2023-2024 Akademik Yılı için Feng 497/498 Proje Konuları *(Feng 497/498 Project Subjects for 2023-2024 Academic Year)*

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IEU AY 2023-2024 FENG-497-8 Projects Proposed under the supervision of Fabrizio Pinto

Project 1: Autonomous optical and inertial navigation of a realistic solar-sail propelled CubeSat class spacecraft targeting orbits around Mars and its moons.

In Project 1, students will develop software tools capable of simulating the acquisition of star fields by a CCD camera coupled to a small optical system onboard a CubeSat-class vehicle traveling to an orbit around Mars by using the thrust produced by a realistic solar sail. The system will automatically determine the plate constants by identifying known stars and it will measure the positions of beacon asteroids in the star field. In order to simulate realistic optical systems of various focal lengths and apertures available for use in CubeSats, Project-1 will include a study of sensor performance and images of star fields obtained by the students by means of mobile phone cameras and commercial DSLR cameras on tripods. By solving an inverse problem, the position and velocity of the spacecraft in space will be calculated and compared to the nominal trajectory (Project 3) so as to obtain necessary corrections in the orientation of the solar sail (Project-2). This information may be augmented by the use of onboard accelerometers for the measurement of non-gravitational forces. The reliability of the final product shall be verified by means of synthetic stellar images, including sources of noise and systematic errors, to enhance the simulations developed by using actual images taken from the ground. Using this toolset, students working on Project 1 shall act as members of the Navigation team for this simulated CubeSat space mission targeting entry into an orbit around Mars, closely interacting with Project-3 students to provide them the dynamical state of the spacecraft. Students working on Project 1 shall interact with Project-2 students, for instance, to schedule and execute imaging, to aim and employ the optical system as needed, and to allocate power and computing resources to process the digital images. Building upon the experience gained by previous thesis students, this Project will use only Free and Free Open Source software tools employed by students in all classes I teach, including, but not necessarily limited to, the Free Wolfram Engine on Jupyter Notebooks, Fortran 95, NASA GMAT, and Scilab/Xcos, in both Windows and Linux emulation environments.

Project 2: Proof-of-concept of a realistic solar-sail propelled CubeSat class spacecraft digital twin targeting orbits around Mars and its moons.

In Project 2, students will develop software tools needed to simulate a spacecraft in actual operating conditions, to serve as a future digital twin, in support of a CubeSat-class mission targeting orbits around Mars by using the thrust produced by a realistic solar sail. The first goal will be to develop a model of the dynamics of the mission by making simplifying assumptions, such as constraining the problem to a 2D geometry. In this phase,

Project-2 may result in a significant contribution to spacecraft design. In a follow up, realistic spacecraft subsystems and behaviors inaccessible to specialized, though highly accurate, dynamic integrators (Project-3) will be added. For the purpose of developing multiphysics models and feedback control strategies, the software tools to be used will be Scilab/Xcos and OpenModelica. The typical problems that Project-2 must be able to address include, but are not limited to: (1) managing at least a few of the critical spacecraft subsystems during the long cruise Earth-Mars transfer phase, such as power, thermal, and attitude control; (2) on instructions from Project-3 students, executing the requested long-term solar sail orientation profile as well as course corrections determined to be necessary by the auto-navigation system; (3) orienting the optical system as needed to image the required starfields for optical navigation, etc. In a later phase, 3D visualizations of the spacecraft status will be obtained with such tools as Blender and NASA 42. Software interfaces between such tools and the output from Scilab/Xcos and OpenModelica will be designed. The aspirational goal is to be able to produce a realistic image of the spacecraft in physical space at any time. The reliability of the final product shall be verified by generating simulated status reports and verifying that the spacecraft is taking appropriate corrective actions. In this final phase, students working on Project 2 shall act as Spacecraft Controllers. Building upon the experience gained by previous thesis students, this Project will use only Free and Free Open Source software tools employed by students in all classes I teach, including, but not necessarily limited to, the Free Wolfram Engine on Jupyter Notebooks, Fortran 95, NASA GMAT, and Scilab/Xcos, in both Windows and Linux emulation environments.

Project 3: Trajectory design and flight dynamics of a realistic solar-sail propelled CubeSat class spacecraft targeting orbits around Mars and its moons.

In Project 3, students will design the trajectory of a CubeSat-class vehicle traveling to specified Mars orbits by using the thrust produced by a realistic solar sail. The goal is to produce a detailed and realistic deterministic nominal trajectory to serve as the blueprint for a mission to take place in an actual upcoming launch window. The starting parking orbit will be geocentric, at an altitude as large as that of geosynchronous satellites but in no case lower than Medium Earth Orbit (MEO). The final goal will be to design the arrival of the spacecraft at Mars matching not just position but also with a velocity appropriate to orbit insertion. The mission will consist of a first phase to spiral out of the Earth-Moon system, a second low-thrust cruise phase to gain energy to reach Mars, and a final phase, aspirationally terminating with orbit insertion around Mars. Although it is acceptable to assume highly idealized sails in a first phase of Project-3, it will be crucial to quickly transition to a realistic description of the properties of solar sails and of the radiative properties of the vehicle. For this purpose, a close interaction with Project-2 students will be established to ensure that the mechanical design of the spacecraft is translated into SPAD files. Project-3 students will make very extensive use of NASA GMAT, both from the GUI but also by scripting, and from within Jupyter Notebooks. The reliability of the final product shall be verified by means of various, independent tools, aided also by analytical calculations, including perturbation theory. All solutions will be extensively tested for numerical accuracy and stability. Close interaction will be established with Project-1 students to ensure that information about the dynamical state of the spacecraft obtained from optical auto-navigation, and possibly also inertial sensors, is translated into trajectory corrections maneuvers to be executed by Project-2 students. The students working on Project 3 shall

act as Trajectory Designers. Building upon the experience gained by previous thesis students, this Project will use only Free and Free Open Source software tools employed by students in all classes I teach, including, but not necessarily limited to, the Free Wolfram Engine on Jupyter Notebooks, Fortran 95, NASA GMAT, and Scilab/Xcos, in both Windows and Linux emulation environments.

Prof. Dr. Diaa Gadelmavla

1. Development of life jacket - integrated antenna for global search and rescue using satellite systems

The target of this project is to develop an antenna that can communicate with open satellite systems for search and rescue applications.
This antenna will be integrated into a life jacket and will be connected to a wireless transceiver module together with a GPS module.
This system should allow reporting of the position and any other data needed for search and rescue operations.

2. Development of a self-charging (energy harvesting) drone

The target of this project is to extend the flight duration of the drone by using renewable energy resources. Solar energy together
with RF energy harvested from the environment will be employed to recharge a secondary battery onboard drones.

Dr. Öğr. Üyesi İzzet Murat Akşit

1. ***CFD Analysis of a Contra Rotating Propeller (Horizontal Propeller Axis)***

In this project, which is intendent to use of a VTOL type UAV, a contra rotating propeller analysis proposed. It represents horizontal flight mode; therefore, propeller axis must be horizontal. Main objective is to investigate the distance between two propellers and its effect on the main thrust.

2. ***CFD Analysis of Two Propellers (Two Vertical Propeller Axis)***

In this project, which is intendent to use of a VTOL type UAV, two propeller analysis proposed using CFD. It represents vertical flight mode; therefore, propeller axis must be vertical. One propeller, which is called aft propeller, is in the pusher configuration. The other is the front propeller, which is a tractor/puller configuration. Main objective is to investigate any obstacle such as wing its effect on the main thrust.

3. ***CFD Analysis of Two Phase Flow***

In this project, which is intendent to use of a evaporator type injector of a micro gas turbine combustor, air and fuel mixture will be modeled using Fluent, Discrete Particle Model and Secondary Break Up models. These models simulate two-phase flows convenient for fuel injection systems.

Dr. Öğr. Üyesi Osman Nuri Şahin

1. **Morphing Wing Design for a Small Tactical UAV**

Wing designs of aircraft are shaped according to the purpose of usage of the aircraft, the criteria determined for the mission and the environmental conditions in which it will perform the mission. This means that the wings of every aircraft are structurally optimized and produced in line with these criteria. In order to overcome this situation, which causes high design and production costs, aircraft designers are working on wing designs which cause changes in the performance of the aircraft and can adapt themselves to different mission scenarios by changing its shape. These wing structures, called morphing wings, will have a great place in the future of the aviation industry. In this study, a small tactical class UAV that uses a morphing wing design that can adapt its structure according to two separate mission scenarios will be developed.

2. **Design and Developement of Ducted Fan UAV for Agricultural Purpose**

One of the usage areas of unmanned aerial vehicles is agricultural use. UAVs used effectively in tasks such as crop spraying, which can be difficult and inconvenient to be done by humans. Ducted fan UAV can be used indoors or in environments with low air circulation. The issue of the development of these vehicles is still up to date. The aim of this project is to develop a UAV of this design that is heavy enough to be carried by a single person and can take part in agricultural missions. What is expected in the development process is to make various concept designs and compare the advantages and disadvantages and select the most suitable design. Then, what is required is to make the necessary power and aerodynamic calculations, to choose the necessary electronic and mechanical equipment for the flight and to detail the design according to the selected equipment. The outcome of the project will be the production of the first ready-to-fly prototype.

Doçent Dr. Cem Tahsin Yücer

1.Investigation and the optimization for the effects of the compressor thermodynamic parameters on the jet engine's performance

The air is driven from the atmosphere to the engine through the air inlet by the compressor. The compressor uses the shaft work to increase the pressure of the outlet air flow. Technical, economic and environmental (if applicable) effects will be studied.

2.Investigation of the cooling techniques for the turbine blades

There are several techniques used to cool turbine blade surface. The combustion gases leave the combustion chamber at approximately 1200 ^{o}C. This temperature is too high and the blade material operates nearly at the melting temperature. Thus, the cooling process is essential for the turbine.

Dr. Öğr. Üyesi Abbasali Saboktakin

1-HYPERVELOCITY IMPACT OF LIGHTWEIGHT COMPOSITE

Finite element modeling is the best technique to address the challenges related to manufacturing high-strength composites while gaining a comprehensive understanding of the mechanical behaviour of these composites when subjected to hypervelocity impacts. Previously, we employed finite element analysis using LS-Dyna software to examine the effects of hypervelocity impacts on composites. Now, our project's goal is to extend this research by investigating how through-thickness influences fibre composite performance. To ensure a stable solution with sufficient accuracy, we will employ an appropriate modeling procedure and our research aims to conduct a series of high-velocity and hypervelocity impact tests, with impact speeds reaching approximately 3 km/s and beyond.

2- DESIGN AND MANUFACTURING OF HYPERSONIC GUN-LAUNCHED VEHICLE

Orbital debris poses increasing threats to the space environment because of increasing space activities. Ground-based experiments and numerical simulation are two essential methods for investigating this matter. A three-stage gas gun, which is highly pertinent to our research, has been designed in its initial phase and now necessitates focused efforts on modification and the preparation of manufacturing drawings. Within this gas gun system, the energy generated during propellant combustion is transferred to a lightweight gas like helium or hydrogen through the pressure piston in the pump pipe. High pressures are applied to this lightweight gas until it reaches the point of diaphragm rupture. The compressed gas is then released into the launch tube, accelerating the projectile. In addition to our experimental work to manufacture some parts of the gas gun, simulations will be employed to identify and assess various operational parameters under test conditions, eliminating any risk to the hypervelocity facility due to factors like high temperature, high pressure, and the presence of explosive gases. This will also aid in validating design concepts and conducting detailed design work, culminating in fabricating and assembling a subscale prototype system for performance evaluation.

3- DESIGN AND MANUFACTURING OF BWB AIRCRAFT

The International Aviation Organizations have set a specific goal of no increase in CO2 emissions from international civil. Furthermore, European and American aircraft manufacturers have announced that they are working to develop advanced technology related to weight reduction and efficiency improvement of aircraft structures and engines.

The aim of this project is to finalize the remaining tasks for the manufacturing of a novel aircraft prototype. This involves integrating advanced technologies for producing lightweight

structural components with intricate geometries using 3D printing methods and composite materials. The primary goal of the project is to successfully construct a prototype for the next-generation BWB aircraft and a crucial component of this research will involve conducting flight tests on the aircraft we manufacture. This endeavor is driven by our desire to enhance our academic engagement and collaborate with international research initiatives.

4- MANUFACTURING AND TESTING OF A SPACE PROPULSION SYSTEM

A high-performance space propulsion system commonly uses pump fed and pressure-fed systems that drive up propellant tank mass and limit space engine performance and design varieties. The project is to complete the rest of the manufacturing stage and test a very lightweight pump. In the first stage of this project, the industry partner manufactured some parts of the components needed for the pump using CNC machines and now we need to complete other parts and test the pump experimentally.