

## CONFIGURING SAFE INDUSTRIAL ROBOT WORKCELL IN MANUFACTURING INDUSTRY

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**ABSTRACT:** This paper presents a proposed framework for determining workspace and safe working area of industrial robot. The focus of this work is on providing a fast and easy configuration approach for safe robot working area. In order to design and develop the proposed Framework for the Robotic Work Cell Configuration (FraRWCC), a research and case study on industrial robot and its specification were carried out and described briefly in this paper. A study on a computer program and CAD software has been conducted to enhance knowledge and information used in this project. Solid Work software was used to create 3D robot workspace while Microsoft Visual Basic. Net was chosen to program a set of object-oriented programming for creating a complete user interface. Users may interact with the developed user interface to determine robot workspace and safe working area. By using this computer program, it may reduce the time for installing the industrial robot and potentially avoid any accident during the robot operation.

**KEYWORDS:** *Industrial Robot, Workspace, Safe working area, Configuration, User Interface.*

## 1.0 INTRODUCTION

The recent statistic issued by the International Federation of Robotics (IFR) in its 2015 World Robotics as shown in Figure 1 indicates an enormous increase of industrial robots supply to the industry by nearly 30% from the previous year to 229,000 worldwide in 2014 [1]. The statistic shows that the demand for industrial robots has accelerated [2] considerably due to the ongoing manufacturing trends toward automation as well as continued innovative technical improvements of technology [3]. Following the current trends, IFR has also predicted that by 2018, global sales of industrial robots will go on average grow year on year by at least 15 percent [1]. This prediction further highlights the importance of the role of industrial robots in enhancing the global competitiveness of future industrial production.

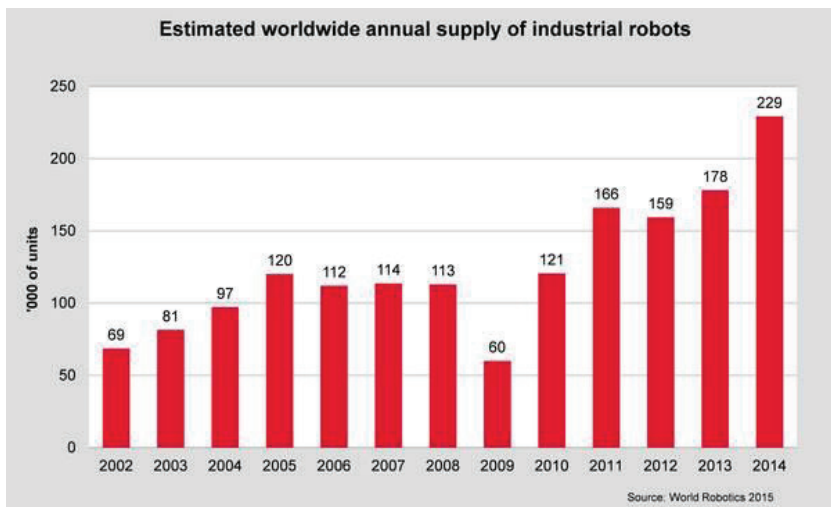


Figure 1 : Estimated Worldwide Annual Supply of Industrial Robots, IFR 2015.

To stay competitive in the global market, manufacturing industries are forced to improve their production processes and lower the costs. With further improvements of robotics technologies and continuous development of intelligent technologies in recent years, robotics application areas have become broader and more reliably cost effective. With the further development and enhancement in technology, the use of industrial robots undoubtedly plays important roles that drives this development. Nevertheless, to meet with the dynamic and advanced usage of industrial robots technology, the

industry also faces a new challenge to configure their current robotic work cell as well as their future robotised factories accordingly [4–10]. The control system and configuration for the robotics work cell in industries are presumably hard to maintain. This is due to the variation in customer demand that may lead to frequent changes in product specifications. It is also tricky and hard to implement as it needs to concern about installation procedures, safety and the flexibility of the robot.

The initiation of this study is aimed to develop a framework for easy configuration of current and future robotic work cell at lower cost with minimal human involvement. This so-called Framework for the Robotic Work Cell Configuration (FraRWCC) is aimed to aid future engineers to easily configure their robotics workcell based on the appropriate standards. The FraRWCC will provide a three dimensional simulation platform prior to the development and configuration of the real robotic workcell. The outcomes of this framework will simplify the process of configuring the robotised factories in the future. It will also further enhance the human-industrial robot interaction as well as optimising the usage of the industrial robots working within the current and future workcell without concern any changes of the product demand. This will certainly reduce the cost and save the future investment as well as reduce the time for developing a new robotic workcell.

## **2.0 REVIEW OF RELEVANT WORK**

The industrial robots used in manufacturing industries pose a new challenge to the safety system and robot installation. This is valid for all people in the industries especially the workers who work in the robot working envelopes. Injury rates for workers has been increased due to the lack of proper safety system, robot installation software, and safe working area [11–15]. So, the need for safety system and robot installations software is important and necessary. All of these things are to ensure the hazards can be minimised and eliminated to an acceptable limit [16].

Most of the industries utilising industrial robots in their factories are facing an issue of ways or methods to maximize the usability of their industrial robots [17]. One of the aspects is an appropriate approach to configure and reconfigure their robotic work cell to adapt with future changes. Ever since the industrial robot was introduced in the manufacturing industries, it has created new challenges for configuring the layout of new cell within factories. The layout of the cell will be much dependant on the workspace of the robot. An example of workspace for the industrial robot is shown in Figure 2 [18].

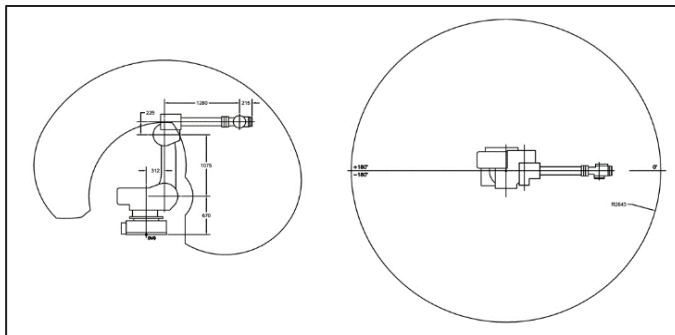


Figure 2 : Example of Industrial Robot Workspace

In order to configure this type of high end and sophisticated robotics system work space, a truly expert is required to consult on the configuration progress. This involves enormous amount of money and eventually will encompasses some time for the consultant engineer to assist in designing the desired layout for the robotic work cell. The robotic workspace helps to clarify and indicates the area needed to provide safe working surrounding for the robot in the work cell. Upon approval of the design layout, the cost of the installation and configuration will be another issue since there is no system or simulation software to forecast the outcomes of the system that include the processing time, installation process, configuration cost and efficiency of the designed layout. The current approach for configuration of the industrial robot to perform new or different tasks requires high cost of investment, more rigorous time and a lot of human involvement [4–10]. For instance, a current approach focuses on designing robotic workcell layout where, the proposed layout is made reconfigurable by the provision of some of extra material-handling system which results in additional cost [19].

### **3.0 METHODOLOGY**

In order to ensure the feasibility of this study, the project scopes for developing the FraRWCC have been clarified. The selected type of process for the study is welding process. The process is chosen due to the fact that most of the industries utilise their industrial robots for this type of process. This study will be focusing on the involvement of industrial robots within the welding process. This includes the structure of the gripper and tools used within the work cell. The proposed framework will also depend on the type of industrial robots and its degree of freedom (DOF) selected. At this stage, six (6) DOF of an articulated type industrial robots have been chosen. The main reason for choosing this type of industrial robot is due to its higher complexity that covers most of the other types of industrial robots. In this study, the structure and anatomy of various single 6-DOF articulated type of industrial robots will be taken into consideration.

Another consideration is the limitation for the number of industrial robots working within the work cell. For the purpose of this project, a maximum four (4) industrial robots are capped for the developed framework. Nevertheless, for potential future development of the framework, this limitation is temporary and the framework may have an endless number ('n' number) of industrial robots within its system. In order to ensure the framework will be much appreciated at the end of its development, the simulation work will be in three dimensional (3D) form. This 3D form will ensure a detailed layout of the proposed robotic workcell can be proposed.

One of the important development for this framework is much dependable on the type of rules applied. Two rules are seen as a potential for the development of this framework that include first come first serve (FCFS) rules as well as forecasting rules. These rules will be applied to the framework as a basis for organising the correct flow of process and predict new process to reconfigure the current process. The successfulness in utilising the rules is the key for determining a better robot's usability, performances and the cost for the implementation.

For the initial choice, a visual basic (VB.NET) will be used to program the framework using the rules. To ease the overall development of the framework, the development of graphical user interface (GUI) for the framework will also use VB.NET. The final supporting form of the framework will be presented in a CAD form so that the user has a better understanding of the proposed robotic work cell. The CAD software chosen is SolidWork. SolidWork is chosen due to its ability to be linked to VB.NET as well as providing a better CAD environment that can be used for other types of analysis in the future.

## 4.0 RESULTS AND DISCUSSION

### 4.1 Configuration structure

Prior to the development of FraRWCC, some formulae will be used in this research based on the configurations and the number of robots. The formulae help to determine the safe working area for robotic workcell. The main formula was based on previous study as shown in Figure 3 [20]. Different formula signifies the robot workspace of different specifications (configuration and number of robot). At this stage the configuration of all robots are in linear arrangement. For general formula development, an articulated type of robot is taken as reference due to it being the most dangerous and widely used robot in industries.

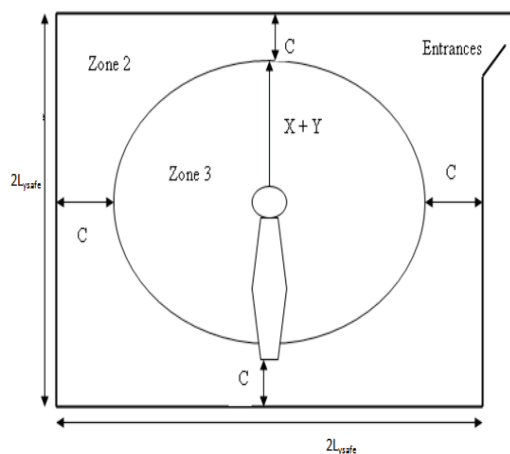


Figure 3 : Basic Illustration of a safe Robot Workcell for Single Robot

The formula for safe distance,  $L_{safe}$  are described as follows:

$$L_{safe} = x + y + c \quad (1)$$

where;

$x$ : Length of robot arm (mm)

$y$ : Length of robot gripper, dedicated tool and work pieces(mm)

$c$ : Clearance for worker movement in a work cell (mm) taken as 650 mm.

The following are the fencing area,  $A_{fence}$  that have been developed from the safe distance formula:

$$\begin{aligned} A_{fence} &= 2L_{xsafe} \times 2L_{ysafe} \\ &= 2(x + y + c) \times 2(x + y + c) \end{aligned} \quad (2)$$

The following are the list of the formula that have been developed accordingly:

Configuring two robots (linear arrangement)

$$A_{fence} = 2L_{xsafe} \times [2(x_1 + y_1) + 2(x_2 + y_2) + 3c] \quad (3)$$

Configuring three robots (linear configuration)

$$A_{fence} = 2L_{xsafe} \times [2(x_1 + y_1) + 2(x_2 + y_2) + 2(x_3 + y_3) + 4c] \quad (4)$$

Configuring four robots (linear configuration)

$$A_{fence} = 2L_{xsafe} \times [2(x_1 + y_1) + 2(x_2 + y_2) + 2(x_3 + y_3) + 2(x_4 + y_4) + 5c] \quad (5)$$

The next phase is to translate the developed structure and to lay it in a form of proof of concept. The structure itself depends on user selection. It will help the user to indicate the overall safe working area of the robot and the desired layout of the robot during the installation and working time. At this stage, the concept will be provided in a form of programming.

## 4.2 Programming Structure

The computer program for FraRWCC is developed by using VB.NET language. The computer program is initially developed for a single robot, followed by two, three robots and lastly four robots. The flow chart of the single robot program is shown in Figure 4. The process begins by choosing the quantity of the robot (S-single, D-double, T-triple and F-quadruple). Then, the user needs to specify the length of  $x$  and  $y$ . After that, the program will calculate by itself and determine the area of the needed space. For two, three and four robots, the flow chart will be extended accordingly to the number of robot. For instance, the flow chart for two robots will extend by entering another robot value ( $x_2$  and  $y_2$ ).

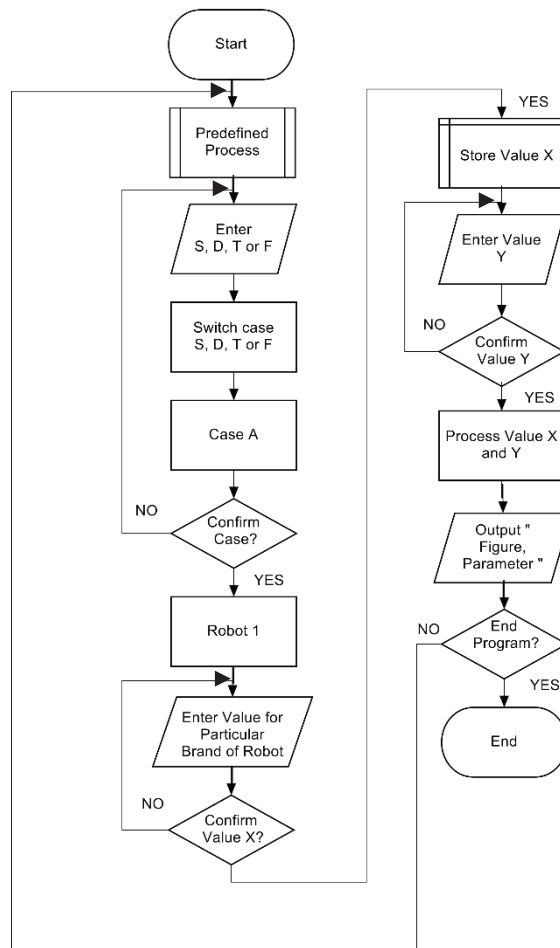


Figure 4 : Single Robot Working Structure



### 4.3 Graphical User Interface

The user interface for this project is divided into 4 levels. The first level is used to select the quantity of the robots. In this level, the maximum quantity of robots is capped at 4 and the minimum quantity of robot is 1. In the second level, the user will choose the brand of each robot. Second level user interface is utilising similar concept of the first level user interface. The current program contains five brands of industrial robot (FANUC, ABB, KUKA, KAWASAKI and MOTOMAN). Once the user click the “Next” button, the next level will appear automatically.

In the third level, the user needs to select the “Model of Robot” based on the brand of industrial robot selected in the previous level. This is to ensure that variation of model with various configuration can be made. The other control in this level is the selection of 2 command buttons (“Next” and “Back”). “Next” command button will present the selected robot drawing and “Back” command button will return to the previous level (Brand of Robot level). The fourth level presents the result of working envelope for the robot according to the information entered by the user in the previous level. This interface will show the proposed layout of the robot workspace and the safe working area. Fourth level user interface or Result Level user interface shows the layout of the workspace as illustrated in Figure 5.

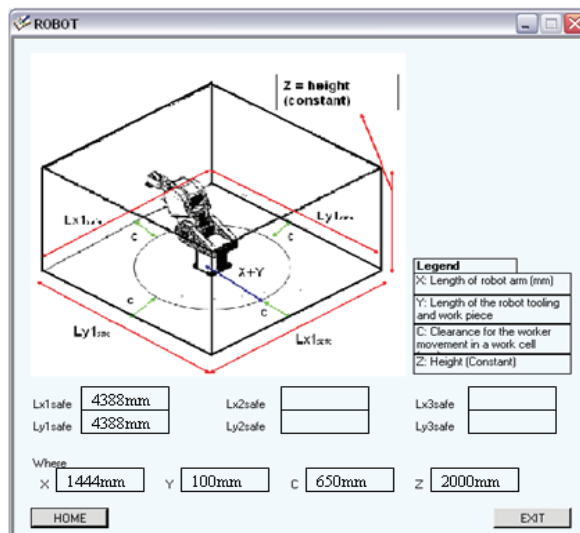


Figure 5 : Forth Level User Interface

This layout will show the length ( $L_{xsafe}$ ), width ( $L_{ysafe}$ ), and height ( $z$ ) dimensions of the workspace. The dimension of safe work envelope depends on the information selected by the user and those dimensions should be considered during installation of the industrial robot. Besides that,  $X$  is length of robot arm;  $Y$  is Length of the robot tooling and work piece;  $C$  is the clearance for the worker movement in a work cell which is constant,  $650mm$ . This is based on 95% tile of shoulder breadth of human, which ranges from  $475mm$  to  $520mm$ . The three dimensions are hidden and they are only shown in the code. All the dimensions are in millimeter ( $mm$ ).

The developed FraRWCC program provides an easy determination of the robot safe working area that may then reduce the risk of hazard in the workplace. The presented program was created for the purpose of determining the 3D robot workspace and safe working area. This program is expected to help the industry to set up the location of robot arm and improve the facility design and reduce hazards in the workspace. The 3D robot workspace and safe working area is used to avoid accidents during the operations of robot. By using this program, the safe working area of a robot can be determined. Besides that, it also has a few arrangements for robot; the robot can be arranged in a few arrangement depending on the location in the factory. Through the proposed layout with the determined safe working area, the user may design the 3 safety zones in the robotic work cell that is used to determine the safety and reliability for robot working area in workcell.

## **5.0 CONCLUSION**

This phase of work produces an initial solution to the current issues through the development of an appropriate framework which can (re-)configure industrial robots in manufacturing industries. It is essential to save the configuration time and cost for robotic work cell in manufacturing industries. The FraRWCC framework is capable to show the flow of the process movement in 3D as the robot is arranged by position in the proposed layout. It also helps in designing an optimal process flow and also can clarify and give ideas to the engineer about the design layouts. Hence, engineers can predict and calculate the efficiency of the design without basing it on field's data to forecast the effectiveness of the system before installation. The

outcome of this study may help in improving the flexibility and agility of the industrial robot in the work cell and utilised the industrial robot's performance in production line. In the next phase, the framework will aid in developing, designing and simulating the 3D simulation for the view of the designed robotic work cell according to the number of work cells (n) that have been given, Degree of Freedom (DOF) of the industrial robot, industrial robot's envelope, process description, types of end effector and industrial robot's performance task. The Framework for the Robotic Work Cell Configuration (FraRWCC) is hoped to aid in boosting the productivity and utilise the performance of the industrial robot in manufacturing industries.

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