Homework 1

Simulation Engineering

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Helicopter simulation

Initial state specification:

- the moment of inertia of the helicopter in y axis $I_{yy} = 3800\ kgm^2$
- the initial yaw rate of the helicopter $\Theta'(0) = 0\ rad/s$
- the initial yaw of the helicopter $\Theta(0) = 0\ rad$
- the torque applied to helicopter $T_y(t) = 0{,}03t\ kgm^2/s^2$
- the initial simulation time $t = 0\ s$
- the simulation time step $\Delta t = 10\ ms$
- the angular velocity $\Theta''_y = T_y(t) / I_{yy}$

Based on the Euler's formula it is possible to calculate approximated values of yaw rate and yaw.

$$\frac{dx}{dt} = \frac{(t+\Delta t)-x(t)}{\Delta t}$$

```
#include <iostream>
#include <conio.h>
using namespace std;
int main() {
   double totalSymTime = 0;
   const double stepSize = 0.01;
   const double momentInertia = 3800;
   double yawRate = 0;
   double yaw = 0;
   while(totalSymTime <= 10){
      yawRate = ((0.3 * totalSymTime * stepSize) / momentInertia) + yawRate;
      yaw = yawRate * stepSize + yaw;
      cout << "Simulation Time = " << totalSymTime <<" | Yaw Rate = "<< yawRate << " | Yaw = " << yaw << endl;
      totalSymTime = totalSymTime + stepSize;
   }
   getch();
   return 0;
}
```

Simulation code.

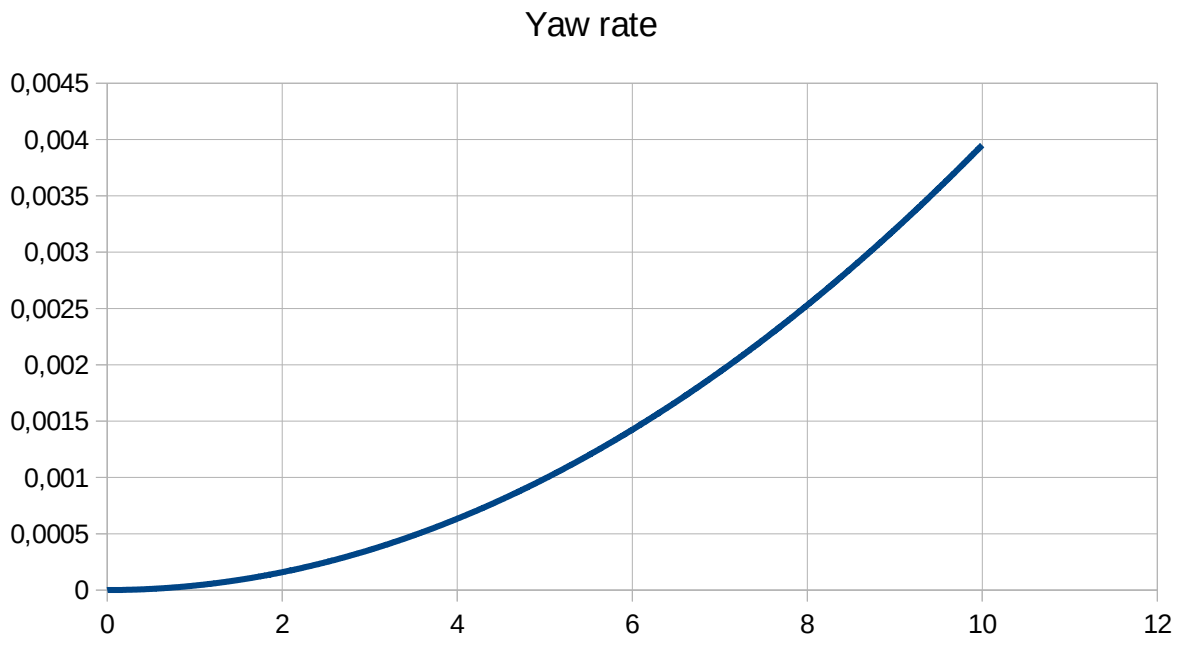
```
double totalSymTime = 0;
const double stepSize = 0.01;
const double momentInertia = 3800;
double yawRate = 0;
double yaw = 0;
```

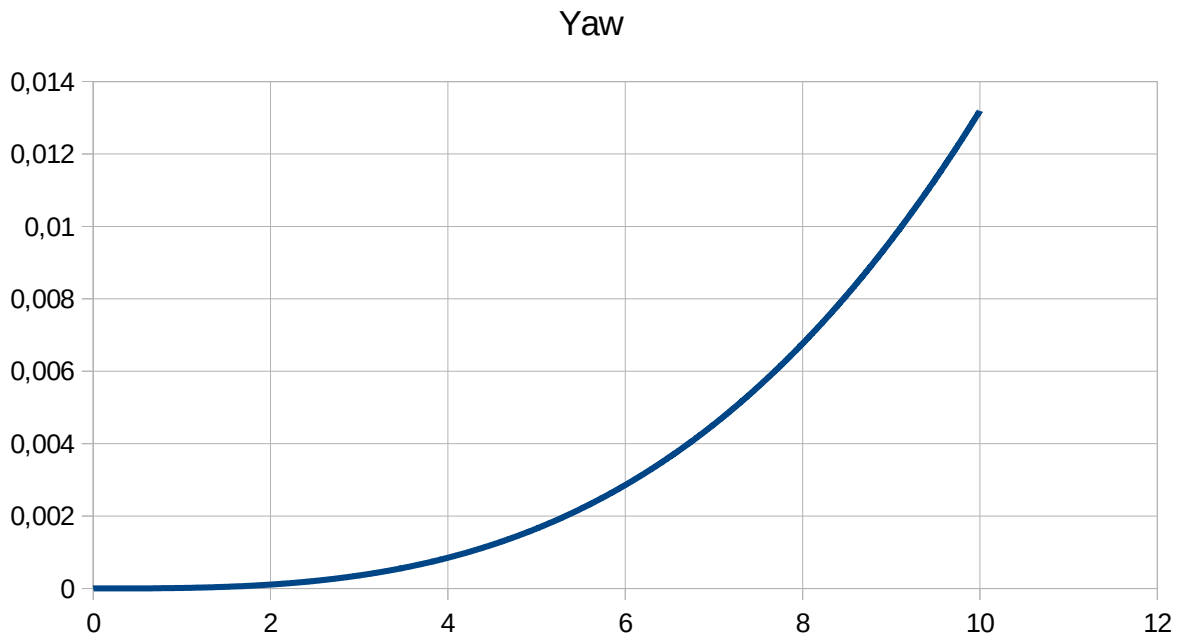
Initial parameters

```
while(totalSymTime <= 10){
   yawRate = ((0.3 * totalSymTime * stepSize) / momentInertia) + yawRate;
   yaw = yawRate * stepSize + yaw;
   cout << "Simulation Time = " << totalSymTime <<" | Yaw Rate = "<< yawRate << " | Yaw = " << yaw << endl;
   totalSymTime = totalSymTime + stepSize;
}
```

Simulation loop

The outputs of simulation are very small which means that the helicopter is working correctly. With the data we gathered from the program it is possible to plot yaw rate and yaw both with the simulation time.





Console output of the simulation:

Simulation Time = 0 | Yaw Rate = 0 | Yaw = 0

Simulation Time = 1 | Yaw Rate = 3.98684e-05 | Yaw = 1.35553e-05

Simulation Time = 2 | Yaw Rate = 0.000158684 | Yaw = 0.000106847

Simulation Time = 3 | Yaw Rate = 0.000356447 | Yaw = 0.000358824

Simulation Time = 4 | Yaw Rate = 0.000633158 | Yaw = 0.000848432

Simulation Time = 5 | Yaw Rate = 0.000988816 | Yaw = 0.00165462

Simulation Time = 6 | Yaw Rate = 0.00142342 | Yaw = 0.00285633

Simulation Time = 7 | Yaw Rate = 0.00193697 | Yaw = 0.00453252

Simulation Time = 8 | Yaw Rate = 0.00252947 | Yaw = 0.00676213

Simulation Time = 9 | Yaw Rate = 0.00320092 | Yaw = 0.0096241

Simulation Time = 10 | Yaw Rate = 0.00395132 | Yaw = 0.0131974

These are only 10 seconds taken from the console since putting all of the outputs would make document too long.