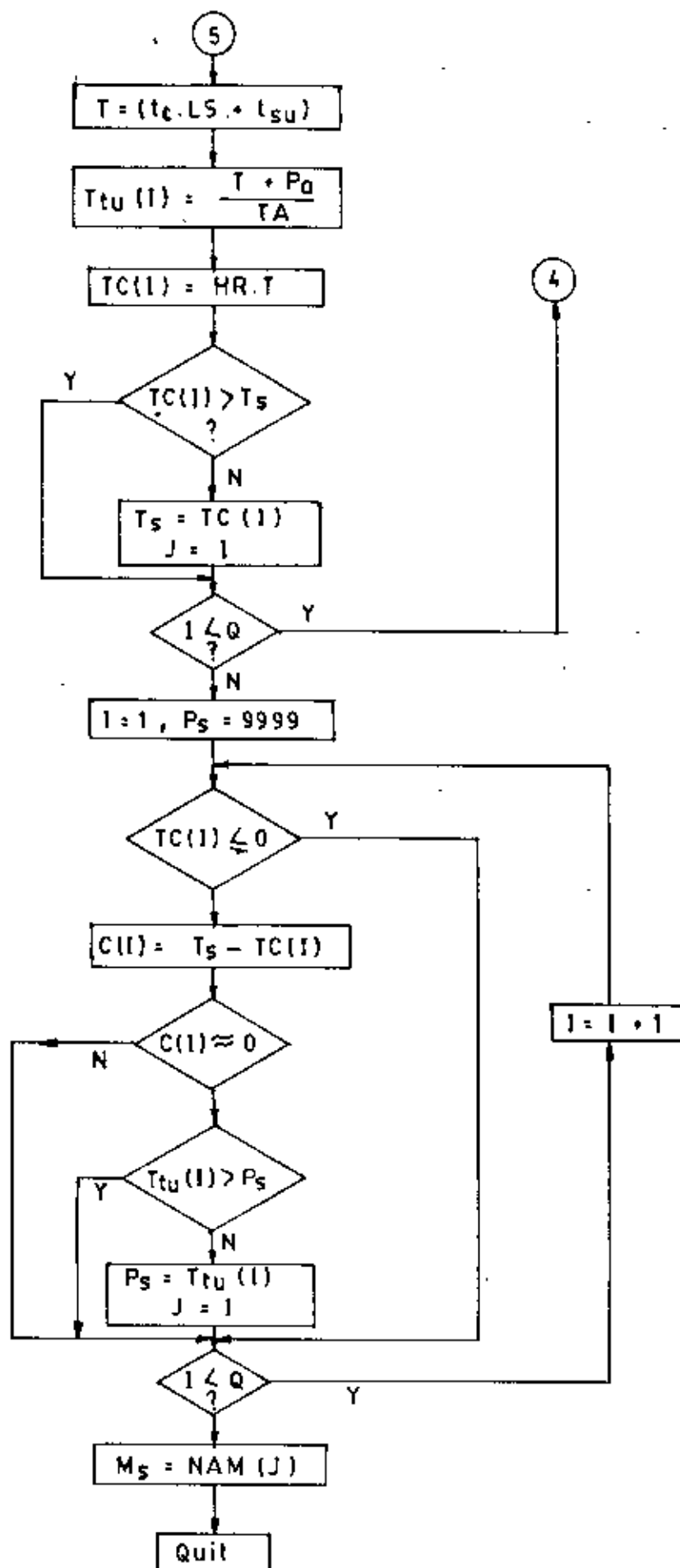
GOOD BYE !!







Contd.



Strategy for lathe selection.

```

10 CLS:COLOR 16,7,0:CLS:LOCATE 11,28:BEEP
20 PRINT "W E L C O M E "
30 LOCATE 14,16
40 PRINT "To the 'EXPERT MANUFACTURING SYSTEM' for suitable "
   SPC(0)"Lathe selection"
50 FOR I=1 TO 2000:NEXT I
60 COLOR 5,3
70 CLS:BEEP
80 LOCATE 8,10:INPUT "DO YOU WANT TO GO FOR SELECTION (Y/N)";A$
90 IF A$="Y" OR A$="y" THEN BEEP:CLS:GOTO 350
100 BEEP:CLS
110 LOCATE 8,10:INPUT "DISPLAY THE STRUCTURE OF SELECTION (Y/N)";A$
120 IF A$="Y" OR A$="y" THEN BEEP:CLS:GOTO 250
130 BEEP:CLS
140 LOCATE 8,10:INPUT "DO YOU WANT TO INPUT OR EDIT DATA (Y/N)";A$
150 IF A$="Y" OR A$="y" THEN BEEP:CLS:GOTO 4870
160 BEEP:CLS
170 LOCATE 8,10:INPUT "DO YOU WANT TO EXIT THE SYSTEM (Y/N)";A$
180 IF A$="Y" OR A$="y" THEN BEEP:CLS:GOTO 5010
190 BEEP:CLS
200 LOCATE 8,10:INPUT "DO YOU WANT SOME HELP (Y/N)";A$
210 IF A$="Y" OR A$="y" THEN CLS:BEEP:GOTO 5040
220 BEEP:CLS:COLOR 16,5,0
230 LOCATE 10,15:PRINT "YOU ARE ABSENT MINDED; PLEASE TRY AGAIN !"
240 FOR I=1 TO 2000 :NEXT:CLS:COLOR 5,2,0:GOTO 70
250 CLS:COLOR 7,0:BEEP
260 LOCATE 9,27,0:PRINT "1) SELECTION OF BLANK"
270 LOCATE 10,27,0:PRINT "2) SELECTION OF OPERATIONS"
280 LOCATE 11,27,0:PRINT "3) SELECTION OF FIXTURE TYPE"
290 LOCATE 12,27,0:PRINT "4) SELECTION OF PARTICULAR MACHINE"
300 LOCATE 13,27,0:PRINT "5) SELECTION OF CUTTING CONDITION"
310 LOCATE 14,27,0:PRINT "6) SELECTION OF TOOL CHARACTERISTICS"
320 LOCATE 15,27,0:PRINT "7) SELECTION OF MISCELLANEOUS"
330 GOSUB 4660
340 GOTO 70
350 REM SELECTION
360 LOCATE 10,30:PRINT "WELCOME IN TO SELECTION"
370 FOR I=1 TO 600:NEXT :CLS:BEEP
380 COLOR 0,7,3:CLS
390 LOCATE 10,30:PRINT 1,"ROTARY JOB"
400 LOCATE 11,30:PRINT 2,"NON ROTARY JOB"
410 LOCATE 12,30:PRINT 3,"EXIT"
420 COLOR 5,3:LOCATE 24,30:PRINT "CHOOSE ANY ONE"
430 LOCATE 14,30:INPUT "YOUR CHOICE:";CHOICE
440 IF (CHOICE<1) OR (CHOICE>3) THEN CLS:LOCATE 10,10:PRINT "BAD "
   SPC(0)"CHOICE NUMBER":FOR I=1 TO 1000 :NEXT:GOTO 380
450 IF CHOICE=1 THEN CLS:GOTO 500
460 IF CHOICE=2 THEN CLS:BEEP:COLOR 0,7:LOCATE 15,30:PRINT "PLEASE "
   SPC(1)"CONSULT WITH AN EXPERT"
470 IF CHOICE =3 THEN 5010
480 GOSUB 4820

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490 GOTO 380
500 LOCATE 8,5:PRINT "NOMINAL DIA.OF FINAL JOB";
510 INPUT D2
520 IF D2<=0 THEN CLS:BEEP:GOTO 650
530 LOCATE 9,5:PRINT "UPPER LIMIT OF TOLERANCE OF DIA.";
540 INPUT J2
550 LOCATE 10,5:PRINT "LOWER LIMIT OF TOLERANCE OF DIA.";
560 INPUT A2
570 LOCATE 11,5:PRINT "SURFACE FINISH OF FINAL JOB";
580 INPUT F2
590 BEEP:CLS
600 LET S1=D2-A2
610 LET S6=D2+J2
620 JA2=J2+A2
630 IF F2=0 OR JA2=0 THEN 650
640 GOTO 670
650 LOCATE 10,10:PRINT "IT IS PRACTICALLY IMPOSSIBLE TO PRODUCE."
660 FOR J=1 TO 1000:NEXT J:CLS:GOTO 500
670 IF D2> 0 AND D2<1.19 THEN 700
680 IF D2>=1.19 AND D2<7.09 THEN 820
690 IF D2>=7.09 THEN 940
700 IF JA2> 0 AND JA2<.00025 THEN AC2=4
710 IF JA2>=.00025 AND JA2<.0004 THEN AC2=5
720 IF JA2>=.0004 AND JA2<.0005 THEN AC2=6
730 IF JA2>=.0005 AND JA2<.0008 THEN AC2=7
740 IF JA2>=.0008 AND JA2<.0012 THEN AC2=8
750 IF JA2>=.0012 AND JA2<.002 THEN AC2=9
760 IF JA2>=.002 AND JA2<.0035 THEN AC2=10
770 IF JA2>=.0035 AND JA2<.005 THEN AC2=11
780 IF JA2>=.005 AND JA2<8.000001E-03 THEN AC2=12
790 IF JA2>=8.000001E-03 AND JA2<.012 THEN AC2=13
800 IF JA2>=.012 THEN AC2=14
810 GOTO 1050
820 IF JA2>0 AND JA2<.0005 THEN AC2=4
830 IF JA2>=.0005 AND JA2<.0007 THEN AC2=5
840 IF JA2>=.0007 AND JA2<.001 THEN AC2=6
850 IF JA2>=.001 AND JA2<.0016 THEN AC2=7
860 IF JA2>=.0016 AND JA2<.0025 THEN AC2=8
870 IF JA2>=.0025 AND JA2<.004 THEN AC2=9
880 IF JA2>=.004 AND JA2<.006 THEN AC2=10
890 IF JA2>=.006 AND JA2<.01 THEN AC2=11
900 IF JA2>=.01 AND JA2<.016 THEN AC2=12
910 IF JA2>=.016 AND JA2<.025 THEN AC2=13
920 IF JA2>=.025 THEN AC2=14
930 GOTO 1050
940 IF JA2>0 AND JA2<.0008 THEN AC2=4
950 IF JA2>=.0008 AND JA2<.001 THEN AC2=5
960 IF JA2>=.001 AND JA2<.0016 THEN AC2=6
970 IF JA2>=.0016 AND JA2<.0025 THEN AC2=7
980 IF JA2>=.0025 AND JA2<.004 THEN AC2=8
990 IF JA2>=.004 AND JA2<.006 THEN AC2=9
1000 IF JA2>=.006 AND JA2<.01 THEN AC2=10

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1010 IF JA2>=.01 AND JA2<.016 THEN AC2=11
1020 IF JA2>=.016 AND JA2<.025 THEN AC2=12
1030 IF JA2>=.025 AND JA2<.04 THEN AC2=13
1040 IF JA2>=.04 THEN AC2=14
1050 CLS:LOCATE 10,20:PRINT "THE GRADES OF ACCURACY OF JOB =";AC2
1060 FOR J=1 TO 1500:NEXT J:CLS:BEEP
1070 LET TS=999:LET S2=999
1080 LET S3=999:LET S4=999:LET S5=999
1090 LET DCC=.04
1100 LET K=0
1110 LET K=K+1
1120 READ D1,A1,J1,F1
1130 LET DDD=(D1-A1)-S1
1140 IF DDD >=0 THEN 1170
1150 IF K=6 AND CK=0 THEN CLS:LOCATE 10,10:PRINT "THE REQUIRED BLANK"
  SPC(0)" IS OUT OF STOCK:":FOR I=1 TO 2000:NEXT I:CLS:GOTO 1370
1160 GOTO 1110
1170 LET DJ(K)=(D1+J1)-S6
1180 IF DJ(K)<=0 THEN 1300
1190 IF DJ(K)>TS THEN 1210
1200 LET TS=DJ(K):LET S2=A1:LET S3=J1:LET S4=F1:LET S5=D1:LET CK=CK+1
1210 IF K<6 THEN 1110
1220 LET DD1=TS
1230 LET I1=1001
1240 IF DD1<=.1 THEN 1270
1250 LET I2=1002:LET FR=.0003:LET ACR=10
1260 IF FR<=F2 AND ACR<=AC2 THEN 1440
1270 LET I3=1003:LET FF=.000016:LET ACF=8
1280 IF FF<=F2 AND ACF<=AC2 THEN 1440
1290 LET I4=1004:GOTO 1440
1300 IF F1<=F2 THEN SSS=1:GOTO 1350
1310 LET FFF=(2*(F1-F2))
1320 IF FFF<=DDD THEN 1340
1330 GOTO 1210
1340 LET I4=1004
1350 LET I1=1006
1360 GOTO 1440
1370 LOCATE 10,10:PRINT "YOU SHOULD HAVE THE BLANK OF"
  SPC(0)"NOMINAL DIA. NOT BELOW THE FOLLOWING -----"
1380 LET D1=(D2+J2)+.1
1390 LOCATE 12,30:PRINT "D1=";D1
1400 GOSUB 4820
1410 LET I3=1003:LET FF=.000016:LET ACF=8
1420 IF FF>F2 OR ACF>AC2 THEN I4=1004
1430 GOTO 1630
1440 IF I1=1001 THEN 1470
1450 IF I1=1006 THEN 1460
1460 LET S5=D1:LET S2=A1:LET S3=J1:LET S4=F1
1470 COLOR 0,7,3:CLS:LOCATE 6,20:PRINT "THE SELECTED BLANK ARE--"
1480 LOCATE 8,20:PRINT "NOMINAL DIA.(D1)=";S5
1490 LOCATE 9,20:PRINT "UPPER TOLERANCE LIMIT(J1)=";S3

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1500 LOCATE 10,20:PRINT "LOWER TOLERANCE LIMIT(A1)=";S2
1510 LOCATE 11,20:PRINT "SURFACE FINISH (F1)=";S4
1520 GOSUB 4660
1530 CLS:LOCATE 10,20:PRINT "DO YOU WANT TO KNOW THE REASON OF "
      SPC(0)"THIS SELECTION:";
1540 INPUT B$
1550 IF B$="Y" OR B$="y" THEN 1570
1560 GOTO 1620
1570 CLS:LOCATE 9,17:PRINT "THIS BLANK IS SELECTED AS IT ENSURES "
1580 LOCATE 10,17:PRINT "THE MINIMUM MATERIAL REMOVAL AND THE MATERIAL"
1590 LOCATE 11,17:PRINT " TO BE REMOVED FOR EACH AVAILABLE BLANK ARE--"
1600 LOCATE 13,15:PRINT DJ(1);DJ(2);DJ(3);DJ(4);DJ(5);DJ(6)
1610 GOSUB 4660
1620 IF SSS=1 THEN CLS:LOCATE 10,25:PRINT "NO OPERATIONS ARE NEEDED !!";
      GOSUB 4660 :GOTO 5010
1630 CLS:LOCATE 10,10:PRINT "DO YOU WANT TO SEE THE OPERATION";
1640 INPUT A$
1650 IF A$="Y" OR A$="y" THEN 1670
1660 CLS:BEEP:GOTO 1750
1670 COLOR 0,7,3:CLS:LOCATE 4,25:PRINT "THR IDENTIFIED OPERATIONS ARE---"
1680 IF I3=1003 THEN LOCATE 8,30:PRINT "FINISH TURNING"
1690 IF I2=1002 THEN LOCATE 7,30:PRINT "ROUGH TURNING"
1700 IF I4=1004 THEN LOCATE 9,30:PRINT "SURFACE FINISHING"
1710 GOSUB 4660
1720 LOCATE 10,20:PRINT "DO YOU WANT TO KNOW THE REASON OF "
      SPC(0)"THIS SELECTION:";
1730 INPUT B$
1740 IF B$="Y" OR B$="y" THEN CLS:GOSUB 5140:GOSUB 4820
1750 LET VV1=D1
1760 LET VV2=F1
1770 RESTORE
1780 CLS:COLOR 0,7,3:LOCATE 10,20:PRINT "PLEASE WAIT ..... "
1790 FOR I=1 TO 6
1800 READ D1,A1,J1,F1
1810 NEXT I
1820 COLOR 5,3
1830 CLS:COLOR 16,5,0:LOCATE 10,20:PRINT "FIXTURE SELECTION !!";
      FOR I=1 TO 2000: NEXT:COLOR 5,3:BEEP:CLS
1840 LOCATE 10,10:PRINT "LENGTH CF FINAL JOB";
1850 INPUT L2
1860 CLS:BEEP
1870 IF L2<=0 THEN CLS:LOCATE 10,20:PRINT "SORRY ! PRACTICALLY IT IS "
      SPC(0)"IMPOSSIBLE: ":GOSUB 4820:GOTO 1840
1880 LOCATE 10,10:PRINT "IS THE LENGTH OF BLANK (L1) KNOWN";
1890 INPUT A$
1900 IF A$="Y" OR A$="y" THEN CLS:GOTO 1970
1910 CLS:BEEP
1920 LET LD=L2/D2
1930 IF LD<=4 THEN X=12 :GOTO 2110
1940 LET L1=L2+.25

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1950 LET LD=L1/D2
1960 GOTO 2060
1970 LOCATE 10,10:PRINT "THE LENGTH OF BLANK (L1)";
1980 INPUT L1
1990 IF L1>=L2 THEN 2030
2000 CLS:LOCATE 10,10:PRINT "THE LENGTH OF BLANK SHOULD BE"
2010 LOCATE 11,10:PRINT "GREATER THAN THAT OF FINISHED JOB."
2020 FOR J=1 TO 2000:NEXT J:CLS:GOTO 1970
2030 LET L3=L1-L2
2040 LET LD=L1/D2
2050 IF LD>=0 AND LD<=4 THEN K1=1
2060 IF LD>4 AND LD<10 THEN K1=2
2070 IF LD>=10 THEN K1=3
2080 IF L3<2 THEN K2=1
2090 IF L3>=2 THEN K2=2
2100 LET X=(10*K1)+K2
2110 LET NP=10
2120 HIM OP$(22),Y(22),N(22)
2130 FOR N=1 TO NP
2140 READ OP$(N),Y(N),N(N)
2150 NEXT N
2160 COLOR 0,7,3:CLS
2170 LET CP=1
2180 LET DG=0
2190 IF DG>0 THEN 2230
2200 LOCATE 2,63:PRINT "INDEX=";X
2210 LOCATE 21,16:PRINT "PRESS ENTER KEY UNLESS THE TWO INDEX ARE EQUAL."
2220 LOCATE 22,16:PRINT "WHEN EQUAL,TYPE 'Y' AND PRESS ENTER KEY "
2230 LOCATE 10,10:PRINT OP$(CP);
2240 IF Y(CP)=0 THEN 2290
2250 INPUT IN$
2260 IF IN$="Y" OR IN$="y" THEN CP=Y(CP):LET DG=DG+1:CLS:GOTO 2190
2270 LET CP=N(CP)
2280 CLS:GOTO 2190
2290 GOSUB 4820:CLS:BEEP
2300 LOCATE 10,20:PRINT "DO YOU WANT TO KNOW THE REASON OF "
      SPC(0)"THIS SELECTION:";
2310 INPUT B$
2320 IF B$="Y" OR B$="y" THEN CLS:GOSUB 5250 :BEEP:GOSUB 4820
2330 CLS:BEEP:LET MAR=0
2340 LOCATE 10,10:PRINT "IS THE CUTTING POWER KNOWN";
2350 INPUT A$
2360 IF A$="Y" OR A$="y" THEN CLS:LET MAR=MAR+1:GOTO 2380
2370 CLS:BEEP
2380 FOR B=4 TO 10
2390 LOCATE B,32,0:PRINT CHR$(186)
2400 NEXT
2410 LOCATE 7,34:PRINT 1,"MILD STEEL"
2420 LOCATE 8,34:PRINT 2,"CAST IRON"
2430 LOCATE 9,34:PRINT 3,"ALUMINIUM"

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2440 LOCATE 8,10: PRINT "JOB MATERIAL";
2450 INPUT JM
2460 CLS:BEEP
2470 IF JM=1 THEN JM$="MS":LET VE=160:LET DC=.07:LET FE=.05:
    LET CY=70050!:GOTO 2510
2480 IF JM=2 THEN JM$="CI":LET VE=130:LET DC=.04:LET FE=.02:
    LET CY=72020!:GOTO 2510
2490 IF JM=3 THEN JM$="AL":LET VE=155:LET DC=.06:LET FE=.05:
    LET CY=70100!:GOTO 2510
2500 BEEP:CLS:LOCATE 10,10:PRINT "BAD CHOICE NUMBER !!":FOR I=1 TO 1000:
    NEXT:CLS:GOTO 2410
2510 IF MAR>0 THEN 2580
2520 LET FT=CY*((DC)^(.77))*((FE)^(.95))
2530 LET HPC=(FT*VE)/33000!
2540 LET HPM=(HPC/.8)+.5
2550 CLS:LOCATE 10,20:PRINT "CUTTING HP.=";HPM
2560 FOR J=1 TO 1500:NEXT J:CLS:BEEP
2570 GOTO 2600
2580 LOCATE 10,10:PRINT "WHAT IS THE VALUE OF CUTTING HP.";
2590 INPUT HPM
2600 CLS:BEEP
2610 LOCATE 10,20:PRINT "PARTICULAR LATHE MACHINE SELECTION !"
2620 FOR I=1 TO 1000:NEXT:CLS:BEEP
2630 LET CC=6
2640 LOCATE 10,20:PRINT "WHAT IS THE TOTAL NO.OF LATHE :";
2650 INPUT NN
2660 IF NN<0 THEN CLS:LOCATE 10,20:PRINT "SORRY ! PRACTICALLY IT IS "
    SPC(0)"IMPOSSIBLE: ":GOSUB 4820:GOTO 2640
2670 IF NN=0 THEN CLS:LOCATE 10,20:PRINT "SORRY ! I HAVE NOTRING TO "
    SPC(0)"SELECT ": GOSUB 4820:GOTO 2640
2680 IF NN>CC THEN CLS:LOCATE 10,20:PRINT "SORRY ! TOTAL NO.OF MACHINE"
    SPC(0)" YOU HAVE ARE: ";CC:GOSUB 4820:GOTO 2640
2690 CLS:LOCATE 10,20:PRINT "LOT SIZR OF THE JOB:";
2700 INPUT LS
2710 IF LS<=0 THEN CLS:BEEP:LOCATE 10,20:PRINT "PRACTICALLY IT IS "
    SPC(0)"IMPOSSIBLE !" :FOR I=1 TO 1000:NEXT:GOTO 2690
2720 LET D1=VV1
2730 LET F1=VV2
2740 CLS:COLOR 0,7,3:LOCATE 10,20:PRINT "PLEASE WAIT....."
2750 LET NP=20
2760 FOR N=1 TO NP
2770 READ OP$(N),Y(N),N(N)
2780 NEXT N
2790 LET TS=9.99E+36
2800 IF X=11 OR X=21 OR X=22 THEN I5=1007
2810 IF X=31 OR X=32 THEN I6=1008
2820 DIM SN(CC),NAM$(CC),S(CC,100),PP(40)
2830 LET I=0:LET PIN=0
2840 LET I=I+1
2850 READ SN(I),NAM$(I)

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2860 FOR Q=1 TO 3
2870 READ BB$(1,Q)
2880 NEXT Q
2890 FOR W=1 TO 3
2900 READ JM$(I,W)
2910 NEXT W
2920 FOR Y=1 TO 4
2930 READ FM$(I,Y)
2940 NEXT Y
2950 FOR J=1 TO 8
2960 READ S(I,J)
2970 NEXT J
2980 FOR V=9 TO 34
2990 READ PP(V)
3000 NEXT V
3010 IF I2=1002 THEN OS$(1)="ROUGH TURNING"
3020 IF I3=1003 THEN OS$(2)="FINISH TURNING"
3030 IF I4=1004 THEN OS$(3)="SURFACE FINISHING"
3040 IF I2=1002 AND OS$(1)<>BB$(1,1) THEN 3960
3050 IF I3=1003 AND OS$(2)<>BB$(1,2) THEN 3960
3060 IF I4=1004 AND OS$(3)<>BB$(1,3) THEN 3960
3070 LET LS(I) =LS
3080 IF JM$=JM$(1,1) OR JM$=JM$(1,2) OR JM$=JM$(1,3) THEN 3090 ELSE 3960
3090 IF X=12 THEN FS$="CHUCKING":GOTO 3170
3100 IF I5=1007 THEN FS$(1) ="FACK PLATR":LET FS$(2)="DOG CLUTCH":
    LET FS$(3)="TAIL STOCK":GOTO 3120
3110 IF I6=1008 THEN FS$="RST":GOTO 3160
3120 IF FS$(1)=FM$(I,1) OR FS$(1)=FM$(I,2) OR FS$(1)=FM$(I,3) OR
    FS$(1)=FM$(I,4) THEN 3130 ELSE 3960
3130 IF FS$(2)=FM$(I,1) OR FS$(2)=FM$(I,2) OR FS$(2)=FM$(I,3) OR
    FS$(2)=FM$(I,4) THEN 3140 ELSE 3960
3140 IF FS$(3)=FM$(I,1) OR FS$(3)=FM$(I,2) OR FS$(3)=FM$(I,3) OR
    FS$(3)=FM$(I,4) THEN 3170
3150 GOTO 3960
3160 IF FS$=FM$(I,4) THEN 3170 ELSE 3960
3170 IF S(I,2)>D1 AND S(I,3)>L1 THEN 3210
3180 IF S(I,1)>D1 AND FS$="CHUCKING" AND S(I,3)>L2 THEN 3210
3190 IF S(I,1)>D1 AND OS$="FACING" AND (S(I,3)-12)>L2 THEN 3210
3200 GOTO 3960
3210 IF S(I,7) <=AC2 AND S(I,5)<=F2 AND S(I,6)<=DCC AND S(I,4)>=HPM
    THEN 3230
3220 GOTO 3960
3230 IF JM$="MS" THEN V=145:LET FE=.02 :LET DC=9.0000001E-02 :GOTO 3260
3240 IF JM$="CI" THEN V=90:LET FE=.02 :LET DC=9.0000001E-02 :GOTO 3260
3250 IF JM$="AL" THEN V=656:LET FE=.02 :LET DC=9.0000001E-02
3260 LET NR=INT((12*V)/(3.141*D1)):LET NOC=INT((D1-D2)/(2*DC))
3270 LET TR=(L2*NOC)/(FE*NR)
3280 COLOR 5,3
3290 CLS:LOCATE 10,10:PRINT "PREVIOUS ASSIGNMENT HOURS OF MACHINE NO.";I
3300 LOCATE 11,10:PRINT "FOR THE PLAN PERIOD";
3310 INPUT PA

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3320 CLS:BEEP
3330 LOCATE 10,10:PRINT "AVAILABLE WORKING HOUR OF THE MACHINE NO. ";I
3340 LOCATE 11,10:PRINT "FOR THE PLAN PERIOD";
3350 INPUT TA
3360 IF TA<= 0 THEN LOCATE 10,20:PRINT "SORRY, PRACTICALLY IT IS "
      SPC(0)"IMPOSSIBLE !" :FOR C=1 TO 1000:NEXT:GOTO 3320
3370 CLS:COLOR 0,7,3:LOCATE 10,20:PRINT "PLEASE WAIT ....."
3380 LET TSU=(PP(30)+PP(31)+PP(32)+PP(33)+PP(34))/5
3390 LET T=((((TR)*LS(I))+TSU)/(.95*60))
3400 LET TTU(I)=((T+PA)/TA)
3410 IF TTU(I)>1 THEN 3540
3420 LET K=0:LET TT=0
3430 IF I2=1002 THEN 3450
3440 LET K=K+1:GOTO 3770
3450 LET NC=INT((I2*V)/(3.141*D1))
3460 LET TEMP=9999999!
3470 FOR M=9 TO 23
3480 LET ND=ABS(PP(M)-NC)
3490 IF ND=0 THEN NM=PP(M):GOTO 3660
3500 IF ND>TEMP THEN 3520
3510 LET TEMP=ND:LET NM=PP(M)
3520 NEXT M
3530 GOTO 3660
3540 LOCATE 10,10:PRINT "THE AVAILABLE TIME FOR LATHE-";I;SPC(0)
      "IS NOT SUFFICIENT."
3550 LET TIG=(T+PA)-TA
3560 LOCATE 11,10:PRINT "IS IT POSSIBLE TO SANCTION AT LEAST";TIG;
      "HOURS"
3570 LOCATE 12,10:PRINT "FOR LATHE-";I;"FOR THE ORDER OR BY "
      SPC(0)"DUPLICATE LATHE" ;
3580 INPUT A$
3590 IF A$="Y" OR A$="y" THEN LET TA=(TA+TIG)+1:GOTO 3400
3600 LET LSS=INT(((60*(TA-PA))/(TR))- .5)
3610 CLS:LOCATE 10,10:PRINT "THE LATHE-";I;"IS CAPABLE OF PROCRSSING"
3620 LOCATE 11,10:PRINT "AT MOST";LSS;"JOB,SO FOR REST CHOOSE ANOTHER."
3630 LET LS(I)=LSS
3640 GOSUB 4820
3650 GOTO 3390
3660 LET TEMP=999
3670 FOR R= 24 TO 29
3680 FD=ABS(FE-PP(R))
3690 IF FD=0 THEN FM=PP(R):GOTO 3730
3700 IF FD>TEMP THEN 3720
3710 LET TEMP=FD:LET FM=PP(R)
3720 NEXT R
3730 LET TOL=((((L2+1/8)*(NOC)))/(FM*NM))
3740 LET TT=TOL+TT
3750 LET K=K+1
3760 IF K>=2 THEN 3830
3770 IF I3=1003 THEN 3790
3780 LET K=K+1:GOTO 3830

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3790 IF JM$="MS" THEN V=175:LET FE=8.999999E-03:LET DC=.05:GOTO 3820
3800 IF JM$="CI" THEN V=110:LET FE=8.999999E-03:LET DC=.05:GOTO 3820
3810 IF JM$="AL" THEN V=1085:LET FE=8.999999E-03:LET DC=.05
3820 GOTO 3450
3830 IF K>=3 THEN 3900
3840 IF I4=1004 THEN 3860
3850 GOTO 3900
3860 IF JM$="MS" THEN V=175:LET FE=.005:LET DC=.02:GOTO 3890
3870 IF JM$="CI" THEN V=110:LET FE=.005:LET DC=.02:GOTO 3890
3880 IF JM$="AL" THEN V=1083:LET FE=.005:LET DC=.02
3890 GOTO 3450
3900 IF TT>4.5E+33 THEN TC(1)=0:GOTO 3960
3910 LET T=((TT*LS(1))+TSU)/(.95*60))
3920 LET TC(1)=(T*S(1,8))
3930 IF TC(1)>TS THEN 3960
3940 LET TS=TC(1):LET P=1
3950 LET PIN=PIN+1
3960 IF I<NN THEN 2840
3970 COLOR 5,3:CLS
3980 IF PIN<=0 THEN CLS:COLOR 5,3:LOCATE 10,20:PRINT "SORRY ! NO"
    SPC(0)" MACHINE CAPABLE OF DOING THIS JOB":GOSUB 4660:GOTO 4320
3990 COLOR 0,7,3:CLS
4000 LET CP=1:LET DG=0:LET CAL=0
4010 IF DG>1 THEN 4080
4020 PRINT TAB(10)"THE COST FOR ALL LATHES ARE-----"
4030 PRINT TAB(9);TC(1);TC(2);TC(3);TC(4);TC(5);TC(6)
4040 PRINT TAB(10)"THE TIME UTILIZATION OF ALL LATHES ARE----"
4050 PRINT TAB(9);TTU(1);TTU(2);TTU(3);TTU(4);TTU(5);TTU(6)
4060 LOCATE 21,10:PRINT "PRESS ENTER KEY UNLESS THE MACHINE & THE DISPLAY"
    SPC(0)"VALUE ARE MATCHED"
4070 LOCATE 22,10:PRINT "WHEN MATCH,TYPE 'Y' AND PRESS ENTER KEY "
4080 LOCATE 15,10:PRINT OP$(CP);
4090 LET CAL=CAL+1
4100 IF Y(CP)=0 THEN 4160
4110 INPUT IN$
4120 IF IN$="Y" OR IN$="y" THEN CP=Y(CP):LET DG=DG+1:CLS:GOTO 4010
4130 LET CP=N(CP)
4140 IF DG=0 THEN DG=DG+1
4150 CLS:GOTO 4010
4160 GOSUB 4820:CLS:BEEP
4170 IF CAL=3 THEN P=1
4180 IF CAL=4 THEN P=2
4190 IF CAL=5 THEN P=3
4200 IF CAL=6 THEN P=4
4210 IF CAL=7 THEN P=5
4220 IF CAL=8 THEN P=6

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4230 IF CAL>8 AND CAL<3 THEN CLS:LOCATE 10,10:PRINT "SORRY !"SPC(0)
      "YOU ARE WRONG.TRY AGAIN":GOTO 4250
4240 GOTO 4260
4250 FOR J=1 TO 1500:NEXT J:BEEP:CLS:GOTO 4000
4260 LOCATE 10,10:PRINT "DO YOU WANT TO KNOW THE TECHNOLOGICAL "
      SPC(0)"SPECIFICATION OF MACHINE:";
4270 INPUT A$
4280 IF A$="Y" OR A$="y" THEN 4410
4290 CLS:LOCATE 10,20:PRINT "DO YOU WANT TO KNOW THE REASON OF "
      SPC(0)"THIS SELECTION:";
4300 INPUT B$
4310 IF B$="Y" OR B$="y" THEN 4560
4320 COLOR 0,7,3:CLS:LOCATE 10,30:PRINT 1,"SELECTION FOR ANOTHER JOB"
4330 LOCATE 11,30:PRINT 2,"MAIN CONTROL STRUCTURE"
4340 LOCATE 12,30:PRINT 3,"EXIT"
4350 COLOR 5,3:LOCATE 24,30:PRINT "CHOOSE ANY ONE"
4360 LOCATE 14,30:INPUT "YOUR CHOICE";CHOICE
4370 IF (CHOICE<1) OR (CHOICE>3) THEN CLS:LOCATE 10,15:PRINT "BAD "
      SPC(0)"CHOICE NO.!! ":FOR I=1 TO 600:NEXT:GOTO 4320
4380 IF CHOICE=1 THEN CLS:ERASE OP$,Y,N,SN,NAM$,S,PP:RESTORE:GOTO 350
4390 IF CHOICE=2 THEN ERASE OP$,Y,N,SN,NAM$,S,PP:RESTORE:GOTO 70
4400 IF CHOICE=3 THEN 5010
4410 CLS:BEEP
4420 LOCATE 3,5:PRINT "SERIAL NO.:"TAB(35) ;SN(P)
4430 LOCATE 4,5:PRINT "MACHINE NAME : "TAB(35) ;NAM$(P)
4440 LOCATE 5,5:PRINT "SWING OVER BED:"TAB(35) ;S(P,1)
4450 LOCATE 6,5:PRINT "SWING OVER CROSS SLIDE:"TAB(35) ;S(P,2)
4460 LOCATE 7,5:PRINT "MAX.JOB LENGTH:"TAB(35) ;S(P,3)
4470 LOCATE 8,5:PRINT "MOTOR POWER:"TAB(35) ;S(P,4)
4480 LOCATE 9,5:PRINT "ACCURACY GRADE:"TAB(35) ;S(P,7)
4490 LOCATE 10,5:PRINT "JOB MATERIAL:"TAB(35) ;JM$(P,1);"/"JM$(P,2);
      "/"JM$(P,3)
4500 LOCATE 11,5:PRINT "FIXTURES : "TAB(35) ;FM$(P,1);"/"FM$(P,2);
      "/"FM$(P,3);"/" FM$(P,4)
4510 LOCATE 12,5:PRINT "SURFACE FINISH CAPACITY:"TAB(35) ;S(P,5)
4520 LOCATE 13,5:PRINT "HOURLY RATE:"TAB(35) ;S(P,8)
4530 LOCATE 14,5:PRINT "OPERATIONS:"TAB(35);BB$(P,1);"/"BB$(P,2);
      "/"BB$(P,3)
4540 GOSUB 4820
4550 GOTO 4290
4560 CLS:LOCATE 7,15:PRINT "THIS MACHINE IS SELECTED AS IT ENSURES THE"
4570 LOCATE 8,15:PRINT "MINIMUM MACHINING COST & TIME UTILIZATION."
4580 LOCATE 10,15:PRINT "THE MACHINING COST OF ALL MACHINE ARE--"
4590 LOCATE 12,16:PRINT TC(1);TC(2);TC(3);TC(4);TC(5);TC(6)
4600 LOCATE 14,15:PRINT "THE TIME UTILIZATION OF ALL MACHINES ARE---"
4610 LOCATE 16,16:PRINT TTU(1);TTU(2);TTU(3);TTU(4);TTU(5);TTU(6)
4620 GOSUB 4660
4630 LOCATE 10,16:PRINT "THE LOT SIZE OF SELECTED LATHE IS--";LS(P)
4640 GOSUB 4660

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4650 GOTO 4320
4660 LOCATE 5,13:PRINT CHR$(201)
4670 FOR A=14 TO 70
4680 LOCATE 5,A,0:PRINT CHR$(205)
4690 NEXT
4700 LOCATE 5,71:PRINT CHR$(187)
4710 FOR B=6 TO 16
4720 LOCATE B,71,0:PRINT CHR$(186)
4730 NEXT
4740 LOCATE 17,71:PRINT CHR$(188)
4750 FOR C=70 TO 14 STEP -1
4760 LOCATE 17,C,0:PRINT CHR$(205)
4770 NEXT
4780 LOCATE 17,13:PRINT CHR$(200)
4790 FOR D=16 TO 6 STEP -1
4800 LOCATE D,13,0:PRINT CHR$(186)
4810 NEXT
4820 COLOR 0,7,3:LOCATE 23,30:PRINT "PRESS ANY KEY TO CONTINUE:"
4830 IF INKEY$<>" " THEN 4830
4840 RESP$=INKEY$:IF RESP$="" THEN 4840
4850 COLOR 5,3:CLS:BEEP
4860 RETURN
4870 CLS:BEEP
4880 LOCATE 10,10:PRINT 1,"BLANK DATA"
4890 LOCATE 11,10:PRINT 2,"KNOWLEDGE BASE"
4900 LOCATE 12,10:PRINT 3,"OPERATION, FIXTURE & MACHINE DATA"
4910 LOCATE 13,10:PRINT 4,"MAIN CONTROL"
4920 LOCATE 14,10:PRINT 5,"EXIT"
4930 LOCATE 22,30:PRINT " CHOOSE ANY ONE "
4940 LOCATE 15,30:INPUT "YOUR CHOICE";CHOICE
4950 IF CHOICE=1 THEN LIST 5320-5330
4960 IF CHOICE=2 THEN LIST 5340-5630
4970 IF CHOICE=3 THEN LIST 5640-
4980 IF CHOICE=4 THEN 70
4990 IF CHOICE=5 THEN 5010
5000 LOCATE 10,15:PRINT "BAD CHOISE NUMBER!!":FOR M=1 TO 1000:NEXT :
      GOTO 4870
5010 CLS:COLOR 16,5,0:LOCATE 10,30:PRINT "GOOD BYE !!!"
5020 FOR I=1 TO 2000:NEXT I
5030 COLOR 5,2:CLS:BEEP:BEEP:BEEP:END
5040 LOCATE 10,10:PRINT "PRESS PRINT SCREEN (PRTSC) KEY FOR PRINTING"
5050 LOCATE 11,10:PRINT "IN CASE OF UNKNOWN VALURS,PUT ZERO."
5060 LOCATE 12,10:PRINT "ALL LENGTH RELATED DIMENSIONS ARE IN INCH."
5070 LOCATE 13,10:PRINT "THE MACHINE IS SELECTED ON THE BASIS OF "
5080 LOCATE 14,10:PRINT "MINIMUM MACHINING COST,IF THE DIFFERENCE"
5090 LOCATE 15,10:PRINT "BETWEEN MINIMUM COST & ALL OTHER COST ARE NOT "
5100 LOCATE 16,10:PRINT "SIGNIFICANT THEN THE SELECTION IS ON THE"
5110 LOCATE 17,10:PRINT "BASIS OF TIME UTILIZATION."
5120 GOSUB 4820

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5130 GOTO 70
5140 PRINT "IF THE DIFFERENCE OF LOWER LIMIT OF DIA.BETN.BLANK"
5150 PRINT "& JOB ,DD1>=0 & THE DIFFERENCE OF HIGHER LIMIT "
5160 PRINT "OF DIA.BETN.THE SAME,DD1<=0 & THE SURFACE FINISHING"
5170 PRINT "OF BLANK IS GREATER THEN THAT OF JOB (f1<f2) "
5180 PRINT "THEN THE OPERATION IS SURFACE FINISHING"
5190 PRINT "IF (0<DD1<=0.1 AND DD2>0) AND (ff<=f2 AND ACf<=AC2 "
5200 PRINT "THEN OPN.IS FINISH TURNING ONLY,ELSE FINISH TURNING"
      SPC(0)"PLUS SURFACE FINISHING"
5210 PRINT "IF (DD1>.1 AND DD2>0) AND (fr<=f2 AND ACr<=AC2) THEN "
5220 PRINT "THE OPN.IS ROUGH TURNINH ONLY,ELSE ROUGH TURNING PLUS"
5230 PRINT "FINISH TURNING OR SURFACE FINISHING"
5240 RETURN
5250 PRINT "IF (L1-UNKNOWN & L2/D2 <=4 ) OR (L1-KNOWN & L1/D2<=4 "
5260 PRINT "& L3=(L1-L2)>=2) THEN CLAMPING IN CHUCK "
5270 PRINT "IF (L2/D2<=4 & L3<2) OR (L2/D2 <10) THEN "
5280 PRINT "PLACE BLANK BETWEEN CENTRES"
5290 PRINT "IF L2/D2>=10 THEN PLACE BLANK BETWEEN CENTRES &"
5300 PRINT " USE REST"
5310 RETURN

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DATABASE AND KNOWLEDGE BASE OF EMS

5320 DATA 1,.02,.05,.008,3,.010,.020,.009,4,.009,.008,.008
 5330 DATA 5,.01,.02,.009,6.5,.030,.040,.007,7,.020,.030,.009
 5340 DATA "IS THE INDEX=11",8,2
 5350 DATA "IS THE INDEX=12",7,3
 5360 DATA "IS THE INDEX=21",8,4
 5370 DATA "IS THE INDEX=22",8,5
 5380 DATA "IS THE INDEX=31",9,6
 5390 DATA "IS THE INDEX=32",9,10
 5400 DATA "CLAMPING IN CHUCK",0,0
 5410 DATA "CLAMPING BETWEEN CENTRE",0,0
 5420 DATA "CLAMPING BETWEEN CENTRE & USE REST",0,0
 5430 DATA "REST OF FIXTURE SELECTION",0,0
 5440 DATA "IS THE COST SAME FOR MORE THAN ONE MACHINE",8,2
 5450 DATA "IS THE COST FOR LATHE-001 MINIMUM (non zero)",14,3
 5460 DATA "IS THE COST FOR LATHE-002 MINIMUM (non zero)",15,4
 5470 DATA "IS THE COST FOR LATHE-003 MINIMUM (non zero)",16,5
 5480 DATA "IS THE COST FOR LATHE-004 MINIMUM (non zero)",17,6
 5490 DATA "IS THE COST FOR LATHE-005 MINIMUM (non zero)",18,7
 5500 DATA "IS THE COST FOR LATHE-006 MINIMUM (non zero)",19,20
 5510 DATA "IS THE TU.FOR LATHE-001 MIN.AMONG THOSE OF SIMILAR COST",14,9
 5520 DATA "IS THE TU.FOR LATHE-002 MIN.AMONG THOSE OF SIMILAR COST",15,10
 5530 DATA "IS THE TU.FOR LATHE-003 MIN.AMONG THOSE OF SIMILAR COST",16,11
 5540 DATA "IS THE TU.FOR LATHE-004 MIN.AMONG THOSE OF SIMILAR COST",17,12
 5550 DATA "IS THE TU.FOR LATHE-005 MIN.AMONG THOSE OF SIMILAR COST",18,13
 5560 DATA "IS THE TU.FOR LATHE-006 MIN.AMONG THOSE OF SIMILAR COST",19,20
 5570 DATA "THE SELECTED LATHE IS BENCH LATHE-001",0,0
 5580 DATA "THE SELECTED LATHE IS BENCH LATHE-002",0,0
 5590 DATA "THE SELECTED LATHE IS ENGINE LATHE-003",0,0
 5600 DATA "THE SELECTED LATHE IS ENGINE LATHE-004",0,0
 5610 DATA "THE SELECTED LATHE IS ENGINE LATHE-005",0,0
 5620 DATA "THE SELECTED LATHE IS ENGINE LATHE-006",0,0
 5630 DATA "THE REST OF MACHINE SELECTION",0,0
 5640 DATA 1,BENCH LATHE-001,"ROUGH TURNING","FINISH TURNING"
 5650 DATA "SURFACE FINISHING","AL","CI","MS","FACE PLATE"
 5660 DATA "DOG CLUTCH","TAIL STOCK","NIL",12,10,100,5,.005,.01
 5670 DATA 10,1,20,30,45,63,88,115,138,165,198,238,285,343,411,535
 5680 DATA 855,.0005,.001,.009,.02,.06,.1,2,3,2.5,4,6
 5690 DATA 2,BENCH LATHE-002,"ROUGH TURNING","FINISH TURNING"
 5700 DATA "SURFACE FINISHING","AL","CI","MS","FACE PLATE"
 5710 DATA "DOG CLUTCH","TAIL STOCK","NIL",15,12,110,6,.001,.005
 5720 DATA 09,2,25,35,45,63,83,108,130,155,186,224,291,378,491,639
 5730 DATA 958,.0006,.001,.009,.01,.08,.15,3,3,2.5,5,6
 5740 DATA 3,ENGINE LATHE-003,"ROUGH TURNING","FINISH TURNING"

5750 DATA "SURFACE FINISHING", "AL", "CI", "MS", "FACE PLATE"
 5760 DATA "DOG CLUTCH", "TAIL STOCK", "REST", 20, 15, 120, 7, .0005, .001
 5770 DATA 8, 2, 38, 60, 72, 95, 118, 130, 185, 260, 375, 455, 590, 740, 815, 1155
 5780 DATA 1600, .0009, .002, .008, .01, .09, .20, 3, 4, 5, 7, 6
 5790 DATA 4, ENGINE LATHE-004, "ROUGH TURNING", "FINISH TURNING"
 5800 DATA "SURFACE FINISHING", "AL", "CI", "MS", "FACE PLATE"
 5810 DATA "DOG CLUTCH", "TAIL STOCK", "REST", 24, 20, 130, 8, .0001, .0009
 5820 DATA 5, 2.5, 25, 30, 45, 68, 101, 152, 228, 342, 479, 670, 870, 1040, 1254
 5830 DATA 1505, 1956, .001, .005, .009, .02, .10, .30, 5, 3, 4, 5, 7
 5840 DATA 5, ENGINE LATHE-005, "ROUGH TURNING", "FINISH TURNING"
 5850 DATA "SURFACE FINISHING", "AL", "CI", "MS", "FACE PLATE"
 5860 DATA "DOG CLUTCH", "TAIL STOCK", "REST", 24, 20, 130, 9, .00009, .0005
 5870 DATA 5, 3, 30, 40, 52, 62, 75, 98, 146, 219, 329, 427, 555, 777, 1088, 1414
 5880 DATA 1839, .001, .006, .009, .03, .15, .40, 5, 4, 4, 5, 7
 5890 DATA 6, ENGINE LATHE-006, "ROUGH TURNING", "FINISH TURNING"
 5900 DATA "SURFACE FINISHING", "AL", "CI", "MS", "FACE PLATE"
 5910 DATA "DOG CLUTCH", "TAIL STOCK", "REST", 24, 20, 130, 10, .00001, .0001
 5920 DATA 4, 4, 35, 52, 79, 118, 177, 266, 399, 598, 897, 1300, 1884, 2637, 3828
 5930 DATA 4457, 5794, .002, .009, .01, .09, .20, .60, 5, 4, 8, 5, 7

