HAROS-HD

Hybrid Adaptive Robust Optimization Strategy for EWIS High Dimensional systems

State of the art – Background

HAROS-HD project aim is to **research and develop an innovative large scale optimization methodology that will help to address, manage and solve the high complexity of EWIS optimization problem.**
Complexity in modern aircrafts is increasing significantly. They incorporate more electric systems than before since other subsystems that used to be pneumatic or hydraulic are being replaced by electric ones. As a consequence, the wire harnesses that are used to connect those systems to each other must also convey more signals and power. Electrical systems are used for flight control, sensors, engine control, flight management, communication, in-flight entertainment and many more systems.
Connecting the electrical power sources and consumers throughout the aircraft is done by the Electrical Wiring Interconnection System (EWIS). The electrical cables linking sources and loads pass through several harnesses. These cables are sized for the current they have to carry, with respect to some thermal and voltage drop constraints. As such, the cable gauge sizing problem is a multi-physics problem. An electrical link between a source and a load can have several cables with different gauges, allowing mass optimisation.

Objectives

Given the large amount of design variables and input/output constraints that describe the design space of real gauge sizing problems, the **challenge of optimizing such system is considered to be a high-dimensional, non-linear and discrete/continuous problem.**
This project has researched and developed a number of specific technologies and methods to address the challenge of optimizing complex and high dimensional systems. The **use of unique machine learning techniques**, implicit metamodeling using **self-organizing maps and graph decomposition techniques has contributed to achieve a flexible, adaptive and scalable optimization strategy that could solve the EWIS problem**. The resulting hybrid, adaptive and robust optimization strategy has demonstrated the optimization of high dimensional systems (HAROS-HD, Hybrid Adaptive Robust Optimization Strategy for High Dimensional systems)

Description of work

The Haros-HD concept originated from engineering design situations in which accuracy of optimized result is as important as the efficient identification of the “good input space” (also called “feasibility region”).
Based on this consideration, the HAROS-HD challenge has been addressed by developing a different approach based on the pre-conditioning of the optimization problem with machine learning algorithms applied to engineering cases. As such, the effort is shifted from the optimization challenge to the ‘feature discovery’ process, where **engineering features of the design and solution spaces are ‘discovered’** and exploited to perform a much faster and tailored optimization process.
This **machine learning process** starts with an analysis of the entities and relations of the electrical wire harness topology to identify subsystems that are independent or loosely coupled between themselves and that can be optimized separately with relatively small or no error (in case of total independence). Once the **problem is decomposed according to its inherent structure**, two machine learning algorithms are started to reduce the newly created subsystems and to learn, for each of them, the feasible region – that is the region of the output space where no constraints are active. In this context, the SOMBAS and the Deep Learning algorithms are used.
The output of this process is not only the definition of the feasible region, but also a set of optimization starting points that are best candidates for the subsequent subsystem optimization. **The information discovered by the machine learning approach is used by specific optimization algorithms** like Cross-Entropy and Annealed Hook&Jeeves that exploit this knowledge by starting from the best points found in the feasible region, thus removing the challenge to handle constraints (that, for the 48 harness, can be up to more than 10000). These optimization algorithms will then iterate till final convergence to the optimal solution for each subsystem. Once this is achieved, the overall system is then reassembled to take into account the various subsystem dependencies and converge to the final optimal configuration for the entire wire harness problem at hand.

Results

The main tangible results of the Haros-HD project are the key enabling technologies and the high dimensional optimization strategy. These technologies and the optimization strategy have been implemented and deployed in a fully functional software prototype.

More specifically, a number of **new technologies have been researched and implemented**:

> **Advanced graph decomposition techniques**, aimed at structuring the information related to the EWIS problem and extracting dependencies and useful information for problem decomposition and sub-structuring.

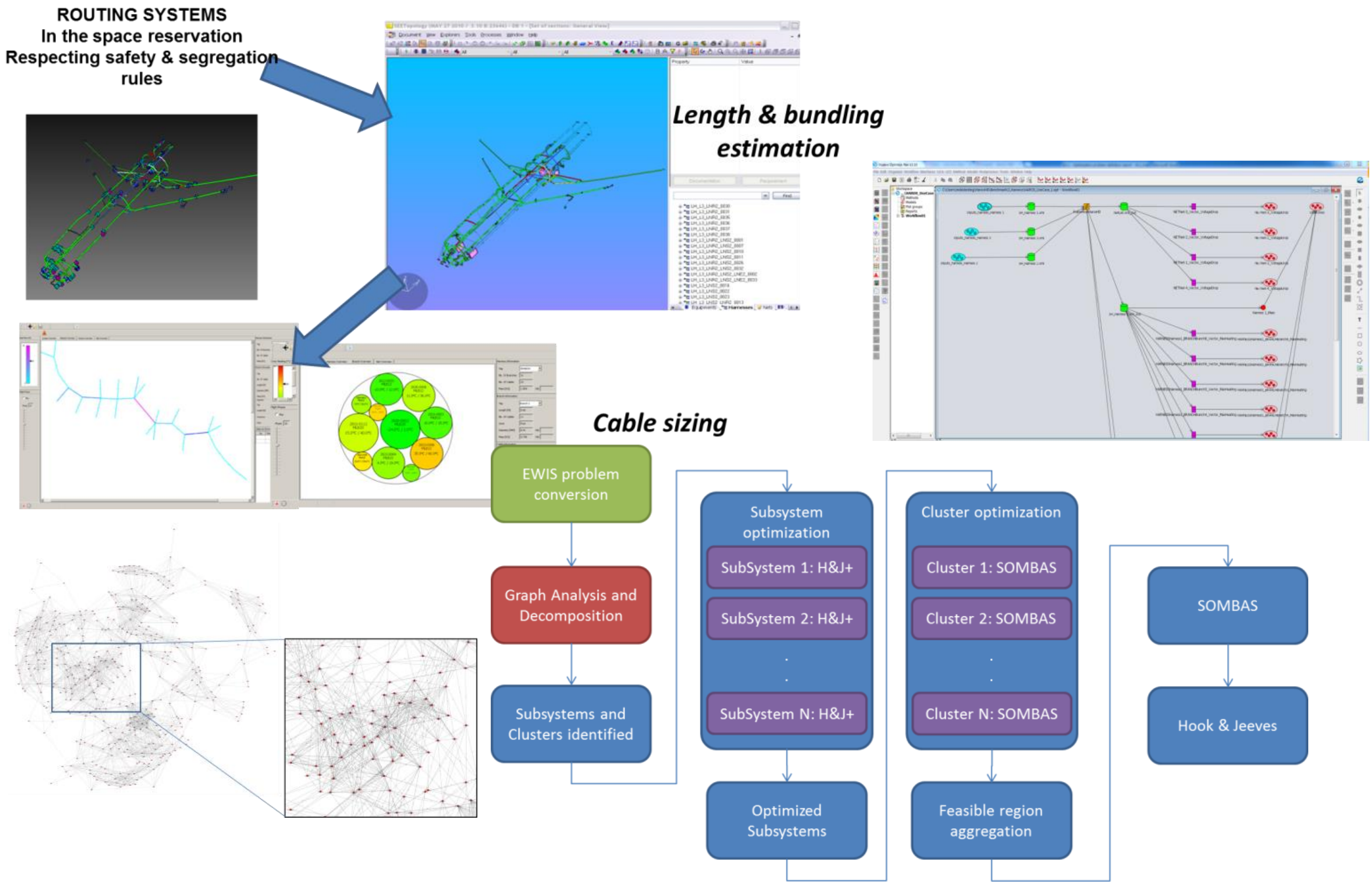
> **Feasible region identification algorithm (named Deep Learning)**, capable of sampling the design space and learning about the feasible region, given the current constraints. This algorithm, acting as an advanced classifier, is coupled with a special type of Neural network response model that, when coupled with the deep learning algorithm, is capable of creating an advanced surrogate model of the EWIS discrete system.

> **Optimization based self organizing maps (SOMBAS) algorithm** that, together with the Deep Learning approach, allow for quick space filling of the feasible region and identify the feasible boundaries, even if they are disconnected regions. The SOMBAS algorithm is a space filling approach based on the results of the Deep Learning one and produces information that is used in the subsequent steps. Together with SOMBAS also Interaction Indexes have been developed to extract information about the correlation between inputs and outputs with a local approach (i.e. not averaged over the whole domain but locally in each subregion of the domain).

> **Adaptive DOE techniques** that speed up the execution of both SOMBAS and Deep Learning, in order to minimize the amount of simulations to be performed.

> **Advanced Cross Entropy and Hook&Jeeves algorithms.** These have been largely enhanced to handle very complex and large scale problems and sub-problems and are particularly efficient in discrete problems. Cross Entropy uses a probabilistic approach to convert discrete problems into continuous ones, while the modified Hook and Jeeves explores the design space more efficiently, thanks to SOMBAS, Deep Learning, Graph decomposition and Cross Entropy results altogether.

Thanks to these technologies, it has been possible to **design and implement a complete hybrid optimization procedure capable of handling high dimensional and large scale optimization problems. The final HAROS-HD prototype has been used to perform EWIS optimization on a 48 harness cable sizing problem with more than 400 design variables and 10000 constraints.**



Project Summary

Acronym :	Haros-HD
Name of proposal:	Hybrid Adaptive Robust Optimization Strategy for EWIS High Dimensional systems
Technical domain:	Integrated design tool to support EWIS optimization
Involved ITD	Systems for Green Operation - SGO
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Instrument:	Clean Sky JU
Total Cost:	296.300,00 Eur
Clean Sky contribution:	148.150,00 Eur
Call:	JTI-CS-2013-1-SGO-02-056
Starting date:	01/01/2014
Ending date:	30/09/2015
Duration:	21 Months

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