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A Study on Ship's Automatic Track-keeping Control considering disturbance effect

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Abstract : 본 연구는 외란하에서 선박 트랙 키핑에 대한 수치시뮬레이션 문제를 다루었다. 이용된 선박 모델은 새누리호 선박을 이용하여, 목포항 입구부터, 목표 부두까지 항로에서의 항로 추종를 자동제어 기법을 이용하여 시뮬레이션 수행하였다. 기존 과거 연구의 선박 트랙 키핑 문제는 주로 정속에서 수행되었으나, 본 연구에서 부두에 접안하기 전 단계까지를 감안하여, 선박 속도를 저하시키며, 접안 하기 직전 선박이 목표 지점에 도달하여 정지할 때까지의 트랙 키핑 문제를 다루었다. 사용 제어 기법은 PID기법, 외란으로 바람 영향을 고려한 트랙키핑 시뮬레이션을 수행하였고, 그 결과 접안 직전 지점까지 적정하게 속도를 저하시키며, 원하는 항로를 따라 자동 제어 됨을 알 수 있었다.

Many researches have been conducted in the field of constructing controllers for ships over 20 years. But still, ship automatic track-keeping controllers has not been designed for ship's automatic berthing as they considered nearly constant ship's speed. This study dealt with this problem to design track-keeping control on ship's model of SAE NURI using nonlinear mathematical expression.

By using this control, the ship is auto track-kept in fare-way at reducing speed to anchorage place. The simulation results proved that this control can be adapted in ship's auto berthing in near future.

Keywords : Simulation, Track-keeping, PID control, Wind-effect, Non-linear expressions

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I. Introduction

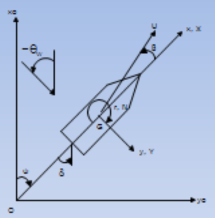
- In the field of maritime safety system, various reports have been given on the research of ship auto track keeping control and ship auto berthing control over a long time but they are all separated with each other.
- Previous researches on automatic track-keeping for ship recommended adaptive intelligent control for ship but they have considered nearly constant speed, which cannot be afforded in berthing circumstance.
- This study is carried out to design auto track keeping for berthing that's why we considered ship's low speed situation in track keeping to adapt with auto berthing system.

II. Ship mathematical model

$$(m + m_x)\dot{u} - (m + m_y)vr = X_H + X_P + X_R + X_W$$

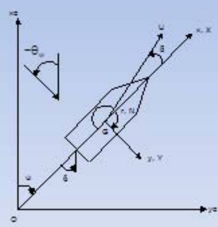
$$(m + m_y)\dot{v} - (m + m_x)ur = Y_H + Y_P + Y_R + Y_W$$

$$(I_{zz} + J_{zz})r = N_H + N_R + N_W$$



m : mass of ship
m_x, m_y : added mass in surge and sway direction.
u, v, r : surge and sway velocity and yaw rate.
J_{zz} : added mass moment of inertia.
I_{zz} : mass moment of inertia.
X_H, Y_H, N_H : hydrodynamic forces acting on ship's hull.
X_P, Y_P : hydrodynamic forces acting on ship's propeller.
X_R, Y_R, N_R : forces and moment due to rudder.
X_W, Y_W, N_W : forces and moment due to wind
$\dot{u}, \dot{v}$: acceleration in surge and sway direction .
$\dot{r}$: acceleration of yaw motion.
δ : rudder angle
Ψ : ship's heading

Model ship: SAE NURI



Coordinate system for ship dynamic

Type	Training ship
LOA	103[m
Lpp	94[m
Width	13.6[m
Draft	5.4[m
Thruster (bow)	49000N
Transverse proj. area	183.3[m2
Lateral projected area	1053.7[m2

III. Disturbance model

- *Wind coefficient:*

$$C_X = A_0 + A_1\frac{2A_L}{L_{OA}^2} + A_2\frac{2A_T}{B^2} + A_3\frac{L_{OA}}{B} + A_4\frac{S}{L_{OA}} + A_5\frac{C}{L_{OA}} + A_6 M$$

$$C_Y = B_0 + B_1\frac{2A_L}{L_{OA}^2} + B_2\frac{2A_T}{B^2} + B_3\frac{L_{OA}}{B} + B_4\frac{S}{L_{OA}} + B_5\frac{C}{L_{OA}} + B_6\frac{A_{SS}}{A_L}$$

$$C_N = C_0 + C_1\frac{2A_L}{L_{OA}^2} + C_2\frac{2A_T}{B^2} + C_3\frac{L_{OA}}{B} + C_4\frac{S}{L_{OA}} + C_5\frac{C}{L_{OA}}$$

Where

C_X : coefficient of fore and aft component of wind force.
C_Y : coefficient of lateral component of wind force.
C_N : coefficient of wind-induced yawing moment.
$A_0 \sim A_6$, $B_0 \sim B_6$, $C_0 \sim C_5$: Isherwood's coefficient for model

Wind force and moment

$$X_W = C_X \frac{1}{2} \rho V_R^2 A_T$$
$$Y_W = C_Y \frac{1}{2} \rho V_R^2 A_L$$
$$N_W = C_N \frac{1}{2} \rho V_R^2 A_L L_{OA}$$

When X_W : Fore and aft component of wind force.
Y_W : Lateral component of wind force.
N_W : Yawing moment
V_R : relative wind speed to ship

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Place taken into simulation

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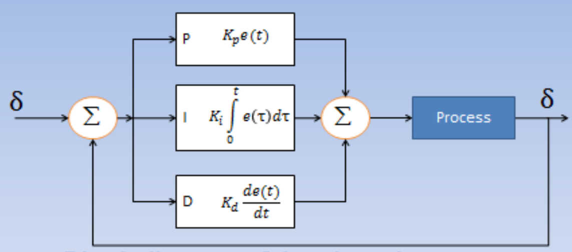
IV. Track-keeping control



Block diagram of the close-loop system using PID control

- K_p, K_d, K_i : gain for controller

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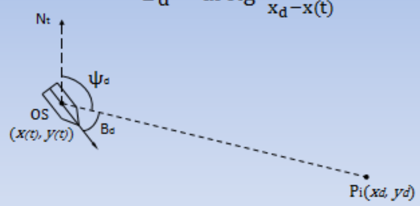
Calculation for ship's target heading angle

- The bearing to current waypoint will be calculated by :

$$B_d = \text{arctg} \frac{y_d - y(t)}{x_d - x(t)}$$



- Then the ship's target heading (ψ_d) be decided for proper quadrant of B_d

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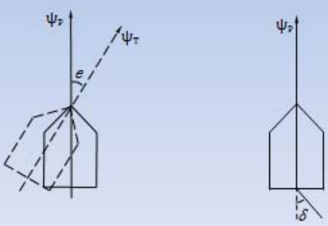
- $\delta = K_p.e(t) + K_d \frac{de(t)}{dt} + K_i \int_0^t e(\tau)d\tau$:designed-angle for rudder (degree)
- $e = (\psi_T - \psi_P)$: error between target heading and current heading angle (degree)



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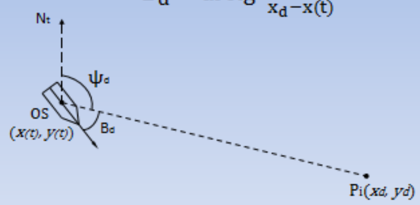
Calculation for ship's target heading angle

- The bearing to current waypoint will be calculated by :

$$B_d = \text{arctg} \frac{y_d - y(t)}{x_d - x(t)}$$



- Then the ship's target heading (ψ_d) be decided for proper quadrant of B_d

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Ship's speed change when keeping track

- From the beginning, ship speed is equal to 10 knots, propeller index is 2.75 rps. At the end of keeping track, ship's speed should be equal to 0 knots. (at waypoint No. 10)
- After reach waypoint one by one the propeller will be reduced for safe approaching to berthing place.
- The "Boosting effect" was added to improve rudder's effect. At low speed turning, it was used in a short time for increasing ship's turn rate.

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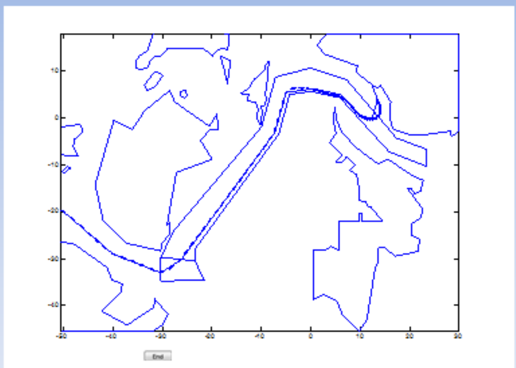
V. Simulation results



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VI. Conclusion & Discussion

1. Conclusion

- This study dealt with PID control method of ship track-keeping for berthing. The effect of track-keeping at low speed situation with "boosting effect" is acceptable according to simulation results.
- The ship can automatic keep track in port domain under wind condition at low speed, into anchorage place. This can be applied to auto berthing control in near future.

2. Future study

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