
```
%%variables

clc
close all
clear
syms x y z roll pitch yaw

syms t

syms weapon_location

tic
%weapon_vel = diff(weapon_location,t);

global state state_dot state_ddot
syms x_dot y_dot z_dot roll_dot pitch_dot yaw_dot weapon_dot
syms x_ddot y_ddot z_ddot roll_ddot pitch_ddot yaw_ddot weapon_ddot

state = [x y z roll pitch yaw,weapon_location];
state_dot = [x_dot y_dot z_dot roll_dot pitch_dot yaw_dot weapon_dot];
state_ddot = [x_ddot y_ddot z_ddot roll_ddot pitch_ddot yaw_ddot
    weapon_ddot];

%%robot constants
chassis_length = 0.6; %real
chassis_width = 0.6; %real
weapon_offset = 0.2;
wheel_radius = 0.1; %estimate
weapon_height = wheel_radius;
weapon_mass = 33; %real
weapon_radius = 0.085; %real

chassis_mass = 80; %real
%robot point mass
%weapon point mass

%%Trust me this was best way to do it
first = [1, 0, 0;...
    0, cos(roll), -sin(roll);...
    0, sin(roll), cos(roll)];

second = [cos(pitch) 0 sin(pitch)
    0 1 0;
    -sin(pitch) 0 cos(pitch)];
third = [cos(yaw) -sin(yaw) 0;
    sin(yaw) cos(yaw) 0
    0 0 1];
```

```

%%ZYX order
matrix = third *second * first; %ditched pitch its annoying
global world_to_robot robot_to_weapon wep_front_transform
wep_back_transform
world_to_robot = [[matrix;0,0,0],[x;y;z;1]];
robot_to_weapon = [[transform(pi/2,0,0);0,0,0],[weapon_offset;0;0;1]];

weapon_spin = [cos(weapon_location) -sin(weapon_location) 0;
sin(weapon_location) cos(weapon_location) 0
0 0 1];

weapon_to_front_tip = [[weapon_spin;0,0,0],[0;0;0;1]] *
[[eye(3);0,0,0],[weapon_radius;0;0;1]];
wep_front_transform = world_to_robot * robot_to_weapon *
wep_to_front_tip;
weapon_to_back_tip = [[weapon_spin;0,0,0],[0;0;0;1]] *
[[eye(3);0,0,0],[-weapon_radius;0;0;1]];
wep_back_transform = world_to_robot * robot_to_weapon *
wep_to_back_tip;

global jacob_weapon_front
global jacob_weapon_back
global jacob_chassis
jacob_weapon_front = jacobian(wep_front_transform * [0;0;0;1], state);
jacob_weapon_back = jacobian(wep_back_transform * [0;0;0;1], state);

jacob_chassis = jacobian(world_to_robot * [0;-0;0;1], state);

state_pos = [1,0,wheel_radius+0.1, -0.3,0,0, pi/2];
state_vel = [0,0,0, 0,0,0, 0];

[k1,p1] =
Dynamics(jacob_chassis,world_to_robot,chassis_mass,state_dot);
[k2,p2] =
Dynamics(jacob_weapon_front,wep_front_transform,weapon_mass/2,state_dot);
[k3,p3] =
Dynamics(jacob_weapon_back,wep_back_transform,weapon_mass/2,state_dot);

disp('After energy')
toc

Lagrange = simplify(k1 + k2 + k3 - p1 -p2 - p3);

syms x_t(t) y_t(t) z_t(t) roll_t(t) pitch_t(t) yaw_t(t) weapon_location_t(t)
state_t = [x_t(t) y_t(t) z_t(t) roll_t(t) pitch_t(t) yaw_t(t)
weapon_location_t(t)];
Lagrange_dstate = jacobian(Lagrange,state);
Lagrange_dstate_dot = jacobian(Lagrange,state_dot);

torque = diff(subs(Lagrange_dstate_dot,[state,state_dot],
[state_t,diff(state_t,t)])) -...

```

```

        subs(Lagrange_dstate,[state,state_dot],
[state_t,diff(state_t,t)]);
torque = subs(torque,diff(diff(state_t,t),t),state_ddot);
torque = transpose(simplify(subs(torque,[state_t,diff(state_t,t)],
[state,state_dot])));
disp('After torque')
toc
M = [
simplify(torque - subs(torque,state_ddot(1),0)),...
simplify(torque - subs(torque,state_ddot(2),0)),...
simplify(torque - subs(torque,state_ddot(3),0)),...
simplify(torque - subs(torque,state_ddot(4),0)),...
simplify(torque - subs(torque,state_ddot(5),0)),...
simplify(torque - subs(torque,state_ddot(6),0)),...
simplify(torque - subs(torque,state_ddot(7),0))];

m = subs(M,state_ddot,[1,1,1,1,1,1,1]);

G = subs(torque,[state_dot,state_ddot],[0,0,0,0,0,0,0,
0,0,0,0,0,0]);

c = simplify(torque - m* transpose(state_ddot) - G);

global m_matrix cqdot_matrix g_matrix robot_transform
m_matrix = matlabFunction(m);%magic function I needed the whole time
cqdot_matrix = matlabFunction(c);
g_matrix = matlabFunction(G);
robot_transform = matlabFunction(world_to_robot);

disp('After matlab function')
toc

%Visualiziation setup
global chassis
chassis = [[-chassis_width/2,-chassis_length/2,0,1];...
[-chassis_width/2,chassis_length/2,0,1];...
[chassis_width/2,chassis_length/2,0,1];...
[chassis_width/2,-chassis_length/2,0,1]];
wheel_angle = pi/6;
global left_wheel right_wheel
left_wheel = [[0,-chassis_width/2,0,1];...%center
[-wheel_radius*sin(wheel_angle),-chassis_width/2,-
wheel_radius*cos(wheel_angle),1];...%forward
[0,-chassis_width/2,-wheel_radius*cos(0),1];...%middle
[wheel_radius*sin(wheel_angle),-chassis_width/2,-
wheel_radius*cos(wheel_angle),1];...%backward
[0,-chassis_width/2,0,1]]; %center
right_wheel = [[0,chassis_width/2,0,1];...%center
[-wheel_radius*sin(wheel_angle),chassis_width/2,-
wheel_radius*cos(wheel_angle),1];...%forward
[0,chassis_width/2,-wheel_radius*cos(0),1];...%middle
[wheel_radius*sin(wheel_angle),chassis_width/2,-
wheel_radius*cos(wheel_angle),1];...%backward

```

```

        [0,chassis_width/2,0,1]]; %center
%wheel_points = subs(world_to_robot *
    transpose([left_wheel;right_wheel]),state,state_pos);

wheel_points = world_to_robot * transpose([left_wheel;right_wheel]);

left_point = wheel_points(1:3,3);
right_point = wheel_points(1:3,8);
left_point_vel = jacobian(left_point,state) * transpose(state_dot)
left_z_vel = left_point_vel(3)
right_point_vel = jacobian(right_point,state) * transpose(state_dot)
right_z_vel = right_point_vel(3)

global right_compute left_compute z_dot_compute roll_dot_compute
right_compute = matlabFunction(right_z_vel)
left_compute = matlabFunction(left_z_vel)

syms left_vel right_vel
solution = solve([left_vel == left_z_vel,right_vel == right_z_vel],
    [z_dot,roll_dot])

z_dot_compute = matlabFunction(solution.z_dot)
roll_dot_compute = matlabFunction(solution.roll_dot)

tf = 1;

[T,X] = ode45(@(t,x)BattleBotODE(t,x),[0 tf],[state_pos,state_vel]);
disp('After ODE')
toc

figure('Name','Positions red is x');
plot(T, X(:,1),'r-');
hold on
plot(T, X(:,2),'b-');
hold on
plot(T, X(:,3),'g-');
hold on

figure('Name','Angles red is yaw');
plot(T, mod(X(:,6),2*pi),'r-');
hold on
plot(T, mod(X(:,5),2*pi),'b-');
hold on
plot(T, mod(X(:,4),2*pi),'g-');
hold on

frames_total = [];
frames_used = [];

% create the video writer with 1 fps
writerObj = VideoWriter(char(string(now)+'.avi'));
writerObj.FrameRate = 3;
% set the seconds per image
% open the video writer

```

```

video = false;
if video
    open(writerObj);

    for t = 1:size(T)
        if(T(t,1)>0.01 )%&& mod(t,10) ==0)
            frame = visualize_bot(X(t,:),t);
            T(t,1)
            res = size(frame.cdata);
            frames_total = [frames_total;frame];

            whos __ writerObj frames_total frames_used
            if(res(1) == 530 && res(2) == 510)
                frames_used = [frames_used;frame];
                writeVideo(writerObj, frame)
            end
            close all
        end
    end

    % close the writer object
    close(writerObj);
end

```

After energy
 Elapsed time is 6.217223 seconds.
 After torque
 Elapsed time is 20.055743 seconds.
 After matlab function
 Elapsed time is 24.858355 seconds.

left_point_vel =

```

x_dot - pitch_dot*((cos(pitch)*cos(roll)*cos(yaw))/10
+ (3*cos(pitch)*cos(yaw)*sin(roll))/10) -
roll_dot*((cos(roll)*sin(yaw))/10 + (3*sin(roll)*sin(yaw))/10
- (cos(yaw)*sin(pitch)*sin(roll))/10 +
(3*cos(roll)*cos(yaw)*sin(pitch))/10) +
yaw_dot*((3*cos(roll)*cos(yaw))/10 - (cos(yaw)*sin(roll))/10
+ (cos(roll)*sin(pitch)*sin(yaw))/10 +
(3*sin(pitch)*sin(roll)*sin(yaw))/10)
y_dot - pitch_dot*((3*cos(pitch)*sin(roll)*sin(yaw))/10
+ (cos(pitch)*cos(roll)*sin(yaw))/10) +
roll_dot*((cos(roll)*cos(yaw))/10 + (3*cos(yaw)*sin(roll))/10
- (3*cos(roll)*sin(pitch)*sin(yaw))/10
+ (sin(pitch)*sin(roll)*sin(yaw))/10) -
yaw_dot*((sin(roll)*sin(yaw))/10 - (3*cos(roll)*sin(yaw))/10
+ (3*cos(yaw)*sin(pitch)*sin(roll))/10 +
(cos(roll)*cos(yaw)*sin(pitch))/10)

```

```

        z_dot - roll_dot*((3*cos(pitch)*cos(roll))/10
- (cos(pitch)*sin(roll))/10) + pitch_dot*((cos(roll)*sin(pitch))/10 +
(3*sin(pitch)*sin(roll))/10)

```

```

left_z_vel =

```

```

z_dot - roll_dot*((3*cos(pitch)*cos(roll))/10 -
(cos(pitch)*sin(roll))/10) + pitch_dot*((cos(roll)*sin(pitch))/10 +
(3*sin(pitch)*sin(roll))/10)

```

```

right_point_vel =

```

```

x_dot - pitch_dot*((cos(pitch)*cos(roll)*cos(yaw))/10
- (3*cos(pitch)*cos(yaw)*sin(roll))/10)
+ roll_dot*((3*sin(roll)*sin(yaw))/10 -
(cos(roll)*sin(yaw))/10 + (cos(yaw)*sin(pitch)*sin(roll))/10
+ (3*cos(roll)*cos(yaw)*sin(pitch))/10) -
yaw_dot*((3*cos(roll)*cos(yaw))/10 + (cos(yaw)*sin(roll))/10
- (cos(roll)*sin(pitch)*sin(yaw))/10 +
(3*sin(pitch)*sin(roll)*sin(yaw))/10)
y_dot + pitch_dot*((3*cos(pitch)*sin(roll)*sin(yaw))/10
- (cos(pitch)*cos(roll)*sin(yaw))/10) +
roll_dot*((cos(roll)*cos(yaw))/10 - (3*cos(yaw)*sin(roll))/10
+ (3*cos(roll)*sin(pitch)*sin(yaw))/10
+ (sin(pitch)*sin(roll)*sin(yaw))/10) -
yaw_dot*((3*cos(roll)*sin(yaw))/10 + (sin(roll)*sin(yaw))/10
- (3*cos(yaw)*sin(pitch)*sin(roll))/10 +
(cos(roll)*cos(yaw)*sin(pitch))/10)

```

```

        z_dot + roll_dot*((3*cos(pitch)*cos(roll))/10
+ (cos(pitch)*sin(roll))/10) + pitch_dot*((cos(roll)*sin(pitch))/10 -
(3*sin(pitch)*sin(roll))/10)

```

```

right_z_vel =

```

```

z_dot + roll_dot*((3*cos(pitch)*cos(roll))/10 +
(cos(pitch)*sin(roll))/10) + pitch_dot*((cos(roll)*sin(pitch))/10 -
(3*sin(pitch)*sin(roll))/10)

```

```

right_compute =

```

```

    function_handle with value:

```

```

    @(pitch,pitch_dot,roll,roll_dot,z_dot)z_dot
+roll_dot.*(cos(pitch).*cos(roll).*(3.0./1.0e1)+cos(pitch).*sin(roll).*(1.0./1.0e1
sin(pitch).*sin(roll).*(3.0./1.0e1))

```

```

left_compute =

    function_handle with value:

        @(pitch,pitch_dot,roll,roll_dot,z_dot)z_dot-
        roll_dot.*(cos(pitch).*cos(roll).*(3.0./1.0e1)-
        cos(pitch).*sin(roll).*(1.0./1.0e1))+pitch_dot.*(cos(roll).*sin(pitch).*(1.0./1.0e1)

solution =

    struct with fields:

        z_dot: [1x1 sym]
        roll_dot: [1x1 sym]

z_dot_compute =

    function_handle with value:

        @(left_vel,pitch,pitch_dot,right_vel,roll)
        (left_vel.*cos(roll).*(1.0./2.0)+right_vel.*cos(roll).*(1.0./2.0)+left_vel.*sin(roll)
        right_vel.*sin(roll).*(1.0./6.0)-
        pitch_dot.*cos(roll).^2.*sin(pitch).*(1.0./1.0e1)-
        pitch_dot.*sin(pitch).*sin(roll).^2.*(1.0./1.0e1))./cos(roll)

roll_dot_compute =

    function_handle with value:

        @(left_vel,pitch,pitch_dot,right_vel,roll)
        (left_vel.*(-5.0./3.0)+right_vel.*(5.0./3.0)+pitch_dot.*sin(pitch).*sin(roll))./(
        cos(pitch).*cos(roll))

```

Defining Functions

```

function dx = BattleBotODE(t,x)

    state_pos = x(1:7);
    state_vel = x(8:14);
    %x y z roll pitch yaw
    global left_wheel right_wheel
    global m_matrix cqdot_matrix g_matrix robot_transform
    world_to_robot =
    robot_transform(state_pos(5),state_pos(4),state_pos(1),state_pos(2),state_pos(6),
    Mmat =
    m_matrix(state_pos(5),state_pos(4),state_pos(7),state_pos(6));
    G_matrix = g_matrix(state_pos(5));
    %(roll,roll_dot,weapon_dot,weapon_location,yaw,yaw_dot)

```

```

        cq =
        cqdot_matrix(state_pos(5),state_vel(5),state_pos(4),state_vel(4),...

state_vel(7),state_pos(7),state_pos(6),state_vel(6));

        goal_vels = [0,0]; %left, right
        wheel_points = world_to_robot *
transpose([left_wheel;right_wheel]);

        before_tau = Mmat\(-cq - G_matrix );

        global right_compute left_compute z_dot_compute
roll_dot_compute
        offset = [0;0;0;0;0;0;0;0];

        l_vel = left_compute(x(5),x(12),x(4),x(11),x(10));
        r_vel = right_compute(x(5),x(12),x(4),x(11),x(10));

        [straight, turn, weapon] = control(state_pos,state_vel,t);
        straight_real = 0;
        turn_real = 0;

        if(min(wheel_points(3,1:5)) > 0)
            %left wheel off ground
        else
            %left wheel on ground
            straight_real = straight_real + straight/2;
            turn_real = turn_real + turn/2;
            offset(3) = offset(3) - before_tau(3)/1.9;
            l_vel = 0 + min(wheel_points(3,1:5))*100;%stop moving it
        end
        if(min(wheel_points(3,6:10)) > 0)
            %right wheel off ground
        else
            %right wheel on ground
            straight_real = straight_real + straight/2;
            turn_real = turn_real + turn/2;
            offset(3) = offset(3) - before_tau(3)/1.9;
            r_vel = 0 + min(wheel_points(3,6:10))*100; %stop moving it
        end
        tau = [cos(state_pos(6)) * straight_real ;sin(state_pos(6)) *
straight_real;...
        0;0;0;turn_real;weapon];
        z_dot = z_dot_compute(l_vel,x(5),x(12),r_vel,x(4));
        roll_dot = roll_dot_compute(l_vel,x(5),x(12),r_vel,x(4));

        t
        dx=zeros(14,1);
        dx(1:7) = state_vel;
        dx(8:14) = before_tau + Mmat\tau ;%+ offset;
        dx(10) = z_dot;
        dx(11) = roll_dot;
        dx(5) = 0;

```

```

        dx(12) = 0;
    end
    function [straight, turn, weapon] = control(state,dstate,t)
        weapon = 0;
        turn = 0;
        straight = 0;
        if(dstate(7) < 1000)
            weapon = 200000;
        end
        if(dstate(6) < 0.5)
            turn = 100;
        end
    end
    end
    function frame = visualize_bot(x,t)
        global state
        global world_to_robot robot_to_weapon wep_front_transform
wep_back_transform
        global left_wheel right_wheel
        global chassis

        disp('start');

        state_pos = x(1:7);
        state_vel = x(8:14);

        wheel_points = subs(world_to_robot *
transpose([left_wheel;right_wheel]),state,state_pos);

        chassis_corners = subs(world_to_robot *
transpose(chassis),state,state_pos);
        weapon_point = subs(world_to_robot * robot_to_weapon *
[0;0;0;1],state,state_pos);
        front_tip = subs(wep_front_transform *
[0;0;0;1],state,state_pos);
        back_tip = subs(wep_back_transform *
[0;0;0;1],state,state_pos);

        fig = figure('Name','Visualize robot ' + string(t),'position',
[0, 0, 500, 500]);
        disp('chassis');

        plot3([chassis_corners(1,:),chassis_corners(1,1)],
[chassis_corners(2,:),chassis_corners(2,1)],
[chassis_corners(3,:),chassis_corners(3,1)])
        hold on

        plot3([chassis_corners(1,4),weapon_point(1),chassis_corners(1,3)]...
,
[chassis_corners(2,4),weapon_point(2),chassis_corners(2,3)],...
[chassis_corners(3,4),weapon_point(3),chassis_corners(3,3)])

```

```

        hold on
        weapon = [back_tip,front_tip]
        disp('weapon');
        plot3(weapon(1,:),weapon(2,:),weapon(3,:));
        disp('wheel');
        hold on
        plot3(wheel_points(1,:),wheel_points(2,:),wheel_points(3,:))
        disp('limits');
        % daspect([1 1 1])
        xlim([-0.2 1.5])
        ylim([-0.6 0.6])
        zlim([0 0.5])
        disp('pixels');
        set(gca,'units','pixels','position',[0,0,500,500])
        set(gcf,'units','pixels','position',[0,0,500,500])
        disp('frame');
        frame = getframe(fig);
    end

```

$t =$

0

$t =$

$3.8173e-11$

$t =$

$5.7259e-11$

$t =$

$1.5269e-10$

$t =$

$1.6966e-10$

$t =$

$1.9086e-10$

$t =$

$1.9086e-10$

$$t = 3.8173e-10$$

$$t = 4.7716e-10$$

$$t = 9.5432e-10$$

$$t = 1.0391e-09$$

$$t = 1.1452e-09$$

$$t = 1.1452e-09$$

$$t = 2.0995e-09$$

$$t = 2.5767e-09$$

$$t = 4.9624e-09$$

$$t = 5.3866e-09$$

$$t = 5.9168e-09$$

$t =$

$5.9168e-09$

$t =$

$1.0688e-08$

$t =$

$1.3074e-08$

$t =$

$2.5003e-08$

$t =$

$2.7124e-08$

$t =$

$2.9775e-08$

$t =$

$2.9775e-08$

$t =$

$5.3633e-08$

$t =$

$6.5561e-08$

$t =$

$1.2521e-07$

$t =$

1.3581e-07

$t =$

1.4906e-07

$t =$

1.4906e-07

$t =$

2.6835e-07

$t =$

3.2800e-07

$t =$

6.2622e-07

$t =$

6.7924e-07

$t =$

7.4551e-07

$t =$

7.4551e-07

$t =$

1.3420e-06

$t =$

1.6402e-06

$t =$

3.1313e-06

$t =$

3.3964e-06

$t =$

3.7277e-06

$t =$

3.7277e-06

$t =$

6.7100e-06

$t =$

8.2011e-06

$t =$

1.5657e-05

$t =$

1.6982e-05

$t =$

1.8639e-05

$t =$

1.8639e-05

$t =$

3.3550e-05

$t =$

$4.1006e-05$

$t =$

$7.8284e-05$

$t =$

$8.4911e-05$

$t =$

$9.3195e-05$

$t =$

$9.3195e-05$

$t =$

$1.6775e-04$

$t =$

$2.0503e-04$

$t =$

$3.9142e-04$

$t =$

$4.2455e-04$

$t =$

$4.6597e-04$

$t =$

$4.6597e-04$

$t =$
 $8.3875e-04$

$t =$
 0.0010

$t =$
 0.0020

$t =$
 0.0021

$t =$
 0.0023

$t =$
 0.0023

$t =$
 $5.8370e-04$

$t =$
 $6.4256e-04$

$t =$
 $9.3686e-04$

$t =$
 $9.8918e-04$

$t =$
 0.0011

$t =$

0.0011

$t =$

$5.2484e-04$

$t =$

$5.5427e-04$

$t =$

$7.0142e-04$

$t =$

$7.2758e-04$

$t =$

$7.6028e-04$

$t =$

$7.6028e-04$

$t =$

$8.1914e-04$

$t =$

$8.4857e-04$

$t =$

$9.9572e-04$

$t =$

0.0010

$t =$

0.0011

$t =$

0.0011

$t =$

7.8981e-04

$t =$

8.0457e-04

$t =$

8.7840e-04

$t =$

8.9152e-04

$t =$

9.0793e-04

$t =$

9.0793e-04

$t =$

9.3746e-04

$t =$

9.5222e-04

$t =$

0.0010

$t =$

0.0010

$t =$

0.0011

$t =$

0.0011

$t =$

9.2551e-04

$t =$

9.3431e-04

$t =$

9.7827e-04

$t =$

9.8609e-04

$t =$

9.9586e-04

$t =$

9.9586e-04

$t =$

0.0010

$$t = 0.0010$$

$$t = 0.0011$$

$$t = 0.0011$$

$$t = 0.0011$$

$$t = 0.0011$$

$$t = 0.0012$$

$$t = 0.0012$$

$$t = 0.0014$$

$$t = 0.0015$$

$$t = 0.0015$$

$$t = 0.0015$$

$$t = 0.0020$$

$$t = 0.0022$$

$$t = 0.0033$$

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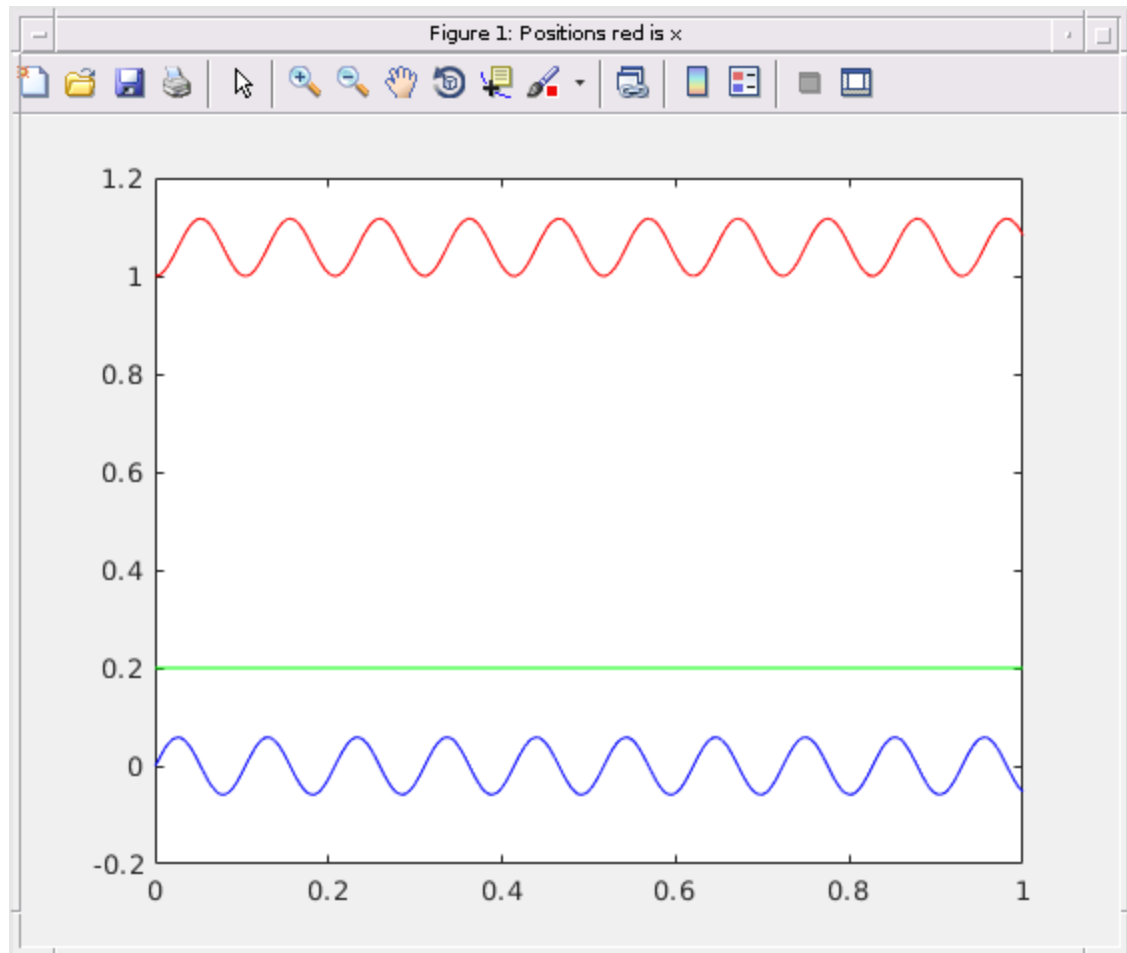
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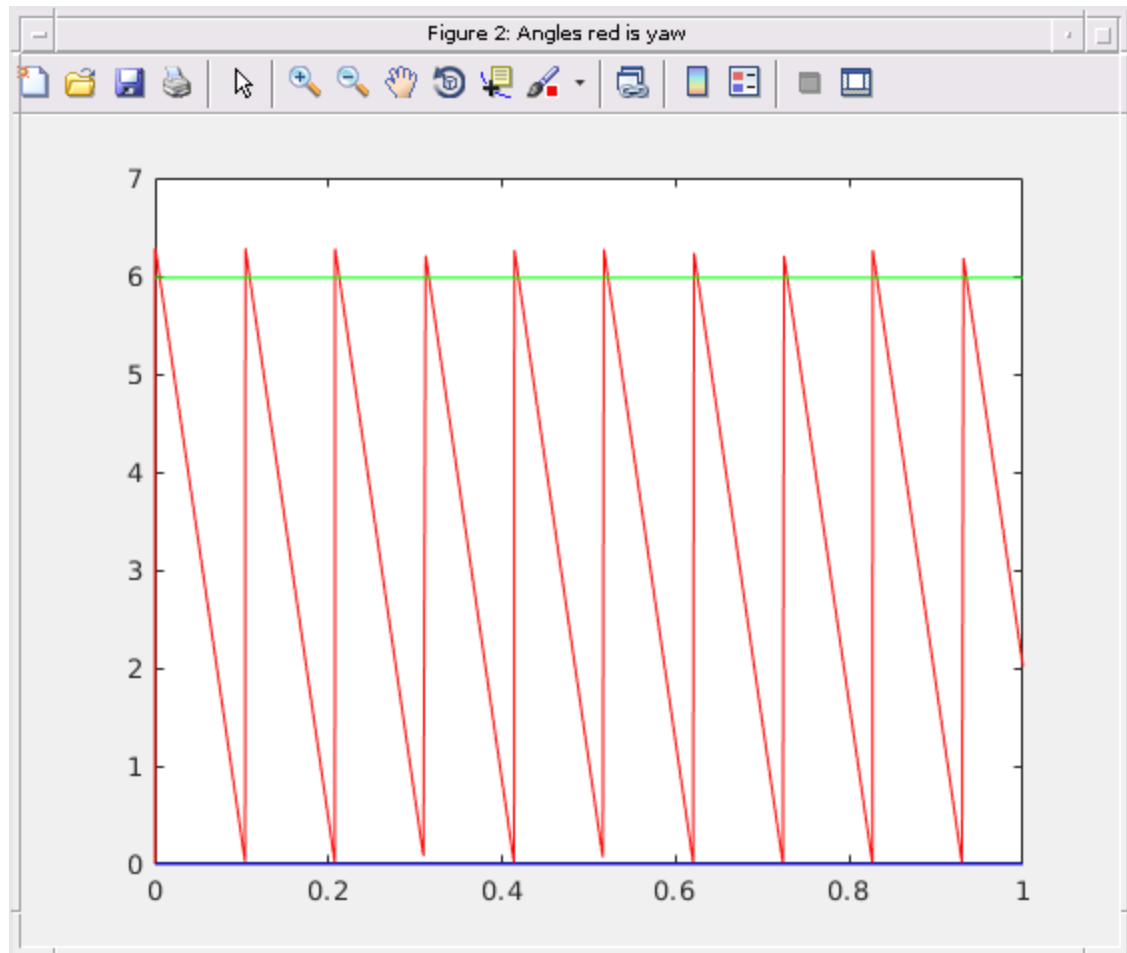
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After ODE

Elapsed time is 26.346086 seconds.





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