Build a 3D Printed Micro-manipulator

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Introduction: Build a 3D Printed Micro-manipulator

Micromanipulators are tools designed to precisely handle objects at the micron scale. They are very important in science as they allow to interact directly with microscopic device, when direct manual handling would most likely result in destruction. However, professional quality micromanipulator can be very expensive (thousands of USD), out of reach of hobbyists and sometimes a scarce resource even for professional researchers.

Some models of 3D printed micromanipulators exist and have been published in open source, but the ones I tried previously suffered from backlash and ratcheted movements due to the sliding of plastic on plastic. In this design, I have tried to remedy these issues by loading all axes with springs and by using metallic rods to prevent any plastic-plastic contact. All sliding surface are metal against printed plastic. The result is a stiff, compact and smoothly moving micromanipulator, not quite up to par with the commercial alternatives, but fit for most applications and accessible for a handful of USD and half an hour of your time.

I have also designed a series of linear and rotational stages for (inexpensive) precision positioning. If interested you may find more information on my other instructables here, and here.

Supplies

Materials:

1. 2x 55mm and 1x 50 mm M3 bolt
2. 3x M3 nuts and washer
3. 3x 40mm springs (40/50 min/max length, 7.5 max outer diameter, 3.5 min inner diameter, 0.6 to 0.8 recommended wire diameter)
4. 4x 52.5, 4x 63.5 and 3x 44.5 mm long 2 mm diameter metallic rod
5. 8x 12mm diameter 3mm thick magnet (other dimensions are possible if preferred, see 3D files description)
6. 4x M3 4mm diameter 4mm long melt inserts (other dimensions are possible if preferred, see 3D files description)

Optional (tool holder head)

1. 4x 8mm M3 screws
2. (straight holder tool) 3x M3 insert 1x 20mm and 2x 14mm M3 screw 1x M3 washer
3. (bended holder tool) 2x M3 insert 2x 14mm M3 screw

3D printed parts:

1. 1x Base
2. 1x Middle
3. 1x Top
4. 1x Z slider
5. 3x Knob
6. 1x Tip holder (depending on your preference)

Tools

1. 3D printer with PLA filament
2. Vice
3. Metal saw
4. File
5. 1.9 or 1.95mm drill bit (slightly undersized compared to your metal rod is preferred)
6. Electric drill/Screw driver
7. Supports removal tools (cutter, pliers...)
8. Melt insert installation tool, or soldering iron (,or lighter if you like it ghetto style)
9. (optional) grease or oil lubricant
10. (optional) glue

Step 1: Print the Parts and Prepare Yourself

Before starting, one word on the design strategy: FDM 3D printing is not precise enough to make rigid printed parts assemble perfectly together without any play (at least not with someone else's printer ^^). This is a huge issue to build a micromanipulator since even a small play can ruin your precision. To go around this difficulty, all the printed parts are designed to be slightly tight and need to be adjusted. However we can use the low transition temperature of PLA to easily achieve a very tight fit. All the parts are connected via metal rods. By spinning these rods very fast with a hand-drill in there assembled position, the friction will heat the rod and the plastic locally where the fit is tightest. As soon as the rod reaches about 70°C, the PLA will start to deform and you will get a perfectly sized hole.

This method is quite efficient but it requires some patience and method. Be cautious not to overheat your parts or you will need to re-print it... Always place all the other rod guides when doing it, to ensure that the two parts are maintained in the right position. Use this method every-time the fit is too tight and the parts do not slide well enough.

The standard files are designed for a printer with a clearance of 0.2mm. If your printer requires a larger clearance it means you will need to take a little more time with the drill, or you can look for "large clearance" files (I plan to add those soon after this tutorial is released). If you don't know the adequate clearance for your printer, you can look at the test part included. I also included various versions of the printing files depending on the type of magnets or melt inserts you have available. Some parts require supports and the printing orientation will influence the final result so make sure to read the description.

Based on those considerations you should look into the files available in the following links and print the most appropriate for you:

https://www.printables.com/model/895311-3-axis-micromanipulator

Step 2: Source Your Materials

I tried to design this project with standard, easy to procure materials but that doesn't guarantee you will have them on stock. Here are some links to help you gather what you need. For each one, I've tried to include one link from Taobao (Chinese platform) and one from Amazon. I nevertheless would like to encourage you to find local providers and limit oversee delivery whenever possible...

- 2x 55mm and 1x 50 mm M3 bolt (2x 60 and 1x 50 would also work, you can off course buy only 55mm and cut one to size) I use mostly internal hex bolts but any kind of head type is ok if you are ready to grind the head perimeter a little.

amazon, taobao

- 3x M3 nuts and washers

amazon, taobaoamazon, taobao (only follow these links if really necessary, you most likely don't need 100...)

- 3x 40mm springs (40/50 min/max length, 7.5 max outer diameter, 3.5 min inner diameter, 0.6 to 0.8 recommended wire diameter)

amazon or amazon, taobao

- 2 mm diameter metallic rod (stainless steel advised, at least 15mm if you want to limit the waste when cutting to size)

amazon, taobao

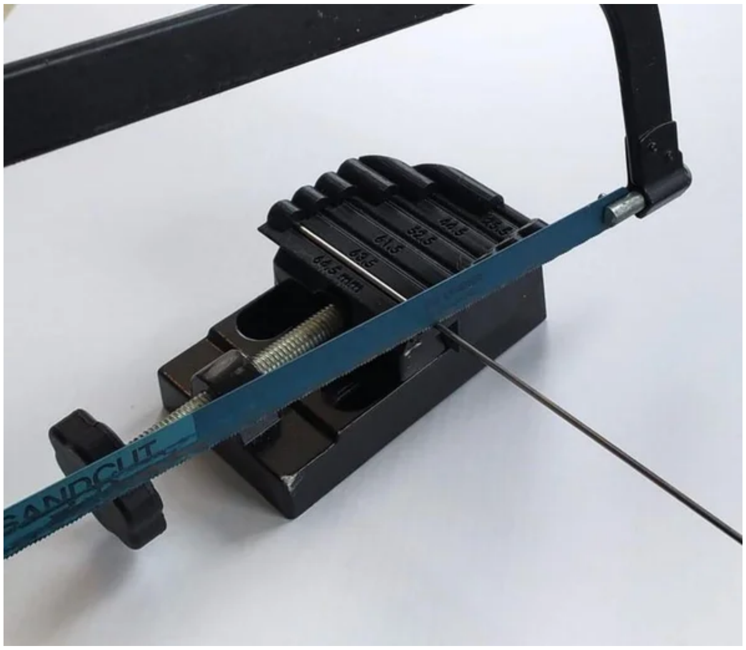
- 8x 12mm diameter 3mm thick magnet (other dimensions are possible if preferred, see 3D files description)

amazon, taobao

- 4x M3 4.2mm diameter 4mm long melt inserts (other dimensions are possible if preferred, see 3D files description)

amazon, taobao

Step 3: Cut the Rods to Length



For this assembly, you will need 2mm rods cut into 4x 52.5mm segments, 4x 63.5mm segments and 3x 44.5mm segments. You can of course cut them by hand, or you can choose to print and use the cutting guide I designed. The one shown in the illustration offers 6 different lengths adapted for this project and to my 3D printed linear axis. You can choose to print the smaller version with only the relevant lengths for the micromanipulator.

To cut the wire, first grind the extremity flat with the file (factory rods are often cut with pliers, causing an uneven top surface) and insert it into the guide. Cut the wire at the adequate length and grind the second end.

To facilitate the insertion, I advise to add a chamfer at one end. To do that, fix the rod in the drill and spin the tip against the file.

Step 4: Install the Magnets and Assemble the Knobs

The first assembly step is the installation of the magnets. The standard base file is designed with 4x 12mm holes to place 2x 3mm thick magnets in each. By alternating the polarity of each magnet pair, you can slightly increase the holding force. It will also prevent the iron substrate from becoming also magnetic and attracting everything around.

After that, you can install the knobs. They are designed to be tight so you can just fix them in a vice and screw the bolts inside. If it is too lose, add a drop of glue on the head.

Step 5: Assemble the Y Axis

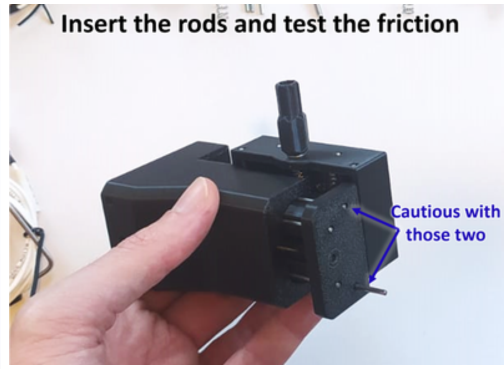
To assemble the Y axis, first insert a nut in the hexagonal hole of the "middle" part. It is designed to be tight and the nut should hold in place. If it is too tight to insert manually, you can place it on a bolt, heat it with a lighter and insert it hot. If it is too lose, you should glue it.

After that you can place the "middle" part into the "base" and insert the 4x 44.5mm rods chamfer first. If insertion is really too difficult, use a slightly undersized (1.9mm or so) drill bit to clean the holes until insertion becomes possible.

You can then test the movements of the two parts. At this point, the fit should be very tight and the parts should have a hard time moving. No problem, take out one of the rods, fix a long rod on your drill and spin it for a dozen second in the hole while moving the parts back and forth. Place back the rod a repeat the process for the other holes until the movement becomes smooth. You may want to make yourself a tool by warping one extremity of a 60 to 90mm rod in tape and tissue until it makes for a comfortable handle. It will be very useful to push rods out of their holes. Be cautious not to overheat the parts and induce play or you are good to print it again...

When the movement is smooth and without play, assemble the "middle" and "base" part with one of the springs and the 50mm bolt. Don't forget to add a washer to reduce the friction. Test that the spring is strong enough to push the junction, if so, you are ready for the next step.

Step 6: Assemble the X Axis



To assemble the X axis, first put a nut on the tip of a bolt and insert it int the hexagonal hole of the "top" part. Like previously, use glue or a lighter if necessary.

Then, position the "top" part atop the "base" and "middle" assembly and place the 63.5 mm rods. Be cautious with the two rods on the bottom side, as they are difficult to remove when fully inserted. Keep a few mm exposed to catch them with a plier or use some longer rods for the adjustment process. Like previously, use a drill and a long rod to heat up the plastic and form the holes to exactly the right diameter. When the two parts slide smoothly add a spring, a 55mm bolt and a washer, and check that the spring is strong enough to push the assembly.

Step 7: Assemble the Z Axis

To assemble the final axis, first insert the melt-inserts and the last nut in the "Z slider". Then place the slider in the assembly and add the 3x 52.5mm rods. Use the drill to adjust the hole size and add the spring and the last 55mm bolt.

At this stage, you can choose to glue the rods in place with a drop of cyanoacrylate at the extremities. Be aware that this will make it very difficult to disassemble, but it can also prevent the rods to come out after repeated use... You can also add a a bit of grease on the rods to make the movement smoother. None of those steps are strictly necessary.

Step 8: Attach a Tool Holder

Micromanipulators are often used to take electrical contacts on microscopic electrodes, but that is not necessarily their only function (see my [pipette adaptor]() for example). For this reason, I tried to make this design as versatile as possible using a fixation plate with 4x M3 melt inserts to allow you to design any tool head you may need. The plate holes are separated by 18mm horizontally and 15mm vertically.

To fix standard microelectronic tip holder, I also provide two different tool heads. One for straight tip holders with a degree of liberty in rotation and one for 90° bended tip holder.

In case you don't have (and need) a tip holder, you can make one with one of the 2mm rods, but this is a story for another Instructable.

Step 9: (optional) Build the Tool Mounting Head

To build the "straight holder", you need to print 1x "straight holder base", 1x "straight holder arm", 1x "straight holder knob" and 2x "holder knob". Assemble the "straight holder knob" with a 20mm bolt and the two "holder knob" with 14mm bolts. Add two melt inserts to the arm and one to the base. Attach the "straight holder arm" to the "straight holder base" with the "straight holder knob" using a washer to ensure rotating the arm will not cause the knob to come lose.

For the 90° holder, you need 1x "90 holder" and 2x "holder knob". Add two melt inserts to the "90 holder" and assemble the knobs with 14mm screws.

Both types are secured to the micromanipulator using 8mm M3 screws.