

**INVESTIGATION ON TASK SCHEDULING FOR ROBOTIC
SYSTEM IN 5G MANUFACTURING INDUSTRY”**

WAN WING SHENG



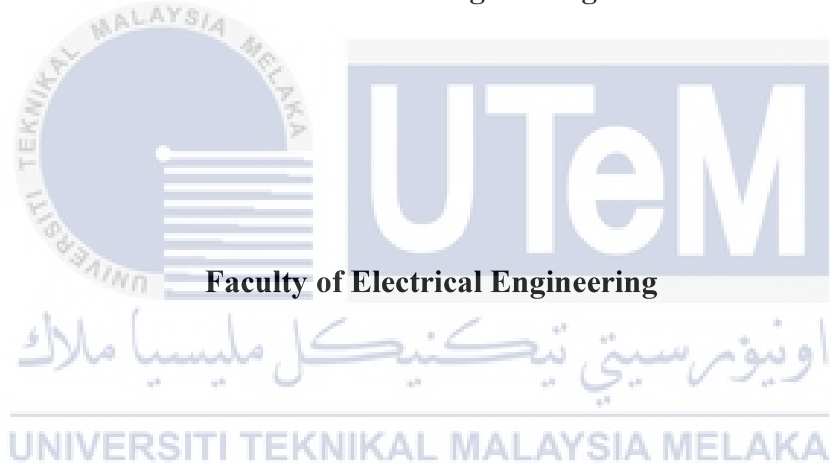
**BACHELOR OF MECHATRONICS ENGINEERING WITH
HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

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**INVESTIGATION ON TASK SCHEDULING FOR ROBOTIC SYSTEM IN 5G
MANUFACTURING INDUSTRY”**

WAN WING SHENG

**A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Mechatronics Engineering with Honours**



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled “INVESTIGATION ON TASK SCHEDULING FOR ROBOTIC SYSTEM IN 5G MANUFACTURING INDUSTRY” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this report entitled “INVESTIGATION ON TASK SCHEDULING FOR ROBOTIC SYSTEM IN 5G MANUFACTURING INDUSTRY” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

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DEDICATIONS

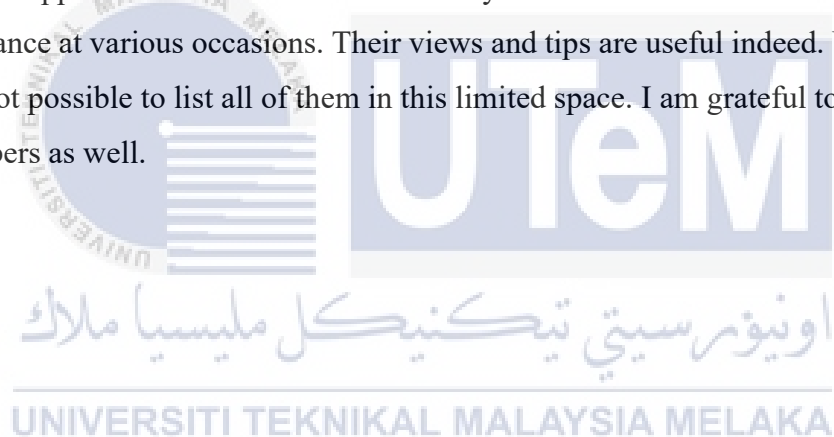
To my beloved mother and father



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ABSTRACT

Task Scheduling is a tool that may help in any type of industrials and smoothen the process flow in production lines specially manufacturing sector. With the development of 5G technology, the robotic system has been bought into industrials but there may not apply them in an optimal performance such as robots cannot complete the tasks on time. Even manufacturer plan the task flow by using project management, an error may occurred and make the tasks overlap to each other because they are using the traditional scheduling method. It may waste a lot of time between the tasks and robots will get into stand-by mode to wait for the next tasks if the scheduling is failed. To obtain a flexible scheduling with the shortest total complete time of all the tasks, an algorithm is needed to arrange the tasks accordingly. Genetic Algorithm (GA) is applied on task scheduling and it provided the better solution from previous result or arrangement due to iteration. In this thesis, an analysis involves multi robots to complete various industrial operations, consisting of multi-tasks. For saving the time during processing and costs in production, GA may help on it with having the optimal value about total complete time to avoid any wastage. In short, manufacturer will have a higher productivity and better performance among the robots when applied a suitable Task Scheduling in the industry or workplace.

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ABSTRAK

'Task Scheduling' adalah alat yang dapat membantu dalam semua jenis industri dan melancarkan aliran proses di barisan pengeluaran khususnya sektor pembuatan. Dengan perkembangan teknologi 5G, sistem robot telah dibeli menjadi industri tetapi mungkin tidak menggunakannya dalam prestasi optimum seperti robot tidak dapat menyelesaikan tugas tepat pada waktunya. Malah pengeluar merancang aliran tugas dengan menggunakan pengurusan projek, kesalahan mungkin terjadi dan membuat tugas saling tumpang tindih kerana mereka menggunakan kaedah penjadualan tradisional. Mungkin membuang banyak masa antara tugas dan robot akan memasuki mod siap sedia untuk menunggu tugas seterusnya sekiranya penjadualan gagal. Untuk mendapatkan penjadualan yang fleksibel dengan jumlah waktu terpendek yang paling pendek dari semua tugas, algoritma diperlukan untuk mengatur tugas dengan sewajarnya. Genetik Algoritma (GA) diterapkan pada penjadualan tugas dan ia memberikan penyelesaian yang lebih baik dari hasil atau susunan sebelumnya kerana ledaran. Dalam tesis ini, analisis melibatkan multi robot untuk menyelesaikan pelbagai operasi industri, yang terdiri daripada pelbagai tugas. Untuk menjimatkan masa semasa pemrosesan dan kos dalam pengeluaran, GA dapat menolongnya dengan memiliki nilai optimum mengenai jumlah waktu lengkap untuk mengelakkan pembaziran. Ringkasnya, pengeluar akan mempunyai produktiviti yang lebih tinggi dan prestasi yang lebih baik di antara robot apabila menggunakan Penjadualan Tugas yang sesuai di industri atau tempat kerja.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Development in manufacturing industries is going fast after applied the concept of Industrial Revolution 4.0 (IR4.0) and started to use robotic system in production lines. The situation is showing in Figure 1.0. Some of the industries are still using man power to complete the tasks but some of them try to replace with robotic system for having higher productivity and lower the cost that hiring workers. Only those industries still using man power that is because they have the inspection tasks to ensure the quality of products.



Figure 1: Robotic system is applied in production lines area but still kept some man-power. [1]

When focusing on industries who using robotic system, those really have the higher efficiency of system running in production lines. But the robotic system is requested some operators to manage tasks and run it. To obtain a better payoff,

operators need to schedule those tasks carefully by calculating the duration, delay time and deadline. The changes along these few years in manufacturing industries like IR4.0, it brings some brand-new technologies such as Internet of Things (IoT), Quality of Service (QoS), Cognitive System, Big Data Analytics, Cloud Computing, Augmented Reality, and Machine Learning as shown in Figure 2.0 to make the jobs can be accomplished in the easiest way [2].



Figure 2: Elements that developing in Industrial Revolution 4.0.

From late 2018, 5G technology is brought to us then it makes the big changes with electronic devices and those machines in production lines. The most different comparing to 4G communication system, 5G has the ultra-low latency connection and it can be less than 1ms. When industries are starting to apply 5G in their area, many applications will be going smoother than before. For example, the control systems, automated assembly lines with robots, machine status reports, process surveillance, and even power grid management. There is bring a higher reliability and productivity specially in manufacturing process [3].

1.2 Motivation

The concept of Industrial Revolution 4.0 (IR4.0) is accepted by more and more company and they are converting their traditional manufacturing process to modern control system. With addition on network connection, the industries are able to do controlling machine by online and real-time monitoring. Therefore, they can know the machine error and malfunction part exactly then having maintenance on the certain part such as sensor and actuator. Back to the point that need to consider is, productivity in a manufacturing industry play the most important role among others. For increasing the productivity as mentioned before, those industries are starting to apply robotic system in production lines. That is because robot will not feel tired, they able to work in a longer time and higher speed. Industries are not only using one robot but many then they should have a very good planning on those robots for getting the optimal performance with good payoff.

There has a lot of methods to have a good task schedule for the robots and the tasks are providing basic information like different duration, deadline and their payoff. To obtain the best payoff, that may use mathematics algorithm to do calculation and reduce the time use for every robot to complete the task. Some of industries are having a large area of production lines and robots need to move from one side to another side for completing a task. That is not a good choice and should be manage another robot that nearby to certain task then solve it.

When the robotic system really helps in manufacturing industries, it means there has a suitable task scheduling to the capacity of robots, the environment, and controlling by operators. 5G technology is just a tool that helping to transfer data information in a shorter time with ultra-low latency and larger bandwidth. Therefore, using the algorithm to run a simulation depending the weight of tasks, different duration, and deadline then placing the robot at certain position and complete the tasks what we order to it.

1.3 Problem Statement

Nowadays, many manufacturing industries are replacing human resources with robotic systems to maximize productivity and reduce the cost of hiring workers. When the number of robotics increases in the factories, task scheduling is needed, especially 5G technology is applied in industries to have an optional performance among those robots with independent tasks. Some factories have five to ten machines but even more than that, like twenty or thirty machines working simultaneously. As a manufacturing industry, there will not only be a task to do; they cooperated with other companies to produce different products. But those factories have not adapted the robotic system quickly. They only use the traditional method of planning the manufacturing process like calculating processing time, delay time, and deadline with pen and paper. There will be time-consuming to do the scheduling with arranging many tasks to multiple robots in production lines. Besides, an error will occur due to hand calculation, and the error may overlap with each other or delay unexpectedly. These all will affect the manufacturing process that cannot go smoothly, and productivity cannot constantly be. A multi-robot can achieve a maximum payoff with an average working duration. Here, an algorithm is crucial for doing the task scheduling with a minimum time.

There has a common algorithm that been used by many users, or we called them manufacturer. The algorithm is named Genetic Algorithm (GA). Although this algorithm can optimize Job Shop Scheduling, we still need to study it due to the different rates of crossover process and mutation process that will affect the total completion time for all the tasks. Therefore, we need to know the better rate of those both processes for having a minimal make-span among multi robots.

1.4 Objectives

There have a few objectives to achieve:

- To investigate the importance and application of task scheduling in manufacturing industries.
- To obtain a feasible schedule of minimal completion time for multi-robots by using Genetic Algorithm.
- To analyze the relationship between rate of crossover/mutation process and the performance in task scheduling based on Genetic Algorithm.

1.5 Scope and limitation

- Using the computer software to generate some data about 50 tasks with processing time for 5 desired robots.
- This scheduling is designed for applying on in-door tasks only to ensure the tasks are stand-by for next empty slot and no delay between the tasks.
- The algorithm will be needed to re-calculate when any robot or machine is facing downtime such as malfunction, undergo maintenance and accident happened.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

When stepping into Industry Revolution 4.0, many field industries and most of them are doing manufacturing or we called it as production lines. Before this, they already use the robotic system in their factory for increasing the productivity or quality of the products. But the issue will come when industry increases the number of robots using in factory. Then, that is the topic which are discussing between the operator or technical department in those industries. It is task scheduling for robotic system that connecting with the latest 5G technology in manufacturing.

2.2 Application of 5G Technology

As everybody knows, 4G technology already impressive and it has been using in many years to transfer data information quickly. From late 2018, 5G is introduced and run the trial at public area at China and some western countries. In the laboratory, technicians have a result about comparing between the connection of 4G and 5G. It is showing 5G that have the higher data rate and more bandwidth when connecting multiple devices. Besides, there has low latency quality of service (QoS) and low interference during controlling the machines in factories [4].

For handling the Internet of Things (IoT) become smoother or we say it as increasing the performance, there might use the 5G technology on it. It will provide a better experience on ease of operation, remotely access control and configurability. Therefore, industries can obtain the inspection data on time even the machines are operating. On the other hand, this kind of experience is not

designing for industry but also applicable on public user such as high-resolution video streaming, self-driven cars, smart environment and e-health care [5].

Comparing to the last time, Internet of Things is facing a difficulty which related to shortage of spectrum resources because of rapid growth of IoT terminals and big data services. So that, the larger bandwidth coming from 5G technology will be solved the problem and perform with transferring data information simultaneously. Obviously, one of the techniques from IoT is Artificial Intelligence (AI) and this is going a big step starting from connected to 5G network. Due to ultra-low latency network, machine and deep learning are developing in AI and becoming a powerful tool in the manufacturing industries for having a higher productivity [5][6].

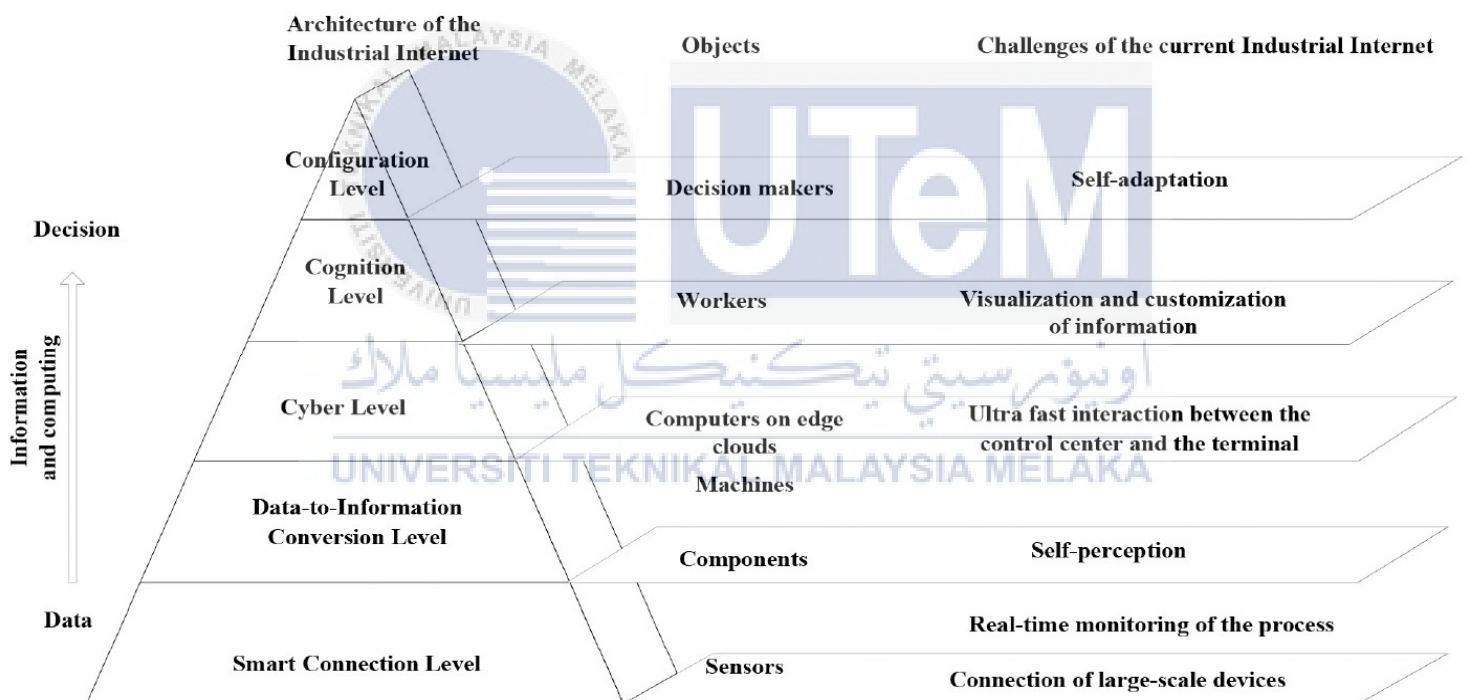


Figure 3:Architecture of the Industrial Internet Connection. [7]

In the industries, they are using many machines or robot in production lines and those operators just need to do their duty for checking every single process in front of control panels. Many sensors and actuators are operating on those machines while they need a real-time monitoring and controlling process. Therefore, 5G network technology is allowing them to have a large-scale devices connection from collecting data to making decision for the output through different level and that is showing in Figure 3.0. [7].

2.3 Differences Between 4G and 5G

About the development on Internet of Things (IoT), 4G Technology actually can be applied but nowadays everyone hopes to have a better performance such as lower latency for getting an output. Then, 5G is found and developed as a new technology which has larger bandwidth with a higher frequency than 4G. Due to the new technology is started to use, different field of applications which are related to Internet of Things have be planned to apply by using 5G. They are media, transportation, healthcare, environment and energy conservation, infrastructure and so on. 5G may applied into different fields that is because its capability is stronger than 4G-LTE. There is showing the similarity and difference between 4G and 5G based their specifications in Table 1 [8][9].

Table 1: Comparison between 4G and 5G. [8][9].

Specification	4G	5G
Full Form	Fourth Generation	Fifth Generation
Start from	2010	2016
Similarity		
Handover Signal	Horizontal and Vertical	
Technologies	Unified IP, seamless integration of broadband LAN/WAN/PAN and WLAN	
Services	Dynamic information access, wearable devices, HD streaming and Global roaming	
Difference		
Data Bandwidth	2Mbps to 1Gbps	1Gbps and higher as per need
Frequency Band	2 to 8 GHz	3 to 300 GHz
Data Average Speed	15Mbps to 50Mbps	50Mbps and up
Latency	Around 50ms	Could drop to 1ms
Core Network	All IP network	Flatter IP network, 5G network interfacing(5g-NI)

According to the information in Table 1, there can know that 5G is having a larger data bandwidth than 4G. Therefore, the latency is lower in 5G compare to 4G and may be applied in more and more applications.

2.4 Application of Robotic System

Robotic system is applied into different production field or maybe not only use for that but also doing repairing, maintenance, delivery services and so on. As we know, a simple robot is built with some actuators like motor, hydraulic and pneumatic system then working together to become a tool for solving our problem [10]. For example, a cleaning robot is designed with sensor and controller. It helps to keep our home or office area that having a clean environment and that show us a robot is making our life become easier or we say it as higher efficiency.

In manufacturing industries, robotic system is playing the role that more important than other places. Since they are keep working on production lines, man power is not enough to maximize the productivity but robotic system may do it better like carrying thousand kilograms of product or repeating the same task in a long period [11]. The reason that manufacturing industrial started to use robotic system in their factories is the robot can be programmable and it will help human begin to solve the difficulty on any tasks through machine learning.

Since the 4G LTE technology came to us, Artificial Intelligence (A.I.) is introduced by engineers and applied into robotic system [12]. But communication delay still happened on that time and made the robot cannot do any motion smoothly or giving the response after a few seconds. Therefore, manufacturers are less to use the robotic system in factories and just keeping the machines run in their production lines. Until 5G technology is announced and have been tested in laboratory that showing a better performance than 4G LTE, robotic system is brought back to public and use by different sector of industrial but most of them are manufacturing.

From the study by an international team named as International Federation of Robotics, the installation for robotic system was showing a decrease obviously in 2019 and that is around 12% to 373,240 units of robots in global (Figure 4.0) [13]. But among those industries, the automotive industry still remains using the most in number of robots. Different field of industries are following like electrical/electronics, metal and machinery, plastic and chemical products and food and beverages. The figure is showing the statistics data and matched with topic that mentioned before, there have less manufacturer are using robot in their factory when 4G Technology is not popular to public in 2019 comparing to 2018.

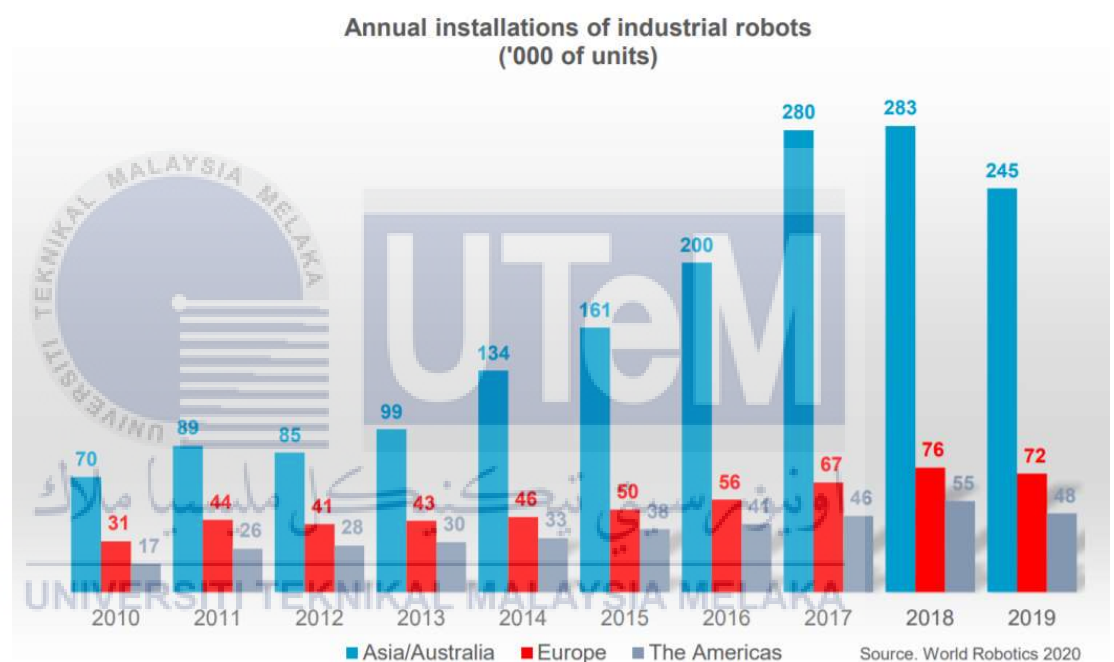


Figure 4: Statistics data for Annual installations of industrial robots in global. [13].

2.5 Review on Scheduling

Scheduling, it can be called as an activity that planning the tasks or jobs by following what we can handle, when we can complete, how we arrange to have the optimal performance and so on. When scheduling is brought to a manufacturing industrial, it will help the manufacturer to arrange the tasks that received from customer orders and distribute those tasks to their machines or

robots in production lines. In that area, it will be renamed as production scheduling or job shop scheduling [14]. Next, it is a tool that using for optimization problem in which various manufacturing tasks or processes are assigned to robots at a particular time while trying to minimize the make span.

Before scheduling is applied into industrial sector, public use it in project management to plan a list of activities with resources and durations. It is using by everyone because the planner is able to track, report and do the communicating on the progress [15]. Then, that is the same in manufacturing industrial how the operators doing in production lines to distribute jobs for multiple robots and know clearly the whole progress. But that is a traditional method which will time-consuming and mistakes may be made by the planner.

From Industrial Revolution 3.0 to 4.0, most of the industries and engineers are applied the Networking into their workspace and the modern scheduling has been brought to the production area. For those manufacturers who still using a lot of man-power, they only can arrange the tasks to workers with scheduling skills. On the other hand, the larger manufacturers are using machines or robots and they need to command the robots for completing the tasks with a smart system which is doing scheduling algorithm. By using the power of Networking from 5G technology, it may help on this because it has the larger bandwidth and ultra-low latency that can transfer the signal to robots within a very short time after the scheduling algorithm is completed [16].

2.6 Task Scheduling Algorithm, Genetic Algorithm

That is one of the algorithms which is applied from working principle of DNA system to solve the problem in our daily life. Genetic Algorithm, it is a general purpose to have a better solution, population-based search algorithm that present the samples from the origin set of all possibilities, whether they are solutions in a problem space, strategies for a game, rules in classifier systems, or arguments for problems in function optimization [17]. But nowadays, people are using this

Genetic Algorithm for having a better scheduling to complete the tasks in workplace. DNA system has a lot of chromosome and people assume the chromosome as the arrangement of tasks or jobs [18]. Then, the genes inside chromosomes will become the individual task and people rearrange them in different sequence to obtain a better arrangement. The process is called as Crossover and Mutation in this Genetic Algorithm. People are repeating the process because the algorithm is needed iteration for having a better solution from previous results. Therefore, Genetic Algorithm is used for doing task scheduling in different sector included the industrial. They need it to manage the tasks and complete them with machines or robots in production lines.

2.7 Comparison with others Scheduling Algorithm

According to the study by M Dewa and B Nleya, they were doing investigation about which scheduling algorithm is better for minimizing the total makespan at galvanizing plant that where they collected data. At first, they studied on how the Genetic Algorithm working and understand every function from each part such as Crossover and Mutation. Then, using the software, MATLAB to run through some stimulation by applying different scheduling algorithm that shown in Table 2 [19].

Table 2: Total makespan for different algorithm [19].

No	Scheduling Algorithm	Makespan (Minutes)
1	Integer Linear Programming	180
2	Shortest Processing Time	192
3	Longest Processing Time	182
4	Genetic Algorithm	176

Integer Linear Programming (ILP) is one of the scheduling algorithms and its working principle will be arrange those tasks in parallel then try to complete all the tasks in same time. Therefore, ILP has the average makespan with multi robots or machines. Besides, the Shortest Processing Time (SPT) and Longest