Guest Editorial

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Computational Intelligence in Aerospace Science and Engineering

In an expanding world with limited resources, Computational Intelligence has become a necessity to handle the complexity of systems and processes. The aerospace sector, in particular, has stringent performance requirements on highly complex systems for which solutions are expected to be optimal and reliable at the same time.

Computational intelligence techniques have been widely used to find solutions to global single or multi-objective optimisation problems, including mixed variables, multi-modal and non-differentiable quantities. Specialised conferences like EUROGEN, for over two decades now, have collected hundreds of scholars to present the use of Computational Intelligence applied to the design and control of aerospace systems. Winning the Humies competition in 2013, the European Space Agency demonstrated how Computational Intelligence can help design better space missions. Companies, like ESTECO, academic groups around the world and research centres, like CIRA in Italy and DLR in Germany have demonstrated how to design complete airplanes with Evolutionary Multi-Objective Optimisation, Self-Organsising Maps, surrogate modelling and other Computational Intelligence techniques. Other groups, like the one of Prof Abbass at UNSW, have used Computational Intelligence for Air Traffic Management. Space companies, like Thales-Alenia Space, the Aerospace Corporation or Deimos Space, have used Computational Intelligence techniques to solve resource allocation problems on the Space Station, the design and deployment of satellite constellations and autonomous planning and scheduling for drones, planetary rovers, robotic arms, rendezvous and docking of space vehicles. Large European projects, worth tens of millions of Euros, like CRESCENDO, UMRIDA and the recent UTOPIAE have advanced the use of Computational Intelligence in Aerospace. In the last two decades, evolutionary computing, fuzzy logic, bio-inspired computing, artificial neural networks, swarm intelligence and other computational intelligence techniques have been used to find optimal trajectories, design optimal constellations or formations, evolve hardware, design robust and optimal aerospace systems (e.g., reusable launch vehicles, re-entry vehicles), evolve scheduled plans for unmanned aerial vehicles, improve aerodynamic design (e.g., airfoil and vehicle shape), optimise structures, improve the control of aerospace vehicles, regulate air traffic, classify galaxies with machine learning, treat uncertainty with rough sets, etc.

These examples demonstrate that, in the aerospace sector, Computational Intelligence has become an important – and in many cases inevitable – tool for tackling complex, difficult problems, providing useful and non-intuitive solutions. Not only has the application of existing Computational Intelligence to Aerospace provided new and effective solutions but has also stimulated the development of substantially new approaches and methods.

This special issue provides a glimpse on the vast world of Computational Intelligence for Aerospace Science and Engineering. The special issue collects four papers that are representative of some of the key areas of Aerospace Science and Engineering, in which Computational Intelligence has proven to be an enabling technology: machine learning in aero-design, evolutionary algorithms for computationally expensive optimisation under uncertainty of aerospace systems, swarm intelligence for path and operation planning, and Markov chains for the control of Unmanned Aerial Vehicles (UAVs).

In the paper "*Robust Design of a Supersonic Natural Laminar Flow Wing-Body*", the authors investigate the use of different metrics to quantify uncertainty in robust aerodynamic design in combination with evolutionary strategies. Covariance Matrix Adaptation, in particular, is used in combination with Value-at-Risk (VaR), Conditional Value-at-Risk (CVaR) and Surrogate-based Local Optimization. The approach differs from the more classical use of mean and variance of the quantity of interest and offers some interesting properties in the context of robust design. The optimization of a quantity of interest under uncertainty is a computationally challenging task and the choice of the proper metric is key to minimizing the computational cost and obtaining a meaningful expression of the effect of uncertainty on the quantity of interest. In this context Computational Intelligence allows one to handle non-differentiable quantities and mixed deterministic stochastic variables.

In the paper "*Modelling Behaviour in UAV Operations using Higher Order Double Chain Markov Models*", the authors propose a Double Chain Markov Models to train operators to improve their control of UAVs. This research, partially supported by Airbus Defense and Space, is of growing importance given the numerous applications of UAVs in infrastructure inspection, monitoring of coastal zones, traffic and disaster management, agriculture and forestry. In many of these applications the performance of the UAV is largely dependent on the training and the ability of the operator. In this context, Computational Intelligence provides tools capable of evaluating and analysing the performance of operators on a massive scale.

In the paper "*An Intelligent Packing Programming for Space Station Extravehicular Missions*", the authors use an Ant Colony Optimisation algorithm with self-adaptation mechanisms based on a novel pheromone heuristic to optimally plan extravehicular activities on the International Space Station. Given that space is an extreme environment and that the resources on the space station are limited, the optimization of extravehicular activities (or space walks) is key to completing all the tasks while minimizing the exposure of the astronauts to the space environment. The problem addressed by the authors, named Extravehicular Missions Packing Programming or EMPP, is mathematically equivalent to a Bin-Packing Problem. In this context, Computational Intelligence offers efficient and robust tools to provide significant improvements in NP-hard complex problems such as the EMPP.

In the paper "*Knowledge Transfer through Machine Learning in Aircraft Design*", the authors review existing methods to reduce the computational cost of aircraft design using what can be defined as virtual prototyping or model-based system engineering. The authors argue that a number of methods, using for example polynomial regressions or Gaussian processes, can be improved by knowledge transfer from previous data sets. A proposal for such an improvement is presented together with an analysis of the possible improvements on a number of significant case studies. This paper highlights the usefulness of machine learning techniques in the context of Multi-Disciplinary Design Optimization.

In all these cases, and related classes of problems, Computational Intelligence provides effective solutions and results that support the progress of aerospace sector.