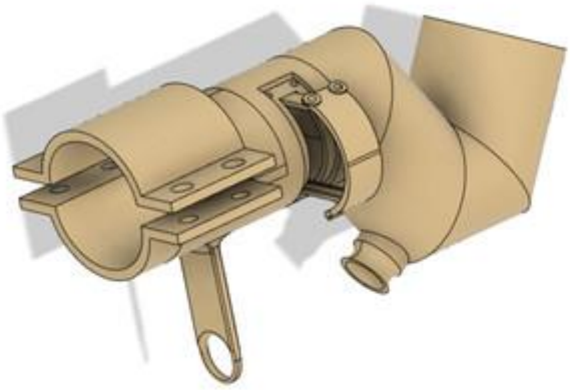
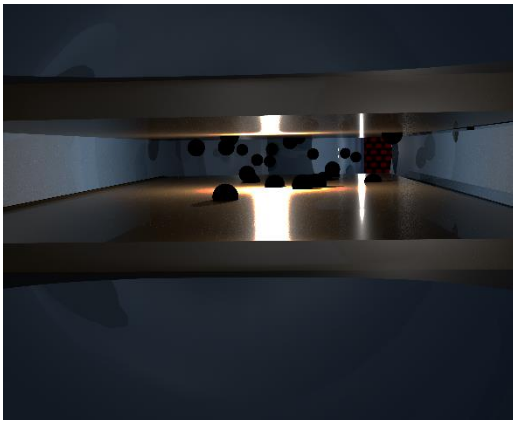
Vayu Singhal – Maker’s Portfolio

Air Filter

Removes particulate matter from the exhaust fumes of highly pollutive auto-rickshaws, highly prevalent in many developing countries.



This is my original design for an air filter to remove particulate matter from the exhaust fumes of highly-pollutive auto-rickshaws.
The main challenge I faced was figuring out how to make sure that the smaller particulates did get caught by the filters. The physical filter clearly wouldn't stop them, so I added some copper plates, which would be charged using a solar panel, and would then electrostatically attract the particulates that the filter couldn't remove. I was still to figure out how to get the copper plates inside the filter itself, however.



Inside of filter from animation - https://www.youtube.com/watch?v=ZZkBWydqKRA

Keeping the same basic principles, but reworking the first iteration, which was rather clunky, I came up with this. I had also found a solution to getting the copper plates in: there would be two slits in one side of the filter, and little notches on the other side (on the inside of the filter), which would ensure that the plates don't get moved out of their position.
I also animated this model to demonstrate how the filtration system works.

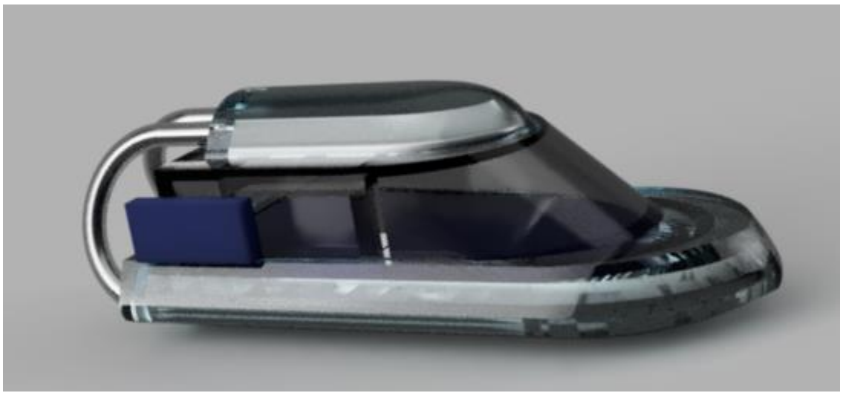
One issue still remained: the safety aspect of it. If the filter got blocked, it could cause the exhaust fumes to flow back into the vehicle, which could cause the vehicle to stall.
To minimise the risk, I moved the physical filter to after the copper plates, so that only the larger particles (which would be harder for the plates to catch) would hit the filter, meaning it would last longer before needing to be replaced.
I also added a couple of extra holes into the design near the start, which were positioned so that only exhaust fumes that were flowing backwards have a path out of the filter. This meant that if the inside did get blocked up, the vehicle would remain safe until the filter was swapped out.

This is a comparison of 3D-printed models of the first and most recent designs of the air filter. It has become significantly less clunky, as well as becoming more effective and safer.

I learnt about the particulate emissions from auto-rickshaws through several research papers I found online. A professional in air filtration systems brought up the issue of the back-flow of the exhaust fumes. The use of copper plates to filter the air was based on the idea of a chimney precipitator, which I learnt about in school.

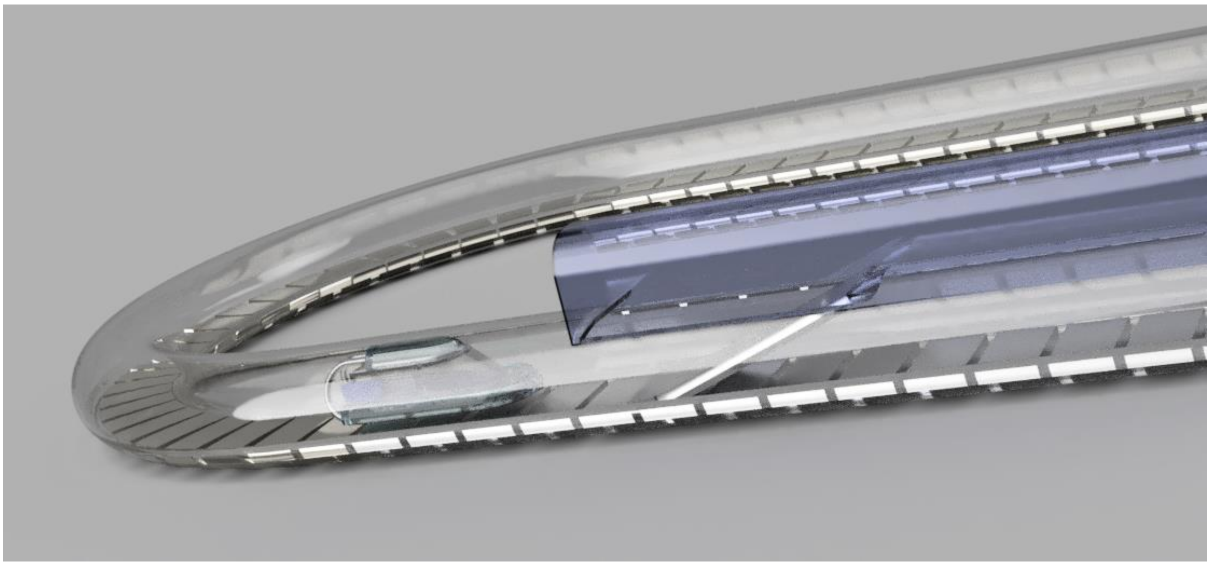
Concept Hyperloop

Uses properties of superconductors and highly insulating materials to find ways to travel more smoothly and efficiently



This design was done out of interest in high temperature superconductors and the Meissner Effect, allowing them to float above magnets, which I had been researching for a while. The idea was fairly simple: I wanted to make a better mode of transport. Most of my research was about YBCO, which becomes a superconductor when below a (relatively high) critical temperature of 90K. Of course, achieving this temperature over a prolonged period of time would be a challenge.

My solution was another material I had learnt about at an earlier date - aerogel. It was a lightweight, highly effective insulator that would be put around the YBCO (bottom of the vehicle), the liquid nitrogen store (top of vehicle), and the pipes connecting them (back of vehicle).



The track of the hyperloop would have to be paved with magnets, of course, for the YBCO to levitate above it, but the most exciting part of this form of maglev is the ability of the vehicle to stay on course, due to the effect of the induced current in the superconductor, and the interaction of the resulting magnetic field with that of the magnets on the track. This would allow sharper turns to be made, as well as facilitating travel up ramps, for example, as shown in the picture.

Another feature of the track would be that it is in a vacuum. This would both increase the efficiency of the mode of transport, and also further resist any change in temperature of the YBCO. There could be specific stations (like the blue part of the image) which are isolated from the rest of the loop, where the pressure can be varied to allow passengers to enter and exit the vehicle.

Though conceptual, this design proved to be an exciting, educating experience.

First Robot (Helper Robot)

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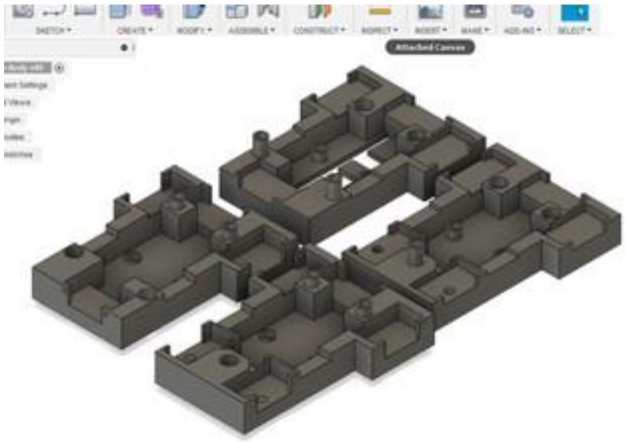
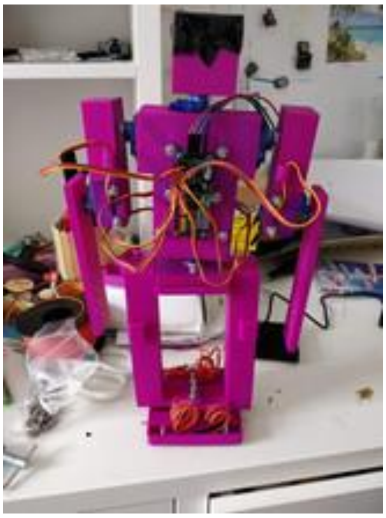
This was a project that I chose specifically to explore the use of components and design that I hadn’t previously, to diversify my engineering abilities.



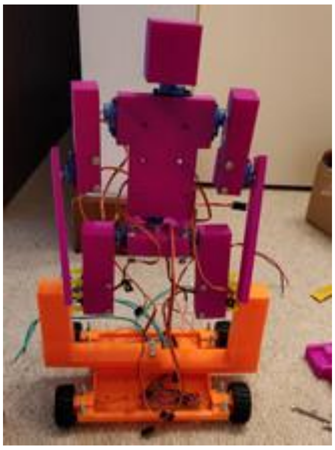
Largely because I hadn't worked much with servos, I decided I wanted to make a helper robot, and I wanted it to be vaguely humanoid. I started by designing two versions of the main body, each of which had a front and back part that would enclose the Arduino nano I would be using to control it. The main aspect of the body was deciding where I wanted the robot to have a way of moving, and which parts I wanted it to have. I was undecided about whether to give the robot the ability to rotate around its waist, or how much control I wanted its legs to be. For that reason, there were two versions of the otherwise similar designs, which I could decide on later.



I decided to go with the design of the robot that could rotate about its waist, and after designing the rest of the body parts, I 3D printed them and got building. Using a servo driver that had space for up to 16 servos, and I was using the smallest servos that were readily available to me - SG90 servos. The idea was to initially build the robot with limited control, and only 6 servos, and I would then add more controls. Initially I had thought about making the robot bipedal, and had ideas about stabilizing it as it walked, like letting it turn its head, which was weighted on the front, allowing me to shift the centre of mass. But again, I decided this could wait, and simply made a single-body base I would attach wheels and motors to.

Before I could give it a proper test run, I needed a way for it to carry the servo driver and the 9V batteries I was using. The only available space for this was the back of the main body of the robot. I went through multiple iterations, until I finally settled on the design in the bottom-right of the image - it was fairly neat, and had space for two batteries, two switches, and the servo driver in the middle of it. As I tested the robot out with the extra weight, it became apparent that the base I had designed was too small, and the robot was falling over. I had to fix that next.

The base ended up taking a total of four design attempts to get right, as I tried to minimise its size and complexity. The two designs at the top of the image were too small, and the robot fell over if I tried using them. The one in the bottom-right seemed promising, until I discovered that there wasn't enough space for the motor mounts to be put inside it. I ended up with the bottom-right design, which worked as I'd hoped.
One thing I only recently noticed was that I had also unwittingly created space in the base where I could put in batteries, which would further help with the stability of the robot. that is definitely the next thing I will be changing about the robot.



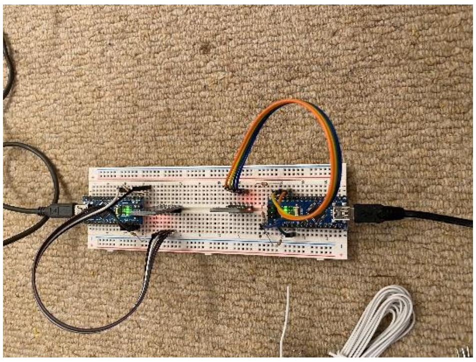
I got to a stage where the robot was functional when commands were given to it directly, and I had added servos to the legs to allow the robot to bend down, but there remain a couple of issues.

Though I had initially hoped to make the robot controlled by an external, wireless device, neither the Bluetooth nor the radio modules that I tried seemed to work. I intend on swapping that out for autonomy, likely using ultrasonic distance sensors and obstacle detectors to make the robot decide how it moves.

The other big issue was with the servos. As the gears inside it were plastic, they struggled against the weight of the robot (which still had the batteries on its back), and the servo connections would bend out of place. The simplest solution would be to buy metal-geared servos, but the price is roughly 5x that of the SG90s.

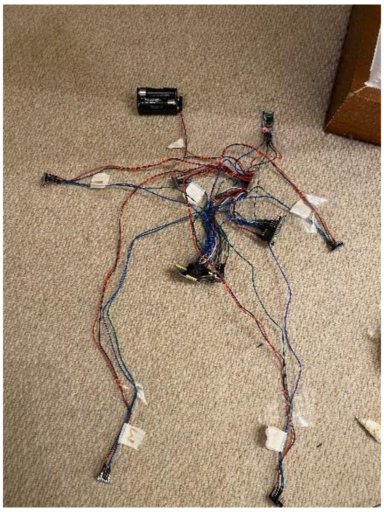
Second Robot (User-Mirroring Robot)

This was a project that I took on to develop from the skills I'd picked up from my earlier projects, learning from mistakes, and incorporating wireless communication.

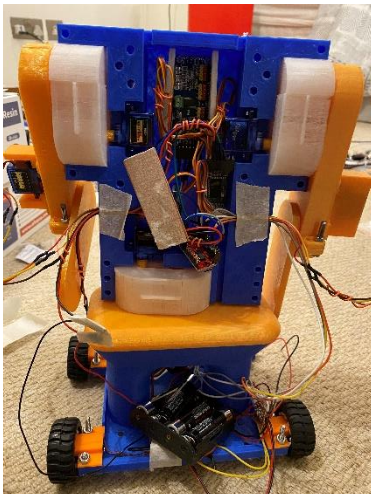


I was messing around with Bluetooth modules, and I managed to get them communicating. I decided to make a robot that built on the last one, taking into account the problems with the last one. I also decided I wanted to step it up a notch, and I decided that I wanted the robot to be controlled by the user's body, which it would mirror. The idea was based loosely on the film "Real Steel" and the robots in it. Of course, this kind of technology could have several applications, allowing people to control robots accurately in dangerous environments, especially if linked to virtual reality.

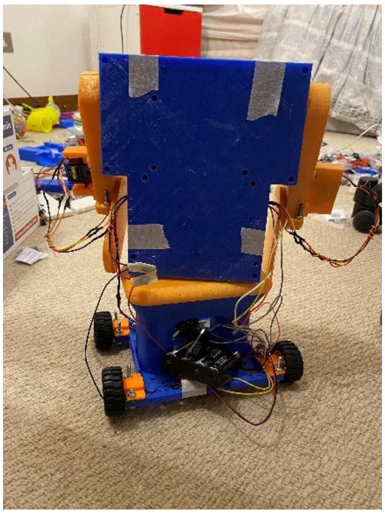
From the previous robot, the main challenge to address was the stress on the servos – both having to support the weight of the parts attached to the servo and withstand forces that weren't perpendicular to the axis of rotation. The solution I came up with was a gearbox that would be held in place by the body, with little extrusions in the sides so that it couldn't slide straight out of its socket. I kept the gearing ratio at 1:1, because I was happy with the speed and power of the servos, and they worked perfectly. There was initially a bit more friction than I'd hoped, but the more they were used, the smoother the movements became.



The next thing to figure out was how to switch between the IMUs to get each of their readings to the Arduino. I used an Arduino Nano, for its size, but it only has one i^2c bus, and the addresses of the IMUs can't be changed. I ended up using two analog multiplexers (for the SDA and SCL lines) to switch between the IMUs. It was really fiddly to get working because of the number of connections, (if any came loose, it would stop the entire system working). Through the multiplexers, some of the IMUs occasionally started off giving extremely high readings (order of magnitude thousands of degrees per second). Though I initially tried to fix this by resoldering all the connections, and then by adding a delay at the start of the code before any readings were taken, these solutions proved ineffective. I ended up just defaulting to a pre-determined value if a threshold was exceeded, which solved the issue because the anomalous readings didn't persist for long after the device was powered on.



The remainder of the electronics and design were fairly similar to the latter iterations first robot, though on a larger scale, to allow the 16-channel servo driver to be put inside the main body. I also used a dual-extruder 3D-printer to print parts with rigid and flexible parts, which allowed me to make holders for the components that were much simpler to use than having to use a huge number of nuts and bolts to attach the parts. With the first robot, the batteries had been problematic both in their weight and in their ability to power all of the components. This time around, I used three battery packs to power the main robot: one each for the servos and DC motors (which both drew a lot of power), and one for the rest of the circuit. I also moved the battery packs to the base of the robots, which hugely improved its stability when moving, which ended up making the extra weight of the batteries advantageous.



Though challenging, this build ended up being successful and educating. It was exciting in its development of an old project, learning from my past mistakes to end up with a cool new build. I used experience I'd gained using gyroscopes in my prosthetic module (later in this portfolio), and servos from the last robot, while simultaneously exploring the application of multiplexers and wireless communication, with which I'd had very little experience prior to this project.

Vayu Singhal – Maker's Portfolio

Electric Guitars

This was sparked by a curiosity in the inner-workings of an instrument that I use every day. I learnt a lot about how the musical instrument works, developing my practical abilities – especially in design and electronics.

These are the first two electric guitars that I built. They were my first engineering project, and I made them out of interest about how guitars work, as well as a way to get a guitar I really liked. The one on the right was simply a "parts-guitar", but was worth the build to learn about how guitars work. I mainly followed information from StewMac and YouTube tutorials about wiring standard guitars.

After making my first guitar, I was far from satisfied - I wanted a deeper understanding of how guitars work, and I decided to make my own guitar pickups, which convert the movement of the guitar strings into electrical signals; essentially, they're miniature generators.. Each pickup was hand wound, with about eight thousand turns of copper wire per pickup. It was a painstaking process, but it did contribute to my knowledge about

guitars, and meant I would become more confident to pursue my own, unique designs. I made them using an old method, involving dipping them in wax (as shown in the image) to insulate the wire between turns.
The pickups ended up sounding remarkably clean, and were far better than the pickups I had used in my first guitar.

Wiring the guitar was my first time dealing with analogue signals. I learnt about high-pass filters that are used to adjust the tone of the guitar, and I also modified the wiring to add in a kill-switch, which is useful for specific acoustic effects.

With my new understanding of guitars and their parts, I decided to design a completely new type of guitar. It would have 12 custom-designed, miniature pickups using two different types of magnet (Alnico and Neodymium), and switches to turn each one on or off at will. I also put in space for more selector switches, which could direct the sound signals towards high- and low-pass filters.
Unfortunately, the cost of getting such a guitar body cut was far beyond my budget, which has delayed the project. For now, I've found a suitably cheap guitar body that will work for some aspects of this guitar, but not every detail. For that, I will likely cut a body by hand

myself, using special drill-bits and chisels.
I am also considering adding an op-amp to use as a comparator, which I will use to distort the signals to get different sounds out of the guitar, but I will decide on this in the future.

For the new guitar design, I also designed my own pickups, twelve of which I have to wind. Previously, I had used a hand-powered coil-winder, but because of the inconsistency of turning speed (due to human control), the thin copper wire kept on snapping. So I quickly put together my own, motor-powered coil winder to overcome this challenge.
The winder had a holder for the spool of copper wire to sit on and freely rotate. I also put a raised bar between the copper and the clamp that would hold the part that was being wound. This bar ensured that the wire stays taut, and has adjustable guides on it, to make sure the wire stays targeted in the right direction.
I 3D-printed the parts I had designed, and, using an N20 motor, a potentiometer, and a switch, I soon had a coil-winder whose speed I could vary as desired. I would also use this winder for other projects, including a motor, a generator that fits on a household tap, and a speaker.

The other challenge I faced when winding pickups was that the wire could get snagged on the edges of the pickup bobbins. For that reason, I incorporated into my new pickup designs a smooth casing, that would direct the copper wire back to the right area should it stray. I used a DLP 3D-printer, so they were really as smooth as possible, and the casing was easy to remove. I was finally able to make the pickups, which will be put into the new guitar as soon as the guitar body is done being painted.

Vayu Singhal – Maker's Portfolio

Prosthetic Module

This was mostly a community service project – I wanted to make lives easier and, having learnt the importance of proprioception through my own struggles with using limbs when I was injured, I knew what I would focus on.

A long-term injury to my arm exposed me to problems I always knew existed on some level, but I had never really understood to an appropriate degree, mostly involving difficulties with limbs and control. My grandfather works closely with a charity in India that offers prosthetic limbs and jobs to individuals in need, and I saw this as an opportunity to have a significant impact on people's lives. A TED talk by David Eagleman discusses the idea of effectively adding senses to the human body, as the mind is capable of quickly learning to interpret and make sense of signals, and I decided to base a device on that. It collects information about the position of a prosthetic limb and haptically relays it to the user. The first feature to design, of course, was the component that would carry the vibration motors. I settled on a design that attaches to the limb at the top, and has space for two vibration motors. With four of these around the prosthetic, a wide range of signals can be delivered.

The next thing to consider was how I was planning on attaching the other components of the product. It had to be removable and adjustable, in case it didn't suit the wearer. I settled on a design that involves two parts which clamp together around the prosthesis using nuts and bolts. It took a few attempts to get the sizes of the parts right, but I ended up with a strong mechanism that worked.
To attach the Arduino Nano and IMU to these rings, I ended up using a dual-extruder 3D printer, and printing part of the component using flexible PLA, which allow the Arduino and IMU to be slotted in and out with ease, and (crucially) held them still while attached.

I used the same idea for the batteries and the IR obstacle detector as I did for the Arduino and IMU. The obstacle detector's angle of operation was 30 degrees, so its holder (on the right) had to be put at an angle. The IR LED also triggered the sensor if they were left as they came, and so I added in a barrier between the two.

This was the finished product. I had coded the Arduino to monitor its orientation by averaging several readings of its angular velocity from the IMU. The vibration motors would be turned on when the angle fell outside a predefined threshold (though I may add a potentiometer that can be used to adjust these thresholds). It would also have a specific pattern of vibration when the prosthesis is close to hitting the ground, so the user can be more aware of its positioning. Of course, there will always be some inaccuracies, which is why I added a bit of code that monitors the angle at the same point in the user's walk cycle (which can be figured out using the obstacle detector) and records the change in angle. This data is stored in the Arduino's EEPROM, and the system learns from it, increasing its accuracy as it's used.
This device will be sent to the charity in India once the pandemic's severity there has decreased, but for now, it must wait.