April 2022

Hello Benefactors. It's time for me to tell you about what I've been working on in April.

It's been a busy one, but mostly behind the scenes work and a lot of learning. It's always tempting to be pushing for a new hardware release each month, but this month I've been working on establishing some new tech, which hopefully in the future will allow us to build some smoother running, quieter devices.

I've also decided that I really need to get my act together, improve the look of my Patreon page and create some self promotion material. I've started that by building a new stand to photograph my machines on.

BLDC Motors

The most potentially exciting bit of work I have done this month has been in the area of brushless DC (BLDC) motors.

A GIMBAL STEADIES A CAMERAPHONE USING THREE BLDC MOTORS, ONE ON EACH AXIS.

Up until now everything I have done with my designs has depended on high powered hobby servos. There are a lot of great things to say about these. They are fast, powerful, easy to get hold of, give the user plenty of options depending on how much they want to spend. They are also very self-contained and very simple to understand.

The downside, as every OSR2/SR6 user can tell you, is noise. It varies depending on the make and model, but in general they are loud. Damn they are loud!

BLDC motors first crossed my radar a year or so ago when Mrs Tempest bought me a gimbal for Christmas. This is a device that will stabilise a video camera, in this case my phone, with a motor on each of several axes. I was astonished how smooth and quiet the motion of the motors was and resolved to look at them more closely in the future.

On the face of it there seemed to be a couple of problems with BLDC gimbal motors.

A BLDC MOTOR

The first problem was that when I looked at the specifications I found that the torque that these motors could apply was generally an order of magnitude below that which the servos we use on our robots. Typically a motor of equivalent cost to a decent servo can achieve a torque of around 2kg.cm, compared to the 20-30kg.cm required for good performance on an OSR2/SR6.

The other problem is one of accessibility and standardisation. I believe that OSR2 and SR6 have been successful because wherever you guys are you can get hold of the parts that you need. It's relatively easy to get hold of a standard sized 20kg.cm servo, wherever you are in the world. This standardisation doesn't seem to exist in gimbal motors in quite the same way.

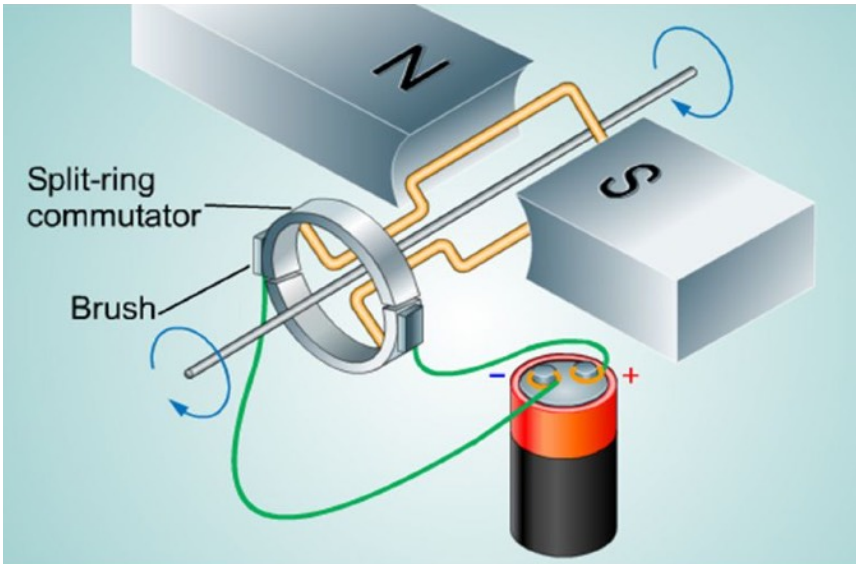
The level of pre-learned skill, and let's not forget technical confidence, required to put together an OSR2 is relatively low. This is deliberate on my part, because I want the device to be accessible to anybody who wants to have a go at building one. Servos are excellent for this because they are self-contained plug-and-play devices.

BLDC motors are more complicated. To work they need external control electronics that are considerably more complicated than those associated with a simple DC motor. They also need to work in conjunction with an encoder or some other form of position sensor. This makes specifying a homebuild design a lot more challenging to say the least!

Nonetheless I have started looking into some designs that use BLDC motors because I think there are some significant benefits that would make for some really awesome devices. We can make robots with movements that are really fast, smooth and above all, quiet!

At this point I'm going to back up and explain what we mean by a BLDC motor.

A DC motor is a motor that uses Direct Current. At the hobby scale that's pretty much every motor you come across. DC motors work by passing an electric current through a coil or coils of wire that are free to rotate inside a set of magnets. The flow of electricity inside the wire creates a magnetic field, which wants to line up with the magnetic fields of the outside magnets. This creates a torque in the coil and makes it turn.



HOW A SIMPLE DC MOTOR (WITH BRUSHES) WORKS

DC MOTOR

If the two magnetic fields line up the motor will not be producing any torque, so to keep the motor turning the electric current through the coil has to be reversed once it has turned more than a certain angle. In a simple DC motor this is done by a device called a commutator, which is a split ring that rotates with the coil and is in contact with two brushes, positive and negative. They're not exactly "brushes" like, say, your toothbrush, they're usually spring-loaded blocks of a material graphite, which is a great conductor and self-lubricating. As the ring rotates the electric circuit through the coil is automatically reversed and this creates a continuous rotation.

DC electric motors are a technology that's been with us for nearly 200 years and they work very well. So why would we want a brushless motor?

There are several reasons. One reason is mechanical: the brushes are physical parts that add complexity to the motor design, resist the movement of the motor, and will eventually wear out requiring the replacement of the brush or the whole motor. Cheap motors fail all the time, and often this is why.

Another reason, and the one that most benefits us, has to do with control, and noise!

In a Brushless DC motor the coils are fixed to the base of the motor and do not rotate. Instead the magnets around the outside of the motor rotate. This is possible because instead of using a mechanical system to control the flow of electricity in the coils, switching them on and off, we can use clever electronics.

INSIDE A BRUSHLESS DC MOTOR

How does this help us reduce the noise on a stroker robot though?

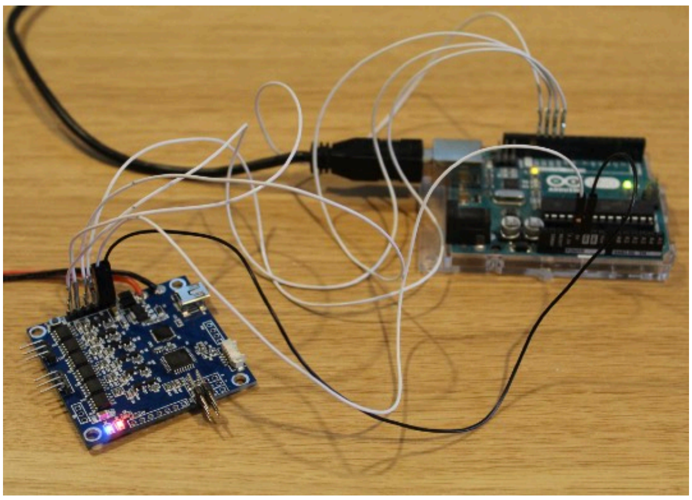
Well, if you want to build a mechanism that makes a lot of noise the best way of going about that is to have a large number of moving parts turning at high speed. Does that sound familiar? The mechanical gearbox inside a servo is a superb candidate for this!

Servos do this because brushed motors are practically impossible to control at very slow speeds. First they have to overcome the friction of the brushes before the motor will start moving. Secondly they get into trouble around the position where the commutator switches the coil polarity. In order to avoid a short circuit there has to be a small angle where the circuit is broken The motor will get stuck if there isn't enough momentum to carry it across the gap.

If we want a quiet mechanism the best thing we can do is the opposite of the servo example above. We want to reduce the number of moving parts and reduce the speed at which everything moves. A BLDC gimbal motor is a perfect example of this: there is no gearbox and 1 moving part, you literally bolt on to either end of the motor. They are practically silent.

A BLDC motor has three wires. By controlling the flow of electricity to and from these we can very precisely control the angle of the magnetic field in the motor. This means we can move the motor very slowly, smoothly and precisely. To do this we need a specific kind of motor controller (a triple half H-bridge in fact) and we need some kind of sensor to detect to current angle of the motor, like a digital magnetic encoder.

Okay, so BLDC motors are great. Where do we start if we want to use them in a stroker robot?



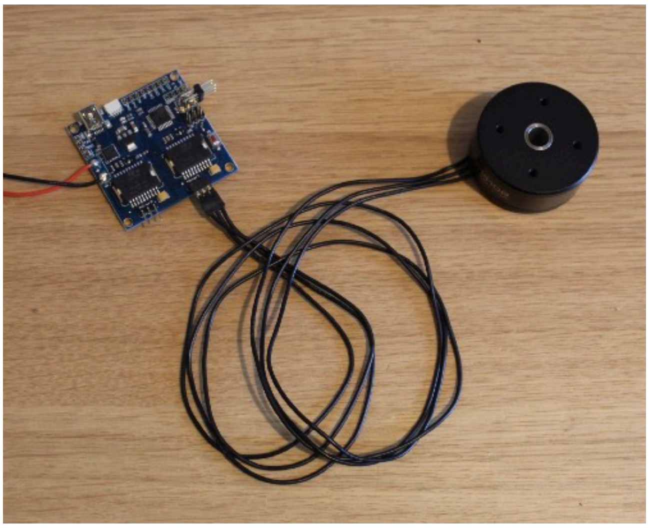
UPLOADING THE ARDUINO BOOTLOADER ONTO A BGC3.0 GIMBAL CONTROLLER

There are generally two hobby applications for brushless motors: drone propellors, and camera gimbals. We can immediately forget drone propellor motors because the speed controllers that come with them will only do movement in one direction and these motors are built to run at high speed. In fact they will damage the controller if they are run too slowly. For our application what we need is something more like a gimbal motor, and a gimbal motor controller.

One thing that's a bit dispiriting is how difficult it has been to get hold of a controller board. A lot of the generic boards that might make experimentation with this sort of stuff easy have been out of stock. Blame the silicon shortage, and the world going mad I guess.

Eventually I was able to get hold of a BGC3 board, which is a 2-axis gimbal controller, and I spent an infuriating day trying to make sense of it. In theory the board is Arduino-based, but it took me hours before I figured out I needed to re-install the bootloader to get it to work. This is the bit of software on the board that allows you to upload software to the board. If you've never done this before (I hadn't) it turns out you can use another Arduino to do this.

Finally I managed to get a sketch loaded onto it. Unfortunately it seemed I would have to go through the tedious process of re-installing the bootloader every time I wanted to re-upload a sketch. An enormous pain in the ass! I gave up on the BGC3 board at this point.



BGC3.1 WITH A BLDC GIMBAL MOTOR

As a last throw of the dice I ordered a second BGC3, which actually turned out to be a BGC3.1. This is a neat little board that has two L6234D controllers on it. It also connected straight to Arduino IDE and accepted programming from the word go, so that was good news! I have no idea if my initial woes were a problem with the BGC3.0 in general, or if I just received a bad board.

The next step was to hook it up to a motor. I got hold of a gimbal motor I found recommended by a tutorial and tried it with some roughly thrown together control code. At the time of writing I have successfully managed to get the motor to spin. The next step will be to hook up an encoder and see if I can use a T-Code implementation to control the motor position.

The more I play with brushless motors, the more convinced I am that there's an enormous amount of potential for a Tempest device. There's certainly not enough torque for direct drive in a device like OSR2. For that it will probably need some gearing, but this will be 3D printed gears like the ones on the new twist. The rotation rates will be slow, so there won't be any high-pitched whining noises. We also need to find a motor with an encoder, or an easily available encoder type.

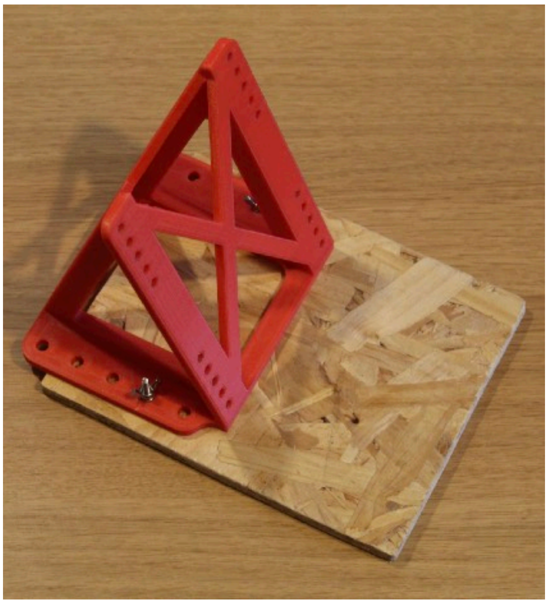
One possibility might be to use a gimbal motor to drive the twist mechanism. The twist actually requires very little torque, but even the latest redesign could benefit from some noise reduction. I'm thinking I could set up the BGC3.1 to basically act as a servo, responding to a PWM signal down a signal wire.

We're some way from a working prototype at this point, but I'll keep you guys informed as I learn more.

One final thought. A cool artefact that comes out of the BLDC motor being connected to an encoder is that in theory it will be possible to calculate the force that the motor is applying. What that means is that this kind of motor might work well with my robo-touch device concept. I wouldn't need the force sensor, which would make the whole thing a lot simpler!

Display Stand

This month I took it upon myself to replace the old display stand that I have been using since the early OSR2 days. When I say a stand, what I mean is a 3D printed frame attached to a rectangle of chipboard, which I had left over from a previous project.



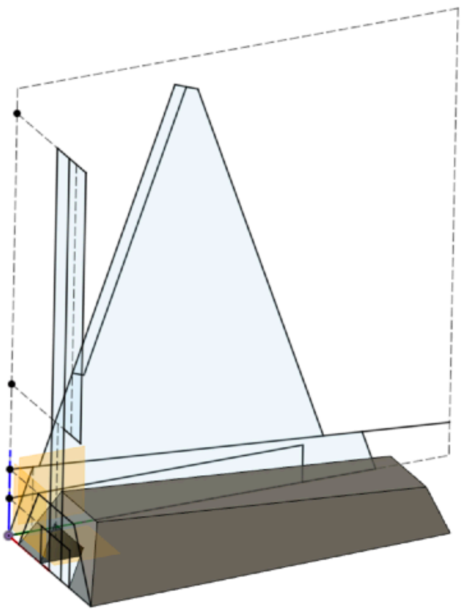
THE OLD DISPLAY STAND

I am in the process of updating all of the photographs of my designs in my build instructions to a more professional level of quality. I have a product photography type setup, which I have talked about in previous dispatches, that features a pleasant blue background. I thought it would be nice to make a stylish stand that would blend in to that background.

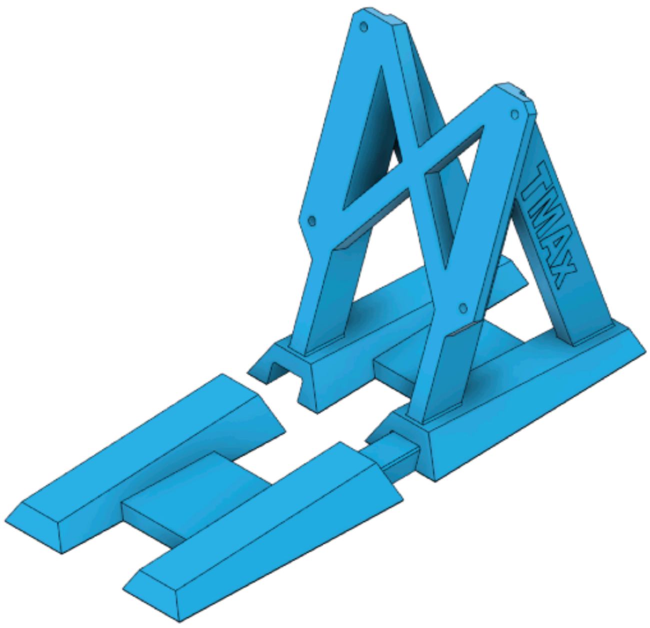
I think that this simple design task is a good example of how to go about creating a design from a clean sheet of paper. I have been a professional design engineer for over 15 years now and I still find that I can get stuck with this first step of the design process. The advantage of experience is being able to recognise it and get unstuck.

The way out always seems to be the same. If you are having trouble starting to lay down the first lines of a design you are probably thinking too hard. You likely have in your head a huge cluster of competing problems and potential solutions that make it impossible to sketch out the simple initial geometry of the thing that you want to design.

Even for something as simple as a display stand there are a whole host of different things to take into account: How tall should the stand be? It has to be in multiple parts because of the limits of the build volume, so how do I join the parts? Should I have multiple possible mounting locations? Will the OSR2/SR6 receiver hit the base if it moves? What angle should the stand be at? How do I make the structure out of a web of beams, but without overhangs so I don't need support structures? Etc, etc, etc.

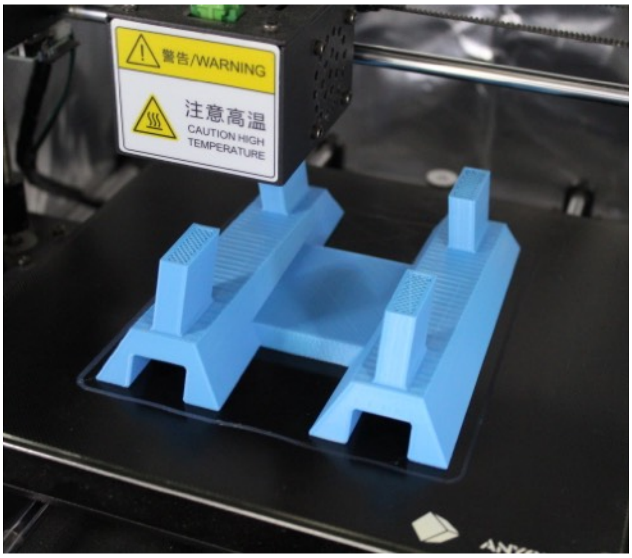


SKETCHING A NEW STAND



THE FINISHED DESIGN

In my experience it is impossible to hold all of these thoughts in your head at the same time and if you try you will certainly never make any headway into the design process. I maintain that the only possible solution is to stop trying to be so damn clever and just draw something. It will be wrong, but that doesn't matter, draw it anyway. The best course of action is to be dumb and to get some initial, imperfect thoughts down on paper, or on screen. Once you have done that, it is far easier to start to gradually sculpt what you have, like clay, into something that might actually work.



PRINTING THE NEW STAND

I have now finished the design and printed out the full stand. You will be seeing it in some of my upcoming product photography.

Finally...

I'd like to say a big thanks to you guys for the support you give me. I'm actually enjoying sharing this glimpse into my creative process with you, so I hope that it's interesting to see and read. I would like to invite you guys to engage more on the discord server, especially if you see something I've posted and you have any questions or suggestions. I'm also definitely open to organising livestreams and hangouts on there too if there's anything particular you'd like to see more of. Let me know.

Thanks again!
Tempest