INDUSTRIAL MACHINE ALLOCATION USING RULE-BASED KNOWLEDGE REPRESENTATION TECHNIQUE

by

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INDUSTRIAL MACHINE ALLOCATION USING RULE-BASED KNOWLEDGE REPRESENTATION TECHNIQUE

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
CDCC	Clinical Decision Support System
DSS	Decision Support System
DSSMS	Decision Support System for Machine Scheduling
EOL	End of Line
FOL	Front of Line
FUMAHES	Fuzzy Multi-Attribute Material Handling Equipment Selection
IC	Integrated Circuit
IMES	Integrated Manufacturing Enterprise System
PLCC	Plastic Leaded Chip Carrier
SME	Small Medium Enterprise
SOIC	Small Outline Integrated Circuit
SPT	Shortest Processing Time
TSSOP	Thin Shrink Small Outline Package
UPH	Unit per Hour

Peruntukan Mesin di Industri Menggunakan Teknik Perwakilan Pengetahuan Berasaskan Peraturan

ABSTRAK

Peruntukan mesin adalah masalah yang rumit di dalam industri pembuatan. Terdapat keperluan alat untuk membantu pengurus baris pengeluaran bagi memutuskan mesin yang diperlukan untuk proses yang berbeza dalam industri pembuatan. Objektif kajian ini adalah untuk menyediakan satu sistem sokongan keputusan (DSS) untuk membantu pengurus dalam melaksanakan tugas tersebut. Pada masa ini, peruntukan mesin ditentukan secara manual yang memerlukan masa yang panjang dan bergantung kepada kemahiran dan pengalaman pengurus baris pengeluaran. Kajian ini menerangkan pembangunan satu sistem sokongan keputusan menggunakan pendekatan berasaskan peraturan yang akan memudahkan pelaksanaan tugas peruntukan mesin dengan memberi pilihan mesin yang boleh digunakan. Salah satu langkah yang penting di dalam sistem sokongan keputusan adalah untuk mendapatkan pengetahuan daripada pakar tentang kriteria yang mereka pertimbangkan untuk peruntukan mesin. Sesi temuduga bersama pakar dikendalikan sebagai kaedah mendapatkan maklumat. Melalui sesi temuduga yang telah dikendalikan, didapati adanya mesin, produktiviti mesin dan masa pemprosesan adalah faktor yang mempengaruhi masalah untuk peruntukan mesin. Kaedah berasaskan peraturan dilaksanakan di dalam sistem sokongan keputusan ini untuk memberi keputusan alternatif dalam membuat peruntukan mesin. Sistem ini akan memberi faedah kepada pihak pengurusan industri pembuatan kerana dapat membuat keputusan untuk memperuntukkan mesin dengan lebih cekap dan dalam jangka masa yang lebih singkat.

Industrial Machine Allocation Using Rule-Based Knowledge Representation Technique

ABSTRACT

Machine allocation is a complex problem in manufacturing industry. There is a need for some tools to aid the production line managers in deciding which machine will be used in the different processes in manufacturing. The objective of this research is to provide a Decision Support System (DSS) to help those managers in carrying out that specific task. Currently it is done manually which time is consuming and dependent on the line manager's expertise and experience. This research describes the development of a rule based DSS which will make their task easier by providing the options of possible machines to be selected. One of the most important steps in DSS is to acquire knowledge from experts on what are the criteria that they consider in allocating machines. Interview sessions with the expert are conducted as the knowledge acquisition method. It is found that machine availability, machine productivity and processing times are the factors that affect the machine allocation problem. The rules are implemented in the proposed DSS in the attempt to provide alternatives solution in deciding machine allocation. It is beneficial for the management in the manufacturing industry to have this decision support system as it can make the machine allocation decision more efficiently and within a shorter time period.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Manufacturing planning and control does many types of activities. There are about fourteen categories of activities such as monitoring production, planning detailed production resources, managing production database, forecasting demand and many others [2]. This research will be based on monitoring production activity which is to plan for the machine allocation in semiconductor industries. This is important in order to fulfill the customer demand. The planner has to allocate order to the machines and determine the machine to be assigned to finish the order.

Basically, in semiconductor industries, the order is processed by lots. A particular lot will be assigned to the machine based on the process in which the lot is in. A prototype of decision support system is built in this research to reduce the planner's task by giving the recommendation of possible solutions in solving the machine allocation problem.

This research is based on a case study carried out at a semiconductor company in Kulim Hi-Tech Park. In the company, the management does the planning every morning in their morning meetings. In the morning meeting, the machines needed and all the details in order to finish the customer's order are discussed. The weakness of planning during morning meetings is that all the planners and managers involved have to assemble to gather information and decide their production planning which includes the machine allocation. Besides, their manual style of planning is time consuming and ultimately the cost will be increased. Therefore, this research will help the management in reducing their planning time.

1.2 Electronic Packaging Process

The product of the organization in the case study is integrated circuit (IC). IC is a small device that carries out several electronic functions. In order to build the IC, there are a few processes that a particular lot have to go through. Figure 1.1 illustrates the electronic packaging process of building the IC. It starts with the raw material in the initial front of line process. The raw material is a thin wafer in a round shape. The wafer then will be cut into small pieces. The wafer will continue with the second process that is the die bond and the last process in front of line is the wire bond. In the beginning of the end of line process, the wafer is put into the mold. Then, the mold will be baked in the oven before it continues to the next steps which start with marking and end with trim and form processes. To make sure the product reaches the target quality, it will go through the inspection and testing processes.

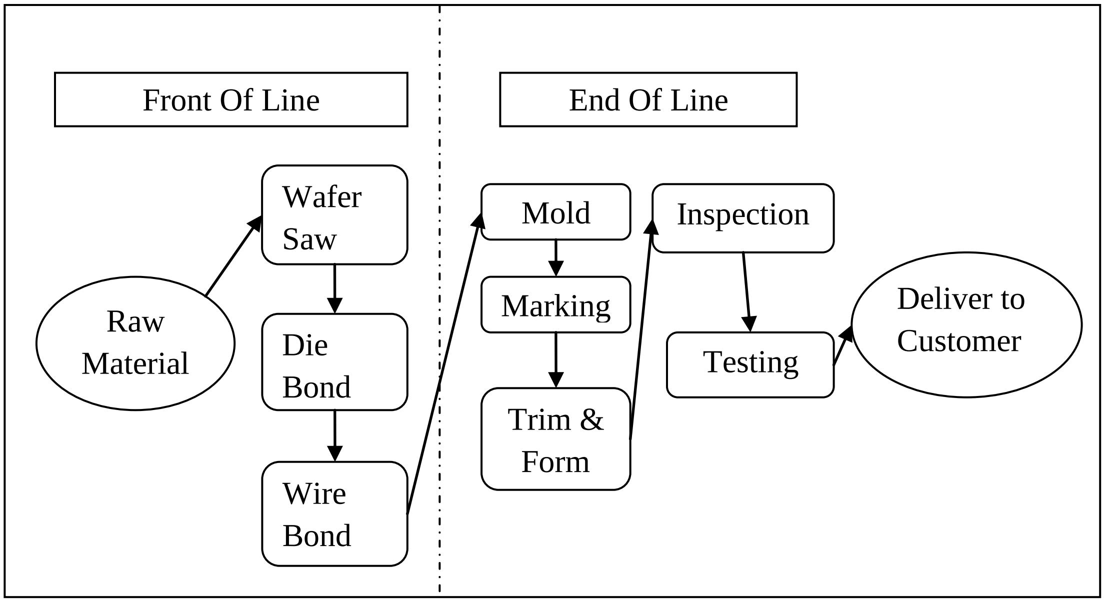


Figure 1.1: Electronic packaging process.

However, this research will only focus on the front of line (FOL) process. As discussed before, the wafer will go through three processes, which are Wafer Saw, Die Bond and Wire Bond processes. More details about the processes will be explained in Sections 1.2.1, 1.2.2 and 1.2.3. These processes will be using different machines because each machine has its own tasks. The number of machines also differs from one process to the other.

1.2.1 Wafer Saw

Wafer saw is the first process in FOL. It is a process where the machine cuts the wafer into individual dice to be assembled in IC packages. The wafer is a thin slice of semiconductor material. Figure 1.2 shows the wafer before the sawing process. In the case study organization, there are 10 machines to do this process. All wafers will be cut using these machines.

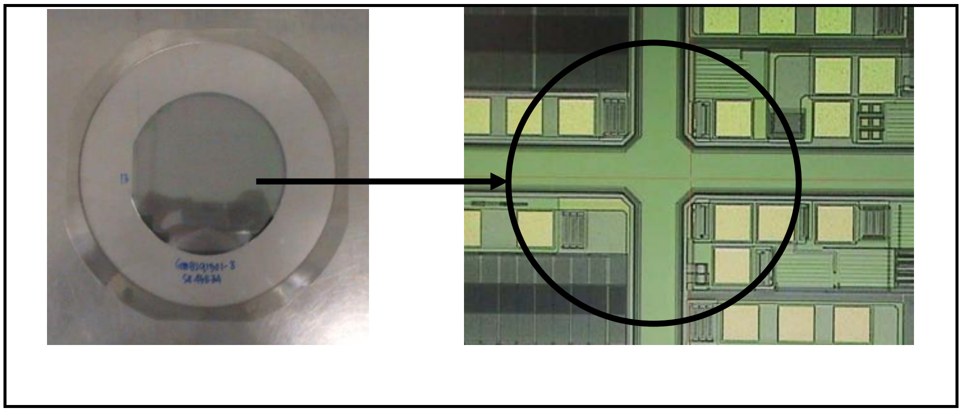


Figure 1.2: Wafer before sawing

Figure 1.3 shows the wafer after the sawing process. After the sawing process, sawing line will be seen as highlighted in the diagram.

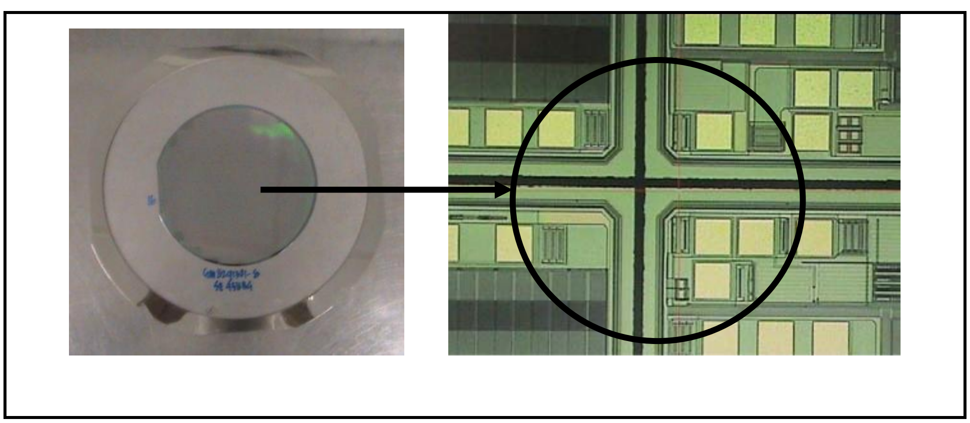


Figure 1.3: Wafer after sawing.

1.2.2 Die Bond

The second process in electronic packaging is die bond. Die bond is a process of attaching the silicon chip to the lead frame of the semiconductor package. The dies are picked from a separated wafer, aligned to a target, and then permanently attached to the lead frame. Both processes use special die attach equipment and die attach tools to mount the die. Figure 1.4 shows the lead frame before the process and Figure 1.5 illustrates the lead frame after the die bond process where the die has been attached to the lead frame. For this process, there are 32 machines in the case study organization.

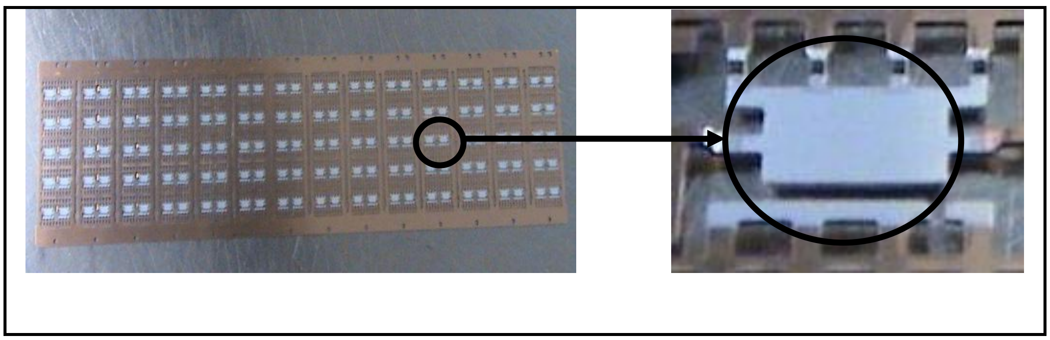


Figure 1.4: Lead frame without die

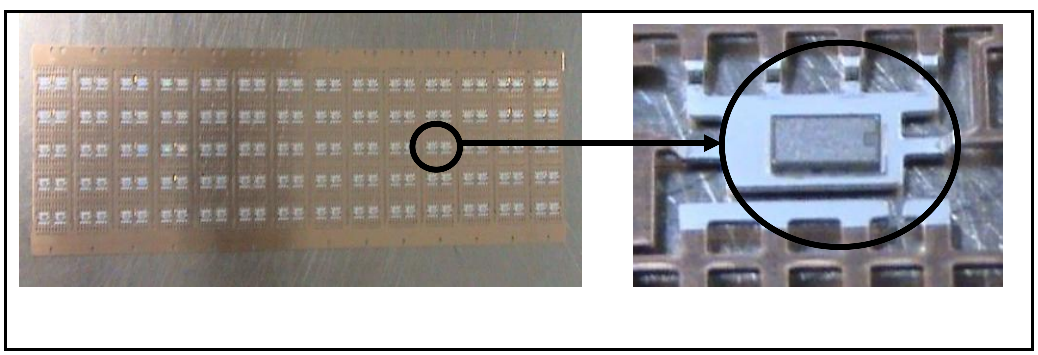
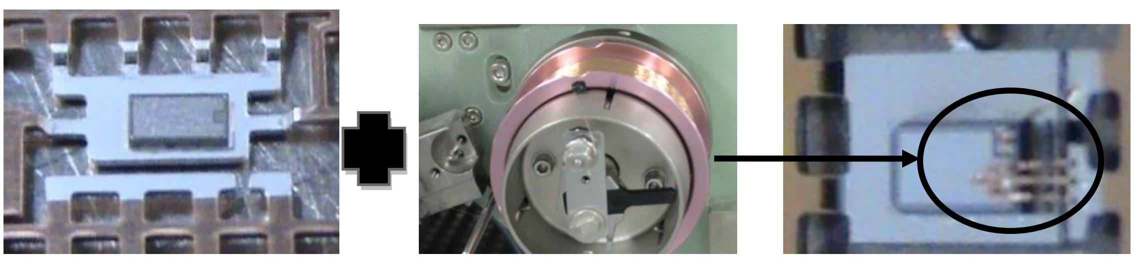


Figure 1.5: Lead frame with die

1.2.3 Wire Bond

Wire bond is the last process in FOL. It is a process of providing electrical connection between the silicon chip and the external leads of the semiconductor device using bonding wires. In the case study organization, a copper wire is used to join the die and the lead. Figure 1.6(a) shows the lead frame with die after the die bond process while in Figure 1.6(b) is the copper wire that will be used to connect to the lead frame. Figure 1.6(c) illustrates the die that has been joined using the copper wire. 120 machines are used in the last process of the front of line.



(a) (b) (c)

Figure 1.6: Wire bond process

(a) Frame with die (b) Copper wire (c) Die with copper wire

The three processes use different types of machines according to their tasks. As mentioned before, the number of machines for each process is different. The planner has to decide on the machine to be used for every lot. Decision support system (DSS) can be beneficial to the planner in providing recommendations in selecting machines in each process.

1.2.4 Machine Allocation in Electronic Packaging Process

For every process in electronic packaging, the management has to allocate machines. Machine allocation is a task where the planners and engineers plan and decide on the machine to be involved when the lot is loaded every day. Every process in FOL has its own machines to do the task. They need to know which machine is able to execute wafer saw, die bond and wire bond process. This task requires knowledge about the machine capability where the capability for each machine is different. Nowadays, in the case study organization, the machine allocation is done manually by the management.

1.3 Definitions and Terms:

There are a few terms in the semiconductor industry that might be used in this research:

- Lot (order)

  Lot is the number of similar parts. Each lot will be having a set of parts to be processed. Every lot must go through the wafer saw, die bond and wire bond processes in FOL. At one time, only one lot can be processed by a single machine. In this DSS, an input of the number of lot (production target) will be made by the decision maker.

- Package

  In this industry, packages can be described as an analogy to products produced in other factory. The package is made according to customer order. For each customer, the design of the package is different, which makes the execution time for making the integrated circuit different because of conversion time. The conversion needs to be made for the machine to process different packages.

- Machine

  Machines have different capabilities. For example, there might be two machines that can process a particular lot but the production output per hour for each machine is different. Then the management can choose to use any one of them by considering time taken in executing the lot using that particular machine. The machine availability also may vary due to interruptions, breakdown or break time.

- Conversion time

  Conversion time is the time taken to set the machines according to design of the package. Machine conversion needs to be done to change the setting of the next package from the previous package that they made.

1.4 Decision Support System

In this research, DSS will assist in the machine allocation problem. The DSS will be a guide to the planner and indicates the machines which are suitable to do the process and let the planner make the final decision. The planner has to insert an input into the DSS and the alternatives of suitable machines will be displayed to the planner.

The objective of DSS is not to replace humans in decision making but to aid them in deciding the best solutions among all the alternatives. Rule based is a technique of knowledge representation to build decision support system and this research uses this technique in building the prototype. Rule based is a well known approach in building DSS as it has been implemented in job shop scheduling [5], evaluating and selecting IS projects [6], and in medical field [7].

Rule base, frames, semantic networks and formulas in first-order predicate calculus are four major ways in knowledge representation in knowledge based system [8]. In this research we will represent knowledge in rule based and apply it to help in machine allocation problem.

1.5 Problem Statement

Manufacturing planning is a process to determine future equipments, manpower and facilities requirements. It is important to enable companies to work efficiently with the necessary abilities to produce products as demanded by customers in today's competitive world. To ensure that the company can fulfill the demand in required time, machine allocation planning is important.

The organization in the case study manages the machine allocation planning manually which is time consuming and requires the presence of planners, technician and engineers together. They also have to think of a few solutions by considering the criteria of selecting machines and make sure that the best possible solution to allocate machine is chosen. In the company, the number of machines and machine capacity is fixed for each process, but using DSS, there will be some guidance provided to find the best solution to allocate the lots to the machines according to the capability of each machine and the shortest processing time.

1.6 Research Motivation

The purpose of developing DSS for the machine allocation problem in the semiconductor industry is to fulfill the needs among the management that requires time and a group of human resources to discuss this matter. It is a complex job for human beings to allocate the lot to the machine because it involves different machines for different process. A lot can be executed only in one machine but the issue is to determine the machine which will execute the lot efficiently. Every machine has its own specifications, meaning that in an hour, the production is based on the units per hour (UPH). For example, machine A can only produce 100 units per hour and machine B can produce 200 units per hour. So the machine UPH for machine A is 100 whereas the UPH for machine B is 200.

In this field study, there are three processes that are wafer saw, die bond and wire bond. The DSS will propose recommendations for the machine allocation for these three processes based on the machine availability, machine productivity and the processing time. Therefore with this proposed work, the management will get the feasible solution efficiently. So it is up to the managerial team to decide on the machine which will be used with the aid from this DSS.

1.7 Research Objective

The main idea of this research is to study the rule base representation technique and apply it in building the DSS for machine allocation. The DSS is designed to help the management choose the best solution for allocating machines in a flexible and user-friendly manner. In real time planning, there will be many alternatives to allocate machines with the customer orders. So, this research will provide the management with the options to assist them in deciding the best solution from time and resources aspects by providing them recommendation of possible machines that they can use to execute the customer orders.

The objectives of this research are:

(a) To acquire knowledge about machine allocation criteria specifically in semiconductor manufacturing industry.

(b) To transcribe the acquired allocation criteria into rule based representation.

(c) To provide a rule based decision support system to assist management in allocating production lots to machines.

1.8 Research Contribution

In this study, we expect to provide:

a) A prototype consisting of a DSS to help the management in choosing the best combination of machines to be allocated to a lot.

b) Reduce dependency on the experts in allocating machine. Currently the engineers, planner and production line manager have to be present in morning meetings to discuss their planning which include machine allocation. With the DSS, the dependency on the experts in the meeting can be reduced.

1.9 Research Scope

This research will only consider the FOL processes in the semiconductor process. The EOL processes will not be considered. Furthermore, the cycle time of the customer order is not taken into account. Cycle time is the time required to finish the order given by the customer starting from the time they make their order until the order is fulfilled.

This research will only look at the ideal situation, assuming all the machines are functioning well. In addition, this research will use data obtained from a semiconductor company at Kulim Hi-Tech, so further specifications and requirements in other semiconductor companies are not included in this research scope. It is domain specific because it relies on detailed knowledge of semiconductor industry.

1.10 Limitations and Assumptions

There are few constraints in planning the machine allocation in semiconductor industry. Two types of constraints can be identified as follows:

- Resources (machines) constraints

  As discussed in Section 1.2, there are few processes involved in the FOL process. Each process has access to particular machines and the number of machines is limited. Every machine can only work on one lot at a given time. Thus, for every machine that has been used, it will not appear in the DSS recommendation list.

- Fixed sequence of process stage

  In producing semiconductors, the parts have to run through the three stages in fixed sequence. The first stage is wafer saw, followed by die bond and the last stage is wire bond. The parts must go through the processes in sequence in order to construct the semiconductor. Which means, even though the machine for die bond is available, it has to wait until wafer saw process is done.

- Correct information from experts

  All the information and data are obtained from the experts after conducting the interviews. In this research, we made assumptions that the respondents of the interviews gave the correct information according to their expertise and experiences. All information were gathered as part of the knowledge acquisition.

1.11 Thesis Organization

This dissertation is organized in six chapters. The following is an overview of each chapter. Chapter 1 briefs about the manufacturing planning in general, decision support system and the rule based knowledge representation technique. In addition, the problem statements of this research study, research purpose and the research scope have also been explained in this chapter. The next chapter of this research will discuss the related research projects that other researchers had done.

Chapter 2 consists of literature review of how the other researchers apply knowledge based system in their research work and decision support system in other related areas. Chapter 3 consists of methodology used in this research. The discussions are research procedures, research framework, justification of research problem and the research design.

Chapter 4 discusses the design of the proposed decision support system. The rules obtained from the knowledge acquisition phase and system flow of the decision support system are discussed in this chapter. Chapter 5 shows the decision support system that has been developed as a module in Integrated Manufacturing Enterprise System (IMES). The user interface of the system is illustrated in this chapter. Chapter 6, the last chapter is the summary of the whole research. The results and implementation of the research are concluded in this chapter. This is also the last chapter for this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Rule based is well known as a knowledge representation technique in knowledge based system [8]. It has been applied in various domains such as health [7], manufacturing [2], information system [6] and many more. This technique also has been used to develop decision support system in clinical decision support system [7]. For further discussion about the literature review, this chapter is divided into two sections for related projects in rule base system and decision support system.

Rule base has been widely applied in various industries including the manufacturing industry. In the manufacturing planning area, there is a need of DSS and rule based is a well known approach to build it. For this research study, the machine allocation problem will be solved with the decision support system using rule based knowledge representation technique.

2.2 Knowledge Based System

Knowledge based system is computer system that contain stored knowledge. The purpose of knowledge based system is to solve problems like human being in a computerized manner. Knowledge based systems is also an approach which can aid in manufacturing planning and control. Several research projects have been done in manufacturing planning as it has broad categories to look into. There are many kinds of approaches in planning and control such as optimization, simulation and combination of techniques [9].

Foxlow [10] discusses the state of knowledge based manufacturing from the problem domain which is manually defined part numbers to identify unique configuration of finished product, subassembly, component parts, and raw material in manufacturing systems and he also suggested the new approach to manufacturing systems. Knowledge based manufacturing simplifies processes for the end user and provides more flexibility, faster response, shorter lead times and more cost-effective operation. Foxlow proposed knowledge based manufacturing which basically creating generic items and products for the ease of product maintenance instead of recognizing the product by part number. This paper proves that knowledge based can be adapted in manufacturing industry.

Meziane *et al.* [11] review a few Artificial Intelligent techniques (AI) and many aspects in using different AI techniques in manufacturing. The AI techniques that were discussed in this work are knowledge based system, neural network, genetic algorithm, fuzzy logic, case based reasoning and hybrid systems. They discussed each technique in few aspects such as the design, process planning, quality management, maintenance and diagnosis, control and scheduling. The design of knowledge based system is developed using the expertise and applied using inference engine. Knowledge based system had widely been use in intelligent design, assisting process planning, fault diagnosis and also quality control to assist decision-makers but there is little work on control and scheduling aspects.

Howard *et al.* [2] describe a rule base for the specification of manufacturing planning and control system activities. This work describes the development of rule base from the conceptual framework of theirs, their rule base structure, and the testing phase which has been conducted in Small Medium Enterprise (SME) companies to know the accuracy and usability. Basically this work intends to gather the specification of manufacturing activities and they had grouped the manufacturing planning and control activities into fourteen categories which enclosed the plan detailed production resources. It is related to our research which is to plan the machine allocation in FOL based on the customer order.

They also gave some examples of activities and one of them is identifying specific scheduling, capacity, material requisitioning and stock holding needs for engineering changes. This strengthens our research objective which is to look at selection of machines for allocation because this step comes before the planner schedules the machines to process lot. Based on their validation and feedback from the companies, rule based have a high satisfactory level of accuracy. The feedbacks from the companies strengthen the use of knowledge based system in manufacturing planning and control activities.

Zheng [12] implements knowledge based system in production line development for car manufacturers. This involves the planning system of the production line. The production of cars has the most complex manufacturing flow and involves many types of data. So to plan the car body production line is difficult. This planning system gathers all information of the car body production lines such as the parts, resources and operations. Zheng defined the knowledge models into four classes that are product, resource, operation and manufacturing features. With these classes, users are able to build and update information libraries, extract knowledge and many other advantages. The idea of decomposing the information into few classes is appropriate to simplify large data. Zheng stated that production process is composed of three basic types of elements, which are parts, resources and operations. In this research, resources (machine) and operations (wafer saw, die bond and wire bond) are important criteria in allocating machines.

Aufenanger *et al.* [9] have exposed the complexity and uncertainty of today's production systems. They also proposed an approach using simulation and knowledge generation for flow shops. There are few rule selection tools such as decision trees and Bayesian networks and they have selected the Naïve Bayes Classifier as their rule selection tool. They claimed that this rule selection tool can process thousands of attributes in a short time, maps the problems and provide the reliability of the generated decision. Aufenanger *et al.* stated that in general, there are three common decisions that have to be taken within scheduling system: selecting a job out of a queue, selecting a machine for one job or selecting a job out of a queue and a machine for the selected job. This DSS prototype is making the common decisions in a scheduling system which is to select machines for one job.

Rule based technique also has been used in a clinical system [7]. The Clinical Decision Support System (CDSS) by Soumey *et. al*, shows the knowledge acquisition phase of developing a decision support system to collect data from the domain expert in medical. This is important for maintenance and extending knowledge base. This approach can also be used by few medical institutions even though the experts do not know much about the system. User interface to input the attributes, relationship and semantics are built. This approach is good for maintaining the knowledge based, but it still has the weakness. The data might be redundant if many experts use the knowledge acquisition system.

2.3 Knowledge Representation

2.3.1 Rule Based Representation

Rule provides some description to solve problems. It consists of if-then rules which are encoded from knowledge. The 'if' statement is the antecedent (condition) of the particular problem and the 'then' statement is the consequence (conclusion). In order to apply rules, facts are needed because rules represent relationships between facts. Facts can be obtained from various sources such as from a database by prompting it for information, or derived by applying the rule to other facts [1].

Some advantages of using rule based technique are this approach is like a natural language and the rules are in a uniform structure that is easy to understand. Rule based is production rules that are similar to natural knowledge representation which means that the if-then rule representation is alike with an expert explaining the problem solving procedure. For example, in explaining a situation, human might say, “In a situation where machine XYZ is not functioning, I will do A and B”. This expression can be represented quite naturally in if-then statement. Moreover, the production rules have the uniform if-then structure and each rule is an independent piece of knowledge. The uniform structure makes rule based technique easy to understand especially when the problem is simple.

There are two reasoning strategies in applying rules; forward chaining and backward chaining. The forward chaining is data driven strategy, where rules are selected and applied in response to the current fact. The system will compare data in the working memory against the conditions of the rules and determines which rules to fire. Whereas the backward chaining is a goal driven strategy which assumes the existence of goal needs to be established [1]. In backward chaining strategy, the system looks for the action of the rules that matches the specified goal.

The schematic representation of forward chaining strategy is shown in Figure 2.1. The conflict set is the conditions that are satisfied, and then the rules will be fired after the conditions are met. By firing the rules, solutions will be given. This research use forward chaining strategy in implementing rule based to the system. This strategy is used because the system is data driven. The system will use the facts given by the user and respond to the facts by firing the rules. This means that the system discovers the solution after facts are provided which is what it should be.

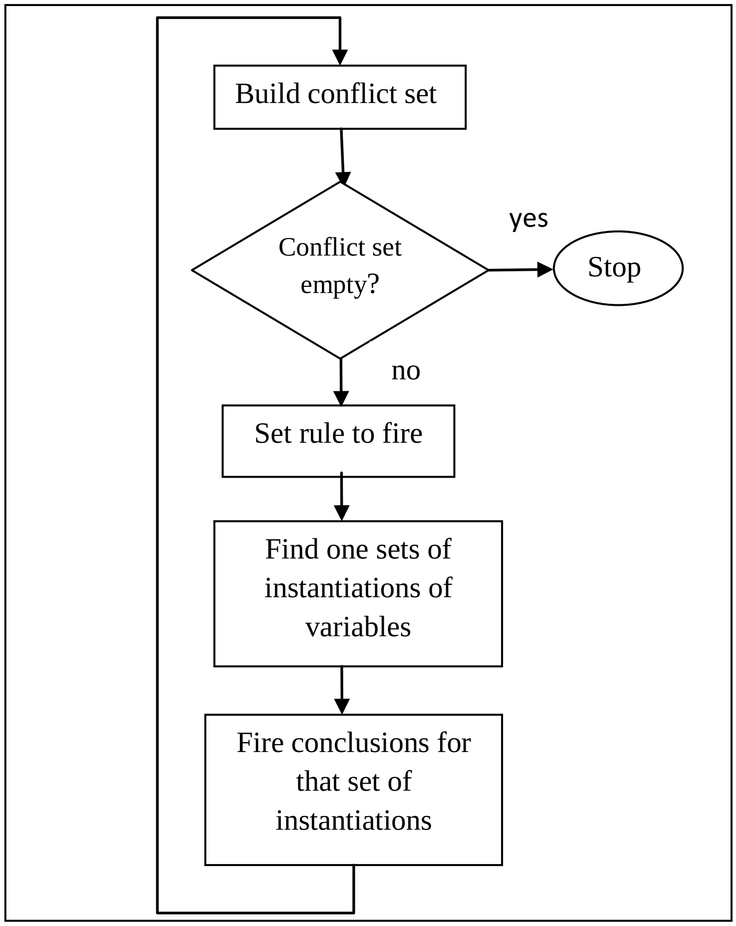


Figure 2.1: Alternatives forms of forward chaining [1]

2.3.2 Semantic Net Representation

Semantic net is a knowledge representation technique where the information is represented as nodes and connected by the arcs. This technique is simple and intuitive. This technique is used to represent connections between objects. The objects are at the nodes while the arcs are the connections. Figure 2.2 demonstrates a simple semantic net to represent a case. In this case, we can retrieve simple information such as 'the mini is a vehicle'.

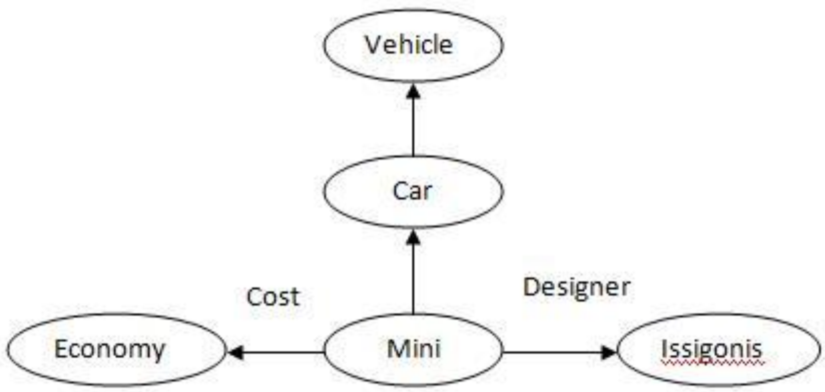


Figure 2.2: A semantic network [13]

The limitations of using semantic net are difficulty in picking the right set of semantic primitives at the outset and the difficulty of expressing a particular knowledge [13]. Furthermore, mapping the problem into a semantic net is easy if the problem is small, but for a complex problem, the complexity of semantic net will also increase.

2.3.3 Case Based Representation

Case based representation uses cases to aid in solving problems. It will a similar case in the database and reuse the scenario to come up with the solutions. Belecheanu *et al.* [14] build a decision support system using case based technique without the need of experts. Their work will be discussed in the next section. To develop a system using case based reasoning, data from past cases are needed to be the knowledge base. If there is a new case, then the solution will be preserved in the database as a new solution. This technique requires a lot of time to collect data from the case study organization.

2.3.4 Summary of Knowledge Representation

Table 2.1 summarizes the knowledge representation techniques that had been discussed in the previous sections. The rule based technique is used in this research because of the similarity to natural language representation where the information obtained from the experts is easy to be interpreted into rules. Furthermore, there are other researchers who build decision support system using rule based technique such as the rule based decision support system for evaluating and selecting IS projects which strengthen this proposed research[6].

Table 2.1: Summary of Knowledge Representation Techniques

Knowledge representation	Advantages	Disadvantages
Rule based	• Similar to natural knowledge representation.	• Knowledge must be obtained from the domain experts.
Semantic net	• The semantic network is simple and intuitive.	• Difficulty in picking the right set of semantic primitives at the outset. • Difficulty in expressing a particular knowledge.
Case based	• The solution of the problem is from past cases, experts are not involved.	• Requires a lot of time to collect data from the case study organization.