SPACE

(Some space topics are also listed under Mechatronic topics)

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Part I SPACE ENGINEERING
1. Vision based satellite formation flying control ( Honour thesis only)

Spacecraft formation flying is an evolving technology with many possible applications, such as long base-line interferometry, stereographic imaging, synthetic apertures, and distinguishing spatial from temporal magnetospheric variations. A significant advantage of distributed spacecraft platforms over a single multi-functional spacecraft is that single point failures can be rectified through replacement of cheaper and smaller spacecraft to maintain mission capability, thus providing a more reliable and robust system. Many missions (in particular interferometry missions) rely on precise relative position and attitude knowledge in order to maintain mission requirements.

The objective of this research is to develop a robust and efficient approach for relative navigation and attitude estimation of spacecraft flying in formation. The approach developed here uses information from an optical sensor that provides a line of sight vector from the master spacecraft to the secondary satellite. The overall system provides a novel, reliable, and autonomous relative navigation and attitude determination system, employing relatively simple electronic circuits with modest digital signal processing requirements and is fully independent of any external systems.
2. Development of a Helmholtz cage for magnetic actuated satellite hardware in loop simulation

The attitude control system is a crucial subsystem for any satellite mission since precise pointing is often required to meet mission objectives. The accuracy and precision requirements are even more challenging for small satellites where limited volume, mass, and power are available for the attitude control system hardware. The magnetic torquer is the most efficient actuator for small satellite attitude control. Although the control system can be designed and simulated using software, like Matlab, it is desired that the control system can be verified in a real scenario. For magnet torquer, it is important to model the Earth magnetic field in the orbit. In this project, we will build a Helmholtz cage working together with the air bearing system for 3-axis control.
3. Nanotheruster Design

The nanotheruster project will investigate a novel charge exchange thruster (CXT) for nanosatellites. Like most spacecraft propulsion methods, electric propulsion works by ejecting mass in a specific direction, which imparts an equal and opposite momentum to the spacecraft, thus providing thrust. The efficiency of spacecraft propulsion is determined by the change in momentum (impulse) per unit weight of propellant, which is known as the specific impulse. Greater propulsion efficiency is achieved by increasing the specific impulse. Electric propulsion methods produce the highest specific impulse, which makes them suitable for spacecraft propulsion because this enables the reduction of the amount of propellant the spacecraft must carry.

Ion propulsion systems consist of three parts: gas ionization, ion acceleration and neutralization. In the latter, electrons are injected into the ion plume so that the charge on the spacecraft will remain neutral - otherwise there will be a build-up of negative charge on the spacecraft that will eventually stop the exit of ions. Although there are several hundred satellites that use ion thrusters, as well as deep space missions such as the DEEP-SPACE 1 mission to Comet Borelly and the SMART 1 mission to the Moon, it remains a challenge to miniaturize these thrusters to make them applicable to nanosatellites. Limits to the available power in a nanosatellite are in the units of watts, and similarly, the total weight is of the order of 1kg. The power requirements and weight of ion thrusters currently in use far exceed these limitations.


Navigation and control algorithms are computation intensive, which normally require a powerful computer to process. For small satellites or UAVs, however, the on-board resources are extremely limited in terms of volume, area and power. It becomes even more challenging
when the algorithms are targeting real-time processing, which normally runs at a high sampling frequency. In this research, we will develop hardware IP cores for the algorithms. The resulting IP cores will be integrated as a peripheral in a system-on-chip architecture, which is currently under development at the Space Engineering research group.

5. Satellite attitude control with a flexible structure and the FASTSAT ( Honour thesis only)

![FASTSAT](image)

The attitude and orbital control system (AOCS) is one of the most essential systems on-board a spacecraft. This thesis will develop a revolutionary new method of executing attitude control for small spacecraft. Through the use smart materials such as Shape Memory Alloys (SMAs) to provide active shape control, it is possible to use a flexible structure to change the attitude of a small central spacecraft bus.

Together with this thesis, we will develop a concept satellite ‘flexible Australian Smart Technologies Satellite (FASTSAT)’, which will demonstrate the feasibility of the satellites based on flexible structures.

PART II NEAR SPACE ENGINEERING

6. High Altitude Balloon

The primary goal of the High Altitude Balloon Project is to build, design, test and operate a satellite on a weather balloon, and be capable of carrying payloads – the student built satellite and scientific instruments, to an altitude exceeding 20 km and successfully collect the data from the payloads using real time down linked telemetry or retrieve stored data after flight. A secondary objective of the High Altitude Balloon project is to study near space environment in the South Hemisphere.
7. Solar Powered High Altitude UAV / Atmospheric Satellite
We are developing a high altitude solar powered UAV (SP-UAV) for near space research. This project initially is to develop a UAV for future Mars exploration. The Mars UAV may be tested terrestrially at a high altitude, which emulates the atmosphere on Mars. It turns out that this type of UAV can be used for science and commercial applications. In this project, the students will be involved in the developing an innovative SP-UAV design. Topics that the student may be involved in include developing a flight control system for station keeping, designing the airframe and the layout of the solar panels and designing an innovative maximum power point tracking (MPPT) system to extract optimal power from the solar panels.

PART III EMBEDDED SYSTEM / MEMS
8. FPGA-based State Estimation via Parallel Unscented Kalman Filters
Kalman Filters in their various forms have been the standard approach to solving many state estimation problems. Indeed for non-linear estimation problems and in particular aerospace applications, the Extended Kalman Filter (EKF) has been a workhorse. More recently a newer variant, the Unscented Kalman Filter (UKF) has gained popularity due to superior performance over the EKF in highly non-linear applications; this benefit of course comes at an increased computing cost. The increased computing cost arises from large matrix manipulations, the sizes of which are related to the size of the state vector. One possible way to alleviate this issue is to segment the state variables and use multiple UKFs in parallel though this raises many more issues. For example, consider a UAV following a pre-computed path in a given map (i.e. known landmarks):

- Which variables should be segmented? (Position and velocity separate? Or only segment the measurements of landmarks?)
- Will segmentation affect the accuracy of the state estimates?
- Will a recombination process (or global update) need to occur? If so, how should this be done?
- What additional overhead will recombination bring and under what conditions (if any) will the parallel implementation be superior?
- How will control actions be incorporated?

This research will involve developing simulations (in Matlab) to answer some of these questions with the possible extension of implementation on a multi-core FPGA system. Ideas for other applications are also welcome.

9. Satellite on a Chip
One trend for satellite is towards small size. For example, CubeSats are becoming popular in scientific and commercial applications. CubeSats are in the nanosatellite category from 1kg to 10kg. The project’s objective is to develop an extreme small satellite, which integrates all the subsystems on a single chip. This project involves multidisciplinary engineering aspects, in particular, we are going to use the micro-electro-mechanical system (MEMS) technology to design sensors and actuators for satellite attitude determination and control. Many innovative MEMS devices can be explored. The students, who are interested in this project, are encouraged to discuss with the supervisor before they choose this topic.