Documentation of path-following controller case

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Introduction

This document describes the Functional Mock-up Units (FMUs) necessary to run the simulation case of a vessel following waypoints (WPs) using line-of-sight (LOS) guidance principle [1]. The VesselFmu.fmu holds a model of the elongated R/V Gunnerus.

Model descriptions

Each component/FMU of the simulation case will be described in the following sections. Only relevant variables will be described for each FMU. The names of the simulation objects are given in the table below. For additional information about the individual FMUs and their variables, unpack the FMU and open the modelDescription.xml file.

Source FMU	Name	Description
TrajectoryController	trackController	Controls the speed and heading angle to make vessel follow path
WaypointProvider2DOF	wpProvider	Issues waypoints (target and previous) to controller
Converter	converter0, converter1	A simple unit conversion
ThrusterDrive	azimuth0_rpmActuator, azimuth1_rpmActuator	
PMAzimuth	azimuth0, azimuth1	
PowerPlant	powerPlant	
VesselFmu	vesselModel	

TrajectoryController.fmu

This FMU holds the controller functionality required in order to converge to a certain desired vessel speed and heading angle. The latter is calculated by the LOS guidance scheme and the aggressiveness may be altered by changing the input variable “lookaheadDistance” > 0. Otherwise, the convergence properties of the speed and heading angle to desired values are controlled by the Proportional-Integral-Derivative (PID) regulator parameters.

Name	I/O	Description
enable	I	Boolean variable. Outputs updated rudder/force commands only if true.
autopilot.heading.kp	I	Proportional gain for heading regulator
autopilot.heading.ki	I	Integral gain for heading regulator
autopilot.heading.kd	I	Derivative gain for heading regulator
autopilot.speed.kp	I	Proportional gain for speed regulator
autopilot.speed.ki	I	Integral gain for speed regulator
autopilot.speed.kd	I	Derivative gain for speed regulator
northPosition	I	North position of vessel [m]
eastPosition	I	East position of vessel [m]

surgeVelocity	I	Velocity of vessel in surge direction [m/s]
swayVelocity	I	Velocity of vessel in sway direction [m/s]
headingAngle	I	Heading angle of vessel [deg]
targetWP.north	I	North position of the target WP
targetWP.east	I	East position of the target WP
prevWP.north	I	North position of the previous WP
prevWP.east	I	East position of the previous WP
forceCommand	O	The force command requested from each of the two main thrusters [N]
rudderCommand	O	The azimuth angle of the two main thrusters [deg]

WaypointProvider2DOF.fmu

This FMU holds the positions (North/East) of the WPs. The TrajectoryController.fmu receives a target WP and a previous WP and tries to converge to the straight line between the two WP in the direction of the target WP. When the horizontal plane distance between the vessel and the target WP is less than the numerical value of the variable "wpSwitchDistance", the next WP in the list is assigned to the target WP and the previous target WP is assigned to the previous WP.

Name	**I/O**	**Description**
northPosition	I	North position of vessel [m]
eastPosition	I	East position of vessel [m]
headingAngle	I	Heading angle of vessel [deg]
mode	I	If mode = 1, the fmu accepts additional wps input at runtime to a list. If mode != 1, the fmu uses a list specified at initialization. Either a hardcoded list (packman shape) or a user-specified list will be used based on the numerical value of wp1. If wp1 is initialized to a value not equal to 0.0, the user-specified list is used.
wpSwitchDistance	I	The horizontal plane distance, between the target WP and the vessel, at which the WP list is incremented. Threshold for accepting a target WP as "reached".

Converter.fmu

This is a simple unit converter created to convert between radians per second, issued by ThrusterDrive.fmu -> Shaft.f, and Revolutions Per Minute (RPM), received by PMAzimuth.fmu -> input_act_revs.

Name	**I/O**	**Description**
input.radPerSec	I	Input frequency in radians per second
output.rpm	O	Output frequency in revolutions per minute

ThrusterDrive.fmu

Name	**I/O**	**Description**
d_in.e	I	
q_in.e	I	
ThrustCom	I	
Shaft.e	I	
d_in.f	O	
q_in.f	O	

Shaft.f	O	

PMAzimuth.fmu

Name	I/O	Description
input_enabled	I	
input_is_main_propulsion	I	
input_x_rel_ap	I	
input_y_rel_cl	I	
input_z_rel_bl	I	
input_prop_diam	I	
input_t	I	
input_distancetohull	I	
input_bilgeradius	I	
input_rho	I	
input_act_revs	I	
input_act_angle	I	
input_cg_x_rel_ap	I	
input_cg_y_rel_cl	I	
input_cg_z_rel_bl	I	
input_cg_surge_vel	I	
input_cg_sway_vel	I	
input_yaw_vel	I	
input_lpp	I	
output_force_heave	O	
output_force_surge	O	
output_force_sway	O	
output_x_rel_ap	O	
output_y_rel_cl	O	
output_z_rel_bl	O	

PowerPlant.fmu

Name	I/O	Description
p1.f[1]	I	
p1.f[2]	I	
p2.f[1]	I	
p2.f[2]	I	
p1.e[1]	O	
p1.e[2]	O	
p2.e[1]	O	
p2.e[2]	O	

VesselFmu.fmu

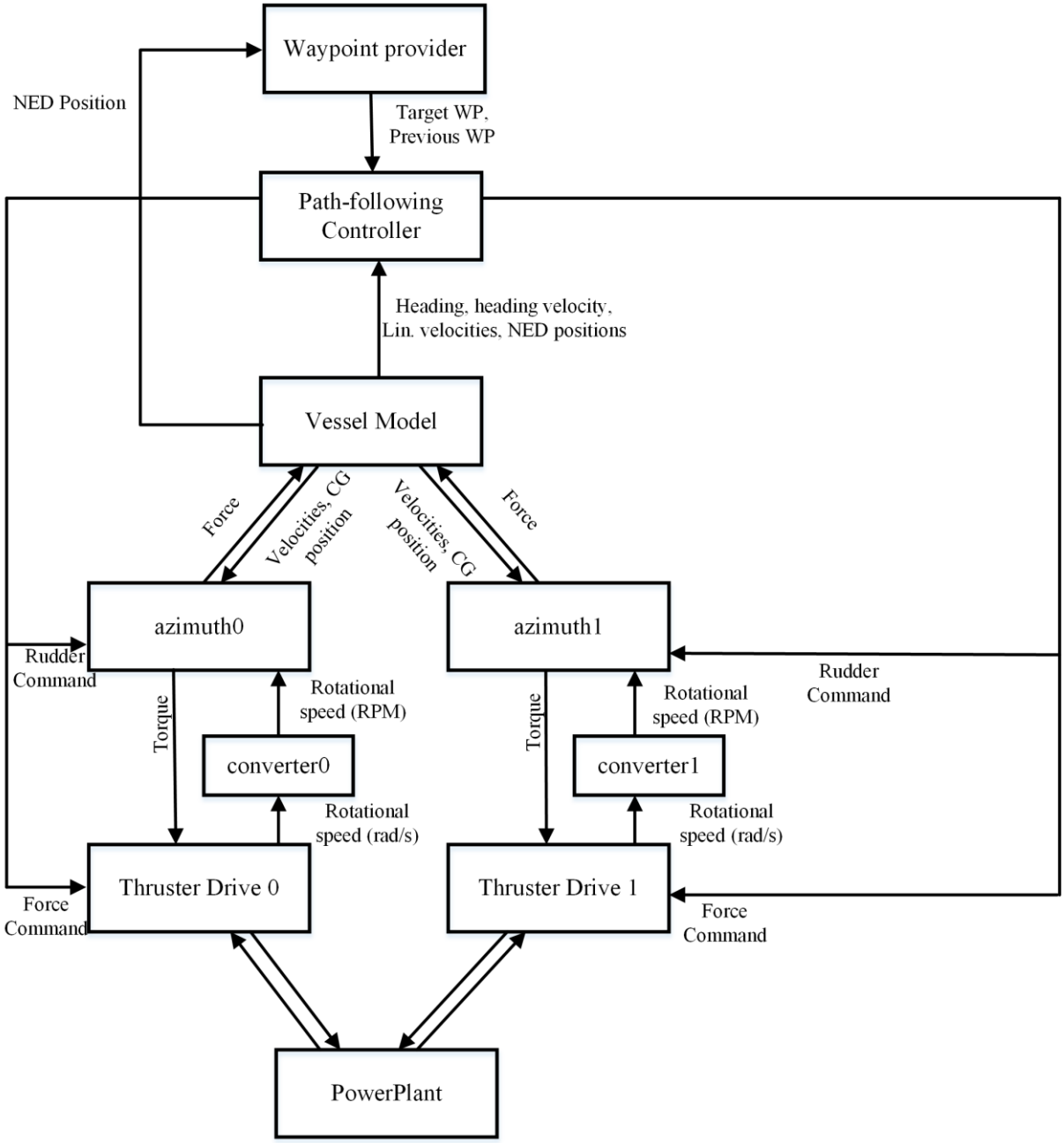
Holds the vessel model and models applying environmental forces onto the vessel.

Name	I/O	Description
vesselZipFile	I	Absolute path of vessel model zip archive
global_cur_dir	I	The direction of ocean current (0 is towards North) [deg]
global_cur_vel	I	The ocean current velocity [m/s]

input_global_wind_dir	I	The wind direction (0 is from North) [deg]
input_global_wind_vel	I	The wind velocity [m/s]
additionalBodyForce[0]	I	Magnitude (Newtons) of surge/sway/heave force produced by the port azimuth thruster and the point of attack of the force on the hull relative to AP/BL/CL.
additionalBodyForce[1]	I	Magnitude (Newtons) of surge/sway/heave force produced by the starboard azimuth thruster and the point of attack of the force on the hull relative to AP/BL/CL.
cgShipMotion.ned.north	O	North position of vessel (1st element of the "NED positions" vector in below figure)
cgShipMotion.ned.east	O	East position of vessel (2nd element of the "NED positions" vector in below figure)
cgShipMotion. angularDisplacement.yaw	O	Yaw angle of the vessel relative to north direction given in the below figure as the "heading" variable
cgShipMotion. angularVelocity.yaw	O	The angular velocity of the vessel about the yaw axis (deg/s)
cgShipMotion.linearVelocity	O	Components of the vessel velocity along the surge, sway and heave axes (m/s)
cg_x_rel_ap, cg_y_rel_cl, cg_z_rel_bl	O	Location of the center of gravity (CG) of the vessel relative to AP/BL/CL

FMU connections

The following figure visualizes the individual FMUs and their connections.



References

[1] T. I. Fossen, “Handbook of Marine Craft Hydrodynamics and Motion Control”, 2011, chapter 10