Helical Turn Controls: Setup and Operation

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The turn controls in the version of MatrixPilot in this directory is an improvement over previous versions of MatrixPilot turn controls in that it relaxes the approximation that the plane is nearly level. Instead, control is exact for the general case of a helical turn. The theory behind the new controls is described in the accompanying documents, HelicalTurnsPart1Conditions.pdf, HelicalTurnsPart2Controls.pdf and HelicalTurnsPart3AoA.pdf Control. It is a turn rate based control in which the required aircraft attitude needed to support a given turn rate and pitch attitude is computed from airspeed, the desired pitch attitude, and the desired turn rate. Feedback control maintains the attitude required for the turn. Feed forward control provides approximate control surface deflections needed to support the turn rate.

As of this writing, the only versions of MatrixPilot that supports the new helical turn rate controls are the branch MatrixPilot_wjp_helicalTurns and the tag MatrixPilot_helicalTurns_Beta. It is expected that the feature will be soon ported to MatrixPilot trunk. If this file is in the main directory of the branch, tag, or trunk that you are using, then it supports the new controls.

One major advantage of the new controls, and the prime motivation for developing them, is that there is no longer any constraint that the control gains must satisfy in order to prevent the controls from flipping the aircraft over into a spiral dive under certain conditions. Performance of the controls for delta wing is expected to be much better.

There are two control modes, fly-by-wire and waypoint navigation. Fly-by-wire replaces stabilized mode in the previous versions of MatrixPilot. The same turn rate control operates in either mode, the only difference is the source of the turn rate command. In waypoint navigation mode, the two turn rate commands (pilot input and navigation) are added, which provides you with a way to adjust the turn trim in waypoint mode. In fly-by-wire mode, pilot input is used to determine the commanded turn rate. If the aircraft has ailerons, the aileron channel is used to command turn rate. If not, then the rudder channel is used.

There are a few changes in the options.h file. The roll-elevator and rudder-elevator mix gains are no longer needed and have been eliminated. Their approximate adjustment of the elevator for the turn has been replaced by an exact method that is valid beyond the limited range of the mixing technique previously used. The AILERON_BOOST gain has also been eliminated. Three new gains have been added:

TURN_RATE_FBW is the maximum turn rate in fly-by-wire mode, in degrees per second. This is the turn rate that the controls will achieve for maximum user input. The largest value that will be recognized is 230 degrees per second. The default value is 60 degrees per second.

TURN_RATE_NAV is the maximum turn rate in waypoint navigation mode, in degrees per second. This is the turn rate that the controls will achieve for navigation heading errors greater than 90 or less than -90 degrees. The largest value that will be recognized is 230 degrees per second. The default value is 30 degrees per second.

FEED_FORWARD is the feed forward gain. The default value is 1.0, which should be approximately correct. The largest value that you can specify is 4.0. You can specify values less than 1.0, all the way down to zero if, for some reason, you do not want to use feed forward. Tests have shown that you can set feed forward gain to zero if you want, the only down side to doing that is turning will not be as aggressive as it is when you use this parameter.

The new controls really do not need any rate feedback, so you can start by setting the rate gains (XXXKD gains) to zero. The only time you might consider using them on a given axis is if the undamped response for that axis is too fast. With the new controls, the rate feedback is computed in the body frame, with the correct feed forward rate offsets for each axis computed exactly from the turn parameters. So if you do decide to use the KD gains for feedback, all they should do is provide damping without otherwise changing flight dynamics.

Set up your options.h file by specifying values for all gains you presently use, except set KD gains to zero and eliminate the gains mentioned above that are no longer used. The old yaw_kp gains are no longer feed forward turn gains, they are now proportional feedback gains for yaw orientation in the body frame.

Evaluate control response using ground tests in fly-by-wire mode, by making the following observations:

1. With control surface sticks centered, and throttle off, roll the plane and make sure the ailerons, if any, respond appropriately to level the plane. Repeat for pitch, the elevator should respond. Repeat for yaw, nothing should happen unless you are using non-zero values for yaw rate feedback.
2. Move the stick for the aileron channel, if you are using it, to full right or left deflection. Otherwise use the rudder channel for the test. Ailerons and/or rudder should respond from a level attitude in such a way as to start the turn.
3. While continuing to apply turn command, roll the plane in the commanded direction. The elevator should deflect for turn coordination, and eventually the ailerons should return to neutral conditions.

Make sure all control deflections are in the correct direction. Double check them, wrong control polarity is a common mistake, and make a crash almost certain.

Estimate whether the amplitude of control surface response is about right. Keep in mind that the response of the control surfaces will probably not be as great as you would expect. The reason for that is airspeed is now part of the control computations, and

airspeed during ground testing is zero. To help you do ground testing, the turn controls assume an airspeed of 5 meters per second if the actual airspeed falls below that. So, what you see is the response you will get at 5 meters per second.

While flying under fly-by-wire control, execute turns with the aileron channel if it is defined, otherwise use the rudder channel. You do not need to do anything with the other control surfaces. For example, for an aircraft with rudder, ailerons and elevator, turn with the aileron channel only. The turn controls will take care of rudder and elevator. However, rudder and elevator manual inputs are still added into the control signals for those surfaces, so you can adjust their trim in flight. The aileron input, on the other hand, is disabled in fly-by-wire and navigation mode in favor of the turn controls.

As of this writing, the new controls have been extensively flight tested on several standard airframes, both with elevator, ailerons and rudder and with elevator and rudder only. They have been only ground tested for delta wing and v-tail, so be careful with those airframe types.

Post any questions that you have to the UDB user's group.

Finally, another optional feature has been added to the turn controls: angle of attack and pitch trim modeling. This feature will generally improve overall pitch performance of the controls, especially for inverted flights. For more information, see the accompanying document describing the setup and operation of angle of attack modeling.