CODIA MARK I

C.O.D.I.A. (Computer operated & delightfully intelligent assistant)
2018

Ellie T. Xu
Garth Webb Secondary School
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RATIONALE

Over 11% of Canadian adults (3 million individuals) suffer from one of these three disabilities: pain, mobility or flexibility (“Disability in Canada”, 2015). Having an artificial assistant when no one is around can greatly improve their lives. Fortunately, advanced robotics is no longer a legend to people, however, seeing one in the average household is still an arm’s length away. Current robotics sees incredible designs with cutting-edge manufacturing, but for the general population, they are mere theories simply because they are too expensive and impractical.

To solve this issue, it is proposed to create an intelligent assistant that helps people with their everyday tasks such as retrieving an object. It would operate with a wireless manual control system through the user’s hand gestures, communicating through a radio frequency of 433 MHz, and 70 cm wavelength. It will also be armed with technologies that are able to complete the basic tasks of everyday life, such as a robotic arm powered through servo motors. Its mechanisms, although serving similar functions as existing technologies, will be designed in a new way, into a more efficient and cost effective build. It will be a robotic assistant available for any type of homes.

ENGINEERING GOALS

To bring the dreams of a robotic assistant in the average household a step closer to reality, C.O.D.I.A. is created as the first generation of an intelligent assistant that helps people with their everyday tasks such as retrieving an object. It has a manual wireless control system that uses a natural user interface (NUI) which is the user's hand gestures monitored by rings. This NUI gives the user the flexibility to engage in various tasks while wearing the controller. C.O.D.I.A. is also equipped with a robotic arm that is able to grab an object and lift it up or drop it down. Its mechanisms, although serving similar functions as existing technologies, is designed in a new way - into a more efficient and cost effective build.

Rudimentary functions

- Finger gesture controller
    - Thumb for moving forward
    - Ring finger for turning
    - Index finger for closing the claw
    - Index and middle finger to move arm up
    - Middle finger to move arm down
- Toxic gas presence
    - Starts blaring if too high (needs speaker)
- Fire detection
    - Starts blaring if fire detected (needs speaker)

Possible advance additions

- Temperature: temperature transistor
- Sings happy birthday

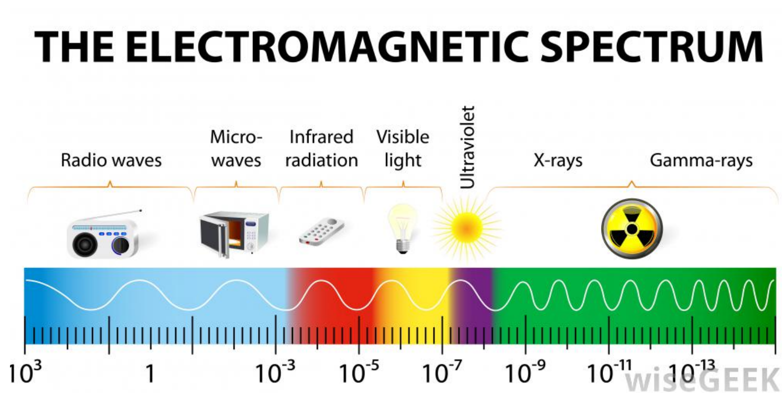
- Has reminders/ calendars set from phone
- Button to call robot (distance sensor)
- Basic voice control
- Automatic charging like a roomba vacuum
- Relay module to control home appliances
- Knows when there is mail
- Call for help
    - Via button and GMS Arduino shield

BACKGROUND

For an Arduino sitting a few meters away from its user to know their finger gestures, there has to be either wireless communication or vision tracking/motion detection.

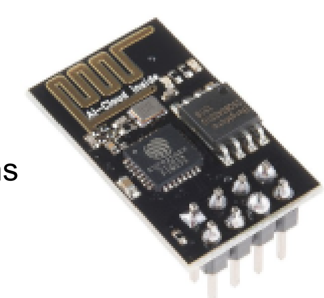
Wireless communication

The most common methods of wireless communication are wifi, bluetooth, IR, and radio frequencies used in RF modules. These are all electromagnetic radiations with wavelengths longer than visible light, making them all invisible to us (Designua, n.d.).



Wifi

Wifi uses microwaves to transmit information across a network. Its frequency is between 2.4GHz and 5GHz (Aakai1056 and ChristinaCCM, 2016). It is widely accepted that wifi is short for Wireless Fidelity. It works by using a wireless adapter, translating data into radio signals, then a router, decoding the radio signals, or vise versa. 802.11 is a set of technology standards for wireless network devices set by the IEEE. It governs the design of wireless devices and how they communicate with each other. The original 802.11 supports a bandwidth of 2Mbps, which is too slow (Mitchell, 2018). 802.11n is the latest protocol,



ESP8266

having 300Mbps of network bandwidth. The 802.11b and 802.11g versions use the 2.4 GHz ISM band, which causes occasional interferences from microwave ovens (since they both use microwaves, just at slightly different frequencies), cordless telephones, and bluetooth devices (Mitchell, 2018). For Arduinos, modules such as the ESP8266 have been created for wifi access. This module uses an FTDI to connect to an Arduino for coding, and has one digital output. It uses the local wireless network, and works with the protocols 802.11b, 802.11g, and 802.11n (ESP8266, 2018).

Advantages: it's commonly used.
Disadvantages: it is limited by large devices like a hub, and uses lots of power.

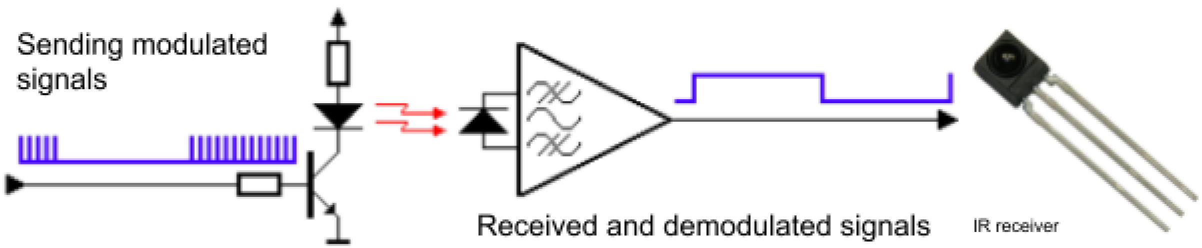
Bluetooth

Bluetooth uses radio waves in a frequency of about 2.45 GHz (Woodford, 2017). It is designed to communicate over short distances that are less than 10m or 30 ft for small amounts of data, and uses little power (Woodford, 2017). Up to eight bluetooth devices can be connected and communicate at the same time. Bluetooth devices can use a technique known as spread-spectrum frequency hopping to communicate when their channel is already taken (there are 79 channels (frequencies) in total) (Woodford, 2017).

Advantages: low possibility of signal interference with another device (e.g. life-support machines) because the low power of the bluetooth transmitter can't carry the signals very far.
Disadvantages: its communication distances are limited to be less than 10m 30ft.

IR

IR devices use infrared radiation to communicate. It is a electromagnetic radiation with longer wavelengths than visible light, but much shorter than radio waves, at 1 micrometer (human hair thickness is around 100 micrometer), and its frequencies range from 430 THz to 300 GHz (“Infrared”, 2018). Such communication methods are often found in devices like TV remotes. The signals sent out by an IR transmitter is modulated, in other words patterned, so the receiver would know that these signals are meant for it (“Infrared”, 2018). When the receiver receives signals, it demodulates it to obtain the data (“Infrared”, 2018).



Advantages: low cost, and IR receivers are small enough to be carried around.
Disadvantages: a wall between the receiver and the transmitter would cause their connection to fail. The receiver has to be pointed directly at the transmitter. This limits its movements.

Radio frequency modules

RF modules use the electromagnetic radiation with the longest wavelength when compared to wifi, bluetooth, IR, and microwaves, being between 1m to 100m. Their frequencies are in the range of 300 MHz to 2400 MHz (“RF module”, 2018). These modules are small devices that has a receiver circuit, a transmitter circuit, or a transceiver circuit. Transmitter modules modulate radio waves, and then the receivers demodulate it to obtain information. A common and affordable RF module pair is the 433MHz transmitter and receiver. It has a maximum distance of 500 meters with a good antenna (Aukru, n.d.).
They send out RF signals when a power supply powers an oscillator, which creates an alternating current, the sine wave (also known as the carrier wave), at the frequency that will be transmitted (Brain, 2000). Then the carrier wave passes through a

modulator, which makes slight increases or decreases to the intensity of the carrier wave to store information (Brain, 2000). Then it goes through an amplifier, which amplifies its power (Brain, 2000). And at last, when it travels to the antenna, the current causes the antenna's electrons to vibrate, hence generating a patterned electromagnetic field emission to the shape of the carrier wave's troughs and crests (Woodford, 2018). This pattern shapes the frequency that is transmitted through the antenna. On the other hand, the receiver receives the frequency through its own antenna, which is able to receive in the first place because the frequency causes its electrons to vibrate, thus producing an alternating current (Woodford, 2018). This current is very weak, so an amplifier strengths it (Brain, 2000). But this current is not just the orignal current, the antenna picked up all signals around it, so a tuner picks out the specific one (Brain, 2000). The rest differs from receiver to receiver, but it ultimately expresses the current in a form such as audio, or a digital signal.

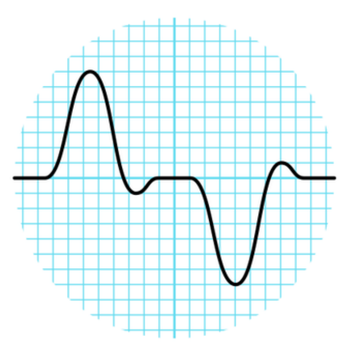
The downside to radio frequency is that, like all electromagnetic frequencies lower than ultraviolet light, it can not pass through metal as metal has a plasma frequency, and any electromagnetic waves at frequencies lower than the plasma frequency are mostly reflected (Fisch, 2017). Hence, phones don't get signals in an elevator. (plasma frequency is the resonant frequency of a plasma oscillation (The Editors of Encyclopaedia Britannica, n.d.). A plasma oscillation (also known as Langmuir waves) is the organized motion of electrons or ions in a plasma or metal. Each particle is positioned so that the total force resulting from all the particles in zero (The Editors of Encyclopaedia Britannica, n.d.). But when an electron is removed from its equilibrium position, the resulting positive charge exerts an electrostatic attraction on the electrons, causing them to oscillate around their equilibrium position. Due to the electrons' strong interactions, they all oscillate at the same frequency (The Editors of Encyclopaedia Britannica, n.d.).)

Microwave communication

Besides from causing water and fat molecules to vibrate, and make them hot, Microwaves were used as the main source of long distance telephone calls before optic fiber (“Microwave transmission", 2018). They have a wavelength of 1mm - 1m (“Microwave transmission", 2018). Their frequency is between 300 GHz - 300 MHz (“Microwave transmission", 2018). Some wireless LAN protocols, such as bluetooth and the IEEE 802.11, use microwaves in the 2.4 GHz ISM band (ISM is radio bands reserved internationally for industrial, scientific, and medical uses outside of telecommunication). Some advantages to microwaves are that they can easily pass the ionosphere, therefore suitable for satellite transmissions ("Microwaves", n.d.). It is also easier to design high gain antenna for microwaves when compared to the longer wavelengthed radio waves because as frequency increases, wavelength decreases, so directivity increases (directionality is a measure of how many directions an antenna can cover. If an antenna radiates equally in all directions, it would have zero directionality), and beam width decreases. However, if the microwave is antenna generated, most mobile phones do not have enough power, so they need to be constantly close to a transmitter, meaning more transmitter towers. They are also easily obstructed by obstacles like buildings.
Contrary to what many people thinks, microwaves is not a health concern as they do not have enough energy to chemically change substances by ionization (Darvill, n.d.).

Vision tracking/motion detection

Vision tracking

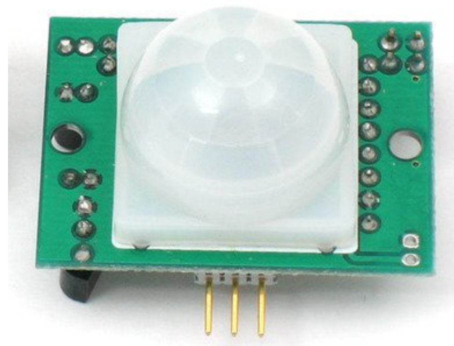


Output signal

Vision tracking uses a camera to visually recognize the user’s movements. This would eliminate the need for any hardware on the hand. The library Opencv (java) is often used for vision tracking. It provides a common infrastructure for computer vision applications.

Motion detection

Motion detection, just like vision tracking, would eliminate the need for any hardware on the user's hand. The difference between the two is that motion detection senses a general motion, such as a wave, whereas vision tracking can distinguish between the complex movements of each individual finger. From the article written by Lady ada and Tony DiCola (2016), the most practical module for motion detection is the Pyroelectric ("passive") infrared sensors. It uses two types of sensors, made of different materials that are sensitive to infrared radiation. When there is no motion, both sensors detect the same amount of IR. But when a warm body passes by, it first intercepts one of the sensors, causing a positive differential change to happen. Then when the warm body leaves, it intercepts the second sensor, causing the reverse to happen, so a negative differential change. Therefore the PIR motion sensor looks for these changes. PIR sensors often have a lens as well. Concave towards the sensor, and convex towards the world. This dome uses optics to maximize the area the sensor can detect.



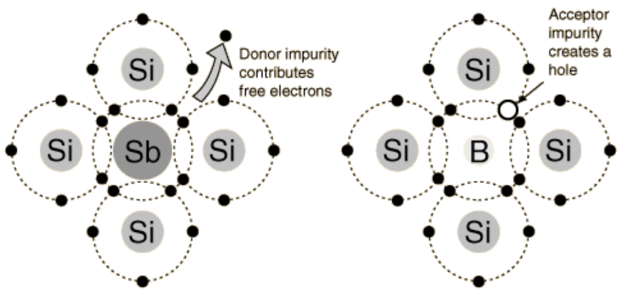
Advantages: no hardware required on user's hand.
Disadvantages: a camera/sensor would be require at every possible angle. Very vulnerable to obstructions.

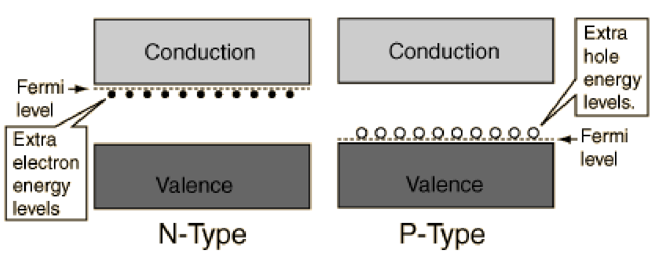
ICs

Integrated circuits are a great way to pack a millions of electronic components into tiny chips. Essentially, instead of having separate components (e.g. resistors, transistors) on a PCB, integrated circuits have everything embed in microscopic levels on a silicon wafer. In other words, they are silicon wafers that have some doped areas, acting as the electrical components, and when all these doped areas are connected in a certain order, it becomes a microscopic circuit.

Semiconductors and Doping

The idea of integrated circuits are made possible by semiconductors. They are not like insulators (e.g. plastic), or conductors (e.g. metal), they are in between. Silicon for instance, is typically acts as an insulator, but doping it causes it to be conductive. Doping is simply the addition of impurities to a semiconductor. Some experience a drastic change in their electrical properties, making them either P or N doped. N doped semiconductors have many fixed positive charges and free electrons. P doped have many fixed negative charges and holes (holes are an absence of electrons. In semiconductors, holes can travel between atoms flowing from positive to negative). For example, an impurity atom with 5 valence electrons make an N-type semiconductor as they contributed extra electrons. Before a semiconductor is doped, they are called intrinsic semiconductors. Meaning that the holes are created by electrons that have been thermally excited to the conduction band, as opposed to doped semiconductors where holes or electrons are supplied by a different atom acting as an impurity. A doped semiconductor has a greatly increased conductivity. Applying the band theory, it is seen that a doped semiconductor has an extra level added by the impurities. They can be easily excited to into the other band. Thus increasing its conductivity. (the band theory is a way to visualize how the conductivities of an atom work. Insulators have a large gap between the

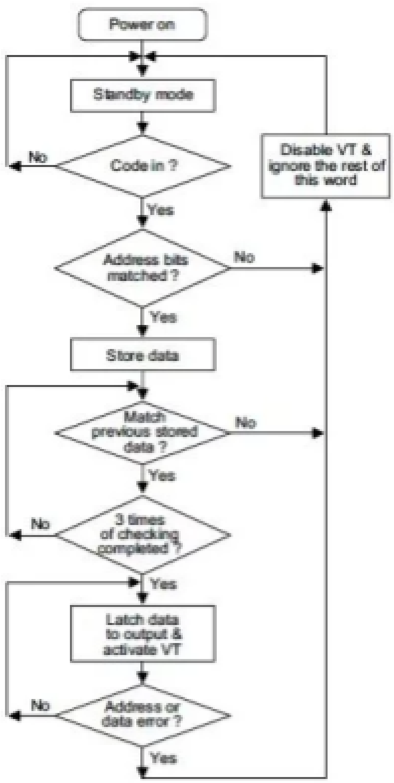




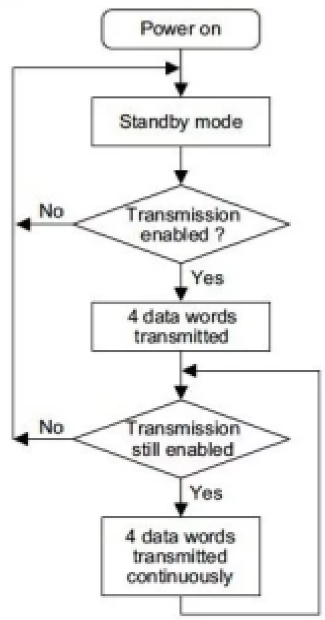
conduction and valence band, while conductors have them overlapped. The bands are formed from the available energy states. The conduction band is how freely electrons can move through a material.)

HT12E & HT12D

Many of the wireless communication modules allow for only one digital input and one output, the 433 MHz RF transmitter and receiver pair for example (Aukru, n.d.). Which means to send and receive parallel data, an encoder/decoder IC pair is required: HT12E and HT12D. This pair is commonly used for RF applications. They are able to encode 12 bits of parallel data into serial data, which is then received, and decoded again into parallel data (George, 2013). These 12 bit parallel data is divided into 8 address bits and 4 data bits (George, 2013).



Work flowchart for HT12D



Work flowchart for HT12E

HT12E:

Pin 1 - 8: input address pins that can provide a security code for the data. They can be connected to the ground or left open.

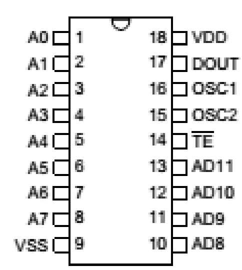
Pin 9 and 18: power and ground.

Pin 10 - 13: input data pins with a common anion.

Pin 14: used to enable the transmission.

Pin 15 - 16: connects to an external resistance for the internal oscillator.

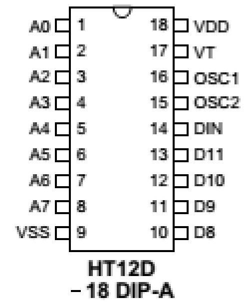
Pin 17: output pin to connect to the RF transmitter.



HT12E
–18 DIP

HT12D:

Pin 1 - 8: input address pins that can provide a security code for the data. They can be connected to the ground or left open, and should match those of the HT12E's.



HT12D
– 18 DIP-A

Pin 9 and 18: power and ground.

Pin 10 - 13: output pins with a common anion.

Pin 14: input pin to connect to the RF receiver.

Pin 15 - 16: connects to an external resistance for the internal oscillator.

Pin 17: VT stands for valid transmission. It will be HIGH when valid data is available at D10 - D13 output pins.

Flexible Resistors

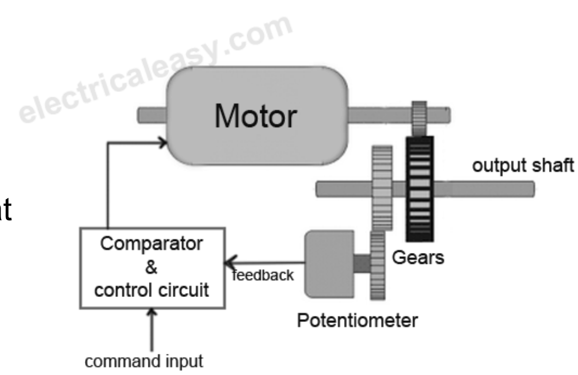
They are resistors whose resistance is dependent on the bending or deflection of itself ("Flex sensor", 2018). There are many different types of flexible resistors. Some works by using conductive ink. When the resistor bends, the conductive layer is stretched, resulting in less/more cross-sectional area. This change causes the resistance to change (Vinod, 2015). The other common and cost efficient type of flexible resistor is the Velostat flex sensor. It uses the pressure sensitive nature of the conductive Velostat to achieve the same results ("Pressure-Sensitive Conductive Sheet", n.d.).

Nintendo Power Glove

This was the first video game controller that allows players to operate Nintendo games with intuitive hand gestures (Baker, 2017). It used flexible resistors to sense the user's gestures. Those are variable resistors that adjust their resistance corresponding to the degree they are being stretched at. These gloves were communicating with the receiver placed on the TV 20 times every second through ultrasonic speakers that triangulates its position, which is slow for gaming, especially when something can happen in the blink of an eye (Baker, 2017). The gloves costed around $100 each in 1989 (which would be around $200 now) (Baker, 2017). They eventually went out of business because of their slow transmission speed and highly inaccurate character control (Baker, 2017).

Motors

Servo Motors



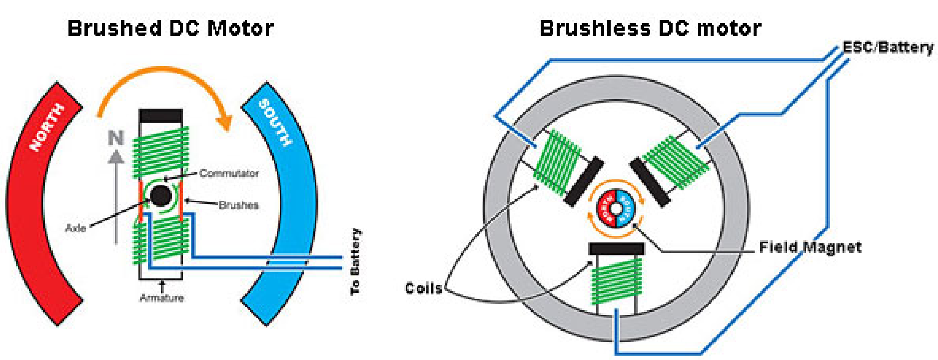
Servo motors are rotary or linear actuators that allow for a precise control of angular or linear position, velocity, and acceleration ("Servo motor", 2018). Internally, it is a motor coupled with an encoder to provide position and speed feedback ("Servo motor", 2018). It works by comparing its physical position with the command position . If they don't match, then an error signal is generated which causes the motor to rotate in either direction until they match. This mechanism is known as a servomechanism, utilizing error sensing negative feedback to correct the action of a mechanism ("Servo motor", 2018). The simplest servo motors use a potentiometer to sense its position, and has a bang-bang control of their motor - going either at full speed, or not going at all ("Servomotor", 2018).

DC Motors

These are motors that operate on direction currents. There exists two major categories of DC motors: the brushed and the brushless.
A brushed DC motor operates with two permanent magnets or electromagnets surrounding an armature ("Brushed vs Brushless motors, n.d.). When a current is sent

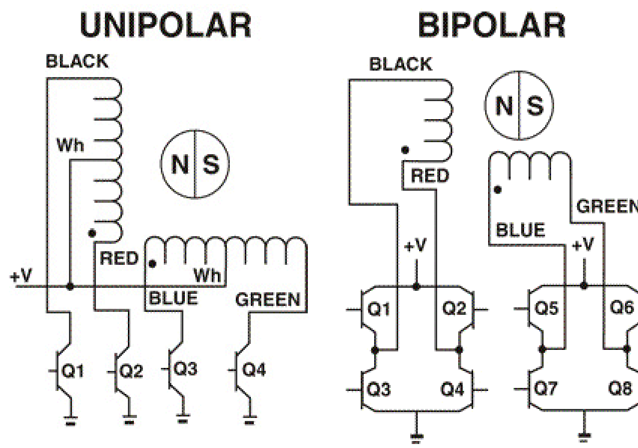
through the brushes to the commutator (which is connected to the armature), a magnetic field is created around the armature, causing it to be pushed away from the magnet with the same pole and towards the other ("Brushed DC electric motor", 2018). When the armature has turned 180 degrees, the current passing through it is now reversed, causing it to spin again and away from the magnet with the same pole ("Brushed DC electric motor", 2018). This process repeats, and motion is created. A disadvantage is that the brushes will often have to be replaced as a lot of friction occurs in this area. On the bright side, they have a cheap initial cost and simplicity ("DC motor", 2018).

A brushless DC motor operates on much the opposite way a brushed one does. Instead of having magnets around an armature, it has a magnet in the centre surrounded by electromagnets (“Brushed vs Brushless motors, n.d.). When a electric current is sent through these electromagnets, a magnetic field is created, causing the center piece to turn. When it has rotated by 180 degrees, the polarity of the electromagnets change so the center piece can continue to rotate. It changes polarity through a system of sensors that detects the angle of the rotor, and controls semiconductor switches such as transistors to switch the current direction through the windings (“Brushed vs Brushless motors, n.d.). They last longer than brushed motors because they have eliminated the need for sliding contacts which causes friction therefore damage.



Stepper Motors

Stepper motors are DC brushless electric motors that divides a full rotation into a number of equal steps (“Stepper motor”, 2018). The motor can be commanded to move a certain number of steps and hold there without any having to use position sensors. Stepper motors can convert a train of input (usually digital) pulses into steps (“Stepper motor”, 2018). Each pulse moving the shaft through a fixed angle (“Stepper motor”, 2018). Internally, it moves with a central gear-shaped piece of iron surrounded by electromagnets that are powered externally (“Stepper motor”, 2018). When one electromagnet is turned on, it magnetically attracts the central gear’s teeth. This causes these teeth to be slightly offset from the next electromagnet (“Stepper motor”, 2018). So when the next one is turned on, and the first one turned off, the gear rotates slightly to align with the next one, and this process repeats, with each rotation known as a “step” (“Stepper motor”, 2018).



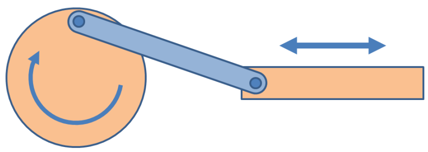
Stepper motors have two major winding arrangements for their electromagnetics: unipolar and bipolar. Winding is basically wires coiled around and around to create the magnet part for the electromagnet. In unipolar stepper motors, there are two pairs of windings, wired in reverse of each other so they can create the opposite poles (BrianV, 2016). These stepper motors typically have 5, 6, or 8 wires (BrianV, 2016). On the other hand, bipolar stepper motors have all their windings going in one direction (BrianV, 2016). They control the poles of the electromagnet by switching the polarity of the power source, usually through an H bridge driver circuit (BrianV, 2016). Bipolar motors normally have four wires.

Rotary motion to linear motion

Motors have rotary motion. To use one to create motion such as the closing and opening of a claw, it would require it to be translated to linear motion.

Ball screws use a stationary screw, and when it spins, it moves the center piece forwards and backwards. Disadvantage: typically large in size and expensive.

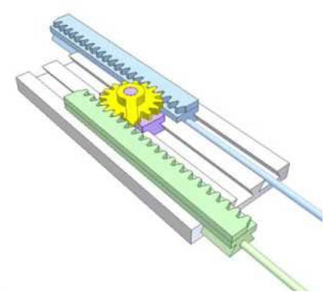
A more traditional method uses a guide and two rods indicated by the picture here:



Disadvantage: requires a large torque from the motor because some of the force applied to the rod (blue in the picture) is against the guide guiding the second rod. Only some force is actually applied directly into forward motion.

A pulley attached to a motor would be able to complete this task as well. It is used in cascading lifts. Disadvantage: goes only in one direction.

Another method would including a gear resting place, while its spinning motion is able to move rods attached to it via teeth. Disadvantage: hard to come by, and such intricate teeth cannot be easily manufactured.



DESIGN

Components on the hand

Purpose: send commands to the Arduino on the robot via finger gestures all the while maintaining a level of comfort and dexterity.

Components:

- Wristband
    - PCB circuit
        - Radio frequency transmitter
        - HT12E IC
        - 1M ohm resistor
        - 8 female wires
        - 4 small rubber bands attached via a stiff metal wire
    - Button battery holder
    - Button battery 3V
    - Velcro
- Base ring
    - Aluminium foil
    - Wire
- Top ring
    - Wire

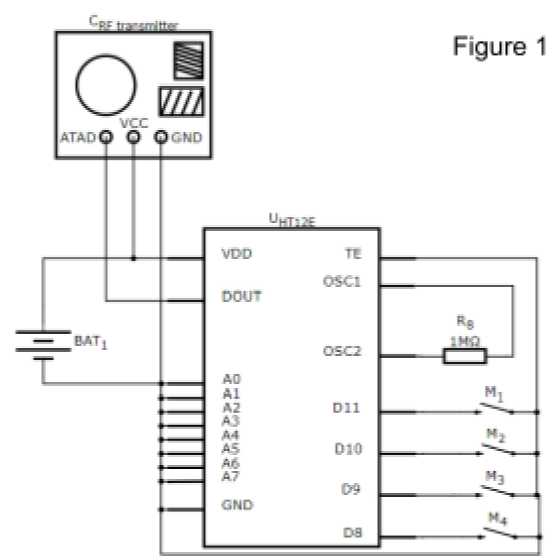
Wristband

(refer to figure 1 and 2)

The wristband (figure 3) serves as a frame for the gesture component. It is designed to provide minimal interference with hand movements, maximum comfort, ease of use, and easy troubleshooting. This is done through an adjustable circumference made to fit as perfectly as possible on the user's wrist, compact PCB layout, attachments designed for easy removal of the components, and extra precautions.

For example, the transmitter PCB is made easy to remove by being secured on with an elastic band at either end instead of sewed on permanently. The compact PCB layout is made possible by having the HT12E IC and the resistor soldered on to the front side of the PCB board, while having the RF transmitter soldered on to the back to minimize space. All wires are cut to be longer than necessary as a precaution against unforeseen circumstances. These extra wires are contained and organized in the six cotton stripes going down either side of the PCB board. The connections between the wires extending out of the rings and the PCB board is made through female connectors so these wires can be removed easily for maintenance and change. Additionally, there is also a 3V button battery attached via a button battery holder, of which is sewed on to the wristband. Finally, there are rubber bands attached to a stiff wire across the PCB board. These function as a tendons to pull the wires (attached the rings) back to a default position when the finger is relaxed. Without it, the wires (on the ring) would flail unpredictably around causing accidental connection.

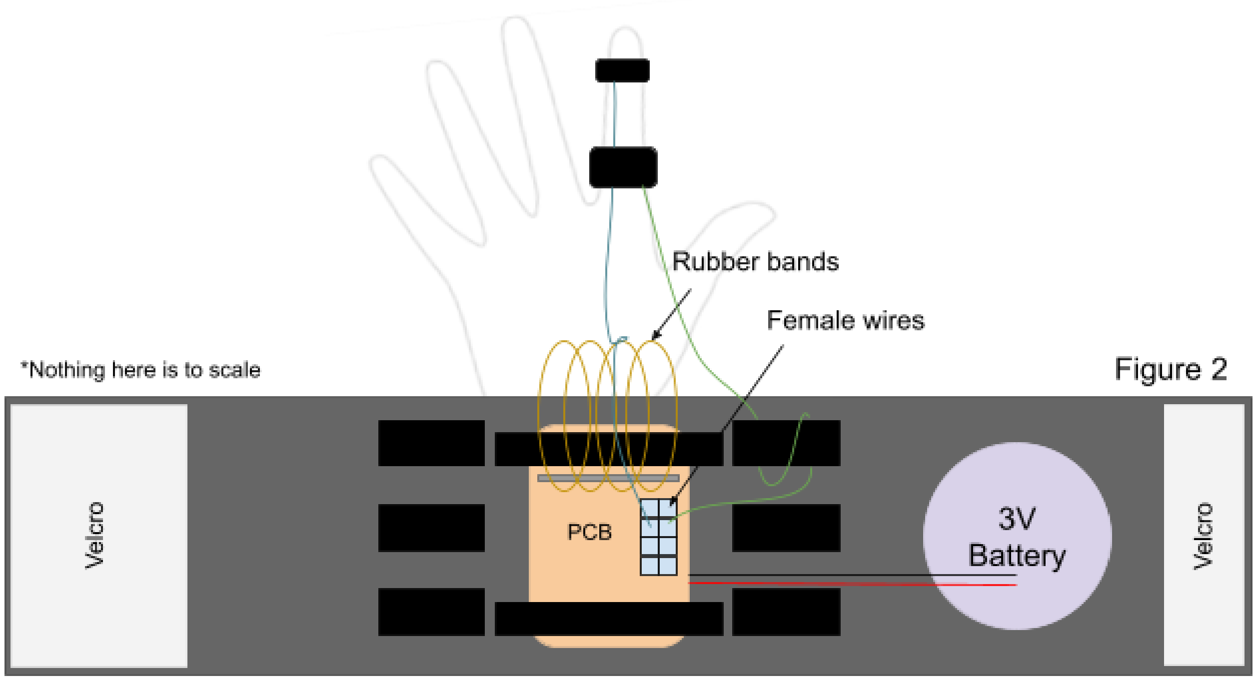
Figure 1



The transmitter circuit soldered on the PCB board with a HT12E IC and a RF transmitter

Figure 1 schematic explanation:

- VDD of the IC and the VCC of the transmitter are connected to 3V of power.
- A0-A7 are all grounded.
- DOUT of the IC is connected to the DATA pin of the transmitter.
- OSC1 and OSC2 are connected by a 1M ohm resistor.
- D8 - D11 are connected to the rings on the fingers.
- GND on both the IC and the transmitter are connected ground.
- The “M” switches are placeholders for the connections of the rings.



Finger gesture rings

(refer to figure 3, 4, and 5)

Eight rings are wrapped around the tip and the base of four fingers. A wire passes through the base ring, and is attached to the top ring. This makes the position of the wire shift in reference to the base ring as the finger bends and relaxes. Conductive aluminium foil is added to the inner side of the base ring, of which is attached to another wire that leads to ground. The wire that is attached to the top ring will have a stripped part near the base ring, and this wire is connected to power. The wire and the rings are placed so that when the finger is bent, the stripped wire will come into contact with the conductive aluminium on the base ring, thus creating a switch. Flexible resistors are not used in place of the rings and wires (even though it seems as if they would make everything simpler) because while they increase or decrease their resistance, making their communication analog, the radio frequency transmitter can only send digital signals.

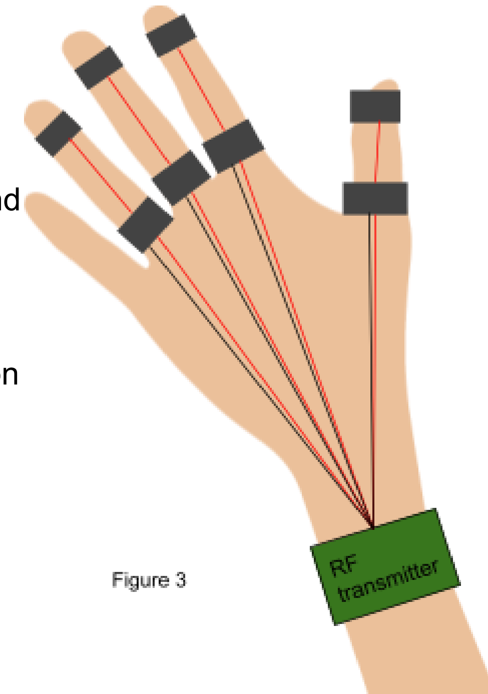


Figure 3

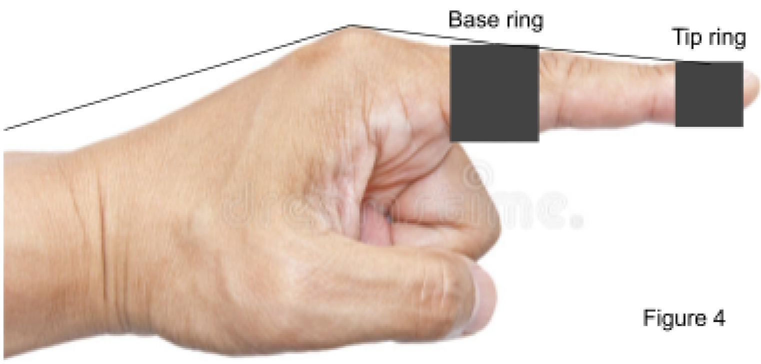
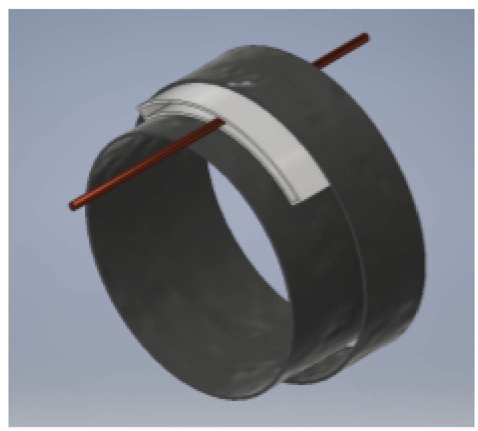


Figure 4

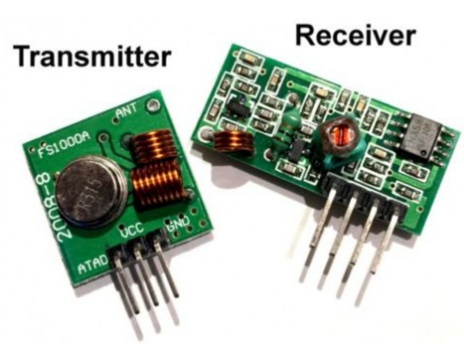


The internal structures of a base ring.
Figure 5

Radio frequency

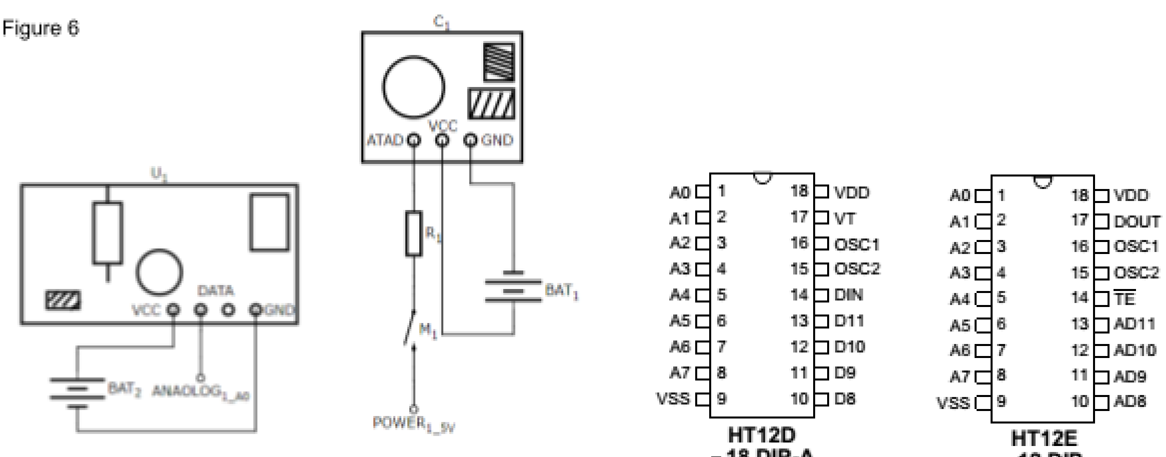
- Gesture > radio transmitter > radio receiver > Arduino > motion

From hand gesture to movements on the robot, this is accomplished by means of radio frequency transmitters/receivers. Radio frequency is used instead of wifi, bluetooth, IR communication, or anything similar is because its transmitters and receivers can communicate over much larger



distances - a common cheap module that uses 433MHz frequency can communicate up to 500 meters, while not having to point right at the receiver (like IR), or needing a complicated big router. Visual controllers/motion detectors are also not used because they only see whatever is in front of them. If their camera is blocked by some reason (i.e. camera is near the ground, and a table sits ahead, blocking its vision to the human user), it would not be able to decipher the commands. This would require a camera installed in every room, and possible angle to ensure it works. Therefore, through this process of elimination, radio frequency is used. A pair of HT12E/HT12D is connected to the RF transmitter/receiver. The HT12E encodes 12-bit parallel data into serial data in order to be sent from the rf transmitter to the rf receiver (rf modules can only send serial data. So to send anything more, they would need an encoder). Then on the other end, at the receiver, the HT12D will decode the 12-bit parallel data again into the serial data. The data is sent in a parallel format in the first place so that multiple gestures can be done at the same time, and get an immediate response. This data eventually reaches an Arduino on the main robot, and the Arduino moves specific components/motors according to the command received.

Figure 6



Basic RF receiver circuit

Basic RF transmitter circuit

The Claw & the Arm

The rotary motion of a mini servo will be converted to linear motion so the claws are able to close (see CAD drawings for the mechanism).

To translate rotary motion to linear motion in order to close and open the claws, a piston design is implemented. This proves to be the best method from research because it is able to be manufactured easily, cost efficient, and able to be made small for this application.

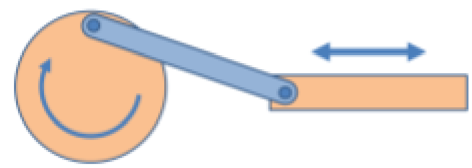


Figure 7

The claw is closed not through moving the fingers directly, but rather through moving a tube that pushes them to be closed.
Three fingers are implemented instead of the traditional two because it provides a better grip.

Rubber bands are added to the end of the tube so when the claws are gripping an object, the gears on the motor would not slip when the motor continuously tries to push the tube forward.

Servo motors are used here in favour of other motors because they are able to provide an exact degree of motion, and they have a greater torque than most DC motors (without gearboxes) which is needed here to lift and close the claw.

Electrical details for the claw & the arm

Figure 8: The DC motors for the wheels have a 120:1 gear ratio (157 RPM, 1.52kg*cm torque), and they are powered not directly from the OUTPUT digital pins on the Arduino (because they don't have enough current), but rather through the Arduino's 5v source via a transistor. The motors are controlled separately to allow them to operate at different speeds to complete the turning action. An H-bridge made out of transistors is used for one of the wheels so it can turn in the other direction in order to complete the rotating action.

2 servo motors is used for the grabber claws, and arm. They can be programmed to rotate to an angle, and this precise movement makes it perfect for the finer movements seen in the claw and the arm. A mini servo is used for the rotary to linear motion, and a continuous servo for moving the arm up and down. A continuous servo is used for this so that as long as the user is sending the signal to move, it continuously moves. Unlike regular servos that stop at a certain degree.

Figure 8

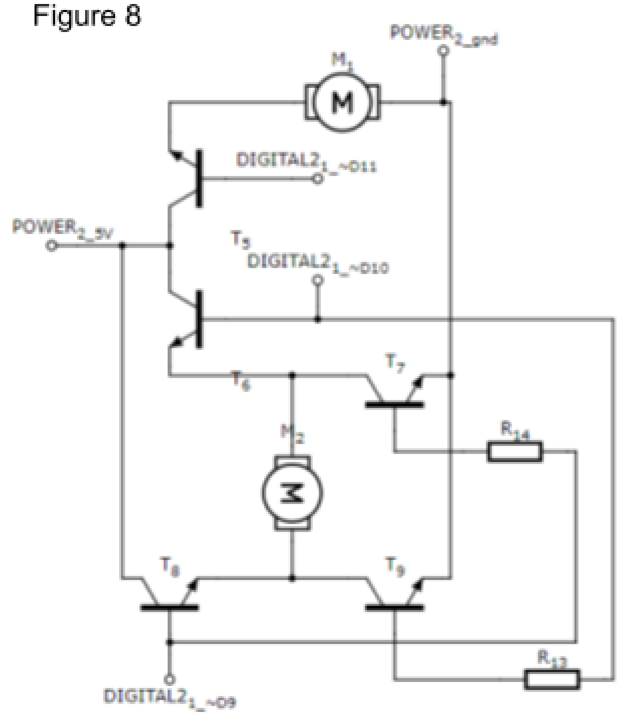


Figure 9: The P_{INPUT} pins are connected to the HT12D. The Arduino DIGITAL input pins (D1, D2, D3, and D4) are not connected directly to their input because that creates a remainder voltage that lingers after it has been disconnected from power. It causes the Arduino to read the DIGITAL input pins as HIGH for 5 additional seconds after its P_{INPUT} pin's power source has been cut off. Through this circuit with the transistors, it effectively grounds any lingering voltage, so eliminating the delayed reaction.
Each resistor has a value of 470Ω.

Figure 10 schematic:

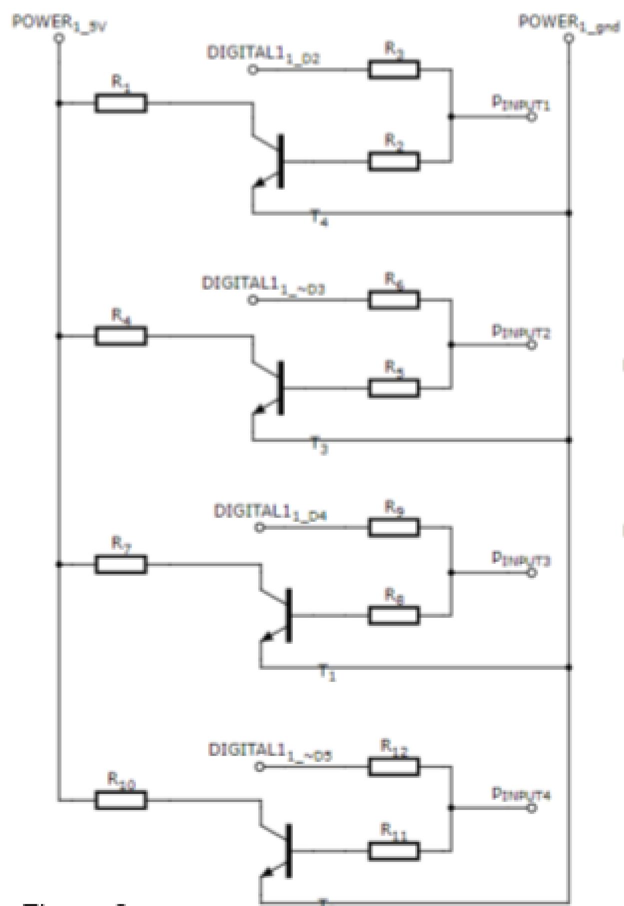
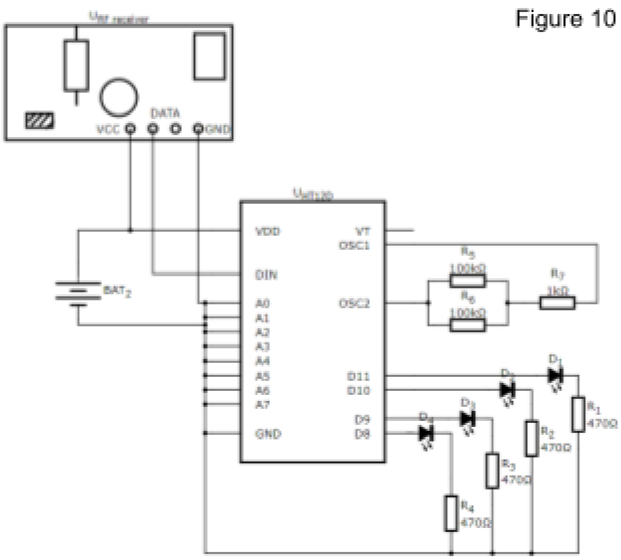


Figure 9

- VDD of the IC and the VCC of the RF receiver are connected to 5V of power.
- A0-A7 are all grounded so the decoder address match the encoder’s.
- DIN of the IC is connected to the DATA pin of the transmitter.
- OSC1 and OSC2 are connected by two 100K ohm resistors in parallel and a 1K resistor in series. This is needed because a total resistance of 51K ohms is needed, but neither 50K or 51K resistors are at hand.
  - Calculations for resistance: $\left(\frac{1}{100}+\frac{1}{100}\right)^{-1}+\ 1\ =\ 51K\Omega$
- D8 - D11 are connected to the P_{INPUT} pins in figure 9.
- GND on both the IC and the transmitter are connected ground.
- The LEDs are placeholders for the connections to the INPUT circuit (figure 9).

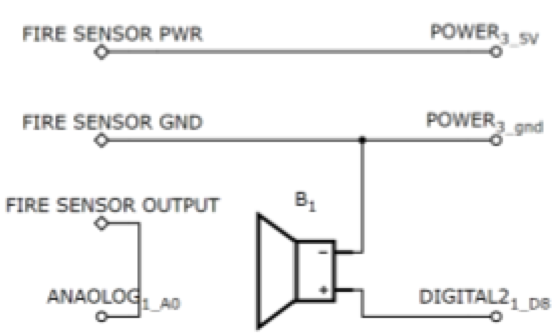
Figure 10



The receiver circuit with a HT12D decoder and a RF receiver.

The fire sensor serves to detect a fire **(figure 11)**. When a fire is present, it turns on the piezo speaker.

Figure 11



MATERIALS

- ❏ Resistors
- ❏ Diodes
- ❏ Multimeter
- ❏ LEDs
- ❏ Jumper wires
- ❏ Arduino UNO
- ❏ Breadboards
- ❏ Goggles
- ❏ Soldering tools
- ❏ Computer and the according softwares (Arduino IDE)
- ❏ FTDI FT232RL
- ❏ ESP8266
- ❏ Radio frequency transmitter and receiver
- ❏ Tmp transistor
- ❏ Aluminium foil
- ❏ Electrical tape
- ❏ Gas detector
- ❏ Fire detector
- ❏ Wheels and axles
- ❏ 2 motor for wheels with gear ratios of 120:1
- ❏ 2 servo motors for arm
- ❏ Rubber bands
- ❏ HT12E & HT12D pair
- ❏ PCB board
- ❏ Acrylic board
- ❏ Wood

- ❏ Shop tools and machines (band saw, files, clamps, etc.)
- ❏ Fire sensor
- ❏ Piezo speaker

PROCEDURE

1. Did research for the mechanisms and drafted a design.
2. Made schematics for the electrical components.
3. Made basic prototypes and circuits.
4. Tested their functionality, and fixed malfunctions.
5. Revised the schematics, and added more to complete the circuits.
6. Improved the basic prototypes until they were in sync with the new schematics.
7. Tested the prototypes.
8. Made improvements to the design, and any more necessary to the schematics.
9. Created the code required to run the component.
10. Tested code on prototype.
11. Edited the code when error was found.
12. Applied finalized code to the final component.
13. Data were collected for the functionality and efficiency of the mechanism.
14. When possible improvements or errors were found, steps 3-16 were repeated.
15. Made next component. Repeating steps 1-17.
16. Assembled all final components together.
17. Observed and recorded the functionality and efficiency of the final project.

METHODS OF DATA COLLECTION

Circuits checked for their functionality by using an indicator LED. When a current passes through the correct path, the desired LED will turn on.
A multimeter used to check the voltage, current, and resistance of the circuit. Useful when double checking the functionality of a circuit, and its safety. For example, making sure the resistors have the right values to reduce the current as not to burn out the connect module. Additionally, it can be used to check a component's battery usage, and thus its energy efficiency.
Interactions between the Arduino and the radio frequency modules are checked by the serial monitor on the Arduino and indicator LEDs. When the input from the radio frequency transmitter matches the output of the radio frequency receiver, then they must be communicating correctly.
A vernier caliper is used to check for correct dimensions.
When the theoretical output matches the actual output, things are working.
A timer and a tape measure is used to calculate speed.
Coding wise, Serial.println() serves to monitor the code's progress.

RISK AND SAFETY

- Any circuit may short-circuit. The danger being that components may smoke and catch on fire. Precaution to take is to double check the circuit before plugging it to a power source, unplug it instantly when a sign of short-circuiting presents itself, and to not work on it when it is connected to power.
- Many workshop machines are dangerous. For example, the soldering rod is extremely hot, the band-saw can easily cut a finger in half. Therefore, safety

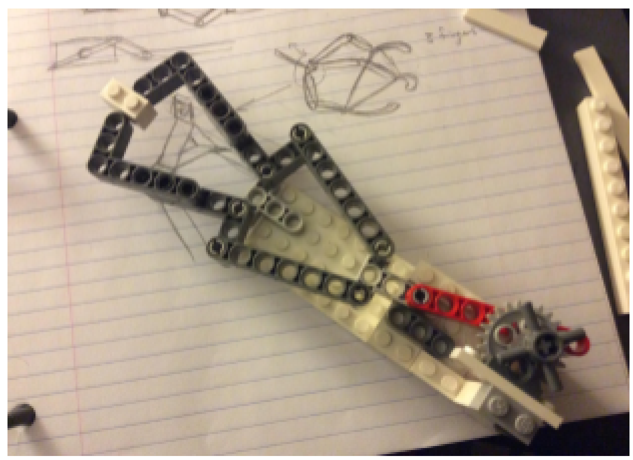
procedures are needed, which is to say goggles on, hair tied-back, place things back when not being used, and shutting off everything when cleaning up.

- Liquids (e.g. water) can short-circuit electronics. The work area should be dry, and clean.
- Electric shock from high voltages/currents. High voltages or currents will not be used in this circuit. But sources such as the outlet still possess such dangers. To avoid it, do not bring water near the outlet, or to poke it with conductive materials (i.e. forks).

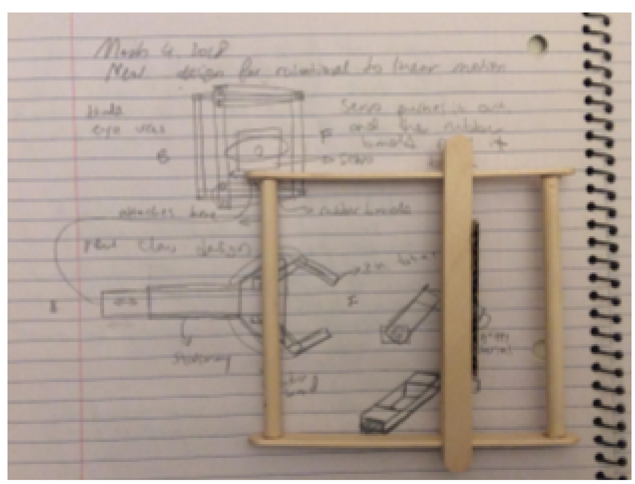
PROTOTYPES

Many models for each mechanism were made until they were finally successful. Even the rotary to linear motion mechanism alone had many models before arriving at the current one.

The first prototype for the rotary to linear motion mechanism is similar to the current model, however, it differs in that the stationary components are different, therefore changing the number of joints needed. This design was not used because it had too many moving components, as well as being impracticable when a third finger is added.



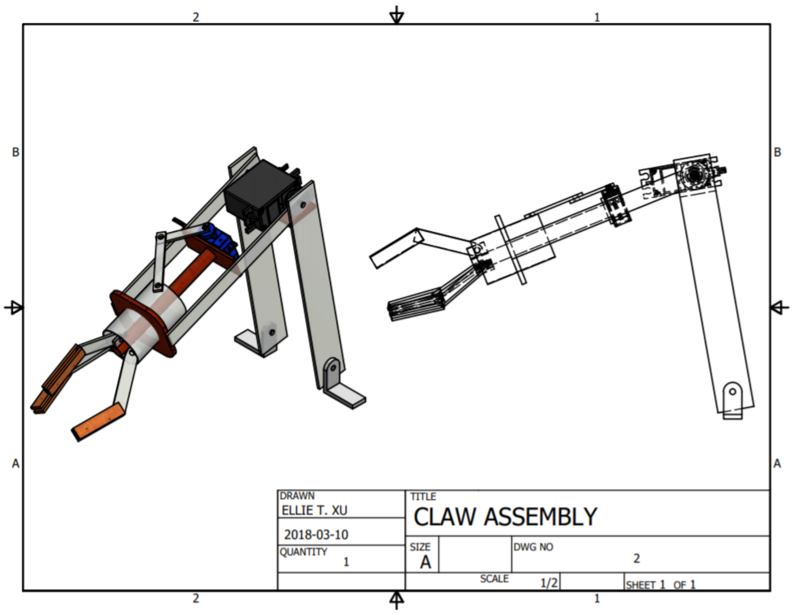
First rotary to linear motion mechanism prototype

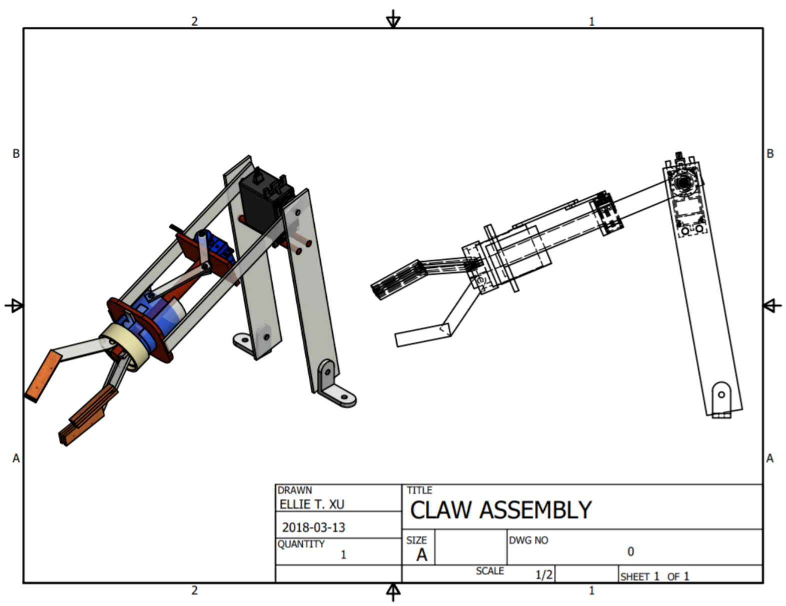


Second rotary to linear motion mechanism prototype

The second prototype involved an ellipse-shaped attachment to the mini servo (powering the rotary to linear mechanism). This pushes a bar away from it as it rotates, then rubber bands pull it back. However, this prototype uses the servo motor's torque very inefficiently, so it was archived.

The arm itself experienced a large development as well.

Initial: 

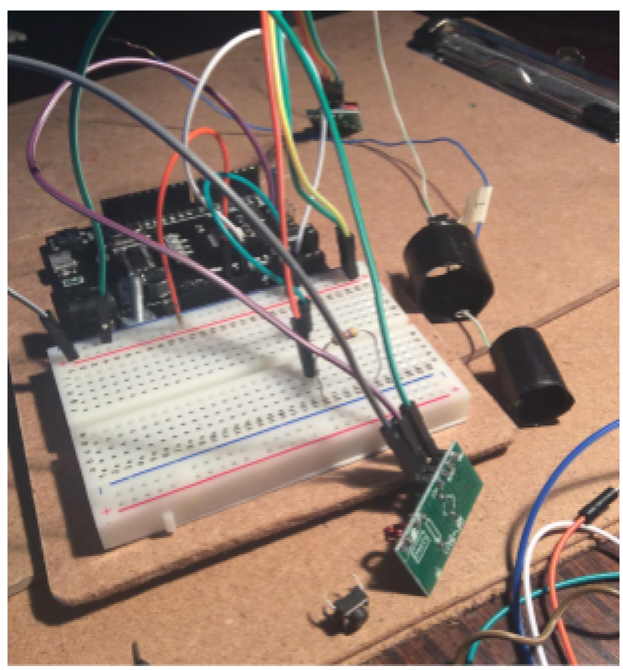
Final: 

Rubber bands were added to cushion the closing of the claw; a long clear plastic guide was added to the piston tube to make sure it always traveled straight; the support system for the continuous motor changed from a simple wooden plank to two rods because the wooden plank blocked the arm's movements; the continuous servo also changed its angle so it can be attached to the rods; a center piece (not visible on the drawings) is added at the tube supporter for the claw it self. Without it, the claw easily wobbled because its only connection point was at the mini servo; adding the central piece caused a strip of the tube to be cut away so it can still move backwards and forwards with the centerpiece in the way.

There were many other prototypes made for different mechanisms beside from the ones above.

MANUFACTURING

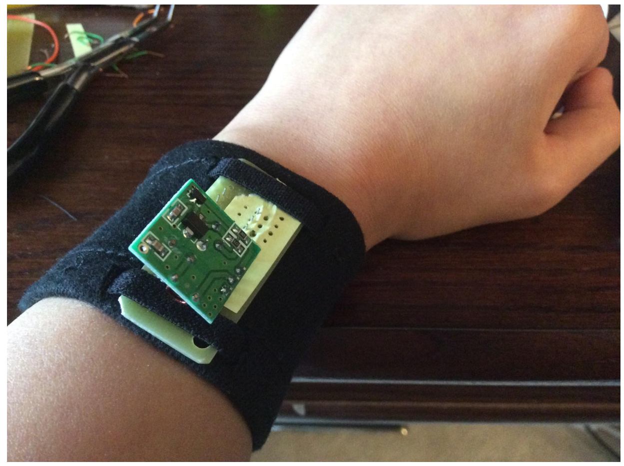
- C.O.D.I.A. is mainly manufactured with wood and 0.8" thick acrylic where needed, for acrylic is flexible and strong.
- A variety of shop tools, such as the bandsaw were used to make the parts.
- A Vernier was used to make precise measurements down to a thou. However, due to the equipment available, they were not able to be cut as precisely as measured, thus



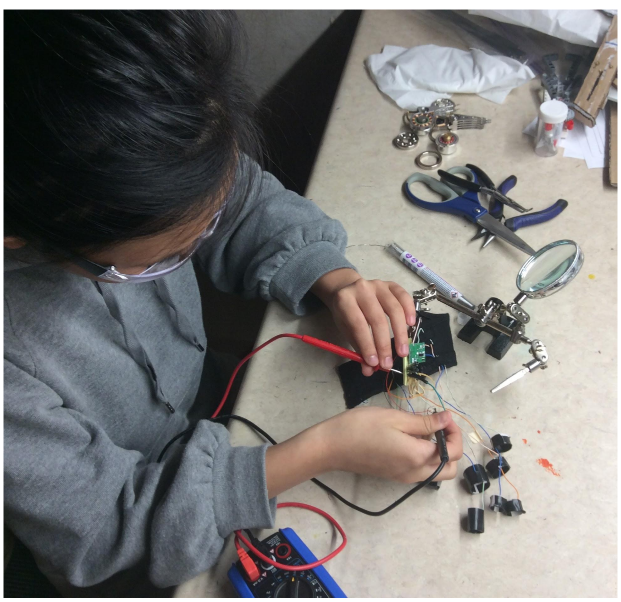
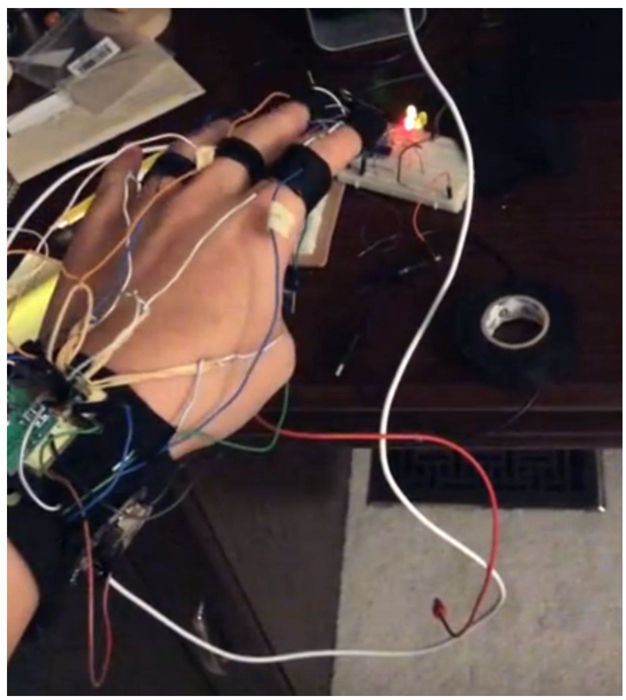
Making the first base ring and top ring pair, as well as the basic RF receiver circuit.

the actual size ended up being 20 thou give or take from the design.

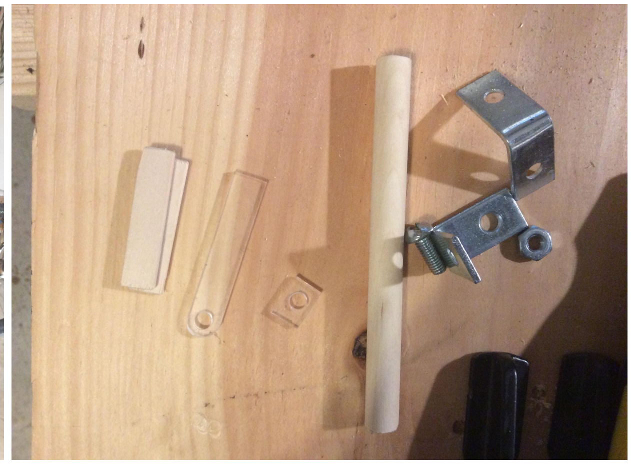
- The components on the wristband is mostly sewed or soldered on.
- A glue gun is used to attach parts too small for screws or bolts, or for temporary attachments.

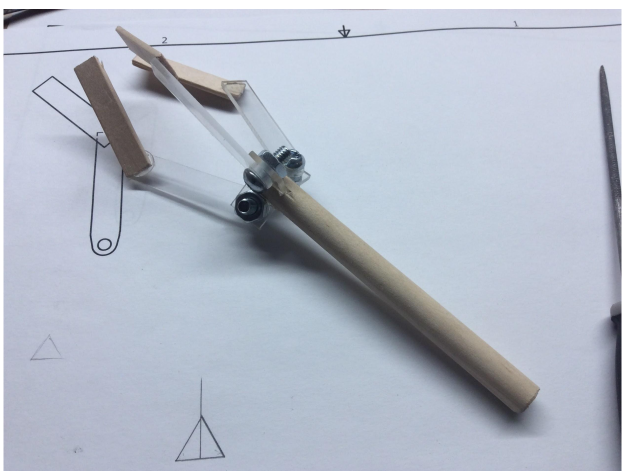
Making the wrist band, and ddding the soldered transmitter circuit on. The IC is on the bottom to save space.

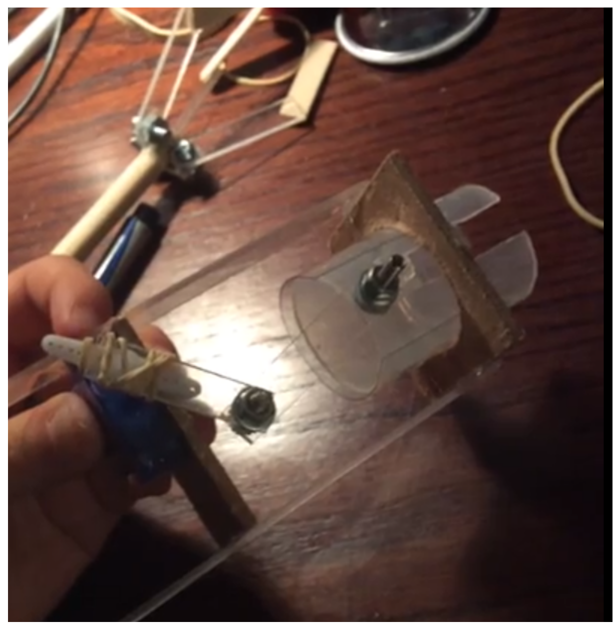



Attaching the rings to the wrist band, and checking their soldered connections. Testing out the product.

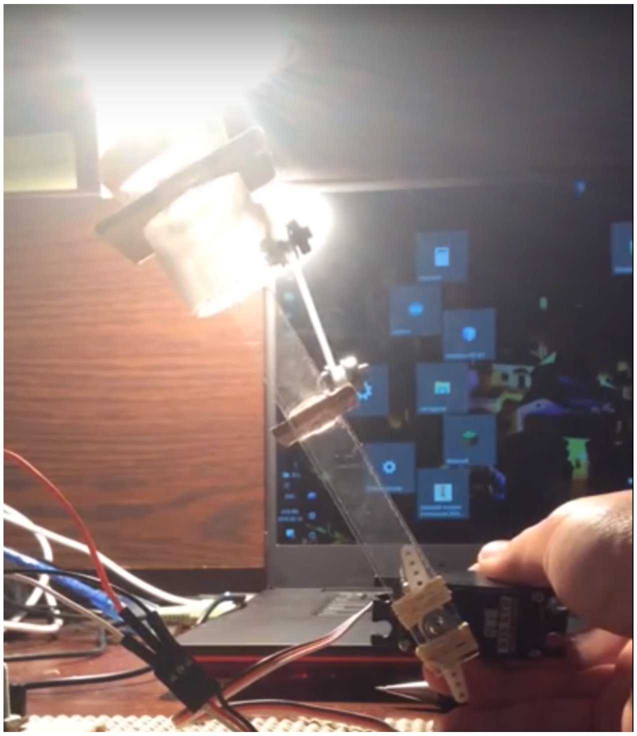


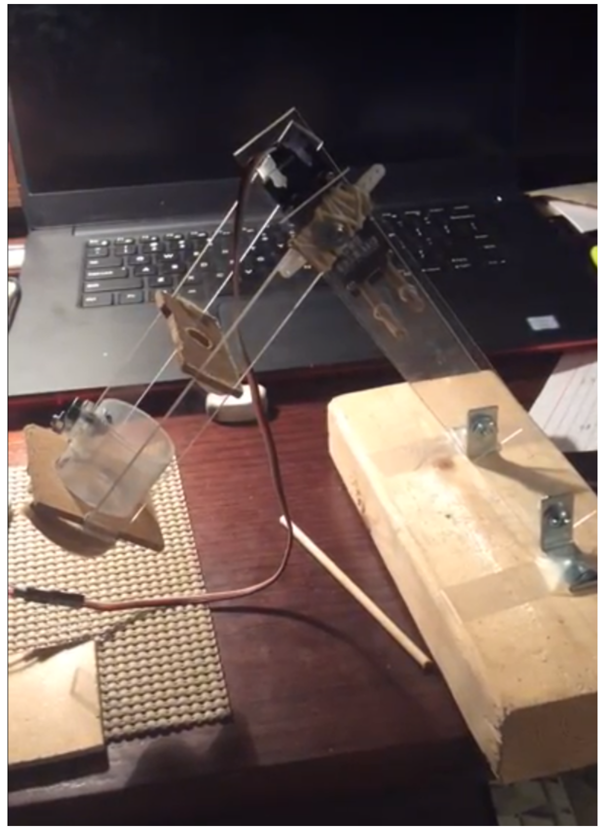
Cutting out parts for the arm and claw.
The cut parts for the claw.



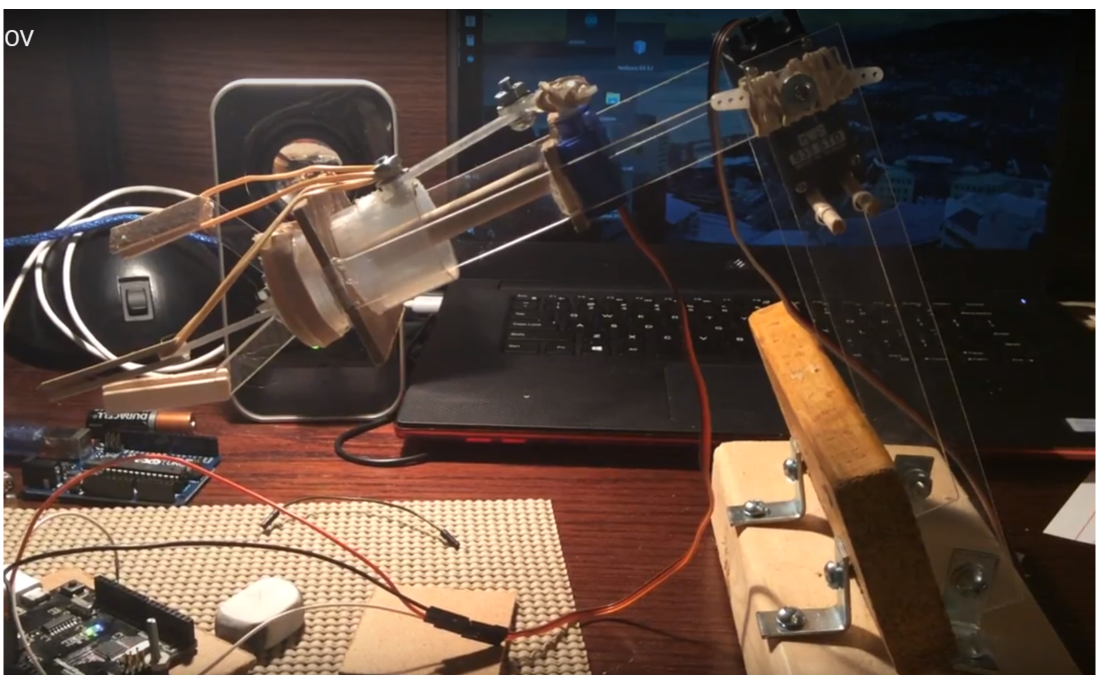


Assembling the claw.
Testing out the rotary to linear design #2. Attached temporarily with rubber bands. Good news: it worked.





Testing out the servo for the entire arm, the moment of truth; and, it worked!
Further testing of the servo for the entire arm.



More testing. This time for the mini servo that is responsible for closing the claw. The rubber bands are there to keep the claw open, the bottom finger doesn't have

a rubber band because gravity does the job. However, adding the rubber bands made it significantly harder for the mini servo to close the grip.

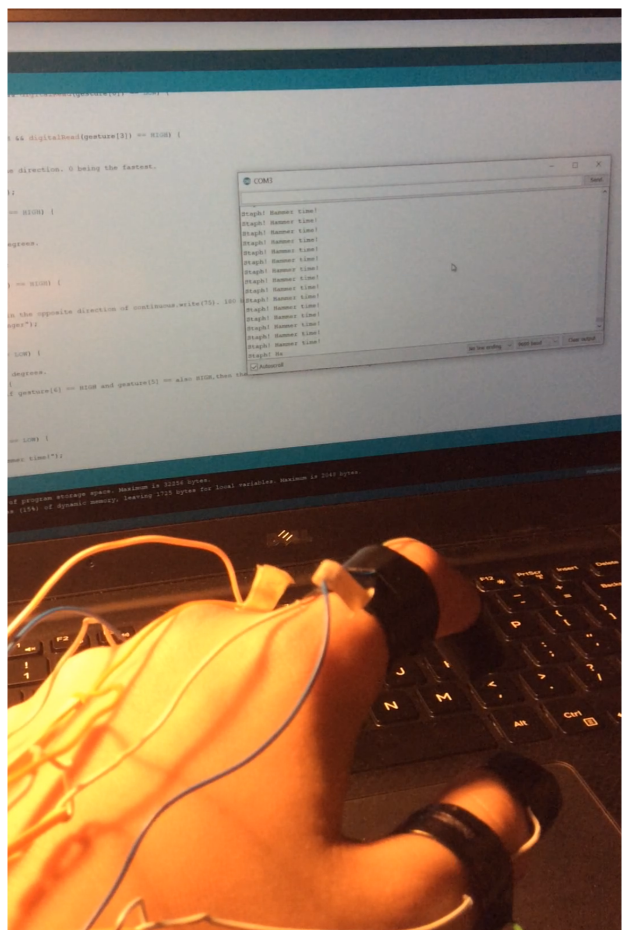
CODING

```
//Arduino code for reading the input from HT12D and acting on it.
#include <Servo.h>
const int gesture [4] = {2, 3, 4, 5}; //pin 2 for turning, pin 3 forward, 4 closing, 5 arm
const int output [5] = {10, 11, 12, 13, 9};
const int pin = 7;
const int speaker = 8;
Servo continous;
Servo mini;
boolean doubleTrouble = false, servo = false;
/**the servo boolean is used to turn the power on and off for the mini servo,
   this is necessary because the Arduino does not have enough power for both the
   mini servo and everything else. So this boolean allows the mini servo's power
   to be switched on just long enough to move it, then shuts it down until a
   command for it to be in a different position is received.
*/

void setup() {
  for (int i = 0; i < 4; i++) {
    pinMode(gesture[i], INPUT);
    pinMode(output[i], OUTPUT);
  }
  pinMode(A0, INPUT); //analog input for the fire sensor
  pinMode(output[4], OUTPUT);
```

```
  pinMode(pin, OUTPUT);
  pinMode(speaker, OUTPUT);
  digitalWrite(speaker, LOW);
  digitalWrite(pin, HIGH);
  digitalWrite(output[4], LOW);
  digitalWrite(output[0], LOW);
  digitalWrite(output[1], LOW);
  digitalWrite(pin, LOW);
  mini.attach(output[2]); // pin 12
  continous.attach(output[3]); // pin 13
  mini.write(43);
  Serial.begin(9600);

}

void loop() {
  if (digitalRead(gesture[0]) == HIGH) {
    //turns on both DC motors to move forward
    digitalWrite(output[1], HIGH);
    digitalWrite(output[4], HIGH);
    Serial.println("dsjfgdsfg");
  }
  if (digitalRead(gesture[0]) == LOW) {
    digitalWrite(output[1], LOW);
    digitalWrite(output[4], LOW);
  }
  if (digitalRead(gesture[1]) == HIGH && digitalRead(gesture[0]) == LOW) {
    //turns DC motors in different directions
    digitalWrite(output[0], HIGH);
```

```
  digitalWrite(output[1], HIGH);
  digitalWrite(output[4], LOW);
}
if (digitalRead(gesture[1]) == LOW && digitalRead(gesture[0]) == LOW) {
  digitalWrite(output[0], LOW);
  digitalWrite(output[1], LOW);
}

if (digitalRead(gesture[2]) == HIGH && digitalRead(gesture[3]) == HIGH) {
  //arm moves up
  continous.write(75);
  //75 is a slow speed going in one direction. 0 being the fastest.
  doubleTrouble = true;
  Serial.println("double trouble");
}
else if (digitalRead(gesture[2]) == HIGH && servo == false) {
  // pin 6 closes claw
  digitalWrite(pin, HIGH);
  mini.write(85);
  //moves the mini servo to 78 degrees.
  doubleTrouble = false;
  Serial.println("just middle");
  servo = true;
  delay(200);
  digitalWrite(pin, LOW);
}
else if (digitalRead(gesture[3]) == HIGH) {
  // pin 8 arm move down
  continous.write(105);
```

```
    //105 is a slow speed going in the opposite direction of continuous.write(75). 180
being the
    Serial.println("just ring finger");
    doubleTrouble = false;
  }
  if (digitalRead(gesture[2]) == LOW && servo == true) {
    digitalWrite(pin, HIGH);
    servo = false;
    mini.write(43);
    Serial.println("Staph");
    //move the mini servo to 43 degrees.
    if (doubleTrouble == true) {
      //because without this, if gesture[6] ==
HIGH and gesture[5] == also HIGH,then the
arm would not be able to move up.
      continous.write(90);
      //90 means not moving
    }
    delay(100);
    digitalWrite(pin, LOW);
  }
  if (digitalRead(gesture[3]) == LOW) {
    // pin 9
    Serial.println("Staph! Hammer time!");
    continous.write(90);
  }
  if (analogRead(A0) > 1050) {
    // reading input from the fire sensor.
    digitalWrite(speaker, HIGH);
```



```
}
else {
  digitalWrite(speaker, LOW);
}}
```

PRODUCT TESTING

Table 1: maximum liftable object weight and the continuous servo's different speeds with a 5v power supply

The purpose of this bar chart is to find the maximum weight of objects the arm is able to lift. Due to the different speeds of the continuous servo, the maximum weight of each are different, therefore tests are required to find the optimal speed. The numbers to represent the different speeds are the code used in the Arduino for controlling the motor's actual speed, therefore it has no units.

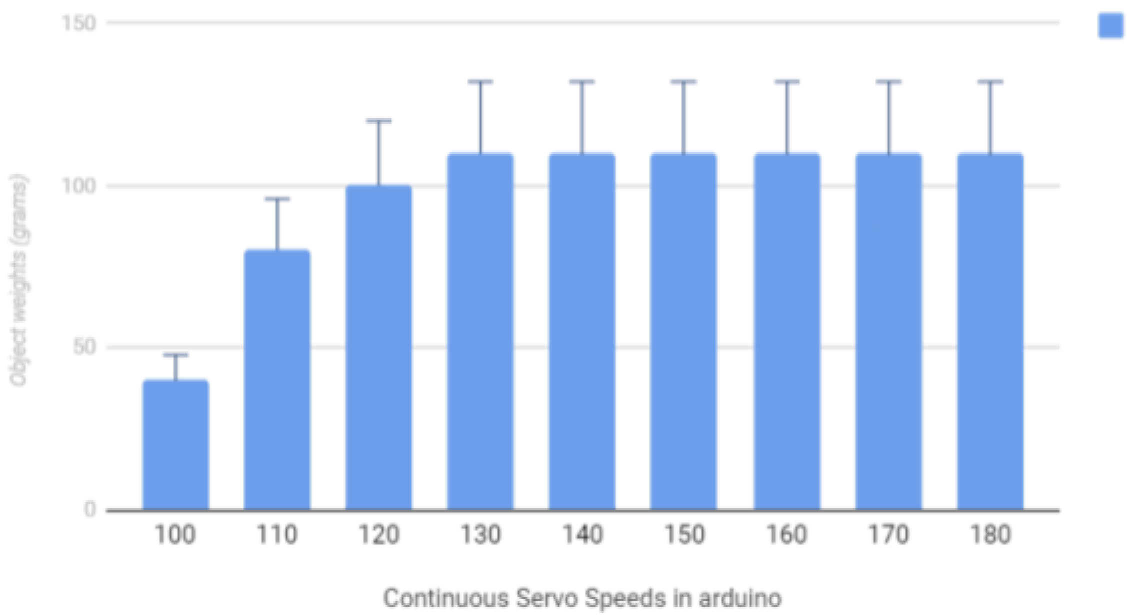
		Weights (g)								
Speeds		40	50	60	70	80	90	100	110	120
0	180	✓	✓	✓	✓	✓	✓	✓	✓	
10	170	✓	✓	✓	✓	✓	✓	✓	✓	
20	160	✓	✓	✓	✓	✓	✓	✓	✓	
30	150	✓	✓	✓	✓	✓	✓	✓	✓	
40	140	✓	✓	✓	✓	✓	✓	✓	✓	
50	130	✓	✓	✓	✓	✓	✓	✓	✓	
60	120	✓	✓	✓	✓	✓	✓	✓		
70	110	✓	✓	✓	✓	✓				
80	100	✓								

Constants:

- Weight size
- Weight position on the arm: gripped by the claws
- 5V power supply from Arduino

Observations: the thin acrylic side of the arm was bending (on the side the continuous motor is attached to) as weight approached 100g.

Figure 12: Maximum liftable object weight and the continuous servo's different speeds with a 5v power supply



It is able to lift daily objects such as: a roll of wires, excel mint can, eraser, clips.

Table 2: different wheel speeds on hardwood floor with 3v power supply

	Time took to cover 2m in seconds on hardwood floor			
Wheel type	Trial 1 (seconds)	Trial 2 (seconds)	Trial 3 (seconds)	Average (seconds)
Thin wheels	10.60	11.79	12.31	11.57
Wide wheels	15.16	17.78	17.85	16.93

Constants:

- 3V from 2 double A batteries in series

Observations:

- Wide wheels: goes much slower than the thinner wheels. The glue gun strips added to the back wheels (for better traction) makes the wheels wobble as it travels, thus sacrificing speed.
- Thin wheels: goes much faster than the wide wheels, and no wobbles were present.

Table 3: time it to took to turn 360°on different surfaces with 4.5v power supply

			Time (seconds) took to turn 180°			
Wheel type	Wheel actions	Surface	Trial 1	Trial 2	Trial 3	Average
Wide wheels	Both back wheels traveling at the same speed in opposite directions	Carpet	19.01	16.93	15.5	17.15
		Hardwood floor	5.45	7.57	8.19	7.07
	One wheel traveling forward while the other is idle	Carpet	Not enough torque			
		Hardwood floor	7.76	8.06	7.33	7.72
Thin wheels	Too much traction between the wheels and the floor for it to successfully turn.					

Constants:

- 4.5V from 3 double A batteries in series

Observations:

- Wide wheels: just like moving in a straight line, there was wobbling in the wheels. The glue gun strips added for grip causes it to shake up and down a little as it turns.
- Thin wheels: due to the great friction between the floor and wheels, it was not able to turn at all. Perhaps more power for more torque would allow it to turn.

PRODUCT ANALYSIS

Analysis on table 1 - max weight for each continuous servo's speed lifting the against gravity with a 5v power supply:

The faster the servo, the easier it is to lift heavy objects. The extra energy applied to increase its speed also adds to additional torque. But the weight maxes out at 110g. This is partially caused by the structural design of the arm. The servo motor is mounted to one acrylic side pane of the arm, the two sides connecting by two rods under the servo. But due to the one sided attachment, the acrylic sides bend, redirecting the servo's forces to balance the arm rather than to lift it. Therefore, as soon as the weight reach 110g, no matter the speed, the servo would not be able to lift the arm fully.

This can be solved by attaching a rod to both acrylic sides of the arm where the servo currently rests, and then by using a chain or equivalent, the servo drives the rod from a different position. This would allow the applied forces to be spread even, therefore eliminating any bending.

Analysis on table 2 - time it to took to turn 360°on different surfaces with 4.5v power supply:

The thinner wheels are significantly faster than the wider wheels. The thinner wheels were able to travel at an average speed of 17 cm per second, while the wider wheels traveled 12 cm per second. This is caused by several factors. The wheel attachments on the wider wheels are less precise than the thinner wheels, causing it rotate slightly off axis, wobbling as it drives by. This wobbling causes its proceeding direction to be anywhere but straight ahead. Other wheels have to be pointing in the exact opposite direction to cancel the forces out in order to move forward. As a result this leaves only a fraction of its original force to push it forward, therefore resulting in a slow motion. The thin wheels do not have this problem, therefore they were able to maximize their torque. The wider wheels also had glue gun strips added to the back wheels for better traction because the hard plastic had a low coefficient of friction while glue gun glue had a higher coefficient of friction. However, the upraised strips acted as speed bumps, slowing down its general movement. The thinner wheels had soft rubber for material, so without the glue gun strips, they were able to travel smoothly.

Analysis on table 3 - time it to took to turn 360°on different surfaces with 4.5v power supply

Gathering from the data collected, having only one wheel to move while the others sit idle does not provide enough torque to turn on the carpet. However, when friction is largely eliminated, having one wheel move vs having two turned out to be quite similar in speed. All in all, having both back wheels move in opposite directions appears to be better than one wheel because of its advantage on carpet. Aside from the analysis on the numerical results, the qualitative observations on the wide wheels point to flaws in the wheels themselves. The glue gun strips added to the back wheels for a better grip hinders its rotational movement. The thinner wheels, while having an advantage going forward due to the traction, could not turn. The force of friction experienced between the soft rubber and the floor was higher than the force of the torque. Increasing the power supply, therefore the torque, would likely solve this problem (provided the wheels' structural integrity is able to hold).

DISCUSSION

The final design is vastly different from the original. Some of the prototypes is shown in the Prototype section of this written report. However, not only did the physical design change, the schematics did drastically as well. Some circuits like the input circuit (figure 9) was added due to unexpected factors.

The final schematics drafts had an unexpectedly large number of transistors because the Arduino's digital pins appear to not have enough volt or current to power the mechanisms. The transistors are used as amplifiers or switches in the H-bridge for the wheel motor.

Attaching the wheels to the motor without a coupler is difficult and unreliable. The wheels would attach not quite perpendicular to the motor, causing it to wobble. This wobble reduced its speed, increases friction, and burns battery.

The wheels move slowly due to the low gear ratio that results in an RMP of 157. In future design, if were to be sped up without losing torque, all four wheels would need a motor to be attached.

Additionally, error wise, most were caused by connections, such as when two wires touch causing short circuiting, or when two wires of the same colour are mistaken for each other. In an ideal situation, there should be colours for every wire to be colour coded. Another error is the precision of the manufactured parts. Due to the equipment available, the parts were cut to be within 20 thou of the designed size. This small difference can cause the attachments to be crooked. A crooked attachment especially at places like the wheel can cause errors such as traveling off axis. To prevent this from happening, the more important a part, the more precise it has to be cut, so the better the equipment.

Last but not least, the Arduino did not have enough power to support everything that is on the breadboard (continuous servo, 2 DC motors, receiver circuit, and the mini servo), and adding another power source like double A batteries does not work because it is not connected to the Arduino's internal circuit, therefore the Arduino's digital INPUT pins would not be able to read it as high when there is power. The main sink for the power is the mini servo. Taking that away, everything else worked. This problem caused the schematics and code to change slightly (schematic change not reflected on the schematics in DESIGN because it is too small). To solve this, another transistor is added to the power source for the mini servo, so when no new commands are being sent to it, it is disconnected from power, allowing everything else to function. When a new command is received, the code turns the power on for the mini servo just long enough to realize the command, then shuts it off again.

RESULTS & CONCLUSION

The final design of C.O.D.I.A. is able to communicate through a gesture wireless control, and a maneuverable body complete with a functional arm. Through functionality tests, it can be seen that the arm is able to lift a maximum of 110g, and the technical specifications show that the RF modules can communicate up to 500 meters, obstructed only by metal. However, there are still many areas, especially structurally wise, that can be improved.

In conclusion, C.O.D.I.A. satisfies the innovation goals. From its current functions, it is able to assist in the basic needs, such as fetching a dropped item on the ground. The cost to make this was $55 for the motors and $20 for the rest; cost efficient when in relation to existing technologies serving similar functions. The efficient cost of this design makes it possible for the average household to afford a robotic assistant, and a step towards human-robot integration in daily life. In the future, as more functions are added to C.O.D.I.A., it will become adapted for more tasks.

APPLICATION

C.O.D.I.A. serves as an assistant to those in need. People that have issues with moving around can adopt this system, and C.O.D.I.A. may aid them in their everyday tasks. As over 11% of Canadian adults, meaning over 3 million individuals, experience one of the three most common disabilities: pain, mobility or flexibility (“Disability in Canada”, 2015), having an artificial assistant when no one else is around can greatly improve their lives.

The wristband’s flexible design eliminates the complications of having a clumsy glove or large solid components commonly seen around this type of technology. It allows the user to keep the dexterity, and fine motor controls of their fingers, and be able to accomplish other tasks all the while wearing this device. This is also a touch-less NUI (Natural user interface), in other words, the user can send commands to C.O.D.I.A. no matter what they are doing and where they are. Additionally, the wristband, unlike other controllers such as a remote that can be easily misplaced, would not be lost as quickly. Furthermore, due to the its communication method that is through radio frequency, it allows for control over a vast distance (of up to 500 meters) and in isolated locations where controlling through wifi would not be applicable. The nature of a RF based control system also removes the need for cameras that are essential to the other popular touchless user interface which is vision tracking, therefore eliminating the issues of the interaction area that is limited by places the camera(s) can see.

Moreover, one of the major factors that are preventing a robotic assistant from entering an average household is cost. C.O.D.I.A.’s user interface design is significantly more cost efficient then other designs that serves a similar purpose. The approximate cost for the wristband and rings is: $1.25 for RF transmitter; $2 for HT12E; $1 for coin cell battery holder; $2 for 3v battery; $2.5 for wires; $1 for PCB. Total: $9.75. Whereas, existing products would cost between $700 - $800. The rest of the current model for

C.O.D.I.A. (arm, claw, and everything attached) costs: $1.25 for RF receiver; $2 for HT12D; $3 for the acrylic; $6 for nails, washers, and nuts; $35 for a mini and a continuous servo; $2.5 for wires, transistors, and resistors; $5 for the fire sensor. Total: $54.75. The overall total being $64.5. This price would be expected to drop if C.O.D.I.A. is made in large quantities.

The efficient cost of this design makes it possible for the average household to afford a robotic assistant, and so a step towards human-robot integration in daily life. In the future, as more functions are added to C.O.D.I.A., it will become adapted for more tasks.

FUTURE DIRECTIONS

- Structural upgrades: better wheels to increase its speed and battery usage; four wheel drive; make everything out of aluminium rather than wood and acrylic which are both very vulnerable to damage; get couplers for the wheel axles; weld or bolt all connections, no glue gun.
- Changes to the position of the continuous servo can be applied as well to eliminate the bending factor when lifting heavy weights.
- A stronger servo with more torque could be applied to the arm and the claw so it can lift and grip heavier objects like a coffee mug.
- Connecting C.O.D.I.A. to an AI can be implemented, making it more intelligent towards commands that are not limited to manual hand-gestures, but through automated verbal commands as well.
- C.O.D.I.A. can be made round to reduce damage to both its surroundings and itself when it bumps into something. Omni wheels can be implemented to improve its ability to quickly maneuver around.
- Ultrasonic distance sensors can be added on the sides so it avoids obstacles.
- The ability to get C.O.D.I.A. to move towards a signal can be very useful if the user has trouble moving around. This can be done through tracking the radio frequency the gesture controller transmits. C.O.D.I.A. would have a directional receiver mechanism or two listening for the broadcast to determine the direction. The directional receiver can made out of a simple RF receiver by isolating it from all directions by a metal casing except for the direction it is to listen towards (as radio signal cannot pass through solid metal). This will determine the direction of the signal. Once the direction is found, the distance between the user and C.O.D.I.A. can be found be measuring the strength of the transmission.
- It can have a connection to the internet through ESP8266 and an FTDI. This way, information from C.O.D.I.A. can be transmitted over the internet, thus accessible

on phones as well. This will also require another encoder/decoder IC pair because ESP8266 sends out serial data.

- A temperature sensor can be added for the ability to detect the ambient temperature .
- Heart rate monitor on the wristband may be a great addition especially for people aged 60 and up, or those vulnerable to heart attacks. With this, the additional function to perform phone calls should be added as well to alert 911 in emergency situations. This can be done through a GSM Arduino shield.
- Charging station through induction.

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