Robotic Operation of ICU Equipment in Contagious Environments

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Introduction

- Ventilators and infusion pumps are critical equipment in treating COVID-19.
- Routine setting changes require staff to enter ICU which requires consuming a full set of PPE and exposes staff to risk of infection by COVID-19. [1]
- Due to security concerns, equipment can not access networks.[1]
- In this poster, we discuss parts of an novel tele-operate robotic systems that aims to recognize key ICU equipment, operate them, and project key information from such equipment straight back to the operator.
- More specifically, we trained an object recognition model to recognize key ICU equipments and implemented an novel end-effector design and corresponding UI to control the robot.

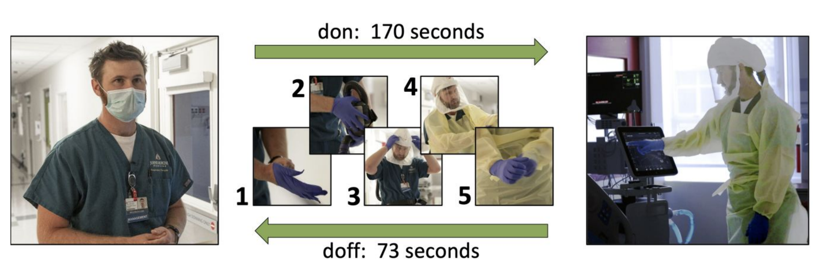


Figure 1 Time estimate of putting on and doping off a PPE suit[1].

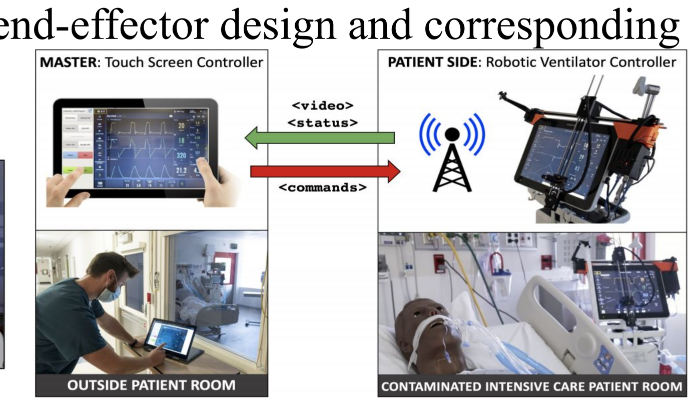


Figure 2 Previous work of stationary telerobotic control of ICU device[1].

Problem Statement

- Covid-19 impacts the respiratory system, about ⅓ of the patients who have COVID-19 will require ICU admission at some point[2].
- Hospitals are trying to minimize ICU staff entering Covid-19 patients' room in light of PPE shortage and risk of exposure[3].
- More specifically, ICU teams need a novel way to remotely monitor and adjust settings on key ICU equipments in order to efficiently monitor and provide consistent healthcare service to all patients as we cope with ICU need surge due to COVID-19.
- Previous work by Vagvolgyi et Al[1], proposed a robotic system that is capable of tele-operate devices using 2D cartesian robot mounted on device.
- To achieve our goal, the problem is broken into 4 functional segment: **Identify device, Go to device, Operate device, and Information feedback.**
- Chart relating functional segments and operational solution is shown below.

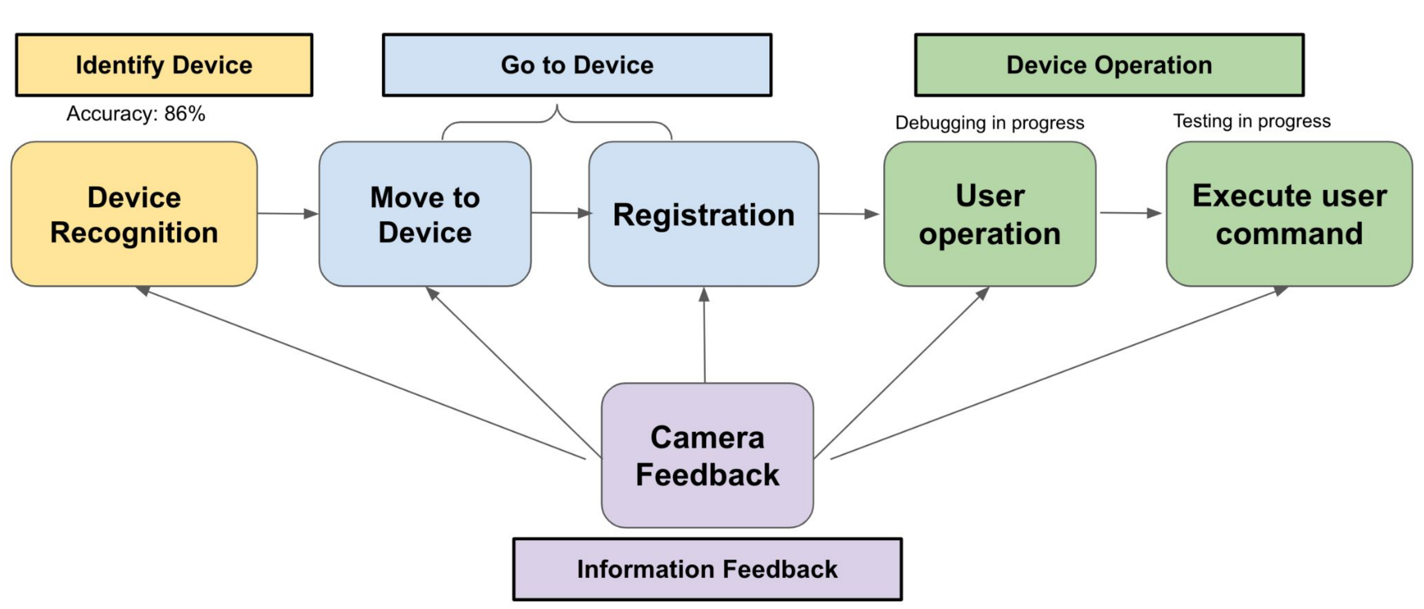


Figure 3 Proposed work flow chart and corresponding functional segment indicated by color

Proposed Solutions

- Modeled target devices with oscilloscope. Simplified the problem from 6 to 3 DOF by assuming robot has already aligned with device at ideal position.
- Trained an object recognition model to recognize the device from distance, and defined json structure to load corresponding interface configuration for device based on user input. Develop other algorithms for 6DOF robot including object recognition and feature matching;
- Build a user interface based on python-ROS system that allows the user to remotely control the robot;
- Designed novel end-effector to interact effectively and accurately with target device. Built a 2D cartesian for testing end effector.
- Incorporated live camera feedback to project important information to user as well as monitor the end-effector interaction with device.

Outcomes and Results

Identify Device:

Object recognition:

The model is trained based on YOLO3 algorithm and the eventual accuracy rate of recognizing the oscilloscope is 86%.

Figure 3. Labelling the oscilloscope among random environment

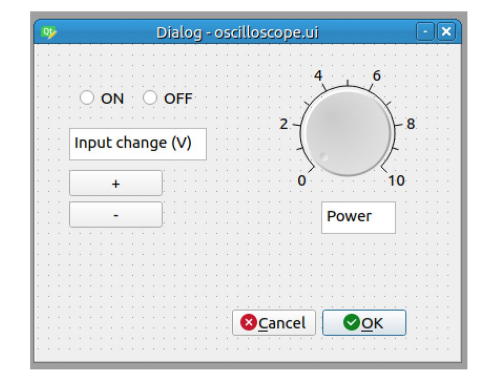


Figure 4. View of the user interface

Operating the Device:

User interface design:

- The user interface is built based on Qt Designer and Qt Creator to interact with ROS in Linux system that is further able to interact with the robot through Arduino.
- We chooses three kinds of buttons on the oscilloscope specifically to test the end effector including push buttons in round and square shape and round knobs.
- The json file that records the configuration of the oscilloscope has been preprocessed by the program.
- The user is able to interact with the four kinds of buttons through the UI.The camera feedback would also be available on the screen.

Execution of user command using end-effector:

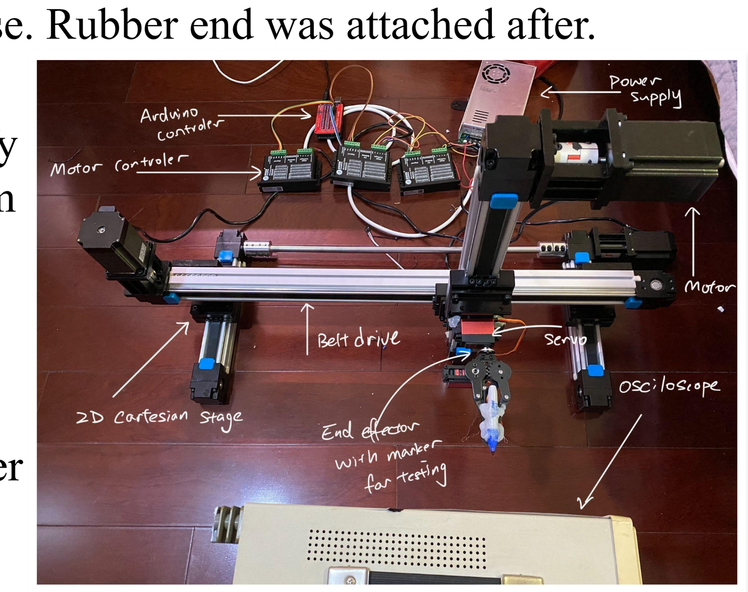
1. End-Effector interaction:

- The design features a 2 DOF two-finger claw design. It contains a squeezing joint and a rotating wrist joint for gripping and turning knobs respectively.
- When separated, the design can utilize a single finger to press and interact with buttons and touchscreen as well.
- At each tip of the finger, is a piece of rubber that can be recognized by touchscreen and to increase friction for interaction with buttons and knobs.
- Adapted off-the shelf product based on our own design criteria instead of 3D printing CAD for prototyping purpose. Rubber end was attached after.

2. Test Bed design:

- Utilizes a 2D cartesian robot to simplify prototyping, assume 6 DOF robotic arm moves only in 2D plane parallel to device when close up interaction.
- Need criteria evaluated first then purchased off the shelf to avoid reinventing the wheel. Utilizes 3 stepper motor and two servo for end-effector.

All the component design and close up image shown below, they were then assembled, actuated using arduino and then tested for accuracy.



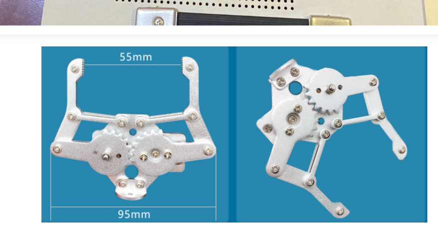
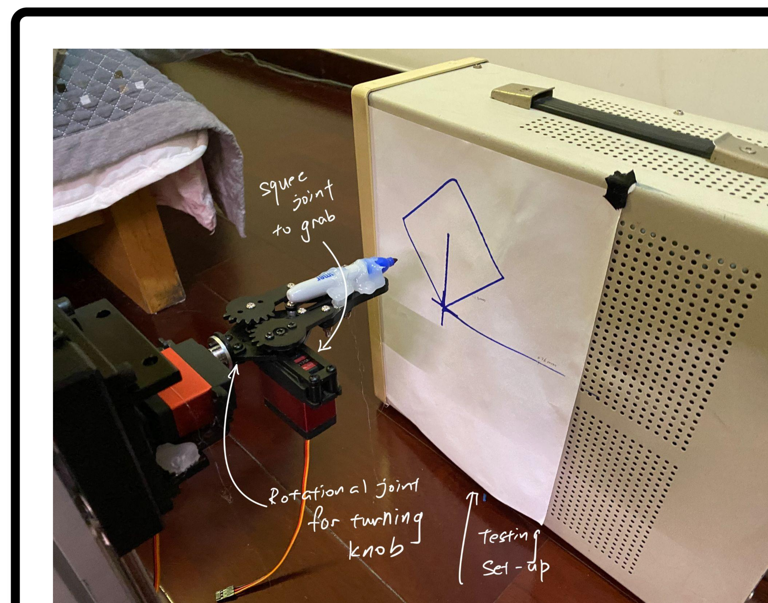


Figure 5 Assembled full robot structure and Demonstration of end-effector (top to bottom).



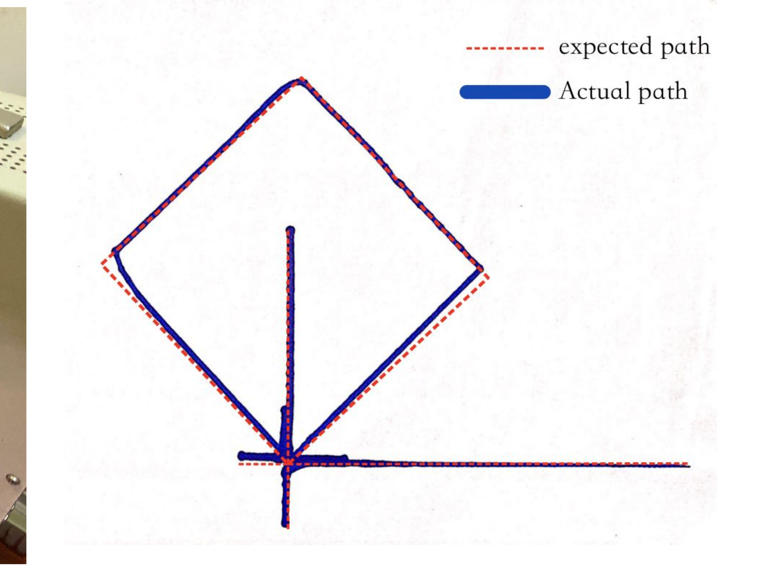


Figure 6 Testing Set Up and test result

Testing for accuracy:

- The test set up shown above is to take a marker stabled on the end-effector, ask the robot to draw a vertical line and a horizontal line of defined length.
- Then at the intersection of these two lines, start and draw a rotated square.
- As shown by the result, we see relatively good path following ability of our robot and end-effector. However, it is obvious that robot is struggling at corners or sharp turn arounds as shown above. Future optimization should be able to solve this issue.

Future Work

- 6DOF robot: the main goal is to build a 6DOF robot that is mobile and can moved to desired place under the instruction of the user.
- Feature matching and pose matching via openCV: The robot needs to recognize its relative pose with the indicated equipment via camera input;
- Movement path design: The robot must be able to move to desired location while avoiding all possible obstacles based on camera input;
- Calibration: movement of the robot might lead to shaking or movement of the whole robot. Calibration of the robot would be required so that the precision of the interaction can be achieved.
- End effector design: certain functions are not incorporated in the current design, especially the intrusion finger that is supposed to be interacting with touchscreen on some types of ventilators.

Lessons Learned

- Operation of Arduino
- Assembling electric circuit
- Design of end effector
- Object recognition including data collection,, labeling images, minimizing loss function, etc.
- Writing the json file for the configuration of the device
- Building user interface via python
- Connecting the UI with ROS using ubuntu: building of virtual machine;

Responsibilities

- Tianyu Wang: lead mechanical design and prototyping of 2D cartesian robot.
- Jiayin Qu: lead computer vision parts of the project and user interface design.

Acknowledgments & References

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[[1] B. P. Vagvolgyi *et al.*, "Telerobotic Operation of Intensive Care Unit Ventilators," *ArXiv201005247 Cs*, Oct. 2020, Accessed: Apr. 12, 2021. [Online]. Available: http://arxiv.org/abs/2010.05247.

[2] M. Conlen, J. Keefe, L. Leatherby, and C. Smart, "How Full Are Hospital I.C.U.s Near You?," *The New York Times*, Dec. 16, 2020.

[3] S. Aziz *et al.*, "Managing ICU surge during the COVID-19 crisis: rapid guidelines," *Intensive Care Med.*, pp. 1–23, Jun. 2020, doi: 10.1007/s00134-020-06092-5.