Stewart Platform Iteration 1 Standard Notes

July 27, 2023

Contents

1 Mechanical Design

The goal being established is to the end of making the basic mechanical model of the Stewart platform.

1.1 4/5/23

1.1.1 Summary

Today was mostly research of the Stewart platform with some basic design. I found out that all Stewart platforms are termed rigid machines meaning their inverse kinematics solutions are significantly easier than forward. This means if we know the final position of the platform the math to determine angles of the actuators is easier than if we knew the angles of actuators and wanted the output. Study robotic kinematics further to understand these concepts. You may use either linear or rotary actuators, but the math will differ. The references and resources section contains some good examples and someone has done the math for control. Stewart platforms also use joint ends which are universal or spherical, this prevents the response and drive platforms from binding on each other and makes the math model simpler.

Some early design decisions that are more than obvious is the use of spherical joints, I believe I've found some cheap ones online. Further, a long horn on the driving servos will be chosen to maximize the travel of the driven platform; draw this out if you're confused: a platform where stub horns vs long horns are used. I'm also pretty confident I'll be using two triangular platforms which overlap like David's Star, with the driven triangle transitioning into a circular 'cage' housing for the LiDAR.

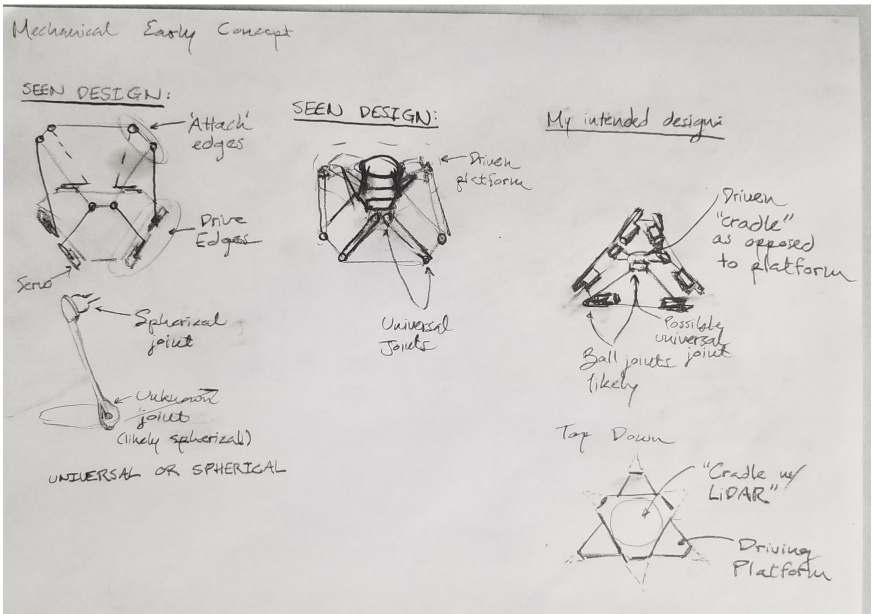

Figure 1: Mechanical sketches seen at the right

The first version of the eye will probably just be for practice controls and mechanical effectiveness. The first and final will share the same motors, joints, and most mounting; however, the final will include additional mounting for fixture to the rover, improved linkages, and additional components to make the whole assembly water/rubble resistant.

1.2 4/6/23

1.2.1 Summary

Continued research into the design of the Stewart platform. Notes on many of the design projects and research papers were completed in the 'Scratch Notes' document found in the drive. Perhaps in the future some notes summarizing the math and theory behind Stewart platforms can be written.

1.3 4/7/23

1.3.1 Summary

Continued research, like yesterday. Some part selection and purchasing based on my current knowledge. Didn't purchase ball joint linkages, but instead came up with a method of grabbing the 3D file desired from McMaster-Carr and printing; see an explanation below.

1.3.2 Roadblock: Horrible Prices...

In the design of the Stewart platform some threaded ball joint linkages were needed. Note that ball joint linkages and ball joints are different in that the former has a linkage built into the ball of the joint. When I tried to purchase these online I saw prices of **$ 18.00 each**... and I need 12 of these minimum. Obviously this won't do, and plastic hobby ones found for resale on Ebay appear incredibly sketchy.

Instead, I pick the ball joint linkage size I desire from McMaster-Carr, then press 'download 3D model', (make sure it's set to download the STEP file). From there I can model with the STEP in Fusion360, or use an online, free converted to convert to STL, then print it. For things like ball joint linkages I strongly encourage you to use a resin printer, since it can print high resolution and threads pretty well.

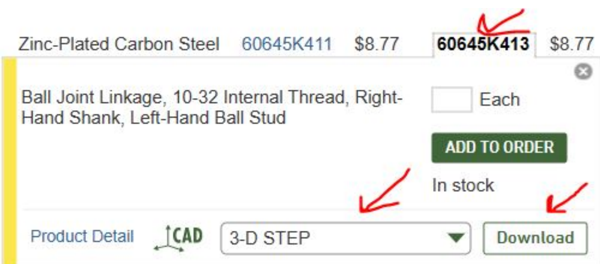

Figure 2: Selecting a part, then file type, then download

When modeling with STEP files in Fusion360, it's advised to make slight modifications and redesigns for the purpose of 3D printing. Make sure to save both a Fusion360 part file and an STL version. If I do this with the ball joint linkages I'll detail and snapshot how I edited them.

1.4 4/9/23

1.4.1 Summary

Continued research and mechanical modelling today. I found many parts through McMaster-Carr and GrabCAD so I didn't have to model them myself. The entire first iteration was modelled. Custom ball joints and servo horns were created.

Models were output in the discord server to be printed; ball joints and horns on the resin printer, major jig on the FDM printer. Future developments in the 'sleekness' of the LiDAR housing, the mounting of servos, and some tolerances (especially for wires) should be considered.

1.4.2 Roadblock: Tricky Design Parameters

In designing on paper I found myself running into lots of intricately related design parameters. The mount that holds the LiDAR must obviously be based on the LiDAR's major diameter; however, it must also roughly match, yet be smaller, than the 'circular' array of servos; by which I mean the circle that circumscribes all points on the triangle the servo's are placed on. The reason is to not occupy a large default angle, giving us more room for motion. Assuming this to be the case then the servos have to be arranged first, the horns have to be placed, and the linkages placed on the horns. From there a circle slightly smaller than the servos' circle is created some appreciable distance away from the face of the servo housing; this circle defines the location of the attach points for the upper platform. The rest of the upper platform is built around this.

The design involves plenty of reference and construction geometry. The base servo circle was referenced from **another** circle which transcribed all 6 vertices of the unequal hexagon, whos larger side length was based on 2 servo lengths, 1 gap length, and 2 constants for a total length of a kind number. You can see this hexagonal shape in the very first sketch created in the assembly file. From there some 'wings' were extruded to support the servos. From platform center to furthest vertex a radius of roughly 7" extends. A smaller, driven cradle was then created slightly smaller in radius of roughly 6", placed such that the face of the LiDAR sits 5" above the baseplate. Note that this LiDAR distance isn't set in stone, the linkages will dictate the final location. The details of design are self explanitory through the Fusion360 design history.

The final product can be seen in figure 3 with the LiDAR, servos, and ball joint linkages visualized; though the linkages connecting the two platforms are not visible.

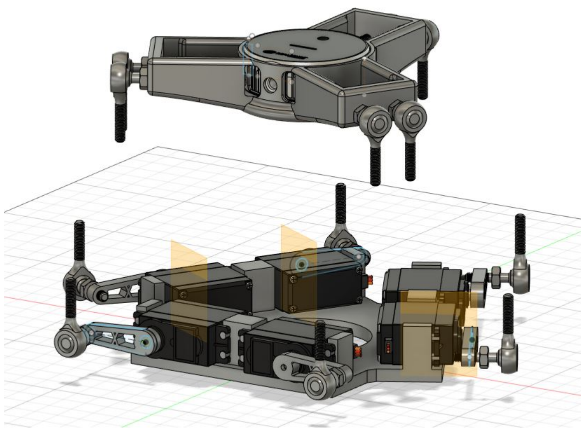

Figure 3: A 3D view of the completed first iteration

If you look down from the top (as seen in figure 4) you might be able to pick out the two triangles fashioned to the Star of David. Note that the closest, adjacent ball joint linkages will be connected.

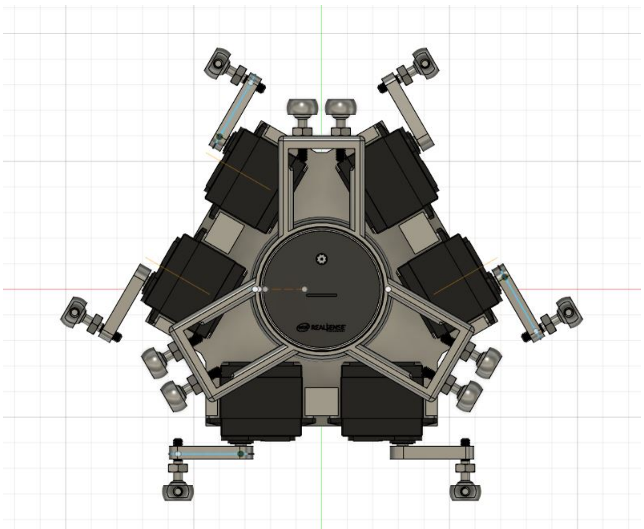

Figure 4: Selecting a part, then file type, then download

1.4.3 Roadblock: Unfit Ball Joint Linkages

The ball joint linkages were presumably manufactured to just be balls in an close fit socket, rotating on their contact. This wouldn't work for 3D printing (as the slicer would bring the ball and socket together), so modifications had to be made. The socket was designed to actually house a ball that has a printable gap. I also made sure to shrink the ball neck as to give more motion. Finally, the bottoms were extended and lined up to permit easy printing; only the threads of the stud should need support. Visuals can be seen in figure 5.

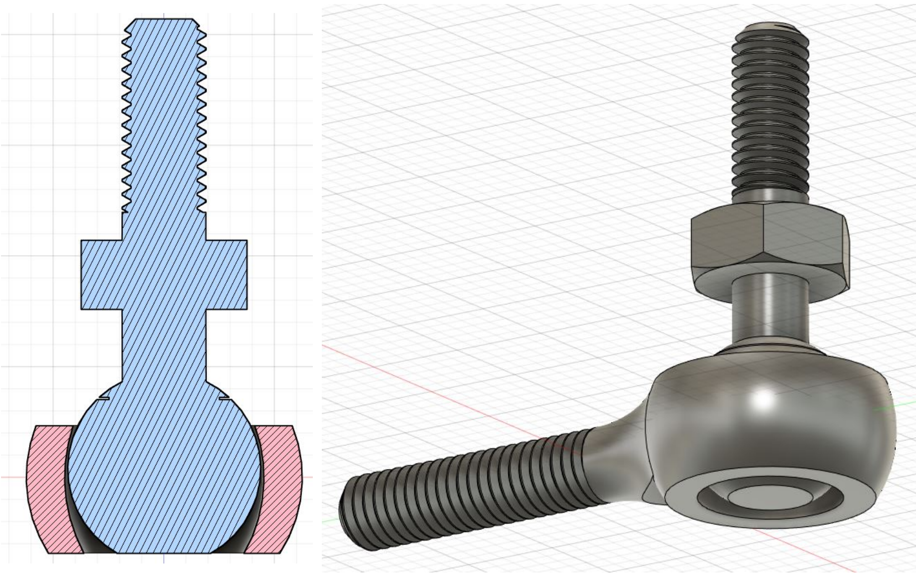

Figure 5: Section of the ball joint showing no interference, next to its 3D model

1.5 4/13/23

Unfortunately these dates were tagged but written into documentation retroactively. The following information is largely from memory.

1.5.1 Summary

Some other minor corrections not worth major note were made. The device was printed and tested for the first time. A rough draft of a script was written, and combined with the electrical succeeded in very basically adjusting the position of the LIDAR.

1.5.2 Roadblock: 3D modelling and print issues

Overall the device printed fine. There were almost no fit issues whatsoever, only 3D print post-processing. Starting at the base, the screw holes for the servos were poor; they were cylindrical indents which required pulling out extremely small support inserts. Furthermore, too much material was removed and the self-tapping screws used to mount the servos didn't hold well. If a cone indent is used in the future, no supports should need to be removed, there would be more material to grab by the screws, and the cone would act as a self-centering mechanism.

Continuning on to the servo and linkage arrangements themselves. The sideways layout took up more space than necessary, a future iteration should see them vertical. The linkages have far too many connect points, future iterations should remove as much threading as possible. The threading itself also warped as the material was cured, meaning we had to go back and tap; tapping broke the part 25% of the time when done by an experienced student. Perhaps techniques to very minimally shrink the threads, as to compensate for expansion would be a good move. The linkages themselves could be shorter, and have less material overall.

Finally I discuss the cradle. The cradle is bit too bulky, and some plastic can be removed. The fit for the LIDAR was almost too perfect; maybe some ramps to guide it in for future iterations, or you'll need to do a lot of post-processing.

1.5.3 Roadblock: Early Software

Currently the software we've developed is extremely rudimentary and based on the work of others on the internet. It's not perfect and has minimal interaction. I didn't give it it's own section as of now because of how in its infancy it is, but I will with time. I need a better understanding of the math and the software architecture before I'm going to give it it's own section.

1.6 Reflections and Future Developments

In retrospect this was a great first iteration, and served well as a test platform. For the next build only minor fit issues, (mostly mentioned above) need to be corrected. The servos should be reoriented upwards to save space, and the linkages should be simplified, (especially to cut out threading). The total weight should be minimized as much as possible with the use of intelligent parametric design. The cradle obviously needs to be redesigned for its eventual use cases, right now it's just a test platform.

The greatest change comes in understanding. Future iterations will come out of an extremely strong understanding of parallel robot design, the mathematics that govern the mechanics of Stewart platforms, and well-established design principles. Without these things future developments will be - at best - a random wandering from error-fix to error-fix. I recommend a rigorous study of robot kinematics, mechanics, and parallel robotics, as well as the plenty of available research.

The second greatest change comes from the software. Like I've mentioned above, the software is in an extremely rudimentary state, virtually non-functional, and certainly incapable of integration. Like the last point effective change to the software will come from effective understanding of the math and modelling. Only from there can we properly engineer this tech.

Other minor or distant changes that can be made is consideration for additional actuated elements, like eyelids or rotation. Currently the Stewart platform just has 6 servos, but the electronics was designed for 8. This is because we plan on putting in see-through eyelids, actuated by 2 minor servos. Work might also be towards additional methods of movement (like rotation on a track).

1.7 References/Resources

- A great example which includes a lot of mention of kinematics is seen here
- What might be called a treatise on Stewart platforms is found here
- An instructables on making a ghetto Stewart platform with Servos here
- All robotic devices need kinematics models to work; this article provides a kinematic model for Stewart platforms powered by rotary means (ie servo)
- Another good design example found here
- Though it uses linear actuators, has some good examples of tests that might be performed on Stewart platforms here
- Another good design example
- A good instructables; however, this one uses linear actuators
- A good design example with potentially useful testing procedures
- A lovely design that looks nice and has a nice circular platform
- No tutorial, just great inspiration
- *Parallel Robots* by J.P. Merlet
- *Introduction to Robotics: Analysis, Control, Applications* by Saeed Niku

2 Electrical Design

2.1 4/5/23

2.1.1 Summary

Today some work was done in the way of planning the electrical; however, it relies all on existing knowledge of electronics. I may do more research in the future to ensure the the electrical is robust and end up changing the plans. Currently a solderable GikFun board will be used to provide all power and convey signal. Additionally, an Arduino Mega will be used for direct control of servos, but will recieve its instructions from the Nano.

Pins 2-7 on the Mega will convey logic through the GikFun board to the 6 movement servos, while pipns 10-11 will convey logic to the 'eyelids' of the protective housing. The GikFun will have a 5V barell jack that will recieve power from the PCB PDS of the rover. The Mega will recieve power from the GikFun, also a barell jack. The Mega will also be connected to the Nano via a standard USB printer cable. The Mega and Nano will communicate through ROS. An image below of the rough schematic can be seen.

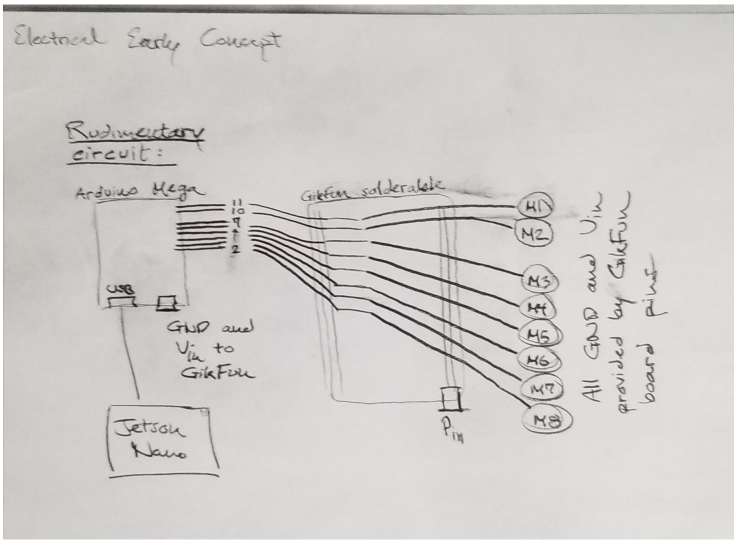

Figure 6: Rudimentary electrical sketches

2.2 4/7/23

2.2.1 Summary

Some thought worth noting was put into the electrical. A 3D model of the complete circuit will be completed, and then a housing created. The printable housing will act as a sort of 'guide' for soldering components.

Because of it's superior clock speed, RAM, and electronics, we'll be opting to use the Arduino Due over the Mega. The Due has the exact same footprint as the Mega so nothing will change in the schematics.

2.3 4/13/23

2.3.1 Summary

The electrical was tested and performed OK. There were some bugs, and it was difficult getting it started; but, the Arduino powered and the Stewart platform actuated. Some inspection might go into the electronics to ensure everything is properly connected and robust, but this is a great test platform.

2.4 Reflections and Future Developments

The electronics for the Stewart platform are currently extremely simple. The test rig only includes 6 servos for platform actuation, and 2 for eyelid motion, (whenever these are developed). It's built upon a GikFun solderable breadboard rubber-band strapped to a 3D printed Arduino housing. We might be able to find or make our own control board, the former being more economical, the latter being more educational and possibly compact.

Consideration towards 'clean power' should also be given. We have no capacitors or diodes, or redundant circuitry on our board. We only assume the best conditions.