 TITLE Project Overview **PROJECT** Robotic Arm

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Short and Quiz of it: build a robotic arm with the parts that would be cheap and affordable. Arm should be able to do many things like 3D printing, folding clothes, and others.

Process of building: knowleye of robotic arms is limited so first I will be familiarizing myself with the basics of robotic arms and how the different systems work.

- then I am going to go model the arm in Solidworks and manufacture it
- then learn how to program it with the parts I choose while modeling it.

Project Constraints:

1. arm must be able to lift a significant amount of weight.
2. it must be easily reparable / moddable
3. arm must be persise in its movements.
4. ~~3.~~ arm must be affordable
5. arm must be able to work quickly, this means that the code as well as the actuall motors will not create time problems and lagging while instructions complete.
6. tool attachment changes need to be ~~not~~ standard and happen automaticaly.
7. needs to all be open source and well documented.
8. arm needs to be able to work continuosly without repeated failures.
9. While arm can be built out of non standard parts it needs to be able to fit standard parts.

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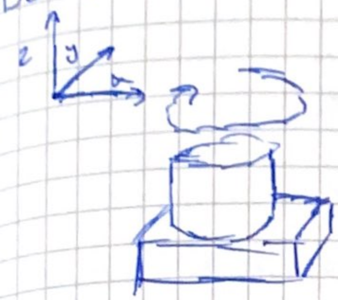
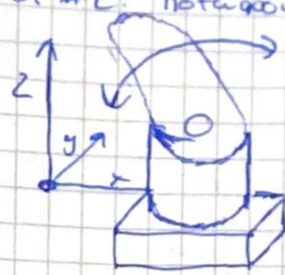
Basic Designs:

Degrees of freedom: robotic arm needs at least 5 DOF and at most 7 DOF

DoF #1: Rotation around the base / z axis / roll

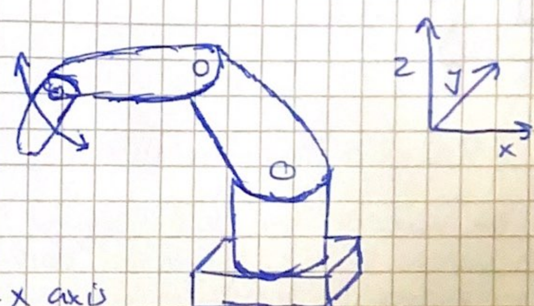


DoF #2: Rotaround the y axis/pitch

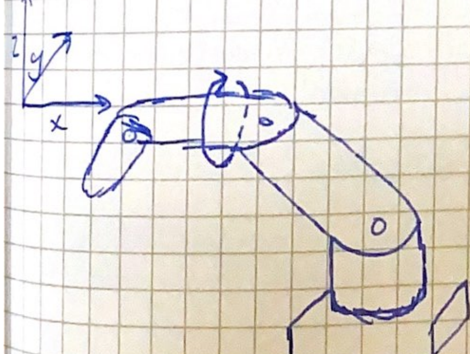


DoF#3: Rotation around y axis, pitch

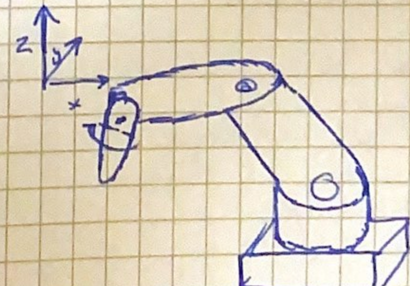
DoF# 4: Rotation around y axis/pitch



DoF#5: Rotation around x axis



DoF#6: Rotation around x axis



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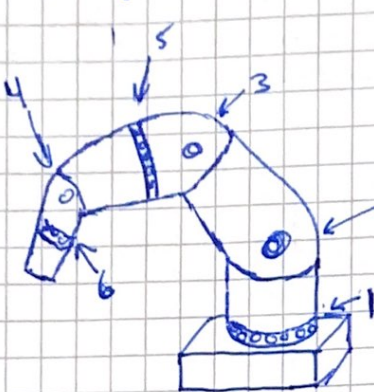
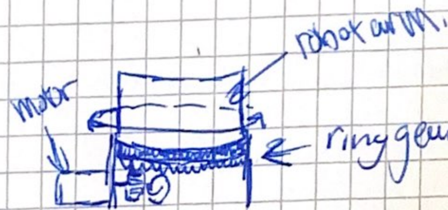
DoF Final Design: because 6 DoF results in all possible movement of the arm then 6 DoF should be the minimum. 7 DoF only adds possible points of ~~failure~~ failure and as such should be avoided. max number DoF will be 6 DoF.

Joint Layout of Design:

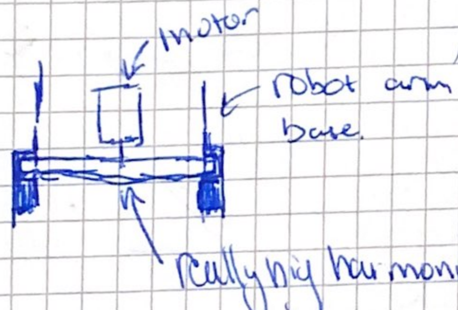


Joint 1: Provides Rotation around the base actuator/motor can be located in the base to make the robot lighter

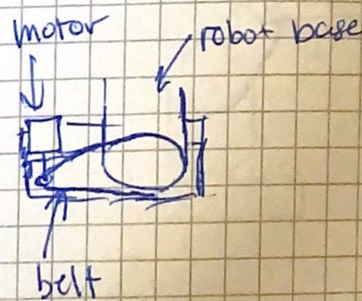
Can be driven in a variety of diff ways.



Notes: design is fun There is nothing hard or bad about the design.



Notes: Not backdrivable so that's good. Provides alot of torque. Might be hard to manufacture. To many places printer can messup.



Notes: Introduces alot of feedback into the system. Robot arm will not be as solid. Might skip teeth. Easy to build.

~~Desicion~~ Decision:

going to use the ring gear design
- It's easy to build
- easy to get high torque
- no chance of slipage or breakage
- easy to repair.

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THE Weight Problem: If heavy components get to far from the base of the Arm then the effectiveness of the arm decreases.

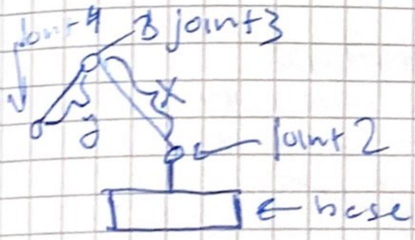
Because of the weight problem there are some factors that need considering. The main one being "how do you make sure that you are able to keep weight above robot base while also effectively transfering power to ~~motors~~ joints from motors".

IDEAS!

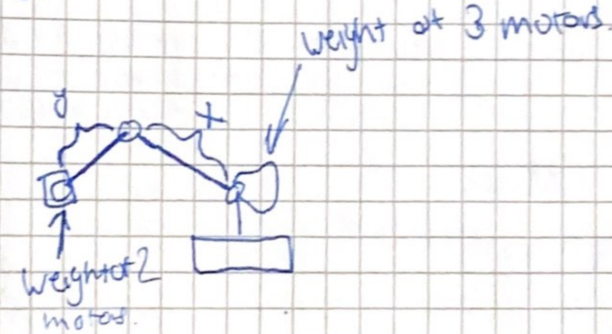
1. Turn Joint 2 into a multi motor joint. This means that many motors will be placed on joint 2 and power transfered to other joints through some sort of drive train.

2. turn Joint 3 into a multi motor joint. Same as above

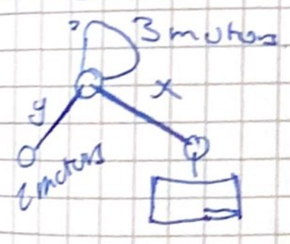
Evaluating Both Ideas.

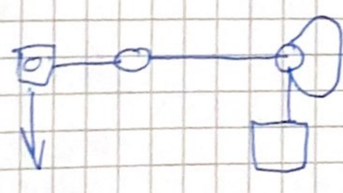


Joint 2 situation.



Joint 3 situation!





$\text{Torque} = 30Mx + 20M(x+y)$

So far Torque on Joint 2 is looking much better.

$\text{Torque} = (2M)g(\cancel{x}+y)$

$\text{Torque} = 20M(x+y)$

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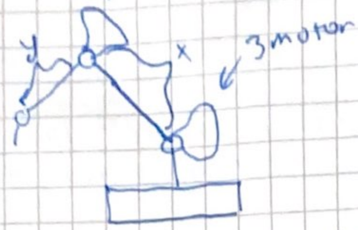
Option 3: possible combination of both options 1 and option 2.
Drawbacks of option 3: Requires alot of complicated gear trains and also introduces more problems with coding because must account for other parts moving and that effect on the gear train.



Note: All torque calculations assume that the rest of the robot ~~weight~~ is weight less. This can be done because it will be mostly the same on all motor placements.

Torque: $(2M)g(x)$

Torque: $20M(x)$

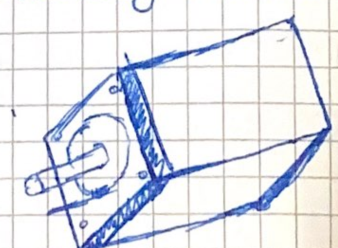
Final Choice: Option 3: makes the robot more complicated however it also makes it as effective and as "powerfull" as it can be. However development will take much longer.

Materials of Construction:

Constraints: needs to be affordable.
needs to be easaly attanable
needs to be easily machinable.

Motors:

Stepper	motor & encoder	servo
• persise	persise	precise
• great holding torque	• high efficiency	• limited range of motion.
• easy to controll	• expensive	Jitter.
• limited high speed torque	• low noise	high torque.
	• can opperate fast.	



Winner STEPPER MOTOR

• reasoning: Stepper motors are affordable, provide great holding torque and are easily controllable. Some may have problems with them skipping steps. This can be solved by getting a stepper with an encoder on it. This however is beyond the budget.

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Drivetrains: Outside the scope of base Design.

Controller: ~~need~~
Requirements: 1. needs to be affordable
2. needs to be opensource
3. needs to have a wide range of interest / prior
~~4.~~ development.
4. needs to be easy to obtain
5. needs to have many breakout boards / shields
6. easily programable.
7. needs to have long term support.

Research Possible Controllers:

Arduino Mega / Mega 2560: Pros: great community, lots of out put pins. Has 5 volt operation voltage / logic. Has extensive documentation. Has many pre made hats and shields included ~~in the class~~. cost is only around $25 for a knock off version. Plenty of inputs / out puts. Both analog and digital.
Cons: very low processing power. it's only an 8-bit board so that means the code needs to be able to handel alot of pre processing and basically just offload instructions to the arduino.

Beagle Bone Black: Pros: very high power, has half a gigabyte of ram. Has plenty of out puts, around $52 dollars. Has extensive documentation however the community is quite small. Uses 3.3 volt logic.
Cons: very few outside boards / sheilds are compatable with this board. Means alot of the hard ware will have to be made by ~~hast~~ hand which is un apealing for a long and easily availible robot arm.

State of the Market. As of this time there is very little competition to something like the arduino mega 2560. The comunity around the product is massive and becase of all the knock offs there is supprisingly little competition.

Winner Arduino Mega 2560.

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7 TITLE Basic Design.

PROJECT ~~Robotic~~ Robot Arm.

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Frame Materials: made from mostly 3D printed parts and or solid pieces of wood board and sheet metal, metal bars / extrusions.

Metal: Aluminum.
3D printed plastic: PLA+ or possibly PetG

Power Supply: generic 12 volt power supply any should work.

Custom PCB's are a goal of this project however they are later in the project life time when more is going to work.

Code: Our use of code is defined by the constraints of the microcontroller

Main Drives: ROS, C++, Python.

ROS: Ros or Robot Operating system will be used for Robot simulations as well as possibly operating the robot.

C++: is the code that the arduino Mega 2560 uses and because of that the C++ code is needed to opperate the motors and do possible gcode parsing

Python: its the language that ROS uses and as such will be used.

Wireless or not?
Maybe, to early to tell. If it can be added it will otherwise a usb A cable will be needed to communicate from a computer to the arduino

All code will be open source and will attempt to be as clean as possible. Code should follow the Unix phylosophy. Small modular componets that are able to interface with one another. and it needs to be completely open source.

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Problem: Stepper motors, do not have the torque required to be able to drive / actuate the robotic arm.

Solution: Make a gearbox capable of fitting onto the end of a commercial stepper motor. more specifically the Nema17 spec stepper motors.

Notes on Gears / Gear Principles:

Pitch Diameter: the imaginary circle where 2 gear teeth mesh.

Outside Diameter: diameter around the outer edge of a gear's teeth

Root: Bottom part of a gear wheel

Pitch: measure of tooth spacing along a gear

Diametral Pitch: is the number of teeth per inch of pitch diameter and is also an index of tooth size

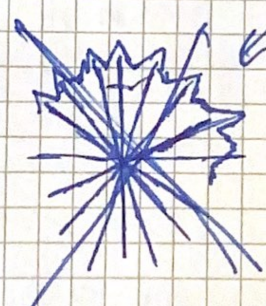
$$D_p = \frac{\text{number of teeth}}{\text{Pitch diameter}}$$

GEARS WILL ONLY MESH IF DP IS EQUAL

Module: metric equivalent of diameter pitch

$$M = \frac{\text{Pitch diameter}}{\text{number of teeth}}$$

For this project we will only use the module to make our gears.



bad gear drawing.

Center Distance: the distance between the centers of 2 gear shafts. Standard is

$\frac{1}{2} \sum P.D$

Pitch Point: Where gears make contact.

Goal for our gear box make a gear box that is able to effectively transfer torque to the arm mechanism.

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 TITLE ~~Mechanical Design: Gearbox~~ Basic Design Robot Arm specs. PROJECT Robot Arm.

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~~Constraints. one of the constraints is the nema 17 stepper motor.~~

~~Gearbox~~ can not be wider than a nema 17 motor

Revision: gear box can be bigger, should design gearbox to be optimal and make sure it works then change dimensions.

Robot Arm Desired Specs:

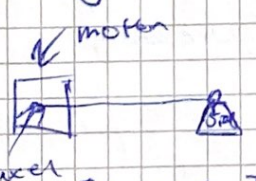
1. 24 inches of reach.: when arm is fully extended horizontally
2. able to lift at least 5 pounds at the full extent of its reach.
3. able to have "workspace attachments.

Workspace: an arm that allows the robot to do different tasks such as draw or 3D printing

Some Rough math to get things working.

Nema 17 motors have a holding ~~force~~ torque of 3.17 $\frac{kg}{cm}$

meaning at 1 cm from motor axel it can exert the force of 3.17 Kg-cm or 0.3108 ~~N~~-m



5 lb = 2.268 Kg

Force at end = 2.268kg · 10 $\frac{m}{s^2}$ = 22.68N

Torque = 22.68N · .6096 m = 13.825 ~~N-m~~ Nm

Provided Torque 0.3108 Nm

gear reduction = 44.5 minimum

gear reduction with 33% overhead = 60

gear reduction at 60.

Should make one gearbox that can be used at all points in the design.

Splitring planetary testing will progress from here.

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Split Ring Planetary Concepts

Planetary Restrictions: $z_r = z_s + 2 \cdot z_p$

z_r = number of teeth in a ~~plan~~ ring
z_s = number of teeth in sun
z_p = number of teeth in planet

This formula is needed to make sure that the planetary gears mesh

Figuring out gear ratios of planetary

Formula $(z_r + z_s) \cdot T_c = z_r \cdot T_r + T_s \cdot z_s$ z = same as above

Gear Ratio of Split Ring Planetary:

T_c = Carrier turns
T_r = turns of the ring
T_s = Turns of sun.

gear ratio is equal to turns of planet around central axis - amount of turns of output gear of output gear.

Formula: long haha. For all intents and purposes this is fairly impossible to calculate by hand. The repeated computations would take forever to accomplish.

Method of choosing gear Ratios: ~~Identifying~~

1. identify what is possible to be 3D printed.
2. guess and check values in a calculator. ~~S~~
3. Simulate in Solid Works
~~3.~~4. 3D print final prototype.

Number of Teeth on the stepper motor gear

Minimum: 14

Number of planets

Minimum: 3 The more the better.

Attempt #1: Using ~~Stor~~ Sawgstad.net/gear-animation/index.html

gear ratio: ~~160:1~~ 117:1 5 planets.

input gear: 20 input teeth 39 output teeth 40 base

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 TITLE Mechanical Design: Gearbox PROJECT Robot Arm

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Gearbox was modelled in solidworks using dxf files.

Model 1 testing:

Material PLA+ : printed fairly well, 20% infill with small adjustment the default of ultra quality.

Post Processing: none

Printer : Creality CR-10s stock: small modification to cooling solution

Notes and Observations about Gears: Gears mesh okay, need to be sanded down more for post processing to make sure that they are going to mesh cleanely. PLA+ shows signs of warping. It is not back drivable at all but is able to withstand lots of loads.

Model #2 testing

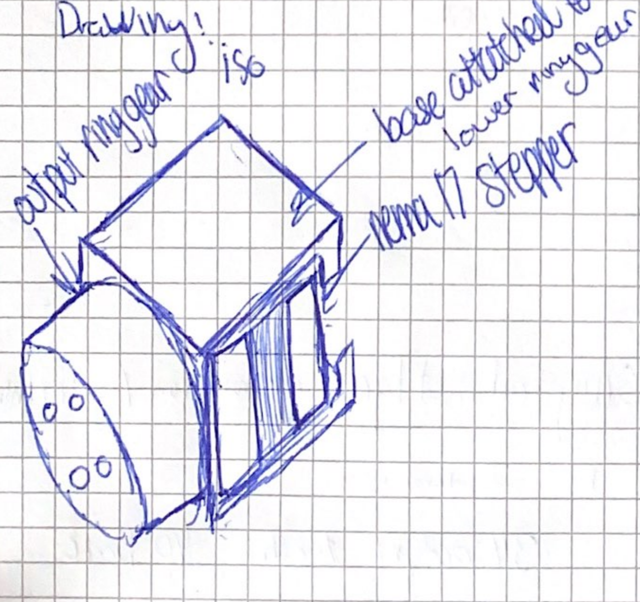
Changes: enclosure around the nema 17 stepper, modified output gear to include a couple of wholes to see the rotation more clearly.

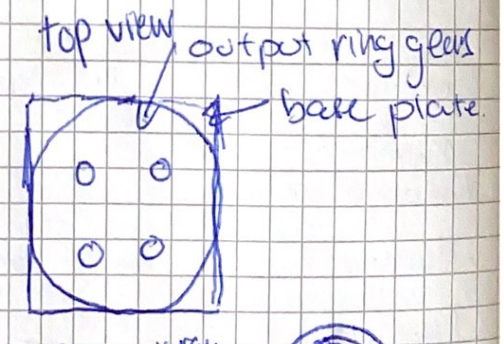
Material: PLA+ settings were same as those above.

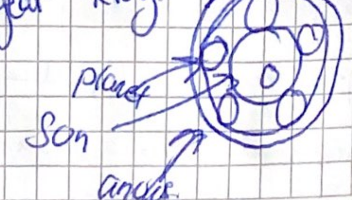
Post Processing: None

Printer: Creality CR-10s: same printer as above.

Drawing:







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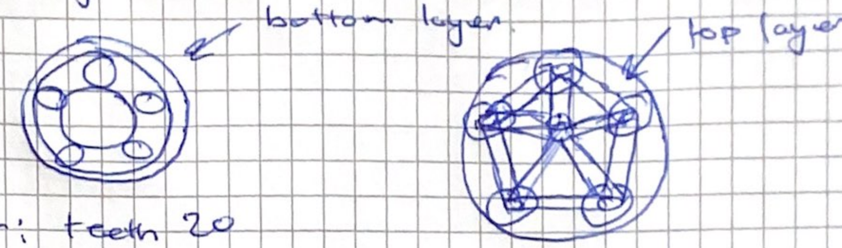
Gearbox:



Sun gear: teeth 20

Planet gears: teeth 10
ring gear: teeth 40
planet Carrier: N/A

Sun gear: N/a
Planet Gear: teeth 10
ring gear: teeth 41
planet Carrier: included.

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