POLITECNICO MILANO 1863

DIPARTIMENTO DI SCIENZE E TECNOLOGIE AEROSPAZIALI

Shallow and Deep Learning Models for Closed-Loop Space Guidance

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Abstract

Autonomous and unconstrained exploration of small and large bodies of the solar system requires the development of a new class of intelligent systems capable of integrating in real-time stream of sensor data and autonomously take optimal decisions, i.e. decide the best course of action. For example, future missions to asteroids and comets will require that the spacecraft be able to autonomously navigate in uncertain dynamical environments by executing a precise sequence of maneuvers (e.g. hovering, landing, touch-and-go) based on processed information collected during the close-proximity operations phase. Currently, optimal trajectories are determined by solving optimal guidance problems for a variety of scenarios, generally yielding open-loop trajectories that must be tracked by the guidance system. Although deeply rooted in the powerful tools of optimal control theory, such trajectories are computationally expensive and must be computed off-line, thus hindering the ability to optimally adapt and respond to uncertainties in real-time.

Over the past few years, there has been an explosion of machine learning techniques involving the use of shallow and deep neural networks to solve a variety of problems spanning from object detection to image recognition to natural language processing and sentiment analysis. The recent success of deep learning is due to concurrent advancement of fundamental understanding on how to train deep architecture, the availability of large amount of data and critical advancements in computing power (e.g. extensive use of GPUs). One can naturally ask the following: how can such techniques help the development of the next generation of robust and adaptive algorithms for space guidance that can learn optimal actions during the course of space exploration? In this talk, I will address this problem by presenting a variety of methods and techniques that have been recently developed by my research team in the context of planetary landing and close proximity operations around small bodies. The methodologies span from supervised learning to deep reinforcement learning and demonstrate that such approach can be successfully implemented to develop a class of closed-loop algorithms capable of learning and optimally operating in space dynamical environments.

Brief Bio

Prof. Furfaro is currently Associate Professor (tenured) and director of the Space Systems Engineering Laboratory (SSEL), Department of Systems and industrial Engineering, Department of Aerospace and Mechanical Engineering, University of Arizona. He is also the Director of the Space Situational Awareness Arizona (SSA-Arizona) Initiative at the Defense and Security Research Institute (DSRI). He has a broad range of expertise and research interests. He has been working on a numerous and diverse projects including remote sensing of vegetation from satellites and UAV platforms, development of guidance navigation and control of planetary landers, systems engineering for close-proximity operations on small bodies, fuzzy expert systems for life detection on planetary bodies, machine learning applications to space situational awareness, wind-based hot-air balloon navigation for Titan as well as NASA funded projects involving glacier mapping and intelligent data analysis algorithms. The total amount of funds received by NASA ad other agencies over the past 10 years surpass a total of $7M. He published 40 peer-reviewed journal papers and more than 150 conference papers and abstracts. Since 2013, he has been appointed technical member of the American Astronautical Society (AAS) and he served as Technical Chair of the 2015 AAS/AIAA Spaceflight Mechanic Meeting (Williamsburg Virginia). During phase B-D of the OSIRIS REx Asteroid Sample Return Mission he acted in multiple roles, i.e. 1) Ground Segment Systems Engineer 2) Science Processing and Operations (SPOC) systems engineering team lead and 3) SPOC-Science Team interface. For his contribution to the OSIRIS REx mission, the asteroid 2003 WX3 was renamed 133474 RobertoFurfaro.

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12 December 2017 at 10:00
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