Your unique nine-digit application reference number can be found on the "Getting Started" page of your MIT Application at apply.mitadmissions.org/apply. Your reference number is also listed at the top of your applicant status page that appears after you submit your MIT Application.

405657172

Maker Portfolio

* indicates a required field

After you complete this general form, you'll be instructed to complete at least one detailed project writeup. Use the uploader tool later in the portfolio to share more media about your work.

1. What category should your primary reviewer should be an expert in?

This helps us match your portfolio to the reviewer best equipped to take a first look at it. If multiple categories apply, select the one that feels most relevant.

DO NOT select “Other” unless NONE of the existing categories apply. We will make sure that cross-disciplinary portfolios get seen by the right people.

Mechatronics

2. [Optional] Does your portfolio need review from an expert in a second category?

This helps us match your portfolio to additional reviewers if it contains significant cross-disciplinary work that cannot be reviewed by experts in your primary category.

DO NOT select “Other” unless NONE of the existing categories apply.

Electronics

3. What search keywords would you use to describe the contents of your portfolio?

This is used to help us match your portfolio to specific reviewers. Please provide a few comma-separated tags describing the project(s) you are submitting.

Helpful tag examples: foam cosplay armor, stuffed animals, algae biofuel, 3d printed electronics enclosures, geospatial data analysis, linear regression classifier
Unhelpful tag examples: sustainability (too vague, doesn’t tell us what you made), the name of a programming language or chip you used (too niche, doesn’t actually tell us what you made), creative, art, app, AI/ML, 3d print

robotic hands, robotic manipulators, quadrupeds

4. Portfolio summary

We are trying to learn how ***you*** understand the things you make, whether they are specific solutions to important problems, open-ended explorations of long-held curiosities, or just how you pass the time.

My projects have always reflected my changing interests and curiosities, whether it be RC cars, racing drones, or Bluetooth speakers. I've always loved to build robots for fun, even bringing them to school to show my teachers and peers.

It wasn't until high school, however, when I started learning Arduino, marking a massive shift in the way I interpret my creations. If I could autonomously control my projects, then I could have them perform tasks to assist people. Thus, I started implementing inverse/forward kinematics and motion planning into my projects, introducing the element of control. As I step into college and beyond, I aim to design prosthetic devices with improved dexterity and assistive software that help users adjust to a new lifestyle while also being more affordable. While I still make projects for fun, I now realize the positive impact I can bring within my community.

5. Maker context

Help us understand the environment you make in. What communities are you a part of? What spaces do you make in? Who has inspired, mentored, or supported your work? What resources do you use?

My grandfather has had a large influence in inspiring me to pursue the projects I make. In fourth grade, he showed me how to wire a model car. I watched the car race across the floor, wondering how the circuit allowed the car to move. Inspired, I took to YouTube to learn about electric circuits and DIY projects. Through these videos, I was motivated to take on ambitious (and sometimes wacky) projects, such as my RC mannequin head on wheels.

I create in my garage, on a workbench that I have been expanding since sixth grade. One drawer stores Arduino parts: jumpers, servos, breadboards; another contains tools, wood, and glue. The best part of my workbench, however, is the shelf above–displaying all my inventions since elementary school, each holding its own memories. It offers me a chance to reflect on my progress, and appreciate all the support I've received in my love for creation.

6. Motivations and interests

Why do you make the things you make? Who do you make for?

Robotics is meaningful because it is the combination of everything I love into one discipline, including mechanical systems, circuits, hardware, and programming. Creating robots serves as a creative outlet for me to challenge myself. From drawing a plan on paper to 3D designing, assembling, and programming, each step of the design process presents its own challenges that require me to think of unique solutions.

Whether it be short circuiting a $50 receiver module, or wasting 10 hours 3D printing a faulty part, I have had my fair share of frustrations. With each setback, an opportunity for growth and improvement presents itself. Through these experiences, I've grown to love the process of creation.

7. What have you made that holds the most personal meaning for you, and why?

You might also tell us about what challenges you encountered while making this, and how you went about solving these issues.

In my seventh-grade science class, I was assigned to create a human hand model with a paper cutout and strings. When I pulled the strings, the fingers contracted; when I released them, the fingers relaxed. Applying my experience from past projects, I revised the design by connecting the strings to DC motors. With a transmitter and receiver, I could contract and relax each finger.
This project was the catalyst that sparked my enthusiasm for humanoids and prosthetics. Since then, I have created two more prosthetic hand designs, improving on the flaws of the previous.
Throughout my prototypes, I have noticed a major issue–limited dexterity. It is hard to replicate the various intricacies of the human hand with just motors and strings, and I've encountered numerous challenges with designing the functionality of fingers. I aspire to tackle these issues in my professional career.

8. [Optional] Personal website or Github, if applicable

We do not guarantee that we will go through all supplementary material, but it may be helpful to us. Just like the work you include in the Maker Portfolio, it should be clear that all linked material is your own work. (Note: there is no bonus for having a personal website.)

It is easiest for us if your web identity matches your application. However, we understand that you may have many reasons not to attach your full legal name to your web presence. If so, consider a creative workaround, like an unlisted page that will allow us to somehow verify that your website belongs to you.

https://devpost.com/software/plutohelps

Project 1 - Maker Portfolio

* indicates a required field

At least one detailed project writeup is required for the maker portfolio. The project writeup helps us better understand the context around what you make—your build process, constraints, highlights, learnings, and more.

If you have a series of similar projects all made in similar contexts (for example, some craft you have practiced many times), you may combine them into one project writeup. Use the media uploader tool later in the portfolio to share more media about your work.

1. Project title

Quadruped Spider Project

2. Checklist: Is this project okay to submit to the Maker Portfolio?

All items must be true in order for a project to be appropriate for the Maker Portfolio.

This is an engineering or crafting project that I made.|This is NOT a musical composition, screenplay, performance, or video reel.|This is NOT a traditional visual art or architecture portfolio. (Artistic projects are welcome as long as you are submitting a writeup about your engineering/crafting build process.)|This is NOT poetry, essays, or creative writing.|I am NOT submitting a patent, patent application, or other legal document.|I am NOT submitting a business proposal, project idea, pitch slide deck, or advertisement.|This is NOT a project I made by following a tutorial or class assignment.|I understand that generated work (like material generated by machine learning) is not appropriate for the maker portfolio.

3. Representative picture/video of your project

Attach a photo or short video clip of your project that gives a clear sense of what you made. You will have the chance to upload more media attachments later in the portfolio. (Note that only 2 minutes of total video is permitted per portfolio, including what you upload in the media section.)

spiderCoverImage.jpg

4. Project summary

What is it? If it's not obvious, what does it do and how does it work?

Be clear about what work is completed versus still in progress. It is fine to submit works in progress, but we can only review the work you have completed so far.

This is a 4-legged spider robot that will use inverse/forward kinematics to walk. Inspired by the spider baby character from Toy Story, I wanted to challenge myself by taking on a larger scale project. Due to 3D printer issues, I only have three legs complete so far.

I assigned a 3D coordinate system to each leg, but soon realized that I had no way of actually knowing the location of each joint. This is essential, as it allows me to track each leg and create an algorithm for a crawling motion. To fix this, I plan on deriving and programming forward-kinematic equations using a homogeneous transformation matrix.

Ultimately, the goal for this project is to create a spider that can autonomously walk with 4 legs across a smooth surface, using cameras and ultrasonic sensors to navigate its environment.

5. Project highlight

Explain your favorite thing about this project and why.

By far, this has been the biggest and most challenging project that I've taken on, and I've enjoyed seeing it slowly come to life over the past few months. My favorite thing about this project is how it combines everything I have learned about robotics into one project, including 3D design, circuitry, programming, and more. The failures and setbacks throughout the process have taught me to appreciate the small progressions. Many things did not go as planned: failed prints, incorrect formulas/code causing the spider to flail out of control, and redoing the PCB board. These challenges, however, have been essential to the learning process, allowing me to grow from my mistakes. Seeing the spider finally stand after so many attempts felt so rewarding.

6. Contributions and credit

What was your personal role in this project? If you made changes to an existing project, explain what you started with and what you changed. Name any collaborators/mentors and summarize their roles. Tell us if any of your collaborators are also possibly submitting an MIT Maker Portfolio this year.

Cite any work that was not done by you or your direct collaborators. For example: tutorials/guides/resources, existing patterns (for sewing, crochet, woodworking, etc.), existing models (for 3d printing, games, ML, etc), existing nonstandard hardware (off the shelf parts, kit parts), existing firmware. If you relied on platforms or engines such as game-making engines or pattern generators, describe what they do.

I have been creating this project by myself, without the help of any outside collaborators. I wanted to put the Fusion 360 skills I learned from my school's engineering class to the test, so I designed each 3D printed part on my own. Additionally, I derived the trigonometric formulas needed to move the legs by myself.

7. Background context

Tell us any goals that might help us better understand your project. “Having fun” and “learning” are valid goals.

Context: Who is it for? How is it used? Don't assume these answers are obvious. If you have made a tool or product to address some problem, what else already exists to solve the same problem?

Describe constraints like budget, space, available tooling, etc. If your project was submitted to an annual competition with a complex ruleset (like FIRST Robotics or VEX Robotics), summarize the most important constraints.

My main goal with this project is to have fun while also strengthening my robotics skills through a passion project. Before programming cameras and sensors, I will start with a controller that can remotely operate the spider in order to get a better sense of how it moves and interacts with its environment, using a 12 channel receiver with my FS-I6X controller.

However, I’d also be lying if I said I didn’t want to scare my family with the spider. It would be hilarious to see their reactions to a four-legged spider with a mannequin head walking into their room, or to watch my dogs try to attack it.
The biggest constraint on this project has been my 3D printer, as it frequently breaks. I have spent hours unclogging the nozzle and leveling the print bed, just for a part to fail mid-print.

8. [Optional] Supplementary links, if relevant

For coding projects: we will only review coding projects if you provide your codebase so we can verify that it was not plagiarized. A version controlled host such as Github is preferable. If this is not possible, you may upload within SlideRoom. We will not accept Google Doc links.

If applicable, link us to any team websites, competition rules, or places where your project operates online.
Do not expect us to read all supplementary content. Only include links that may be necessary for our technical understanding of the project. We are NOT interested in advertisements, business proposals, or third-party media coverage about your project.

9. Build process

Tell us more about your build. What was your approach, and why did you decide to do it that way? If there was a design/testing process, what did you do? Consider attaching photos in the subsequent media uploader page to demonstrate your build process.

You can assume your reviewer has general expertise in your Maker Portfolio category, but please explain things that might not be obvious if we have not done the exact kind of project you are submitting.

The bulk of this project involved designing parts in Fusion and 3D printing them. It took numerous attempts to create the legs, requiring a perfect fit for the motor and screw tappings. Additionally, the tibia joint that touches the ground was too short, so I had to reprint each tibia part. In total, I spent about 150-170 hours printing parts, many of which either failed mid-print or didn't have the right measurements.
I also soldered a custom PCB board that holds an Arduino Nano, a power input, and 12 sets of pins for the servo motors. I decided to sketch the PCB layout in MS Paint as a guide, and carefully soldered all components.
Next, I derived inverse kinematic equations to move the legs, graphing a top & side view of one leg on paper. With some basic trig, I calculated equations for each joint angle. To know locations of each joint, I must also implement forward kinematics.

10. Reflection and learnings

What changed along the way? Did the result fulfill your intended goals? What turned out well? What mistakes did you make? If things broke, why? Are there things you would like to do differently next time? What did you learn?

One mistake I made early on was printing entire parts without ensuring that they had the right screw/motor fit. This would waste a lot of time, as I would have to redesign and reprint the entire part with the correct fit. To address this, I made test prints with different screw tappings and bearing sizes to ensure I had the right sizes before printing the entire part. I learned that taking time to properly design and test a part not only saves time but also improves the quality of the project.

Making a guide for the PCB board also proved to be effective, as I could visualize the entire circuit and save myself hours of tediously rewiring incorrect connections. However, I still made errors when soldering the power rails, almost short circuiting the Arduino. In the future, I aim to learn how to design PCBs using computer applications, allowing for a more polished and efficient circuit.

[Optional] Project 2 - Maker Portfolio

* indicates a required field

While only one project writeup is required, you may share a second project in detail here.

If you have a series of similar projects all made in similar contexts (for example, some craft you have practiced many times), you may combine them into one project writeup. Use the media uploader tool later in the portfolio to share more media about your work.

1. Do you have a second project you would like to feature?

Yes

1.1. Project title

Your ASL Translator

1.2. Checklist: Is this project okay to submit to the Maker Portfolio?

All items must be true in order for a project to be appropriate for the Maker Portfolio.

This is an engineering or crafting project that I made.|This is NOT a musical composition, screenplay, performance, or video reel.|This is NOT a traditional visual art or architecture portfolio. (Artistic projects are welcome as long as you are submitting a writeup about your engineering/crafting build process.)|This is NOT poetry, essays, or creative writing.|I am NOT submitting a patent, patent application, or other legal document.|I am NOT submitting a business proposal, project idea, pitch slide deck, or advertisement.|This is NOT a project I made by following a tutorial or class assignment.|I understand that generated work (like material generated by machine learning) is not appropriate for the maker portfolio.

1.3. Representative picture/video of your project

Attach a photo or short video clip of your project that gives a clear sense of what you made. You will have the chance to upload more media attachments later in the portfolio. (Note that only 2 minutes of total video is permitted per portfolio, including what you upload in the media section.)

handCover.jpg

1.4. Project summary

What is it? If it's not obvious, what does it do and how does it work?

Be clear about what work is completed versus still in progress. It is fine to submit works in progress, but we can only review the work you have completed so far.

For my district’s Congressional App Challenge, in which we won 3rd place, I wanted to apply the programming and robotics skills I have developed throughout the years to a project with community impact. Teamed with a friend, we created “Your ASL Translator”: the personal text-to-ASL translating assistant.
“Your ASL Translator” is a robotic hand that translates text to ASL signs. An Arduino controls six servos with pulleys that are attached to strings; each string is then threaded into the fingers. The servos pull the string forward or backward as they rotate, which causes the fingers to contract or relax. For the hand to communicate in ASL, the user must first input a word or letter into the terminal. Our Arduino software then decodes the word or letter and translates it into servo motor angles. Lastly, the Arduino sends a signal that writes each angle to their respective servo motor.

1.5. Project highlight

Explain your favorite thing about this project and why.

My favorite part of this project was creating the algorithm that converts text to ASL signs. I initially attempted to map letters to their corresponding angles using Arduino's HashMap library, but quickly discovered that HashMaps are quite intensive on the Arduino CPU. Instead, I used parallel arrays that functioned similarly to HashMaps.
With the basic structure in place, I needed to find a way to identify the location of letters in the parallel arrays. I first used a sequential search algorithm, but realized that as we expand our database in the future, we would need a faster search algorithm. So, I landed on a recursive binary search algorithm to locate letters faster.
Creating this algorithm challenged me, requiring me to apply my problem-solving and critical thinking skills to find unique ways to find the most optimal solution.

1.6. Contributions and credit

What was your personal role in this project? If you made changes to an existing project, explain what you started with and what you changed. Name any collaborators/mentors and summarize their roles. Tell us if any of your collaborators are also possibly submitting an MIT Maker Portfolio this year.

Cite any work that was not done by you or your direct collaborators. For example: tutorials/guides/resources, existing patterns (for sewing, crochet, woodworking, etc.), existing models (for 3d printing, games, ML, etc), existing nonstandard hardware (off the shelf parts, kit parts), existing firmware. If you relied on platforms or engines such as game-making engines or pattern generators, describe what they do.

To construct the hand, we used the open-source 3D hand model "InMoov", created by Gael Langevin. My teammate, who will be submitting a Maker Portfolio next year, was responsible for 3D printing and assembling most of the hand, while I soldered the circuit board and programmed the hardware.

Due to incompatibility issues with the model and our servos, we had to drill some additional holes into the hand to create room for fasteners.

1.7. Background context

Tell us any goals that might help us better understand your project. “Having fun” and “learning” are valid goals.

Context: Who is it for? How is it used? Don't assume these answers are obvious. If you have made a tool or product to address some problem, what else already exists to solve the same problem?

Describe constraints like budget, space, available tooling, etc. If your project was submitted to an annual competition with a complex ruleset (like FIRST Robotics or VEX Robotics), summarize the most important constraints.

Often, there is a difficult language barrier between deaf and non-deaf individuals. Our aim is to mitigate this challenge by enabling easy communication through a robotic hand that replicates American Sign Language (ASL), allowing users to interact directly with ASL speakers without having to know ASL themselves. With our translator, we strive to facilitate communication with ASL speakers in the event there is no one to translate, as well as provide a helpful tool for those wishing to learn ASL.

1.8. [Optional] Supplementary links, if relevant

For coding projects: we will only review coding projects if you provide your codebase so we can verify that it was not plagiarized. A version controlled host such as Github is preferable. If this is not possible, you may upload within SlideRoom. We will not accept Google Doc links.

If applicable, link us to any team websites, competition rules, or places where your project operates online.
Do not expect us to read all supplementary content. Only include links that may be necessary for our technical understanding of the project. We are NOT interested in advertisements, business proposals, or third-party media coverage about your project.

1.9. Build process

Tell us more about your build. What was your approach, and why did you decide to do it that way? If there was a design/testing process, what did you do? Consider attaching photos in the subsequent media uploader page to demonstrate your build process.

You can assume your reviewer has general expertise in your Maker Portfolio category, but please explain things that might not be obvious if we have not done the exact kind of project you are submitting.

One physical issue we encountered was that the 3D model did not fit as intended. Improvising, we made adjustments by removing some elements as well as reprinting the forearm that holds the servos. In doing this, we were able to create a better fit for the servos and improve functionality of the hand. Responsible for creating the circuit board, I sketched a guide on MS paint and soldered all components accordingly. I accidentally connected the ground and VCC rails, almost short circuiting the arduino.

Due to mobility limitations and lack of an opposable thumb, the hand cannot properly articulate every letter. As a result, we were unable to sign letters such as 'c', 'g', 'h', 'j', 'k', m-u, 'x', and 'z'. So, we set up our software to detect and handle these letters for the time being. As we continue to add more degrees of freedom, we will be able to program more letters.

1.10. Reflection and learnings

What changed along the way? Did the result fulfill your intended goals? What turned out well? What mistakes did you make? If things broke, why? Are there things you would like to do differently next time? What did you learn?

When we were testing our ASL translator, we discovered that certain finger movements caused the index finger and thumb to get trapped on one other. With the fingers trapped and pushing on each other, the hinge holding them snapped off. This set us back many hours, requiring us to reprint the entire hand model. While programming, I created an algorithm that reads the positions of all fingers and determines the order and speed of movement. This way, we mitigate potential damage to the hand. I have learned that motion planning is essential to robotics, as without a set order of movement, joints can easily get caught on each other.

As we continue to develop our ASL translator, one of our main goals is to expand into more letters. This will require us to develop our own hand model with the ability for fingers to move side to side, and the wrist to have 3 DOF.

[Optional] Project 3 - Maker Portfolio

* indicates a required field

While only one project writeup is required, you may share a third project in detail here.

If you have a series of similar projects all made in similar contexts (for example, some craft you have practiced many times), you may combine them into one project writeup.
Use the media uploader tool later in the portfolio to share more media about your work.

1. Do you have a third project you would like to feature?

No

Portfolio acknowledgement

* indicates a required field

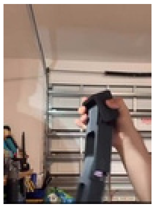
1. Please acknowledge that the work in this portfolio was created by you.

In the case of collaborative work, you have detailed your specific contributions and credited all collaborators.

I acknowledge that the work in this portfolio was created by me, and that collaborators have been credited.

Herman, Ely 42017530920

PORTFOLIO

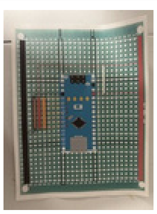


☐ First Movement Test

This was the first leg that I assembled. I connected the servo motors to a receiver and used a remote control to test the up and down movement.

☐ Bottom of the circuit board

I soldered the signal pins that connect to the digital arduino pins in a horizontal configuration. The two vertical rows of solder to the right are the VCC and Ground rails respectively, providing power to the arduino. There were some mistakes made, as seen by the yellow coloration on the right of the board, so I had to use a desoldering pump to remove the mistake and restart.



☐ Diagram of the PCB

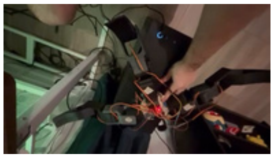
This diagram made it easier for me to solder everything. There is a positive and negative rail to the right and left of the page, which provides power to all pins. The box with the brown, red, and orange columns represent the connectors for each servo. Brown being ground, red being VCC, and orange being signal. Originally, this PCB was used for my robotic hand project as part of "Your ASL Translator," so I had to add more connector pins to make room for the 12 servo motors of the spider.

☐ Circuit Board Top View

Top view of the circuit board. The pins to the right are the connectors for each servo motor, and the blue box on the bottom is the power input.

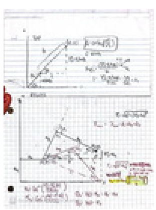
☐ Spider with three legs attached

Currently, I have three legs complete for this project. This is an image of all three attached to the body of the spider. I temporarily taped the circuit board to the body as I am still in the testing phase. When I am confident that the spider functions as intended, I will screw the circuit board into place.



☐ Legs moving in a controlled motion

This video shows the three legs moving in sync with each other, starting in a contracted position and slowly relaxing. To get this motion, I used a for-loop that slowly decrements the Z-axis position of each end effector, and using inverse kinematics, calculates the required angle for each servo to reach a specific coordinate. I plan to filter the motion of the servo motors to get smoother and more efficient movement.



☐ Inverse Kinematics

These are the equations I created to find the angles needed for each joint. X_0_3, Y_0_3, and Z_0_3 represent the coordinate of the end effector, or the desired end position of the leg. Theta1 is for the shoulder, Theta2 is for the femur, and Theta3 is for the tibia. To find these three angles, I created various triangles and made sub angles alpha1, alpha2, alpha3, alpha4. Using the law of cosines, I could find all the alpha angles. Knowing that a triangle contains 180 degrees, theta2 and theta3 can easily be found. To find theta1, I used the inverse tangent function. These calculations still need some work, but with this basis I can already start programming the legs to see how different coordinate values affect leg positions, adjusting the eqatuions accordingly.

☐ Kinematic Model

This is a kinematic model of a single leg of the spider. I used the right-hand rule to properly assign coordinate frames to each joint. With these frames, I will create a homogenous transformation matrix consisting of rotation and displacement. This will allow me to track the exact positions of each leg joint.

CAD model of the spider

I designed the entire spider in Fusion 360, and used the "joint" function to join each individual part. On the left sidebar are all the individual parts that make up the spider, each with many iterations and tweaks.

ASL Movement

This video shows the hand signing various letters.

Forearm

These 5 servo motors control each finger. The pulleys on the top are threaded with a string that will pull the fingers up and down

Hand

This is the hand model. Each finger has a fishing line threaded inside. One side of the thread is responsible for moving the finger down, while the other is responsible for moving the finger up.

Wrist gear / thread management

This gear is what controls the wrist movement of the hand. A servo motor with a gear attachment is placed inside, allowing the wrist to rotate. Embedded into the gear is 10 holes. The top 5 holes contain string that moves each finger down, while the bottom 5 holes contain string that moves each finger up.

Wrist Movement

This is a video of the wrist rotating. We connected the wrist servo to a RC controller, allowing us to test its motion.

Circuit board for the robotic hand

This was the same board I used for the spider, but this one has fewer pins as it was created to hold the 6 motors of the hand.

Mortal Enemies

A new challenger approaches.

The Box of Shame

This box holds approximately 50-60 hours worth of faulty prints. These prints either had incorrect measurements, failed mid-print, or were replaced with a different design. This box is a reminder for me to not rush the design process, as it will come back to bite later.