

Improved Usability in DP Tracking Operations

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Waypoint Tracking

- **Natural extension to ordinary DP functionality**
- **Controls the vessel along a track of predefined waypoints**
- **Different heading and speed control modes available**



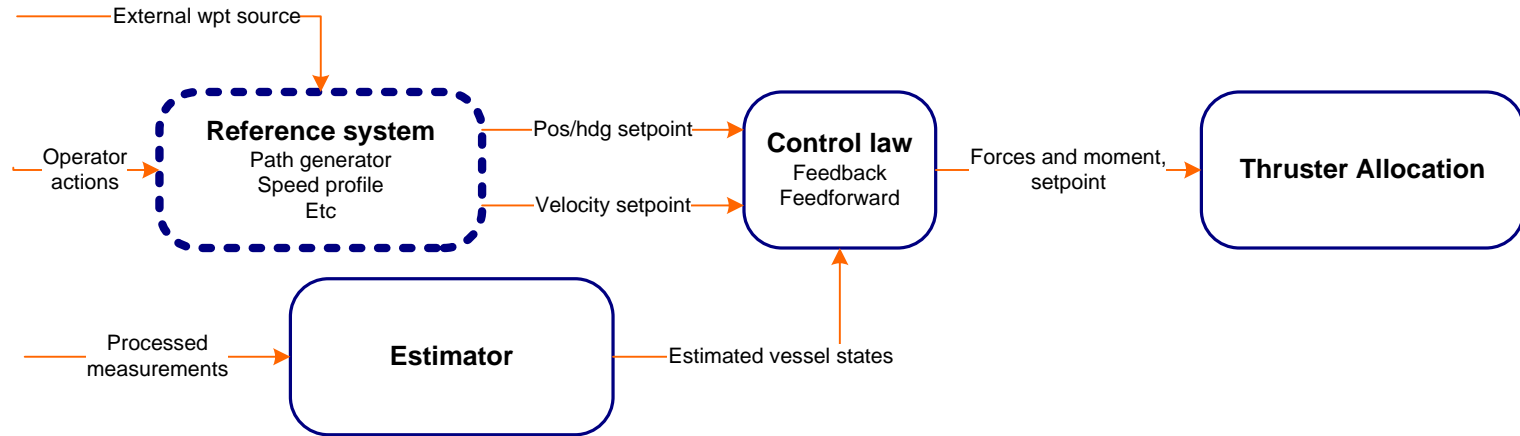
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Usability

- **Some definitions:**
 - “The degree to which an object, device, software application, etc. is easy to use with no specific training ”
 - “The study of the ease with which people can employ a particular tool or other human-made object in order to achieve a particular goal. ”
- **Associated with product functionality *and* as a user interface characteristic**
- **More than just**
 - User-friendly, accessibility
 - Ergonomics/human factors

Introduction

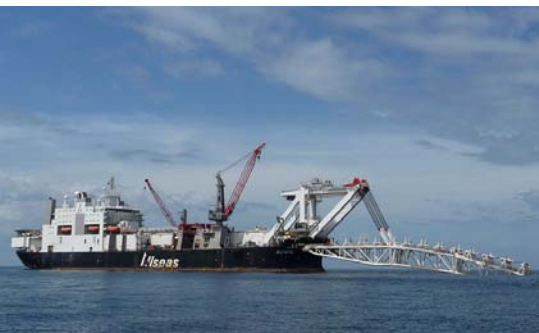
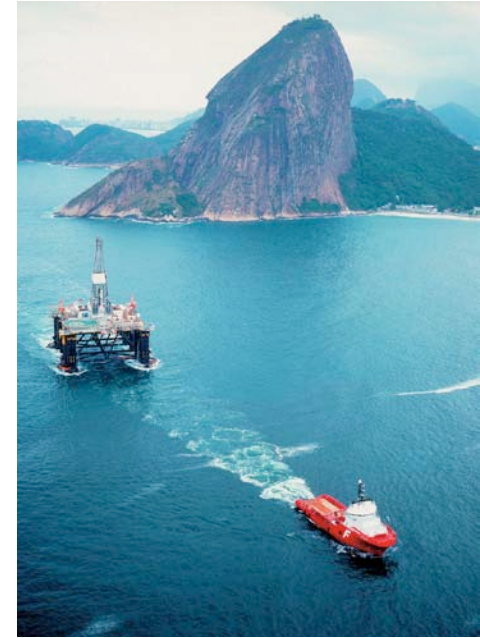
- **Reference model in the control loop:**



- **Low-speed waypoint tracking implementation**
- **Applicable (in parts) to high-speed tracking schemes**

DP applications

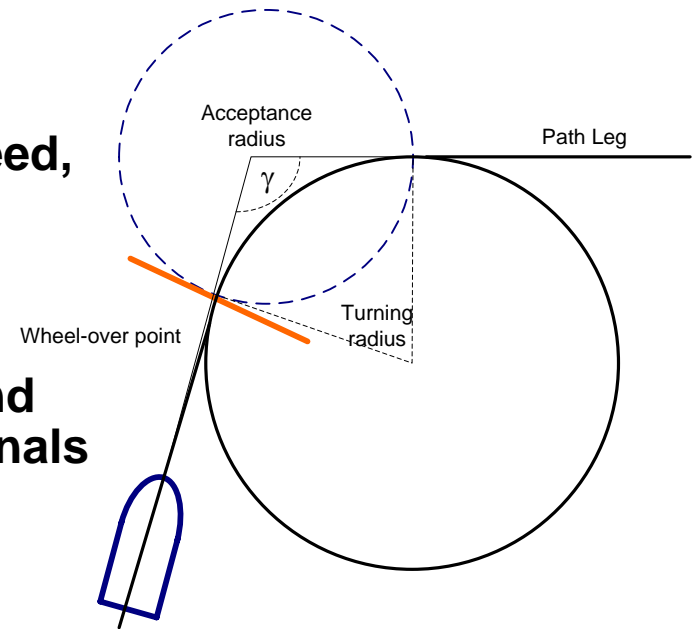
- **Tracking: Enabler for DP applications**
- **Offshore survey support**
- **Pipelay, cable lay**
- **Trenching, dredging, rock dumping**



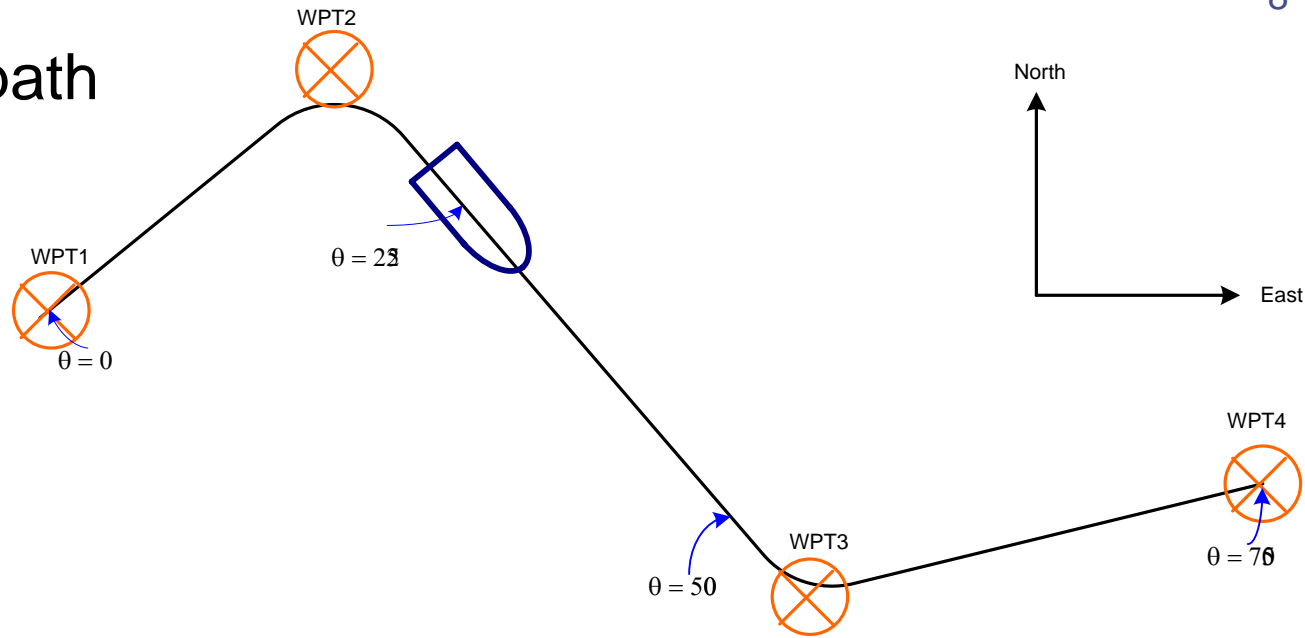
Path Construction and Analysis

Points and paths

- **Waypoint: position (turning radius, speed, heading setpoint)**
- **Waypoints are converted into a path and used to generate smooth reference signals to the control law**
- **Path creation methods**
 - Straight-lines and circle arcs
 - Interpolation techniques
 - Optimization:
 - shortest route through a set of points
 - minimum time and energy
 - vessel speed and acceleration constraints

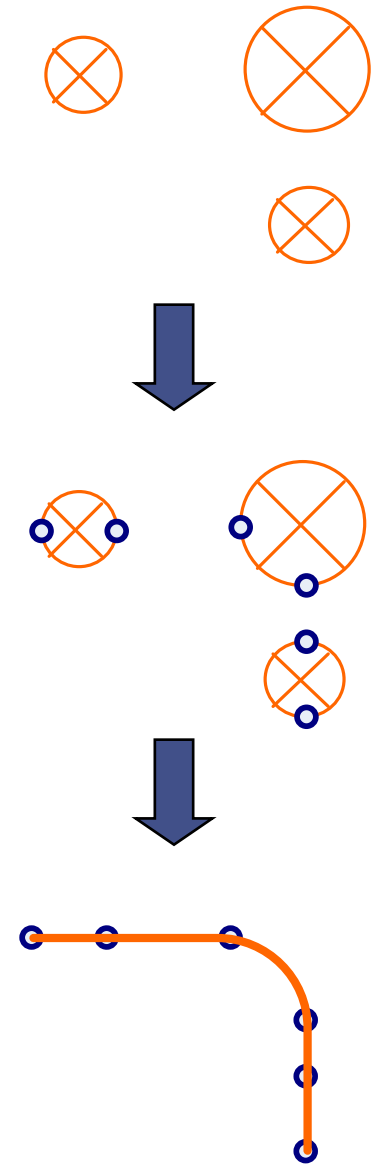


Parameterized path



Path construction algorithm

1. Find suitable path segment endpoints based on a list of waypoint location and acceptance radius.
2. Determine endpoint derivatives. Smoothness of the entire path follows by using similar endpoint values for path segments before and after endpoint.
3. Find polynomial representation for path segment using a suitable parameterization length.



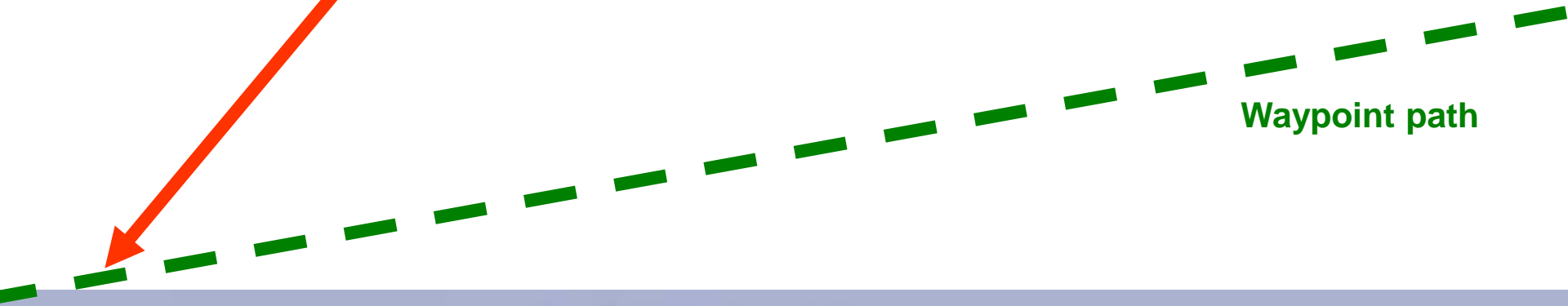
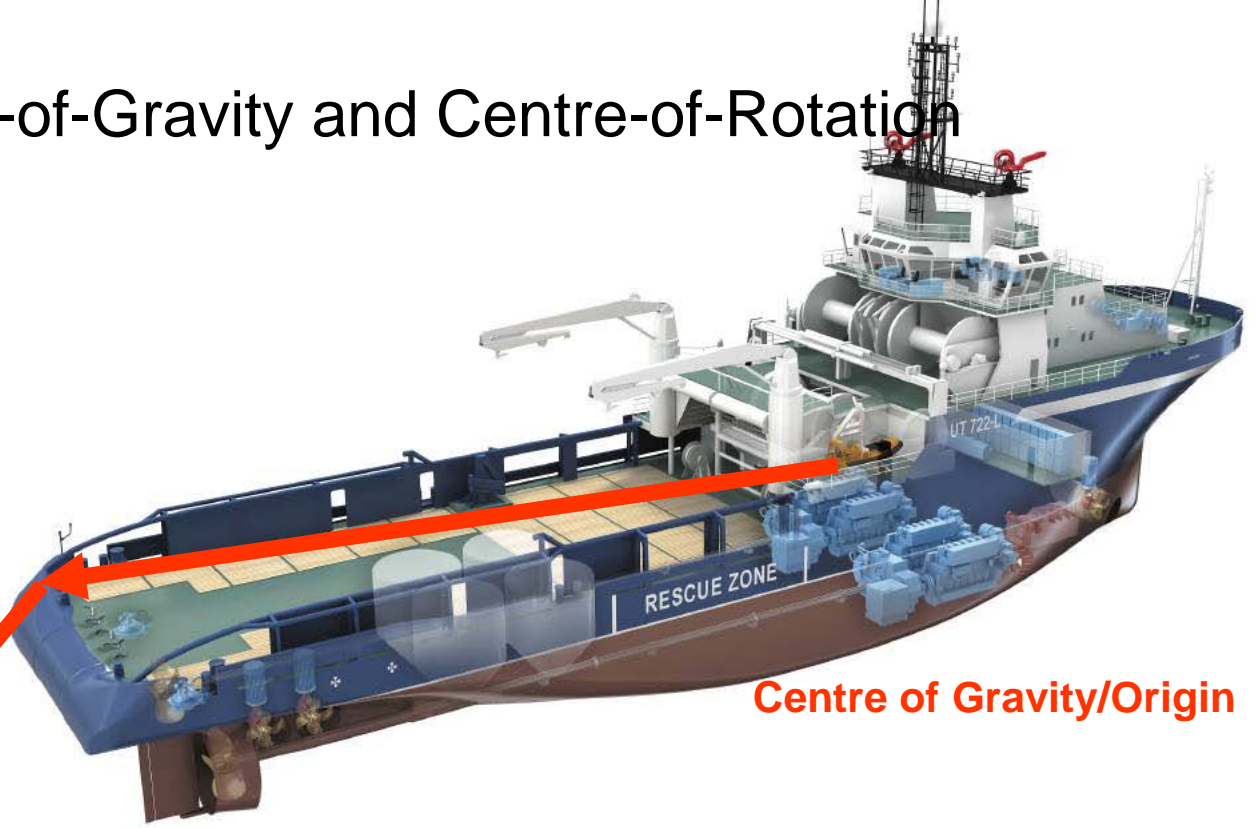
Paths for Centre-of-Gravity and Centre-of-Rotation



Centre of Rotation

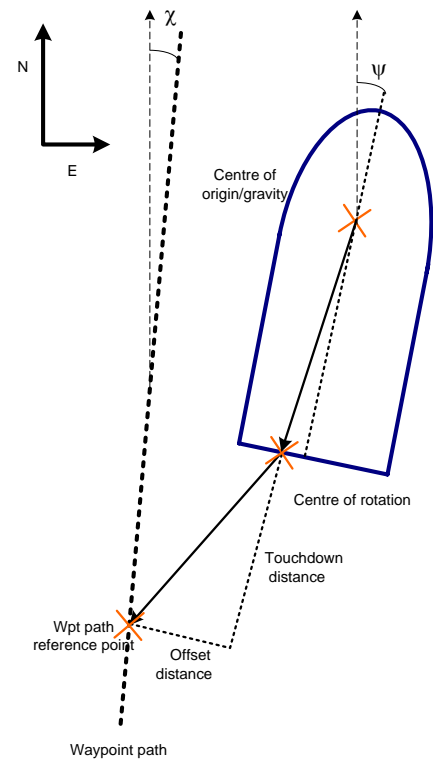
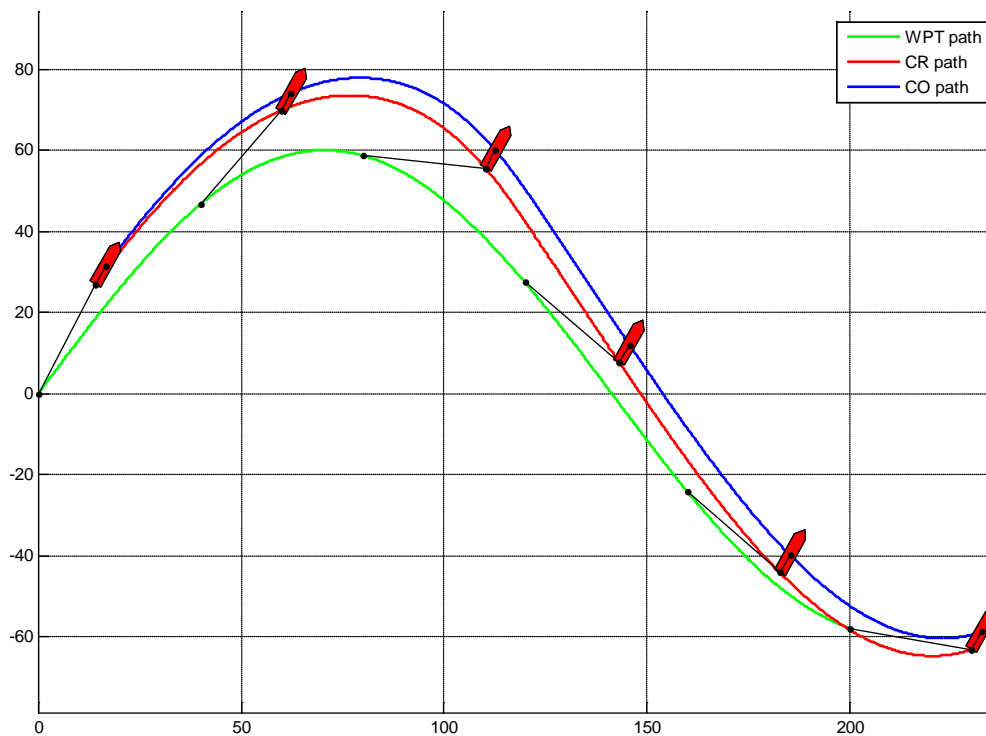
Centre of Gravity/Origin

Waypoint path



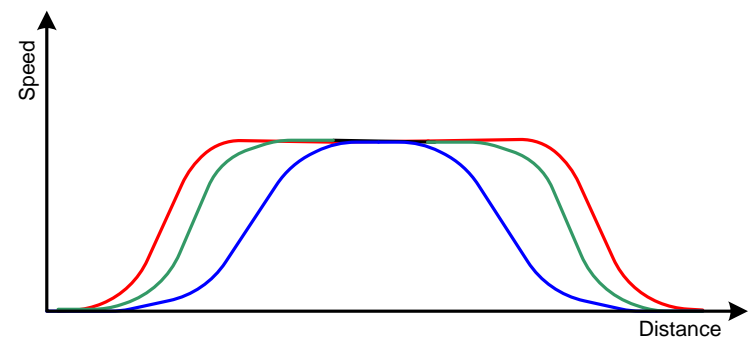
Paths for CG and CR

- Path for the centre of rotation
- Path for the centre of gravity

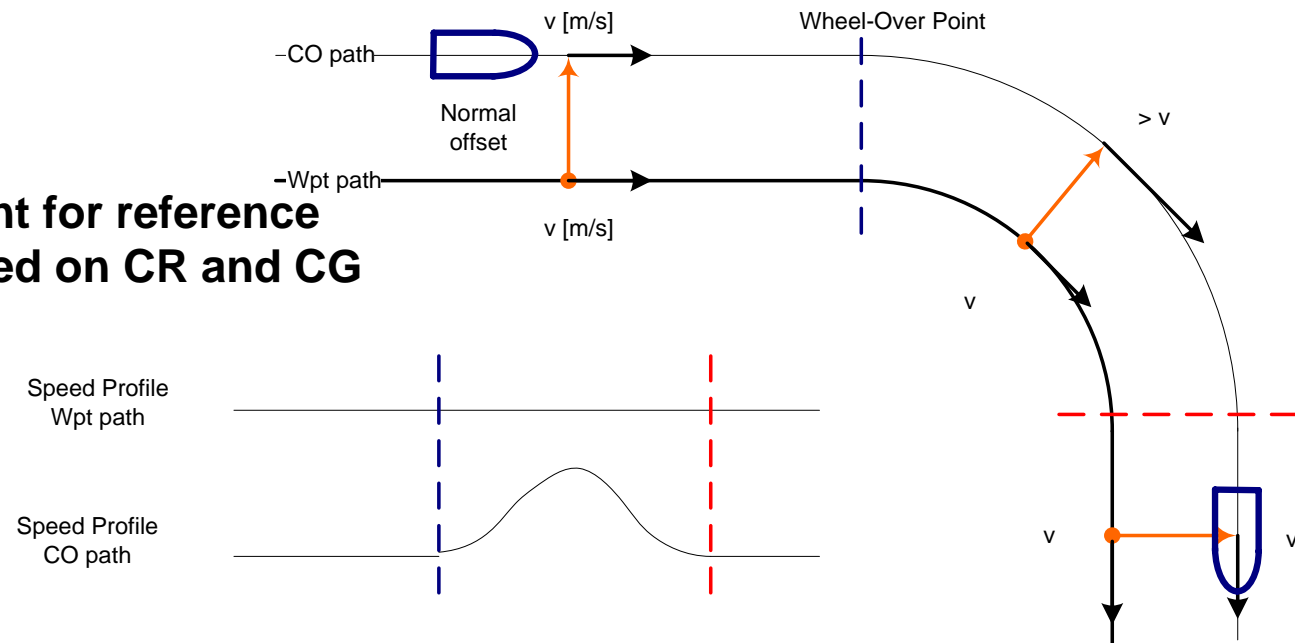


Path speed profile

- **Dynamic assignments on path:**
 - keep constant speed along path,
 - maintain a steady speed minutes
 - be at waypoint at time ,
 - complete track at minimum time, and
 - specified force for acceleration/braking



- **Speed assignment for reference point affects speed on CR and CG path**



Combined path and speed profile information

- **New information enable us to:**

- find speed and acceleration values on all paths
- analyze path speed profile against limiting factors for entire waypoint, CR, and CO path.
- detect conflicts between simultaneous operations
- calculate new speed setpoints to eliminate conflicts

- **Some limiting factors**

- vessel speed in turns,
- rotation during heading change,
- vessel speed/acceleration/rate limits,
- reference point limits

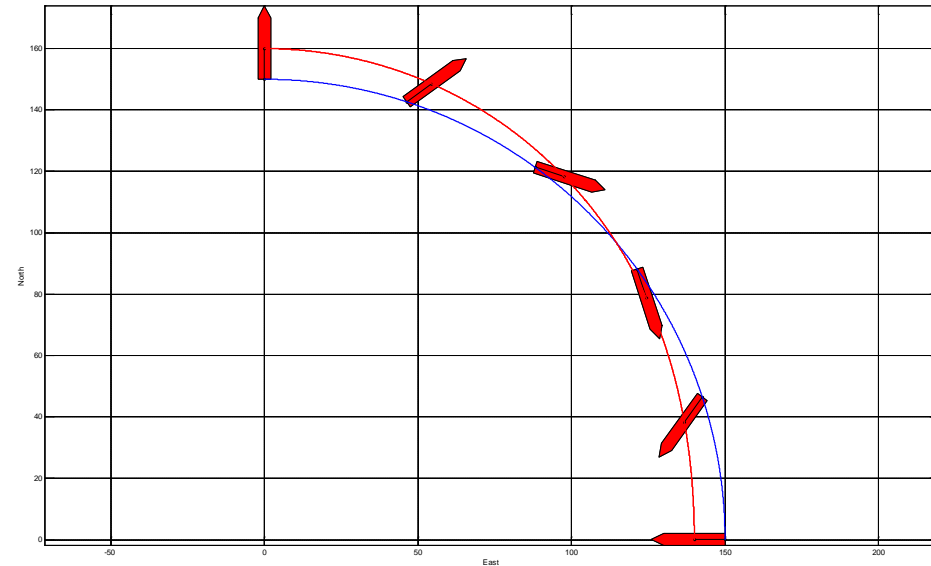
Example: Max speed vs vessel speed limits and heading change

- **Heading change (270 CW) during 90 turn**
- **Objectives:**
 - Follow WPT/CR path with a given speed
 - CO path speed within limits
 - Finish heading change before end of turn

CR speed vs vessel speed limits:

Relate CO-CR path speed

Relate vessel speed and CR path speed

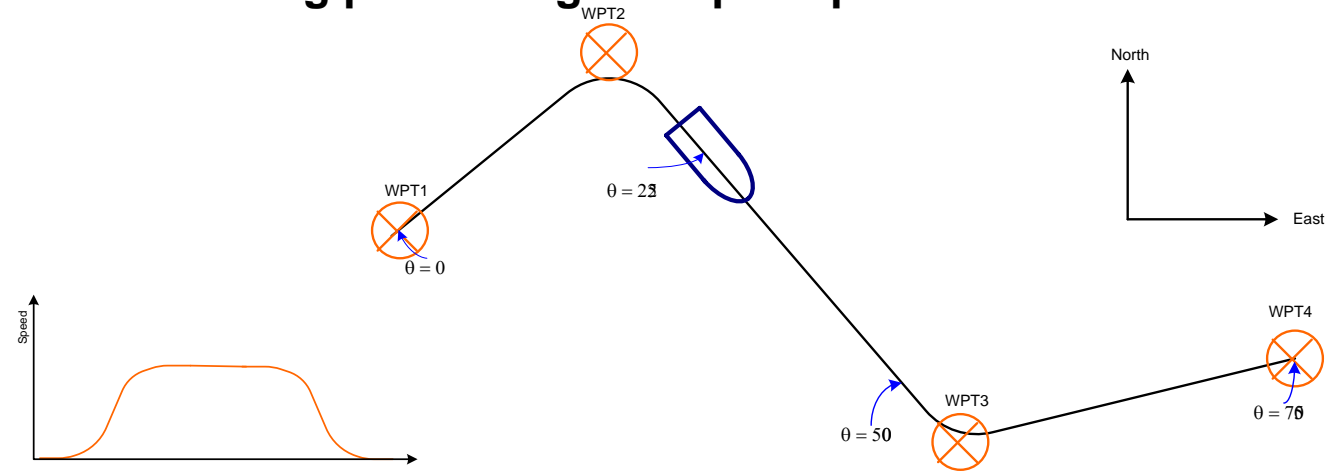


↑
Use surge and
sway limits

↑
Find max path
speed

Path parameter update law

- Steer reference model along path with given speed profile

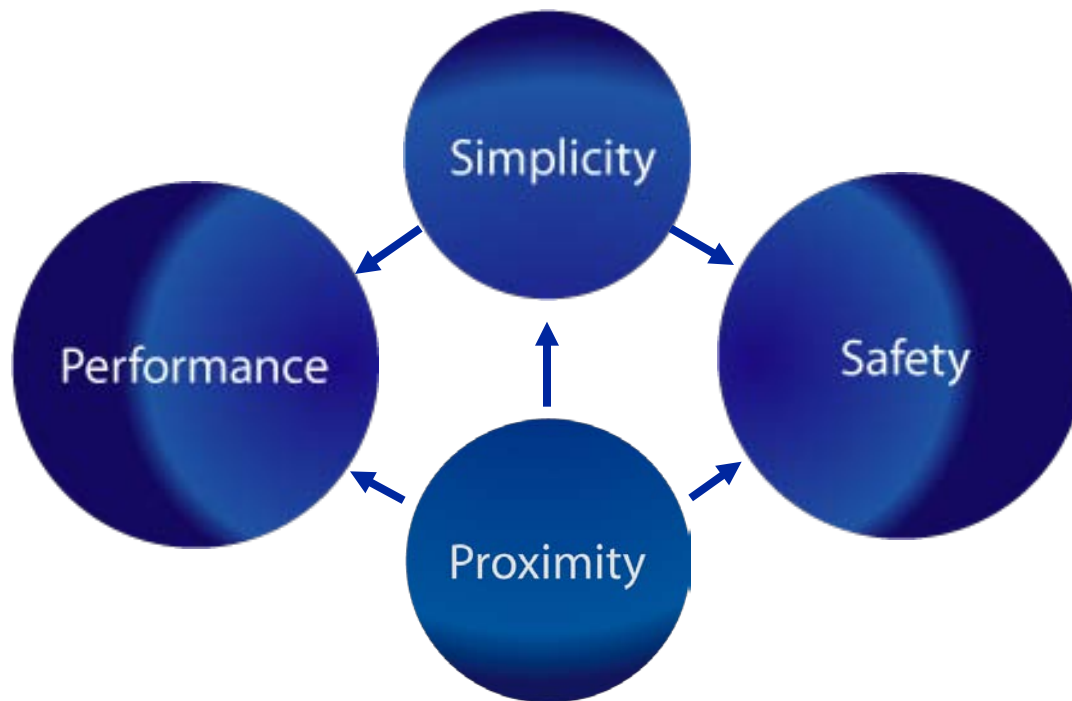


- Reference model is inaccurate compared to real-life



- Vessel state feedback needed
- Design mechanisms that ensures path parameter progress keeps up with vessel

Operator Interaction

Design principles







Waypoint Table

Operation								
	Name	Progress	Lat	Long	Radius	Speed	Heading	Applied
	WP1	 ▾	N 0°0' 03.9"	W 0°0' 03.9"	20.0	0.99	11.0	
	WP2		N 0°0' 12.0"	W 0°0' 03.9"	30.0	1.01	12.0	
	WP3		N 0°0' 12.0"	E 0°0' 05.1"	35.0	1.03	13.0	
	WP4		N 0°0' 08.7"	E 0°0' 05.1"	35.0	1.05	14.0	
	WP5		N 0°0' 08.7"	W 0°0' 03.9"	20.0	1.07	15.0	
	WP6		N 0°0' 03.9"	E 0°0' 05.2"	20.0	1.09	16.0	
	WP7		N 0°0' 03.9"	E 0°0' 09.2"	20.0	1.11	17.0	

Track name: **R Track 0**

Chart com link status:

 +
  +
  +
 
 

3D scene

The screenshot displays a comprehensive control interface for a ship's navigation system. On the left, there are two main panels: 'Settings' and 'Operation'. The 'Settings' panel includes a table for configuration parameters:

Icon	Name	Value
	Pos gain	medium
	Surge Acc Factor	10.0 %
	Sway Acc Factor	15.0 %
	Speed Limit	1.0 kt
	Warning Limit	4.0 m
	Alarm Limit	5.0 m

The 'Operation' panel features a 'Waypoint' dropdown and several control buttons for 'Offset', 'Offset spd', 'Hdg', and 'Spd'. The main display area contains several data-rich panels: 'SRG ton' and 'SWY ton' gauges, a heading gauge showing 358.8 degrees, a 'POSITION' gauge with a 5.0m limit, a 'SPEED' gauge with 0.0 kt, and a 'CURRENT POS' gauge showing coordinates S 0° 0' 00.0" and W 0° 0' 00.1". A route map shows five waypoints (WP 1-5) connected by yellow lines. A 'CLASS MONITOR' panel on the right lists system statuses: Class: 2, Thrusters (green), Power (green), Capability (green), Posref (red), Sensors (green), and System (red). A 'POWER' panel at the bottom right shows MBus2 and MBus1 levels. The bottom status bar includes a scale of 6.8m, a speed of 20, and a UTC timestamp of 2009-11-24 10:51:45.



Operation-specific User Interface

Settings

Icon	Name	Value
	Pos gain	medium
	Surge Acc Factor	10.0 %
	Sway Acc Factor	15.0 %
↑	Speed Limit	1.0 kt
⌚	Warning Limit	4.0 m
⚠	Alarm Limit	5.0 m

Operation

Waypoint:

Offset: 40.0 [←] [→]

Offset spd: 0.49 [←] [→]

Hdg: [←] [→] [Table]

Spd: 0.10 [←] [→] [Operator]

Buttons: Show track, Start/rev, Exit, Cancel, Apply

SRG ton: 0.1
SWY ton: 2.9

TRACK DEVIATION: XTE 0.1 m, Lim 15.0m

TRACK PROGRESS: 152 WP, Spd 0.1 kt, Dist 0.1 m

OFFSET: TRACK 40 m

CLASS MONITOR: Class: 2, Thrusters ✓, Power ✓, Capability ✓, Posref ▲, Sensors ✓, System ▲

POWER: MBus2, MBus1

WIND / R.FORCE: 077, 11 kt

CURRENT POS: N 0° 0' 00.1", W 0° 0' 00.1"

SPEED: 0.1, 0.0, 0.2, Speed lim 1.0 kt, Rot lim 40.0 °/min

GPS Rel Gyro

Waypoint Trk. 6.8m

UTC 2009-11-24 11:01:16

TRACK DEVIATION

XTE 0.1 m, Lim 15.0m

TRACK PROGRESS

WP1 SP 177 WP2, Spd 2.00 kt, Dist 2.00 m, 0.60 m

OFFSET

TRACK 0, NORTH 0, EAST 0 m

Split, Zoom out, Zoom in, Cam ctrl, Alarms, DP System, Monitoring, Operation



Error Handling

CRITICAL CHOICE [!]

Recovered from critical state.

Go to last known pos or exit tracking.

[Last pos] [End tracking] [Apply]

TRACK DEVIATION
XTE -22.6 m
Lim 5.0m

TRACK PROGRESS
54 Wp4
3.00 0.44
paused

OFFSET
TRACK 0
NORTH W/P 0
EAST 0

CLASS MONITOR
Class: 0
Thrusters ?
Power ?
Capability ?
Posref ?
Sensors ?
System ?

SPEED
0.0
Speed lim 3.0
3.3
Rot lim 40.0

CURRENT POS
N 62° 42' 06.7"
E 7° 2' 11.3"

WIND / R.FORCE
077
13

Operation
Waypoint: [v]
Offset: 0.0
Geographic Offset: N 0.0 E 0.0
Offset spd: 0.26
Hdg: 13.0
Spd: 3.00
[Show track]
[Start tracking] [Fwd Rev] [Cancel] [Apply]

Waypoint Trk. 6.0m

UTC 1970-01-01 00:00:00

Thank you for your attention!

