REAL-TIME SCHEDULING OF FLEXIBLE MANUFACTURING SYSTEMS

By

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Supervisor

Prof. Kasim Mousa Al-Aubidy

This thesis was submitted in partial fulfillment of the requirement for the Master's Degree in Mechatronics.

Deanship of Academic Research and Graduate Studies
Philadelphia University

January, 2016

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DEDICATION

I dedicate this work to the one who raised, helped and supported me to get to the position I am in today, my father. I also dedicate this work to my mother, who caressed me with her love, may God protect her, to my wife who shared and encouraged me, to my brothers and sisters who helped me despite all bad conditions that they have gone through, to my sons and my daughters, and to beloved country Iraq I dedicate the fruits of my labor.

Yasir Mohammed Mejthab

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Yasir Mohammed Mejthab

Amman, January 2016

ABSTRACT

Flexible Manufacturing Systems are computer controlled systems consisting of programmable numerically controlled machines, tools, load/unload stations, automated material handling system, and a real-time control system.

It is required to design and implement real-time scheduling algorithms to generate a sequence of operations and task flows in order to use available resources. Therefore, it is necessary to assign a priority for each operation and each task in order to balance the workload of available machines and tools. This can be achieved by using real-time fuzzy-based scheduling algorithms to minimize the time required to complete each task. Several parameters related to the required operations have been considered in sequencing and routing.

In this research, an FMS with four CNC machines (two drilling machines, and two milling machines) combined with a load/unload station and a conveyor belt are proposed.

The labVIEW environment has been used for the system realization and testing. A fuzzy logic algorithm was used in scheduling modules to reduce system complexity when dealing with incomplete data and vague information. Three fuzzy-based algorithms were applied; the first one for operation sequencing, the second one for task sequencing, while the third one is used for task routing.

Computer simulations for several case studies have been done to test and proof the flexibility of the system and the effectiveness of the proposed schedulers. The obtained results concluded that the proposed methodology for sequencing and routing is promising for such FMS. The performances of the proposed fuzzy scheduling algorithms are compared with those obtained from published literature. The obtained results show clear improvement has been achieved by applying fuzzy algorithms in sequencing and routing.

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Chapter One

INTRODUCTION

1.1 Project Motivation

Nowadays, the increasing demand for different variations of low-cost products, together with increasing competition in the global market, face lower profit margins by increasing productivity[1]. To meet these needs, the concepts of computer intelligence and Flexible Manufacturing System (FMS) can be applied. The purpose of any FMS is to efficiently manufacture low to medium volume production of goods with considerable cost. This can be achieved through optimal or sub-optimal control of all machines and tools in the FMS.

1.2 Flexible Manufacturing Systems

Flexible manufacturing system is a computer-controlled integrated manufacturing system with multi-functional Computer Numerically Controlled (CNC) machines and a material handling system such as mobile robot, Automated Guided Vehicle (AGV), and conveyor [2]. FMS mainly consists of the following flexibilities:

- Machine Flexibility (MF): ability to adapt to a variety of products.
- Material Handling Flexibility (MHF): a measure of the systems ability with which different part types can be transported and properly positioned at the various machine tools.
- Operation Flexibility (OF): measures adaptability to alternative process a part type an operation sequences in processing a part type.
- System Volume Flexibility (SVF): the system’s capability to operate efficiently at different volumes of the part types.
- System Routing Flexibility (SRF): the system’s ability to use multiple machines to perform the same operation on a part. It is a measure of the alternative paths that a part can effectively follow through a system for a given process plan [2].

The performance of the system improves as the flexibilities increase. Therefore, the major objective is to develop a methodology that minimizes the manufacturing completion time of all jobs. The flexibility of any FMS depends upon several variables such as:

- Production planning activities (machine setup and job routing).
- Available equipment and tools.
- The implemented control methodology.

If these variables are used perfectly, a FMS could help in minimizing machine setup time, reducing the manufacturing completion time of all jobs and increasing productivity within a manufacturing facility, and reducing the total cost of the product.

1.3 Scheduling Algorithms

Scheduling in conventional manufacturing system involves jobs that travel along some fixed routes through various machines of a process. While, in an FMS environment, the routing is not fixed, as several machines can perform different types of operations, by allowing jobs to travel through several routes, hence the system is flexible. Scheduling in FMS deals with principles, models, methods, and logical results which provides us with a deep insight about the timing operation. Scheduling, include planning and prioritization of activities that need to be done in an order. Scheduling is a kind of decision-making process which during its the schedule is set.

System elements can operate either in a synchronous or an asynchronous mode. In an asynchronous mode the scheduling problems are more complex. The components are highly interrelated and contain multiple part types with alternative routings. FMS performance can be enhanced by better co-ordination and scheduling of production machines and material handling equipment. In FMS, when the production parameters are specified, careful production planning and scheduling of resources are required. The goal of scheduling is to make an efficient use of the available resources over a certain period of time to meet some performance criteria [3].

1.4 Thesis Organization

This thesis discusses the scheduling problems in an FMS using fuzzy algorithms together with labVIEW environment as a simulation tool. The rest of the thesis is organized as follows:

- Chapter two: presents a comprehensive study and literature review of flexible manufacturing systems' architecture and showed related work concerning scheduling, and real-time control of FMS.
- Chapter three: addresses a general topology that considers the system's layout and the underlying system machines. It also describes all the component that are used in the proposed system and its construction using LabVIEW environment.
- Chapter four: explains the proposed fuzzy scheduler algorithm and the rules that combine the input and output elements together. A scheduling system is illustrated for both priority sequence algorithms and routing algorithms.
- Chapter five: includes the acquired data from the proposed system and the diagnosis and analysis done to provide a complete study for the behavior of the system. Also, a comparative study for others related work is done.
- Chapter six: outlines the conclusion of this thesis together with some suggestions for future work and modifications.

Chapter Two

LITERATURE REVIEW

Flexible manufacturing systems include programmable machines, material handling units, and a real-time computer control algorithms. It has ability to flexible deal with mixed part types and varied product designs. To reach a successful results for the implemented FMS, it is necessary to obtain suitable design, planning, scheduling and real-time control of each unit.

This chapter deals with literature review in the field of an FMS design and scheduling. Since the late 1970's, a considerable research literature has accumulated in the area of flexible manufacturing systems. Most of these reviews focused on analytical models of an FMS, and the scheduling problems.

2.1 Flexible Manufacturing Systems: Definition and Architecture

Through the literature review in this field, there is no universally accepted definition of FMS. According to Tempelmeier and Kuhn [4]. An FMS is " a production system consisting of identical multipurpose numerically controlled machines (workstations), automated material and tools handling the system, load and unload station, inspection stations, storage areas and a hierarchical control system". It is clear that such a system is a complex one and needs an intelligent control algorithm to deal with variety of machines and tools. The CNC machines in any FMS differ from one application to another. However, some published papers indicate that about 60% of the FMSs have less than eight workstations and work on less than ten parts [5]. Any manufacturing system to be flexible, it should has some built in hardware redundancies. These hardware redundancies are useful and necessary for most FMSs, and at the same time create some control problems. Therefore, it is necessary to make balance between flexibility and control ability of such a system. The suitable selection of CNC machines and tools will solve the problem of the hardware redundancies.

Singh and his group presented a real-time system that controls the routing flexibility of an FMS system using combination of variable flexible systems with full routing methodologies [5]. This allows for increased production efficiency by choosing the shortest path for the routing system, to achieve better performance and shorter production time.

Threshold-based alternating routing is a methodology developed by Ozmutlu for optimizing mean flow time for FMSs [6]. This methodology assigns a carefully selected threshold value to a certain system then the workload is divided based on the threshold. Such a technique showed great potential with FMS and showed greater success over other optimizing techniques.

A system that contained six flexible machines with three AGVs material handling systems was studied by Felix T.S. Chan et.al [7]. As an impact of response-time to decision-making, an average processing time of job had been considered sufficiently larger than that of decision processing time. The parts can be routed through the different machines for processing, depending on the level of routing flexibility available in the system.

Kyouny Seok Shin et.al proposed multi types of flexibilities in FMSs using certain number of machines [8]. Each machine can perform a variety of operations balancing the machine workload, minimizing part movements, and minimizing tool changes with multi-objective FMS process planning.

A systematic approach for dynamic routing of active products in FMS was conducted by Yves Sallez et.al [9]. Fifteen workstations nodes, twenty-four divergent transfer, and twenty-four convergent transfer gates were used to build an efficient routing system. This system is capable to find the best routing solutions in real-time and of adapting to new traffic situations and changes in the conveying network's connectivity of an FMS.

2.2 Real-Time Control of FMS

One of the main problems of FMS operation is the real-time control to achieve the desired flexibility of the system. Throughout the literature review, this problem is divided into three categories based on the time frame; there are long-term, medium-term, and short-term control levels.

As mentioned in literature, the long-term control level deals with production planning strategies for the produce groups over a long time period. The medium-term control level mainly deals with plant operation according to what specified at the strategic production planning level. The short-term control level deals with real-time control and management of the plan according to the medium-level control level setting. Therefore, the short-term control level is the most important level to achieve the desired flexibility of the FMS [10].

Mehdi Souier et.al proposed a real-time rescheduling algorithms applied to an FMS with routing flexibility [11]. The simulation used various methodologies and compared them to build a complete routing algorithm. It also showed the effects of real-time rescheduling on the production time and the performance of the FMS.

Statistical analysis control and structural data mining can be used to establish an efficient dynamic real-time scheduling algorithm [12]. A decision tree, constructed mainly from the data gathered from the surrounding industrial environment, is used. Statistical analysis is used to monitor the decision trees performance and update its rules whenever the conditions are changed. Genetic algorithms could be used to reduce production time in real-time FMSs. Andrea Rossi andGino Dini proposed a real-time scheduling to establish an algorithm capable of dynamically changing according to its environment [13]. The number of iterations required to produce an optimal scheduling system using a genetic algorithm should be minimized using an evolutionary minimizing strategy.

2.3 FMS Scheduling

The definition of scheduling is "a decision-making process, which plays an important role in most manufacturing and production systems as well as in most information processing environments. It is also important in transportation and distribution settings and in other types of service industries "[14]. From control point of view, the scheduling in any FMS represents the short-term control level. Scheduling can be divided into four types:

- Timing scheduling: when one inserts an order or task into the system.
- Sequencing scheduling: ordering of task to be inserted in the system.

- Routing scheduling: where to send a task for execution by a suitable machine.
- Priority setting: setting the priority for operations, tasks, machines, tools, and other resources. Scheduling is a processing control algorithm that is commonly used in industrial environments including FMS. It organizes multiple tasks in order to reduce the production time required for the process.

Several researches have been implemented in the field of FMS scheduling. The scheduling methodology depends mainly on the architecture of the FMS and concepts used in the design of the applied algorithms. Robotic material handling system with a heuristic-based scheduling algorithm was applied to solve robot scheduling problem in make-to-order environments for mass customization to maximize production[15]. The FMS consists of nine process stations, one loading/ unloading station and a rotary robot. The robot is used to transport parts among a loading/unloading station and process stations. Another FMS system that uses paper dealing with Automated Guided Vehicle (AGV) as material handling system[16]. Ant colony optimization technique was used in the design of the AGV scheduler to reduce the systems production time and increase its production efficiency. This was achieved by applying a unique scheduling algorithm that utilizes the production load of the system and organizing the workload of an AGV systems.

Multi criteria dynamic scheduling methodology was proposed by Shnits Rubinovitz and Sinreich to control a FMS using two control algorithms [17]. The first one is concerned with routing the workload, and the other is specified for utilizing the workload on each machine. This methodology was implemented by simulating the required work path and deciding the best way for operation.

F.T.S. Chan et.al proposed a method for evaluating scheduling systems, where a real-time scheduling approach was proposed using pre-emptive method for machines dispatching rules in an FMS [18]. The dispatching rule is changing dynamically, through a series of computation and evaluation on the system's performance criteria. Five general-purpose machine workstations and one loading/unloading station are used as an application for the algorithm. The obtained result showed minimum mean flow time, mean tardiness, and mean earliness.

On the other hand, scheduling robustness of a complex FMS was conducted by Olivier Cardin et.al, the experimentations on a complex flexible manufacturing system has been done in order to determine whether or not the flexibility of the group scheduling method can absorb uncertainties. The idea was to introduce flexibility during the predictive phase in order to obtain a robust schedule to absorb the perturbations during its execution. This is called proactive scheduling. This algorithm was applied on six machines job shop, with automated transfers. Each machine has a finite capacity upstream queue. Automated transfers between machines are performed by 42 unidirectional transporters, stored in a store house during the inactivity periods [19].

A novel scheduling approach that uses genetic algorithms to schedule a FMS is proposed by A. Prakash et.al. [20]. Three AGVs were used with three machines and three load/unload stations. The obtained results showed enhanced throughput and mean flow time in the scheduling system.

Fuzzy scheduling algorithms are efficient methods compared with conventional scheduling algorithms [21]. A fuzzy scheduler designed for complex systems is used and compared with other scheduling algorithms. Simulation of real-time FMS was used with workload during the evaluation and design process. The results showed that a probability driven scheduler showed better outcome than standard scheduling algorithms (conventional mathematically based algorithm). To be more exact, the used fuzzy scheduler provided a 10% improvement in production time than standard conventional scheduling algorithms.

There are numerous ways for analyzing the efficiency and routing job priority for any scheduling system. This work focused on establishing an efficient method for routing analysis and priority. Maximizing the load distribution for the utilization of four machines that have different tools and magazines is the main objective of the research work [22].

2.4 Summary and Work Novelty

Work novelty in this thesis includes establishing a fully interfaced system using LabVIEW environment. Compared with previous literature reviews, the proposed FMS system has an additional layer of scheduling. The first scheduling algorithm for operation sequencing, the second one for task sequencing, while the third scheduler is for routing. Most of published papers use one or two scheduling modules for scheduling and/or routing. In addition, this research presents a fully graphical representation of the proposed FMS showing all machines in their real-time operation. This provides a user-friendly advantage for this proposed research.

Chapter Three

THE PROPOSED FLEXIBLE MANUFACTURING SYSTEM

A simple FMS system has been designed and implemented using LabVIEW design environment. The interface system is divided into two main windows; the user interface screen, and the control interface window. The user interface screen includes several machines and system sequence visualizations. The control interface window includes the control algorithm that manages the system operation. Manipulating the control interface screen causes the user interface screen to change according to the provided algorithm. This chapter discusses the system layout architecture and LabVIEW design of each element of the proposed FMS.

3.1 System Layout

Flexible manufacturing systems have different design layouts according to the distribution of the components and machines. Each layout has special design features and characteristics that makes it differs from others [23]. In general, there are five well-known layouts, show below;

1. In- line: the CNC machines are arranged in a straight line with the material handling systems. It consists of two types; the first one is the unidirectional layout in which the parts move in one direction as shown in Fig. 3.1 (a), and the second type is the bidirectional layout, in which the part moves in both directions to increase flexibility for the system as shown in Fig.3.1 (b).
2. Loop layout: It is distinguished by its circular handling system that serves the parts to machines distributed alongside with the handling system. To transfer parts between the handling system and the machines, a secondary handling system is installed on each machine. This design has its load/unload station connected to it at the end of the path, as shown in Fig.3.1 (c). The rectangular layout is an alternative design for this layout, that allows for returning the part to its initial position by separating the load and unload station as shown in Fig.3.1 (d).

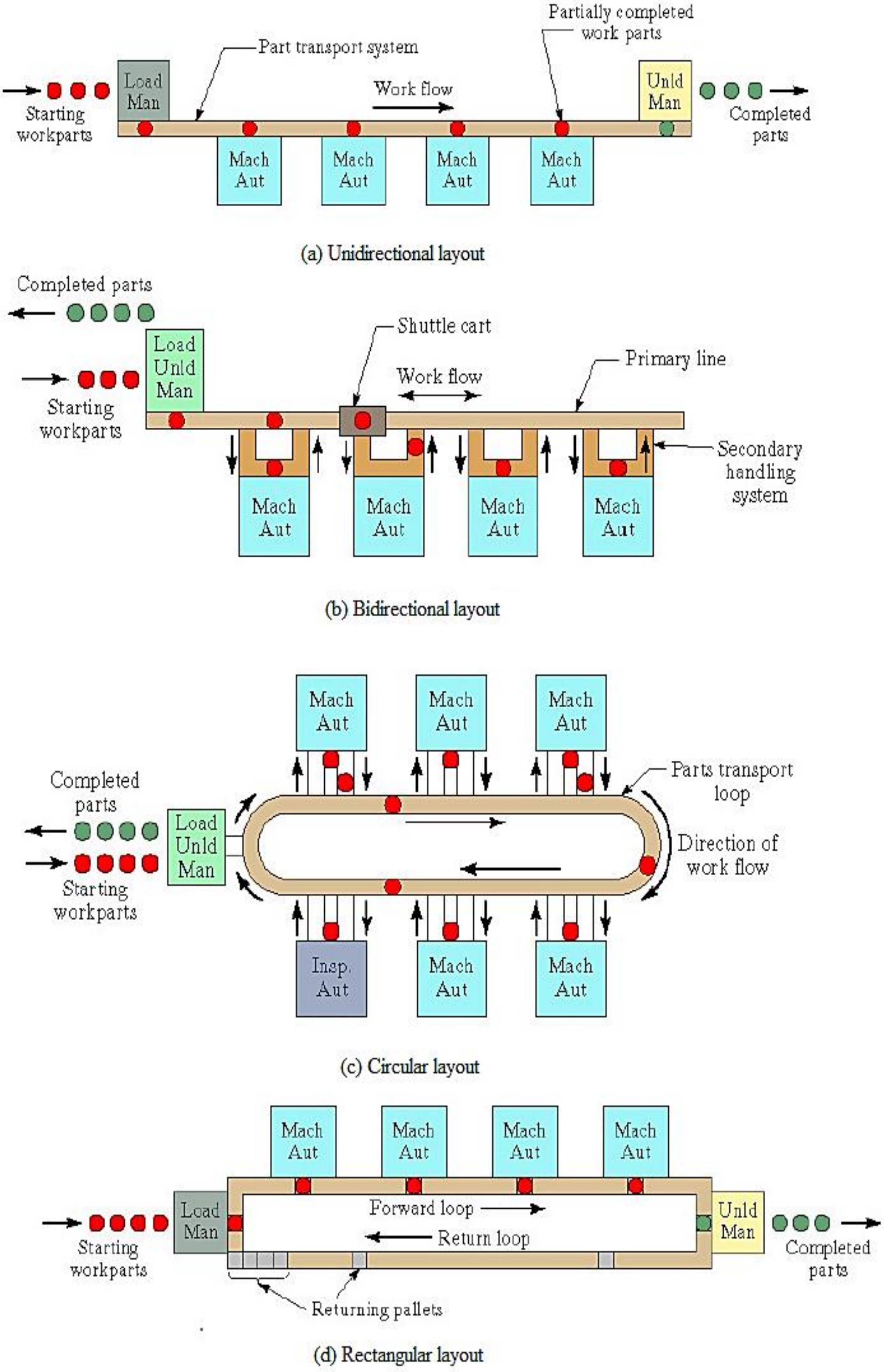

Figure 3.1: FMS layouts [23].

3. Ladder layout: it consist of multiple distributed loops over each rung increases the ways between the machines, and eliminates the need for secondary handling systems as shown in Fig.3.2 (a).
4. Open field layout: it consists of multiple loops and ladders. It is used to distribute large numbers of parts while having limited programmable machines, as illustrated in Fig.3.2 (b).
5. Robot-centered layout: a robotic arm is used as the main handling system, while the different programmable machines are distributed around the robotic arms, as given in Fig.3.2 (c).

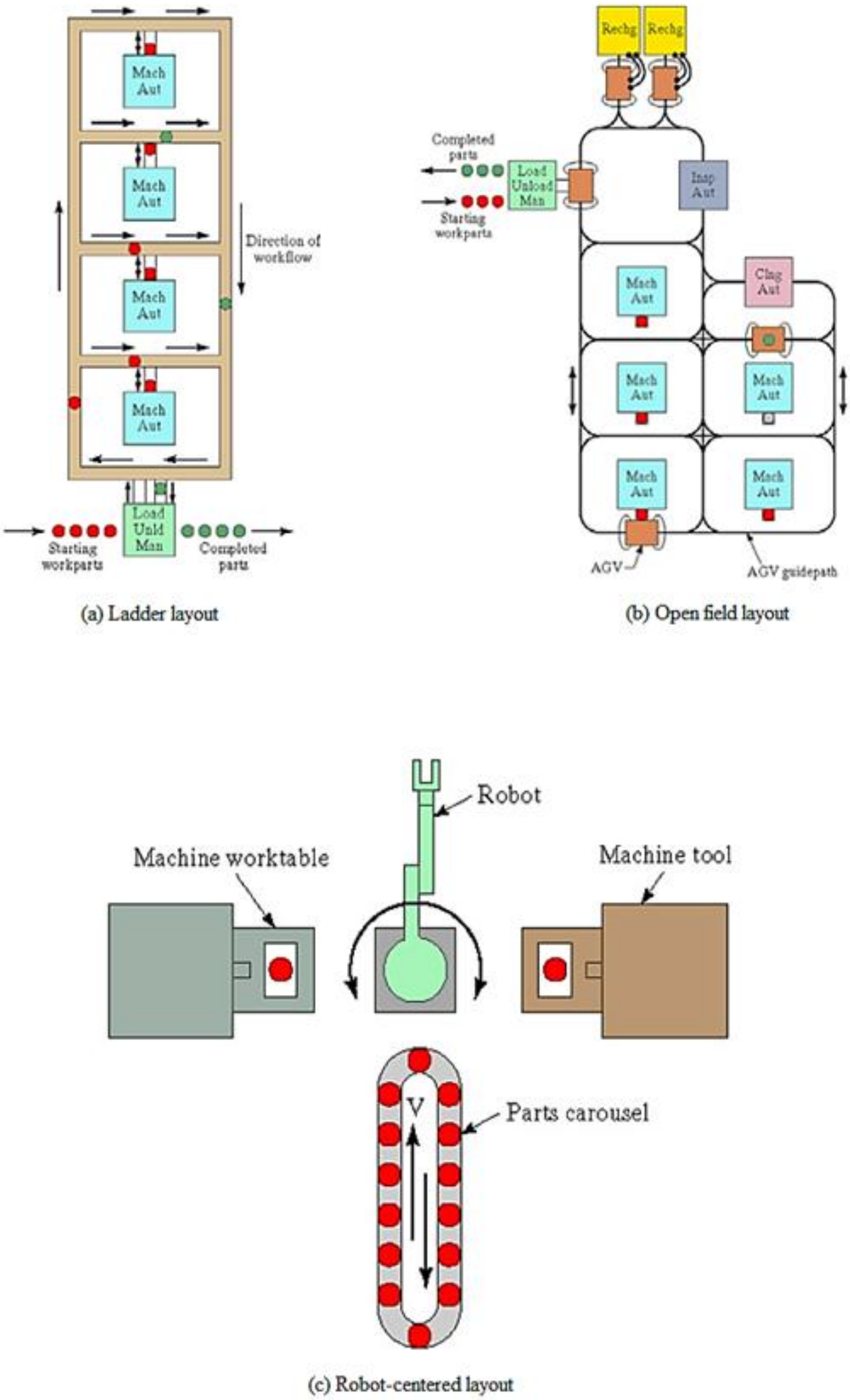

Figure 3.2: Further layouts of FMSs [23].

3.2 LabVIEW Environment

LabVIEW stands for (Laboratory Virtual Instrument Engineering Workbench) developed by National Instruments company [24]. It is a development tool that uses graphical programming language to simulate and control engineering applications. LabVIEW has numerous tools for development, storing, data basing, simulation, control and display. Figure 3.3 shows the main screen for LabVIEW in order to create new Virtual Instrument (VI) and to create a new project or load an existing project in addition to various options regarding configuring the project.

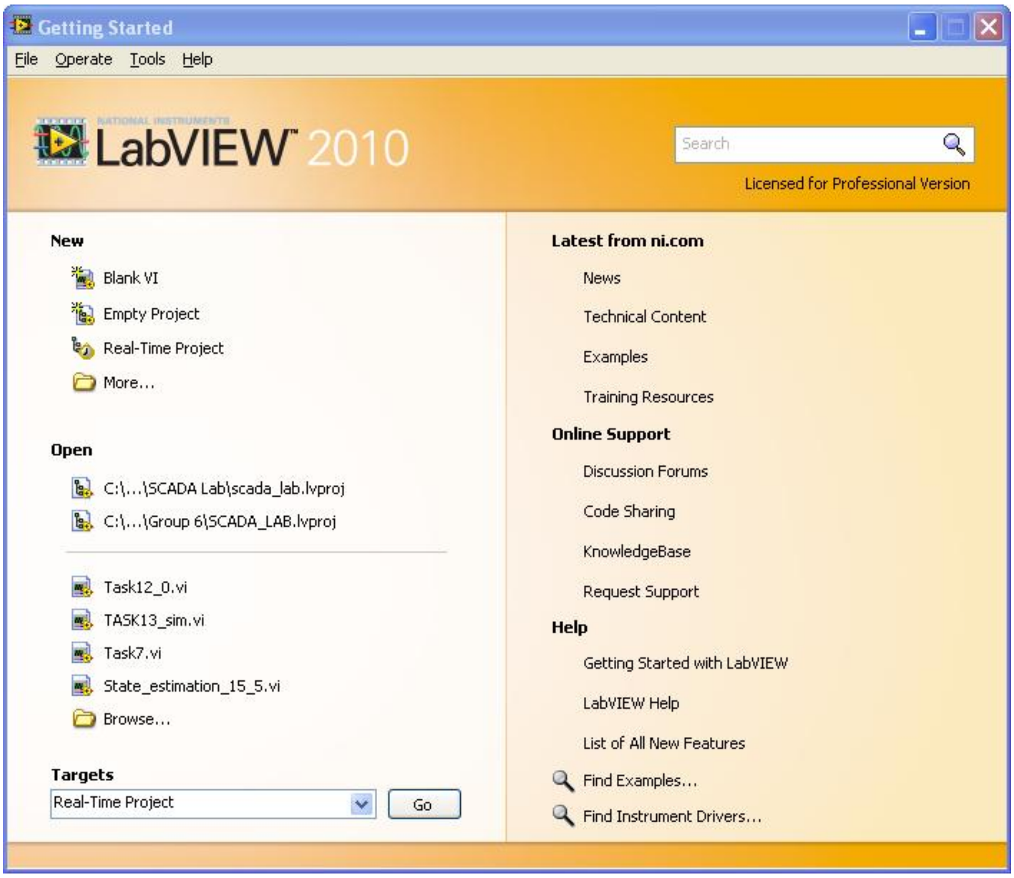

Figure 3.3: Main labVIEW entrance screen [24].

Once a new blank VI is opened a front panel page appears that consider one of the two main labVIEW window screens that are used to establish a new VI. The other window contains the block diagram. The front panel window has control and indication buttons that define the interactivity of the input and output terminals of the VI. The control buttons are knobs, push buttons, dials and various input devices. While the indicator buttons are graphs, LEDs and other display instruments. Control buttons supply the block diagram VI with data while the indicators simulate the instrument output and display the acquired data or the result of the generated data in the controls as shown in Fig 3.4.

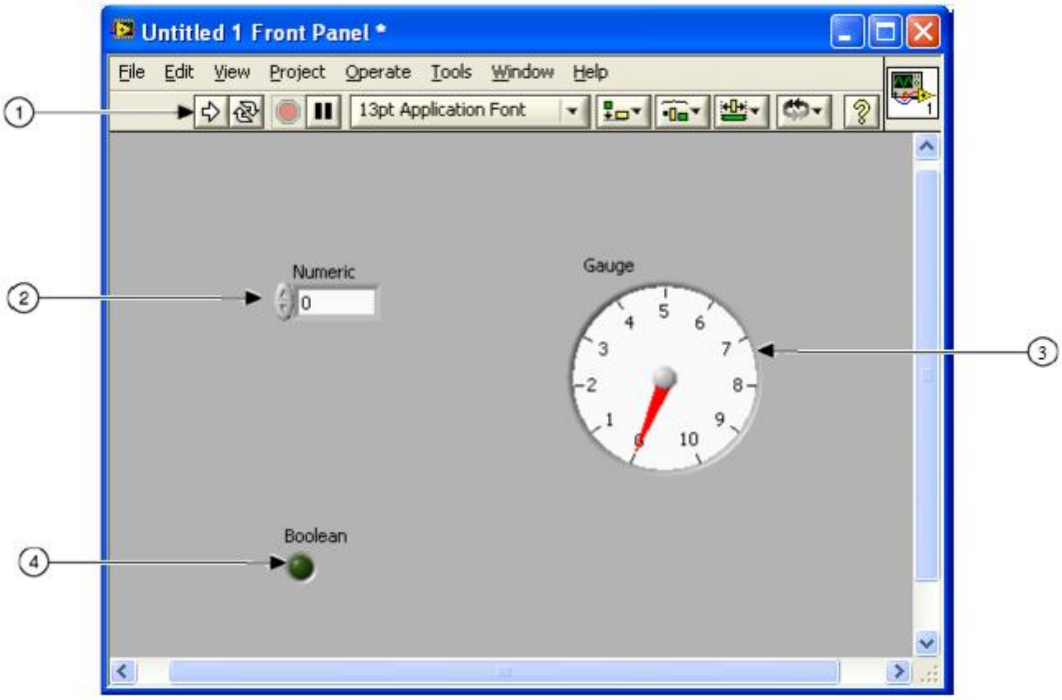

Figure 3.4: LabVIEW front panel window [24].

The component shown in Fig 3.4 are as follows:

1) Tool bar: it is a group of icons represents shortcuts that can be clicked to perform functions related to the icon.
2) Numeric variable: it is a bar used to insert numerical data to the block diagram window.
3) Numeric indicator: it is used to input numerical data to the block diagram window.
4) LED indicator: it is used to output Boolean data from the block diagram window in a light system interface.

To control the front panel screen of the VI window, a graphical representation of the code is required. The interface screen appears as a terminal in the programming code screen, then the data is transferred between the interface and coding block diagram screen, as illustrated in Fig. 3.5. This step is initiated after building the interface screen.

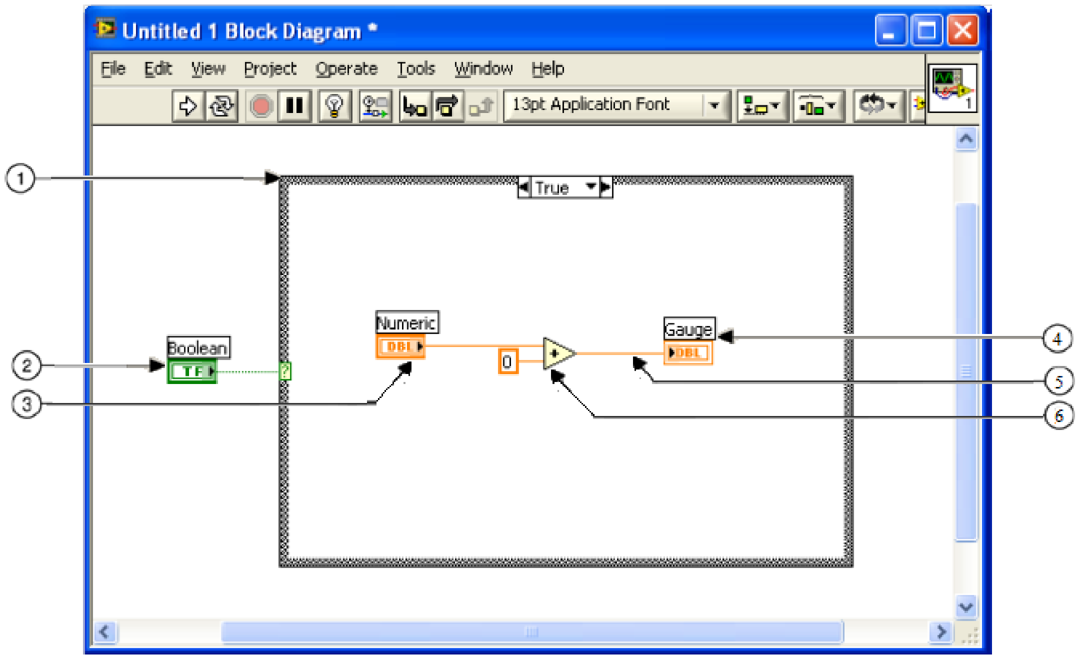

Figure 3.5: Block diagram window [24].

The graphical representation of the code is initiated in the block diagram page. It shows a reassembled flowchart of the interface function which is connected with wires, functions and subVIs that transfer data among the chosen blocks. As illustrated in Figure 3.5, the following component are used;

1) Switch case structure: it is used to implement a switch case scenario within the labVIEW block diagram window.
2) Boolean constant: it is used to input Boolean data to the block diagram window.
3) Numeric variable control: used to transfer data from the interface screen to the block diagram window.
4) Output control terminal: it is used for displaying numeric data in LabVIEW applications.
5) Wire data path: connects a certain data terminal with another data terminal.
6) Summation function: it represents a summation process between two integers.

The Data logging and Supervisory Control (DSC) library of the LabVIEW development environment includes many visual images that can be used in building the FMS. Using such a tool provides numerous advantages, as it adds the opportunity to update and add new libraries to the academic research. It also offers tools and instrumentations that allows for testing theoretical concepts while offering graphical simulation system design and performing complex computations [24]. Appendix (A) gives more information regarding design and constructing a suitable project using LabVIEW.

3.3 The Proposed FMS Layout

Throughout the literature review, it is found that most of the research papers consider an FMS with four programmable machines together with a source of handling unit [25], [26], and [27]. Material handling units varies from system to another. In this research, the proposed FMS has four programmable machines; two machines are used for drilling while the other two for milling, along with a single load/unload station. These machines are distributed along the load/unload stations throughout a conveyer belt, as shown in Fig.3.6.

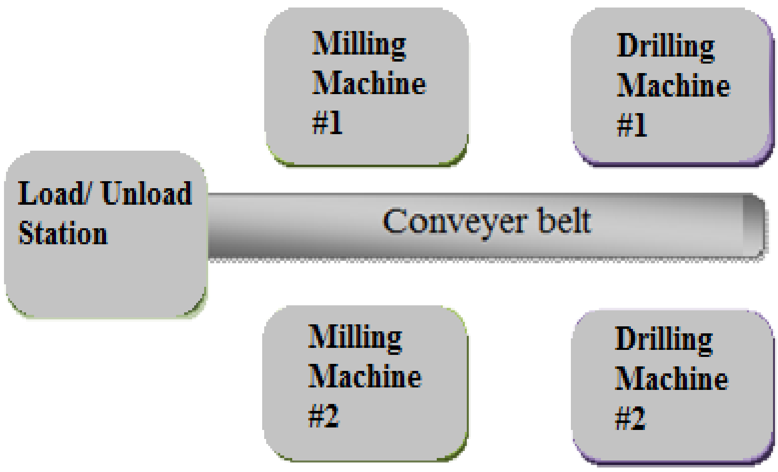

Figure 3.6: Layout of the proposed FMS.

3.3.1 Drilling machine specifications

The proposed drilling machine is a Medium Density Fiberboard (MDF) woodworking multi drilling machine. This machine has been selected in this research to perform drilling operation [28].

Objects from the DSC library can be inserted as shown in Fig. 3.7. These objects have many items categories that can be used to build any Supervisory Control And Data

Acquisition (SCADA) system or user visual simulation. Figure 3.8 illustrates the design procedures used to realize the required drilling machine.

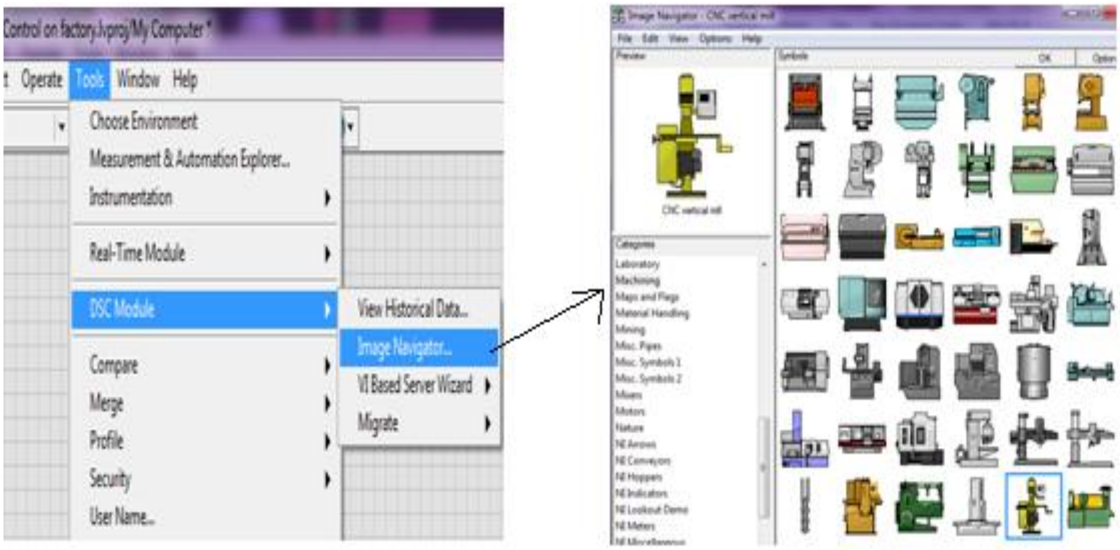

Figure 3.7: DSC library- image navigator for drilling machine.

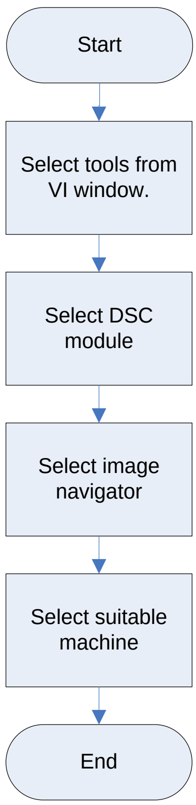

Figure 3.8: LabVIEW procedures to select required machine

3.3.2 Milling machine specifications:

The CNC Mill 5400 machine has been chosen in this research. This machine can operate with various materials including plastic, wax, wood, aluminum and brass. The machine has four motors; two of them are responsible for the movement of the work piece on the X-axis, and the Y-axis. The third motor is spindle responsible for the feed process which is connected to a forth motor that controls the movement on the Z-axis. The linear movement across the X-axis and the Y-axis is accomplished using lead screws attached to the motors [29].

The selected CNC milling machine is similar to a real CNC machine available in the Mechatronics engineering department. It is mainly specified for milling operations, and it can be used for minor drilling operations, if necessary. Figure 3.9 shows the X-axis, and Y-axis movement for the motors of the CNC mill 5400 machine.

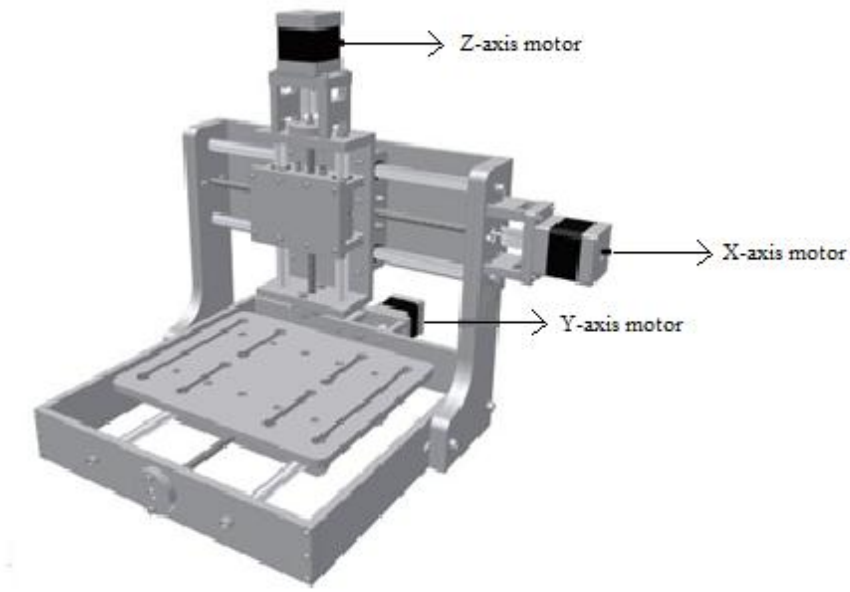

Figure 3.9: X-axis, Y-axis and Z-axis motors for the CNC machine [30].

The DSC library has many items categories that can be used to build the desired milling machine, as shown in Fig. 3.10. Now, the same selection procedure given in Fig.3.7 can be used in realizing the required milling machine.

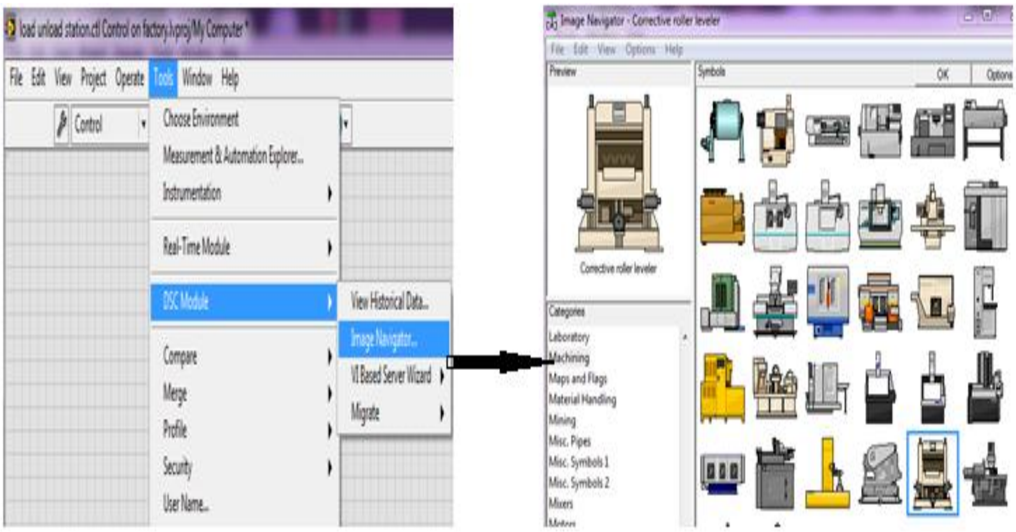

Figure 3.10: DSC library - image navigator for milling machine.

3.3.3 Load /unload station and conveyor belt

In any FMS, there is a need for load/unload station that is responsible for receiving the work piece as soon as it arrives and after the operation is finished. As illustrated in Fig.3.11, a suitable conveyer belt and load/unload station have been selected as a material handling system. For load/unload station and conveyor belt realization, the same design procedure, given in Fig.3.8, can be applied.

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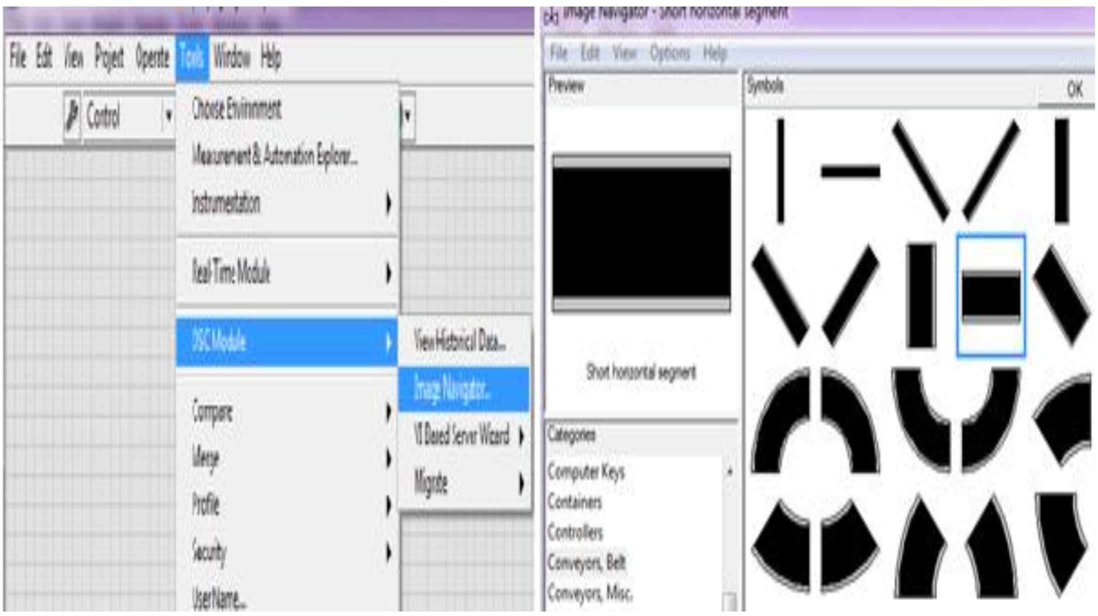


Figure 3.11: Library - image navigator for load/ unload station and conveyor.

3.3.4 System synchronization

Pneumatic cylinders and proximity sensors are required in the FMS design to synchronize the movement of several parts. As illustrated in Fig.3.12, the DSC library has several cylinders, and according to the system design requirements, you can select the suitable one using the same procedure given in Fig.3.8.

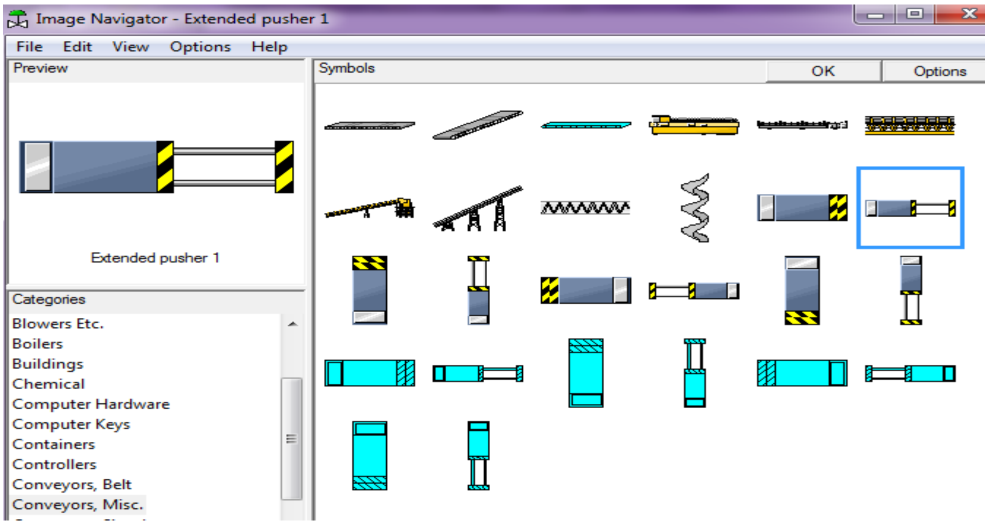


Figure 3.12: DSC library - image navigator for cylinder.

The Light Emitting Diode (LED) indicator can be used to represent the function of the proximity sensor, as shown in Fig.3.12.

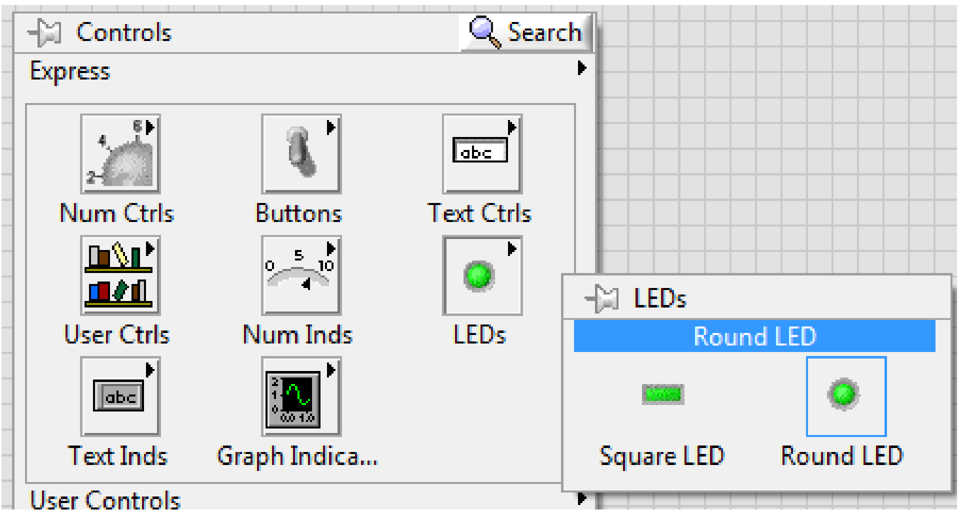


Figure 3.13: Insertion of the LED indicator.

3.4 Summary

The overall layout of the proposed FMS system is given in Fig.3.14 that represents the front panel final layout of the system that was built using LabVIEW. It contains all interface components used for the FMS design. These component can be classified as the following:

1. Output components: LEDs indicators, Tables of results, and system machines.
2. Virtual components: the parts motion.
3. Input components: specify the workloads of the system.

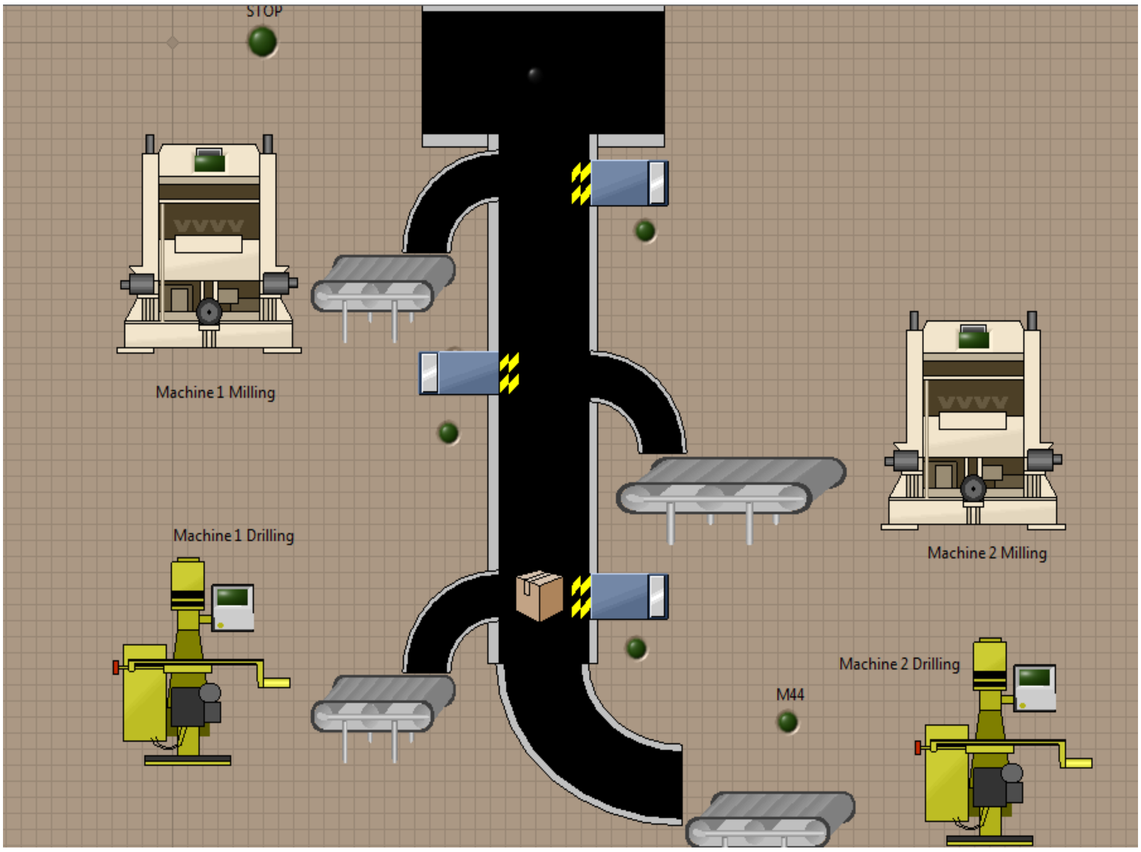


Figure 3.14: Final system front panel layout for user interface.

The control panel screen for the shown layout is given in Fig. 3.15 that uses flat sequence instructions for programming. Which is a programming technique that uses prearranged switch cases connected to together in series.

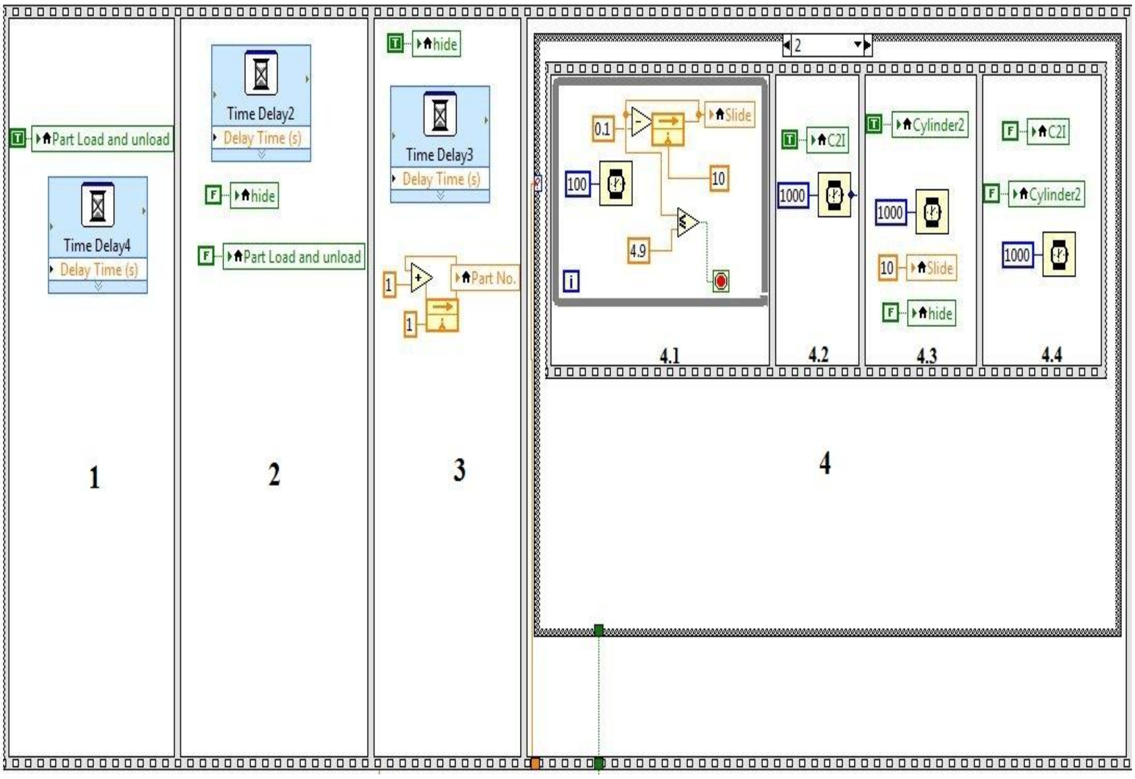


Figure 3.15: Control panel for the front panel layout.

The organization of the flat sequence is shown as numbers from one to four; where the sequence of the execution process starts from left to right. The first sequence should be completed before starting the second sequence and so on. The function of each sequence in Fig. 3.15 is illustrated as follows:

1. Sequence (1): is responsible for animating the work piece over the load/unload station. a time delay is used to show the animation in progress.
2. Sequence (2): is responsible for hiding the work pieces on the load/unload station.
3. Sequence (3): is a counter that counts the number of work piece that enters the system.
4. Sequence (4): is responsible for programming the work pieces movement from the conveyer belt to the required machine. This sequence is divided into four subsequences as follows:

   4.1 The work piece is delivered from the conveyor belt that has a length of ten units and every machine location is set on the conveyor belt to the required machine. The case shown in Figure 3.15 represents the code for moving the work piece to machine (M2). Where the location of M2 is set to 4.9 units along the conveyor belt. As soon as 4.1 sub sequence starts the work piece starts moving and the required distance is reduced by 0.1 unit per cycle until the work piece reaches the required destination.

4.2 This subsequence is responsible for the proximity sensor that indicates the arrival of the work piece to M2. A time delay is set to show the indication of the arrival in a LED interfaces way.

4.3 This subsequence is responsible for operating the pneumatic cylinder that pushes the work piece to M2.

4.4 This subsequence is responsible for turning off the LED interface indicator and retracting the pneumatic cylinder.

The above sequences are replicated for the operation of every machine in the proposed FMS.

Chapter Four

DESIGN OF SCHEDULING ALGORITHMS

Scheduling of an FMS is not an easy task, specifically in real-time dynamic environments. The main objective of scheduling in any FMS is to reduce the processing time in order to increase the benefit of production. Using fuzzy-based scheduling algorithm gives a powerful tool in systems flexibility. Scheduling and routing procedures depend on several parameters related to the FMS architecture and processing time. This chapter covers the design and realization of operation/tasks sequence scheduling and routing for a real-time flexible manufacturing system.

4.1 Definitions and Assumptions

In this research the sequence scheduling is divided into two parts; sequence of operations and sequence of tasks that are put inside of the operation. Two parameters are considered for operations sequence scheduling, Arrival Time (AT) and Due Time (DT). Three parameters are considered for sequence tasks scheduling, Processing Time (PT), Due time (DT), and Number of Tasks (NT). While for the task routing other three parameters were considered, Work in Queue (WIQ), Traveling Time (TT), and Processing Time (PT). These parameters have great impact on system's performance [31], [32], and [33]. The following definitions and assumptions are used to describe the fuzzy scheduler's parameters:

- Operation: an organized activity that requires multiple tasks that differ from one product to another.
- Task: a summation of a group of tasks generates an operation, if the operation is a chair or table, the task refers to a combination of work pieces that are made of wood, wax or plastic.
- Processing Time (PT): the time required to complete a certain task.
- Due Time (DT): the time limitation to complete the operation on the part depending on the customer's need.
- Arrival Time (AT): the instant at which the work piece arrives to the load/unload station.

- Work In Queue (WIQ): the minimum time period that indicates the machine which has least time for work in queue.
- Traveling Time (TT): the time required to transfer the work pieces from the load/unload station to the specified machine. [34].
- Number of Tasks (NT): the number of tasks in each operation.
- Operation Sequence Priority (OSP): the order of operations.
- Task Sequence Priority (TSP): the order of the tasks at hand.
- Priority Routing (PR): the suitable machine for the next task.

4.2 Fuzzy-Based Scheduling

The implemented FMS contains multi input operations, each operation consists of multiple tasks. Three fuzzy algorithms are used to perform the scheduling and routing operations for the entire system. The first algorithm is used to define the sequence priority of operations, the second algorithm defines the sequence priority of the tasks, while the third algorithm defines the routing priority to select the suitable machine for executing the selected task. A fuzzy-based scheduling algorithm has its benefits over conventional scheduling algorithms for the following reasons:

- It uses both the numerical results from previous operations and scheduling experiences from previous observations, and it is easy to use.
- The fuzzy scheduler has an interpolation property that allows the system to be stable in regions that are not previously determined.
- Easy to simulate, modify and applied on various system.
- Fuzzy logic provides a simple and flexible way to arrive at a definite conclusion based upon imprecise, noisy, or incomplete input information.
- Improves the characteristics of the real-time system itself.
- Any real-time system can be used as the target of a fuzzy scheduling algorithm [35].

The proposed fuzzy scheduler has four units: the fuzzification unit, the inference engine unit, the rule base, and the defuzzification unit, as illustrated in Fig. 4.1.

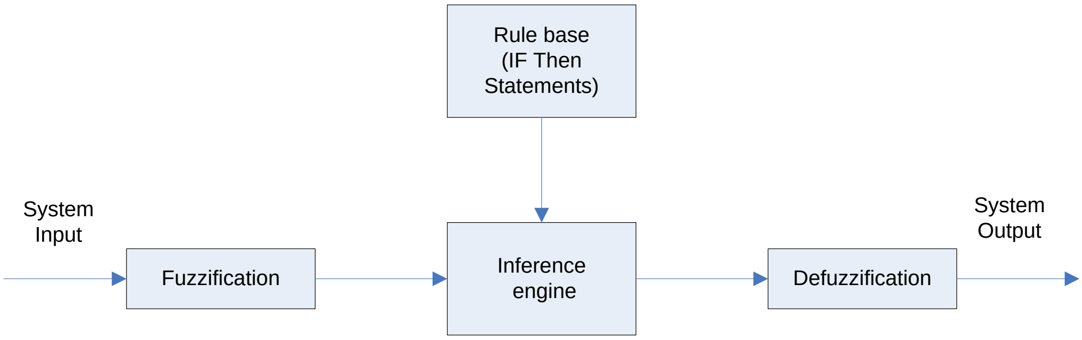


Figure 4.1: Fuzzy logic general elements

The Fuzzification unit is responsible for transforming the crisp input into fuzzy set. The fuzzy sets are processed by the inference engine for defining the fuzzy output signal. The inference engine uses the fuzzy sets and the rules (defined by the user) to generate the proper fuzzy output vector. The output is then sent to the defuzzification unit where it is returned to its crisp format and sent to the system.

4.3 Fuzzy-Based Sequence Scheduler

The fuzzy sequence scheduler is used to improve the performance of the tasks management system by assigning new priority for each operation and task in operation according to its input parameters as illustrated in Fig. 4.2. The sequence scheduler is divided into two main categories:

4.3.1 Operation Sequence Scheduler

The operation sequence scheduler has two input variables (DT, AT) and single output variable (OSP). Each input variable has three fuzzy sets; Low (L), Medium (M) and High (H). The output variable (OSP) has six fuzzy sets: Minimum (Mn), Small (S), Medium (M), High (H), Very High (VH) and Maximum (Mx), as shown in Fig. 4.3.

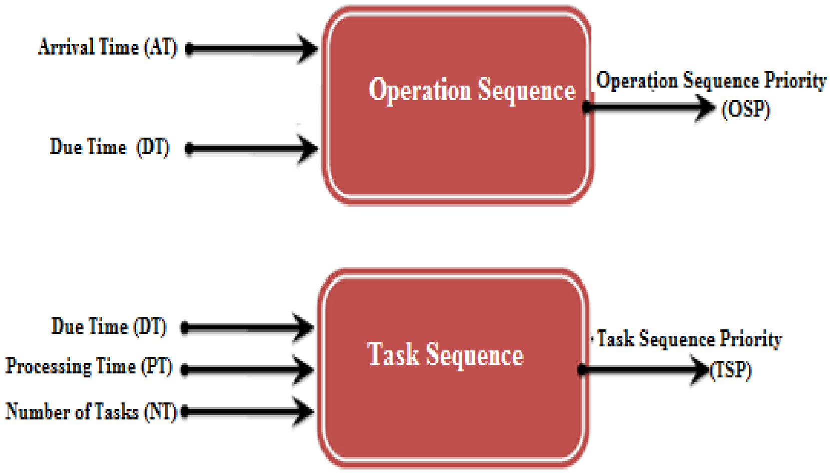


Figure 4.2: Fuzzy-based sequence scheduler.

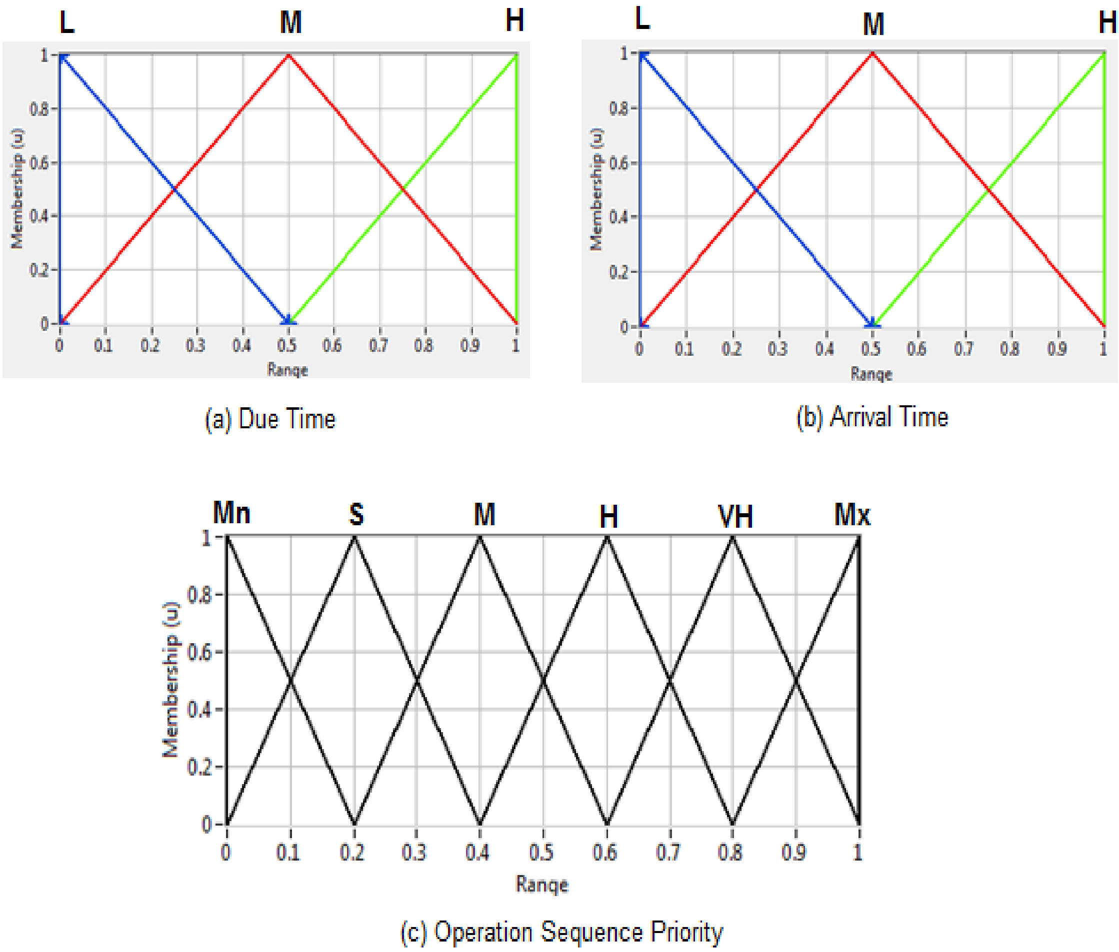


Figure 4.3 Membership function for operation sequence scheduler.

There are nine rules in the operation schedulers inference engine, each rule uses the previously mentioned input and output variables, as shown in Table 4.2. These rules use IF and THEN statement, for examples:

IF ATS AND DTM THEN OSPS

This means that if the arrival time is small and the due time is medium then the operation sequence priority is small. A defuzzifier is used to convert the output fuzzy set into a crisp value by using center of gravity (COG) method [36].

$$\mathbf{COG} = \frac{\sum_{\mathbf{i=1}}^{\mathbf{M}} \boldsymbol{\omega}(\mathbf{i}) * F(\mathbf{i})}{\sum_{\mathbf{i=1}}^{\mathbf{M}} \boldsymbol{\omega}\,(\mathbf{i})} \qquad [1]$$

where; ω(i): is the aggregated output membership function,

i: is the sample of points values on the interval from i to M.

Table 4.1: Operation scheduler rules.

DT	AT	OSP
S	S	Mn
S	M	S
S	H	M
M	S	S
M	M	H
M	H	VH
H	S	M
H	M	VH
H	H	Mx

4.3.2 Task sequence scheduler

The task sequence scheduler has three input variables (NT, PT, DT) and a single output (TSP), as illustrated in Fig. 4.2. Each input variable has three fuzzy sets; Low(L), Medium (M) and High (H). The output variable (TSP) has ten fuzzy sets: Too Low (TL), Very Very Low (VVL), Very Low (VL), Low (L), Normal (N), Somehow High (SH), High (H), Very High (VH), Very Very High (VVH), and Too High (TH), as shown in Fig. 4.4.

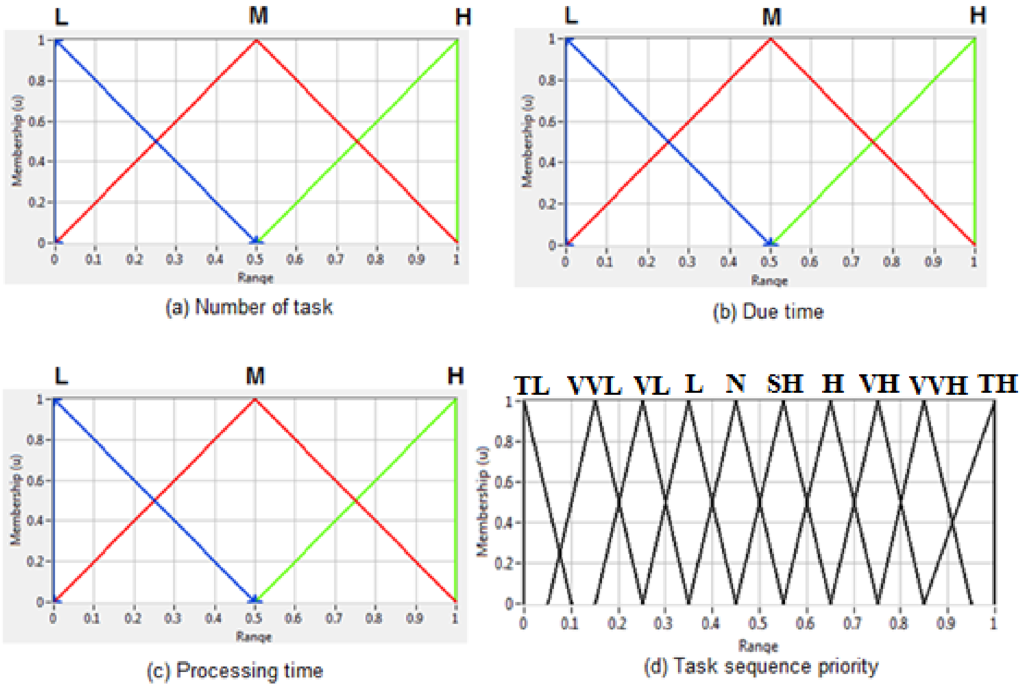


Figure 4.4: Membership function for tasks sequence scheduler.

There are twenty-seven rules in the task schedulers inference engine, each rule uses the previously mentioned input variables to produce a single output (TSP), as shown in Table 4.4. The fuzzy scheduler rules use IF and THEN statement, for examples:

IF NTL AND DTM AND PTH THEN TSPH

This means that if number of task is low and due time is medium and processing time is high then the task sequence priority output variable is high.

Table 4.2: Task Sequence Scheduler's fuzzy rules.

NT	PT			DT
	L	M	H	
L	VH	VHP	N	**L**
M	SH	VH	VVH	**M**
H	VVL	SH	VH	**H**
L	N	VH	VVL	**H**
M	TL	L	L	**L**
H	VVL	L	VVH	**M**
L	L	L	H	**M**
M	SH	L	N	**H**
H	TH	VVL	L	**L**

The Mamdani-style inference approach has been used in the scheduler design, the defuzzification process uses equation (1) as mentioned before.

4.4 Fuzzy-Based Routing Scheduler

As mentioned before, a fuzzy-based scheduler is required to specify the suitable machine for each task. Three input variables (PT,WIQ, and TT) and single output variable (PR) were considered in this scheduler, as illustrated in Fig. 4.5.

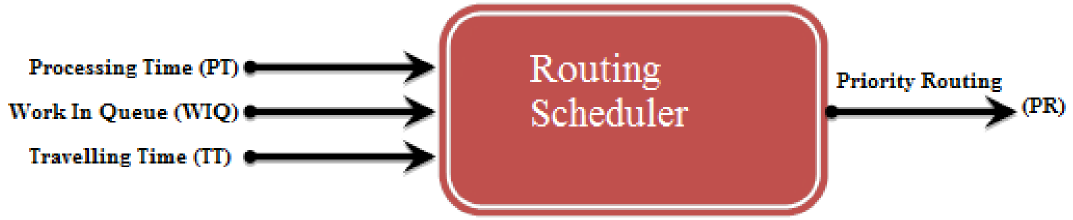


Figure 4.5: General layout of the routing scheduler.

Each input variable has three fuzzy sets: Low(L), Medium (M) and High (H). The output variable (PR) has ten fuzzy sets; Too Low (TL), Very Very Low (VVL), Very Low (VL), Low (L), Normal (N), Somehow High (SH), High (H), Very High (VH), Very Very High (VVH), and Too High (TH). Figure 4.6 shows the membership functions of the fuzzy sets used for input and output variables of the routing scheduler.

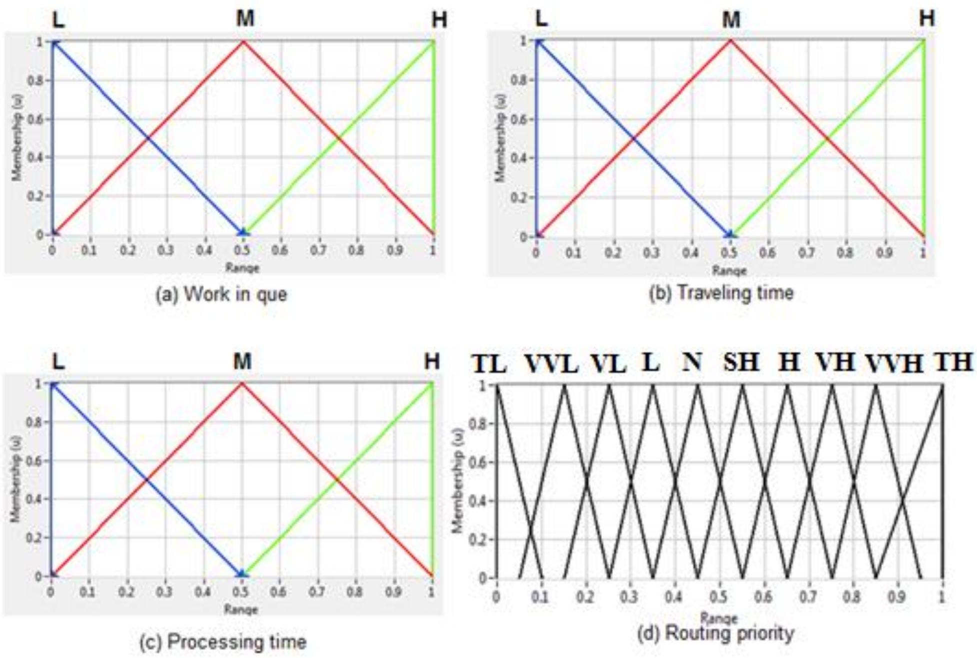


Fig. 4.6 Membership functions for routing.

There are twenty-seven rules; each rule uses the previously mentioned input variables to produce a single output (RP), as given in Table 4.6. Each rule of the fuzzy scheduler uses IF and THEN statement, for example:

IF TTL AND WIQL AND PTL THEN RPVH

This means that when variable the traveling time is low, and the work in queue is low, and processing time is also low then the routing priority is very high. The defuzzification process uses Mamdani- style as previously mentioned in equation (1).

Table 4.3: Fuzzy-based routing scheduler rules.

TT	WIQ			PT
	L	**M**	**H**	
L	VH	VVH	TH	**L**
M	SH	VH	VVH	**M**
H	TL	SH	VH	**H**
L	N	VH	VVH	**H**
M	VL	L	L	**L**
H	VVL	L	VVH	**M**
L	L	L	H	**M**
M	N	L	N	**H**
H	VVL	VVL	N	**L**

4.5 Fuzzy Scheduler Flowchart

As illustrated in Fig. 4.7, the fuzzy-based sequence scheduler calculates in real-time mode the priority of each operation order. Then the task priority is calculated for each task in the selected operation using the task scheduler. According to the task priority the routing scheduler will select the suitable machine to perform that task.

The routing scheduler select the suitable machine taking into account the following facts:

- Perform tasks with the highest priority for the selected operation.
- Select machine with no work or minimal waiting time.
- Select machine that perform tasks faster.
- Select nearest machine to reduce traveling time.

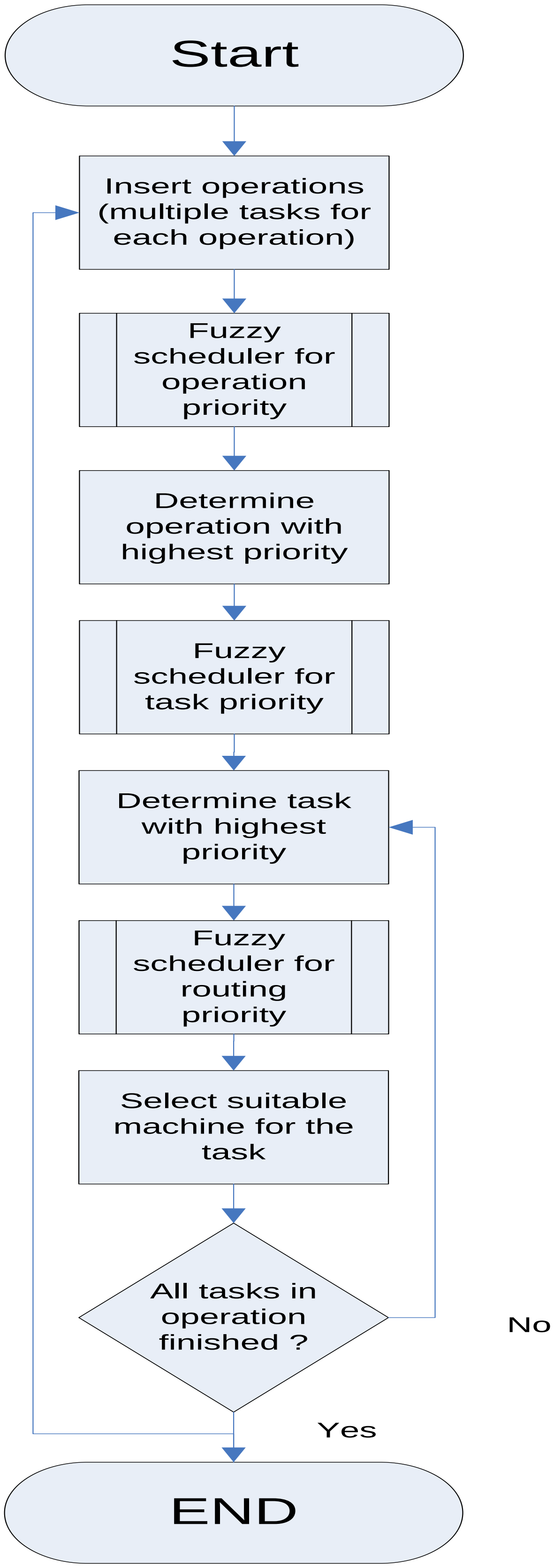


Figure 4.7: FMS scheduling flowchart.

4.6 Summary

In order to deal with the flexibility of the manufacturing system a fuzzy scheduling methodology has been designed and tested for the proposed FMS. The scheduling process has two parts: sequence scheduling and routing scheduling. Sequence fuzzy algorithms are used to determine the operation priority and task priority, while the routing scheduling is used to select which machine used for each task according to the task priority that has been given from the sequence step.

Chapter Five

SYSTEM ANALYSIS AND EVALUATION

The proposed FMS consists of four programmable CNC machines for drilling and milling operations. Also, it has a load/unload station along with a conveyor belt. This chapter demonstrates how the fuzzy schedulers optimize the time response for the proposed FMS by prioritizing the operations and their corresponding tasks according to suitable machine for each task.

The following points illustrate assumption made in the proposed FMS:

- The milling machine can do both milling and drilling operation but the drilling operation in milling machine will need more time to be performed.
- The drilling machine can perform drilling operations only.

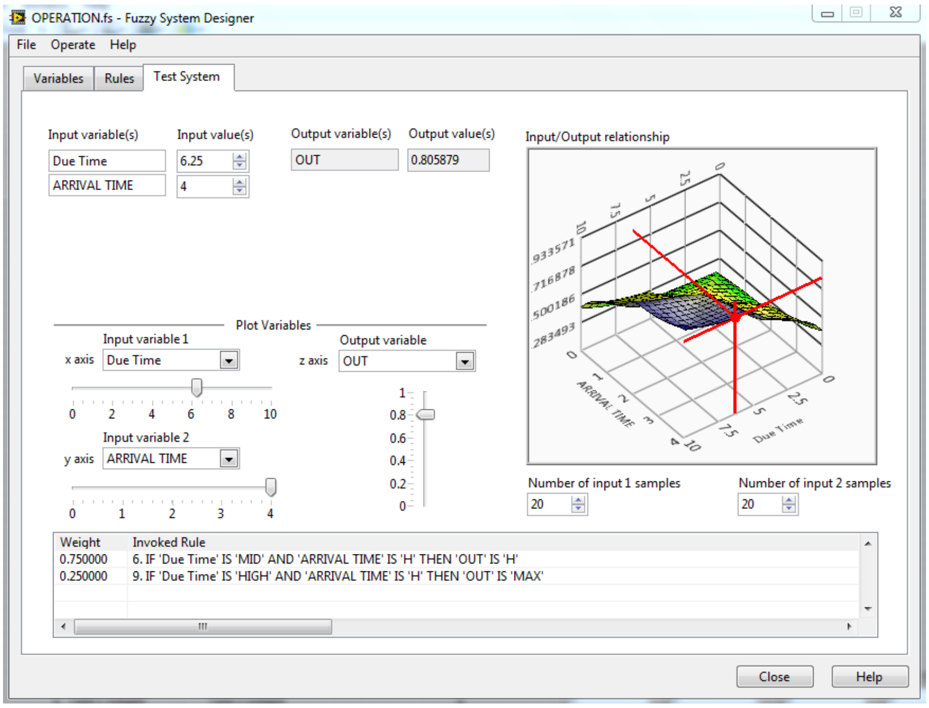
5.1 Operation Data Acquisition:

This section is concerned with data acquisition and implementation of the fuzzy scheduling algorithm for the operation sequence process. Table 5.1 shows the arrival time and due time for the given operations.

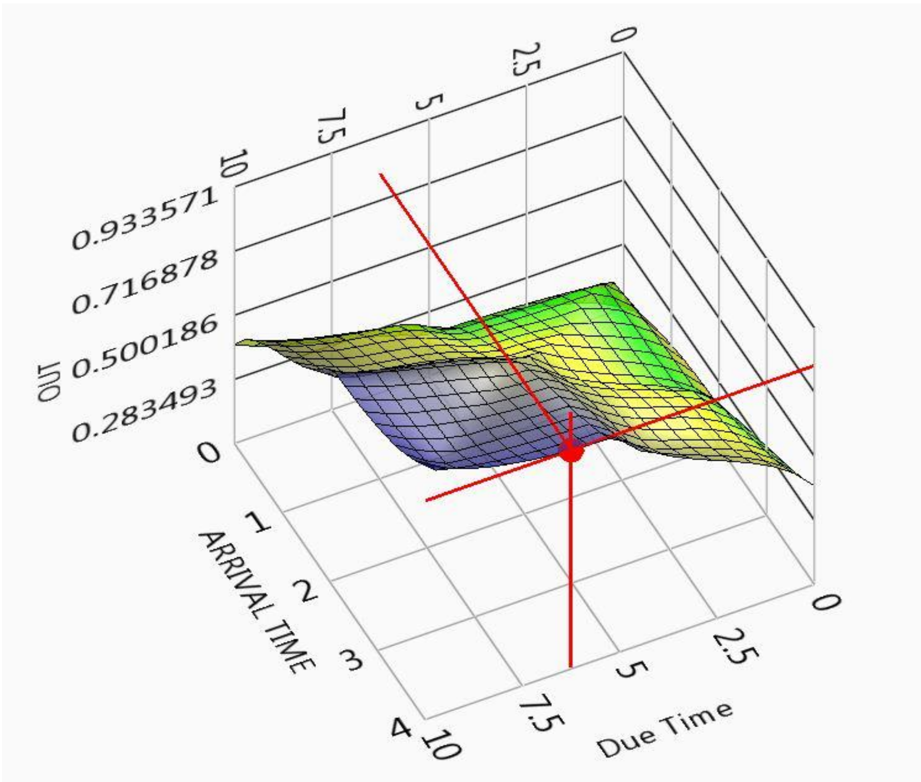
Table 5.1: Operation sequence parameters

Operations	Arrival time [pu]	Due time [pu]
Op1	2.8	9
Op2	2	5
Op3	1	8
Op4	4	6.25

Figure 5.1 shows operation priority calculation based on the given input parameters (due time and arrival time). A fuzzy-based operation sequence scheduler has been used to process the input parameters to obtain the priority of each operation. scheduler and the output data is obtained.



(a) Test system for operation priority



(b) Three dimensional graph of operation priority

Figure 5.1: Operation priority calculation using LabVIEW.

Figure 5.2 shows the acquired data from the LabVIEW environment, where the highest priority operation (Op4) has the largest weight value (0.690985). According to the calculated weight of each operation, the sequence of operation is; Op4 (first), Op1, Op3, then Op2.

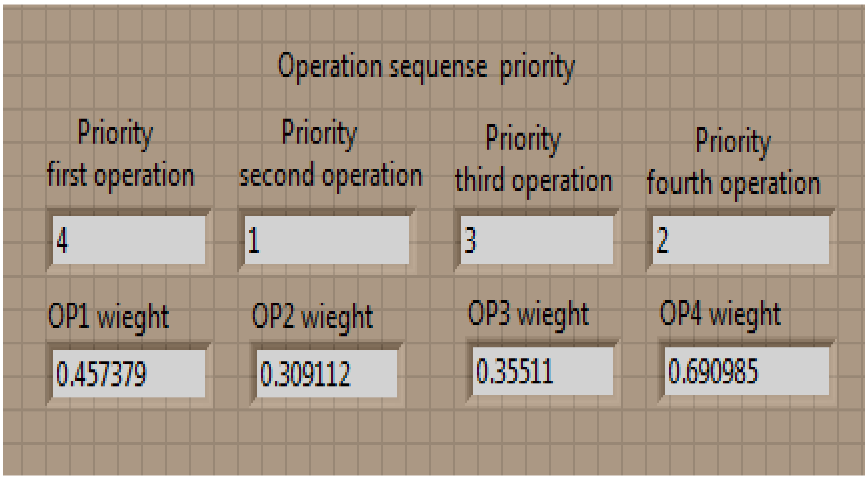
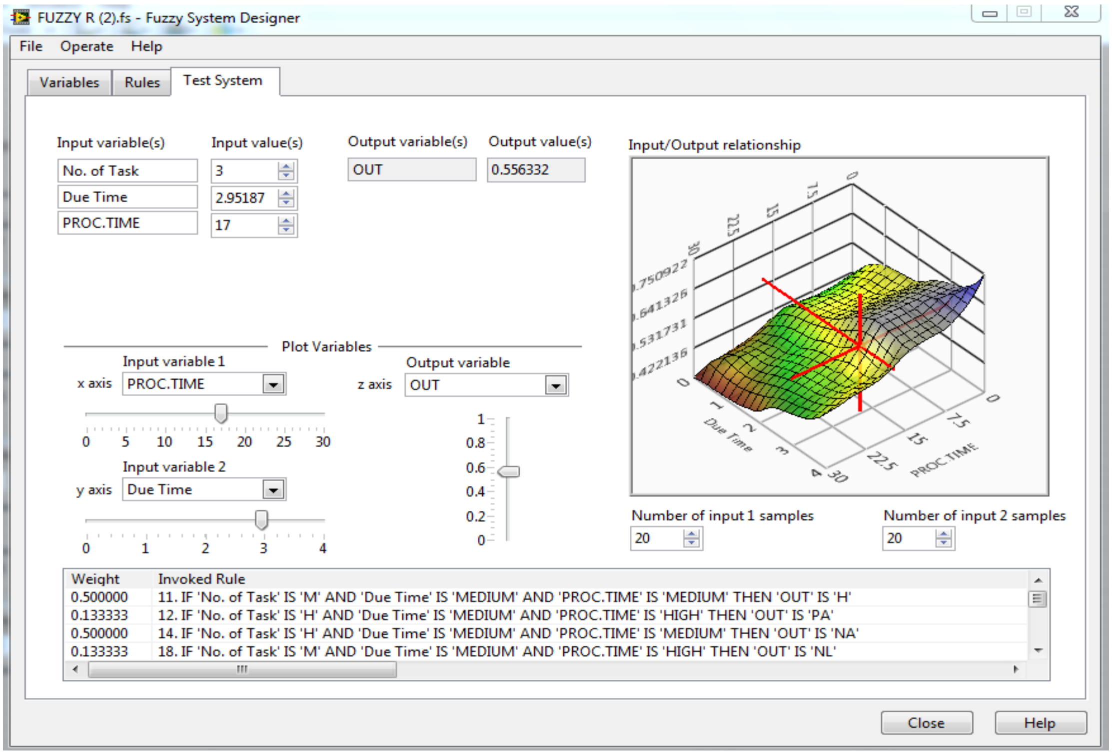


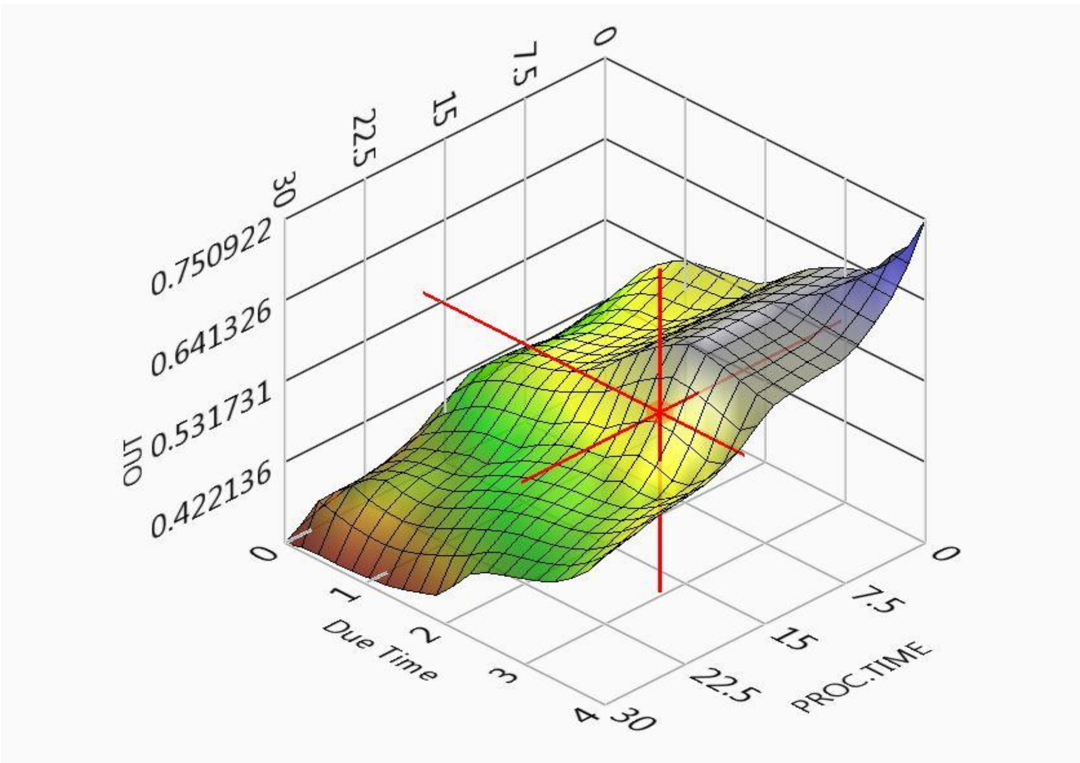
Figure 5.2: Acquired weight and priority for operation.

5.2 Data Acquisition Task:

As mentioned before, each operation has number of tasks to be performed by the FMS machines. In this case it is required to specify priority for each task using fuzzy-based task scheduler. Three input parameters (NT, DT, and PT) were used to calculate the priority for each task in each operation. Figure 5.3 illustrates the value of input parameters and effected rules used by the scheduler to calculate the weights (priority) of each task in each operation.



(a) Test system for task priority



(b) Three dimensional graph for task priority

Figure 5.3: Task sequence calculation using LabVIEW.

To verify the ability of the sequence scheduler for both operations and tasks within each operation the following case study has been considered. Four operations are to be performed by the FMS, where operation (Op1) has four tasks, operation (Op2) has two tasks, while operations (Op3 & Op4) has three tasks each. According to the input parameters of the given tasks, the scheduler will specify a certain priority for each task, as given in Table 5.2.

Table 5.2: Task sequence analysis.

Operation	Tasks	Due time [pu]	Number of task	Processing time [pu]	Weight value	TSP
Op 4	T1 milling	2.75	2	13	0.551132	3rd
	T2 milling	1.5	3	11	0.597803	2nd
	T3 drilling	2	4	18	0.731361	1st
Op 1	T1 milling	2	2	12.5	0.592905	1st
	T2 milling	1.75	4	8.5	0.317833	4th
	T3 drilling	2.25	3	5	0.510538	2nd
	T4 drilling	3	1	9	0.320153	3rd
Op 3	T1 drilling	2	2	12.5	0.53831	1st
	T2 drilling	2.25	4	8.5	0.528288	2nd
	T3 milling	3.75	2	12.5	0.510538	3rd
Op 2	T1 milling	2	1	17	0.387772	2nd
	T2 drilling	3	4	19	0.45434	1st

The scheduler assigns a weight value for each task embedded within the operations, as illustrated in Fig. 5.4. The sequence of operations and tasks are rearranged as follows:

Op4 (T3-T2-T1), Op1 (T1-T3-T4-T2), Op3 (T1-T2-T3), and Op2 (T2-T1).

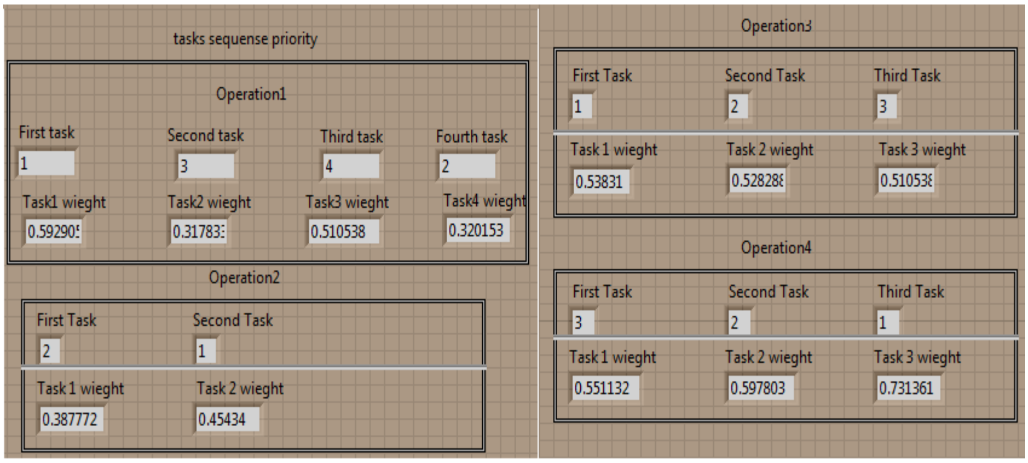
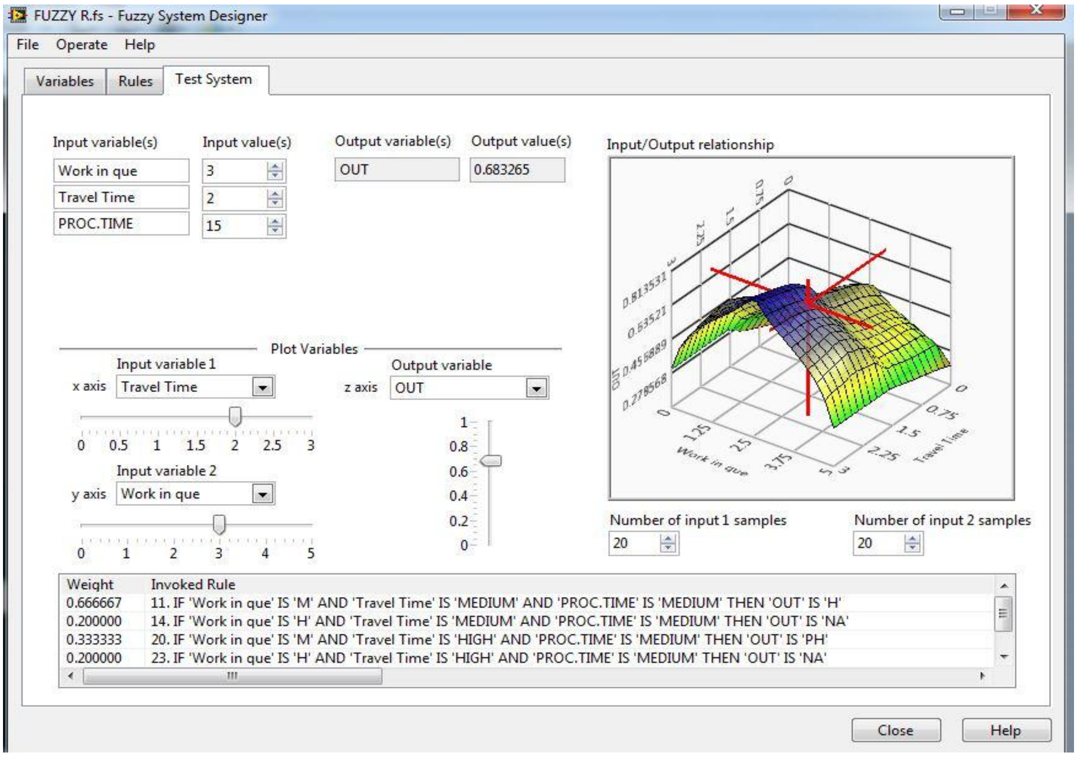


Figure 5.4: Weights for each task inside each operation.

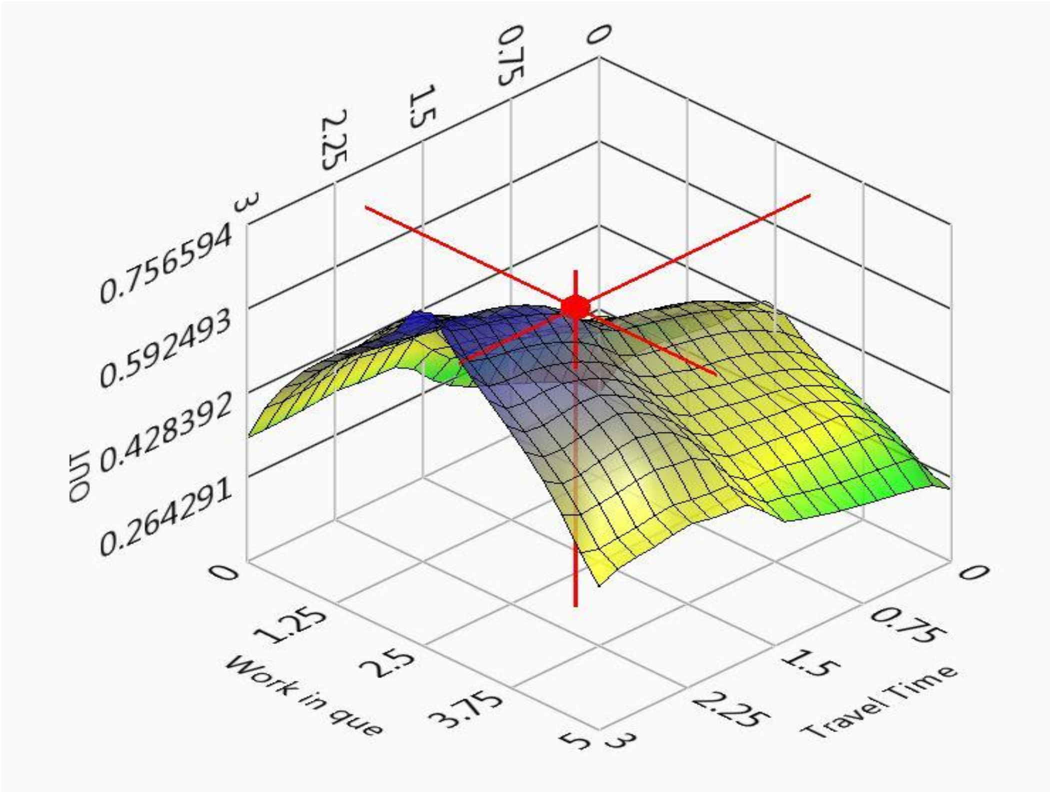
5.3 Routing Data Acquisition

The real-time control of the proposed FMS has two schedulers, sequence control, and routing control. The first scheduler is required to assign priority for each operation and each task in the operation. The second scheduler is necessary to choose a suitable machine to perform the selected task.

For task routing, three input parameters (WIQ, TT, and PT) were used to calculate the weight of each machine and then to specify which machine is suitable to perform the selected task for the given operation. Priority for each task in each operation. Figure 5.5 illustrates the values of input parameters and fired rules used by the scheduler to calculate the weight of each machine. This weight shows how a certain machine is efficient to perform that task. In this case the priority scheduler select machine with largest weight value.



(a) System test for routing



(b) Three dimensional graph for routing

Figure 5.5: Test system for routing algorithm

Table 5.3 shows selected machines to perform tasks of the given operations. It is clear that for operation (Op1), machine (M3) is used to perform task (T3), machine (M1) for task (T1), and machine (M2) for task (T1). In this case, the scheduler selects drilling machine (M3) instead of drilling machine (M4) because it is closer to the task (T3), where the weight value of machine (M3) is greater than that for machine (M4).

Table 5.3: Best machine route selection

Operation	Tasks	Machine Priority Routing				Selected Machine	Best Route
		M1	M2	M3	M4		
Op 4	T3 drilling	0.546168	0.547899	0.587942	0.577942	M3	3-1-2
	T2 milling	0.365882	0.364594	0.0000	0.00000	M1	
	T1 milling	0.365882	0.423990	0.0000	0.0000	M2	
Op 1	T1 milling	0.424605	0.423990	0.0000	0.00000	M1	1-4-3-2
	T3 drilling	0.566807	0.596067	0.587942	0.598112	M4	
	T4 drilling	0.566807	0.596067	0.598112	0.598112	M3	
	T2 milling	0.424605	0.458730	0.0000	0.00000	M2	
Op 3	T1 drilling	0.595366	0.596067	0.598112	0.612289	M4	4-3-1
	T2 drilling	0.595366	0.596067	0.612289	0.612289	M3	
	T3 milling	0.459012	0.458730	0.0000	0.00000	M1	
Op 2	T2 drilling	0.595366	0.618968	0.612289	0.629537	M4	4-2
	T1 milling	0.459012	0.481585	0.0000	0.00000	M2	

5.4 Data Analysis and Evaluation

It is required to calculate the execution time for each operation by adding the execution time required for each task in the operation. The execution time (TE) of an operation can be expressed by the following;

$$TE = \sum_{i=0}^{NT} TP + TT \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Where: TE: is the execution time of an operation
NT: is the number of tasks
TP: is the processing time for each task
TT: is the travelling time for each task

The processing time (TP) of a task is the sum of the processing, loading, and waiting times of the task. Table 5.4 illustrates the execution time of all tasks and operation for the given case study. The measurements of time parameters are given by time unit [pu] which is proportional to the time required in a real-time system.

Table 5.4: Excution time for each task

Operation	Tasks	Traveling Time [pu]	Processing time [pu]	Execution time [pu]
Op 4	T1 milling	2.75	13	15.75
	T2 milling	1.5	11	12.5
	T3 drilling	2	18	20
Op 1	T1 milling	2	12.5	14.5
	T2 milling	1.75	8.5	10.25
	T3 drilling	2.25	5	7.25
	T4 drilling	3	9	11
Op 3	T1 drilling	2	12.5	14.5
	T2 drilling	2.25	8.5	10.75
	T3 milling	3.75	12.5	16.25
Op 2	T1 milling	2	17	19
	T2 drilling	3	19	22

The execution time percentage for each operation for the given case study is shown in Fig. 5.6. It also shows the route of each tasks performed in each operation.

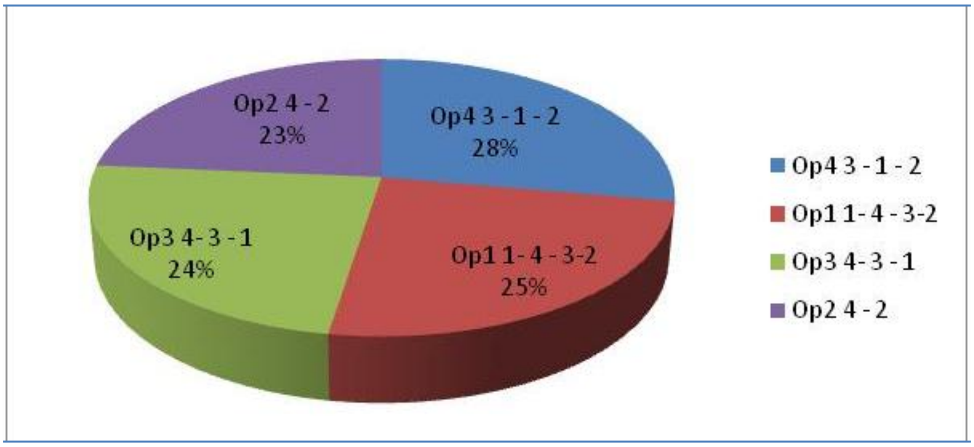


Figure 5.6: Execution time percentage of operations.

As mentioned earlier, the operation and task sequence schedulers assign priority for each operation and each task, according to the input parameters, as pointed out in Fig. 5.9.

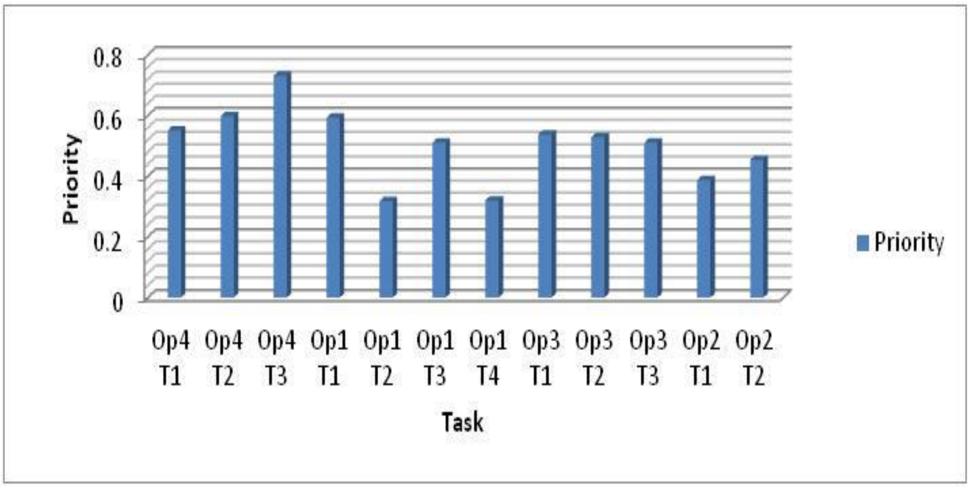


Figure 5.7: Priority calculation of tasks for each operation.

<u>Case Study (1):</u>

A case study is taken into consideration, where six milling and six drilling operations are required to be performed using the proposed FMS. The distributed load among each machine is illustrated in Fig. 5.10. Generally speaking, since the proposed FMS has two drilling machines and two milling machines, the work should be distributed equally between these machines if the scheduling algorithm works properly. This simple task was chosen as a case study to check if the algorithm provides the ideal result in this situation.

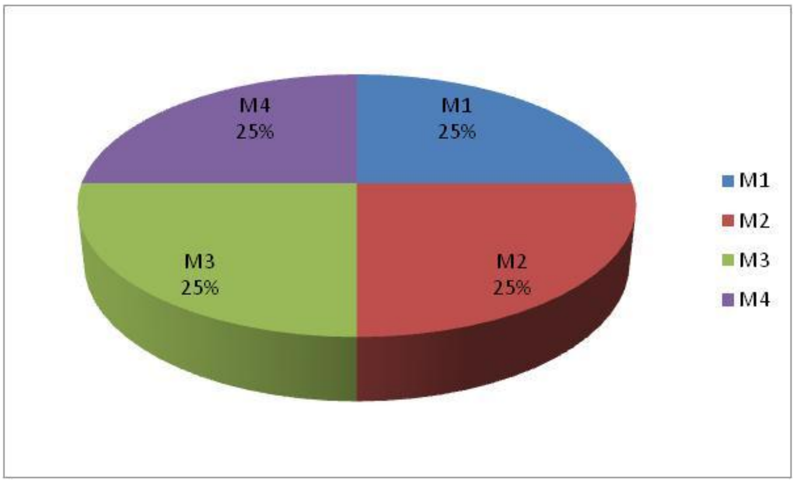


Figure 5.8: Workload for each machine (case study1)

<u>Case Study (2):</u>

In this case study, ten drilling operations are inserted into the FMS without using fuzzy scheduler. Table 5.5 illustrated the time inserted, time completed, time of start, time of finish, and time delay for each operation entered to the FMS. Then the same operations are performed by the same FMS with fuzzy schedulers to study its response and to compare both results. Drilling operations take two time units when sent to a drilling machine but it takes three and half time units when sent to a milling machine. The operation and task sequence schedulers and the task routing scheduler are used to achieve the objective of the proposed FMS by reducing time and improving its performance, as given in Table 5.6 and Fig. 5.11.

Table 5.5: Drilling operations without using fuzzy scheduler.

Operation		Machine #	Time of insert [pu]	Time of complete [pu]	Time of start [pu]	Time of finish [pu]	Delay [pu]
1	Drilling	3	0	2	0	2	0
2	Drilling	4	0.5	2.5	0.5	2.5	0
3	Drilling	3	1	3	2	4	1
4	Drilling	4	1.5	3.5	2.5	4.5	1
5	Drilling	3	2	4	4	6	2
6	Drilling	4	2.5	4.5	4.5	6.5	2
7	Drilling	3	3	5	6	8	3
8	Drilling	4	3.5	5.5	6.5	8.5	3
9	Drilling	3	4	6	8	10	4
10	Drilling	4	4.5	6.5	8.5	10.5	4

Table 5.6 : Drilling operations using fuzzy scheduler.

Operation		Machine #	Time of insert [pu]	Time of complete [pu]	Time of start [pu]	Time of finish [pu]	Delay [pu]
1	Drilling	3	0	2	0	2	0
2	Drilling	4	0.5	2.5	0.5	2.5	0
3	Drilling	1	1	4.5	1	4.5	0
4	Drilling	2	1.5	5	1.5	5	0
5	Drilling	3	2	4	2	4	0
6	Drilling	4	2.5	4.5	2.5	4.5	0
7	Drilling	1	3	6.5	4.5	8	1.5
8	Drilling	2	3.5	7	5	8.5	1.5
9	Drilling	3	4	6	4	6	0
10	Drilling	4	4.5	6.5	4.5	6.5	0

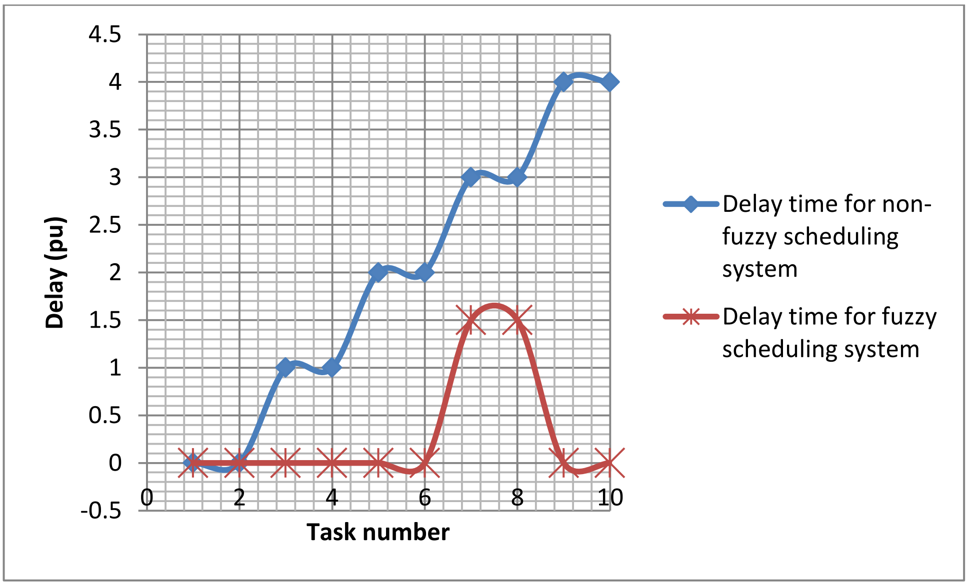


Figure 5.9:Impact of using fuzzy schedulers.

By comparing the results given in Table 5.5 and Table 5.6, it is clear the impact of fuzzy schedulers in improving the effectiveness of the FMS by reducing the delay time as illustrated in Fig. 5.11.

5.5 A Comparative Study

To verify the ability of the sequence and routing schedulers of the proposed FMS, its performance has been compared with a similar FMS proposed by Rajkiran Bramhane [22]. Table 5.7 gives the general comparison between both systems.

Table 5.7: General comaprison between [22] and proposed scheduler

Comparison Metrics	The Proposed Scheduler	Tajhurab Scheduler [22]
Number of Machines	Four CNC machines	Four CNC machines
Material Handling System:	Conveyor belt	Automatic Guided Vehicle (AGV)
Methodology	Three scheduling algorithms for operations and task sequence, and for routing	Two scheduling algorithms for job sequence and routing.
Scheduling Algorithm	- Fuzzy scheduler for operation and task scheduling. - Fuzzy scheduler for routing.	- Neuro- fuzzy scheduler for task scheduling. - Fuzzy scheduler for routing.
Used tools	LabVIEW for numerical system design and graphical interfacing.	Matlab for numerical system design.

Table 5.8: Processing time for each machine

Operation #	Machines			
	M1	M2	M3	M4
Op1	12.5	9	5	8.5
Op2	0	19	0	17
Op3	12.5	0	8.5	12.5
Op4	11	18	13	0

The processing time of the operations with available drilling and milling machines is given in Table 5.8. The processing time (given in pu) is distributed among the four machines depending on the required processing time for each task. After extracting the processing time data for each machine, a comparison is made between results obtained from the two methods, as illustrated in Fig. 5.12.

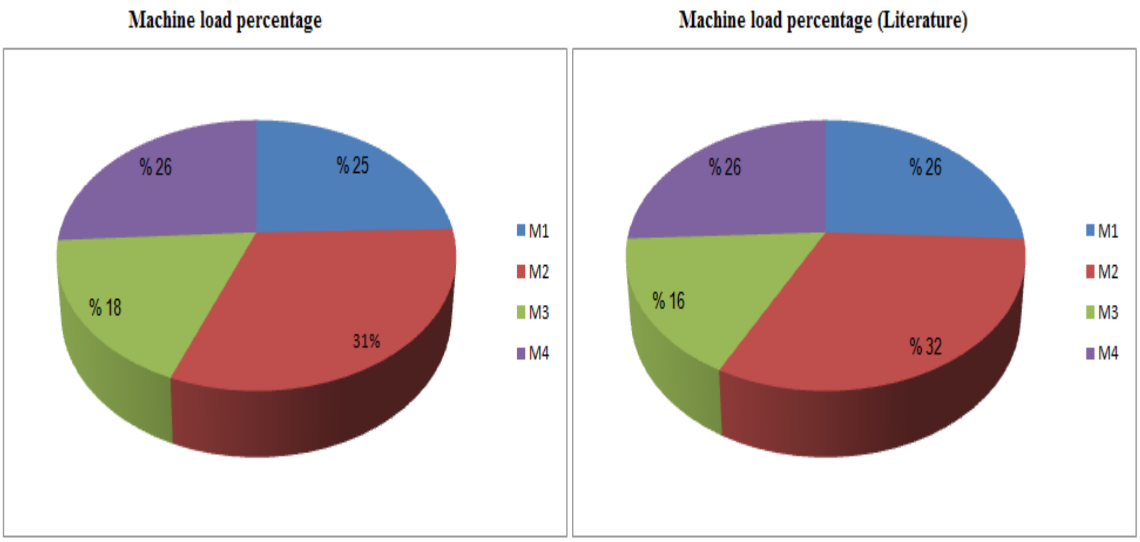


Figure 5.10: Machine load percentage from both systems.

The machine load percentage should be distributed equally among all the machines in ideal cases. As the parameters reach an equal state between each other, the shortest possible time is established. For example, if the four operations and their corresponding tasks are distributed among four machines and the machine load is equal between them then all machine have been used efficiently, which is the case of comparison between these two systems.

It is found that the difference between the maximum machine load and the minimum machine load percentage is 13%. While the percentage between the machine load distribution between the maximum and minimum machine load percentage in the other system is 16%. However, in ideal situations the machine workload difference must be 0% if the machines are fairly distributed and the closer the system to this values allows an efficient mean for comparing systems.

The reason behind this behavior is interpreted by the fact that three layer of fuzzy scheduling algorithms were used and the tasks in each operations are studied firmly. This provides a more accurate and precise scheduling than using two layers of priority.

Chapter Six

CONCLUSION AND FUTURE WORK

6.1 Conclusion

The main objective of this work was the design and realization of a real-time scheduling of a FMS with four CNC machines, a load/ unload station and a conveyor belt. The following conclusions can be pointed out:

- Three fuzzy scheduling algorithms were applied to the proposed FMS to distribute the work among available machines. The first scheduling algorithm is concerned with operation sequencing, the second scheduler for task sequencing within operation, while the third algorithm is for task routing to assign the best machine for the selected task.
- A real-time simulation for the operation was established using LabVIEW. An animated interface screen was designed to show the layout of the system component and illustrate the movement, control and distribution.
- Data acquisition methodologies were used to extract the features and specifications of the system, these data were used to analyze, compare and enhance the system features.
- System test and analysis were used to study the behavior of the system, multiple modifications were made to establish the best mean for scheduling.
- The work presented in this thesis has been compared to similar research work [22] published in 2014. Load distribution over the machines was the comparison parameter. The results showed that the proposed algorithm enhances the distributed load for the machines.

6.2 Suggestions for Future Work

Future work can be achieved to improve and enhance the performance of FMS scheduling methodologies, these may include:

- More parameters could be added to improve the performance of the scheduler, the more input parameters taken into consideration causes increased rules this causes improvements in accuracy.
- Neuro-fuzzy scheduler may be applied to improve overall performance of the FMS.
- Adding features for controlling the number of machines could be modified to establish connection between various machines to increase the adaptability of the system to work in different industrial environments.
- Real-time implementation of the scheduling algorithms on real systems with actual drilling and milling machines, tool selection, load/unload station and material handling system including mobile robot or AGV.
- Adding a reschedule adaptive mechanism in case of any malfunction will take place whether in software or hardware part.

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APPENDIX A

Project Design Using LabVIEW

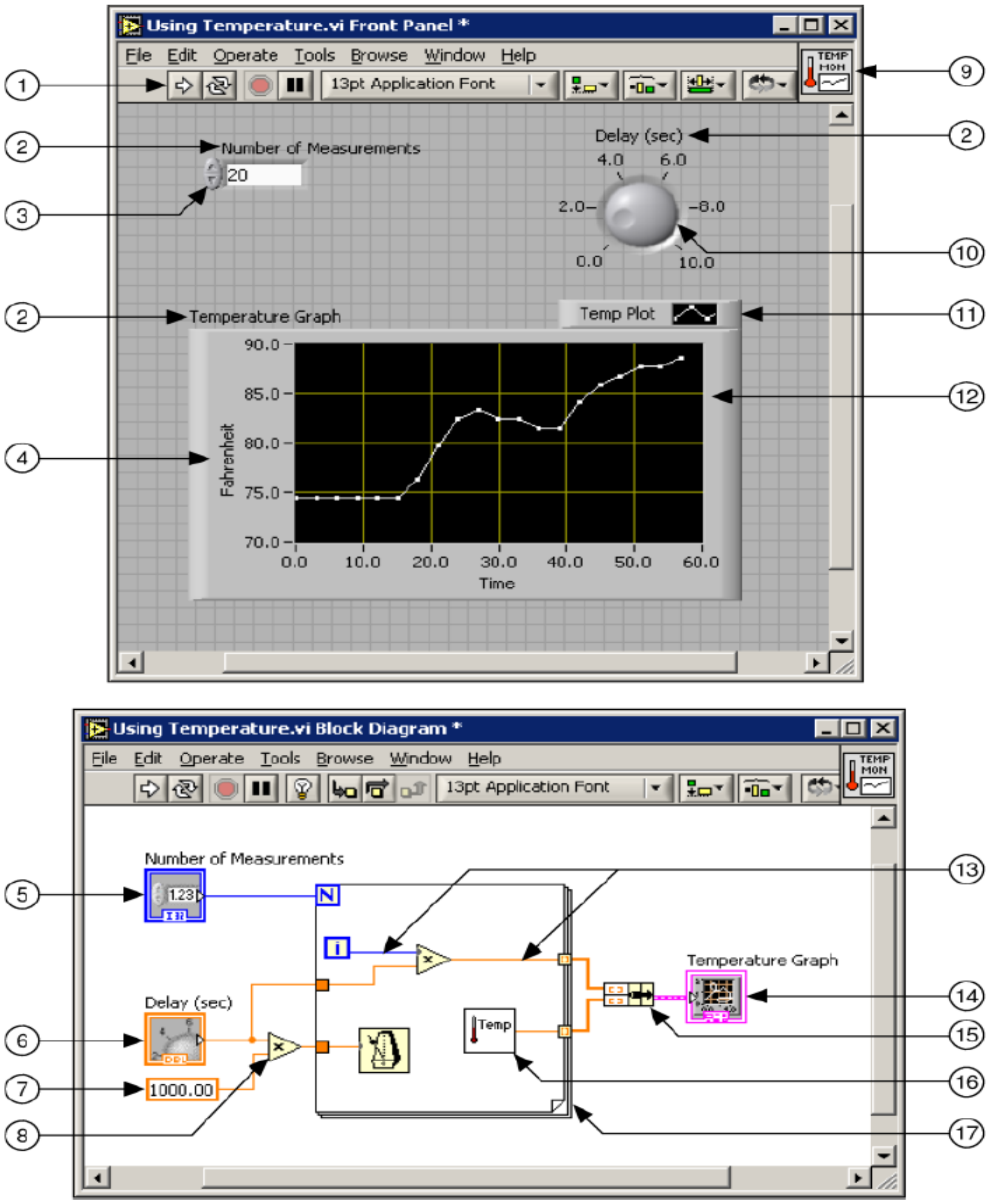

Figure 0.1: Interface and block VI screen [24].

The components shown in Figure A.1 are illustrated as :

1. Toolbar: it is a group of icons represents shortcuts that can be clicked to perform functions related to the icon.

2. Owned Label: labels that are attached with the object, each time you move an object the label moves with the object. But when you move the label the object doesn't necessarily move.
3. Numeric Control: a tap that can control a numeric value that is attached to an input in the system.
4. Free Label: labels that are not attached with any object. You can move them freely in the software, and they are used to document the code.
5. Numeric Control Terminal: this is used for displaying numeric data in LabVIEW applications.
6. Knob Terminal: a wire that provides variable data to the application.
7. Numeric Constant: a block that represents a fixed number, that can be used as an input operation.
8. Multiply Function: this block represent a multiplication process between two integers.
9. Icon: a graphical representation for a certain shortcut in the tools bar.
10. Knob Control: a whirly button in the interface screen used to control the value of the knob terminal graphically.
11. Plot Legend: this represents the legend of a certain graph where all the symbols of the system are explained.
12. XY Graph: a graph where X and Y coordinates are plotted.
13. Wire Data Path: connects a data terminal with another data terminal.
14. XY Graph Terminal: an application NI terminal that receives data from the application and shows it on the interface XY graph.
15. Bundle Function: a bundle function stores data received from the application in groups.
16. SubVI: a VI that is called which can be used to simplify and organize the overall setup of the application.
17. For Loop Structure: a logic for loop that is represented graphically.

To establish a standardized project application using labVIEW environment, the following steps are required:

1. Configure the project in LabVIEW according to the required functions and libraries and open the application window.

2. Define the required VIs and save them in the application window according to the application and store them into memory.
3. Right click on my computer to build the required specifications and choose "New" application from the shortcut menu to show the property box.
4. Fulfill the following information in the property box:
   - Enter a unique name for the build project operation in the project name textbox that shouldn't interfere with already existing names.
   - Save the required project and make sure that the extension of the provided name is an executable file (.exe).
   - Choose the directory of the build application and make sure it is suitable and could be found easily.
   - In the version properties decide the required version for the build operation.
5. On the source file page the following information must be completed:
   - Define the required startup VI files from the project file tree. These file run as the application starts. This allows for an initialization process for the VIs also known as top-level VI.
   - Right click the VIs from the VI list box to move the required VI to the startup VI list box.
   - From the project file tree choose the dynamically operated VIs and the non-required VIs (not supported files).
   - Right click the VIs from the VI list box to change the status of the VI to the dynamically operated VI list box.
6. Add the required destinations to in the destination list box.
7. If a VI is specified correctly as a dynamically operated VI the VI should change its location automatically according to the destination list box.
8. Choose the required icons to add to the application from the icon property list.
9. Configure advanced settings from the advanced property list box.
10. Set the language preferences from the run time file page.
11. Generate a preview file from the preview page to show the used VIs.
12. Click OK in the dialog box to configure the building process.
13. Go to the destination folder to see the result of the build operation.

جدولة انظمة التصنيع المرنة في الزمن الحقيقي

الملخص

يتناول المشروع موضوع جدولة العمليات والمهام في انظمة التصنيع المرنة من خلال توزيع المهام على المكائن المبرمجة بالشكل الذي يضمن الاستخدام الافضل للمكائن والعدد والاجهزة المتوفرة والذي يؤدي الى تقليل وقت التنفيذ وزيادة الكفاءة وبالتالي انخفاض الكلفة.

تضمنت الدراسة استخدام برمجيات (LabVIEW) لتصميم نظام تصنيع مرن مكون من اربعة مكائن تحكم رقمي مبرمجة لتنفيذ عمليات الثقب و/أو عمليات الحفر مع وحدة تخزين ونظام نقل المواد من خلال الحزام الناقل. ولغرض جعل منظومة التصنيع مرنة وتعمل بكفاءة عالية لتنفيذ عمليات مختلفة فلا بد من تصميم وبناء خوارزميات لجدولة العمليات والمهام وتوزيعها على المكائن المبرمجة. لقد تم استخدام مفاهيم المنطق المضبب في تصميم ثلاث خوارزميات، حيث تستخدم الخوارزمية الاولى لترتيب العمليات المطلوب تنفيذها، فيما تستخدم الخوارزمية الثانية لترتيب المهام ضمن العملية الواحدة، أما الخوارزمية الثالثة فكانت لتوزيع المهام على المكائن المبرمجة.

يهدف البحث الى تصميم و تطبيق خوارزميات جدولة بالزمن الحقيقي لتوزيع المهام على المكائن المبرمجة المتوفرة وبمرونة تضمن تقليل الزمن المطلوب وتحديد اقصر طريق عمل لوصول قطعة العمل إلى الماكنة المختارة، وهذا سيؤدي إلى اختصار زمن الانتظار لتحقيق انتاجية افضل باقل كلفة ممكنة.

تشير النتائج التي تم الحصول عليها من البحث الى كفاءة الخوارزميات الثلاث في الادارة المرنة لنظام التصنيع. وللتاكد من قابلية النظام المقترح وكفائته تم مقارنة النتائج مع دراسة مماثلة نشرت عام ٢٠١٤ والتي استخدمت خوارزمتين فقط لجدولة المهام وتوزيعها حيث استخدمت برمجية مهجنة (منطق مضبب مع شبكات عصبونية) في عملية جدولة المهام وخوارزمية منطق مضبب في توزيع المهام على المكائن المبرمجة. تشير نتائج المقارنة الى كفاءة ومرونة النظام المقترح وشموليته في التعامل مع عمليات مختلفة (اكثر من عملية) لوجود خوارزمية تحديد الاسبقية للعملية المطلوب تنفيذها.

جدولة أنظمة التصنيع المرنة في الزمن الحقيقي

اعداد

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إشراف

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قدمت هذه الرسالة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة الميكاترونكس

عمادة البحث العلمي والدراسات العليا

جامعة فيلادلفيا

كانون الثاني- ٢٠١٦