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VanGoBOT an assistive drawing device

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Abstract

In 1920, Karel Čapek coined the term robot for his play *Rossum's Universal Robots*, to describe the mass produced workers that were created by a company that lacked nothing but a soul. Due to this description and the present use of them to perform laborious tasks, robots aren't thought to be used as creative vessels. The robotic art assistant aims to add some soul to the robot by allowing the robot and its users to be more creative and express themselves through their artwork. This paper will discuss the motivation for the project and the design of the different subsystems. Then the paper will shift to the technical feasibility of the robot, discuss the results of the final design of the robot, and end with conclusions and final recommendations about the uses for the machine.

Motivation

Students with varying physical capabilities have trouble actively participating alongside the teacher and their peers throughout art class. Modifications currently include hand-over-hand drawing with an aid which gives the student little to no independence. Additionally, there are implementations such as tennis balls or special handles that increase the width of art tools' handles and allow for easier gripping. These implementations often do not provide the students with a fully successful experience. The Robotic Art Assist aims to change this by creating a device that responds to user input through a variety of adaptable interfaces, and produces a physical creation at the end of the process. The goal of this project is to increase inclusivity in art education, like how P20068 Robotic Drum Assist aimed to increase inclusivity in music education. The main goal of the project is to design, test, and build a device that allows students with varying abilities to participate in art education alongside their peers. The Robotic Art Drawing Assist device should allow students to control a variety of sizes, colors, and mediums to create collage paintings with some independence in a 30-minute art class

Design

User Interface Subsystem

The User Interface subsystem was designed as part of the Robotic Art Assist to enable users to be able to easily control the device in order to produce art. The subsystem is made up of two parts, namely, the Teacher Input, and the Student Input. Both parts of the User Interface provide different functionality when operating the device to maximize ease of use and utility.

Teacher Input

The Teacher Input is a digital interface that allows the teacher to input the size of the paper being used, set sensitivity of the device, as well as the pressure applied to the paper when drawing, change the drawing utensil being used, and even remotely control the drawing function of the device itself, overriding the student input. The Teacher Input was loaded into a Raspberry Pi microcontroller and designed using Python due to ease of use as well as the fact that Raspberry Pi microcontrollers can run Python programs. Figure 1 shows part of the final design of the teacher's input.

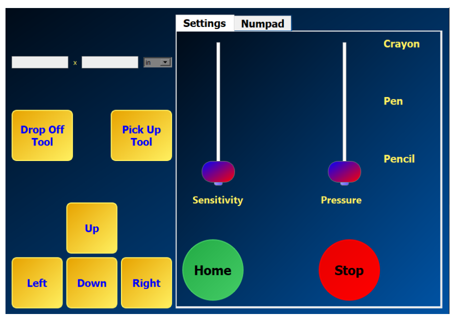

Figure 1.1: Teacher Input Settings UI

The teacher's input enables users to move the tool with arrow keys, move the gripper to a home location in the corner, stop the device, and pick-up/drop-off tools. Additionally, users can set up the device. Parameters such as sensitivity and pressure of the tool and paper size need to be set when the device is powered on. In order to combat the necessity of using a keyboard to enter paper width and height, a number pad was added to the UI. The number pad can be accessed through the switching tabs and contains all the numbers in a grid, along with clear and enter buttons. Figure 1.2 shows the design of the UI number pad.

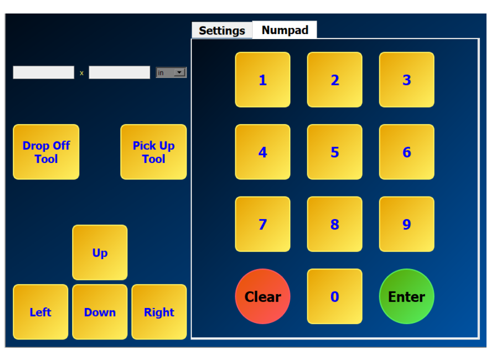

Figure 1.2: Teacher Input Numpad UI

Student Input

The student input only allows for movement of the device without any opportunity to set up the device to ensure the student will have a successful experience with the device. All setup was designed to be done using the teacher input.

The student input makes use of an Arduino Nano for the microcontroller as it allows for low power and fast execution of code. The microcontroller is connected to four buttons to control the four directions that the tool can move while drawing. A fifth button moves the gripper up and down to place the art utensil in and out of contact with the paper. A second set up of a joystick and single button allows the student to draw and move the utensil. The implementation of two plug-and-play student input methods allows the device to be more inclusive.

Control

The control system was kept simple to reduce complexity for the teacher and the student. The stepper motors are configured to turn at one quarter micro steps which allows for a good combination of torque and precision. When a button is pressed the motor moves one step. The sensitivity bar allows for the step rate to be adjusted, which determines the number of steps taken in one second. The step rate can be varied in discrete steps which are 1, 10, 50, 100, 200, 500, 1000, 2000, 5000, 10000. With the higher step rates corresponding to less sensitivity and a higher location on the bar.

The servo motors were configured so that when the drop off tool button is pressed the gripper is opened by changing the PWM signal to 5. The PWM signal operates at 50Hz which is based on the datasheet for the servos. To pick up the tool, the gripper is closed by changing the PWM signal to 7.5. The draw/not draw button controls the servo on the gripper which tilts the entire gripper assembly. The PWM signal of that servo is controlled by the pressure bar on the teacher's interface. The PWM signal can be either 7.4 or 3.4 with a value of 7.4 raising the gripper off the paper and a value of 3.4 lowering the gripper to the paper.
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Motors and Belt Subsystem

The motor and belt subsystem was designed to keep the cost to a minimum using only three belts and two motors. Two stepper motors were used, one for the X axis and one for the Y axis. The belts used are different lengths and are high quality durable belts.

Motors

For the motors we needed to use motors that would have enough power to move the whole gripper assembly and also are accurate enough. We decided to go with stepper motors for the motion of the device. These work by taking individual steps that move the motor a pre decided amount. In our case each step is .9 degrees which then translates to the carriage. Since these motors work in steps they move almost the exact same amount each step so it is easier to track the position of the carriage. We went with motors that have 63 oz-in which is enough power to move the carriage.

Belts (insert picture of belt system)

In order for the belts to work for the system three belts are used, one for the x motion and two for the y motion. These are attached on one side to the motor to control them, and then in the middle they are connected with a 3D printed part to the carriage. The 3D printed part is fit to the belt and applies pressure to ensure that it does not slip. On the other end, the belts are attached to pulleys which can be tightened or loosened to tension the belts.

Carriages (insert picture of rail system)

The carriages are attached to the belts and sit on top of rails in order to guide the linear motion. For the X axis, the carriage holding the gripper is mounted on two bars. For the Y axis motion, the carriages are mounted to one bar on either side. For the Y axis motion the rails are left slightly loose to prevent the system from locking up. In the X axis the bars are held sturdy because there are two bars being used in close proximity. Each of the carriages are mounted on round bushings that are slightly larger than the rails in order to allow smooth motion.

Mechanical Subsystem

The mechanical subsystem includes the base, framework, and other components. The framework and base drawing surface is the body of the device. This is where the power subsystem, motors, belts and gripper all mount to.

Base Drawing Surface

The drawing surface is made from a PVC sheet that was cut to have a drawing area of 20” x 24”. This large drawing surface allows the user to select a wide array of paper sizes including index card (3” x 5”), legal (8.5” x 14”) and up to 12” x 20”. The PVC sheet that was chosen is 0.25” thick to ensure a sturdy drawing surface. To secure the paper in place while the device is in use, a thin magnetic sheet was placed on the base, where magnets will hold the paper to the drawing surface. On the top of the base drawing surface, there is 8020 aluminum extrusion connected in a “U” shape around the base to allow easy mounting of the motor and belt subsystems. Aluminum extrusion is a perfect material for this application as it is very modular and makes mounting of different components very simple.

Framework Legs

The device is elevated approximately two inches above the table to allow the electronics that power the device to reside under the base. Two inch legs were constructed from 8020 aluminum extrusion, and were placed in each corner as well as legs mid way down on each side for added support and stability. Rubber feet screwed into the bottom help reduce vibration and noise, as well as protect the desk from scratches.

Side Covers

To keep the electronics safe and to prevent any possible safety hazards, side covers were added beneath the base drawing surface. The side covers prevent dust and debris from entering the electronics; moreover, they were designed to be removable to allow for easy access to the electronics.

Power Subsystem

The power subsystem was designed to power the drawing assist for at least a 30-minute art class. The main device and student input are powered separately. Splitting the power subsystem into these parts allowed the elimination of wiring from the student input on the wheelchair table to the device on a separate table.

Main Device Power

The primary power system includes the Raspberry Pi, teacher input screen, servos for the gripper, and motors. Based on the component specifications, the total current and power were 9.86A and 82.66W, respectively. The device could either plug into a standard outlet or use a rechargeable battery. Due to the size, weight, and cost of the batteries with the required capacity, plugging the device in was the better choice. Additionally, using a 12V battery to power the Raspberry Pi would require precise conversion to 5V and additional challenges.

A 12V output AC/DC converter was sourced for the conversion of the AC voltage from the wall to DC voltage for the components. The 12V was stepped down to 7.4V for the servos and 3V for the motors using DC/DC buck converters. After the buck converters, the components are fused per their specifications to ensure no damage if current spikes. The power for the motors is wired to the motor plate that connects with the Raspberry Pi.

The Raspberry Pi gets power via the standard power cord. The standard power cord ensures the Pi gets the precise 5V input voltage needed and is properly fused. Finally, both the Pi's power cord and the AC/DC converter are plugged into a power strip with a long cord to ensure the device does not need to be next to an outlet. This design choice makes it easier for the teacher, as they will only need to plug in one cord. The final block diagram is shown below in Figure 5.1.a. Figure 5.1.b shows the physical circuit design

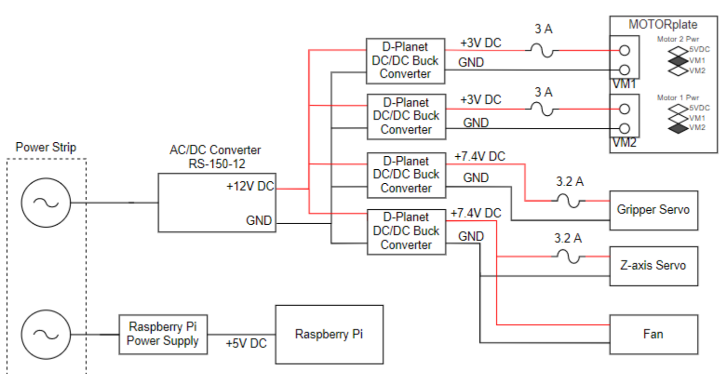

Figure 5.1.a: Main Device Power Block Diagram

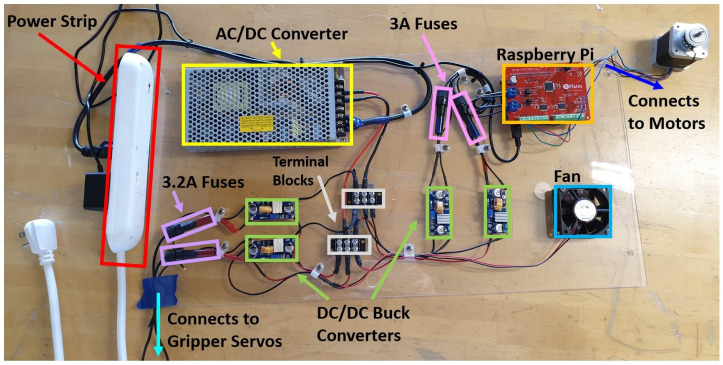

Figure 5.1.b: Main Device Power Physical Circuit - Labeled

Student Input Power

The student input system includes only the Arduino Nano. A lithium-ion 5V battery provides power to the Arduino Nano through its USB port. The 5V battery is easy for the user to store, recharge, and plug into the Arduino. The block diagram for the student input power is shown below in Figure 5.2.

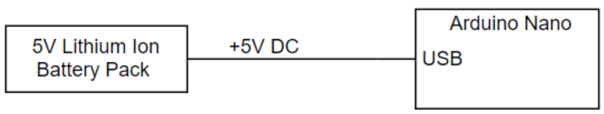

Figure 5.2: Student Input Power Block Diagram

Gripper Subsystem

The gripper was designed to be able to accommodate a wide variety of tools. To achieve this, a two jaw design was created, similar to how a human hand opens and closes around a tool. The main mechanism for the gripper was designed to move in two discrete motions, opening and closing the jaws, and raising and lowering the tool. Another main goal of the design was to include the least number of parts possible and simplify the design down to its core functions. By simplifying the design, we were able to reduce the time spent prototyping each iteration, problem solve over the course of more iterations, and reduce the overall cost of the assembly with less off the shelf parts. Due to the motions of opening and closing the jaws of the gripper being separate from one another, two servos must be used instead of one; each with their own inputs coming from the user interface. Each servo is paired with a set of gears that rotate either the lower half of the assembly raising and lowering the tool, or the jaws to open and close, clamping onto the tool. In order to meet the tight time constraint, 3D printing was used to rapidly prototype and solve many of the design challenges as they arose.

Design

As part of the first design iteration a piece of bent sheet metal was used as the center cradle to hold all of the adjoining parts together. This design proved to be too complicated to make with the tools and skills available to us. To solve this issue, we adapted the design from a sheet metal part into a 3D printable part. Once the design was reinterpreted, we were able to quickly modify and reprint the part to test its strength and fitment with the other parts. One of

the main design changes that came about through testing was the addition of a support at the top of the jaws. The original thickness of the jaw layers combined with the overall height of the jaw assembly meant that the 3D printed parts were bending under load and not providing sufficient grip strength on the tool. By increasing the thickness of each jaw layer and mirroring the design of the bottom jaw on the top of the assembly, rigidity of the assembly and overall grip strength, were greatly increased as a result. As an extra precaution to increase grip strength, foam covers were added to the ends of the jaw layers to prevent the tool from sliding vertically.

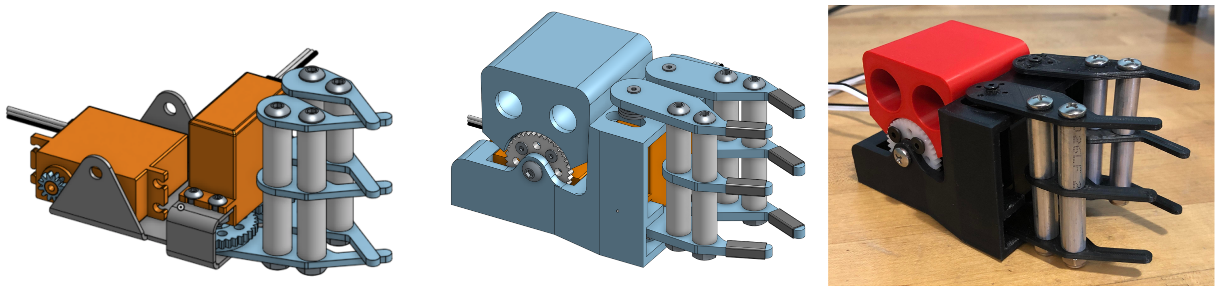

Figure 6.1: Shows the different gripper iterations from initial concept to the final product.

Safety

Because the gripper is one of the most accessible parts of the machine, mitigating safety concerns is an important aspect of the design. The biggest risk of injury would be the number of pinch points between moving parts and gears. This risk is mitigated by enclosing all of the moving parts to locations in the assembly deeper in the assembly where one could not reach their hand or finger into. The grip strength of the jaws has shown to be strong enough to firmly grasp tools, but not strong enough to cause pain if someone were to close the jaws around their finger.

Technical Feasibility

Results and Discussion

Integration of Subsystems

Gripper

Integrating the gripper assembly into the machine at large was straightforward given the small amount of mechanical interaction between the gripper and the rest of the VanGoBOT. The gripper gets its information and power supply from the user interface through a wired connection protected by a flexible conduit allowing the gripper to move freely without damaging the wires. The main mechanical connection between the gripper and the VanGoBOT is the connections to the Belt and Framework subsystems using low friction bushings to slide across smooth rails.

Conclusion and Recommendations

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