TTK4190 - Assignment 3

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1 Part 3: Speed Control

1.1 Problem 1: Propeller Revolution and Speed Control

1.1.1 Problem 1a

After using the wageningen-function, the updated values are $K_T = 0.6367$ and $K_Q = 0.1390$

1.1.2 Problem 1b

The code is updated to include the dynamics of the prime mover system with the following equations.

$$\frac{Q_m}{Y}(s) = \frac{K}{Ts+1} \tag{1}$$

$$\dot{Q_m} = -\frac{Q_m}{T} + \frac{K}{t}(m_c - n) \tag{2}$$

The shaft speed dynamics $\dot{n}$ is also updated, and the code is shown below.

$$\dot{n} = \frac{Q_m - Q - Q_f}{I_m} \tag{3}$$

1.1.3 Problem 1c

```
% propeller dynamics
Im = 100000; Tm = 10; Km = 0.6;             % propulsion parameters

% added feedforward
Td = U_d*Xu/(t_thr-1); % desired thrust (N)

n_term = Td/(rho * Dia^4 * KT);
n_d = sign(n_term) * sqrt(abs(n_term));     % desired propeller speed (rps)

Qf = 0;                                     % friction torque (Nm)
Qd =  rho * Dia^4 * KQ * abs(n_d) * n_d;    % desired propeller moment (Nm)
Y = Qd/Km;                                  % control input to main motor

Qm_dot = -Qm/Tm + Km/Tm*Y;
n_dot = (Qm-Q-Qf)/Im;

% store simulation data in a table (for testing)
simdata(i,:) = [t n_d Δ_c n Δ eta' nu' u_d psi_d r_d z];

% Euler integration
xd = euler2(xd_dot,xd,h);               % reference model
z = euler2(e_psi,z,h);                  % integral state
Qm = euler2(Qm_dot,Qm,h);
eta = euler2(eta_dot,eta,h);
nu  = euler2(nu_dot,nu,h);
Δ = euler2(Δ_dot,Δ,h);
n  = euler2(n_dot,n,h);
```

Listing 1: Full code propeller dynamics

1.1.4 Problem 1d

Assuming $u_r = u$, $\dot{u} = \dot{u_r} = 0$, $u = U$, $x_{\delta\delta}\delta^2 = 0$, U is given by

$$U = \frac{(t-1)T}{x_u} \tag{4}$$

1.2 Problem 1e

With the equation from the last problem we get

$$T_d = \frac{U_d x_u}{t-1} \tag{5}$$

and

$$n_{term} = \frac{T_d}{\rho * d^4 * K_T} \tag{6}$$

$$n_d = sign(n_{term})\sqrt{abs(n_{term})} \tag{7}$$

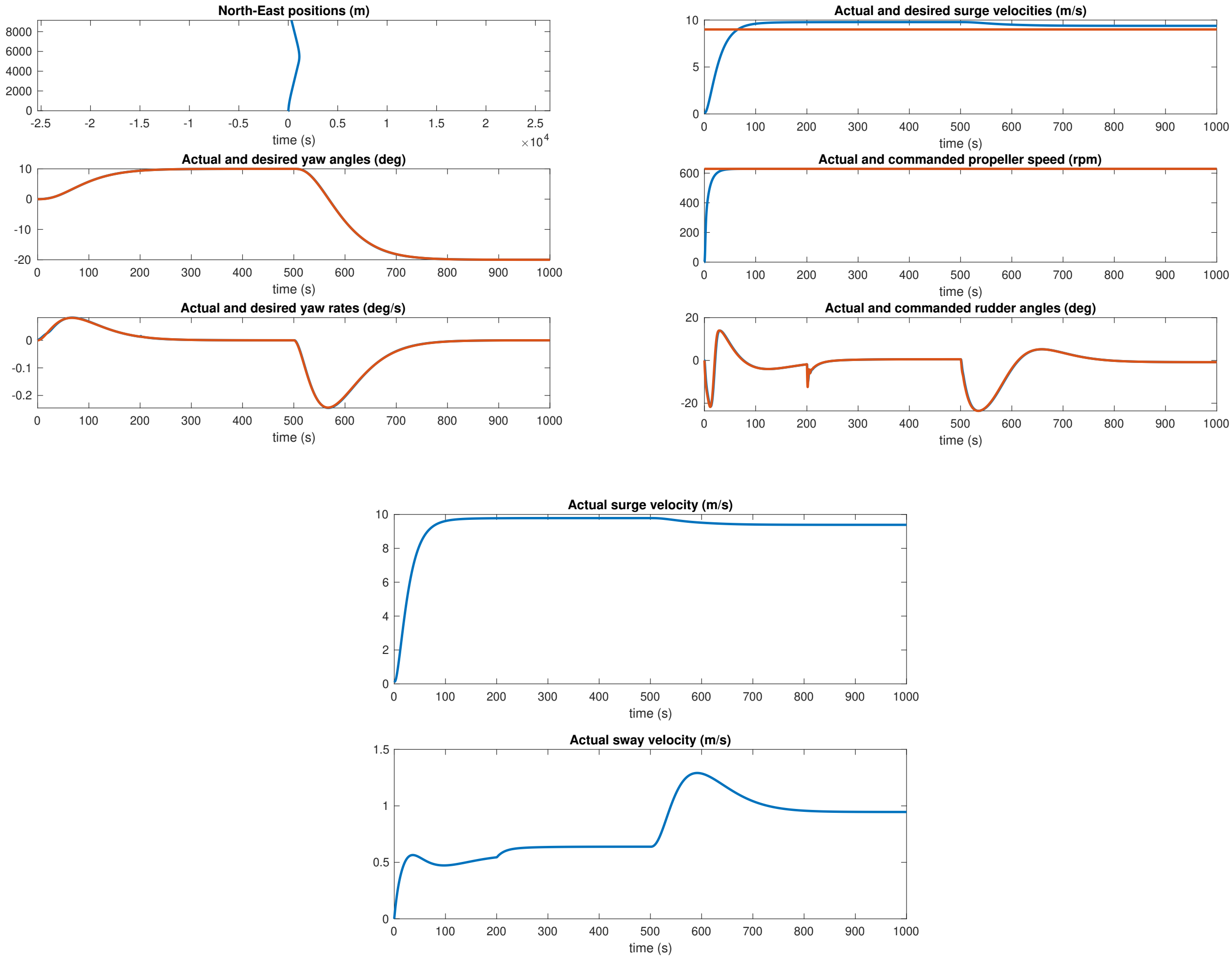

Figure 1: Ship behaviour with Propeller Revolution and Speed Control

No, we do not achieve the desired speed with constant heading angle. The surge velocity has a stationary error and does not reach the reference speed of $U_d = 9[m/s]$. This is because of the assumptions in the equation in problem 1d. To fix this we can add a feed-forward controller:

```
%Problem 1e: added feedforward
Td = (U_d-nu_c(1))*Xu/(t_thr-1);
```

Listing 2: Feed-forward

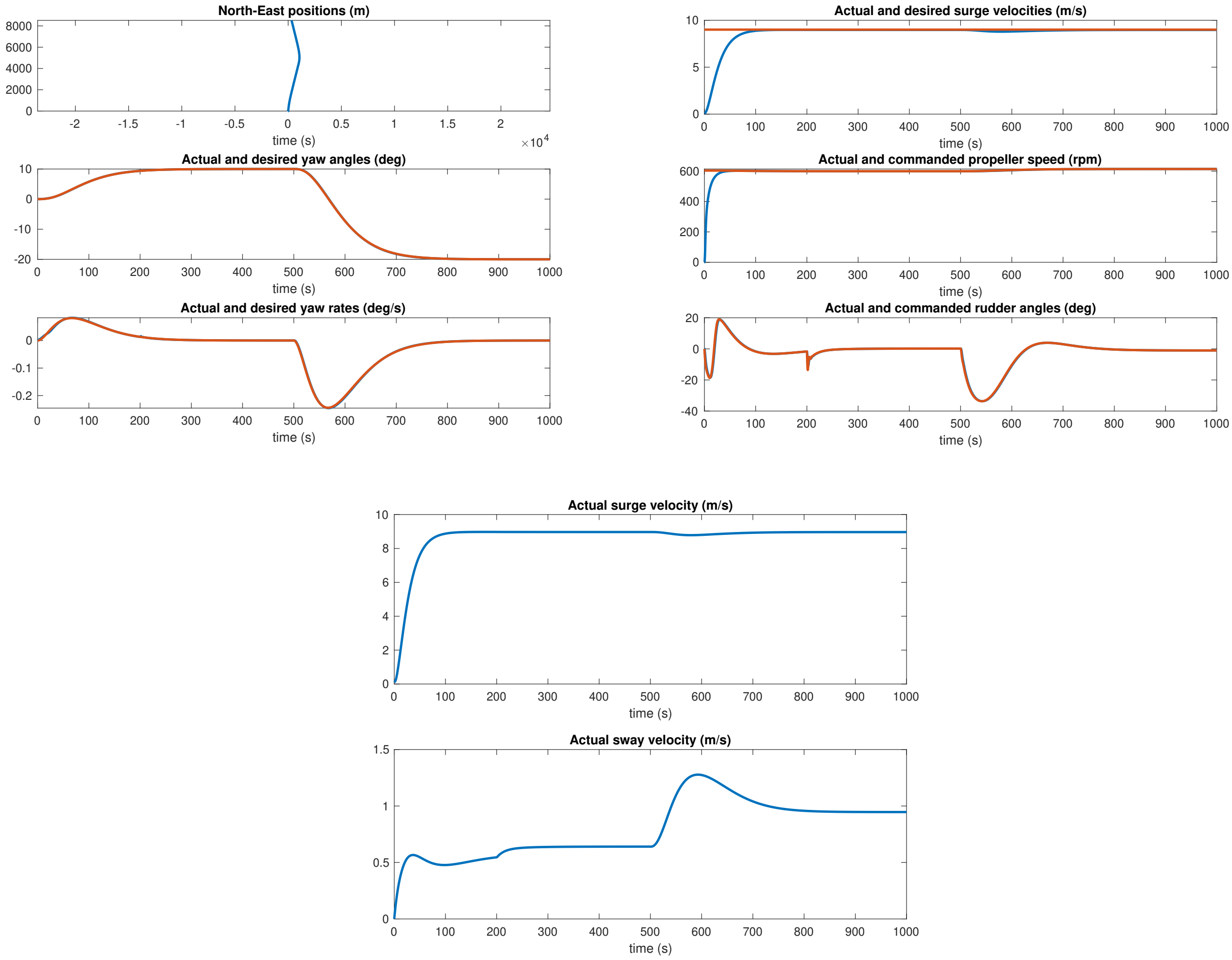

Figure 2: Ship behaviour with feed-forward

1.3 Problem 1f

Yes, with a $20[deg]$ setpoint change in heading, the speed will drop for a small period. This can be seen in figure 2. This is because of the sway velocity during the turn, so it need to be decomposed to be corrected to reference again.