



## Lab Design of FANUC Robot Operation for Engineering Technology Major Students

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## **INTRODUCTION**

Nowadays, automated equipment and machines are widely used in industry to reduce labor and increase profit, efficiency and producing ability. Robotics arms, as one type of automated devices, are vital importance in packaging lines, dangerous working environments and other jobs, which are relatively dangerous for human workers. Several companies produce robotics arms around the world because of the large need in the market. FANUC is one of the most famous companies and is commonly used in the industries. The most common type of robotic arm is their 6-joint robot, which is similar to the robot that is utilized in this project. As Mechanical Engineering Technology (MET) and Mechatronics Engineering Technology (MCET) students, being able to program automated machinery is crucial for them to find jobs. The school has been offering Programmable Logic Controllers, Process Control and CNC machine courses to build students' strength. In order to complete all aspects of automation industries, this project is designed to make up the lack of robotics programming education. Furthermore, this project will also prepare students who are interested in taking robotics concentrations later.

FANUC America, as one of the largest companies producing automation products and systems, produces FANUC industrial robots, which are widely used in the fields. The main goal of these labs is to prepare MET/MCET students to take robotics concentration courses at Purdue University Northwest and to work in automation/robotics fields in the future.

All the labs will be performed with FANUC LR Mate 200iD educational robot. It has six axes: base, shoulder, elbow, rotation of the arm, pitch of the wrist, and rotation of the hand plate. The first lab will be a safety lab, which includes rules and guidelines that students need to follow or be aware of during lab sessions. The educational robots are mainly designed for training purposes. Also, to fit in the goal of this project, which is preparing students for more advanced robotics courses, the programs that will be created for the project can't exceed the limitations of these educational robots. For instance, the grabber size is limited by one size and it cannot lift too much weight, the pick-and-place simulation lab objects are limited to quarters.

## DESIGN PHASE

The project describes five labs in total covering from safety to writing programs and testing. Each lab focuses on a topic. After performing all the labs, students will be familiar with writing programs and running them continuously or systematically. The following are the topics for all the labs:

Lab 1 – Safety Lab

Lab 2 – Introductory Lab

Lab 3 – Programming Fundamentals

Lab 4 – 2D Sketching Implementing

Lab 5 – Pick-And-Place Simulation

### Lab1 – Safety Lab

The first lab of the project is safety lab. There are safety equipment and technology that are built with the robot to protect itself and personnel. This lab includes the main design and rules that students need to follow when they perform labs. For instance, the Deadman switch is included in this lab so that students would know to press and hold the Deadman switch while programming and running the robot. The objective of this lab is to provide detailed information of FANUC robot safety devices and programs to prevent any accidents while performing labs.

Safety is one of the significant topics to cover at the beginning of any labs that are conducted with moving machines. Even though the robots for this project is not moving with a high speed, there are still potential hazards for students and personnel who work with the robot, which is the reason why safety lab is the first lab to be introduced. This lab ensures that instructors and students are both aware of hazards during the lab to prevent any accidents from happening.

Personnel safety is the first element of the lab. In the discussion portion, general safety instructions are provided, such as never wearing watches, rings, neckties, scarves, or loose clothes, and before operating, visually inspect the robot and work envelope to make sure that no potentially hazardous conditions exist.

Equipment safety is the second element introduced. For different working environment set-ups, the equipment safety could be different. In this project, a fenceless robot is the most common use of all labs. When work with fenceless work envelope, make sure that there are no objects on the



**Figure 1 Fenceless Robot**



**Figure 2 Deadman Switch**

robot's moving path. The indication lights are above the robot and mounted to the back wall of the work envelope. The lights only work when the robot is running in auto mode. It is connected to the sensor underneath the working surface that senses distance. Depending on the distance between the operator and the robot, the green light will light up first if it is a safe distance, followed by the yellow light if the operators standing at a potentially dangerous distance. The red light will light up when the operator gets within 3 feet from the robot.

During the operation phase, Deadman switch should always be held in the right position to protect the operators.

Before testing the programs, use a low motion speed and single step the program for at least one full cycle. Use a low motion speed, test run the program continuously for at least one full cycle. The current moving speed is shown on the right top corner of the screen.

Dual check safety (DCS) is one of the features that built within the system. It checks the speed and position data of motors with two independent CPUs in the robot controller. It uses only the built-in servo motor sensors for this function.

## Lab 2 – Introductory Lab

The second lab of the course is an introductory lab. This lab mainly introduces the components of the robot. It provides a detailed description of each component, as well as functions keys on the teaching pendant. The components include the main controller, teaching pendant, and the robot itself.

This lab focuses on providing information of each component and students can always refer back to this lab when they perform further labs later on. Robots contain mechanical and electrical parts and designs. In order for students to move forward with the following labs, they should be able to identify each component and its function.

The object of this lab is to provide information of operation FANUC robots and programming device.

## Robot components

FANUC LR Mate 200iD will be utilized in all of the labs. It is a 6-axes robot. The axes are base, shoulder, elbow, rotation of arm, pitch of wrist, and face plate. An electric servomotor drives each axis. When jogging the robot, each axis can jog separately or together under different frames.



**Figure 3 Main Controller**

Main controller: The main controller is where the power switch, emergency stop, and mode switch are located. It contains the computer that operates the robot.

1. Power switch: power ON and OFF the robot, the main controller, and the teaching pendant, which will be covered in the next section.
2. Mode switch: allow robot to switch between AUTO and T1. Each mode will allow robot to jog under a specific motion speed range.
3. Emergency stop: to shut down the robot when emergency happens.



**Figure 4 Teaching Pendant**

Teaching pendant: The teaching pendant is the device used to give motion control to the operator, move the robot, create and edit programs, test programs and perform manual movements.

1. Teaching Mode switch: in order to use the Teaching pendant to program the robot, this switch has to be ON so that the teaching pendant can control the robot.
2. Emergency stop: to shut down the robot when an emergency happens. Emergency stop should be popped up when programming or jogging the robot.
3. Function key: the functions of each key on the teaching pendant will be discussed in more detail in the future labs. In different display screens, each function key performs different functions.
4. Jog key: there are 12 jog keys on the pendant to jog the robot in different directions and modes.

## Lab 3 – Programming Fundamentals Lab

This lab mainly focuses on how to create a program for the robot using the teaching pendant. In the lab, each student is required to create at least one program to get familiar with the steps.

First, they will learn to power up the robot. Once the robot is powered on, they will learn how to jog the robot by joints. Then, they can switch frames and jog the robot within different frames. After feeling comfortable with jogging the robot, they will start to learn how to create a program. The idea of writing programs for FANUC robots is picking points and recording positions on the teaching pendant. The lab contains detailed procedures of how to pick and record points. The first program of each student should contain at least five points. After creating the program, they will run the entire program for at least one full cycle.

The objective is to power up, jog the robots and initial setup the robots, and create a simple program and test it.

### Powering up the robot

Firstly, to power up the robot, turn the power switch counterclockwise as seen in Figure 3. Then wait a few seconds until the teaching pendant is also turned ON. Secondly, check the AUTO/T1 switch to ensure it is on T1 mode. At the main time, ensure the teaching pendant is ON. Finally yet importantly, the emergency stops on both main controller and teaching pendant should be ON. Refer to the second lab to locate where the emergency stop is on the teaching pendant.



**Figure 5 emergency stop on TP**

### Jog the robot

To jog the robot, the operator should first hold on the Deadman switch at its second position.

1. Press and hold “shift”, and hit “reset” until the “fault” light is clear.
2. While holding both Deadman switch and “shift”, press any jog keys to jog the robot.



**Figure 6 Job the robot**

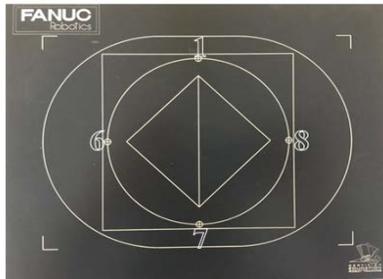
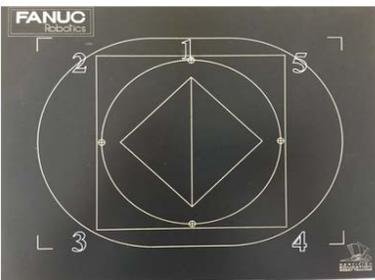
In this lab, students are required to first jog the robots, and then create a simple program containing at least five points to become familiar with recording points.

Students will follow a list of instructions to create their programs.

Each student should have different programs from one and another. Then, each of them should be able to test the program and run it in full cycle. In the practice portion of the lab, each student should attempt to create a more complex program and test it.

#### Lab 4 – 2D Sketch Implementing

The introductory lab is following by a 2D sketch-implementing lab. Students will use a template as shown in figure 1 that is printed on the working surface of the fenceless robot. In the lab, a number indicates points in sequence so that students can follow the figures to create the program. The reason why this lab starts with the drawing in figure 1 is that it contains linear motion and circular motion, which are basic motion types that FANUC robots are able to complete. As far as applications of FANUC robots in industry, linear and circular motions are also fundamental for creating complex shapes using any modelling software. Performing this lab will allow students to



**Figure 7 Templates for 2D sketch implementing**

get familiar with programming shapes in FANUC robots. Later on, they can apply this knowledge to any applications that requiring motion types in the industry. The objective is to create a 2D sketch using CAD software, and program the robot to trace out the 2D sketch.

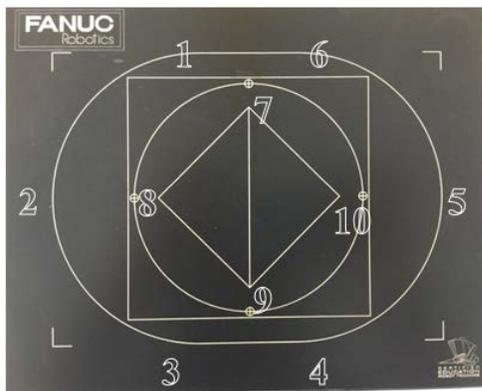
One of the reasons why robotic arms are widely used in industry is to avoid using laborers in any hazardous or dangerous situations. For example, cutting sheet metal into desired shapes may injure personnel. In this case, the robotic arm can replace human workers and get the work done precisely. The robot will move exactly as the program.

However, before the robot can start working, programming the path for the robot to follow is necessary.

Therefore, this lab will ask students to create a program that can trace the template shown in figure 1. After the program is tested, students will create their own 2D sketch and implement their sketch on the robot. The laser light attached to the grabber will be ON during the recording stage to make sure all the points are recorded as accurately as possible. After recording all the points in the drawing, instructions are added into the program so that the robot can grab a marker and draw the shape out on a white board.

The goal of this lab is to simulate a working environment of using robots to cut out specific shapes and parts. Students should also be familiar with different types of motions with FANUC robots.

Students should follow the templates in figure 7 to create their programs including all eight points indicated. In order to practice with motion types, students will need to continue with the program and create new lines for the small square in the center and the slot shape around the big square.



**Figure 8 Template for practice**

The points do not need to be at exact positions as shown. Students will need to locate each point approximately and record them.

Points 1 through 3 form a half circle. Points 4 through 6 form a half circle.

The motion type from 1 to 6, and from 3 to 4, should be linear motion.

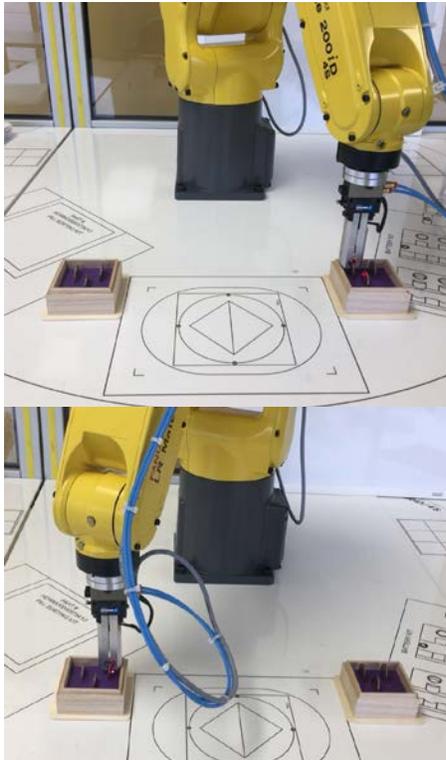
A YouTube video link of the complete program is provided at the end of this lab as reference for students. <https://www.youtube.com/watch?v=72HgSb6haPI>

### Lab 5 – Pick-and-place Simulation

The last lab of the project is a pick-and-place simulation. This lab addresses the most common use of robotic arms in the industry, which is pick-and-place. Students start the program with a pre-written portion of the first two pick-and-place movements. Then, they will record the next two movements themselves to make the robot pick up desired objects and place them at specific positions. This lab incorporates functions in a program, such as paste, insert, etc. It will be beneficial for the students when programming the robot with repeating motions. The objective is to complete a pre-written program of pick-and-place simulation.

This lab will focus on one of the most common uses of robotics arms in the industries, which is pick-and-place. While working with an automated packing line, repeatedly picking an object from the conveyor and placing it at another location is widely seen. However, the labor cost for

this simple movement can lead to a huge amount of money. Hence, using robotic arms to replace labor seems to be an efficient way to cut down the cost.



To complete the program, two boxes with quarters are placed on the working surface. This program will contain open/close grabber, repeating instructions, and moving along one user frame. The laser will be ON during the programming phase and it should be OFF when running the entire program.

Figure 9 indicate the set-up for this lab. Students will program the robot to move between the two boxes and move the quarters.

A YouTube video link of the complete program is provided at the end of this lab as reference for students.

<https://www.youtube.com/watch?v=v0kS6fbO5CU>

**Figure 9 Pick-and-place lab set-up**

## CONCLUSION

This paper discussed five labs, which are essential for students to learn, including safety lab, introduction lab, programming lab, 2D sketch implementing lab, and pick-place simulation lab. All the labs cover enough knowledge for students to successfully perform the labs and create programs as required, when keeping theories at basic level so that they would still be interested in taking robotics concentrations to learn more about FANUC and other types of robots out there. Students generally would have an idea of how robots track positions and points as they are programmed to move within its working envelope. The labs also include practice sections for students to move forward after creating required programs. Moving forward with the project, there are still space to perfect the lab materials. Since Mechanical Engineering Technology and Mechatronics Engineering Technology students do not have many experiences with programming or coding, these labs tend to keep a simple yet informational format throughout the

entire project so that all information is clear and straightforward for students to read. After completing these senior design project, it definitely opens a vision on how widely robotics and automated machineries used and how much work they can do. Pursuing concentrations on automation and robotics has become significant.

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