The Floating Satellite System as an Educational Platform for Space Applications

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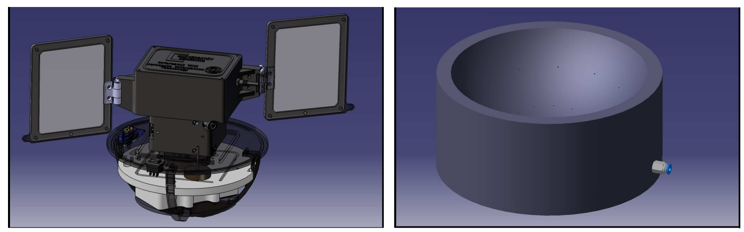
***Abstract*—In this paper, an approach is presented for building a small laboratory based Floating–Satellite(Float–Sat). This Float–Sat will serve as a test–bench for the students to learn basic satellite subsystems. This can also be used for the development and verification of different control algorithms and strategies for various kinds of space missions. This Float–Sat also provides a near–to a frictionless environment similar to space.**

***Index Terms*—Aerospace, Real–time–operating–systems, Operational Modes of Satellites.**



a: FloatSat   b: Floating Platform (SABU)

Fig. 1: The Floating Satellite (FloatSat) system

I. Introduction

The main objective of this research was to design and built a floating–satellite–simulator which is placed in a sphere for free movement. This floating Satellite (FloatSat) has been developed to help students to understand and get familiar with basic satellite subsystems. It gives a unique opportunity to develop the algorithms for attitude determination and control systems of aerospace vehicles in a quite frictionless environment to simulate the effect of zero gravity in the space.

II. State–of–the–Art

In the field of Aerospace technology several projects are conducted to simulate the small satellites. In this section a brief description is provided about the similar efforts people have done for space research and development:

- 3DoF test bench for CubeSats (A three degree-of-freedom (3DoF) test–bench for CubeSats from University of Montpellier France)[1].
- Simulation Satellite; A Ground Based Platform For Demonstrating Satellite Attitude Dynamics And Control (SimSat)[2].
- “The open prototype for educational NanoSats: Fixing the other side of the small satellite cost equation”: An open–source development platform to build a low–cost Cubesat[3].

The goals of all the simulators described above were quite same but their structure and Attitude Determination and Control System (ADCS) are different. In the paper [4] the author has described many more simulators people have invented for the simulations of an aerospace vehicle.

III. Mechanical Structure and Description of FloatSat Systems

The FloatSat system consists mainly of a mechanical structure that contains the basic satellite subsystems with one reaction wheel mounted at the centre of the horizontal plane of the structure. This reaction wheel is used to control the orientation of the satellite in one dimension. Two deployable solar panels attached by flexible joints on the sides of the upper part of the structure are used to demonstrate the deployment mechanism and to verify the robustness of the attitude controller during the deployment. The deployment mechanism is based on using the heat generated from passing high current through a thick film resistor to cut a nylon wire that holds the solar panels in a folded state prior to deployment. In addition, two movable masses to adjust the Centre of Mass (CoM) of the structure in the horizontal plane have been employed. A battery pack using four lithium iron phosphate battery ($LiFePO_4$) is placed on the lower part of the structure with charging ports mounted on the outer part of the middle layer of the structure for easy charging access as shown in the Fig. 1 (a). This structure is placed into an Acrylic glass hemisphere shell of a 20cm diameter that it is floating inside a Spherical Air Bearing Unit (SABU). The air bearing unit requires pressurized air input with a flow rate that may vary depending on the mass of the floating unit as depicted in Fig. 1 (b). The Avionics included in the FloatSat are consists mainly on a STM32F4Discovery development board attached to an extension board. The extension board was developed in such a way that it contains all the necessary electronic components needed to steer the satellite. It

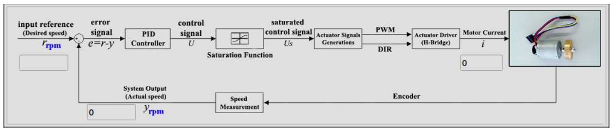


Fig. 2: Motor Speed Controller

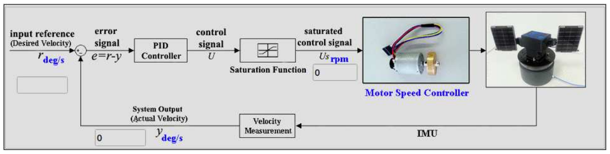


Fig. 3: Velocity Controller

has multiple DC-DC converters on-board with four H-Bridges and a deep discharge battery protection circuit. A Bluetooth and Wifi modules are available for communicating with the satellite. An Inertial Measurement Unit (IMU) that packs a 3-axis Gyroscope, 3-axis Accelerometer, 3-axis Magnetometer and a temperature sensor is mounted on the extension board and it is used to measures and reports on the satelliteâs velocity and orientation. A camera, luminosity sensor, and a contact-less infra-red thermopile sensor are also being used in the system and are mounted on the sides of the structure.

IV. Operation of the Float-Sat

There are three modes of operation of the Float–Sat, these are described as below:

A. Motor–speed mode

The rotation speed of Float–Sat is determined by an encoder attached with its DC motor. The encoder includes dual–channel Hall Effect sensor. The encoder senses the rotation of the magnetic disc and provides a resolution of 16 counts per revolution of the motor shaft. After considering all these limitations and requirements the motor–speed controller is designed as depicted in figure 2.

B. Velocity mode

In the velocity mode a cascade controller is used where the first controller is the velocity controller which calculates the motor speed in rotation per minute (rpm) to rotate the Float–Sat with the desired velocity. This means that the output of the first controller is the required motor speed (RPM) to attain the desired velocity of the Float–Sat, this velocity controller of the Float–Sat is shown in figure 3.

C. Position mode

Regarding the Position controller, a cascade controller is used where the first controller is the position controller and it calculate how much motor speed in RPM is needed to set the motor to in order to reach a desired satellite position. The position controller of the Float–Sat is displayed in figure 4. The cascade controller scheme gives the ability to control exactly the response of the system by separating the response of the motor from the satellite response. So first the motor

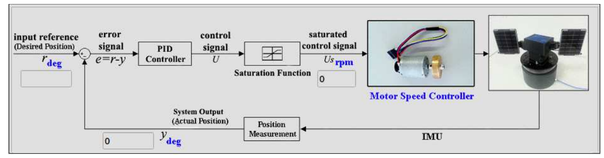


Fig. 4: Position Controller

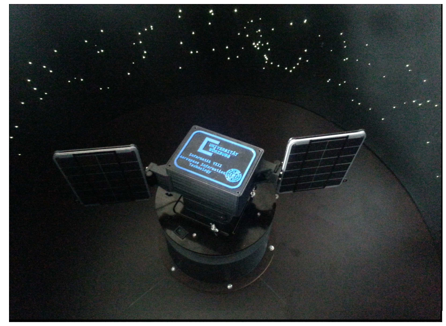


Fig. 5: Star Tracking using FloatSat

controller is tuned until a good response (very fast with small overshoot) is achieved then the Velocity controller is tuned for a fast but very small overshoot and for the position the controller is tuned for slow with no overshoot.

V. Software Architecture of Float-Sat

All of the functions of the Float–Sat are supervised under a specially developed Real–Time Object Oriented Dependable Operating System (RODOS). RODOS is ported on Cortex–M4 based microcontroller. It is specifically developed for aerospace applications as it has minimal footprint and it is also very well suited for the applications which demand high dependability. Software components in RODOS adjust each other to provide dependable computing[5].

VI. Conclusion

Float-Sat was tested on an air–bearing platform which resulted in in a very smooth and stable floating with the adjustment of the weights. Payload or the mission of the satellite is the real objective of its existence. The missions regarding the star tracking and the scanning of the planet surface are depicted in the figure 5 and 6 respectively. The Float–Sat's platform is being actively used to train bachelor and master's students to write different control Algorithms for a spacecraft and perform diverse missions.

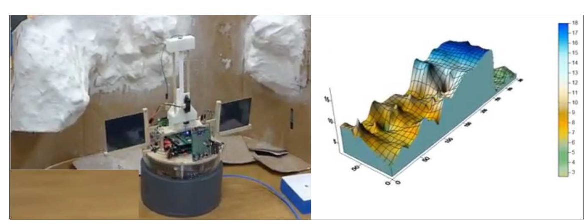


Fig. 6: Three dimensional scanning of an Analogues surface of a Planet

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