

## **Preface: Nonlinear Computational and Control Methods in Aerospace Engineering**

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In practice, almost all real engineering systems are essentially nonlinear. Linear systems are just idealized models that approximate the nonlinear systems in a prescribed situation subject to a certain accuracy. Once nonlinearity is included, analytical solutions are rarely available for almost all real problems. Therefore, nonlinear computational methods are becoming important. In most aerospace problems, however, a relatively high-fidelity nonlinear model has to be established, especially when the system is immersing in a complicated environment and nonlinearity is not negligible anymore. Many complex phenomena, i.e., bifurcation, limit cycle oscillation, chaos, turbulence, may occur in a variety of aerospace systems, which may be described by nonlinear Ordinary Differential Equations (ODEs) for rigid body problems or Partial Differential Equations (PDEs) for flexible solids or fluid mechanics problems. In general, nonlinearity in aerospace systems is often regarded as unwanted and troublemaker, due to the fact that considering nonlinearity makes the solution methods as well as the control methods more difficult. Therefore, there has been a general tendency to circumvent, design around them, control them, or simply ignore them.

However, in recent years, advanced computational and control methods have been developing so fast that complex nonlinear systems become more and more solvable. So, exploiting the benefits arising from systems' nonlinearities turns out to be a novel and crucial subject. This special issue is dedicated to the study of the dynamics and control of piratical aerospace engineering problems related to aircraft, missile and spacecraft, and theoretical models that may show complex nonlinear behaviors. In summary, thirteen papers are selected to form this special issue, which can be classified into three subjects.

Novel nonlinear computational methods are developed for dynamical systems. Tang et al. [Tang, Zheng, Yang et al. (2020)] proposed a novel kind of finite particle method (FPM) which does not require the assembly or solution of global matrices, and the evaluations of the element equivalent forces and particle displacements are decoupled in nature, which makes this method suitable for parallelization. For an optimal control problem of nonlinear

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Received: 13 November 2019; Accepted: 26 November 2019.

dynamical system, the Hamiltonian formulation is useful. However, the resulting Euler-Lagrange equations are not easy to solve, when the performance index is complicated, because a two-point boundary value problem has to be solved. Normally, it is hard to exactly preserve all the specified conditions. Liu et al. [Liu, Kuo and Chang (2020)] develop a novel algorithm to find the solution of the optimal control problem of nonlinear Duffing oscillator, which can exactly satisfy all the required conditions for the minimality of the performance index. For solving nonlinear stochastic systems with non-smoothness, Ma et al. [Ma, Ning and Wang (2020)] proposed a generalized cell mapping method without approximate transformation. The accuracy of this method is verified in solving the Coulomb and Dahl force models.

Nonlinear control methods for spacecraft and flight vehicles are studied. Wang et al. [Wang, Yue, Wen et al. (2020)] proposed a hybrid passive/active vibration (HPAV) controller for a loosely connected spacecraft consisting of a servicing satellite, a target and an X-shape structure isolator. The novel structure is first proposed to suppress vibrations of the system when subjected to the impulsive external excitations during the on-orbit missions. Zhang et al. [Zhang, Wei and Yin (2020)] investigated a novel quasi fixed-time orbit tracking control method for spacecraft around an asteroid in the presence of unknown dynamics and uncertainties. To quantitatively characterizing the transient and steady-state responses of orbit tracking error system, a continuous performance function is devised via using a quadric polynomial. Then, integrating backstepping control technique and barrier Lyapunov function leads to a quasi fixed-time convergent orbit tracking controller without using any fractional state information and symbolic functions. In addition, a roll stabilization controller with aerodynamic disturbance and actuator failure consideration for spinning flight vehicle is proposed by Ma et al. [Ma, Gao, Wang et al. (2020)]. More specifically, an adaptive second-order sliding mode observer is presented to select the proper design parameters and estimate the knowledge of aerodynamic disturbance and actuator failure. Liu et al. [Liu, Hou, She et al. (2020)] studied the reentry attitude tracking control problem for hypersonic vehicles (HSV) equipped with reaction control systems (RCS) and aerodynamic surfaces.

Efficient methods for precise guidance of flight vehicles, orbital dynamics, and parameter identification of satellite are explored. A novel two-level optimization strategy for multi-debris removal mission in LEO is proposed by Zhao et al. [Zhao, Feng and Yuan (2020)], which includes the low-level and high-level optimization process. To improve the overall performance of the multi-debris active removal mission and obtain multiple Pareto-optimal solutions, the ADR mission is seen as a Time-Dependant Traveling Salesman Problem (TDTSP) with two objective functions to minimize the total mission duration and the total propellant consumption. To study the parameter estimating effects of a free-floating tumbling space target, the extended Kalman filter (EKF) scheme is utilized with different high-nonlinear translational and rotational coupled kinematic and dynamic models on the LIDAR measurements in Hou et al. [Hou and Qiao (2020)]. Aimed at the problem of final translation of space rendezvous for the applications, optimal straight-

line guidance algorithm based on pulse/continuous low-thrust in the context of Clohessy-Wiltshire dynamics is proposed by Gong et al. [Gong, He and Zhang (2020)]. Two modes of guidance strategy: varying-speed and fixed-speed approaching scheme for V-bar and R-bar approach by using constant/finite low-thrust propulsion respectively are studied. Furthermore, a closed-form solution to the angles-only initial relative orbit determination (IROD) problem for space rendezvous with non-cooperated target is developed and the sensitivity of the solution accuracy to the formation geometry, observation numbers is discussed [Gong, Li, Zheng et al. (2020)]. Zhao et al. [Zhao, Du and Li (2020)] investigated the agile satellite observation scheduling problem of dense points targets. A mission planning algorithm of task clustering is proposed to reduce the frequency of calculation and therefore improve the observation efficiency of agile satellite, which can make agile satellite observe more targets and therefore save a significant amount of observation resources. Based on wave interference, a methodology to realize the total transmission phenomenon of SH0 waves is proposed in Yue [Yue, Chen, Zhang et al. (2020)]. Using this method, an exact frequency is obtained in a flat plate consisting of another medium with finite length. Overall, this special issue is dedicated to stimulating an intense interaction between the area of practical aerospace engineering and the area of theoretical studies of complex nonlinear systems, and bringing new computational methods, control methods, modeling methods, and experiment methods from one area to the other.

**Conflicts of Interest:** The authors declare that they have no conflicts of interest to report regarding the present study.

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