CysBOX

Autopilot Algorithm Tuning

SOMMAIRE

Autopilot Algorithm, detailed operation :

When using the autopilot, the central unit calculates the position of the helm (angle in degrees) necessary for the boat's handling according to the instructions given to it (apparent or real wind angle, compass or GPS) and the chosen algorithm. Then it sends this position to the helm actuator.
In the "rudder angle" mode, it sends the instruction directly to the rudder actuator (rudder angle).

1 "Simple" Algorithm:

To calculate the "rudder angle instruction" in **simple** mode, the central unit uses the following formula, inspired by industrial automation:

Rudder angle = (**G/Ground speed**) *(**P*Error + D*Rotation + I*Sum of errors + H*Roll angle**) + **O**

- **G/Ground speed** : This parameter should be set to the average speed of the boat to reduce the amplitude of the rudder movements in the event of acceleration (the lift of the rudder is higher at high speed).
  If the value of G = 0, this parameter is not used.
  *The calculated correction (**G/ground speed**) is limited to the interval [0.3, 2].*

- **P*Error** : The error corresponds to the difference between the instructions and reality (eg: I want to sail at 30° from the apparent wind, I sail at 35°, I therefore have an error of 5°). Therefore, the greater the deviation from the set point, the further the rudder angle will be from 0.
  *The **Error** value is limited to the interval [-60, 60].*

- **D*Rotation** : The rotation corresponds to the rotation speed of the boat given by the Gyroscope. This parameter helps counter the rotating inertia of the boat. If the boat approaches the setpoint too quickly, it will exceed it and therefore oscillate around the target value. (e.g.: The boat is approaching the setpoint at 10°/s and D = 1, the central unit will therefore provide a counter-rudder of 10° to limit overshoots)

- **I*Sum of errors** : The error is integrated over time (Sum of errors) to compensate for the fact that the boat can maintain a stable heading but offset from the setpoint in certain P and D configurations.
  (e.g.: My boat maintains a stable heading at 10° while its setpoint is 15°. The more time passes, the boat being further from this setpoint, the more the rudder angle will be corrected to get closer to the setpoint).
  The sum of errors is bounded in the interval [-10, 10]

- **H*Roll angle** : The rudder angle is corrected according to the roll angle of the boat. This makes it possible to compensate for the change in direction linked solely to the shape of the hull. (for example, across the swell, my boat luffs up/bears aways with each roll due to swell or gust of wind. I can compensate for this effect by adjusting this parameter.) Normally this parameter depends on the shape of the hull and should perhaps be able to be edited once set.

- **O** : This parameter is the rudder offset. It indicates the balance point of the rudder in the current configuration around which the rudder will oscillate to maintain the course. (e.g. I am upwind under sail, my boat suffers from slight weather helm, to maintain a straight course my helm is balanced at -5° rudder angle. I therefore set the rudder offset to -5° so that the rudder angle calculations oscillate around this balance point).

Suggested initial adjustment procedure:

- Sail and trim the boat so that it's easy to steer.
- Set the **G** parameter to average speed.
- Set the **O** parameter (rudder offset) to the average rudder angle value or to 0 if the boat's handling is neutral.
- Set **P** to 0.2, and **D**, **I** and **H** to 0.
- Switch Autopilot On
- Gradually increase the **P** parameter until the boat keeps the setpoint by oscillating around.
- Then increase the D parameter, until the oscillation stops
- If the boat maintains a stable course offset from the setpoint, increase **I** parameter until corrected. If the boat becomes unstable, lower **I**.
- If the boat's trajectory oscillates with each roll change, increase **H** until corrected.

⇨ **The Autopilot is set.**

In the event of "going off course", the autopilot should be stopped and returned to the last known stable configuration (pilot and sails).

Case-by-case :

- The boat oscillates around the setpoint without the roll changing:
  - **D** is too low
  - **P** is too high
  - **I** is too high

- - The boat oscillates around the set point with each roll change:
  - **H** is too low (the boat luffs up when heeling, bears aways when conterhilling)
    or **H** is too high (the boat bears aways when heeling, luffs up when conterhilling)

- The boat corrects too slowly and does not reach the set point:
  - **P** is too low
  - The boat suffers from weather helm or lee helm, and the rudder offset is not set.

- The boat keeps the instructions but shifted:
  - **I** is too low
  - If it is impossible to maintain the stability of the boat when raising **I**, it is possible to shift the setpoint.

- The boat tends to lurch when it goes surfing:
  - Wind smoothing is too strong (adjust ap.smooth_factor_wind in autopilot configuration)
  - **G** parameter is not set properly or it is deactivated (value set to 0)

- Rudder movements are considered too large:
  - **P** is too high

2 "Autotune" Algorithm:

This is a variation of the "simple" algorithm: the **PIDH** parameters are automatically adjusted according to wind variations (force and direction) from a typical adjustment table.
This mode allows automatic adaptation of parameters according to navigation conditions.

The **M** parameter allows you to define the measurement period for calculating the parameters:

- **M**: period in seconds over which the force, direction of the wind and the speed of the boat are averaged.
  The period M is bounded in the interval [1.60]

Parameter **G** is automatically set to the average speed of the boat over the period defined by parameter **M**.

3 "Learning" Algorithm:

Under development.