POLITEKNIK MALAYSIA

KEMENTERIAN PENDIDIKAN MALAYSIA

KOLEJ KOMUNITI MALAYSIA

PROCEEDING

CiE-TVET 2019

9th National Conference in Education
Technical & Vocational Education and Training

20-21 AUGUST 2019
POLITEKNIK BANTING SELANGOR

THEME:
LEVERAGING TVET FOR A BETTER FUTURE

50 JUBLI EMAS

PROSIDING

9th National Connference in Education

Technical & Vocational Education and Training

" LEVERAGING TVET FOR A BETTER FUTURE"

Anjuran

Diterbitkan oleh Jabatan Pendidikan Politeknik & Kolej Komuniti (JPPKK), Kementerian Pendidikan Malaysia
dengan kerjasama Politeknik Banting Selangor

Proceeding of the 9th National Conference in Education - Technical & Vocational Education and Training (CiE-TVET) 2019

eISBN: 978-967-11412-7-4

Cetakan Pertama : November 2019

Diterbitkan oleh

Politeknik Banting Selangor
Jalan Sultan Abdul Samad,
42700 Banting, Selangor
http://www.polibanting.edu.my

Diterbitkan oleh Jabatan Pendidikan Politeknik & Kolej Komuniti (JPPKK), Kementerian Pendidikan Malaysia dengan kerjasama Politeknik Banting Selangor

MEC16

A Review: The Integration of Measurement Technologies with Robotics

Dina Izzati Hashim[1], Ahmad Salleh Buang[2], Muhammad Anas Mohamad Sayuti[3]

[123]Department of Mechanical Engineering, Polytechnic Banting Selangor
Corresponding author: [1]*dinaizzati@gmail.com*

ABSTRACT

Turning the vision of industry 4.0 into reality, it requires automation of flexible, precise and fast measuring processes in order to ensure the quality of components. In particular, this applies to modern manufacturing in industries. Therefore, to develop and deploy advances in measurement, robotic system has been used by integrating with the measurement technologies. Robotics is efficient than humans because it is highly capable, easily tasked, perceptive and can operate safely by humans to perform a task. At the same time, the result of measurement is accurate and precise. When measurement technologies integrated with robotics, this technology offers benefits and advantages to the organization by manufacturing a product or from the production processes.

Key Words: Automation, Measurement technologies, robotic

1.0 INTRODUCTION

The role of automation has increased in current modern world for sustaining the development manufacturing or service processes in 21st century. Automation is the independent accomplishment of a function by a device or system that was formerly carried out by a human [1]. The main objective of enhancing automation in the process is to increase the productivity and the quality of products beyond what can be achieved by humans, frees space, time and energy consumed by humans to deal with new, non-routine challenge of developing innovative and more advanced technologies. In other word, automation can defined as "Doing More with Less" and it can be the goal of automation [2]. Now days, there are two types of trends in automation solutions for manufacturing: measuring technologies and implementation of robotic solutions. The use of measuring technologies can be found inside every manufacturing organization. With the evolution of this machinery and their related processes, all the manufacturer of high-to-medium volume part producer are facing high inspections to obtained high accuracy measurements. Since, humans are not capable of doing it and manufacturers start to find for the advancements in the measurement technology such as the speed of measurement, the ability to inspect parts with greater accuracy and precisely. Therefore, the integration of measurement technologies with robotics becomes the need in the manufacturing process or systems. Robots are smarter, faster and taking more on human capabilities and traits such as sensing, dexterity, memory and trainability. Some robots are designed especially for difficult job which humans will not able to perform. By integrating the measurement technology with robotics, manufacturers manage to obtain the high accuracy result during measuring their product or part.

2.0 MEASUREMENT TECHNOLOGIES IN AUTOMATION

Automation is the use of a machine that comprising a control systems and computer applications which involving IT solution to improve manufacturing processes and industrial productivity that would previously do manually. According to Instrument Society of America (ISA), the automation is define as an establishment and application of technology which to monitor and control the production and delivery of product and services [8]. Automation emphasizes on productivity, efficiency, quality and reliability while focusing on systems operating independently which is often in structured environments over long periods, and on the unambiguous structuring of such environments [9].

In other hand, it should not to be confused or misled with mechanisation, which includes the mechanical completion handled by workers as part of the manufacturing process. Automation is different from mechanisation where automation eliminates the need of workers in operating the machines consequently increasing in terms of speed, capacity load, and repeatability.

Nowadays, the integration of automation and process in manufacturing is endlessly improving consequently of current technological developments. This paper will review two new tendencies in automation solutions for manufacturing system which the usage of measurement technologies and the application of robotics solutions.

Measurement is an activity which has been widely used in every manufacturing organization [4]. This activity of measurements comprises for internal regulations which to meet the terms of govern operation's rules within the organization such as safety and health. While, measurements for external regulations comprise activities which to conform the rules that govern the effects of operations on the outside organization is comply, such as the inspection of green-house gas emissions. This operation involves the measurement of the production process to certify correct operation to improve product quality. In other hand, some organizations have their in-house research and development (R&D) in order to develop the measurement activities within an organization towards improving the current measurement system.

All these measurements are an indispensable requirement for the success of the organization. Having consistent results of measurement and testing, it is very important to ensure compliance with regulations. At the same time, it is important to keep the measurement of the production operation meets the national standard. Without this measurement standard, companies may be less competitive.

The latest technological developments in measurement technology gave two new developments that give a high impact on the automation system. Firstly, this measurement technologies are more accurate and sophisticated that became obtainable on the market. Thus, allows measurement data previously unmeasurable and improving conventional measurement solutions by offering accuracy, precision and repeatability. Besides that, the measurement technology can now be used in a new way in an automation process, predominantly in process control. In order to demonstrate this latter development, it is important to understand the control procedures prior to acknowledge the extent of automation and advanced measurement technologies to give value to this procedure.

The role of measurement of process control-loop, represented graphically in *Figure 1* [5], is defined as:

- *Process*: It is the manufacturing process itself, which can be the installation of equipment, input materials, and the use of workers to produce goods. This process can be subject to interference from both internal sources that are under the control of the manufacturer, and outsiders or disturbance.

- *Measurement*: The measurements provide information about the dynamics of the process variables to be controlled. These steps can be for a variety of things such as pressure, temperature, flow, position, speed, etc. In an automation manufacturing system, these measures are then translated into analogue or digital signals to be processed by the control system.
- *Evaluation*: The controller compares the measurement result with a desired value and determining the response in order to eliminate or reduce such diversity.
- *Control*: A control element in the feedback loop is a component of feed for action to be taken back into the process. The control device such as valves, pumps, motors, brake, or other device will receive signals from the controller and perform the required operations to bring the process meet the specification and more balance.

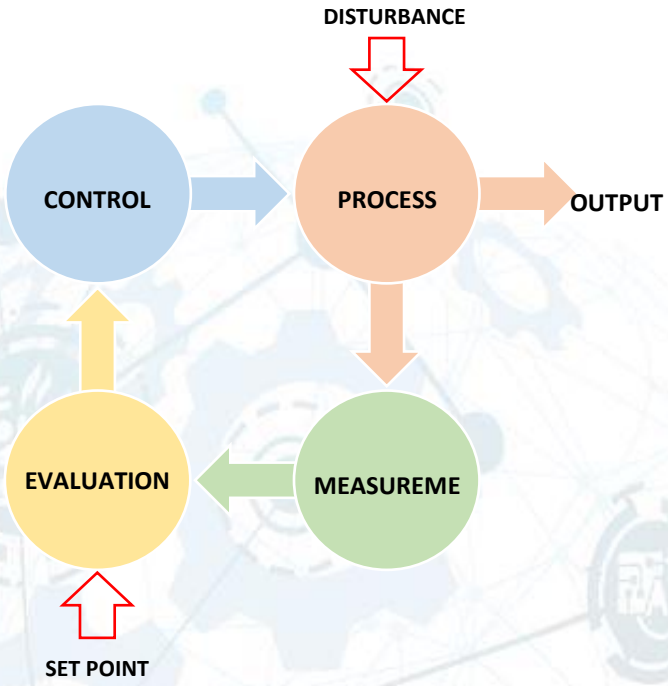

Figure 1: The Role of Measurement in Process Control-loop [5]

This role of measurement technologies is significant as measurement establishes one of the four (4) stages in process control loops. The tool can be used to measure such a robot, pumps, quality control, pressure valve, thermometer, and some examples of different tools they are expected to play a role in the production [6].

3.0 ROBOTICS

Robotics is combination of mechanical, electrical and electronic and computer system which incorporated in design, operation and construction of machines to perform tasks which traditionally done by human beings. *Robotics* highlights on a systems which incorporating sensors and actuators that operate independently or semi-independently with support by human thus stressing on intelligence and adaptability to deal with unstructured environments [11]. According to the International Federation of Robots (IFR), an *industrial* robotics defined as "*an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications*" [7]. Industrial robots are different with *service robots* which are not involved in manufacturing operations. Since there are a lot of studies that covers the trend of the use of robotics in manufacturing for automation solutions, it will highlight on the developments in industrial robotic solutions rather than service robotics.

Robots have mostly and widely been used in industrial manufacturing system [8]. However, the industrial revolution as a result of the development of this technology, the use of robotics is the most famous and widely in the manufacturing of automotive industry [9] (Figure 2). Most of the industrial robot is programmed to carry out specific actions repetitively with some variations, but with the high level of accuracy and precision.

Figure 2: Spot-welding performed by robots on an assembly line [3]

As part of robot function, essentially performing 3 main functions which are sense, think and act (Figure 3). Robots will sense environment by stimulation or visualization which is sensor. From this stimulation, they think by processing pre-set algorithms which is stored in the processor. The processor will process these algorithms and then translated into physical movement or act. In automation manufacturing, the usage of robots which can be pick up a parts or place it into conveyer or clamp a welding torch in welding metal parts.

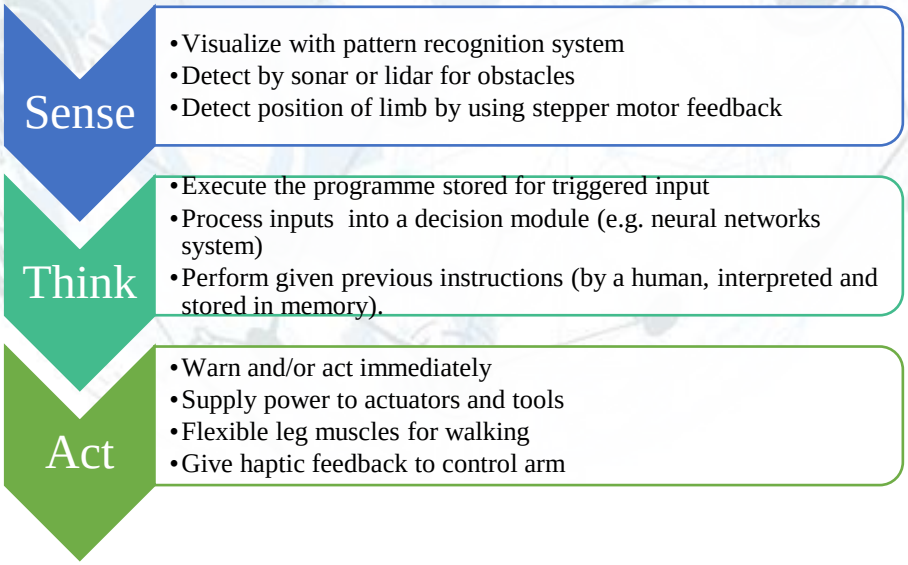

Figure 3: Basic robotic functions [8]

The latest technological advances in robotics have been intended to bring robot solutions to industries where they should not be used in advance such as packaging, food processing and waste management. This reform is a more effective solution where it can identify different objects orientation and the type of material and adjust their behaviour accordingly. Currently, some of new development of robot is user-friendly which provide more flexibility in term of more intuitive and

simpler of programming by its function. In addition, these developments of robot allow user works within the same space safely and even cooperate with one another.

4.0 INTEGRATION OF MEASUREMENT TECHNOLOGY WITH ROBOTICS AND APPLICATIONS

Few years back, measurement processes in manufacturing organization were carried out by manual system. But as the technologies developing, manufacturers started to use automation for measuring process. Measurement technology has become a necessity for any manufacturing organizations because the precision and speed is highly essential. For example, in semiconductors industry, measurement process is one of their main elements in the operation. Because electronic components have a very fine structures and manufactured in big volumes. In this case, at Fujitsu, they manufacture semiconductors, hard disk drives (HDDs), display elements, and micro electro mechanical systems (MEMS) devices, 3D measurement technology that enables fast, accurate measurement of solid shapes in the sub-micron to sub-nanometer region has become essential [12]. To improve these types of measurement technologies, it needs the helps from a robot in order to achieve the speed and fulfil the outcomes.

Furthermore, IHI group companies have introduce their R&D activities to allow industrial robots to work in bin picking, payload handling, assembly, and similar operations. These R&D activities integrate with IHI's advanced technologies: such as sensing and measuring technology, control technology and mechanism technology, to automate operations not possible for conventional robots [13].In the past, factory production lines were automated with many industrial robots and machines. But recently, flexible manufacturing systems (cell production system) have been introduced in the manufacturing factories. Its more toward an entire product is assembled by one worker. Many tasks in flexible manufacturing system is heavily depend on workers because the number of parts to be handled is larger and if this task transferred into robot's job description, the time and cost will be greater. Due to the drop of population in Japan, they realised that it is the right time to prioritize automation in the manufacturing system. Few human tasks will be automated and some of it still lack of automation level. Therefore, IHI's R&D would like to discover and develop a new technology using robot for advanced sensing technology, control technology and mechanics technology. In this paper, the concept of a system which industrial robots are applied to picking work, handling work and assembly work. Usually, the parts are arranged and transferred in the bin by the workers. Humans can easily recognize the parts such as bolts and perform the task but robots faced the difficulties in measure the part with sensor, recognize the parts and take them out. IHI has developed bin picking robotics using 3D object recognition technology. This system adopts the laser as three-dimensional measurement method unlike using cameras which is less efficient. Handling parts in bin requires complicated recognition processing of large amount of 3D measurement data and operation cannot be completed within the targeted time. Figure 1 shows the bin picking robotics using 3D object recognition where it able to complete the measurement, transfer, inspection and arrangement in 12 seconds. Table 1 shows the basic specification of the systems such as measurement, recognition, target object and basic configuration.

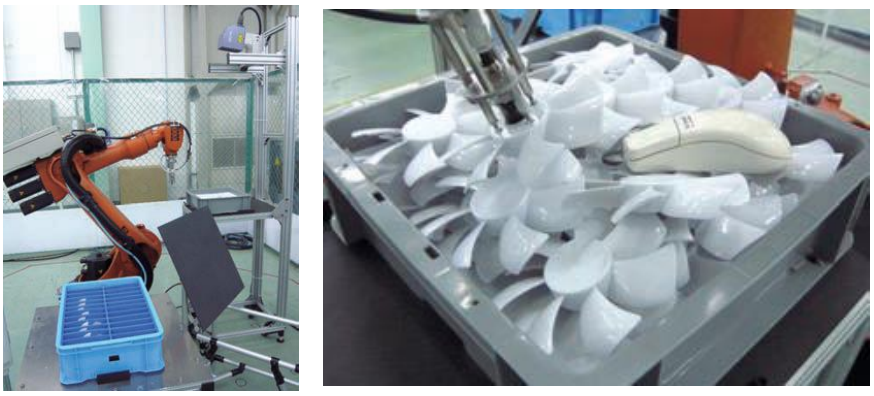

Figure 4: Bin picking robotics using 3D object recognition; (a) Configuration of entire system, (b) How workpieces are picked.

Table 1: Specifications of bin picking robotics

Items		Specifications
Measurement	Method	Three-Dimensional measurement using lasers
	Distance	500 to 1000 mm
	Range	250 × 250 to 500 × 500 mm
	Time	Depending on the measurement range
Recognition	Method	Recognition of three-dimensional shapes by comparison with three-dimensional data
	Processing Time	Depending on the situation
Target Object		Parts, etc. (min. 50 × 50 mm or so)
Basic Configuration		Control unit, robot, robot controller, hand and range sensor

This is how the measurement technologies have been integrated with the robots so that all tasks can be performed accurately. Even a small difference in the measurement can failed the whole operation because the measurement identification is the first step before proceed to next step.

In today's global market, the importance of accurate, precise, reliable and comparable measurements is the key factor for achieving quality in activities and procedures in every area of industry. The majority of modern industrial measurements can be categorized as GDT (Geometrical Dimensioning and Tolerancing). Increasingly, measurements obtained by coordinate measuring machines (CMM) are being used [14]. CMM is a measuring device with high measuring speed even though the positioning and rotation of the measured object are always performed manually. It can measure the object from few different sides but the object need to be positioned in the position relative to the CMM. So, whenever the measured object position changed, it will cause increased cost in control and production processes. Therefore, the purpose of this paper is to reduce this cost by introducing several options for positioning measured object inside the working area of a CMM by using an industrial robot. Robots are widely used in manufacturing sectors which requires high productivity and high quality. It supports the manufacturing process by positioning the part during machining, assembling, transportation and etc.

Before conducting this experiment, there is research done on the CMM using industrial robots. The Robot-CMM integration was performed by the Mitutoyo Company for the first time [15]. They developed a software module to adjust the actions of CMM and robotic handling machines used to manipulate the measured part relative to CMM. They also provide the code for the vendor to develop the products in future. This research did not made any achievements during at those times. Therefore, the goal of this research was to access whether robots can used to manipulate the measured part in complex measuring system using uncertainty analysis and estimating the factors

affecting it. Figure 3 illustrates the typical fixturing assembly for CMM measurement. The part is too complexity and major time consuming when CMM measure the part. To measure it, the part position needs to be manipulated different sides due to complex part shapes. The experiments were done in three different systems in order to test the possibility;

1. Measuring fixed object with CMM only
2. Measuring with complex CMM-robot system, with fixed mass of measured object
3. Measuring with complex CMM-robot system, with variable mass of measured object

Equipment used in this experiment is using five degrees of freedom robot called Robot RV-2AJ and the coordinate measuring machine (CMM) named Zeiss Contura G2 700 Aktiv. The main objective of this research is to open new opportunities in this field and encourage more improvements towards the usage of the CMM machines in order to shortening the procedure and decreasing the measurement cycle time. Finally, this research paper concluded that the measurement data obtained from the three types of system above is varied due to the impacts and vibration occurs during the measurement process. But, current situation can be improved by using different design of CMM and robot combination in order to reduce the impact and vibration and also suggested to use more accurate, great capability, repeatability and etc. robot. So, automating a measurement process with a robot is much more efficiency because it more accurate and faster process than human involving in the process.

Most of the industries are already start utilizing robotic measuring technology which is very accurate and precise result compared to manual process. In this case, JSR Ultrasonic company from New York is using online robotic to measure thickness and colour measurement of their product. In this company, the parts or products being coated are large and the volumes are high. So, measurement of process output was obtained using manual gauge. They found that manual measurement is difficult because it only can measure few colours and body style combinations. It takes a long day to complete this measurement.

Therefore, an online automated measurement system can make it possible to significantly increase the rate which samples of paint process can be obtained, especially for different combinations of colours, parts, or body styles and paint application booths. This dramatic increase in sample size along with a corresponding reduction in measurement time lag can lead to a significant improvement in control and optimization of the paint application process and facilitate troubleshooting of process problems. In turn, improved control over the process will provide benefits such as enhanced paint quality and reductions in both material usage and environmental emissions. In addition to reducing time lag in obtaining paint process measurement feedback, there are other advantages to utilizing an automatic online measurement system. [16]. Other than that, this robotic can eliminate many issues such as to get measurement on the curved surfaces even though it is quite challenging. All the measurement was done by using a non-contacting ultrasonic sensor gauge. This gauge is fixed at the tip of robot arm like illustrated in the figure 3 below.

Figure 5: Availability of automated online film thickness measurement using robotic technology

The use of more powerful measurement technologies with robotics really helps the productivity of manufacturers. Winterthur Instruments and Laytec for example provide solutions which benefit their clients from understanding in real-time whether there is an error in their manufacturing process. Conventional solutions would not allow for this, meaning a large amount of wasted produce before the error is detected, resulting in large unnecessary costs. Early error detection also increases quality and client trust in turn [19]. This is because robotics with measurement technologies actually will complete the process or task without any defects on the product. Moreover, error elimination will lead to high quality of product. Therefore, the clients will be happy to expand their business when we produce high quality of product.

Food safety in the food and beverage industries is an important concern. That is why the risk of contamination of the foodstuffs is taken with great attention, especially when considering manufacturing processes. Following that, reducing the need for workers to come into contact with the product is an asset. This can be done with the use of robots. Another example of such an application is ensuring the quality through the use of integrated measurement technologies. Automation solutions in this industry minimises chances of contaminated produce, benefitting the customer, and minimising liability for the manufacturer [19]. Food manufacturer is very concern about their product because consumer is very concern about the quality of the product. Their company image is depends on the food quality and also the packaging itself. In food manufacturing company, there are plenty packaging process and they need more workers. In order to reduce the workers cost, they need to apply robotics in their production processes.

Communities closely linked with large factories usually have feared towards automation solution such as robotics. This is because most workers who work in the large factories lost their jobs when robotic were introduced production line. In fact, the opposite is true as manufacturing businesses have the possibilities to save and create more jobs than eliminating them [19]. Even though this looks like an issue for the communities but actually they need more workers to control and operate the robotics like robotics expertise. Therefore, robotics will not be harmful in human's life but it will be helpful.

Promoting on research and development (R&D) in integrating measurement technologies with robotics will advanced the technologies for the future. There are no limitations for technologies because it always will be more cost-effective and flexible. Finally, few manufacturing industries actually recycle the existing robots and change the function of it by applying measuring technologies into it. For example, welding robotics can reuse by re-programming that particular robot for sealant robot application. Now, the usage of sealant become limited compared to manual sealant application in automotive company. This application reduces the cost of material (sealant) and eliminates the cost of purchasing new robots for such an applications.

5.0 ADVANTAGES AND DISADVANTAGES

Most of the manufacturing organizations have both measurement technologies and robots to manufacture a product. Measurement technologies are needed to verify the product quality and compliance with standard and organizations, whereas robotics can provide solutions to improve the manufacturing processes. The integration of measurement technologies with robotics become a new trend in advanced manufacturing technologies where manufacturer seeking to achieve competitive advantages. These types of automation benefit the entire manufacturer in term of the manufacturing process and also the end products.

Integration of measurement technologies with robotics in the manufacturing processes can help improve the consistency of products or processes. The use of this type automation will remove the variables that can be attributed to human error. Human error is defined as a failure of a planned action by human to produce a desired outcome. For example, the operators on the production line will become tired and bored by performing the same task like measuring a part for the whole day. So, when we eliminate all the variability, it can lead to assist the standardization of manufacturing process and products.

At the same time, this automation can improve the product quality as a result increased precision in the production process. When measurement process was done by human is not accurate or precise enough compared to the robotics. For example, manual painting work by human has more difference in result compared to painting robotics. Robotics is efficient than manual painting by human because the paint material used accurately to paint according the measurement data programming in the robot. This application is widely used the automotive sectors especially in painting process. In addition, it also eliminates human error.

Other than that, this automation also can reduce the cost in manufacturing sector. For example, a robot can perform the same task as human did once it programmed and allowing to reduce the number of worker that particular measuring task. It will lead to reduce in manpower cost and the product itself. Another example of how automation could help reduce cost through measurement technologies integrated with robotics is human attention are needed for continuous measurement taken. If lack of concentration from human when necessary, it may affect the product by producing faulty product.

Measurement technologies could be implemented with robotics in order to better understand the performance or status of all the different devices within the manufacturing process. This would allow in predicting the abnormalities of the devices and planning the maintenance strategies accordingly. Integrating measurements within production as it goes on would also help reduce time lost correcting production errors, thus minimising time spent producing the end-product [17]. Lastly, health and safety becomes organization's concerned because sometimes workers need to do the measuring task in hazardous or unsafe environment such as measuring paint quality in painting booth at automotive industry. It can harm health of workers due to the paint chemical. Therefore, they introduce a method using robots to measure the quality of the layer coat paint instead of human and improve the quality as well.

However, there are disadvantages faced by the manufacturing organizations when they integrate measuring technologies with robotics. Research and development (R&D) for creating a new technology such as integration of measuring technology with robotics is high cost compared to the worker cost for that particular task. Other than that, weak bonding connection between the measuring devices with robots can affect the measurement process by produce incorrect data. To avoid these things happen, need to do regular maintenance on the robot and it consumes high cost. Then, need an expertise to handle this type of robots. So, the current workers need a special training for programming and interacting with new robotic equipment. It will take time and financial output for create an expertise on full knowledgeable about robotics.

Furthermore, return on investment (ROI) of this kind robotics becomes a disadvantage for the manufacturing industries. Incorporating industrial robots does not guarantee results. Devising a specific production plan from the beginning to the end is absolutely crucial. If a company has a bottleneck farther down the line, incorporating automation may not help achieve the goals needed [18]. This type of technology can increase the barriers to entry in numerous segments of industry. Usually, small-to-medium size (SME) companies do not have financial support to absorb advance technology in their manufacturing system. There are few SME still using manual operation than automation systems.

The unemployment rate will also increase due to the robotic application. Previously, workers are demanding for measurement but now, organizations start looking towards robotics that can produce precise and accurate results. At the same time, robotic with a measuring device can work in the factory with limitations of functionality and lack of intelligence. Most of the tasks related to creativity, decision making, adaptation and job learning only can be performed by human because human can think and robots act according to the programming coded by humans. An organization is not only spending in the initial investment is robotics, but they also spending for the electricity cost to operate the robots. Sometimes, robots can be extremely dangerous either for those people around it or people who operating it. Robots with measuring device require more measurement sequence for each difficult part. As a conclusion, robots with measuring technology do have wide range of advantages and disadvantages. Its utilization will only be demanding through time and with more technological advances like integration of measurement technologies with robotics.

6.0 CONCLUSION

The principal idea of this paper is to study on the integration of measurement technologies with robotics as new technology in current market. In the current and modern manufacturing system, utilization of industrial robots has increased in various industries sectors such as automotive, food, aerospace and others. Measurement technologies and robotics are two of the latest trend in the automation. Measurement technologies used for operational and regulatory purposes and also improves the accuracy of the data collected. In the other hand, robotics involves in designing, assembling and construction which previously conducted by humans. Therefore, by integrating these both trends, a new trend is introduced with both functions commit together. Now days, there are many application related to this trend such as online robot integrated thickness and colour measurement, CMM-robotics, and many more. These types of application actually benefit the manufacturer in terms of the quality product and precise production process. When both technologies are combined together into one, manufacturers are ready to invest in purchasing this robot instead of buying two different assets which may lead to high cost. The advantages of this new technology such safety, quality, production and savings actually overlap the disadvantages when manufacturer consume it. Consumer need to know the right time when to use the robots so that it only can profit them. However, as the technologies advanced towards the future, unemployment rate is going to increase and more humans going to go through a miserable life. Last but not least, not all the task can be done by robots and there are some task can only be completed by human’s brain.

REFERENCES

[1] National Research Council (NRC), 1998; Parasuraman & Riley, 1997

[2] Billings, C. E. (1996). Human –centered aviation automation: Principles and guidelines. Moffett Field, CA: National Aeronautics and Space Administration, Ames Research Center.

[3] Kalpakjan. Schmid. (2008). *Manufacturing Processes for Engineering Materials*. 5th edition.

[4] Swann, P.G.M. (2009). The Economics of Metrology and Measurement. Report for the National Measurement Office. Department for Business, Innovation and Skills. Final Draft.

[5] Hughes T.A. (2007) *Measurement and Control Basics*, 4th edition, Research Triangle Park, NC: The Instrumentation, Systems and Automation Society

[6] European Commission (2003), The Future of Manufacturing in Europe 2015-2020, *The Challenge for Sustainability Factory of the Future roadmap 2010*, HLG report on AMT

[7] International Federation of Robotics definition of an industrial robot. Available from: *http://www.ifr.org/industrial-robots/*

[8] Forge, S. and Blackman, C. (2010). *A Helping Hand for Europe; The Competitive Outlook for the EU robotics industry*. JRC: Institute for Prospective Technological Studies.

[9] International Federation of Robotics statistics. Source from: http://www.ifr.org/industrial-robots/statistics/

[10] Instrument Society of America. Source from:*https://www.isa.org/about-isa/what-is-automation/*

[11] IEEE's Robotics and Automation Society source from: *http://www.ieeeras.org/educational-resources-outreach/un-symposium*

[12] Hiroyuki Tsukahara (2006), *Three-Dimensional Measurement Technologies for Advanced Manufacturing*

[13] Ono Kazuya, Hayashi Toshihiro, Fujii Masakazu, Shibasaki Nobuhiro & Sonehara Mitsuharu (Vol. 42 No.2 2009), *Development for Industrial Robotics Applications*

[14] Samir Lemes, Damir Strbac & Malik Cabaravdic (2012), *Using Industrial Robots to Manipulate the Measured Object in CMM*, International Journal of Advanced Robotic Systems

[15] L. Adams, Wrapper Ties Robot to CMM, Quality, Vol.41, Issue 6, pp 22, 2003

[16] S. Rosenberg (2006), *Online/Robotic Integrated Thickness and Color Measurement* source from: www.jsrultrasonics.com/documents/ipp0106-ultrasonicsreprint.pdf

[17] Peter Zelinski (2013), *The Unexpected Advantages of Robotic Automation* source from:http://www.mmsonline.com/articles/the-unexpected-advantages-of-robotic-automation

[18] Advantages and Disadvantages of Automating with Industrial Robots source from: https://www.robots.com/blog/viewing/advantages-and-disadvantages-of-automating-with-industrial-robots

[19] Laurent Probst, Erica Monfardini, Laurent Frideres, Steven Clarke, Dawit Demetri & Alain Kauffmann, PwC Luxembourg (2013), *Advanced Manufacturing: Measurement Technologies and Robotics*

CiE-TVET 2019

9th National Connference in Education

Technical & Vocational Education and Training

eISBN 978-967-11412-7-4

Diterbitkan oleh Jabatan Pendidikan Politeknik & Kolej Komuniti (JPPKK), Kementerian Pendidikan Malaysia
dengan kerjasama Politeknik Banting Selangor