Pan Tilt Design report

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Abstract

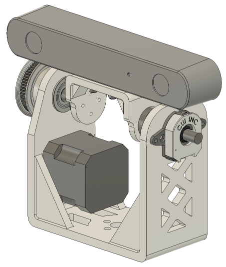
The aim of this project is to develop a 2 degree of freedom purely rotational pan-tilt mechanism which can provide stable rotation about the Yaw(for Pan) and Pitch(for Tilt) axes. This mechanism can be used for application such as terrain mapping (using a limited FOV stereo/ RGB-D camera), object tracking and as a gimbal (for stable camera feed).

1 Introduction

In this design report, the following parts are going to be covered in detail:

1. Design and fabrication
2. Component description and BOM
3. Mathematical model of system (state variable matrix, transformation matrix)
4. HSM control equations with driver
5. First step towards developing system architecture

2 Design and Fabrication

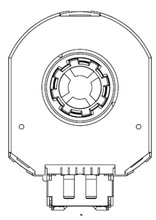


3 Components used in the Tilt mechanism-

1. Stepper motor
    - Step angle = 1.8 degree/pulse or 200 pulse/revolution
    - Rated voltage = 12V
    - Rated current = 0.4A
    - Phase resistance = 30Ω
    - Phase Inductance = 60mH
    - Holding torque = 4.2kg-cm
    - Detent torque = 220g.cm
    - Rotor inertia = $54g.cm^2$
    - Weight = 0.28kg
2. CUI AMT22 MODULAR ABSOLUTE ENCODER
    - Full duplex Serial Peripheral Interface (SPI)
    - 12-bit absolute position
    - Checksum bits for error detection
    - Digitally settable zero position

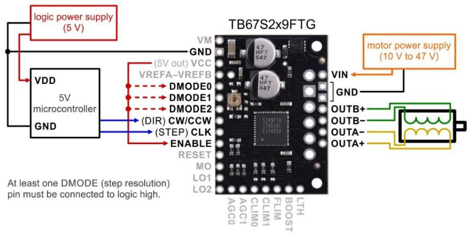
PINOUT CONNECTOR	
#	Function
1	+5 V
2	SCLK
3	MOSI
4	GND
5	MISO
6	CHIP SELECT

AMT222



3. IMU (accelerometer and gyroscope) -
   6-axis Gyroscope and Accelerometer used to acquire the angular velocity and linear acceleration of the camera frame w.r.t. the ground frame.

4. Stepper motor driver

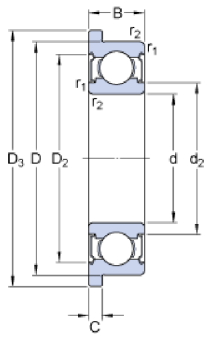


5. Timing Pulley and Belt

   - Driver pulley properties-
     - No. of teeth: 15
     - Pitch diameter: 9.70mm
   - Driven pulley properties-
     - No. of teeth: 60
     - Pitch diameter: 38.81mm
   - Timing belt properties-
     - No of grooves: 90
     - Centre-to-centre distance: 51.4 mm

6. Flanged ball bearings -

Dimensions



d		8	mm
D		22	mm
B		7	mm
d_2	≈	10.5	mm
D_2	≈	19.03	mm
D_3		25	mm
C		1.5	mm
$r_{1,2}$	min.	0.3	mm

4 Mathematical model of system

The nonlinear model based on the Lagrange-Euler equation is as follows.

$$\mu = M(\theta)\ddot{\theta} + C(\theta, \dot{\theta})\dot{\theta} + F(\dot{\theta}) + g(\alpha)$$

We can *emphasis* some words, i.e., make them *italic*, and we can make some words **bold**. Note how using a new line in the code does not correspond to a new line in the output file. Same if we have a large white space.

Instead, if we want a new line/new paragraph, you need to press enter twice, or use
which starts a new line but not a new paragraph.

5 Hybrid Stepper Motor Control equations -

Stepper motors are controlled using off-the shelf driver modules which acquires a square pulse as input from a microcontroller or a timer circuit and based on time period of the single pulse, the motor rotates by a certain step (1.8 degree) or microstep (factors of 1.8). A trail of pulse is required to rotate the motor to a desired angle.

$$\alpha = F[M, Tout]$$

Where,
α = required step/micro-step angle
M= desired microstepping factor
Tout = Time period of the input square pulse

5.1 Micro-stepping angle-

The default step angle of our stepper motor is 1.8 degrees per pulse. This indicates that when microstepping factor(M) is unity, the shaft of the motor will rotate by 1.8 degree when a square pulse is applied at the 'STEP' pin of the driver.

In certain drivers, there is an feature called "Micro-stepping" using which we can reduce this step angle to finer values like 0.9 degrees, 0.45 degrees and so on. The general equation for micro-stepping can be written as -

$$\alpha = 1.8/M$$

This equation will yeild the microstep angle α in degrees. To maintain our calculations in S.I. units, we convert this value to radians using the following conversion -

$$\alpha = (1.8/M) * (\pi/180)$$

$$\alpha = \pi/(100M)$$

A point to be noted here is that since we are using a pulley-belt reduction mechanism, our load(camera) will be rotating 4 times slower than the motor. This means that if the motor's step angle changes by α, the load's angle would change by $\alpha^{'}$ and $\alpha^{'}$ can be denoted as -

$$\boxed{\alpha^{'} = \pi/(400M)} \tag{1}$$

5.2 Angular Speed of the motor -

For simplicity, we will enter the maximum desired angular rotation ω of the load in terms of rpm (revolutions per minute). But in order to keep all calculations in S.I. unit, we calculate $\omega^{'}$ which represents angular rotation in rad/sec -

$$\boxed{\omega^{'} = [(2\pi)/60] * \omega} \tag{2}$$

5.3 Frequency of the square pulse to be generated -

Since we now have the values for $\alpha^{'}$ and $\omega^{'}$, we now calculate the Frequency (Fout) and Time period (Tout) of the square pulse needed to be generated.

$$\omega^{'} = \alpha^{'}/Tout$$

$$\omega^{'} = \alpha^{'} * Fout$$

$$Fout = \omega^{'}/\alpha^{'}$$

$$Fout = [(2\pi/60) * \omega] * [(400M)/\pi]$$

$$\boxed{Fout = (40/3) * M\omega} \tag{3}$$

5.4 Determine the number of pulses -

Now with the calculated value of Fout or Tout, we know that on applying one such pulse the motor will rotate by a step or micro-step. But if we want the motor to rotate to a certain angle say θ_{final}, we need to send a trail of square pulses which would continuously rotate the shaft of the motor in discrete micro-steps at a speed depending on the value of Tout.
To determine this value of pulse count (pls_{count}), we make a simple comparison as follows -
If one pulse of frequency Fout corresponds to $\alpha^{'}$ where $\alpha^{'} = \pi/(400M)$;
'pls_{count}' number of pulses of frequency Fout should correspond to θ_{final}
On comparison we get,

$$pls_{count} * \alpha^{'} = \theta_{final}$$

$$pls_{count} = \frac{(4M) * \theta_{final}}{1.8}$$

$$\boxed{pls_{count} = \frac{20 * M\theta_{final}}{9}} \tag{4}$$

6 First step towards system development-

LaTeX [1] also allows you to cite your sources. For more details on how this can be done, we refer the reader to [2, sec: Embedded System]. But once you have a bibliography, you can use the cite command easily. Finally we add Figure **??** to show how to add graphics. Note that we first need to make sure to have the graphic uploaded to Overleaf or saved in the same folder as your tex file (whichever is relevant to your case). Notice how the picture was resized using the scale command and that LaTeX determine that the picture looks better above.

References

[1] Leslie Lamport, *LaTeX: a document preparation system*, Addison Wesley, Massachusetts, 2nd edition, 1994.

[2] Wikibooks, *LaTeX/Bibliography Management*, [0nline], Accessed at https://en.wikibooks.org/wiki/LaTeX/Bibliography_Management, (DATE ACCESSED).