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***Logbook***

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| **Date** | **Work Accomplished** |
|  | * *List any work accomplished and note down lessons learnt.* * *Explain any design choices briefly (more in-depth explanation of your design decisions should go in your design concepts and overview document)* * *Set any goals for next time.* * *Include evidence and references (screenshots, photos, links etc.)* |
| 19/04/2025 | Researched what a b-dot controller is, found a few articles on a standard b-dot and a non-standard one.  A screenshot of a computer  AI-generated content may be incorrect. |
|  | I watched Monte Carlos videos on the mathematics behind b-dot controllers, along with some more information about attitude determination, some orbital mechanics and magnetorquers.  https://www.youtube.com/watch?v=uNZeDMmDdbo&list=PL\_D7\_GvGz-v3mDQ9iR-cfjXsQf4DeR1\_H&index=7 |
|  | Researched what a magnetorquer was.  It is essentially the armature section of a dc motor, it uses the current inputted, and the earth’s magnetic field that passes through it to produce a torque about axis that it is aligned with.  The basic principle of using it to detumble is that the torque applied by the magnetorquer is supposed to oppose the change in the earths magnetic field that passes through this axis.  Since the end result should be that CubeSat flies through the inertial magnetic field, converts it to the magnetic field in the body frame and thus this body frame magnetic field should not change over time, the angular velocity in each axis of the cubesat should not change, therefore being de-tumbled.  Thus moment applied by a magnetoruer is as follows:  moment = n\*A\*I,  where n = number of turns in the wire,  A = cross sectional area of the wire assembly.  I = current.  The torque applied by a magnetorquer is then the cross product between the magnetic moment and the earths magnetic field in the coils frame of reference.  Magnetorquer photo: |
|  | Researched the basic principle of the b-dot controller.  The idea is that the rate of change of the magnetic field passing through the magnetorquer should eventually drop to zero. Which means that the cubesat is not spinning on any of its axis.  This means that if you have some way of reducing that rate of change of magnetic field, then you have a way of de-tumbling the cubesat.  The simplest method is to just produce a torque that opposes this rate of change, with some gain added. This is the basic b-dot algorithm, take the derivative of the magnetic field through each of the body axis of the cubesat, and multiply it by some gain value ‘k’, and use that in the equation that defined the angular acceleration, which by integration, affects the angular velocity.  The equation for the b-dot is then:  Where  (and B is in the body frame)  There are other methods of doing this aswell, that I currently do not know how to explain.  For next time:  Research another b-dot algorithm and start coding a cubesat |
|  | Started coding a simple orbiter in matlab using monte carlos’ code as a base.  Plot of orbiter:  A graph of a sphere with colored lines  AI-generated content may be incorrect.  This took way longer than expected and I forgot to add in all the small details in coding this.  The method of making the above plot was first to get an initial state that the cubesat was in, so I gave it a standard 56 degree 500km altitude LEO.  The starting xyz position is the altitude on only the x direction, so no y or z components in the intertial frame as seen by the red axes above.  Then the velocity in each inertial direction must be found, at is assumed that the cubesat is not moving on or out of the x-direction at the initial state, but moving perpendicular to it, which means that there is velocity on both the y and z direction, defined by the speed at which a 500 km circular orbit shall move at mutlipled by the cosine and sine respectively of the orbital inclination.  Then the acceleration in each axis is taken as just gravity acting alone.  The quaternion pose frame of the cubesat is the exact same pose as the earths xyz frame for simplicity.  Then the angular velocity is defined by me to be some random number positive or negative to show the angular velocity behavior. |
|  | Added magnetic field components to the simulation with the igrf model.  The igrf model is very strange, it returns magnetic field components in the North East Down frame, which I don’t fully understand. But with the help of monte carlos’ videos I was able to get these strange components into the intertial x y and z components frame which makes way more sense.  The magnetic field of the inertial frame over the orbit : |
|  | Changed numerical integrator to one that I made myself using monte carlos’ one as a base. Since ode45 is extremely slow.  The new integrator is:    It takes small iterative additions to the current state then adds them together. |
|  | Wrote my own satellite function, it takes in the xyz position, translation velocity in xyz, the angular velocity of the cubesat in the body frame, and the quarternion pose of the cubesat.  It then calculates the derivative of all these components.  The derivative of the position is simply the translational velocity of xyz.  The derivative of the translational velocity is take as the acceleration due to gravity. It is possible to take other forces into account, but at this scale its hard to tell what the solar radiation pressure is, also its much less significant than gravity at this low earth orbit.  The derivative of the quarternions is take as a kind of complicated relationship using the angular velocity as pre-defined matrix, the relationship is show below:    Pqr is the angular velocity in the xyz directions respectively.  The derivative of the angular velocity is the really important section of this satellite module, as this is the section that the b-dot algorithm can take affect. Since the formula is as such:    The ‘I’ matris is the 3x3 inertia matrix, which is to say its just a 1x3 matrix with each x y and z inertia, taken as a column vector, multiplied by the identity matrix so that it can be multiplied and inverted and cross producted with.  The omega above is the angular velocity, pqr. And the ‘Tmt’ vector is just the torque applied by the magnetorquer.  This relationship is the most important as this is where the de-tumbling happens.  There are a few more additions to this satellite module that use quaternions to change reference frames, but the previously stated relationships are the main equations that define the cubesat behaviour.  The whole function is:  % This function computes the derivative of the position, velocity,  % quarternions and angular velocity for numerical integration  function dstatedt = Satellite(t, state)  % format: position xyz (1:3), velocity in xyz directions (4:6),  % quarternion orientation (7:10), angular velocity (11:13)  % init\_state = [x0; y0; z0; xdot0; ydot0; zdot0; quart0; p0; q0; r0];  quart = state(7:10); % [q1, q2, q3, q4]  angvel = state(11:13); % [p, q, r]  p = angvel(1);  q = angvel(2);  r = angvel(3);  %%% get inertial parameters %%%  InertialParams  %%% Gravity Model %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  % Get earth params  Planet  dist\_vect = state(1:3); %[x, y, z]  dist = norm(dist\_vect);  distvect\_hat = dist\_vect/dist;  F\_gravity = ((-G\*M\*mass)/(dist^2))\*distvect\_hat;  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  %%% Translation Kinematics %%%%%%%  vel = state(4:6); % [vx, vy, vz]  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  %%% Translational Dynamics %%%%%%%  force = F\_gravity;  accel = force/mass;  p = angvel(1);  q = angvel(2);  r = angvel(3);  rpqmat = [ 0, -r, q;  r, 0, -p;  -q, p, 0];  %accel = (1/mass)\*state(1:3) - (rpqmat\*vel);  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  %%% Rotational Kinematics %%%%%%%%%%%%%%%%%%%  angvel\_mat = [ 0 -p -q -r ;  p 0 r -q ;  q -r 0 p ;  r q -p 0 ];  quartder = (1/2).\*(angvel\_mat\*quart);  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  %%% Rotational Dynamics %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  invInertia = inv(Inertia);  H = Inertia\*angvel;  x = state(1);  y = state(2);  z = state(3);  magfieldinertial = MagneticField(x, y, z)';  magfieldbody = TBIquat(quart)\*magfieldinertial;  MagnetorquerParams  mag\_torque = Controller(magfieldbody, angvel, n, A);  angvelder = invInertia\*(-cross(angvel, H) + mag\_torque);  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  dstatedt = [vel; accel; quartder; angvelder]; |
|  | Programmed my first b-dot controller using the iterative method of the magnetic field derivative, which is the standard b-dot.  Realised that the ode45 integrator is extremely slow, so I changed to the runge-kutta 4 method which is very common in orbital mechanics. And coded it myself to cut down on time, also since it is only a style of integrator not a function in matlab.  The photo below shows the integrator and the method b-dot:    The angular velocity from this de-tumbling (after a whole load of time figuring out what value of k wouldn’t send the cubeat into infinite spin or do nothing)    After hours and days of debilitating I realised that this is the best I could ever get from the iterative method, im not sure where I went wrong, but it was a very interesting way of doing b-dot  This made me think I could do way better, so I researched some more and realised that monte carlos’ aerospace paper would have the most in-depth dive into orbital mechanics. Which it did and I found another way of writing a b-dot without using any iterative method  For next time:  Re-write algorithm to be non-iterative |
|  | The basic idea is that the derivative of the magnetic field is equal to that of the cross product between the angular velocity and the magnetic field in the body frame.  Then the magnetic moment applied by the magnetorquer is a gain value ‘k’ multiplied by this cross product.  After this the torque applied is then moment cross producted with the magnetic field through the body:  This method is much more analytical and relies on currently known values of the angular velocity and magnetic field to reliably make decisions on how much torque to apply, also the de-tumbling works much better than the iterative method:  A graph of a function  AI-generated content may be incorrect.  A value for ‘k’ that resulted in this is 4000.  The cubesat de-tumbles much quicker and actually tends to zero, making it the superior model. |
|  | Stuff I forgot to add but had to deal with:   * Changed cubesat inertial parameters as they were around 100 times to large, which ultimatly reverted the now working b-dot controller back to a non-working b-dot controller. |
|  | The above method can also be simplified to the equation below:  A group of mathematical equations  AI-generated content may be incorrect.  LMN are the torques on each xyz axis respectively. |
|  | Started writing my block diagram using the new non-iterative b-dot controller |
|  | Started writing the logical flowchart. |
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