Zagazig University, Faculty of Engineering,
Mechatronics Program

ZuKa

Deployment of industrial KUKA robot in CNC machining and visual servoing through Kinect interfacing on ROS

Graduation project for the degree Bachelor of Science (B.Sc.) submitted to Mechatronics Program, Faculty of Engineering, Zagazig University, Egypt

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Abstract

The first industrial revolution marked the transition to new manufacturing processes in eighteenth century, which is arguably similar to the transition introduced by the use of robotic manipulators in different industrial aspects in the late twentieth century. This project is motivated by the major developments in the industrial sector thanks to robots, especially in machining processes. Robots offer more flexibility, cost reduction and higher level of details, all of which are essential characteristics to any successful industry. Although these characteristics can be obtained by conventional CNC machines, however, the level and rate of production differ on larger scales, in favor of the robots.

The main problem can be summarized in Four points; accuracy, ease of use, flexibility and safety, and the solution to these problems defines the scope of our project. As for accuracy, it is obtained by implementing the robot itself, which offers multiple-axes movement, enabling the possibility for higher level of details than the conventional CNC machines. Ease of use is demonstrated in the user-friendly robot interface that enables the implementation of projects easily and without the need to multiple machines or tasks to deliver the final results. Flexibility is provided through the multiple programmable interfaces that offer multiple methods of control; Inline programming through KUKA's smartPAD, offline programming through converting G-codes from CAD files into KRL and ROS. Safety is increased in the work space of the robot by introducing a vision based safety system that reduces the robot's operating speed when someone enters this work space.

The results of the aforementioned methods and applications are diverse, offering milling in multiple dimensions and thus widening the scope of final products. In addition to introducing further control methods, which opens up new doors towards further developments and applications that were not applicable earlier.

Acknowledgements

This graduation project consumed huge amount of work, research and dedication. Still, accomplishment would not have been possible if we did not have a support of many individuals. Therefore we would like to extend our sincere gratitude to all of them.

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we express our warm thanks to ......, ..., and .... for making the .... robot available to us and the time they spend assisting us to carry out the field experiments. Without their superior knowledge and experience, the experiments would not have that like in quality of outcomes, and thus their support has been essential. In addition, we wish to express our sincere gratitude to .... for helping when we had questions as well as frustrations.

We would like to thank all the numerous people in the internet who ask questions and provide answers for programming problems (specifically in ROS) and for the very useful code and tools they share with others.

we would like to most importantly acknowledge the effort of our families, who encouraged us to pursue higher education and support us through the difficulties associated with such a goal even when we was not sure we would make it through.

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> *"There is nothing more difficult to take in hand, more perilous to conduct or more uncertain in its success than to take the lead in the introduction of a new order of things."*
>
> *— Niccolo Machiavelli, (Italian writer and statesman, Florentine patriot, author of 'The Prince', 1469-1527)*

Chapter 1
Introduction

Industrial robots are reshaping the present and future of most, and very soon all, industrial aspects. They are currently used in a broad spectrum of industries, some of which include car parts assembly as in BMW and Mercedes factories, industrial automation as in Yaskawa factories, metal industries that include welding and machining processes and many others. While there is a controversial part in replacing humans with robots in factories, it, nevertheless, offers more accuracy and higher production rate with more space for development. The growth of the Global Industrial Robotics Market is driven by many factors, of which the need to reduce manufacturing cost in industries is one of the main drivers. Industrial robotics aids companies in reducing the cost due to product failure and product wastage.

Some of the pioneering companies in the Industrial robotics market are ABB Ltd., Fanuc Corp., Yaskawa Electric Corp., Apex Automation and Robotics, Mistubishi Electric Corp. and KUKA AG. We had the opportunity to work with the latter, KUKA AG, on the implementation of our project (*ZuKa: Deployment of the industrial KUKA robotic manipulator in CNC machining and visual servoing through Kinect interfacing on ROS*). Over the course of our final year, this project helped increase our knowledge, not only on the main topic, machining and visual servoing, but also on the KUKA platform itself, which is considered an advanced platform widely used in today's industries.

The project is inspired by the aforementioned development in the industrial sector. The scope of the project can be summarized in the following three points; firstly, the commissioning and operation of the KUKA KR6 R900 sixx robotic manipulator, which included the installation of the related software and creating a network that facilitates communications with the robot. In addition to software commissioning, hands-on experience with the KUKA robot language (KRL) platform was achieved through learning the basic and advanced forms of KRL, which later helped in the development of software tools that facilitates the main objective of the project; the milling process.

Secondly, the design and manufacturing of a base to support the robot during heavy duty operation, this included performing mathematical calculations based on the robot's weight and forces to obtain the optimal dimensions and weight for the base, besides performing CAD studies on the manipulator's body to support the results of the mathematical analysis.

Finally, the development of various software tools to achieve the purposes of remotely controlling the robot and milling. These tools include an Inkscape extension for converting 2D G-code to KRL, directly using sketches from Inkscape, an independent toolkit for converting 3 axis G-code to KRL. In addition to Python tools; one Python class for reading and writing system variables, and a Python library for controlling the arm motions from pc. The development also included editing openni_tracker for publishing uncalibrated person's depth and creating ROS nodes for safety operation distance and visual servoing (hand guiding) for the robot.

Initially, the project scope was limited to the milling process in addition to minor ideas in the smart development of the workspace, however, over the course of the semester we encountered many problems that required extended research in all the previously mentioned aspects, which eventually led to broadening the scope of the project to include these development tools, both relevant and irrelevant to milling.

1.1 Project Contributions

The results of the project studies and implementation include, but not limited to;

- The manufacturing of the robot's base, with mathematically calculated data endorsed by CAD studies, contributing in a stable, secure and robust base that can support the weight of the robot and tolerate the forces resulting from the robot's motion without major failure or errors.
- The attachment and operation of a pneumatic gripper, leading to the development and implementation of software tools for drawing and palletizing.
- The development of different software tools to obtain the appropriate KRL codes used in the milling process.
- The development of a safety system in the robot's workspace, similar to KUKA AG's own Collision detection, which stops thee robot from moving when it hits a solid surface. However, being more efficient and safe, in terms that it does not require actual contact or collision but significantly reduced the operation speed of the robot when someone enters a defined perimeter of the robot's workspace. This is achieved using a Microsoft Kinect device for obtaining visual input of the workspace.

The results of the work exceeded both the preset expectations and goals for the project, resulting in a wide variety of applications and an extension in our own knowledge base, which is the most important achievement.

just some text for text

1.2 overview

some data

1.2.1 Flower Power

Figure 1.1: This is a test figure. You can use it as a template for your figures

"It is impossible for us, who live in the latter ages of the world, to make observations in criticism, morality, or in any art or science, which have not been touched upon by others. We have little else left us but to represent the common sense of mankind in more strong, more beautiful, or more uncommon lights."

— Joseph Addison, (English essayist, poet, and politician, 1672–1719), Spectator, No. 253

Chapter 2
State of the Art

"A computer would deserve to be called intelligent if it could deceive a human into believing that it was human."

— Alan Turing, (British pioneering computer scientist, cryptanalyst,⋯, and philosopher, 1912–1954)

Chapter 3

Architecture Overview

"Be sure you put your feet in the right place, then stand firm."

— Abraham Lincoln, (American 16th President, 1809–1865)

Chapter 4

Robot Foot Ground Contact

"Look up at the stars and not down at your feet. Try to make sense of what you see, and wonder about what makes the universe exist. Be curious."

— Stephen Hawking, (British theoretical physicist, and cosmologist

Chapter 5

Short–Range Embodied Terrain Classification

"I think setting a goal, getting a visual image of what it is you want. You've got to see what it is you want to achieve before you can pursue it."
— Chuck Norris, (American martial artist, actor, film producer and screenwriter)

Chapter 6

Long–Range Visual Terrain Classification

"You have brains in your head. You have feet in your shoes. You can steer yourself in any direction you choose. You're on your own, and you know what you know. And you are the guy who'll decide where to go."

— Dr. Seuss, (American writer and cartoonist, 1904–1991)

Chapter 7
Path Planning and Following

"It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong."

— Richard P. Feynman, (American theoretical physicist, 1918–1988)

Chapter 8

Experiments and Results

The true function of philosophy is to educate us in the principles of reasoning and not to put an end to further reasoning by the introduction of fixed conclusions.

— George Henry Lewes, (English philosopher and critic of literature, 1817–1878)

Chapter 9

Conclusions and Future Outlook

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