



Remote Machine Vision Lab Design and Evaluation using AI based Mobile Robot

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COVID-19 has made hands-on lab education a challenging task to achieve. A remote lab was developed to overcome barriers such as equipment cost and limited lab time, and to provide authentic and self-paced learning experiences. This paper describes the development and preliminary evaluation of a remote lab for machine vision built upon an AI-based Cozmo robot. Students were asked to (1) view a video on how to access the remote lab, (2) observe how the system works, and (3) execute a set of code to understand what will happen. They were then asked to modify the code to accomplish a more complex object recognition task. Preliminary results suggest that while they were very interested in learning more about the Cozmo robot platform, modifying the existing code to accomplish a new task was not straightforward. Suggestions include providing more explanation about the existing code and providing assistance as needed throughout the implementation process. Future directions include enhancing the platform for use in teaching real-time imaging processing techniques such as histograms, profiles, projections, filtering and edge detection and using a virtual voice assistant for each image processing operation.

Motivation

Hands-on experience is an essential part of the manufacturing education program or degree. However, the cost of industrial scale equipment, limited lab time, and large student population have hindered this desired experience. The idea of having a remote lab was first proposed in 1991 by a researcher at Purdue University who created a remotely shared control systems lab [1]. Remote labs have received more attention as Internet technology has become mainstream. Remote labs are designed to alleviate the challenges listed above [2-8].

A web based standalone telerobotic system called Telegarden, first introduced to the public by Ken Goldberg's team in 1995, featured a digital camera and an air jet device mounted on a robot arm that allowed anyone on the Internet to view and excavate artifacts in a sandbox in a robotics lab at the University of Southern California [9]. Marin et. al. [10] introduced a vision-based robot system to enhance user and robot interaction experience with a novel features such as adjustable autonomy to reduce the cognitive fatigue resulting from remote operation and a 3D virtual environment to predict the results of user's actions before sending the command to the real robot.

There has also been increasing interest in teaching mobile robot navigation to college and high school students by using a painted track on the floor and/or self-navigation through a confined maze environment from. Cardeira and Costa [11] present a low cost mobile robot that uses a normal laptop to guide itself through a track. A laptop mounted with cameras sitting on the top of the platform serves as the mobile platform controller. The motors are battery operated and interface with the laptop via an USB card. The user initiates a remote desktop session with the laptop to control the mobile robot movements. Remote control of the mobile robot is limited to a few local users.

Candelas et al. [12] describes a virtual and remote laboratory for computer vision and robotics education at the University of Alicante (Spain). A developed system called ROBOLAB allows

students to work with a simulation of an industrial robot to carry out operations with a real robot through teleoperation. A second tool, VISUAL, allows students to quickly design and test computer vision algorithms using a high-level graphical interface. VISUAL uses an open modular library of image processing operations, and also allows the student to implement new operations. Sergei et al. [13] describes remote computer vision education for ITMO University students specializing in control systems and robotics. The topics of the laboratory course include histograms, profiles, projections, image geometric transformations, filtering and edges detection, images segmentation, Hough transformation, and image morphologic analysis.

Cozmo is an AI-enabled robot with a built-in camera for computer vision. The system can be used to demonstrate AI, computer vision technologies, and finite state automata. It can have multiple applications as a pick-and-place mobile robot with advanced capabilities such as stacking and rolling cubes and making pyramids; speech generation and speech recognition; and landmark-based navigation. Kusumota et al. [14] present the development and implementation of an educational platform for Cozmo mobile robot, with several features, including web server for user interface, computer vision, voice recognition, and robot trajectory tracking control. Functions for educational purposes were implemented, including mathematical operations, spelling, directions, and questioning functions that allowed teachers to create their own scripts to teach about math, science, and programming. Students' and teachers' recorded impressions suggest that the proposed system can be a useful educational tool. Recent work by Ahmad et al. [15] explores the use of the Cozmo robot to deliver mathematics education for children between 14-17 years of age. Results suggest that participants' subjective ratings of their math knowledge changed significantly after the interaction, suggesting a positive influence of employing Cozmo with this age group and the need to do more research with affordable non-humanoid, autonomous social robots in schools. Relatively few reports have been found that investigate use of the Cozmo robot within undergraduate engineering education in robotic and machine vision.

In short, real time image processing in a dynamic environment is an important and challenging area with many practical applications such as real-time autonomous vehicle navigation and environment and process monitoring and control. It can be challenging to find cost-effective products or equipment that provide an authentic learning experience and allow social distance to be maintained.

Objectives

The paper describes (1) how the Cozmo robot was customized for remote access; (2) the design and evaluation of lab exercises for machine vision applications; and (3) suggestions for future development.

Remote Cozmo Robot Architecture

The remote Cozmo robot system consists of (1) user work station to control robot remotely, (2) web server that host the web page and Cozmo SDK software, (3) mobile phone/ tablet to run the Cozmo app; and (4) Cozmo robot and sensor cubes. The information flow is depicted in Figure 1. Details are:

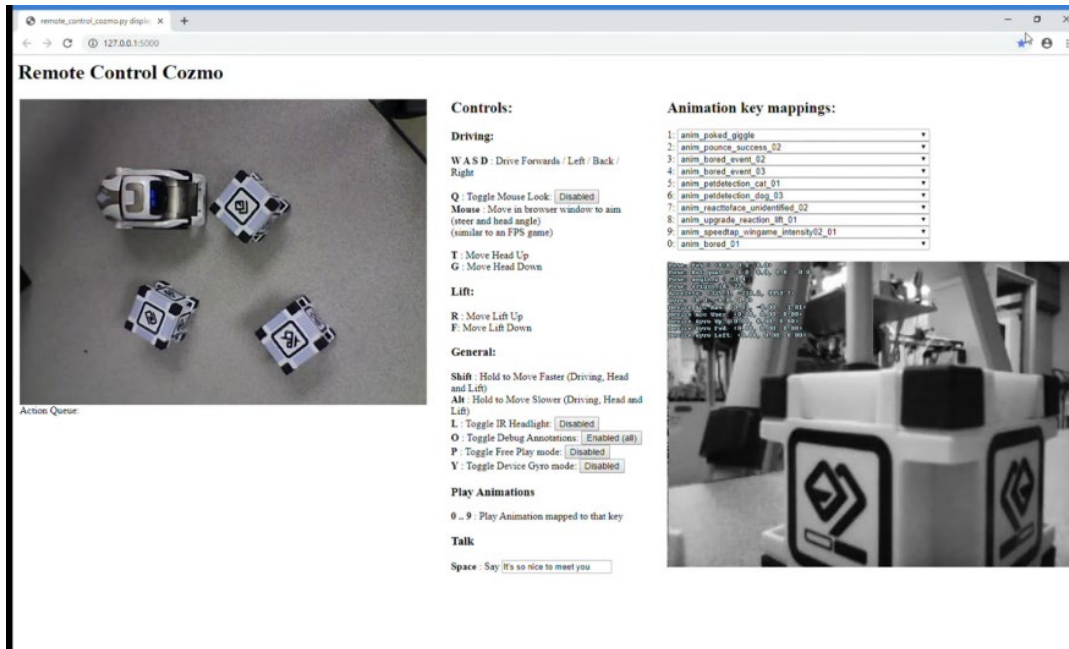


Figure 2. Screenshot of Graphical User Interface for Remote Cozmo Robot Ssystem.

Lab Exercises

The Remote Cozmo lab exercises are designed to allow students to explore the Cozmo Robot's basic functions; and understand concepts such as mobile robot navigation (exercise 1), object recognition (exercise 2), and speech generation (exercise 3). Exercise 4 was designed to integrate the above concept to accomplish an approximate-to-real-life application. Following are the lab exercises:

Exercise #1: Remote control and coding of Cozmo robot

- Step 1. Watch the video about navigation of the remote Cozmo Robot system.
- Step 2. Log in to the remote system and manipulate the basic function.
- Step 3. Execute the "Hello World" and "Drive and Turn" programs.
- Step 4. Observe the robot and the code window on the computer screen.
- Step 5. Modify the greeting of "Hello World" program to "Hello Friend"
- Step 6. Modify the "Drive and Turn" program so that the robot moves backwards and makes a 90-degree left turn"
- Step 7. Generate your own idea for a robot motion and create a new program based on the examples stored in the tutorial folder.

Exercise #2: Object recognition

- Step 1. Watch the video about Cozmo robot object recognition.
- Step 2. Execute the `stack_or_roll` Python script.
- Step 3. Observe Cozmo picking and stacking the cubes.
- Step 4. Analyze the source code in the code window
- Step 5. Execute the sample code for `pickup_furthest`, and `go_to_object_test` (Figure 3)
- Step 6. Each ArUco marker is a unique identifier. Select a marker and write Python code to program Cozmo to go towards that marker when it sees it.

Step 7. Place the ArUco marker near the wall/PC and demo your program.

```
import asyncio

import cozmo
from cozmo.util import degrees, distance_mm

def go_to_object_test(robot: cozmo.robot.Robot):
    """The core of the go to object test program"""

    # Move lift down and tilt the head up
    robot.move_lift(-3)
    robot.set_head_angle(degrees(0)).wait_for_completed()

    # look around and try to find a cube
    look_around = robot.start_behavior(cozmo.behavior.BehaviorTypes.LookAroundInPlace)

    cube = None
    try:
        cube = robot.world.wait_for_observed_light_cube(timeout=30)
        print("Found cube: %s" % cube)
    except asyncio.TimeoutError:
        print("Didn't find a cube")
    finally:
        # whether we find it or not, we want to stop the behavior
        look_around.stop()
    if cube:
        # Drive to 70mm away from the cube (much closer and Cozmo
        # will likely hit the cube) and then stop.
        action = robot.go_to_object(cube, distance_mm(70.0))
        action.wait_for_completed()
        print("Completed action: result = %s" % action)
        print("Done.")
    cozmo.run_program(go_to_object_test)
```

Table 1. Sample code for Go_to_Object

Lab Exercise #3: Speech Generation and Recognition

- Step 1. Watch the video about Cozmo robot speech recognition.
- Step 2. Execute the quizmaster_cozmo Python script.
- Step 3. Analyze the source code in the code window
- Step 4. Come up with 4 quiz questions and integrate them into the code.
- Step 5. Execute and demonstrate the program with the changes.

Lab Exercise #4: Part Sorting and Stacking – Arrange cubes #1, #2, and #3 in sequence from top to bottom and speak the number found on each cube.

- Step 1. Watch the created video about part sorting using Cozmo robot.
- Step 2. Create ArUco markers for numbers 1, 2, and 3 and paste the maker on the cubes.
- Step 3. Generate a sequence of events for the Cozmo robot to accomplish the task.
- Step 4. Review related Python examples for tasks such as object recognition.
- Step 5. Write a program to execute the sequence of events.
- Step 6. Execute the code and refine as needed.

Step 7. Write a report that lists the sequence of events with the corresponding code for each event.

Preliminary Evaluation

A few undergraduate students have participated in pilot-testing of the designed remote lab for machine vision lab exercises. General comments included: (1) the remote interface works well and being able to move the robot with a single key stroke is very fun and exciting, (2) the basic lab exercises are easy to follow, but (3) the extended exercises are not straightforward.

Conclusion and Future Directions

This paper describes the design of a remote lab for machine vision and how Cozmo's SDK was utilized in developing the lab. During pilot testing, undergraduate students displayed great interest in using and learning to program the robot. Students noted that having the ability to run and interact with the robot gave them a better perspective on how a robot can be controlled from a distance. Future directions include revising and evaluating the lab exercises and platform with a larger student population. Additional lab exercises may include use of real-time image processing techniques such as histograms, profiles, projections, filtering and edges detection and use of a virtual voice assistant to perform image processing operations. We will also expand the Cozmo robot system to perform tasks such as search and rescue and demining, and enhance the robot by adding an inference engine and knowledge base for intelligent conversation. We may also incorporate a higher-level structured language such as Calypso for programming and controlling Cozmo to ease the challenge of programming for complex tasks.

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