MatrixNav1.7 Installation, Setup and Operation

MatrixNav version 1.7, now includes the following functions:

- Control modes continue to include manual, stabilized, and return-to-launch (RTL)
- Stabilized and return-to-launch modes now include both yaw and pitch stabilization with proportional and rate feedback, rudder-elevator mixing, and optional altitude hold.

MatrixNav version 1.7 will control the rudder, elevator and throttle of your aircraft. It was developed on a Gentle Lady sailplane with an electric motor, but it should work on any aircraft with a rudder channel and an elevator channel. You may connect your throttle directly to your Rx or you may connect your throttle through MatrixNav if you wish to use the optional altitude-hold feature.

Take the zip file that you have downloaded, and unzip it to a new directory. Open the project, compile it, and program it into your board. Open the MatrixNavRed project if you have the UAV Dev “redboard”, or the MatrixNavGreen project if you have the previous version of the board, the “greenboard”.

The gains that you need to adjust are all in the file “controlGains.h”. Use the same gains for both the red board and the greenboard. The difference in the gyro gains between the two boards is incorporated in the definitions of YAWKD and PITCHKD, which include the scaling parameter SCALEGYRO.

The firmware has been thoroughly flight tested. All features have been tested, including manual control, stabilization, return to launch (RTL) and altitude control. Everything works very reliably including manual control. The only thing that you need to make sure of before you launch is that all of the connections are good, especially to your battery and receiver, and that the servo reversing switches both on your transmitter and on the board are in the correct position. Also, obviously you will want to do a walk around to understand what to expect the controls to do.

One thing that was recently discovered (it was no surprise) is that the LISY gyros on the red board are disrupted by vibration. If you have the red board, you can check whether or not your mounting arrangement exposes the gyros to excessive vibration by running the roll-pitch-yaw demo with and without the motor running. If the performance is much better with the motor off, you should take steps to reduce the vibration that the board is subjected to. Mount the board at a low vibration location, such as near the center of gravity of the plane, and use foam rubber between the board and the plane.

If you have the green board, there is no need to take any steps to mitigate vibration.

Altitude hold is a new feature in this release. Altitude hold adjusts the throttle and elevator to maintain a desired altitude. During stabilized mode and commanded return to launch mode, the desired altitude is set according to the throttle stick on the transmitter. This achieves a similar feel to the controls in both manual and stabilized mode. You can still control the elevator and the throttle from the transmitter with altitude hold turned on. The only difference is that altitude hold will add signals to the throttle and the elevator to maintain altitude. Altitude hold can be used during takeoff and landing. For takeoff, you use maximum throttle. For landing, you use minimum throttle.

If the radio signal is lost, (pulses no longer arriving at the PWM inputs of the board) the firmware will apply return-to-launch control to the elevator and rudder, with the motor turned down to idle, on the theory that you have lost control, and that you want the plane to return to you, circle, and make a landing. Of course, if your receiver has a fail-safe feature, the firmware will respond according to how you set the receiver's fail-safe feature.

The altitude control works as follows:

- Everything is based on the throttle stick, which sets the desired height above the launch point.
- Whenever the actual height is below the desired height minus 50 meters, the control sets the throttle for full power, and sets the target pitch to PITCHATMAXTHROTTLE.
- Whenever the actual height is above the desired height minus 50 meters, but less than the desired height, the throttle is gradually reduced and the pitch is readjusted. When the plane is approaching the desired height, the throttle will be at minimum throttle, and the pitch set accordingly. Under normal operation, altitude hold will stabilize the altitude slightly below the target altitude.
- Whenever the actual height is more than the desired height, the throttle will be turned off, and the plane will go into a glide mode. This feature is intended mostly for sailplane pilots, but it should work fine for any type of plane, provided you set the parameter PITCHATZEROTHROTTLE to a value suitable for your plane. For a sailplane, this parameter should be set to about zero, to ride thermals. For other types of planes, this parameter might be set slightly negative to achieve penetration into the wind, and to send the plane back down to the desired altitude.

Installation and connections

Install the board in your plane with the GPS connector facing forward and the components facing up. Try to get the board level when the plane is level, but it is all right if it is a little bit off.

Connect the GPS to the board, and also make the following connections:

- Rudder control. Connect whatever channel on your Rx that you like to use for the rudder to channel 1 input to the board.
- Elevator control. Connect whatever channel on your Rx that you like to use for elevator to channel 2 input to the board.
- Throttle control. If you are using altitude hold, connect whatever channel on your Rx that you like to use for throttle to channel 3 input of the board. If you are not using altitude hold, connect the throttle servo or ESC input directly to the Rx.
- Manual/stabilized/RTL mode control. Connect whatever channel on your Rx that you are going to use for mode control to channel 4 input to the board.
- Connect servo 1 output from the board to your rudder servo.
- Connect servo 2 output from the board to your elevator servo.
- If you are using altitude hold, connect servo 3 output from the board to your throttle servo or electronic speed control.

The ordering of the pins on the board are the ground connections are nearest the edge of the board, the power connection is in the middle, and the signal is farthest from the edge. If you are using cables with black-red-white wires, the black wire connects closest to the edge. If you are using cables with brown-red-orange wires, the brown wire connects closest to the edge. Connections from the board PWM input channels to your radio will require special cables with female connectors on both ends.

Do an initial check of everything. It might be best to do it outside to get a faster GPS lock.

Power up and manual checkout

Power everything up. *Turn on your transmitter first, and then your plane.* If you are using an electronic speed control, make very sure that the throttle stick is set for minimum throttle and the mode control is set for manual. Otherwise your motor could possibly come on during the initialization sequence. *It might be a good idea to prepare for the possibility that the motor will come on during initialization, until you go through the setup process once.*

Hold the plane level and steady during the first 10 seconds of power up. During the first 10 seconds, the rudder will deflect significantly, and will not respond to manual control. There will not be any pulses being sent to the electronic speed control, so the motor should not come on.

At the end of 10 seconds, the gyro and accelerometer offsets are recorded, and you are then free to move the plane. The deflection of the rudder will reduce. It is at this point that manual control will be turned on, and pulses will be sent to the electronic speed control (ESC). *If you have an ESC that requires you to cycle the throttle to full and then back to off, now is the time to do that*.

Mode control works the same as for previous versions of MatrixNav, so if you use the same setup on the mode control channel it should work the same way. Start out in manual mode. If you are using a stick and trim tab to select the control mode, leave the stick centered and move the trim tab all the way to the left. On a Futaba, the servo reversing switch for the channel should be in the normal position.

When manual control comes on, check the directions of elevator and rudder under manual control. If either of them is in the wrong direction, fix it by changing the servo reversing switch on your transmitter.

Now you need to wait for GPS lock, it may take a minute or two. After the GPS locks, the rudder should "waggle" a few times. When it stops waggling, the controls are ready for further setup.

Stabilization checkout

Test the stabilization functions, including altitude hold. If you are using a stick and trim tab, move the trim tab all the way to the right. *Make sure the throttle is in the off position. Put the controls in "stabilize mode", but be prepared for the possibility that the motor will come on.* Now is the time to check that the throttle reversing switch SR3, is in the right position. Make sure the controls are in the stabilize mode, and advance the throttle. If you have the throttle reversing switch SR3 in the correct position, the throttle will “snap” on to the minimum throttle setting. If you have the throttle reversing switch SR3 in the wrong position, the altitude hold will not engage, and the motor will stay off. So, if the motor does not come on, then switch SR3 is in the wrong position, flip it the other way. Once you have SR3 in the correct position, test out the altitude hold function by slowly increasing the throttle. What you are doing is changing the commanded altitude. At some point, the motor will turn on rather abruptly. Switch back and forth between manual and stabilized mode and notice the different throttle response in the two modes.

Next, set the throttle back to off, still in the stabilized mode, and then check pitch and yaw response, when you pitch and yaw the plane, the elevator and rudder should respond. The elevator should respond to pitch, the rudder to yaw.

Check that the directions of responses are correct. When the nose pitches down, the elevator should deflect up. The pitch control is proportional to the pitch error and pitch rate.

When you yaw the plane, the rudder should move in a direction to resist the yaw. The amount of deflection is proportional to yaw rate.

Test the rudder-elevator mixing. When the plane is level, the elevator should not respond to the any rudder command. When the plane is banked, deflecting the rudder in the direction that corresponds to the turning direction should cause the elevator to deflect upwards. Deflecting the rudder in the opposite direction will cause the elevator to deflect downwards.

If either the elevator or the rudder control feedback is in the wrong position, fix it by changing the position of the control servo reversing switches on the board. SR1 is for the rudder. SR2 is for the elevator. Once you get the correct feedback control directions for "stabilize mode", they will also be correct for return to launch.

If you change SR1, SR2, or SR3, remember to change them back when you go back to using a different plane.

Return to launch checkout

Once you have stabilize mode checked out, test the RTL function. You can do that by either shutting the transmitter off, or by moving the trim tab and stick for the control mode all the way to the right. Keep in mind that, depending on your settings, the motor may come on. If your receiver has loss-of-signal fail-safe, program the fail safe to command RTL.

Do the same sorts of things that you did to check out RTL for earlier versions of MatrixNav. Walk around and see what the rudder and elevator do. The elevator should continue pitch control. The rudder should stabilize yaw and also try to turn the plane back to the RTL point.

If everything looks good to you, then you are ready for flight. If not, then you might want to change some of the gains. Here is what they are, and how to set them.

Gains

There are several gains that you can set in the file controlGains.h. It is best to set them all to positive numbers and do any sign reversals with board reversing switches SR1, SR2 and SR3. Use the same gains on either the red board or the green board, the appropriate multipliers are now built into the firmware.

- YAWKP – This is the turning gain used by RTL for using the rudder to make a turn. Typical value is 0.1. Larger values will produce tighter turns. Using a value that is too large will produce a “dutch roll”. Maximum valid value is 1.999.
- YAWKD – This is a yaw damping term used both by stabilization and RTL to reduce the impact of the wind, and to help stabilize the yaw control. Typical value is (0.25*SCALEGYRO). Maximum valid value is (0.5*SCALEGYRO).
- YAWBOOST – This is an amplification, or “boost” factor for manual control of the rudder, used during stabilized mode to restore control authority to the rudder in the face of the damping effect of YAWKD. Typical value is 1.0. This factor is in addition to the manual control, so a value of YAWBOOST of 0 turns the boost off, and provides unmodified response to manual control. A YAWBOOST of 1 makes the rudder response to manual control approximately twice as great.

If YAWBOOST of 1.0 makes the yaw control more sensitive than you would like, try 0.5. Maximum valid value is 1.999.

- PITCHGAIN – This is the proportional feedback for the elevator control of pitch. Setting it higher will improve precision of the pitch leveling. If you set it too high, it may cause pitch flutter, but it is not dangerous, just annoying. Typical value is 0.250. Maximum valid value is 1.999.
- PITCHKD – This is the pitch rate (measured in the earth coordinate system!) damping feedback for the elevator. Typical value is (0.25*SCALEGYRO). Maximum valid value is (0.50*SCALEGYRO).
- PITCHBOOST – This is an amplification, or "boost" factor for manual control of the elevator, used during stabilized mode to restore control authority to the elevator in the face of the damping effect of YAWKD. Typical value is 0.5. This factor is in addition to the manual control, so a value of PITCHBOOST of 0 turns the boost off, and provides unmodified response to manual control. A PITCHBOOST of 1 makes the elevator response to manual control approximately twice as great. Maximum valid value is 1.999.
- RUDDERELEVMIX – This is the amount of rudder-elevator mixing that you want. Typical value is 1.0. Set this parameter to 0 if you do not want to use mixing. Maximum valid value is 1.999.
- RTLPITCHDOWN – This is used if you want the nose to pitch down during return to launch. It is the same as in previous versions of MatrixNav. If you use this feature, enter a positive value for this parameter, which is the angle, in degrees, that you want the nose to pitch down during RTL. The idea is that you may have a dead motor and a head wind during a loss of signal RTL, so you might be willing to sacrifice some altitude to get your plane back to you. Some pilots use this feature, some do not. Typical value if you use it is 2. If you do not use it, set it to zero. Maximum recommended value is 10.0.
- SERVOSAT – This is used to limit the servo throw. Typical value is 1.0. Maximum recommended value is 1.0, maximum valid value is 1.999.

The following are the gains for altitude hold, if you are using it. If you turn off altitude hold by not defining the symbol ALTITUDEHOLD, then it does not matter what the values are:

- ALTITUDEHOLD – Define this symbol if you want to include altitude hold in your firmware, or comment out this line if you want to remove altitude hold, in which case you will need to connect your throttle directly to your receiver.

- MINIMUMTHROTTLE – This parameter sets a value for the minimum amount of throttle during altitude hold. Typical value is 0.5, define a value between 0.0 and 1.0
- HEIGHTMAX – This is the maximum target height, in meters, above the launch point. Typical value is 100. The commanded height for altitude hold is proportional to the throttle, up to this maximum height. Altitude hold will command full throttle until the plane is within 50 meters of the commanded height. It will gradually reduce throttle as it climbs higher. It will reduce to minimum throttle at the commanded height. If it continues to climb higher, the motor will be cut off completely.
- PITCHATMINTHROTTLE – This is the pitch angle, in degrees, that the control will attempt to hold the plane's pitch, at minimum throttle. The suggested value for this parameter for a sailplane is 0. If you want the altitude hold feature to maintain altitude without turning off the motor, select a slightly negative value for this parameter, such as -2. If you do not want to use this feature, set it to 0. Otherwise, set it the pitch angle that you would normally control the plane at minimum throttle. Positive values means the nose points upward, negative values means the nose pitches downward.
- PITCHATMAXTHROTTLE – This is the pitch angle, in degrees, that the control will attempt to hold the plane's pitch, at MAXIMUM throttle. The suggested value for this parameter is 10. Otherwise, set the pitch angle that you would normally control the plane at maximum throttle. Positive values means the nose points upward, negative values means the nose pitches downward.
- PITCHATZEROTHROTTLE – This is the pitch angle, in degrees, that the control will attempt to hold the plane's pitch, at ZERO throttle. In other words, this is the pitch angle that you want when your sailplane is gliding, or when your plane is flying "dead stick". The suggested value for this parameter is 0. If you do not want to use this feature, set it to 0. Otherwise, set it the pitch angle that you would normally control the plane at zero throttle. Positive values means the nose points upward, negative values means the nose pitches downward.

All gains should be positive, or zero. Do not use negative gains, use the servo reversing switches instead.

Operation

You are now ready for flight. Basically, the process is similar as that used for previous versions of MatrixNav, with an extra step for altitude hold. You power up with the plane level and motionless, and the throttle set for off for an ESC, or for low idle for a fueled engine. It does not matter what direction your plane points when it powers up, north, south, east or west. It will achieve yaw lock in a few seconds after takeoff.

The rudder will deflect on power up, and then move closer to center after 10 seconds. Then you can let go of the plane. If you have an ESC that needs for you to move the throttle stick to maximum and back, now is the time to do it. There is a filter in the altitude hold control of the throttle, so it may take a little bit longer for your ESC to acknowledge minimum and maximum throttle setting.

Next, wait for GPS lock. When the GPS is locked, the rudder will waggle. When it stops waggling, the RTL point is set, and you are ready for flight.

Before you launch, it is best to check the deflection direction of rudder and elevator one more time, for both manual and stabilized control.

If everything checks out, you are ready for flight. If you have a fueled engine, now is the time to start it. You are cleared for takeoff.

With respect to altitude hold, operation is as follows:

- Altitude hold is turned on whenever you have selected either stabilized mode or RTL.
- Altitude hold treats the throttle setting as the desired altitude.
- Typical operation is to turn stabilized mode on prior to launch and do your takeoff and climb out in the usual fashion. When you get to the altitude that you want, turn the throttle down to what you think is cruising power, just enough power to hold altitude. The altitude hold function will then adjust throttle and pitch to maintain that altitude.

The three things you will probably have to experiment with are the pitch trim setting on your radio, the parameter MINIMUMTHROTTLE and the parameter PITCHATMAXTHROTTLE. You will probably set both PITCHATMINTHROTTLE and PITCHATZEROTHROTTLE to zero.

Typical value for MINIMUMTHROTTLE is 0.5. If you typically fly in windy conditions, and want to penetrate the wind, use a larger value of MINIMUMTHROTTLE. If you want to control altitude with pitch only, with the motor running at full power, set MINIMUMTHROTTLE to 1.0.

You may also have to experiment with the pitch trim on your radio to achieve a reasonable performance compromise between climb out and descent.

If everything checks out, you are ready for flight. Your first flight should be in manual control during takeoff/launch. After a few flights, if everything checks out, you can try stabilized control mode during takeoff. It actually makes takeoff a lot easier, once you have tuned the gains.

When you are leveled off, and ready, switch to stabilized control. This will improve the damping of the yaw and pitch axes, and improve the rudder authority. Also, altitude hold will be engaged in stabilized mode.

If the gains are too high, your plane may flutter around the pitch or the yaw axis in the stabilized mode. I have seen it during my test flights when the gains were too high. It is not dangerous, but it is annoying it.

Once you are comfortable with stabilized control and ready, you should test RTL. If your plane is flying 180 degrees away from you when you change over to RTL mode, it will turn back toward you, level out, and then fly straight to the RTL point. Depending on the values of YAWKP and YAWKD that you select, it may or may not overshoot during the initial turn around. Raising YAWKD will widen the turn, and reduce overshoot. Raising YAWKP will tighten the turn, and produce some overshoot.