

An Indian-Australian research partnership

Project Title:	Design and development of autonomous airships	
Project Number	IMURA0370	
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Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?

(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1. **Advanced computational engineering, simulation and manufacture**
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research

The research problem

The research activity is to design and implement robust control architecture, so that the airship can be operated in an autonomous mode. To do this, a six-DOF model of the airship dynamics will have to be developed. One such model was presented by Cook [1] which is based on modeling the dynamics of remotely controlled underwater vehicle (ROV) operating in similar conditions. This model was improved by Gomes [2] by implementing aerodynamic data generated through extensive wind-tunnel testing. A similar model was developed by LAAS/CNRS group [3], France.

For autonomous operation of airship, choosing appropriate control method plays an important role. Several control approaches have been proposed for the same. In classical methods, PI and H^∞ have been investigated. In advanced methods, Dynamic Inversion for AURORA project and Backstepping approach for DIVA project [4] were executed. Model predictive control has been proposed by Fukushima et al. [5] in 2006. Recently, Yang et al. [6] have investigated sliding mode control also. This project will deal with choosing the improved positive definite function for Backstepping method. To look on the advanced and robust control methods as Neuro-adaptive controller, Dynamic surface control, transverse feedback linearization. Also further extension can be development of Collision avoidance algorithm. Last will part will be designing hardware control system which will consists of sensors, camera, GPS-INS, processor.

The key steps in this study are as follows : -

- Multidisciplinary optimization for the development of an airship design methodology for use within closed premises (indoor) for teaching and research.
 - Development of dynamic model and Investigation of Autonomous Control Strategies will be carried out.
 - A hybrid vehicle will be built on a larger scale, while maintaining similar geometric relationships for outdoor use (outdoor) and validation in real environments.
 - Design and Integration of Autonomous Control System.
 - Flight Test of Autonomous Airship and study of Flight Test Results.

A key requirement is that the engines have a much more important function of providing agility to respond to disturbances than actually winning continuous and strong winds. Interestingly, the design of the aircraft for the worst cases of winds has always been a rule project. However, especially for lighter-than-air, having high drag due to their large volume, the philosophy of facing the worst winds is overly punitive. It is therefore proposed an approach to relax this requirement, using the wind as an ally to aid navigation as proposed by Elfes et al. [7].

In this sense, a topic to be addressed is the mapping of the wind field for navigation itself, i.e. the estimation of the wind field through "samplings" of the atmosphere and the use of this information as learning and choice of trajectories optimized for minimum fuel consumption.

The topics addressed will then airship design, multidisciplinary optimization, dynamic model development, navigation assisted by winds and implementation of chosen control approach.

References:

- [1] Cook M. V., "The Linearized Small Perturbation Equations of Motion for an Airship", Working Paper No. WP 8, Aerodynamics Department, College of Aeronautics, C.I.T., Cranfield, July 1987.
- [2] Gomes, S.B.V., Ramos, J. G., "Airship Dynamic Modeling for Autonomous Operation", *Proceedings of the 1998 IEEE International Conference on Robotics & Automation*, Belgium, pp.3462-3467, 1998.
- [3] Hygounenc, E., Jung, I-K., Soueres, P. and Lacroix, S., "The Autonomous Blimp Project of LAAS-CNRS: Achievements in Flight Control and Terrain Mapping", *International Journal of Robotic Research*, Vol. 23, No. 4-5, pp.473-511, 2004.
- [4] Moutinho, A. B., Mirisola L., Azinheira J.R., Dias J., "Project DIVA: Guidance and Vision Surveillance Techniques for an Autonomous Airship", *Robotics Research Trends*, pp. 77-120, Nova Publishers, 2008.

[5] Fukushima, H., Saito, R., Matsuno, F., Hada, Y., Kawabata, K., Asama, H., "Model predictive control of an autonomous blimp with input and output constraints", *Computer Aided Control System Design, 2006 IEEE International Conference on Control Applications, 2006 IEEE International Symposium on Intelligent Control, 2006 IEEE*, pp.2184-2189, 4-6 Oct. 2006.

[6] Yang, Y. N., Wu J., Zheng, W., "Trajectory tracking for an autonomous airship using fuzzy adaptive sliding mode control", *Journal of Zhejiang University-SCIENCE C*, Vol. 10, No. 2, pp. 1-10, 2012.

[7] Elfes A., Reh k., Beauchamp P., Fathpour N., Blackmore L., Newman C., Kuwata Y., Wolf M., and Assad C., "Implications of Wind-Assisted Aerial Navigation for Titan Mission Planning and Science Exploration". In Proceedings of the 2010 IEEE Aerospace Conference, Big Sky, MT, March 2010.

Project aims

This study aims to develop a six-DOF nonlinear dynamic model of an airship, which includes the effect of ballonet dynamics, tail configurations and aerodynamic effects. Robust control architecture will be designed and implemented for different flight phases such as vertical take-off and landing and trajectory tracking. Proper advanced control algorithm will be chosen from control methods such as gain scheduling, dynamic inversion, backstepping control, sliding mode Control and fuzzy control which directly acts on nonlinear dynamics. Control strategies will be tested with and without wind.

Expected outcomes

Airships are lighter-than-air systems which can act as an **aerial platform** for several applications such as aerial observation and scientific data-gathering. If such outdoor airships can also be configured to operate in an autonomous mode, their **efficacy is greatly enhanced**.

The key outcome of this project will be a **significant advancement of the knowledge base and skill sets** related to outdoor autonomous airships, resulting in **joint publications** in international archival journals. This technology also has an excellent **potential to be scientifically and commercially exploited**, if the autonomous control strategies investigated as part of this project are found to be robust enough to provide autonomous operation capability to outdoor airships under the normal weather conditions prevalent at both the countries. Some of this work may also be **patentable**, both in airship design and fabrication, as well as in control system architecture. If the behavior of control approach is found acceptable, it can be utilized commercially.

How will the project address the Goals of the above Themes?

Testing and implementation of such controllers needs rigorous computational work. The work will lead to significant contribution to the state-of-art in control system design. A detailed methodology of conceptual sizing and design will add to the knowledge and skills of fabrication and manufacturing of an outdoor airship.

Capabilities and Degrees Required

Bachelor or Masters in Aerospace or Electrical Engineering with specialization in Control Systems

1. Knowledge of kinematics and dynamics formulation.
2. Understanding of control literature and mathematical tools.
3. Knowledge of ODEs.
4. Exposure to MATLAB® and SCILAB.