Session G Abstracts

Creating a Second LEONARDO (LEgs ONboARD drOne) with Updated Components and Revamped Hardware
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Mentor: Soon-Jo Chung

LEONARDO is an innovative robotics system that combines a bipedal robot with a propeller-based stabilization system, this combination allows it to navigate terrain inaccessible to traditional bipedal robots while achieving higher energy efficiency compared to conventional drones in the same weight class. The existing LEONARDO robot has stayed relatively unchanged since its completion in order to preserve its functionality, this project seeks to create an updated version of the LEONARDO robot using existing designs but with updated hardware and software which would facilitate further testing of the bipedal-drone system. One such test involves the installation of wheels onto LEONARDO which would allow it to traverse flat terrain at a significantly higher energy efficiency; ongoing efforts have been made to enable cooperation between multiple robots made possible by the construction of a second LEONARDO.

Autonomous Flying Ambulance: Hardware Integration and Testing
Zhonghe Catherine Zheng
Mentors: Soon-Jo Chung, Matthew Anderson, and Joshua Cho

The overarching goal of the project is to build a scaled-down version of an Autonomous Flying Ambulance (AFA), an emergency vehicle capable of carrying patients and medics to hospitals. In the current 4th iteration of the AFA, researchers are developing a new fault-control algorithm that stabilizes the aircraft when one or multiple motors fail. Testing the algorithm is dangerous and costly if done on the actual AFA model; hence, the algorithm is currently being developed on a skeletal prototype. While the fuselage of the model was already manufactured, the model still lacked the electronics required to fly. This project focuses on integrating those electronics into the model, which involves designing and fabricating the electronic casing, wiring the components, and calibrating the hardware for the new system.

Both the prototype and the AFA model use a Pixhawk flight controller with ArduPilot and an onboard computer to run the algorithm. While the prototype is an eVTOL octocopter, the model has both eVTOL and fixed-wing modes, meaning it can take off vertically while also using its wings to produce lift when flying. This more sophisticated flight model allows algorithms to be demonstrated on a higher fidelity aircraft, producing more accurate data and results.

Hardware Design and Software Integration for the Autonomous Flying Ambulance
Brittany Wright
Mentors: Soon-Jo Chung, Joshua Cho, and Matthew Anderson

The autonomous flying ambulance (AFA) is an eight-motored vertical take-off and landing vehicle that is intended to transport a patient and paramedic to a medical facility faster than land-based emergency transportation. The AFA is on its 4th iteration with a testbed (a 4x2 grid of motors with electronics attached) that runs Neural-Fly, a deep-learning model for unmanned aircrafts. This testbed functions as a research platform for fault-tolerant control where in the event of a motor failure, the aircraft re-allocates motor efficiencies to maintain steady flight. Apart from this testbed, a 1/5th model of the AFA's fuselage has been built. On this model, we install the testbed electronics which include a flight controller that uses adaptive control and an onboard computer that runs Neural-Fly. This installation involves designing mounts to secure the electronics while accounting for constraints like space, wire management, power management, and mass distribution. This also includes integrating the flight software, Ardupilot, onto the electronics and using open-source applications such as Mission Planner to set flight parameters. After completing this hardware and software integration, we intend to have this 1/5th model fly with the same capabilities as the testbed.

Building an Autonomous Testbed for Motion Planning Algorithms on a Modified RC Car
Aditi Chandrashekar
Mentors: Soon-Jo Chung, John Lathrop, and Ben Rivière

The INDY Autonomous Project is a global competition aimed at advancing autonomous vehicle technology through the design of high speed self-driving race cars. There is significant financial risk in testing planning and control algorithms on real race cars. There is a need for a fully functional autonomous testbed on an RC car. To this end, a Traxxas X-Maxx RC car was modified to carry an NVIDIA Jetson Orin for onboard computing as well as a ZED 2 AI camera for perception, object detection, and odometry. This hardware stack was tested with path planning and control algorithms including the A* algorithm. This testbed will enable the development of more sophisticated motion planning algorithms in the future.
GPS-Guided Thermal Image Annotation via Orthorectified RGB Aerial Imagery
Saraswati Soedarmadji
Mentors: Soon-Jo Chung and Connor Lee

Unmanned Aerial Vehicles (UAVs) have found widespread use in a variety of applications, ranging from agriculture and defense, to remote sensing and entertainment. To enable nighttime operations, UAVs are typically equipped with long-wave infrared cameras that can capture live thermal images for aiding in navigation and scene understanding. Today, deep neural network-based models can provide scene understanding for RGB imagery through the forms of 2D/3D object detection and image segmentation. However, applying such models to perform similar analysis in the thermal domain presents a challenge due to the lack of available thermal scene-specific training data. Unlike RGB cameras, thermal cameras are not ubiquitous, thus making data collection expensive. Even when such datasets are available, most are not annotated as they look very different from what people often expect, thus requiring experience and expertise to annotate. In this work, we focus specifically on developing a method using machine learning segmentation models to automatically annotate thermal data for training semantic segmentation models. After developing the thermal segmentation model, we will use the model on various thermal image segmentation tasks to help aid navigation and scene-understanding of UAVs during their nighttime operations.

Developing a Secondary LEONARDO (LEgsONbARDdrOne) System
Matteo Kimura
Mentor: Soon-Jo Chung

This project focused on developing an updated LEONARDO system, a bipedal robot enhanced with quadcopter motors, to utilize new hardware and an updated control system. I worked on determining new, updated hardware to integrate onto a second version of the LEONARDO robot in addition to rewriting parts of the software to reflect these changes in the hardware. Developing this system has been relatively successful, however, there were several challenges that had to be overcome with troubleshooting much of the new hardware and integrating it with the rest of the system. Overall, this secondary LEONARDO provides an exciting updated and adequate test platform to continue testing multimodal forms of robotic locomotion.

Orbit Design for Formation-Flying Missions
Andres Torres
Mentor: Soon-Jo Chung

Multi-satellite missions have been well-established for a long time, particularly constellation swarms. A frontier of multi-satellite missions is formation flying satellites, which enables much more complicated and expanded satellite capabilities. One major difficulty in formation flying is determining suitable orbits for each satellite. Our goal is to design orbits that: (1) best position satellites to achieve their mission objectives; and (2) minimize fuel costs needed to maintain the orbits. This problem can be transformed into an optimization problem. One approach that we have applied with success and are actively improving is a genetic algorithm, which iteratively improves a formation into a better one. However, despite the success of the genetic algorithm there are still two main challenges: (1) it can get stuck in local extrema, meaning that the formation generated might not be the best possible one; and (2) it takes a while to converge to an acceptable formation. An alternative is using deep reinforcement learning, which after training, can provide high quality formations significantly faster than the genetic algorithm. We apply and compare both methods to NASA’s Distributed Aperture Radar Tomographic Sensors (DARTS) mission concept which has the goal of drastically improve radar imaging of the Earth.

Probing Thin-Shell Structure Stability: Efficacy of the 3-D Printing Approach to Optimize Design Parameters
Sage Cooley
Mentors: Sergio Pellegrino and Meital Carmi

Longeron is a thin-shell structure found in the Caltech Space Solar Power Project deployable architecture. They derive the majority of their stiffness from geometry rather than mass; however, thin shells buckle unpredictably. Thin-shell stability analysis has recently advanced to include an energy landscape approach which can be used to identify resilient longeron geometric configurations under pure bending. Finding a more stable geometry is important for longerons because the composite material configuration has been shown to have highly unstable behavior. Efforts to uniformly 3-D print thermoplastic (PLA, PET-G, RGD 525) longerons reveal the potential for additive manufacturing to produce uniform, strong, and flexible thin shells appropriate for probing experiments. Initial bending and probing tests show the ability for 3-D printing samples to accelerate geometry optimization through iterative changes in the cross-section and comparison between energetic quantities.
Design and Physical Prototyping of a Reconfigurable Surface Structure
Audrey Wong
Mentors: Sergio Pellegrino and Alexander Wen

The shape of a structure is often closely tied to its function, and can optimize performance when tailored to a specific application. As a result, structures capable of changing shape to achieve different results are highly desirable. Kirigami-inspired structures permit large deformations without permanent damage and are advantageous in design versatility. While folding cannot intrinsically change the curvature of a structure, it can approximate multiple target surfaces of varying curvatures. The objective is to design and prototype a structure which achieves a set of desired target configurations, implement the necessary torsion spring stiffness values, and restrict the hinge rotations to the required ranges. This structure is designed to achieve rigidity in multiple target configurations through the placement of unilateral constraints and springs.