PROJECT TITLE

Advanced estimation methods via Kalman filters, resonator gyroscopes and machine learning

PROJECT DESCRIPTION

The technological advancements and increasing usability of automation systems, IoT, robots, autonomous drones, and satellite swarms have triggered what can be defined as the fourth industrial revolution. The enabling tool underlying the widespread use of these latest two innovative technologies is, therefore, the ability to estimate, in a faster, more accurate, and reliable manner, the position of each agent in the team or swarm to be coordinated, ensuring safe utilization. It is expected that, in this context and in the near future, the use of resonant gyroscopes, or innovative inertial sensors in general, can progressively and effectively replace most of the previous techniques in avionic and aerospace contexts. This phenomenon is strongly motivated by the performance that can be achieved through the use of such technology compared to alternative methods. However, the pervasive use of these techniques and devices is currently limited by certain conceptual and technological challenges, mainly concerning the study, analysis, and implementation of control methods that allow for the operability of the measuring instrument in the widest possible range of operating conditions. The objective of the proposal will therefore be twofold. On the one hand, the aim is to study this problem from both a theoretical and practical perspective, in order to adapt tools (or potentially define entirely new ones) for the analysis and synthesis of complex nonlinear, switching, and hybrid systems to the specific context under consideration. The fusion of these techniques and algorithms, along with the necessary studies to refine them in the avionic and aerospace field, will provide a new level of reliability in such measuring instruments, supported and validated by their implementation on certifiable real-time architectures. Lastly, given the intrinsic complexity of the necessarily approximate models currently available to capture the interactions involved in the study of such systems, it is reasonable to assume that some of the aforementioned techniques will necessarily need to be complemented by the fundamental use of Machine Learning and Artificial Intelligence methods. These artificial intelligence techniques will, for example, allow for systematic synthesis and autonomous calibration of the degrees of freedom involved in defining the control law, optimizing it for the specific application context each time. Furthermore, similar artificial intelligence techniques can be extended to address the problem of data fusion from heterogeneous sensors for localization and navigation. On the other hand, in order to give the research conducted during this Ph.D. a broader scientific perspective, the aim is also to study more general and fundamental techniques related to the measurement filtering and estimation problem. The purpose is, therefore, to critically and methodically revisit the use of the celebrated Kalman Filter, laying the foundations for its more efficient use in scientific and industrial fields.

The Ph.D. candidate will need to study the basic physical phenomena that allow for an understanding of the functioning of resonant gyroscopes, both within their specific application context and at the conceptual operability level. This knowledge will then be accompanied by a detailed study of numerous basic and innovative techniques for synthesizing control laws for nonlinear systems. Given the nature and complexity of the problem at hand, also due to the typically restrictive requirements associated with the use of such measuring instruments in practical applications, the student will need to delve into the study of systems that exhibit a dual "continuous-time" and "discrete-event" nature, namely switching systems or the even broader class of hybrid systems. These will provide the necessary tools to address the problem of control under a wide range of operational conditions. The student will actively participate in the activities of a research group where they can develop not only technical-scientific skills but also collaborative and research organizational abilities specific to the Automation sector, which should become fully competent by the end of the program. The student must learn to interact with

Northrop Grumman Italia, the partner in this Ph.D. project, and translate theoretical scientific objectives into real-time implementable results by acquiring both theoretical and practical skills.

RELEVANT REFERENCES

[1] Zhang Fu. Control and Self-Calibration of Microscale Rate Integrating Gyroscopes (MRIGs). PhD thesis, University of California, Berkeley, 2015.

[2] DD Lynch. "Vibratory gyro analysis by the method of averaging". In: Proc. 2nd St. Petersburg Conf. on Gyroscopic Technology and Navigation, St. Petersburg. 1995, pp. 26– 34.

[3] Goebel, Rafal, Ricardo G. Sanfelice, and Andrew R. Teel. "Hybrid dynamical systems." *IEEE control systems magazine* 29.2 (2009): 28-93.

[4] Kalman, R.E. (1960). "A new approach to linear filtering and prediction problems" . Journal of Basic Engineering. 82 (1): 35–45.

Type of scholarship:

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