The parts sourced here are in reference to the MORPHOLOGICAL CHART and the various sensors, actuators, and ‘brains’ required for the project. Note that since no specific solution has been selected yet (need exactly this research into feasibility of various parts) each of the researched parts of the design below are solution agnostic and are intended to provide insight into what is *possible*, rather than exactly what will be done.

# Board

## 1.1 System Brain

* Arduino
  + Website: arduino.cc
  + Specific Possibilities
    - Nano
      * Smallest Arduino board
      * No DC power jack, only pin
      * Mini-B cable required to program
    - Nano Every
      * Same as nano, more powerful processor
      * More program memory than Nano, Uno, etc.
      * Micro-USB cable required to program
      * Cheapest option
    - Uno Rev 3
      * Most used in family
      * Well documented
      * USB-B cable required to program
    - Leonardo
      * Like Uno
      * Built-in USB communication – no need for secondary processor
      * Virtual (CDC) serial/COM port
    - Mega 2560 Rev 3
      * 54 digital pins, 16 analog ins, 4 serial ports
      * Higher $
    - Due
      * 54 digital pins, 12 analog in, 2 DAC, 2 CAN
      * “For powerful larger scale Arduino projects”
      * First Arduino based on 32-bit ARM core microcontroller
      * 3.3V only
      * Higher $
      * Faster clock
    - Micro
      * Micro-USB cable required to program
      * Is to the Leonardo as the Nano is to the Uno
    - Etc. - those listed so far should encompass any/all needs for the system, but if something different is required of the ‘brain’ of the system there’s more available on the website and/or look for shields
  + Comparison of popular Arduino boards: <https://maker.pro/arduino/tutorial/a-comparison-of-popular-arduino-boards>
    - Uno
      * Pin header arrangement rapidly becoming industry standard
      * Power jack + Vin
      * 5V & 3.3V
      * Relatively small dimensions
    - Nano
      * Uno shrunk to small profile – weight and space reduction
      * Cannot connect to shields
      * Useful for breadboard prototyping or PCBs
      * Cheap
    - Due
      * ARM core
      * Powerful
      * 3.3V, else irreparable damage
      * No on-board EEPROM
      * Expensive
      * Pin-compatible with standard Arduino shields
      * Software compatibility not guaranteed
      * Large
    - Mega
      * Software compatibility not guaranteed
      * Large
      * 5V
    - In general:
      * Excellent support to all boards
      * Common architecture, language, IDE – few device-specific traps
      * Easily transfer code to diff boards
      * Deciding factor for each project: hardware and cost
      * Nano smallest, Uno medium, Mega and Due large
      * Due best processing power
      * Due and Mega have plenty of GPIO
      * Due has best analog comatibility: 12 analog in and 2 analog out
  + Features/Complications
    - Simple/rapid implementation
    - Simple/rapid programming
    - Very limited memory
    - Open Source
    - More complex tasks are difficult to accomplish
    - Due alone is 32 bit, all others 8 bit
* Raspberry Pi
  + Specific Possibilities - mostly range from RPi1 thru RPi4, A and B models. Comparison: <https://socialcompare.com/en/comparison/raspberrypi-models-comparison>
    - Pico
      * Cheap (4USD)
      * Weaker core
      * Micro-USB, 2xSPI, 26 GPIO pins, 2xUART serial
      * No wireless connectivity on-board
      * Small
      * Not a full computer
      * Similar to Arduino Nano
    - Zero
      * Smallest and cheapest true RPi (5USD)
      * Still a full computer
      * More wired options than Pico
      * No wireless connectivity on-board
      * Lowest current draw RPi
      * Least capable Pi besides Pico
    - Zero W
      * Cheap (10USD)
      * Relatively low current draw
      * RPi Zero with WiFi and Bluetooth
    - Zero WH
      * Cheap (15 USD)
      * RPi Zero W with header already soldered
    - Others
      * Higher generation number is more powerful
      * Higher generation number is more expensive, for the most part
      * Model A usually smaller, less RAM than Model B
  + Features/Complications
    - Supports complex software – can host an operating system
    - Various ports to interact with – a general solution
    - Implies more difficult software implementation
    - Basically, a full computer on a small board
    - Variety of ports available
* Direct Implementation of a microcontroller
  + Specific Possibilities
    - ATMEL
    - STM
    - Microchip
  + Features/Complications
    - Much harder to implement – flash, finicky details, etc.
    - Higher flexibility – many different microcontrollers available (hence, none specifically researched; depends on the application itself)

## 1.2 Circuit Implementation

The circuits for the microcontroller to interface with sensors and actuators

* Printed Circuit Board
  + Specific Possibilities
    - <https://www.pcbway.com/>
      * Very cheap – as low as 5$/board? (CAD? USD?)
      * Chinese – not supporting Canadian business, long lead time
    - <https://www.pcbgogo.com/>
      * Very cheap – as low as 5$/board? (CAD? USD?)
      * Chinese – not supporting Canadian business, long lead time
    - <https://oshpark.com/#services>
      * Manufactured in USA
      * 3 copies for 5$/square inch (likely USD) ships in 9-12 days
      * 3 copies for 10$/square inch (likely USD) ships in 4-5 business days
      * Volume discount if buying in bulk
    - MyRO PCB <http://www.myropcb.com/online-quote/pcb-production-quote/>
      * Canadian (Ottawa)
      * Standard PCB order: 20$ (likely CAD?), 5PCBs, 2 layer, 4x4 inch, 6 day lead time
    - Bittele
      * I think my company used them for a board that I designed on a work term
    - Various other Chinese manufacturers (e.g. jlcpcb) – there are also North American options; selection will probably depend on timeline (shipping) and cost preference
  + Features/Complications
    - Need supplier
    - Not DIY and therefore less accessible to the consumer
    - Contained, guaranteed working circuit (if design is good)
* Breadboard
  + Various sizes available
  + Features/Complications
    - Extremely flexible
    - Extremely accessible to the layperson
    - Chance user could damage electrical components by making bad circuits
    - Ambiguous power rating
    - Parasitic capacitances, inductances
    - Widely available
* Perf board
  + Various sizes available
  + Like breadboard, but requires soldering – better anchoring
  + Features/Complications
    - Flexible
    - Accessible to anyone who can use a soldering iron
    - Chance user could damage electrical components by making bad circuits

# Sensors

## 2.1 Light

* Laser
  + Eye safety concerns
  + Good at distance
  + Lightweight
  + Single point measurement
* Interrupted Beam
  + Simple premise
  + Boolean logic
  + Must align – any bump out of position is no bueno
* Image Recognition
  + All logic in software
  + Less dependent on sensor itself as treatment of data
  + Need better controller to manage – may be pricier
* Photoresistor
  + Very cheap
  + Analog
  + Medium sensitivity
* Photodiode
  + Very cheap
  + Fast
  + Less sensitive than phototransistor
* Phototransistor
  + Cheap
  + Slower than photodiode
  + Very sensitive

## 2.2 Magnetic

* Hall Effect
  + Lower measuring accuracy than fluxgate magnetometers or magnetoresistance-based sensors
  + Drift, need compensation
  + Does not suffer mechanical switch problems, if used as a switch
  + For magnetic-field-strength measurement – can measure wide range of fields, sign and amplitude

## 2.3 Electrical

* Conductivity
* Capacitive
  + Detect or measure anything that is conductive or has a dielectric different from air
    - Mutual capacitance: object alters coupling of electrodes
    - Self-capacitance: object loads the sensor or increases parasitic capacitance
* Inductive
  + Current induced when magnetic field changes (or vice versa)

## 2.4 Sonic

* Ultrasonic & accelerometer
  + Distance to object
  + Cost varies with quality

## 2.5 Interface

* Lights and buttons
  + Very cheap
  + Easy electrical implementation
  + Simple commands
  + Low-level
* Touchscreen
  + Varied qualities/costs available
  + Customisable display
  + Combined input/output
* LCD & buttons
  + Cheap
  + Customisable display
  + Electronics and software simple, low-level
* IOT+App/Website
  + Integrated solution
* Voice Commands/Speaker
  + Accessibility
  + Much software work required
  + Sonic I/O electronically simple
  + Can be cheap or expensive depending on I/O quality required (out usually simpler than in)
* Gesture Control
  + Accessibility
  + Much software work required

# Actuators

## 3.1 Motors

Need to know more about physical dimensions, required power, etc. Point is, there are a variety of motors out there for any actuating need, but they depend on other design aspects

I don’t feel comfortable discussing various primarily-mechanical actuators at this time