Tilting multicopters architecture high-level overview

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April 2023

PR: https://github.com/PX4/PX4-Autopilot/pull/21476
Related paper: https://salvatoremarcellini.netlify.app/publication/tilting_drones_px4/
Video : https://youtu.be/ro6ycqkI33M

1 Recap

The following changes to the firmware were made starting from the stable version v1.13.2 (or v1.13.1, I don't remember exactly) and allowed me to control a tilting multirotor in different flight modes (stabilized, altitude, position, and offboard). The firmware has been tested both in simulation and on 2 real drones.
The airframes introduced consist of two main classes:

1. tilting omnidirectional drones: these are drones with a servomotor installed on each arm that is independent of the others. The rotation axis is perpendicular to the section of the arm and allows to generate of a lateral force
2. one-tilt drones: these have only one servomotor (or two, but with the same angle setpoint value) and are usually H-shaped drones. The servomotor allows to rotate of all the rotors in one direction, giving the system an additional degree of freedom

Both types of drones are mainly used in tasks that require interaction with the environment because can exert a force in a desired direction, without changing the attitude of the drone's body.
Notice that the one-tilt drone is something that I have seen only in my laboratory and in other few, so the changes relative to that can be discarded even if they are very few. For them, what I've done is mainly to map on the servomotor the desired roll (or pitch depending on the airframe) angle evaluated by the position controller, taking also in account the desired attitude angle given for the body.

2 Files added

1. New class of airframes for multicopters with tiltable rotors [**tilting multicopters**]
2. New actuator effectiveness [**ActuatorEffectivenessTiltingMultirotor**]
3. New message for the one-tilt drone servomotors setpoint [**tilting_servo_sp**]
4. New message for desired roll and pitch body angle setpoint **tilting_mc_desired_angles**]
5. New airframes and URDF models for tilting drones
6. New example module to give a desired orientation to the drone, to test without requiring an external computer [**examplesangles_test**]

3 Files modified

1. In [**ActuatorEffectivenessRotors.hpp**] added a parameter to the constructor for the tilting drone
2. In [**ActuatorEffectivenessRotors.cpp**] added the allocation matrix for a tilting omnidirectional drone. This is a static matrix as explained in [1] with 6 rows and $2N$ columns, with N being the number of rotors. Considering that a matrix with double the column would be considered by PX4 as a drone with double the actuators, I have used something similar to the VTOL strategy. I used two matrices: one for the vertical forces and one for the lateral ones.
3. In [**ControlAllocator.hpp**] added the ID for "TILTING_MULTIROTOR" effectiveness source
4. In [**ControlAllocator.cpp**] added the tilting multirotor allocation function. The allocation evaluates the angles for the servomotors and the rotor velocities as in [1]
5. In [**control_allocatormodule.yaml**] added the tilting multirotor class
6. In [**mc_att_control.hpp**] added some parameters and the subscriber to the topic for the desired body attitude
7. In [**mc_att_control_main.cpp**] added the evaluation of the desired XY thrusts from the radio controller to fly in stabilized flight mode
8. In [**mc_att_control_params.c**] added some custom parameters for tilting drones
9. In [**MulticopterPositionControl.hpp**] added some custom parameters for tilting drones

10. In [**MulticopterPositionControl.cpp**] added the evaluation of XY thrust for tilting drones

11. In [**mc_pos_control_params.c**] added some custom parameters for tilting drones

12. In [**MulticopterRateControl.hpp**] added parameters variables to recognize the tilting drones ID

13. In [**MulticopterRateControl.cpp**] here the only changes were made to send a full 3D vector of thrust (plus the tilting angle for the one-tilt tilting drone). I think that these changes are no more needed because in the new version, it is something already implemented.

References

[1] M. Kamel, S. Verling, O. Elkhatib, C. Sprecher, P. Wulkop, Z. Taylor, R. Siegwart, and I. Gilitschenski, "The voliro omniorientational hexacopter: An agile and maneuverable tiltable-rotor aerial vehicle," *IEEE Robotics Automation Magazine*, vol. 25, no. 4, pp. 34–44, 2018.