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BULLETIN

Drive Workbench Tuning

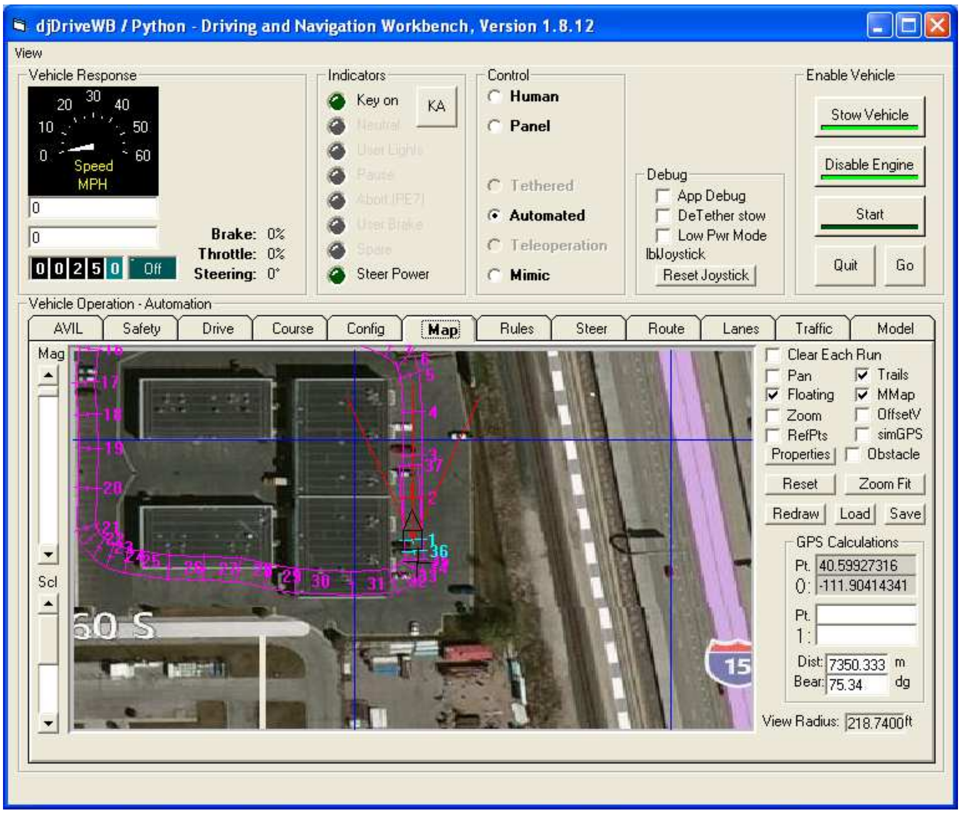
Introduction

Drive Workbench is a highly configurable program that manages the pathing of a vehicle with the Pronto4 Series4 agnostic autonomy kit installed. The usage of Drive Workbench is controlled by a number of configuration parameters that must be set properly in order to achieve the desired results.

Overview

This document walks you through the primary configuration screens and provides a quick synopsis of the critical controls and their settings for usage of the P4S4 in pathing operations on both Land and Surface vessels.

This document indicates the nominal settings that are required or not-required for general operation of the P4S4 in pathing operations.



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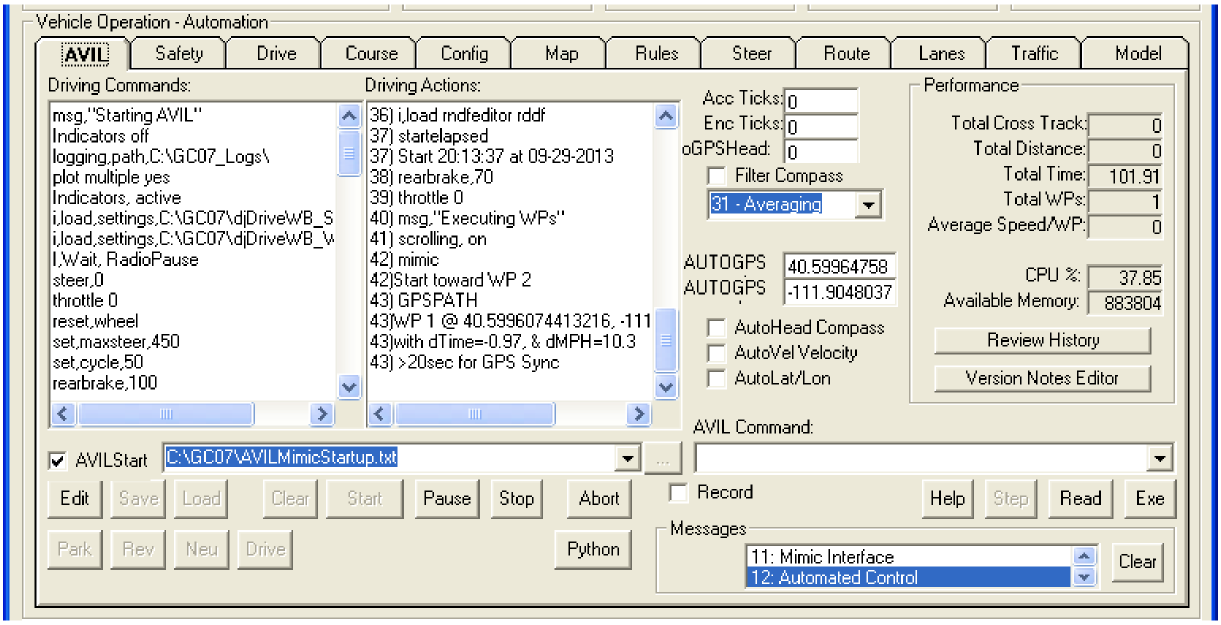


This set of tabs provides the primary control for the vehicle pathing operations. It is accessed by making the 'Automated' selection under the control area of the main page. The displayed tab 'AVIL' shows the scripting language used for the primary control of the vehicle during pathing as well as the management of performance statistics.

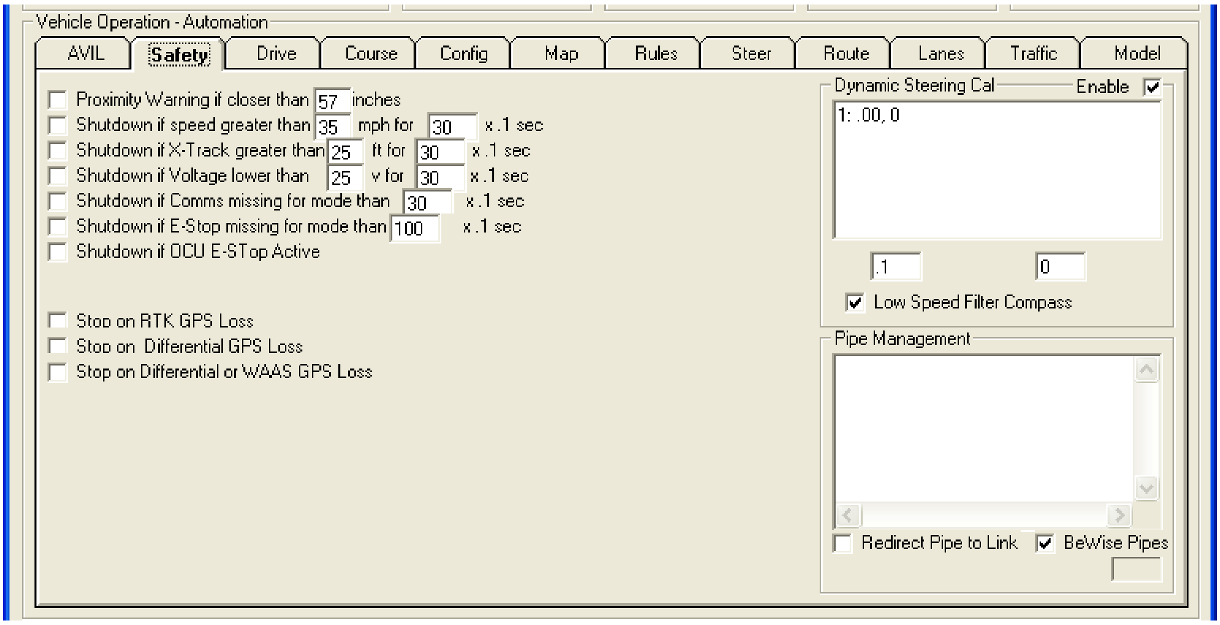
__Assure selection of the Proper GPS sources:

Check that the following are unchecked:

□Filter Compass	- Applies clarity filters to compass heading
□AutoHead Compass	- Alternate managed source for compass
□AutoHead Velocity	- Alternate managed source for Velocity
□AutoLat/Lon	- Alternate managed source for GPS

__Check that the GPS values are dithering.

__When moving, check that the heading value is ditheringing as well



There are many types of safety scenarios where the vehicle is used. These selections determine what the vehicle will do as each of the indicated safety related events occur. It is not always desirable for the vehicle to abort operation based upon an indicated safety event. The selection is up to the scenario under consideration.

__Make sure that the following check boxes are unchecked.

- □Dynamic Steering Cal - Automatic adjustment of steering offset
- □Redirect Pipe to Link - All pipe transmission sent through remote access

__Make sure that the following check boxes are checked

- ■Low Speed Filter Compass - Clarity of compass value at Low Speed

__If Not Using Shepherd as the OCU, make sure that these are unchecked

- □BeWise Pipes - Usage of alternate piping software structure

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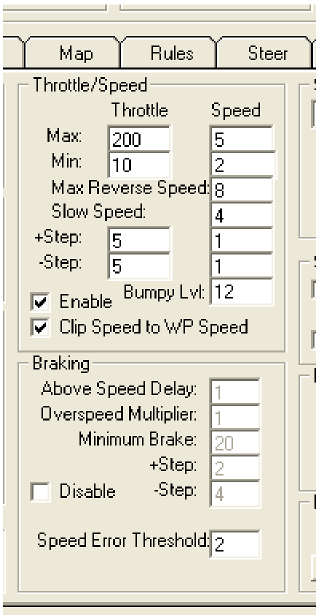

Speed and Braking limits are controlled from this pane on the 'Driving' tab.

__Assure that the Max throttle is set as desired 0-1000
Set to limit max engine RPM

__Assure that the Minimum throttle is set as desired 0-1000
Usually in the 0-300 range based upon throttle

__ Assure that the Maximum speed is set as desired 0-100mph
Limits how fast the vehicle can go.

__Assure that the Minimum speed is set as desired
When the vehicle dynamically slows down to low speed

__Assure Slow Speed is the set
The minimum speed used during steerage operations, 4 mph is common. If set higher than the lowest speed, the vehicle will "speed up" in turns.

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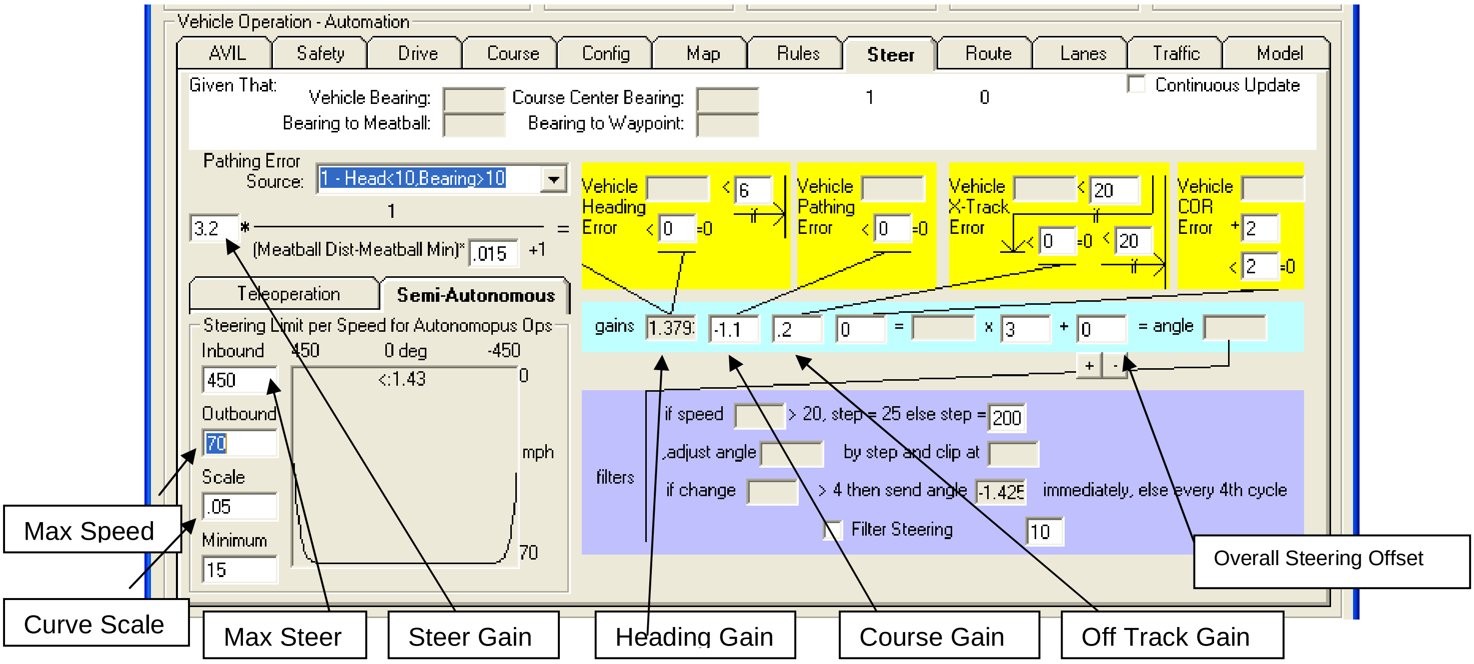


The ‘Steering’ tab has all of the controls used to adjust steering responsiveness to path following operations. This has the effect of limiting steering as the vehicle is traveling at higher speeds, or progressive steering.

__Assure that the ‘Max Speed’ is set much greater than the desired speed
If high speed operations are desired, set to higher speed

__Assure that the ‘Curve Scale’ yields a curve that meets operation needs
Values less than 1 increase total steering sensitivity at most speeds
Values greater than 1 decrease total steering sensitivity as speed increases

__Make sure that ‘Max Steer’ angle is set properly for vehicle.

__’Steer Gain’ is the overall steering gain used for the vehicle direction control
Nominal 3.2 for Land Vehicles, more responsive
Nominal 2.1 for Surface Vessels, less responsive

---’Heading Gain’ is how aggressive the vehicle aims at the meatball location
This gain is set and calculated by Steer Gain and the formula shown

__’Course Gain’ is how aggressive the vehicle aligns with course direction

-1.1 is common for Land Vehicles
-1 is common for Surface Vessels

__'Off Track Gain' is how aggressively the vehicle maintains course center
.1 is common for Land Vehicles
0 is common for Surface Vessels as the vessel slides laterally

__Overall Steering Offset -This offset is applied to the desired steering angle after all of the gains have been applied. It has the effect of moving the steering wheel left or right. It has simple inc/dec buttons below to assist in tuning the steering angle.

This can be used to compensate for a poorly calibrated steering wheel or a mismatch between the steering ring zero and the true straight driving vehicle steering wheel zero.

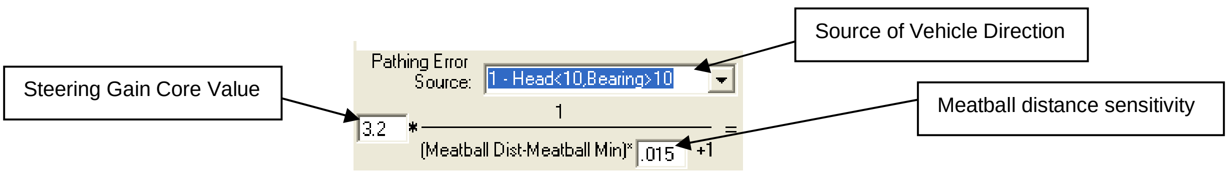
The Total Steering Gain is generated by a series of gains all summed together. The beginning of that summing chain occurs based upon the total distance of the meatball from its starting point. Effectively, the further out the meatball, the less sensitive the steering is.

Additional Adjustment Detail

The following detail is largely provided for additional understanding of the system and more advanced usage. In most cases this not required for normal operations.

Steering Gain Source

The steering gain chain starts with these values. The results of this initial calculation is fed into the steering gain chain.

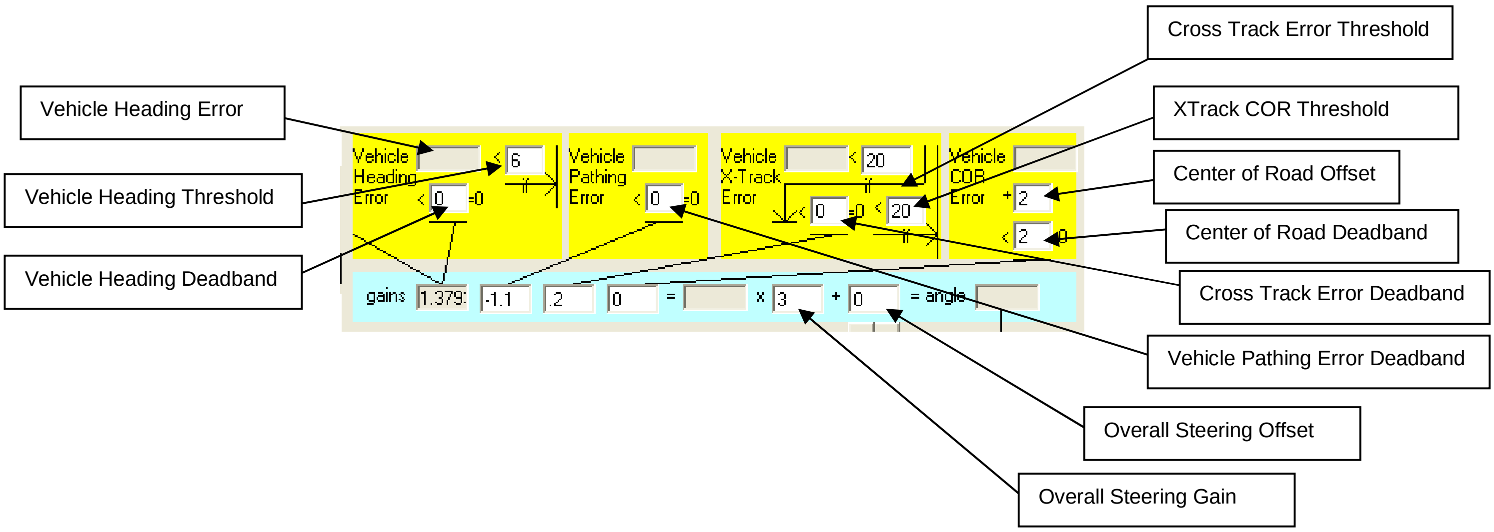


Source of Vehicle Direction -Calculate the vehicle direction of travel based upon its GPS heading or based upon is history of travel.

Heading is instantaneous compass direction supplied by a compass or GPS
Bearing is the history of the vehicle traveling

1 - Head<10,Bearing>10	- Use Heading<10MPH, use Bearing above 10MPH
2 - Heading to Meatball	- Use bearing to meatball
3 - Current Bearing	- Use bearing only
4 - Heading to nxt WP	- Use angle to next waypoint

Steering Gain Core Value	-The beginning gain value used for vehicle steering. Small changes in this value yield large results. A lower value is less sensitive and a larger vakue is more sensitive. 2.8 is used for boats, 3.0 for large vehicles and 3.2 for common vehicles.
Meatball distance sensitivity	-The further away the meatball is from the vehicle the less sensitive the vehicle reactions should be. This value commonly does not change at all because it puts the vehicle at risk of a large steering transition while driving fast. It is nominally .015.



Vehicle Heading Error	-Difference between vehicle bearing and desired bearing to meatball. This is the first error of the 3 stage driving system.

Vehicle Heading Deadband	-Below this value, the Vehicle Heading Error is zeroed and ignored.
Vehicle Heading Threshold	-Below this value, the Vehicle Heading Error is the only error generated. The pathing error is ignored.
Vehicle Pathing Deadband	-Below this value, the Vehicle Pathing Error gain is zeroed and ignored.
** Vehicle Pathing Threshold	-Below this value, the Vehicle Heading Error is the only error generated. The pathing error is ignored.

**There is no Vehicle Pathing Threshold, Cross Track Threshold is used instead

Cross Track Deadband	-Below this value, the Cross Track Error gain is zeroed and ignored.
Cross Track Threshold	-Above this value, the Cross Track Error Gain is not generated and is zeroed. If we are too far off course then we use other gains to get us much closer.

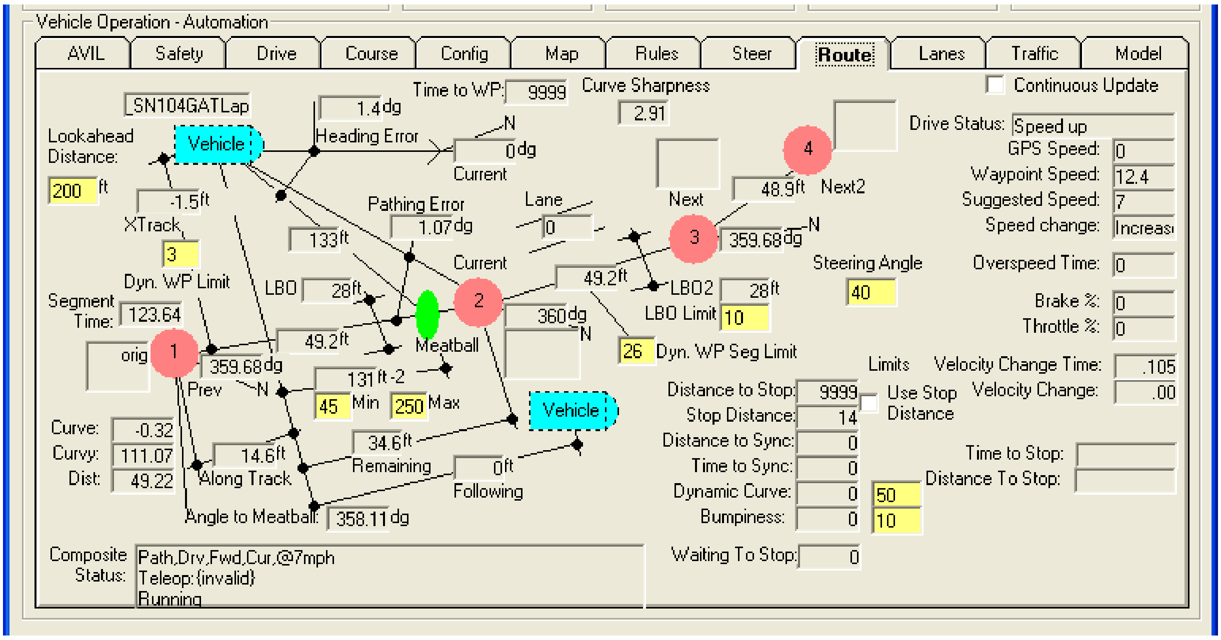
There is a center of road provision that uses fusion of a camera and a laser scanner. It does require more hardware and sensors to implement. These inputs are generall not used, but are placed here for completeness.

Center of Road Threshold	-If Cross Track is above this value then we do not fuse the Center of Road sensor or use its correction
Center of Road Offset	-This offset is applied if the Center of Road sensor sub-system is used.
Center of Road Deadband	-This offset is applied if the Center of Road sensor sub-system is used.

Overall Steering Adjustment

After all of the factors have been applied to the steering gain, an overall gain is applied as well as an offset to the final steering position.

Overall Steering Gain	-This gain is multiplied by the final steering gain before it is applied to the steering output. It is applied last.
Overall Steering Offset	-This offset is applied to the desired steering angle after all of the gains have been applied. It has the effect of moving the steering wheel left or right. It has simple inc/dec buttons below to assist in tuning the steering angle.



__Lookahead Distance
-How far to look ahead on the course to accumulate the curveyness of the course
-Nominally set to less than the meatball distance, shorter for higher speeds

-The lower the number the less curveyness accumulated
Land Vehicles 50
Surface Vessels 100

__XTrack
-If Cross Track error is greater than this limit
the meatball distance is reduced
the speed cannot increase if off by greater than 2x
-Speed is indirectly affected by meatball distance
-Steering aggressiveness is directly affected by meatball distance
Land Vehicles 3
Surface Vessels 10

__Meatball Min
-The minimum distance the meatball is located from the vehicle/vessel
- When the meatball is close steering is aggressive, but more accurate

__Meatball Max
-The maximum distance the meatball is located from the vehicle/vessel
-When the meatball is far, steering is less responsive, higher speed is possible

__Dynamic WP Segment Limit
-Seg. distances are at 50ft max by the Douglass-Puecker GPS point reduction
-The distances may be less if required to maintain course accuracy.
-If the next segment distance is less than this value, the meatball is pulled in
-Set this value to be less than the 50ft Max for it to detect shorter segments
Land Vehicles 26
Surface Vehicles 40

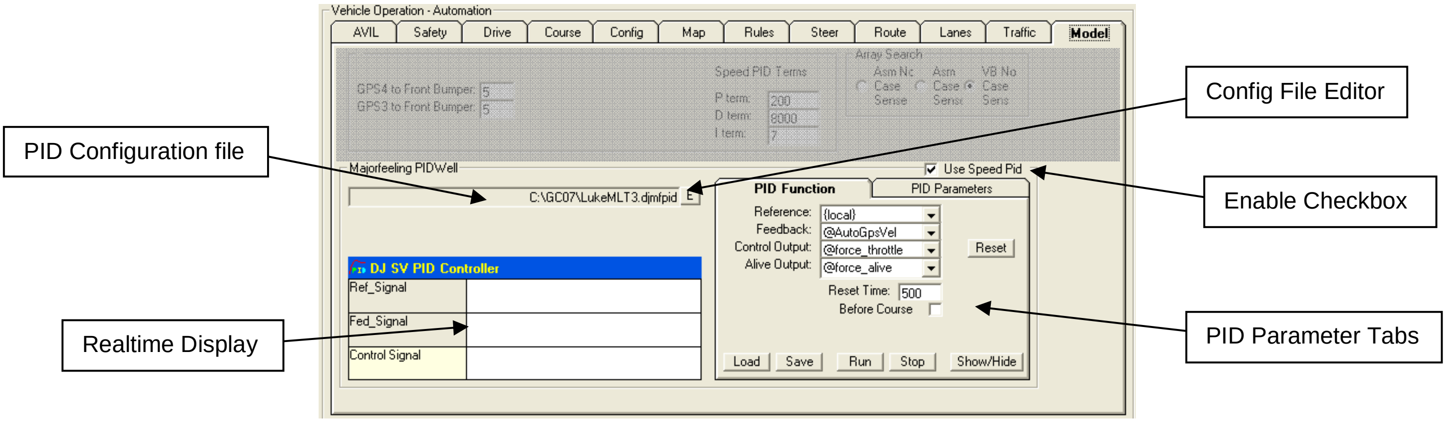
__LBO Limit
Currently has no effect
LBO Limit in RDDF file only indicates narrow course if less than 6ft
Narrow course slows vehicle don by pulling meatball in

__Steering Angle
If requested steering angle is greater that this value speed cannot increase
Basically is there is a lot of steering required, vehicle can't go fast

__Dynamic Curve Limit
If curveyness is greater than this limit, speed cannot increase

__Bumpiness

If bumpyness is greater than this limit, speed cannot increase

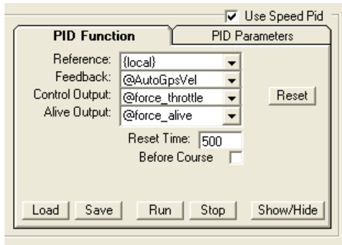


PID Based Speed Control

The speed of the vehicle can be controlled either by a dual slope approach or by using a PID. The PID based speed control is enabled based upon the “Use Speed Pid” checkbox.

As the PID is operating its values can be seen operating in realtime on the Realtime Display.

The PID is configured for operation by the entry of values and parameters in the PID Parameters Tab. These entries can be edited in the parameters tab and then saved or recalled from a PID configuration file. The contents of the PID configuration file can be directly edited with Notepad by pressing the ‘E’ button next to the filename.



Reference -Source of the PID reference signal. This is the Set Point of the PID. {local} indicates that is is supplied by the program, any other value or shared variable becomes the source of the Set Point.

Feedback -Source of the feedback signal for the PID. Should be in the same units as the reference. Is normally a shared variable from GPS or Wheel odometry suce as @AutoGpsVel. The @ symbol is required to denote a Shared Variable.

Control Output - Destination of the control output. Requires the @ to denote a shared variable. Commonly @force_throttle

Alive Output - Alive output updated each cycle of the PID. This assure that the PID is processing the signal and has not stopped functioning, normally @force_alive.

There is an internal FORCE structure that forces the outputs and inputs of various control sub-systems to external values above and beyond that of the internal system. The alive counts are what enable the usage of the external throttle.

Load Button -Loads the external configuration file and updates the parameters

Save Button -Saves the external configuration file and

Run Button -Begin the operation of the PID controller

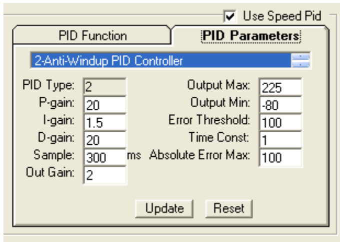
Stop Button -Stop the operation of the PID controller

Show Button -Show or Hide the realtime display

Reset Button -Force the PID controller to mathematically star over.

Reset Time -Causes a periodic Rest of the PID controller. A simple way to keep from integral buildup.

Reset Before Course - Reset PID at start of each course



PID Type:	- The type of PID controller to use. This is generally an Anti-Windup PID.
P-Gain:	-The Proportional Gain of the System
I-Gain:	-Integral Gain of the system
D-Gain:	-Derivative Gain of the system
Sample:	Sample Rate
Out Gain:	Gain applied to the output
Output Max:	Maximum value of the output Positive is throttle, negative is brake
Output Min:	Minimum value of the output Positive is throttle, negative is brake
Error Threshold:	Error value below which it is ignored
Time Const:	Derivative Time Constant
Absolute Error Max:	Maximum error allowed, clipped above
Update Button	- Update any changes made to paramaters
Reset Button	- Reset the PID controller

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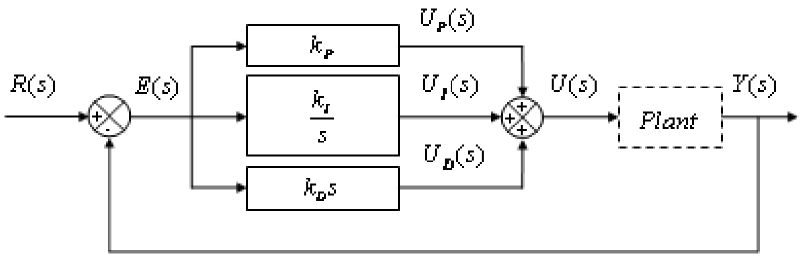


General PID Controller

The popularity of the General PID Controller is credited to its versatility and simplicity. The controller has three parameters to be tuned per se:

Proportional gain

Bigger proportional gain can:

reduce rising time and steady-state error; however, increase overshoot and may incur instability.

Integral gain

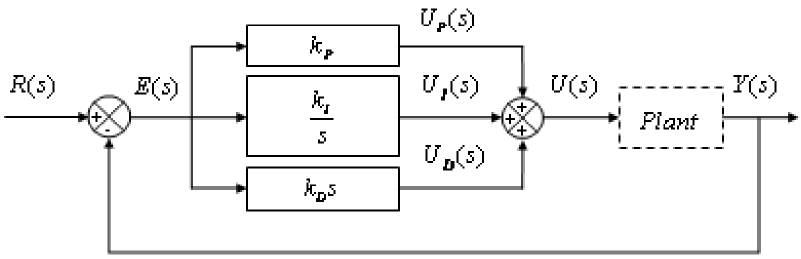
Bigger integral gain can:

reduce steady-state error dramatically;

however, increase overshoot and setting time, and may incur instability.

Derivative gain

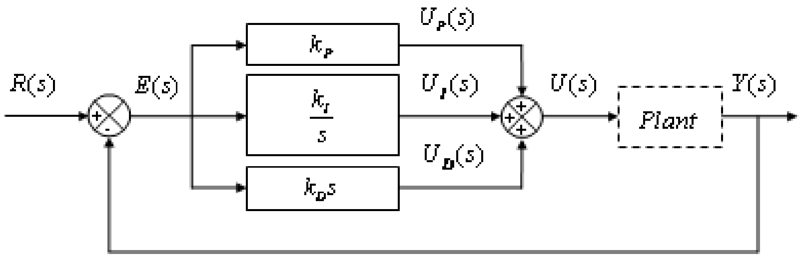
Bigger derivative gain can reduce overshoot, settling time, and improve stability.



PID Controller with Integration Separation

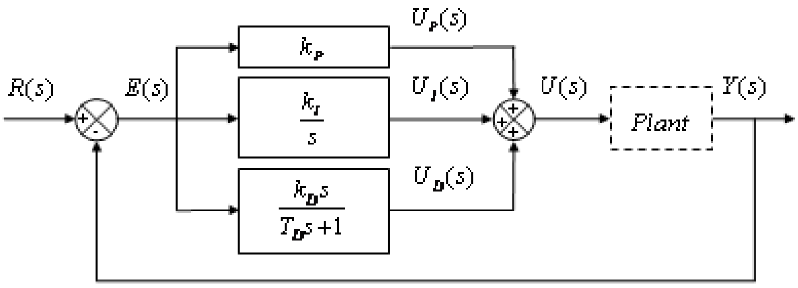
The PID Controller with Integration Separation addresses the problem that bigger integral gain will increase overshoot during transient process. The structure of the controller as well as the control system are identical to the General PID Controller based control system. In addition to the Proportional gain , Integral gain and Derivative gain , an estimated Maximal Error is required to compute the Integral Rate β.

Note: If the Maximal Error is zero, Integral Rate will be set to 1, i.e., the effect of integration separation is lost.



Anti-Windup PID Controller

The Anti-Windup PID Controller addresses the saturation problem associated with the Integral Term. The structure of the controller as well as the control system are the same as the general PID controller based control system. The controller has three parameters need tuning: Proportional gain , Integral gain and Derivative gain .



PID Controller with Partial Differential

The principle of the PID controller with Partial Differential is adding a low pass filter to improve the performance of the control system during transient process. Introducing a low pass filter can suppress high frequency noise. The structure of the control system is similar to the general PID controller based control system. In addition to the Proportional gain , Integral gain and Derivative gain , the user should also designate the Derivative Time Constant .

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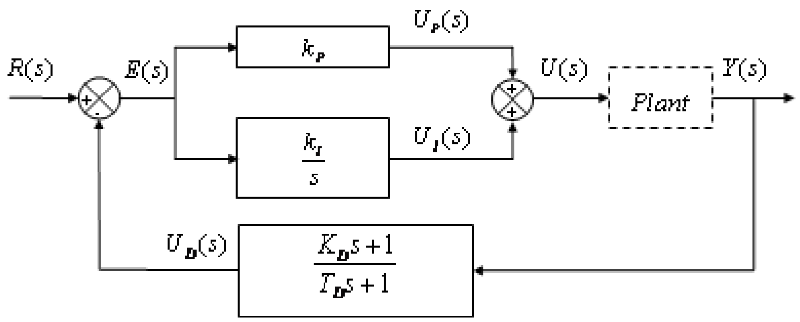
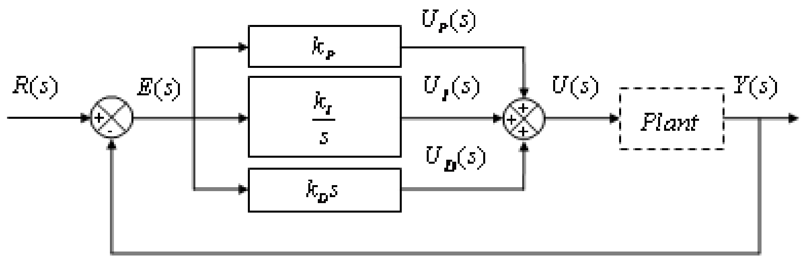


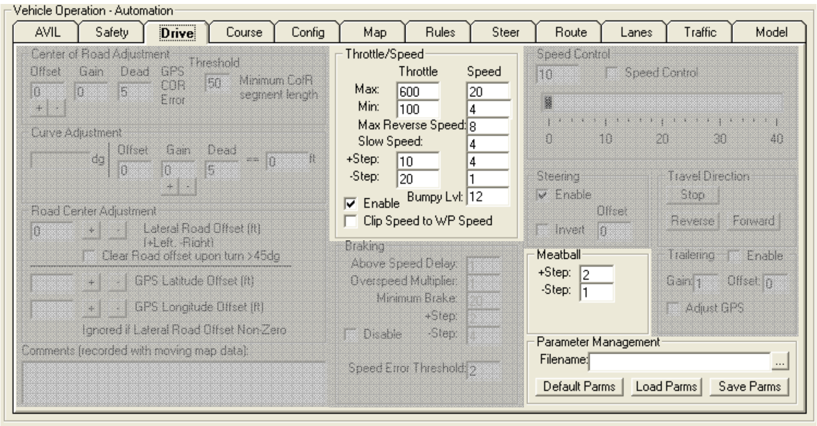
PID Controller with Differential in Advance

The PID controller with Differential in Advance is suitable for the situation where the reference signal changes violently. The purpose of differentiating Feedback signal , to the exclusion of Reference signal , is to avoid system oscillation. In addition to the Proportional gain , Integral gain and Derivative gain , the user should also designate the Derivative Time Constant .



PID Controller with Dead Zone

The PID Controller with Dead Zone is another solution to avoid system oscillation caused by the plant's undue sensitivity to the Control signal . The structure of the controller as well as the control system are identical to the General PID Controller based control system. In addition to the Proportional gain , Integral gain and Derivative gain , the user should also designate the Error Threshold ε.



Throttle/Speed Frame

The limits of actual throttle and desired speed and the slopes to achieve new values are controlled from this frame.

Throttle Max -The maximum value that the throttle output can achieve. Actual throttle output is clipped to this value.

Throttle Min -The minimum value that the throttle output can achieve. Actual throttle output is clipped to this value.

Speed Max -The maximum value that the desired speed can achieve. Actual desired speed is clipped to this value.

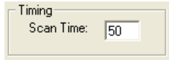
Speed Min -The Minimum value that the desired speed can achieve. Actual desired speed is clipped to this value.

Max Reverse Speed -The maximum value that the desired speed in reverse can achieve. Actual desired speed is clipped to this value.

Slow Speed - When slow speed operations are desired, such as maneuvering through tighter turns, this is the value that is used as desired.

Clip Speed to WP Speed -The maximum speed is clipped to desired Way Point speed. This is only applied if selected and the desired speed is greater that the WP speed.

The processing tick time of DriveWB is set in the Timing Frame on the Config Tab. It is nominally 50ms.



The overall performance of the system can be viewed in the Performance Frame on the AVIL Tab. CPU% should be in the 10% range when the vehicle is not driving or pathing

The system increments and decrements the actual throttle and desired speed along a slope that is set by + and – values. These values are added or subtracted from the throttle or speed on a per system cycle basis. At a nominal timer tick of 50ms, the adjusts occur at a 20hz rate.

Throttle +Step	-The throttle is incremented to the desired value at a nominal 20hz rate using this step. There is no overshoot and the final step achieves the exact value desired.
Throttle -Step	-The throttle is decremented to the desired value at a nominal 20hz rate using this step. There is no undershoot and the final step achieves the exact value desired.
Speed +Step	-The desired speed is incremented to the desired value at a nominal 20hz rate using this step. There is no overshoot and the final step achieves the exact value desired.
Speed -Step	-The desired speed is decremented to the desired value at a nominal 20hz rate using this step. There is no undershoot and the final step achieves the exact value desired.

The Meatball is the target for the vehicle to follow. Since the distance that the meatball is located from the front of the vehicle is variable, it is also controlled by an step values.

Meatball +Step	-The calculated distance that the meatball is to achieve from the vehicle is incremented by this value from the current distance to a greater distance. There is no overshoot and the final step achieves the exact value desired.
Meatball -Step	- The calculated distance that the meatball is to achieve from the vehicle is decremented by this value from the current distance to a

lesser distance. There is no undershoot and the final step achieves the exact value desired.

Parameter Management Frame

All of the user changeable parameters used by DriveWB are save upon exit from the program if desired. The user is asked to save or not upon program exit. This frame allows the user to save and restore all of the parameters at will for operations and testing.

By default the parameters are save upon program exit and reloaded upon program start to the “C:\GC07\dj_drv.ini” named file. This file can be loaded and saved using Paramater Management as desired.

Conclusion

There are many parameters that control the operation of the vehicle/vessel under different scenarios. The Kairos Autonomi Drive Workbench is always evolving based upon customer feedback and requests to include an ever increasing array of driving operations under those scenarios.