

Autopilot Route OpenCPN plugin

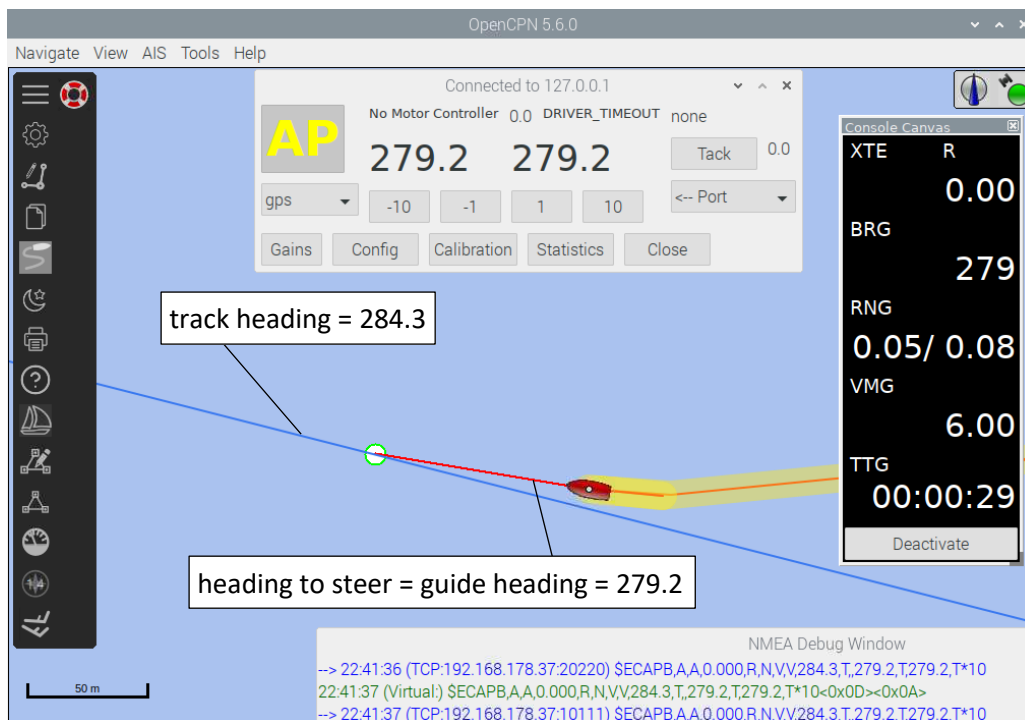
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The following is an analysis of the calculations that are done by the algorithms inside the Autopilot Route OpenCPN plugin. Tests are done with a plugin directly compiled from https://github.com/seandepagnier/autopilot_route_pi. The plugin is configured to generate RMC and APB sentences, and these are forwarded to pypilot with a data connection on TCP socket 20220, that *only outputs* to pypilot, and only lets through RMC and APB messages.

NOTE: the boat heading in some screen dumps has been fixed as to show the (solid red) heading to steer vector.

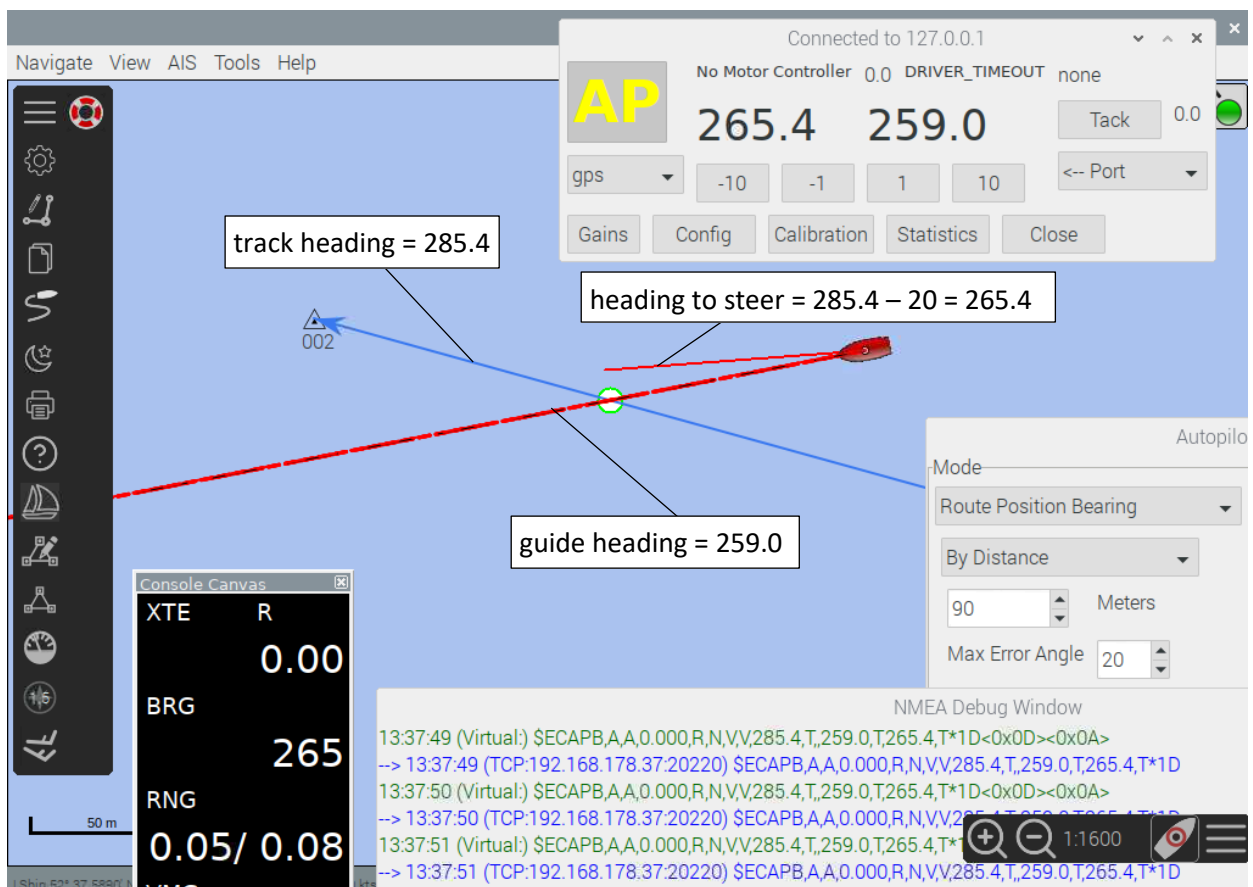
Route Position Bearing – normal operation

- Let's define the green circle as the *guide point*, and the heading from the boat towards the guide point the *guide heading*. Then, we can also talk about the *guide vector* and the *guide radius* (= By Distance setting).
- Normally, the *heading to steer* is equal to the guide heading: 279.2
- The heading to steer is put into the final field in the APB sentence, "Heading to steer (to destination waypoint)".
- An autopilot is supposed to steer this heading. Because XTE is set to 0, the autopilot is not expected or assumed to correct for an XTE.
- This heading shows up in the BRG field in the console canvas, and this is used by pypilot.
- The first figure in the RNG field is -by definition- equal to the guide radius (0.05NM = 90m). The second figure is supposed to be the normal range, but it seems to be larger than the range so that does not add up.
- Default for the guide radius (By Distance setting) is 100m. At small XTE's, this constitutes 11 degrees correction angle per 0.01 NM.



Route Position Bearing – route intercept

- If the guide heading *exceeds* the track heading (285.4) by more than Max Error Angle, the heading to steer is set to the track heading minus the max error angle: $285.4 - 20 = 265.4$.
- Running on max error angle could be seen as a way to intercept the route, e.g. after initially activating the route.
- In intercept state, the red steering vector does not end up in the guide point, like it normally does.
- Default for the Max Error Angle was 20 and has now been changed to 30 degrees. This is important not as much for maintaining a track, but more for initially intercepting the track. A too large value will make the boat react in a haphazard way intercepting the track, including multiple times overshoot at joining the track.



\$ECAPB	
A	1. Status A = Data valid V = Loran-C Blink or SNR warning V = general warning flag
A	2. Status V = Loran-C Cycle Lock warning flag A = OK or not used
0	3. Cross Track Error Magnitude
R	4. Direction to steer, L or R
N	5. Cross Track Units, N = Nautical Miles
V	6. Status A = Arrival Circle Entered
V	7. Status A = Perpendicular passed at waypoint
285.4	8. Bearing origin to destination
T	9. M = Magnetic, T = True
	10. Destination Waypoint ID
259	11. Bearing, present position to Destination
T	12. M = Magnetic, T = True
265.4	13. Heading to steer to destination waypoint
T	14. M = Magnetic, T = True
*1B	15. Checksum

Waypoint bearing

The screenshot displays the OpenCPN interface in Waypoint Bearing mode. The map shows a red boat icon and a green circle around a waypoint labeled '002'. A red dashed line indicates the path to the waypoint, and a blue line shows the heading to steer. A callout box points to the heading value, stating "heading to steer = 272.7". The top right panel shows the autopilot mode set to "Waypoint Bearing" with a heading of 272.7 and a target heading of 260.0. The bottom left panel displays the following data:

XTE	R
0.00	
BRG	273
RNG	0.10/ 0.16

The bottom right panel shows the NMEA Debug Window with the following log entries:

```
14:15:21 (Virtual:) $ECAPB,A,A,0.000,R,N,V,V,284.1,T,002,272.7,T,272.7,T*20<0x0D><0x0A>
--> 14:15:21 (TCP:192.168.178.37:20220) $ECAPB,A,A,0.000,R,N,V,V,284.1,T,002,272.7,T,272.7,T*20
14:15:22 (Virtual:) $ECAPB,A,A,0.000,R,N,V,V,284.1,T,002,272.7,T,272.7,T*20<0x0D><0x0A>
--> 14:15:22 (TCP:192.168.178.37:20220) $ECAPB,A,A,0.000,R,N,V,V,284.1,T,002,272.7,T,272.7,T*20
14:15:23 (Virtual:) $ECAPB,A,A,0.000,R,N,V,V,284.1,T,002,272.7,T,272.7,T*20<0x0D><0x0A>
--> 14:15:23 (TCP:192.168.178.37:20220) $ECAPB,A,A,0.000,R,N,V,V,284.1,T,002,272.7,T,272.7,T*20
```

- In this mode, the guide point is the next waypoint, the heading to steer is the same as the guide heading, so the autopilot steers straight to the next waypoint at all times, irrespective of any cross track error (as XTE is set to 0).

Standard XTE

The screenshot shows the OpenCPN interface with the following elements:

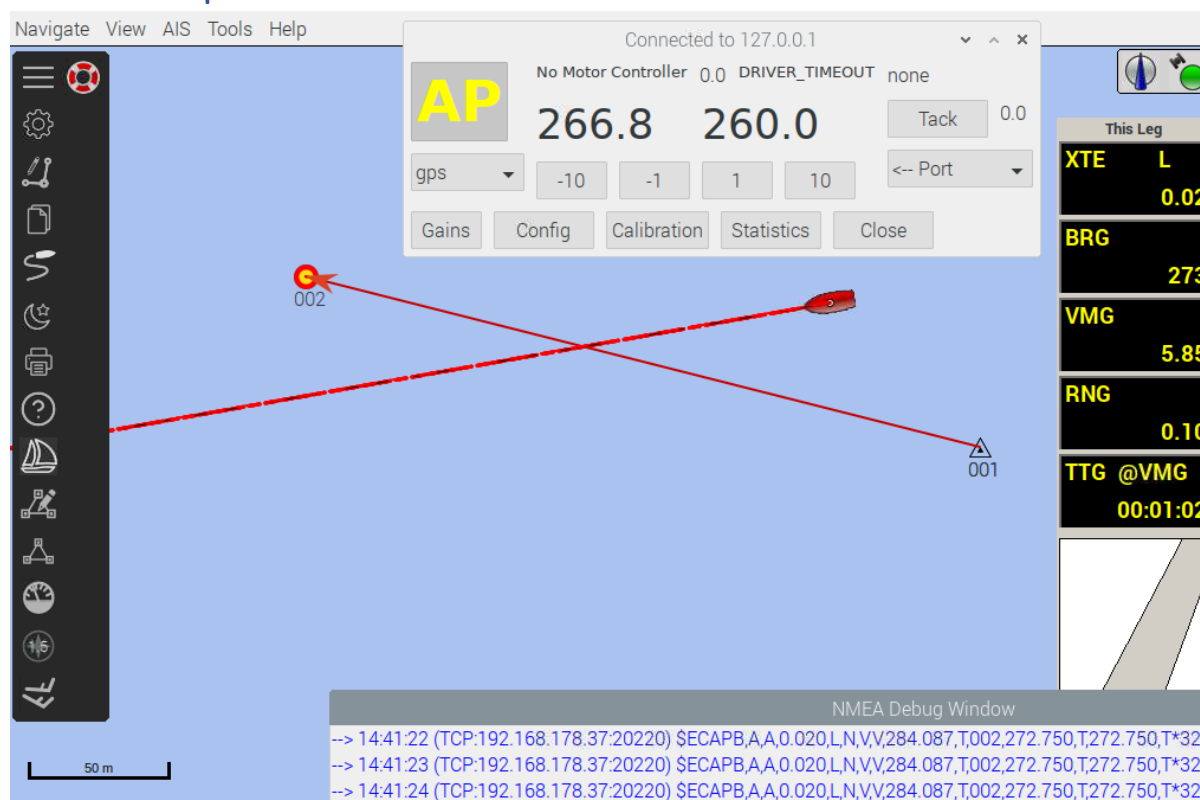
- AP Panel:** Shows 'AP' mode, 'No Motor Controller 0,0 DRIVER_TIMEOUT none', heading '275.1', and track heading '260.0'. It includes buttons for 'Tack', 'Port', 'Gains', 'Config', 'Calibration', 'Statistics', and 'Close'.
- Map:** Displays a green circle around a waypoint '002'. A red dashed line indicates the track, and a blue arrow shows the heading to steer.
- Console Canvas:** Shows 'XTE L 0.03', 'BRG 284', and 'RNG 0.10/ 0.18'.
- NMEA Debug Window:** Shows log entries for '\$ECAPB,A,A,0.030,L,N,V,V,284.1,T,002,272.7,T,284.1,T*32<0x0D><0x0A>'.

- In Standard XTE mode, the heading to steer is equal to the track heading.
- It is up to the autopilot to correct that heading given the XTE.
- In the example above, the real XTE is 0.02NM, but because of the XTE multiplier (150%), 0.03NM is displayed. The bearing 284 is the track heading.
- Pypilot steers 9 degrees left of the track heading, because the default pypilot apb.xte.gain factor is set to 300:
 - $XTE\ Correction = 300 * -0.03 = -9\ degrees.$
 - $Heading\ to\ steer = Track\ Heading + XTE\ correction = 284 - 9 = 275.$
- First figure of Range is Distance to Waypoint = 0.1NM. Second figure is the [normal range](#) which is incorrect.

General remarks Autopilot Route plugin

- The Boundary functionality (GUID, Width and Generate) has been removed since May 2018. That part of the user interface is obsolete.
- The option “Intercept Route on Current Course” has been removed since version 0.5, November 2021.

Standard OpenCPN behavior



- Interestingly enough, standard OpenCPN active route behavior does not put the track heading (284) in the heading to steer, but the bearing to waypoint (273). This is corrected by pypilot with -6 degrees: $273 - 6 = 267$.
 - Six degrees, because $0.02 * 300 = 6$
- The upshot of this is seems to be that by using the Zero XTE function in OpenCPN, you can steer directly to the next waypoint.
- Note that the pypilot default `apb.xte.gain` set to 300 constitutes for all XTE's a correction angle of 3 degrees per 0.01NM cross track error. This is almost a factor 4 less than the default gain of 11 degrees per 0.01NM cross track error that the default values of the Route Position Bearing algorithm constitute.
- Therefore, it could be said that by increasing the pypilot gain to 1200 would make the standard, OpenCPN/XTE based solution comparable to the Autopilot Route Plugin solution. This does not hold for 2 reasons:
 - With such a high gain, in the absence of a Max Error Angle, during intercepting a route the correction angle would be very high.
 - Also, the behavior at waypoint arrivals, where suddenly a new waypoint is selected and the XTE makes large jumps, would also become erratic.

So in here lies the real benefit of the Autopilot Route Plugin solution, and more specifically the Route Position Bearing algorithm.