Advanced control methods of robotic arm with computer vision integration

Author: Ing. Oliver Kudzia
Supervisor: doc. Ing. Peter Papcun, PhD.

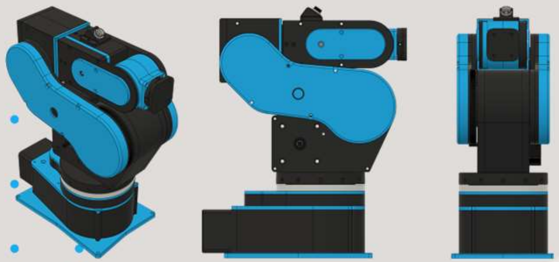
TECHNICAL UNIVERSITY OF KOŠICE
Faculty of Electrical Engineering and Informatics

Abstract

The aim of thesis is to model, physically construct and program a six-axis robotic arm capable of grasping objects based on visual feedback from a computer vision system using a Kinect sensor. Challenges involved in the process includes the control theory behind robotic arm as well as what kind of actuators to use, implementation of object recognition based on depth map gathered from Kinect and designing a reliable communication architecture between robotic arm and computer vision system. This project do not use any third-party robotic arm, instead it presents a custom one. The work covers its design and construction aspects, describes the software part of the arm‘s control, and also explains communication structure of a robotic system. Real-time visualization in form of digital twin, and a graphical user interface are also part of the work. User interface acts like a controller for the robot and provides control of the entire robotic system.

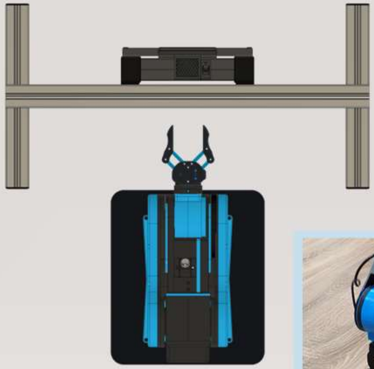
Goals

- create fully functional robotic arm model
- develop object recognition system based on Kinect
- create visualization for the robotic arm as well as graphical user interface (GUI) for the robotic system
- assemble simple three-component part using this robotic system
- conduct experiments based on real-world scenarios



Our approach

The whole process can be divided into several stages in order to meet the goal of assembling part with the custom robotic arm. Initially, it is necessary to consider specification of the arm (its topology, design etc.) and to choose right tools for its physical manufacturing. We decided to use stepper motors for driving the joints of the robot and the construction is 3D printed from PLA material. Besides robotic arm it is also crucial to develop object recognition module capable of extraction the data from Kinect depth camera sensor. Kinect is capable of providing depth information. Then using programming language Python we transform collected data into useful information (acquiring position of present object an its type).
Due to the fact that the robotic arm and computer vision system can work standalone, it is necessary to properly interconnect them in order to be able to communicate with each other. We came up with decentralized architecture where part of the computation is performed on a laptop (inverse kinematics etc.), and part is performed locally inside the robot own control unit. The entire system uses a client-server architecture and facilitates data exchange between these two mentioned parts. Additionally, we also created a virtual representation of the arm which acts like digital twin of the physical model of robot. The robotic system at first scans surface to search for parts. Then after recognizing topmost object and moving it to a storage area using the robotic arm, it is checked whether a three-component part can be assembled. If the conditions are met, the simple three-component part is then assembled by the robotic arm without any user intervention.



Results

We verified individual parts of the robotic system by a series of steps which are hierarchically interconnected. The final assembly of the three-component part relies on correct arrangement. In order to ensure an incremental form of testing, the evaluation of the solution was divided into three phases. Firstly, the robotic arm and its ability to grip objects were tested. Secondly, the reliability of the recognition algorithm was evaluated. Finally, the success rate of assembling designated three-component part was experimentally verified. Results are shown below in the table.

Full assemblies	Partial assemblies	Unsuccessful assemblies
12	4	4