Colibri, A freeflyer for zero g

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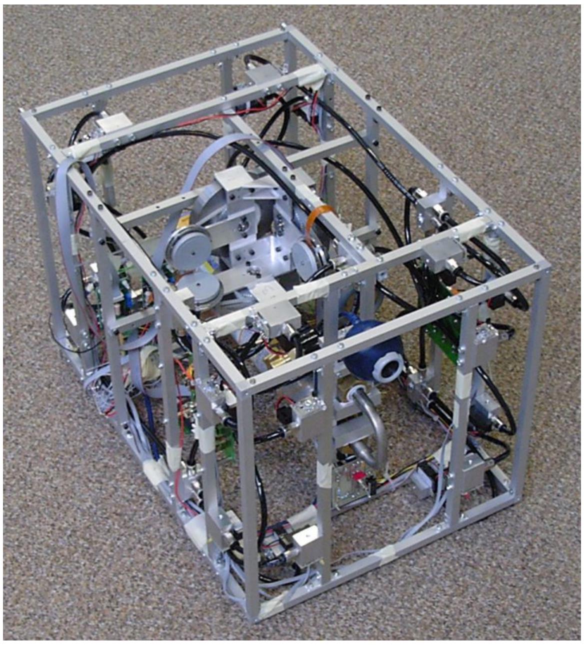
The goal of this project is to design and build a 6 dof freeflyer for use in microgravity. The robot will have to be able to move with or without atmosphere and use locomotion and control systems compatible with a space utilsation. The dynamic and control will be tested in real conditions during ESA's student parabolic flight campaign in the summer.



The Colibri freeflyer

The freeflyer uses two types of actuators. Three momentum wheels control the attitude by changing their speed. The conservation of cinetical momentum forces the freeflyer to spin around one of its axis when the speed of a wheel changes. The control brings the freeflyer to a particular attitude by giving a triangular speed profile to the wheels.

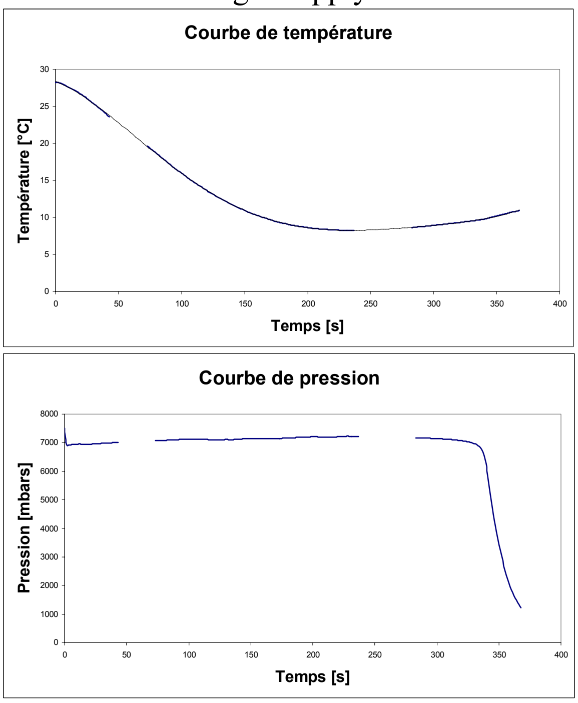
The translation movements are actuated by 4 valves on each side. Those valves eject CO_2 to obtain a thrust up to 2 N per side. The thrust amplitude is proportionnal to the output pression of the pressure reducer:

$$F_{prop} = a \cdot P_{out} + b$$

The thrust of the valve can be adapted as they are proportionnal to the duty cycle of the opening and closing of the valves:

$$F = RC(\%) \cdot F_{Jet\_continu}$$

The main autonomy restriction is due to the temperature that decreases really fast. The limit operating temperature is about 5 °C and can be regulated using a close-loop control. The thrust remains constant during the full use of the gas supply.



Temperature and pressure of the gas vessel during a continuous ejection until the end of the bottle

The valves system could also be used to rotate the freeflyer, but their main goal is the translation.

The freeflyer can achieve a maximal acceleration of 13.9 [cm/s^2] in tranlation and a maximal angular acceleration of 10.4 [°/s^2] in rotation.

The freeflyer must be completly autonomous. Thus, it has to use its own sensors to localise itself in order to control its behaviour. The attitude is computed by the integration of the angular velocity returned by three gyrometers. This method incrases the error over time, but as the freeflyer will be tested during parabolas that last less than 20 seconds, the result can be used as we won't have more than an error of 5 [°]. The same method cannot be implemented to know the position using an acceleration mesurement, because the double integration gives too much error. Instead, the freeflyer computes its position compared to a target by mean of an onboard webcam. The target is recognized by its color and the knowledge of its size allows to compute the distances. The resolution is dependent from the distance and the size of the image. With our 320 pixels wide image, we have a theoretical resolution of 6.25 [mm] at a distance of 2 [m].

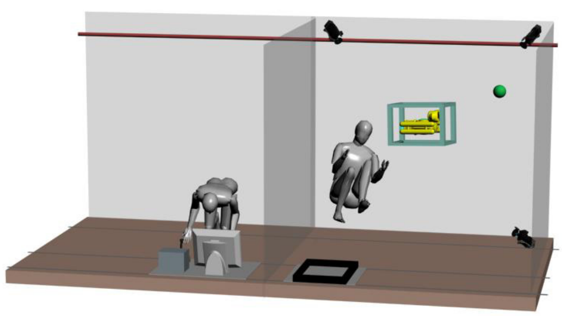
The control loop uses a PD regulator for velocity and a PID for position (target reaching and attitude stabilisation). In order to have a better idea of its behaviour before the real tests in microgravity, the whole system was modelled and simulated on Simulink.

The main design restriction was the mass. The lower the mass, the easier the control and the actuation. The pressure system is responsible for half the weight of the freeflyer, thus increasing the necessary size of other parts, such as the skeleton and the momentum wheels.

The Colibri is controled by an onboard mini-computer, the X-board 861. The computer sends orders to the valves controler using I^2C protocol. Besides, it communicates with the analog motor controlers via a serial transmission. Then, those slave controlers forward the consign to a digital-analog converter throught I^2C, which will convert it for the motors.

The Colibri can also communicate with a monitoring laptop by mean of a Wifi connection to transmit informations like the wecam image. All calculations are autonomously perfomed by the freeflyer's emmbed computer but the controler parameters can be adapted through the monitoring laptop. The Wifi connection is also usefull to allow the user to watch the result of the color recognition algorithm and other calculations.

The tests in microgravity will allow us to test the actuators and the control. The experiment will take place in a 2x2x2 meters area. The freeflyer will face a target and have to control its speed and attitude to reach it in less than 20 seconds.



Experiment set-up in the plane

The trajectory of the freeflyer will be recorded by 3 cameras. Later, the position and attitude will be reconstructed, using the colour LEDs placed on the edge of the Colibri.