Master's Thesis 2022: Design and implementation of the robotic platform for an experimental laboratory task

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Abstract

Advanced robotics does not always have to be associated with Industry 4.0, but can also be applied, for example, in the Smart Hospital concept. Developments in this field have been driven by the coronavirus disease (COVID-19), and any improvement in the work of medical staff is welcome. In this thesis, an experimental robotic platform was designed and implemented whose main function is the swabbing samples of the nasal vestibule. The robotic platform represents a complete integration of software and hardware, where the operator has access to a web-based application and can control a number of functions. The increased safety and collaborative approach cannot be overlooked. The result of this work is a functional prototype of the robotic platform that can be further extended, for example, by using alternative technologies, extending patient safety, or clinical testing and studies.

Keywords: Robotic platform, smart hospital, nasal vestibule swab, advanced robotics, collaborative robotics, machine vision, convolution neural networks, point cloud, Universal Robots UR3, Intel Realsense D435i, ROS, Flask, Robo Medicinae I

Introduction

The influx of COVID-19 has caused mortality and often painful diseases around the world. Intensive research and development to combat this disease is extending to all possible areas, including robotics. In this struggle, robotics plays the role of assistant to the medical staff. Therefore, this thesis also focuses on an experimental laboratory task in the medical field using a collaborative robotic arm and camera system. The aim is to create an advanced robotic platform with the main objective of collecting samples from the nasal vestibule. To solve this task, a UR3 collaborative robot from Universal Robots was used with a customized gripper design consisting of an OnRobot RG2 gripper and a HEX-E sensor, and last but not least, an Intel Realsense D435i 3D camera. The entire solution is then integrated into the software infrastructure, which is mainly powered by Python Flask and the Robotic Operating System. Artificial intelligence, more specifically convolutional neural networks, was also used in this thesis. Primarily to detect the centre of the nostrils.

COVID-19 pandemic brought to light the fact that the most important sector of human society is healthcare. One of the frequent problem in health facilities was that they faced staff shortages. In order to, at least partially, help the medical staff, the idea of an robotic platform for automated antigen-testing was conceived. This is why Robo Medicinae I was created. Robo Medicinae I is an experimental robotic platform that enables human-machine collaboration. It involves an operator connection that has control over the process of collecting nasal vestibule samples for antigen testing from patient. In this thesis, a semi-automated process was proposed, however, it is possible to change this configuration to a fully automated one, but this comes at the cost of safety.

robo medicinae I.

Figure 1. Robo Medicinae I - logo

Robotic Platform Design

The main device of the application is a collaborative robot. As part of the solution, the UR3 cobot from the Cybernetics and Robotics Laboratory in the Institute of Automation and Computer Science (IACS) was chosen. Although during the development phase the ABB YuMi collaborative robot was added, which would also be useful for the solution of the experimental robotic application.

Other integral parts of the design is the Intel Realsense D435i, the RG2, and the HEX-E sensor. These sensors and the gripper came together in the design of the customized gripper. Everything is then connected to the control unit, which can take the form of a powerful single-board or desktop computer. As a web-based application, the operator has the possibility to control it from his or her device (e.g. tablet) using a web browser. However, the condition is that the device must be connected to the same local network. All these sensors and the gripper had to be combined and integrated into a complete gripper. The challenge was to create a modular gripper with individual parts that could be disassembled and replaced, for example, with another type of 3D camera.

Figure 2. Robo Medicinae I - Visualisation of robotic platform

Software Topology

The basic idea of the software topology is to create a local web-server that the operator can connect to from another device on the same local network. This local server is essentially a central unit and controls various parts such as the robot, the sensors, access to the database, etc (Fig. 3). The operator is able to control the entire process and the different parts from a web browser, where the whole HMI (Human-Machine Interface) is produced.

This software topology leads to a division into back-end and front-end. The back-end is understood as all processes that the operator cannot see from the remote access, i.e. everything that the server computer runs in the background. Within the application, this includes, for example, the mapping of URLs, image processing or compute functions. However, in terms of front-end, this can be defined as everything that the user can see from his remote access in a web browser. This includes, for example, page rendering, animations, etc.

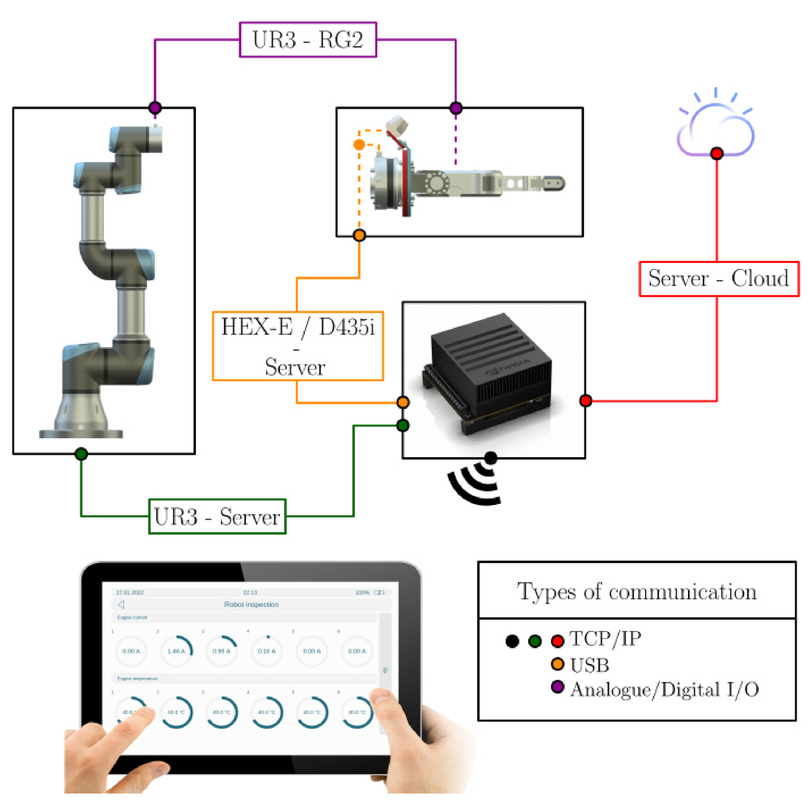

Figure 3. Robo Medicinae I - Software topology

The development of the back-end part of the server was based on the Python 3 with auxiliary scripts in the Bash programming language. The *Poetry* package manager handles all updates and the management of the various Python libraries, which were used. The front-end of the application was based on the programming languages HTML, CSS, and JavaScript. Working with JavaScript has been made easier thanks to the *jQuery* library. A Robotic Operating System (ROS) was chosen to simulate and control the UR3 robot, also control the RG2 two-finger gripper and the HEX-E sensor during real-world testing.

Different libraries were used for the back-end, the front-end, or the ROS. Everything had to be incorporated to make the system work on such a complex scale. Thanks to these technologies, it has been possible to create an application that offers the operator the following possibilities:

- Acces to patient and operators databases
- Search the patient database based on a Personal Identification Number (PIN) or a scanned QR code with a PIN from a color image.
- Display stream color, depth, infared image from 3D camera
- FaceID - matching the patient from the streamed colour image to photo from patient database
- Face Detection - detection of human face landmarks
- Identification center of nostril - segmentation model CNN to detect nostril, on the basis of this centroid calculation
- Face Scan - scan align color to depth image, on the basis of this reconstruct 3D point cloud
- Show point cloud in web browser
- Connect or disconnect robots - switch multiple UR3
- Manual control of robot rotation before scan face is processed
- Start process of motion to detected center of nostril
- Manual control of robot - simple HMI for control cobot joints
- Display digital twin of cobot in web browser
- Display basic data from cobot as a temperature, current or coordinates
- Generate PDF document base on HTML input
- Basic data about weather

Conclusion

The aim of this thesis was to design an experimental robotic platform. In this context, a robotic platform with the name Robo Medicinae I was developed. The main function of this platform is the collection of samples from the nasal vestibule for possible subsequent antigen testing of COVID-19 disease. The design of this experimental robotic platform extends the previous results of scientific and technical teams that have been involved in the collection of samples for the purpose of diagnosing the COVID-19 disease. The result of the thesis is a working prototype that emphasizes patient freedom and safety, but the human factor played a crucial role. Other factors that influenced the actual functionality are the calibration of the robot, the camera, and the hand-eye itself.

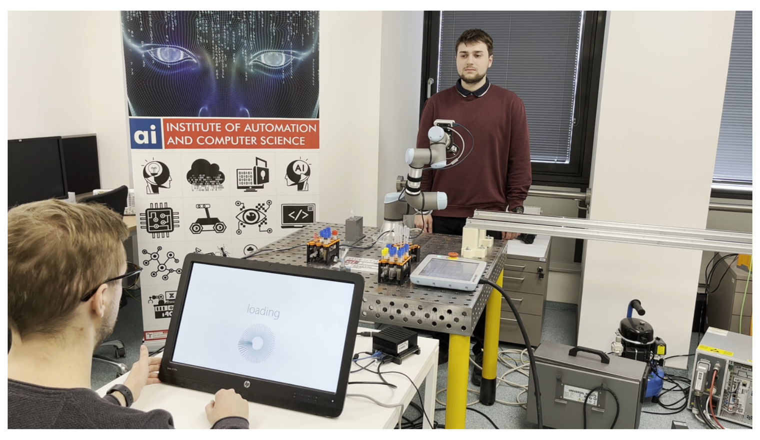

Figure 4. Robo Medicinae I - Real-world test scene

Figure 5. Thesis citation

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