Hogeschool van Arnhem en Nijmegen
HAN University of Applied Sciences

HAN Master Major Project

# Major Project
# Using FANUC R-2000iC/210F (6-axis robot) for improved efficiency in FRC parts formation


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**Date:** 23/01/2020

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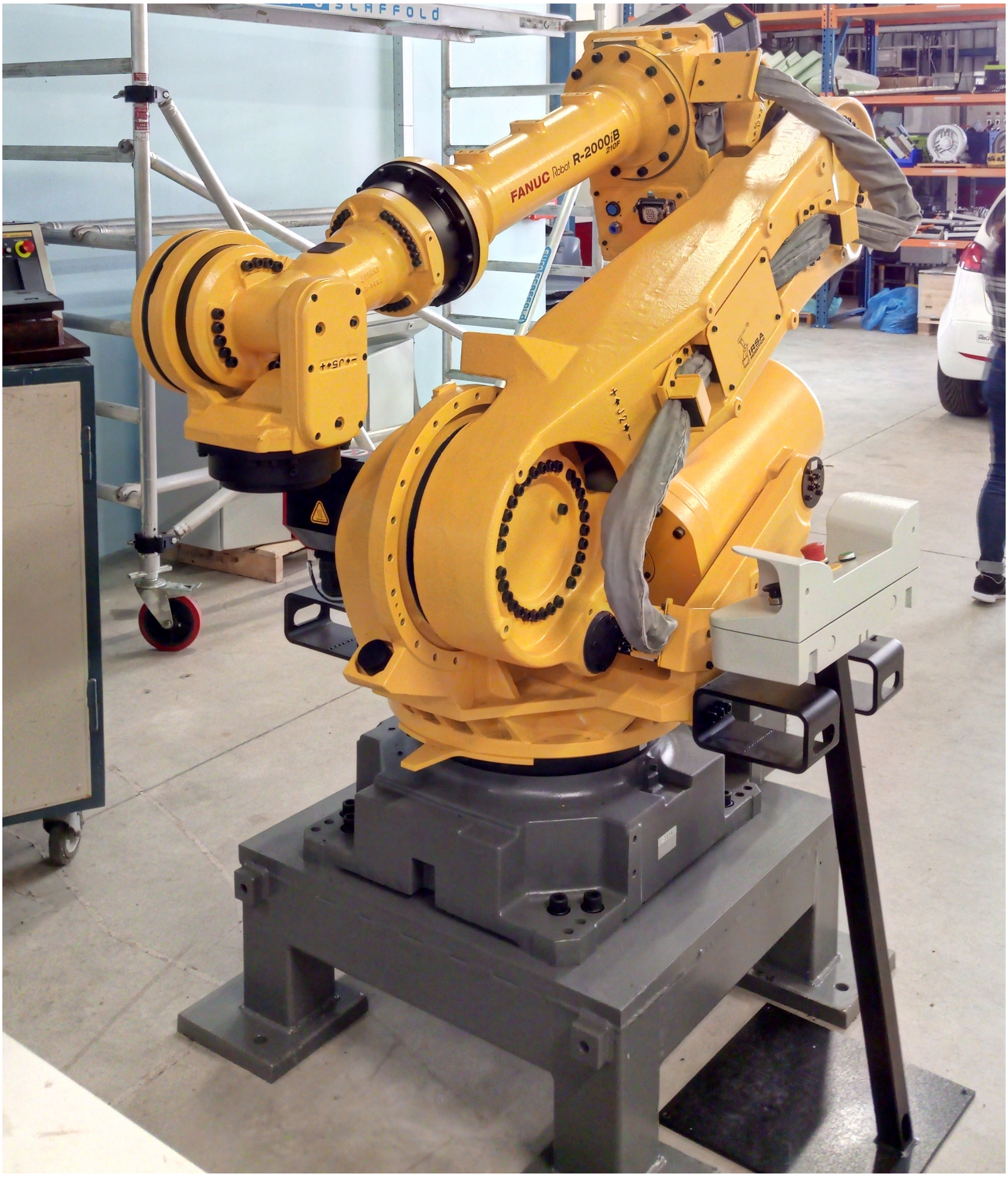


Figure 0.1: FANUC R-2000iC/210F 6-axis industrial robot arm

# Contents

# Abstract

This work aims to integrate a FANUC 210F 6 axis industrial robot arm into an experimental production line. As this production line is set in a research environment, gaining a deeper understanding of all involved systems is desired.

The dynamic behaviour of a physical system is best expressed with an analytical model. In order to control a robot arm, a kinematic model needs to be created. With this model, a control algorithm can be derived.

The objective of this thesis is to derive the complete inverse kinematic model of a 6 degrees of freedom (DOF) robotic arm analytically. For an exact numerical simulation of the device most steps are laid out theoretically and difficulties in the practical implementation are described. Additionally for follow up projects this work also contains a quick start guide and a safety manual for the robot in this setting . Finally to contribute to current research, twinning specifications will be defined.

# Preface

Robots can be defined as programmable movement automatons that can perform tasks without human supervision and can be taught at least repetitive tasks. Increasingly, also ways to sense their surroundings are added and improve their movements according to their surroundings. These additionally to the sensors like pulse encoders at their axes to feedback control their endpoint position accuracy.

I have started working with robots and robotic systems in my bachelor studies. As a starting engineer, I was exploring the possibilities of automated manufacturing with CNC mills and 3D printers. These were very simplistic robotic systems based on a feedforward control with stepper motors for position accuracy. For starting a production process, these devices had to be half automatically calibrated and the position and orientation needed to be taught automatically by pointing the drill/printing head to the markerpoints.

# Summary

# Acronyms

**HAN** Hogeschool van Arnhem en Nijmegen

**SPC** Smart Production Cell

**DOF** degrees of freedom

**FRC** Fibre Reinforced Composites

**DH** Denavit-Hartenberg

**IOT** Internet Of Things

**FHEM** Freundliche Hausautomation und Energie-Messung [1]

**NFC** Near-field communication

**IPKW** Industrial Park Kleevse Waard

**NFC** Near Field Communication

# Problem Definition

For Fibre Reinforced Composites (FRC) part production, a robot arm can be used to load the press with raw material, as it allows for more flexibility in the production line. As the robot arm has many degrees of freedom, there are different strategies for a control cycle. Main constraint is to achieve this movement of materials as fast as possible to minimize the cool-down of the molten FRC. Additionally, the accelerations and forces on the material should be minimized while transferring, to make sure no material is lost in the process. This makes hit hard to find an ideal, fast control strategy to place the raw material into the press.

# Research Plan

In my project plan I stated that "I will demonstrate my master level by understanding and simulating the dynamics of a 6 axis Robot arm."[12]

This should be done by creating a model of the robot arm. To create the model of the robot arm, a view on existing literature is necessary to lay out the best approach.

To start the literature review, a set of first keywords was needed. Through an expert interview with my company supervisor, who had already supervised other thesis projects in the domain of robotics, a list of keywords to start with was obtained. Not all of these keywords were immediately clear, so it was necessary to find clear definitions for these. With the help of scientific databases and search engines, papers for these definitions could be found.

6 axis robot: serial 6 degree of freedom robots ([11] with HANQuest)

industrial robot arm: some form of jointed structure achieved by the linking of a number of rotary and/or linear motions or joints( [13] with ScienceDirect)

inverse kinematics: mathematical process of recovering the movements of an object with kinematic equaions to determine the joint paramters that provide a desired position for each of the robot's end effectors ([8] with Wikipedia)

Peter Corke robotics toolbox: Matlab toolbox for the study and simulation of classical arm-type robotics, for example such things as kinematics, dynamics, and trajectory generation ([5] with Google search)

Motion planning: find a sequence of valid configurations that moves the robot from the source to destination ([2] with Google search)

robot dynamics: relationship between the forces acting on a robot mechanism and the accelerations they produce ([7], with Scholarpedia)

ROS: framework for writing robot software. It is a collection of tools, libraries, and conventions that aim to simplify the task of creating complex and robust robot behaviour across a wide variety of robotic platforms. ([9] with Google search )

Starting from the source for the industrial robot arm, it was determined, that the FANUC 210F is an articulated robot.

# Denavit-Hartenberg-Convention

TheDenavit-Hartenberg (DH)-Convention is a commonly used and simplifies the forward and backward transformation. It was named after Jaques Denavit and Richard Hartenberg who developed a general theory to describe a serial link mechanism. [4]
It consists of following parts:

- DH-Convention for establishing the coordinate systems
- DH-Transformation for generation of the coordinate systems
- DH-Parameters as a result form the transformations

Determining the coordinate systems is done according to set rules. Nevertheless, the choices of coordinate frames are also not uniqe, so different peole will derive different, but correct frame assignments. This freedom of choice should be used to bring as many DH-Parameters as possible to zero. This simplifies subsequent equations and calculations. [14]

Each joint of the robot is described by four parameters.

# References


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[12] Karl Wallkum. “Using FANUC R-2000iC/210F (6-axis robot) for improved efficiency in FRC parts formation”. Major Project Plan. Nov. 2019.

[13] Mike Wilson. *Implementation of Robot Systems*. An Introduction to Robotics, Automation, and Successful Systems Integration in Manufacturing. Butterworth-Heinemann, 2015. DOI: https://doi.org/10.1016/C2012-0-00795-8.

[14] Prof. Dr. Klaus Wuest. *Denavit-Hartenberg-Konventionen*. Technische Hochschule Mittelhessen. Wiesenstrasse 14, 35390 Giessen, Deutschland, June 2018.

# Appendices

# Appendix 1

# Appendix 2

# Robot Quick start guide

A big part of this was derived from [10].

### 3.0.1 Parts of the robot

A quick overview over the visible parts.

#### FANUC R-2000iC/210F 6 axis robotic arm

The robot has 6 movable joints with a possible payload attached to the end. Its features include a wide reach (2655 mm), sturdy but flexible arm design, a spring loaded counterbalance, relatively high payload capacity (210Kg) and fast moving axes. The joints also have hashes to indicate the zero positions which help with the calibration of the robot.

#### R30iA Robot Controller

The Robot is controlled using an original equipment manufacturer controller called the FANUC R30iA controller. Its features include faster sustained speed and superior position accuracies. It also has the I/O ports that are used to connect grippers and other payloads. (It also houses the camera circuits which are required to access the data from the SONY camera provided with the robot. - Delta only) The controller is also provided with a data card slot in which the special SD cards manufactured can be inserted and used as external memory. On the outside of the controller (side of iPendant at Delta) a USB port can be found. With these, programs, firmware files and other files can easily be transferred. Additionally, there is extended connectivity via its Ethernet port e.g. for FTP available.

#### iPendant

The teaching pendant is the primary user interface to the robot. It is used to move the joints of the robot manually, to program specific trajectories, to control the gripper, and various other actions. It also is an interface that can be used for input and output of the robot controller parameters. The user can access the system variables and position variables. (It is provided with a USB port that can be used to connect to a USB drive for external storage. - Delta only) It can also be used to setup an FTP server and client in order to communicate with the PC.

#### Gripper

The robot as handed over does not have an active gripper system. It has been tested though with a pneumatic gripper controlled via the DO ports and pneumatic valves. A 2-way pneumatic valve, some piping and a pressure regulator are still available. (Delta Equipment varies here a lot).

### 3.0.2 iPendant Navigation Manual:

The teaching pendant is the primary user interface to the robot. This section deals with the important buttons on the TP.

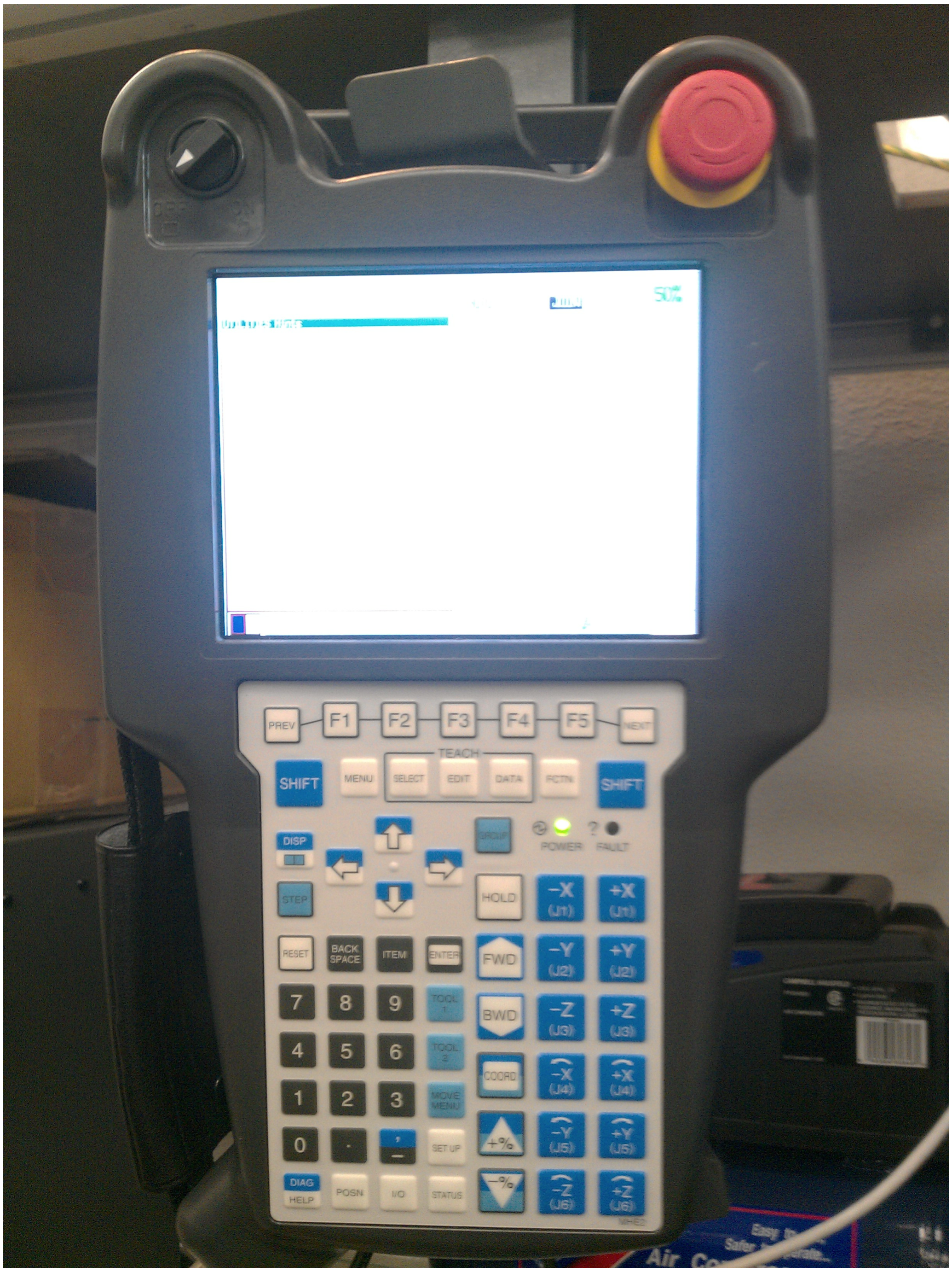


Figure 3.1: Most important iPendant buttons numbered: This image from another iPendant than the ones available was chosen because of its labelling of buttons. Some buttons of the available iPendants are not labelled, so this picture can be used as a reference. Source: [10]

#### Emergency stop:

Makes the robot stop immediately by applying brakes. Use it only when necessary as the brakes wear down. There is also an E-stop on the controller. Press down on the button to activate it. Twist it to the right to release. If a slow and gradual halt is required, press HOLD on the iPendant. TP on/off Below the E-stop button. It should be ON to access any function in the Teach Pendant (Set-ups, calibration, programs etc) and OFF when running in AUTO mode. Deadman switch The 2 yellow bars behind the iPendant. 3 modes are available: Fully released, halfway pressed, fully pressed. Only the middle mode activates control.

# IOT Projects:

The Smart Production Cell (SPC) is a research lab, that is in constant development to show the latest innovations and bring them to use in industrial applications. In the context of the master-thesis "Using FANUC R-2000iC/210F (6-axis robot) for improved efficiency in FRC parts formation" the topic of digital twinning and with that Internet Of Things (IOT) has become a major research point. In order to bring the FRC production line to its full potential, several new projects could be defined. These projects improve comfort, energy-efficiency, ease of use and safety of the lab. Each of these projects is designed to provide a flexible workload for 1-3 students with varying results depending on the students experience level and semester. In case 3 students sign up for a project, the diligence work is expected to be fulfilled. Each student is expected to pick their own range of tasks that they fulfil. Following project ideas are proposed:

## Room Temperature Control System

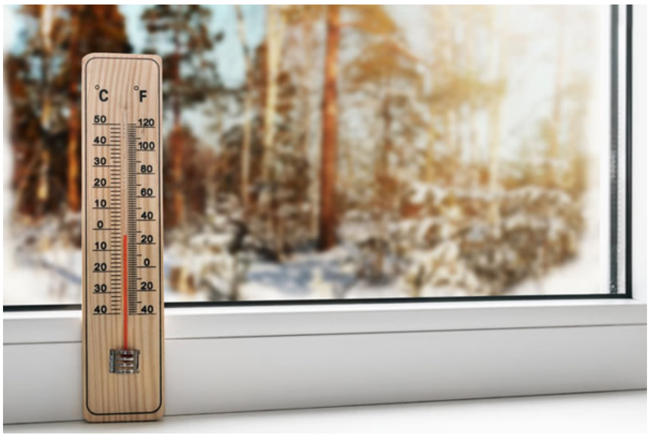


Figure 4.1: Heating when noone needs it is waste! [3]

The Lab of the SPC has an old heating system controlled with electromechanical thermostats. Originally this system was designed to work with steam delivered by the Industrial Park Kleevse Waard (IPKW). Later this System was retrofitted with two gas heaters that have no feedback about the actual heating demand. This needs to be improved for comfort and energy-efficiency.

Your assignment will be to replace the old and manual control with an open-source home automation system. That means choosing sensors, actuators, electronic components and clients as well as the type of home automation servers. A possible approach would be using thermocouples as sensors, transistors to switch the inputs of the heating system, using an ESP8266 for sensing and controlling with Freundliche Hausautomation und Energie-Messung [1] (FHEM) as the underlying home automation server running on a raspberry pi.
diligence work: also include other room thermostats in the offices as well as lights

Why are you the right one for this project? (Not all is required, but some should resonate with you)

- You are interested in automation systems
- You like improving existing systems with electronics
- You have experience with Arduino/ESP8266
- You are not afraid to learn a new programming language to do some basic tasks

- You like Linux
- You like it warm and cozy in the morning :)

## NFC based Machine Access


Figure 4.2: Near Field Communication (NFC) [6]

The Lab of the SPC has several heavy machines that move at high velocities, apply high pressures or create high temperatures. Because of these and other risks, a zoned safety system would make the lab a lot safer, as people would then stay in their assigned working zones while leaving work at other places unaffected. Also machine access needs to be restricted to the assigned student, while still leaving a traceable, temporarily restricted access to other users if necessary.

Your assignment will be creating a NFC card based zone and machine access. You can base this on an existing framework, or do it yourself. You will set up several NFC readers with microcontrollers. These microcontrollers need to send a signal to a server that compares the access parameters delivered from the NFC-card with a database that you set up. In case of a match, a signal is sent back to the Arduino, that switches a relay to open the gate. Additionally the Arduino should listen to other inputs in case a product cycle needs to be finished or additional requirements need to be fulfilled. Also there should be a signal sent back, when someone checks out of a safety zone. Machine access should have a timeout. Make a nice frontend to manage access.
diligence work: Make the communication between server and client hard to hack

Why are you the right one for this project? (Not all is required, but some should resonate with you)

- You are interested in safety/security systems
- You like to integrate something new into an ongoing project
- You have experience with programming
- You like microcontrollers
- You can make a **GUI!** (**GUI!**)
- (For diligence work: You like crypto)