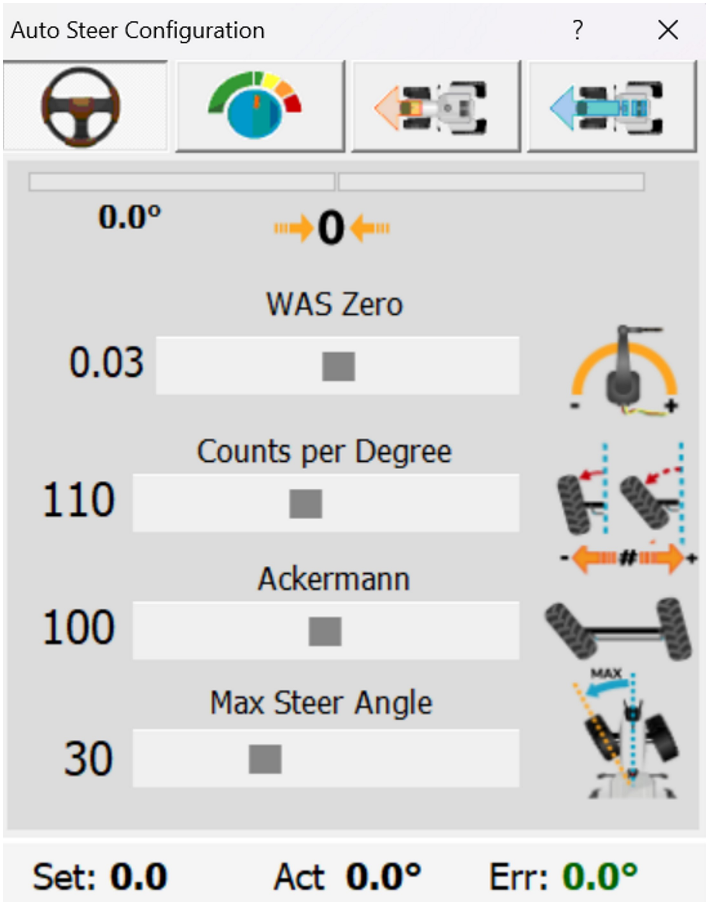
Steering tuning - a guide

14 September 2023 17:55

This is a work in progress - you have been warned ;)

On steering, and how it works

The first page of the steering setup is full of confusing sounding terms, we'll try to make sense of them here.



First of all, "WAS Zero". This is the wheel angle sensor zero (or "straight ahead") compensation. A 5volt wheel angle sensor might ideally read 2.5v when the tractor is steering dead ahead. But sometimes, mounting the wheel angle sensor perfectly so dead-ahead is there without any offset or compensation, is a little difficult. Rather than try and achieve perfection with that mounting, you can compensate a little with this. The easiest way to tune this is to engage drive/PWM mode (covered later), set it to zero and adjust the offset until the tractor heads straight at a point on the horizon without wandering off.

Without a good WAS zero, you will find it hard to keep a good line, so consider this a critical setting.

Counts per degree

Counts per what??? Well, the wheel angle sensor is an analog device, outputting a sensor voltage typically between 1 and 4v for full-left and full-right (for example). But not all sensors are equal. Some might measure 1.15v to 3.85v for example. Some might be 1.75 to 3.25. AOG needs a way to convert this to its own internal steering units, as measured by the analog to digital converter. What this means is that for steering dead ahead, the reading should be zero, for full left it should be around -4000 and full-right around +4000. Counts per degree is a calculation performed across the range of voltage that your device returns so as to give that -4000 to +4000 range.

(insert formula here)

We can derive the correct value for this in the following manner:
(insert REC details here)

Ackermann

The Ackermann value is similar to CPD - tractors do not have the same steering geometry to apply to both wheels. If you watch your wheels at full lock, you'll notice that the wheel on the inside of the turn turns more sharply than the wheel on the outside of the turn (as shown in the icon). Think of this as a compensation factor that will be applied to the CPD value.

(REC function here)

Max Steer Angle

This is a simple enough setting - once you've set the other 3 properly, set this so that AOG won't try to steer past this angle, thus riding the steering hard against the pressure relief valve. You wouldn't do it when driving, so don't do it here either. Of course, setting it way too low means you'll never be able to make a headland turn.

Once you've got these at a good setting, we can look at motor/hydraulic functions.

Motor or Hydraulic Gain

Now, we're onto the good stuff. While it might seem strange to have motor and hydraulic categorised together, they work a similar way. AOG works by outputting a PWM voltage, that is to say a variable voltage - lower voltage means a slow turn, higher voltage (up to 12 or 24v depending on configuration) means a faster turn. If you are using a motor, a low PWM will turn the wheel slowly. If hydraulic, a low PWM will open the valve a small amount.

Clearly, if we are only just off the line, opening the valve hard would not be a good idea - you would overshoot the mark entirely, just as you would if you manually engaged full lock just to make a minor correction. So this page is about tuning AOG to ensure it outputs the *optimal* PWM value at all times.

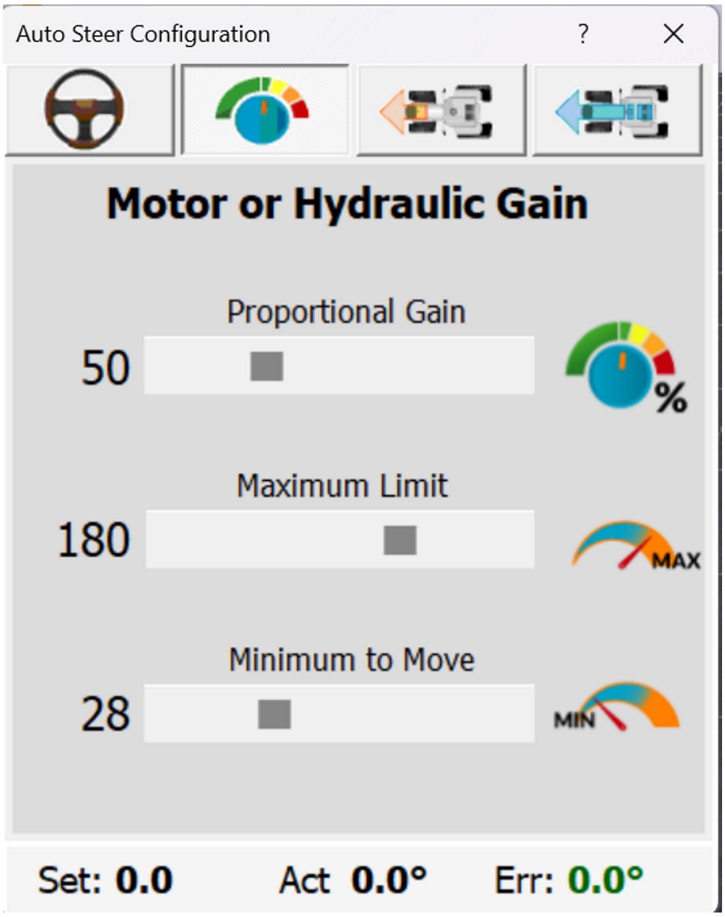
All the settings below amount to one thing - what is the PWM value AOG should output *at this time for the amount of steering required (eg, a hard turn, or a soft one)*.

Notice the italics above - AOG steers towards a destination point; not "the line". The destination point is a point on that line, and the location of that point is calculated by the steering algorithms - Stanley or Pure Pursuit. More on them later.

When AOG decides a turn is required, because the machine is off the line, it looks at the wheel angle sensor, measures the deviation between the actual angle and the desired angle of steer to get it to the *destination point*, and is thus able to decide how much to turn the wheels.

If only a minor correction is required, it might decide that outputting the minimum-to-move is fine and will be enough to bring the machine to the correct location. If it is already way off (for example, you engaged autosteer when a fair distance away), it might decide that a more aggressive turn is needed.

So, how does it work out these values?



It makes sense to review the settings here bottom to top, so we'll start with

Minimum to move (or "min PWM")

Not all systems start steering at the same point. One manufacturers hydraulic valve might only start moving when this value is say at 25, whereas a particular steering motor might only start moving at 30. As a guidance, we should set this to 1 unit below the minimum amount that the system starts actually turning the machine at. So, if it takes a minimum of 29 for the steering to move, set it at 28.

We can find out this value with the Drive mode.

(details on how to find this value here)

Consider two scenarios:

- You are reasonably close to the line already, and engage autosteer. AOG looks at your current wheel angle (from the WAS), looks at the distance to the destination point on the line (distance error) and calculates an intended steer angle. It must then decide how quickly to turn the steering to get to that line, so we need to calculate a final PWM. We take the minimum PWM, apply the distance error and arrive at a final PWM figure to output. This is done, and the tractor is steered gently to the line
- You are far away from the line and engage autosteer - as above, the tractor takes wheel angles, distance errors and such, but now it could also use a helping hand to increase that steering value to steer quicker. This is where Proportional Gain comes in

Proportional Gain

Proportional gain is a multiplication factor to be applied to the minPWM+distance error proportional to the distance away from the line. The further you are away from the line, the more the PWM is multiplied, resulting in a sharper turn. The closer to the line, the less gain is applied, and a gentler turn occurs.

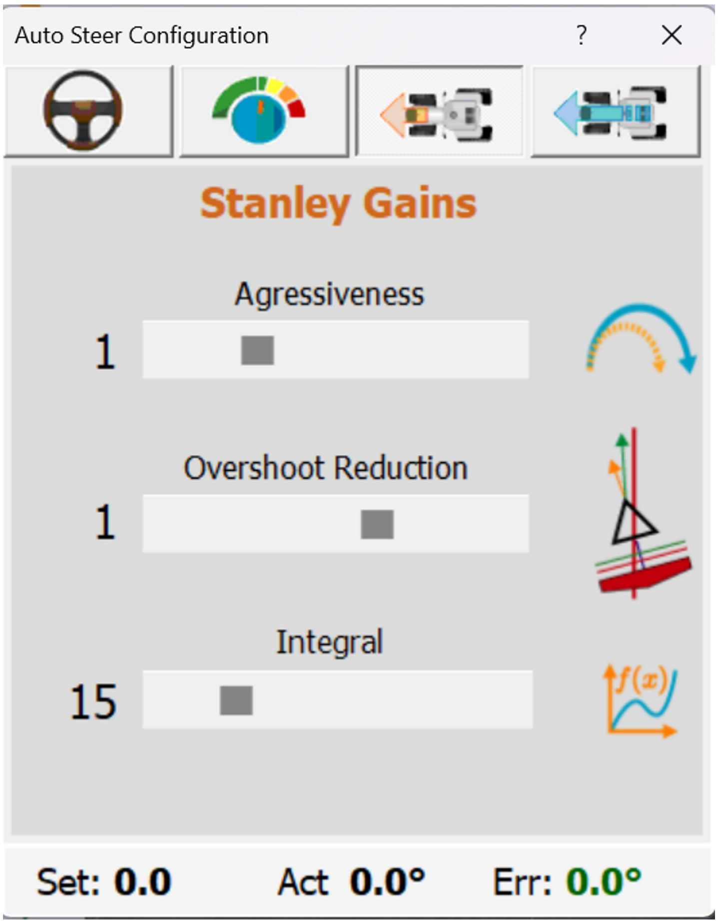
Maximum Limit

Knowing the above, you might guess what this relates to - it's the maximum that we will turn the motor by. If it's a 12V motor, then at 255 (which is 100%), the motor will be at full RPM when that slider is at the top. Likewise, if you set it around 127 (or 50%), it won't get above 6V. So, why would you want to limit it?

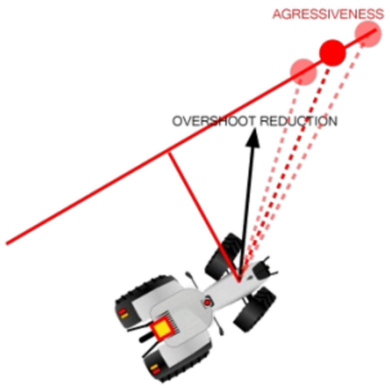
Perhaps things get a little too "exciting" with harsh turns at full speed, so this is one to leave kinda-high and turn it down if things are wild. If you put it too low tho, you'll have issues with oscillation (cris-crossing the line) as the system is unable to steer quickly enough to correct as it goes over.

There are two ways that AOG decides how to get your machine or implement to the required line - the way these calculations are made are called algorithms. Both are in common use with other autosteer manufacturers, they aren't overly specific to AOG.

Stanley steering algorithm

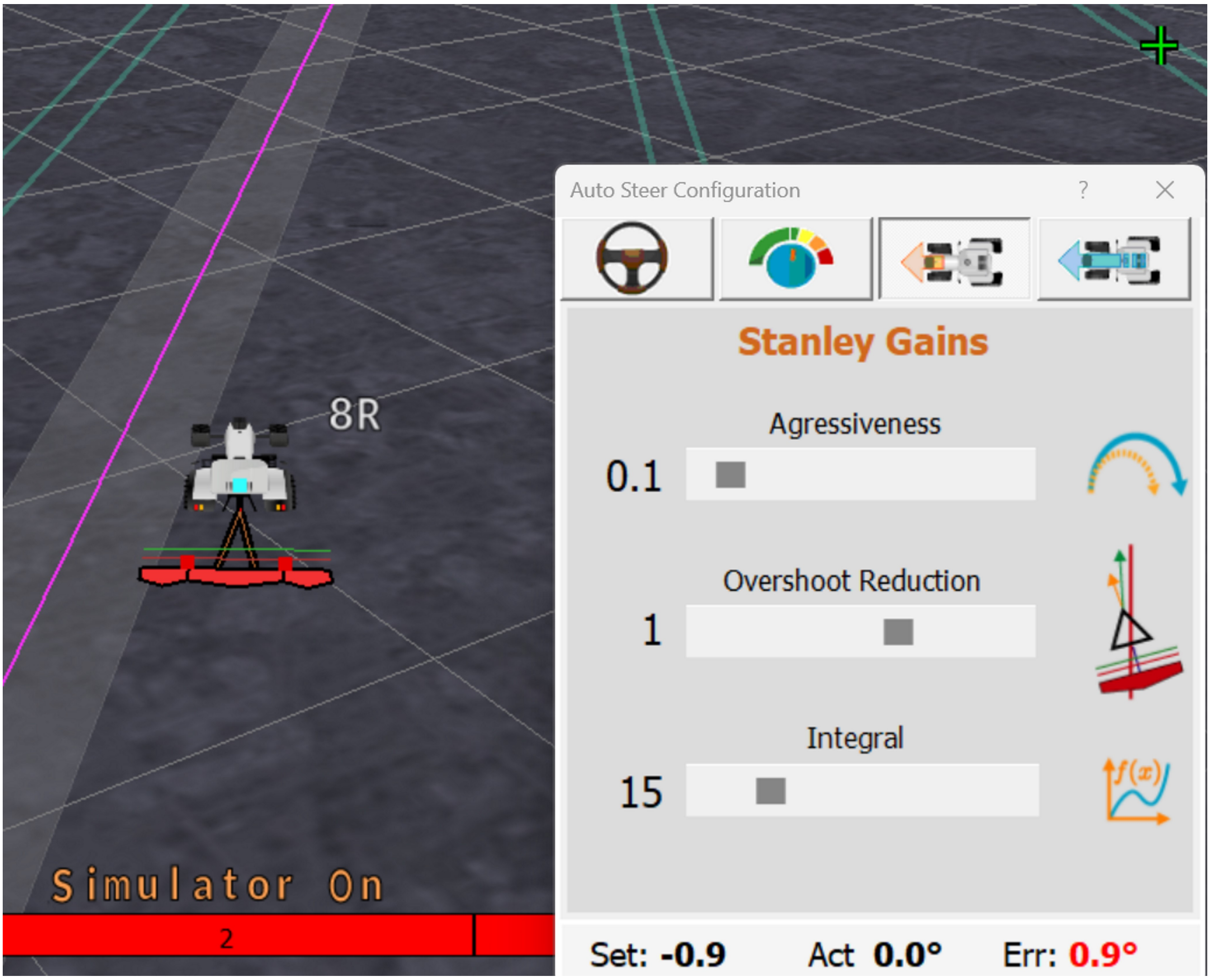


From the manual:

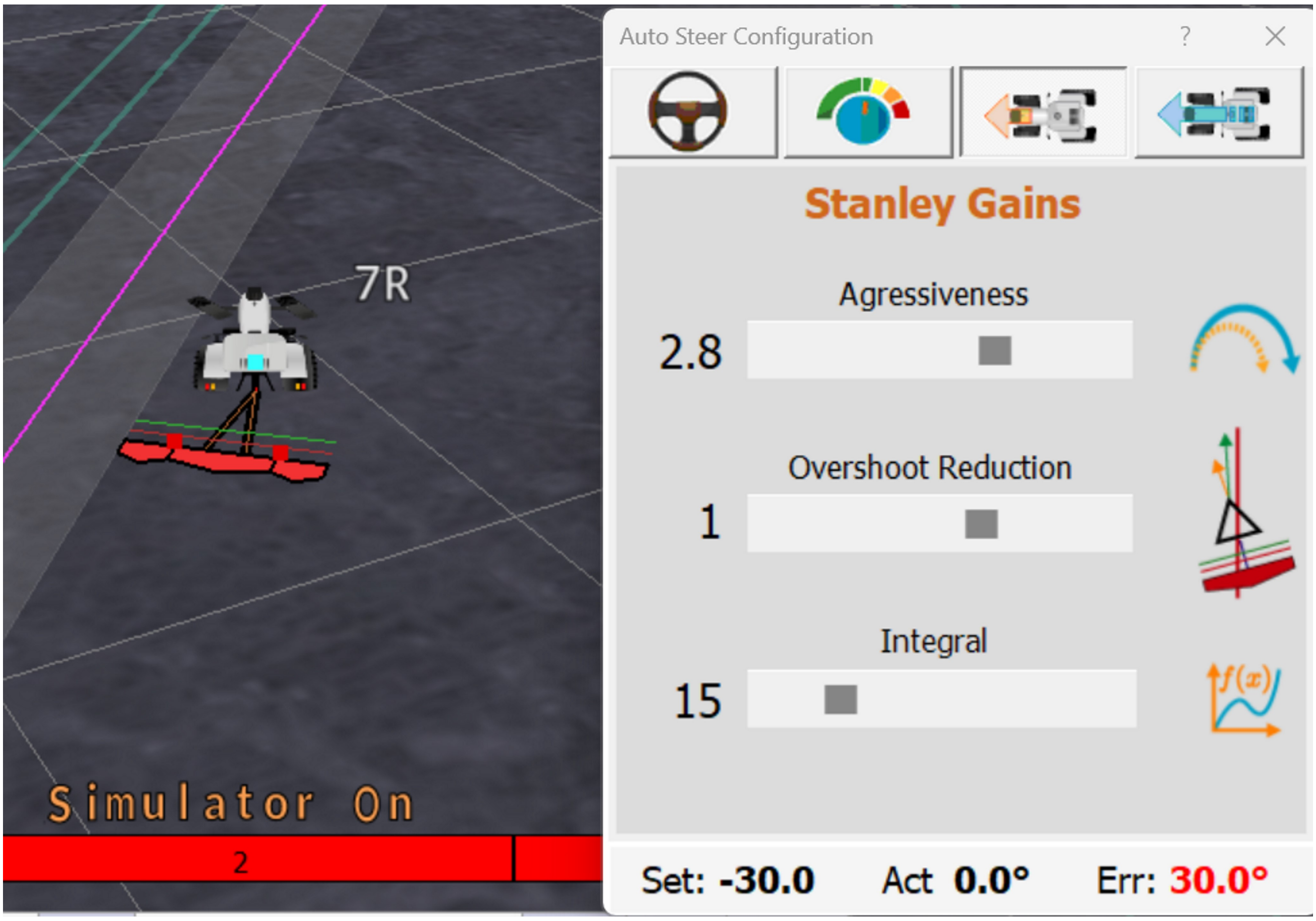


Stanley method use the front axle as its reference point. Meanwhile, it looks at both the heading error and cross-track error. In this method, the cross-track error is defined as the distance between the closest point on the path with the front axle of the vehicle.

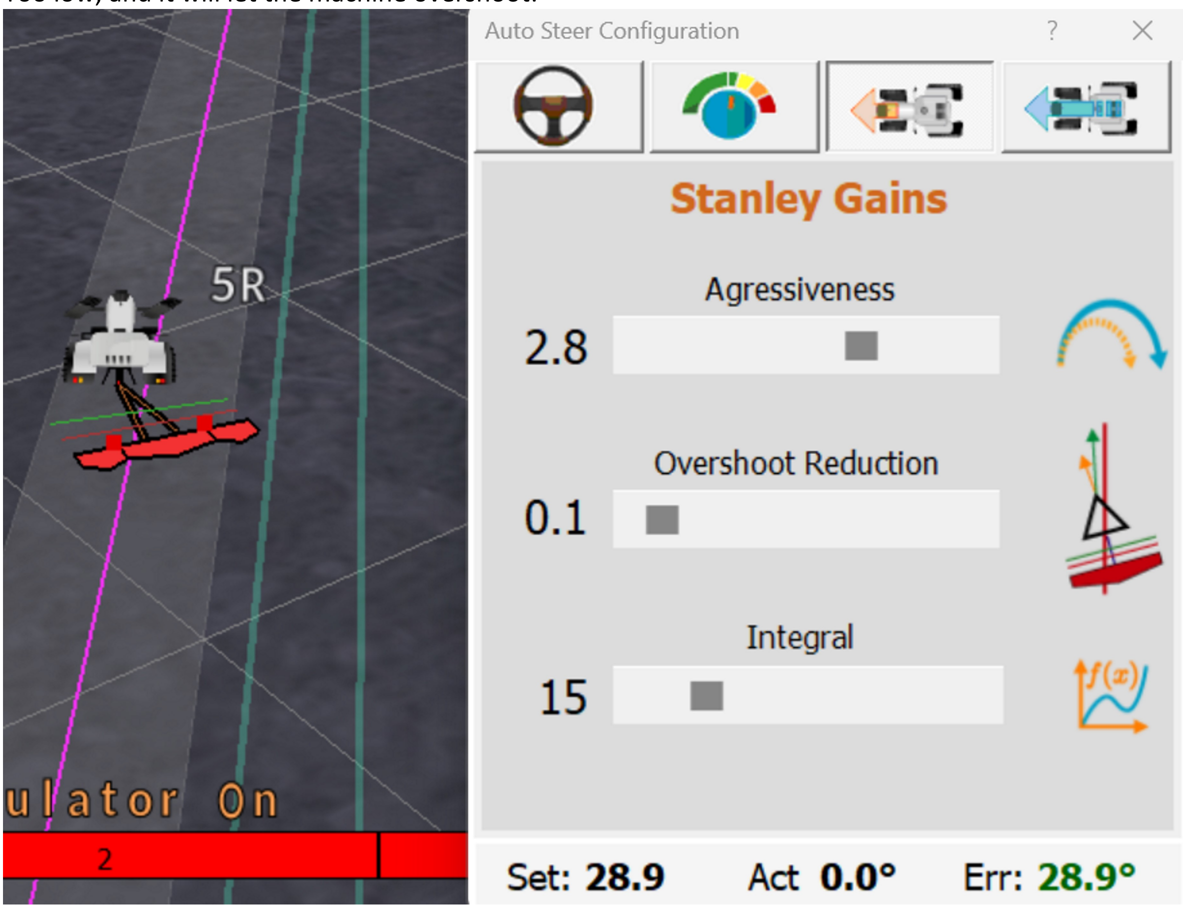
Unlike with Pure Pursuit, in this mode - the front axle is the reference point. Your aggressiveness is how quickly it will try to bring the machine to the line - with a low value (0.1, here), it will steer very gently and take forever. Notice the Set Point here - at 0.9, it's hardly steering at all and that figure isn't going up and the steering isn't noticeably much off-centre.



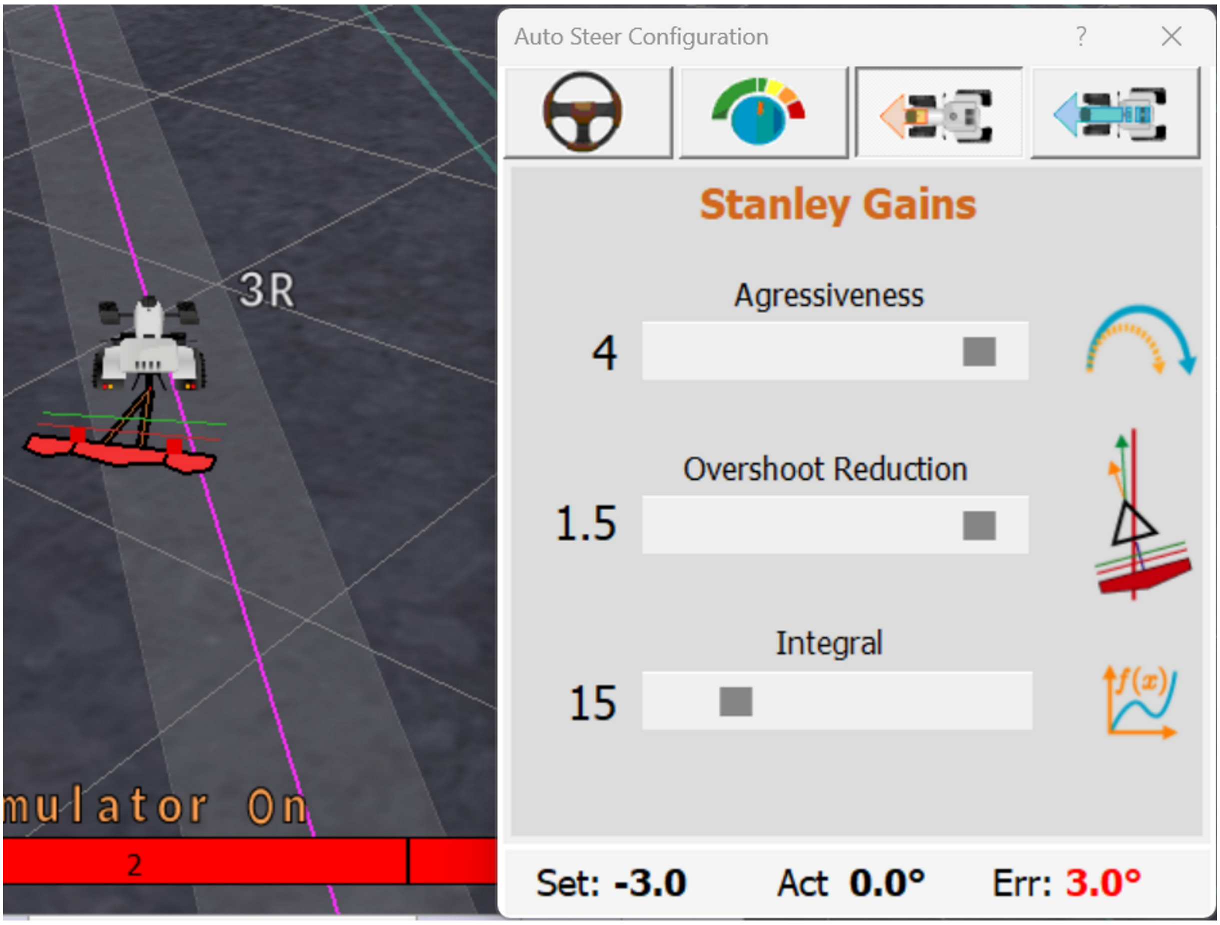
But with higher aggression, it goes up much higher and it's obviously going to get there quick, but with a risk of overshooting the line. Notice here, our setpoint is -30 and the wheels are hard left.



The overshoot reduction counteracts the aggressiveness, basically in a fight against the aggression.
Too low, and it will let the machine overshoot:



Too high, and it will back off the steering earlier, taking longer for the machine to get to the line:



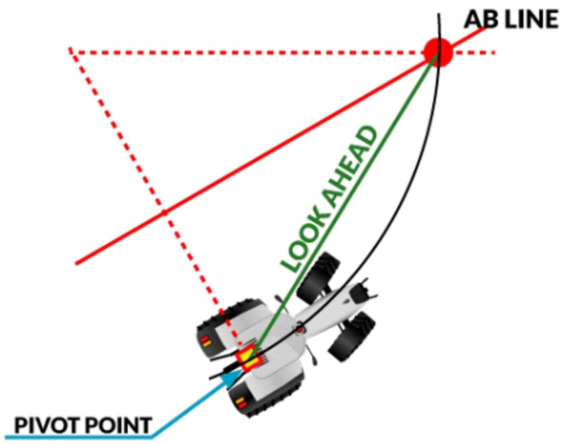
As always, with steering, it's a balancing act - setting one will affect the other.

Integral

Integral allows the distance error to keep adding up to help add steer angle when a normal distance and heading calculation won't bring the machine to the line. This is useful on hillsides or when pulling heavy draft to one side.

Pure Pursuit

Pure pursuit is another steering algorithm.



Pure Pursuit mode uses a look-ahead point which is a fixed distance on the reference path ahead of the vehicle as follows. The vehicle needs to proceed to that point using a steering angle which we need to compute.
In this method, the centre of the rear axle is used as the reference point on the vehicle.

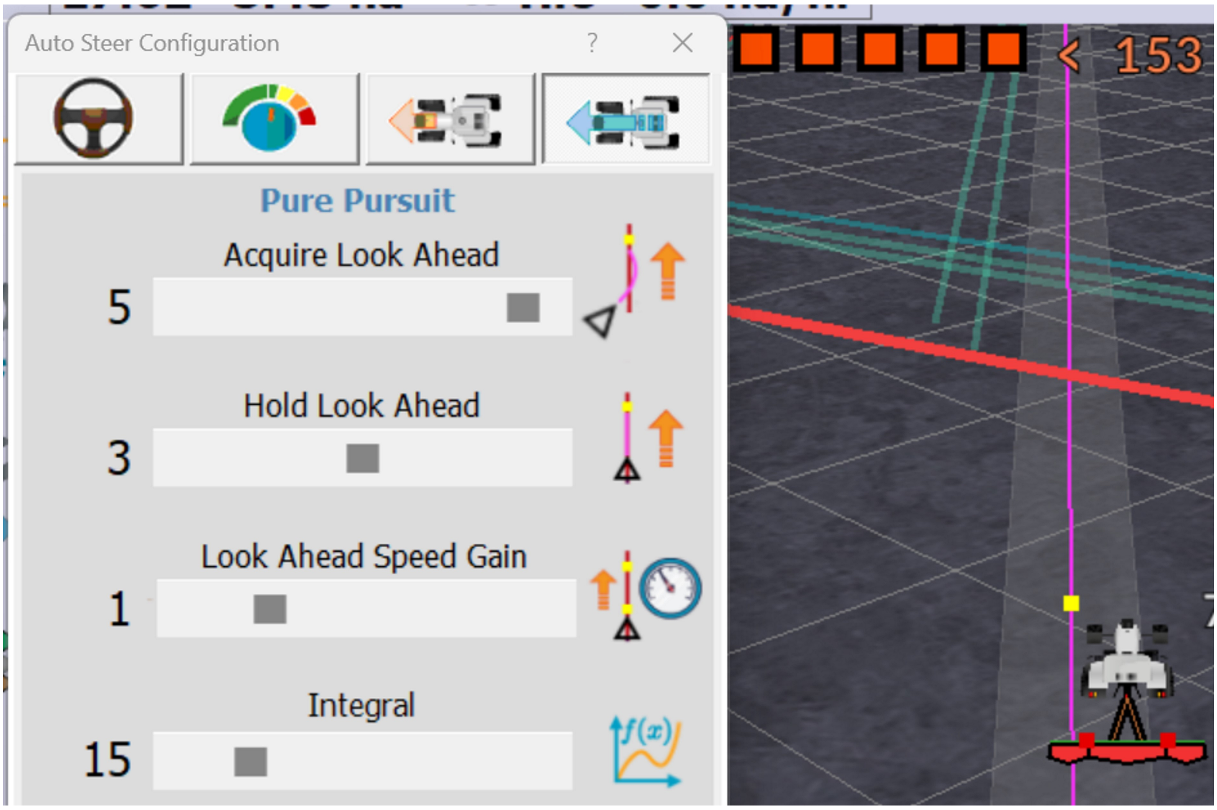
Think of Acquire and Hold as two separate operations - if you are more than 10cm from the line, the system is in Acquire mode. If you are less than 10cm, then the system is in Hold mode.

Imagine a point in front of the tractor - that's where the machine is heading to. If that point is far in front of you, it will steer gently to get to that point. If it's very near you, it will turn aggressively to get there and may turn so aggressively, it will overshoot as an inability of then being unable to straighten up fast enough.

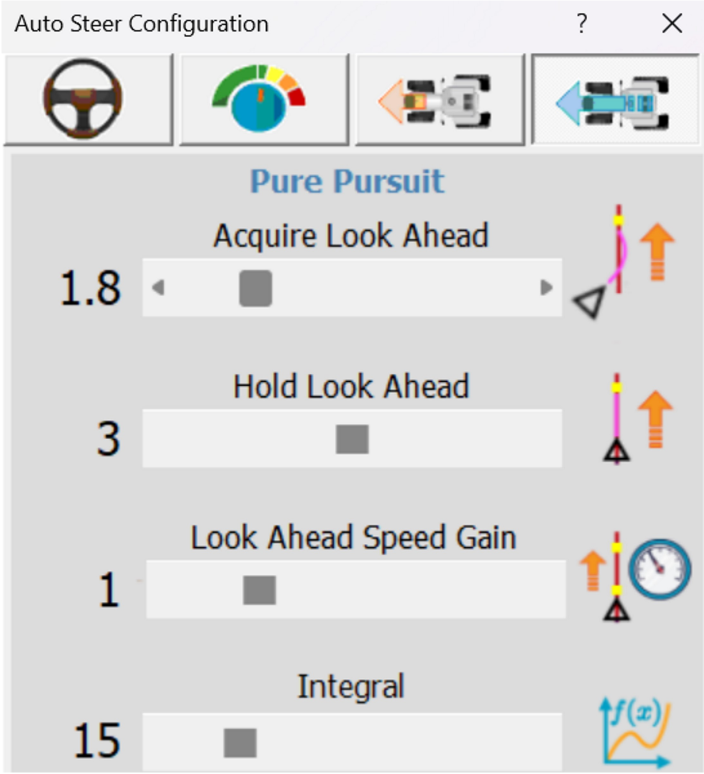
Think of the Hold and Acquire sliders as being aggressiveness for each step. If you set them too high, the destination point will move further away from the tractor, and thus it will take a while to get there. Again, too close and things might get a little unpleasant with lots of over-correction. The thing to note here then, if we consider them as being aggressiveness, is that at higher values, it's less aggressive.

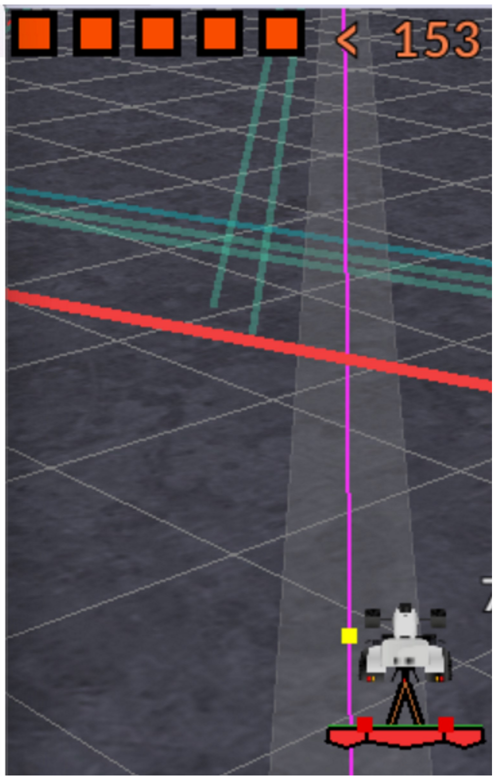
The yellow dot is where we are heading with the centre of the rear axle, if the steering were engaged. In the simulator, the machine here is stopped. We can see the dot is out in front as we are at our maximum look ahead (5), yet the distance (at 153cm) is high. If you want it to steer more aggressively, you bring the point towards you *by lowering* the Acquire Look Ahead. If the value is too low, it might criss-cross the line as it steers too aggressively to get there, then straightens up but overshoots and has to then steer in opposite direction again.

If it's too high, it will be too slow to react to changing situations.



With our above in mind, if we bring that value down to 1.8, the dot moves closer:

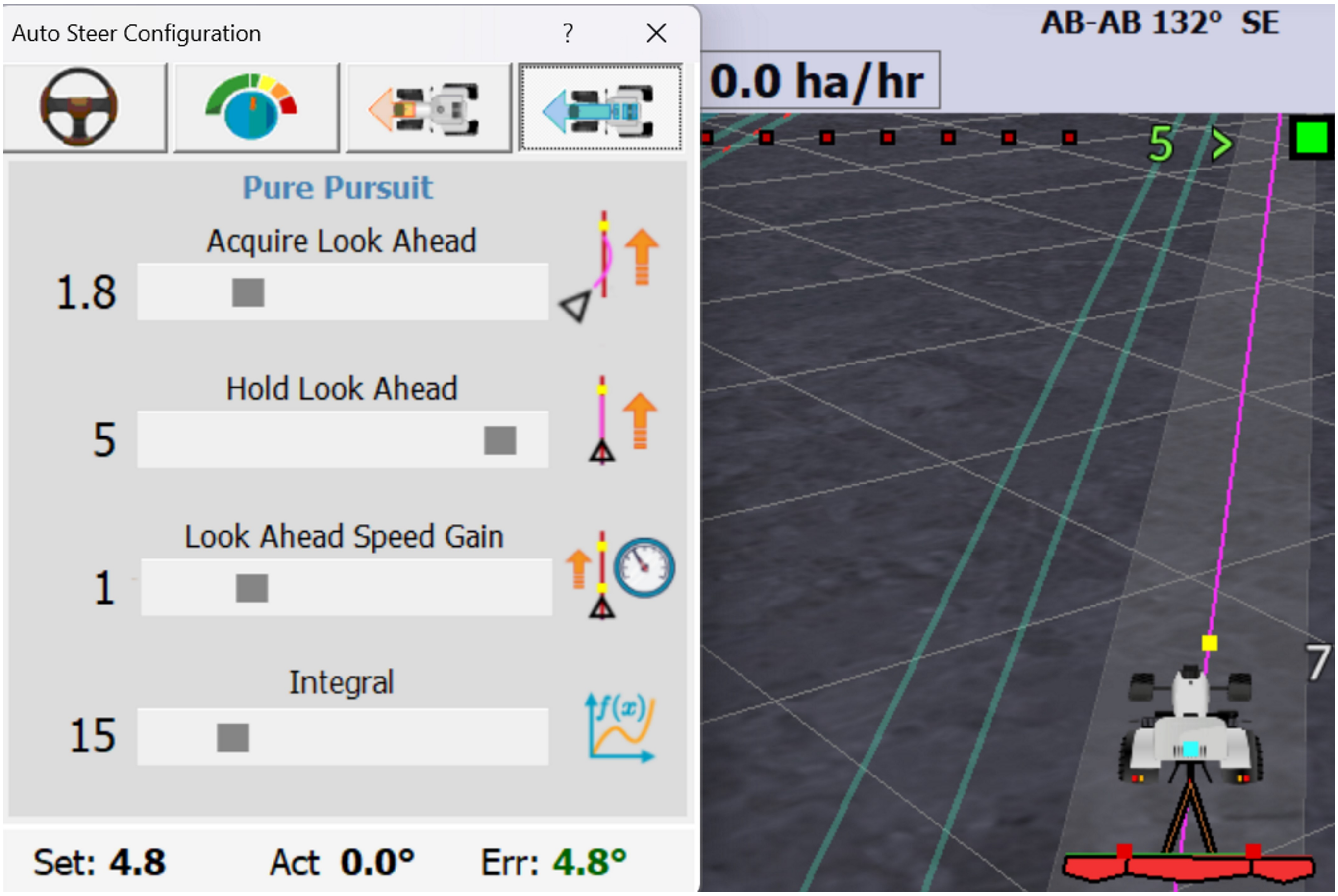




Clearly, the first example will take a gentler approach to the line than the other. Note our distance off the line here, at 153 we're a fair way away, and definitely over 10cm, so we will be influenced by the Acquire figures.

Also, it's worth noting that the dot always stays that distance ahead - you can't catch it or drive past it, it moves with you.

Now, if we look at a distance of less than 10cm, we'll be in Hold mode. Still a yellow dot, but the Acquire slider no longer has any effect if we move it (until we drift further away than 10cm and return to Acquire mode again). Its position is now dictated by the Hold Look Ahead slider.



Again, at 5, we're taking a lazier approach to reaching the destination than at a lower point (below).

And once again, that dot is always moving with you, never caught or passed. As with Acquire, think of it as an aggression for keeping the line, too high a value and it might be so slow to react that you drift so far away you're back into Acquire. Too fast, and it'll be jumpy.

Look Ahead Speed Gain

Look ahead speed gain alters the distance to the yellow point proportional to how fast you're going. If you are doing a job at high speed, you don't want the destination point to be too close no matter how aggressive you might have the Hold set at, so this will push the yellow dot further away the faster you go. The effect is it being more gentle, to save any harsh steering at high speed. Doing this allows you to have a stable response if for example your job is fluctuating in speed (perhaps you speed your mower up in a lighter section, but slow right down in a heavy section) without having to constantly play with the hold/acquire sliders.

The higher the value, the further away the destination point and thus the slower the response

Integral

Integral allows the distance error to keep adding up to help add steer angle when a normal distance and heading calculation won't bring the machine to the line. This is useful on hillsides or when pulling heavy draft to one side.