Multidisciplinary and Multilevel Design Methodology of Unmanned Aerial Vehicles Using Enhanced Collaborative Optimization

Pedro F. Albuquerque, Pedro V. Gamboa, Miguel A. Silvestre

***Abstract*—The present work describes the implementation of the Enhanced Collaborative Optimization (ECO) multilevel architecture with a gradient-based optimization algorithm with the aim of performing a multidisciplinary design optimization of a generic unmanned aerial vehicle with morphing technologies. The concepts of weighting coefficient and dynamic compatibility parameter are presented for the ECO architecture. A routine that calculates the aircraft performance for the user defined mission profile and vehicle's performance requirements has been implemented using low fidelity models for the aerodynamics, stability, propulsion, weight, balance and flight performance. A benchmarking case study for evaluating the advantage of using a variable span wing within the optimization methodology developed is presented.

***Keywords*—Multidisciplinary, Multilevel, Morphing, Enhanced Collaborative Optimization (ECO).

I. Introduction

AERONAUTICAL design involves a comprehensive analysis of a wide range of mutually interacting phenomena, requiring a sound knowledge on disciplines like materials, aerodynamics, structures, fluid-structure interactions, control, stability, performance, among others, thus being an inherently multidisciplinary task. Indeed, aircraft design is commonly regarded as a separate design discipline [1], which is different from the former in the way that the designer needs to be well versed in all of them.

Multidisciplinary design optimization (MDO) is doubtlessly of utmost relevance in this context, hence a topic of intense research. The possibilities MDO methodologies unfold show that they will definitely pave the way of engineering design in a range of subjects that goes far beyond the aerospace industry.

There have been a number of surveys of MDO over the last two decades. Haftka et al [2] were among the first to review the MDO architectures known at the time. Cramer et al [3] formalized the monolithic architectures and detailed the required gradient computation methods. Balling and Sobieski [4] identified a number of possible monolithic approaches and estimated their computational cost. In a collection of articles Alexandrov and Hussaini [5] also gave their contribute. Kroo [6] provided a comprehensive overview of MDO, including a description of both monolithic and distributed architectures. In the same volume, Alexandrov [7] discussed the convergence properties of certain partitioning strategies for distributed architectures, and Balling [8] focused on partitioning as a way to provide disciplinary autonomy. Sobieski and Haftka [9] published an exhaustive survey of the MDO literature.

However, the most recent survey was made by Martins et al [10] where all the optimization architectures known by the time of its publication have been presented. In this review, all the architectures known at the time have been compared using a unified description, not only being the latest but also the most comprehensive effort towards a straightforward comparative evaluation of the existing methodologies.

A primary motivation for decomposing the MDO problem comes from the inherent architecture of the engineering design

Pedro F. Albuquerque is a Researcher and PhD Candidate at the Department of Aerospace Sciences, University of Beira Interior, Covilhã, Portugal (e-mail: pffa@ubi.pt).
Pedro V. Gamboa is an Assistant Professor at the Department of Aerospace Sciences, University of Beira Interior, Covilhã, Portugal (e-mail: pgamboa@ubi.pt).
Miguel A. Silvestre is an Assistant Professor at the Department of Aerospace Sciences, University of Beira Interior, Covilhã, Portugal (e-mail: mars@ubi.pt).

Nomenclature

b	wingspan	ν	kinematic viscosity
c	wing chord	Δ	interval or variation
C_d	2D drag coefficient	Λ	aspect ratio
C_l	2D lift coefficient		Subscripts
C_m	2D pitching moment coefficient	cb	climb
D_{fus}	fuselage diameter	cz	cruise
E	energy	dt	descent
L_{fus}	fuselage length	ene	energy
L_m	main gear length	eng	engine
L_n	nose gear length	fus	fuselage
N	propeller rotational velocity	max	maximum
p	span extension factor	min	minimum
P	power	mlg	main landing gear
R	range	mot	motor
RoC	rate-of-climb	nlg	nose landing gear
S	area	pay	payload
t/c	airfoil relative thickness	$prop$	propeller
V	velocity	ref	reference
W	weight	req	required
β	sideslip angle	to	take-off
δ	thrust setting	vt	vertical tail
η	efficiency	w	wing
λ	taper ratio		