Chapter 1

Development of an Optimization Framework for Parameter Identification and Shape Optimization Problems in Engineering

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ABSTRACT

The use of optimization methods in engineering is increasing. Process and product optimization, inverse problems, shape optimization, and topology optimization are frequent problems both in industry and science communities. In this paper, an optimization framework for engineering inverse problems such as the parameter identification and the shape optimization problems is presented. It inherits the large experience gain in such problems by the SiDoLo code and adds the latest developments in direct search optimization algorithms. User subroutines in SDL allow the program to be customized for particular applications. Several applications in parameter identification and shape optimization topics using SDL Lab are presented. The use of commercial and non-commercial (in-house) Finite Element Method codes to evaluate the objective function can be achieved using the interfaces pre-developed in SDL Lab. The shape optimization problem of the determination of the initial geometry of a blank on a deep drawing square cup problem is analysed and discussed. The main goal of this problem is to determine the optimum shape of the initial blank in order to save latter trimming operations and costs.

INTRODUCTION

The use of optimization methods in engineering is increasing. Process and product optimization, inverse problems, shape optimization and topology optimization are frequent problems in both industry and scientific communities (Andrade-Campos et al., 2007; Ponthot & Kleinermann, 2006; Belegundu & Chandruptla, 1999; Ceretti et al., 2010).

To solve this kind of problems, general mathematical/technical computing software, such as MatLab (2007) and Mathematica (2009), or programming languages (such as C++, Fortran,

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java, etc.) are usually used. In these cases, as these approaches use general-purpose software environments, it is necessary to write and implement the whole optimization algorithm including the objective function, the optimization method, the input/output data, etc. Although computationally very efficient, this approach can be very time consuming and has the prerequisite of full knowledge of a programming language. On the other hand, commercial engineering optimization software packages start to be used by many researchers and technicians. ModeFrontier (2008), Knitro (2007), and Heeds (2009), among others, can be easily used for general-purpose optimization processes. However, these packages have the disadvantage of being a closed *black-box* where the user cannot change any detail in the optimization methodologies or cannot implement new optimization methods.

An engineering optimization framework that aims to contradict the previously mentioned disadvantages is presented in this paper. The SDL optimization lab is a non-commercial framework designed for specific engineering inverse problems such as the parameter identification (Cailletaud & Pilvin, 1994; Liu & Han, 2003 among others) and the shape optimization problems (e.g., Maniatty & Zabaras, 1994; Fourment et al., 1996). Parameter identification problems have emerged due to the increasing demanding of precision in the numerical results obtained by Finite Element Method (FEM) software. High result precision can only be obtained with confident input data and robust numerical techniques. Unfortunately, the large majority of the robust numerical techniques are inherently more complex. Constitutive material models developed to simulate with increasing accuracy the behaviour of different materials are an example of these techniques that became more complex (Andrade-Campos et al., 2009). However, the accuracy of the model is much dependent on the model input data (constitutive model parameters) given by the user. Generally, the number of parameters to be determined increases with the model complexity and, consequently, increases the difficulty of the parameter identification problem. The determination of parameters should always be performed confronting numerical and experimental results leading to the minimum difference between them (minimization of the cost function that is defined as the difference between experimental and numerical results). This problem could be reduced to a curve-fitting problem if physical constraints were not taken into account. However, most material constitutive models have physical constraints such as material parameter boundary values and mathematical relations between them, guaranteeing the physical meaning of the material parameters.

The aim of shape optimization problems is to find the shape which is optimal (minimizes a certain cost functional while satisfying given constraints) for a determined objective. However, frequently, the cost functional (objective function) cannot be evaluated without performing a time-consuming simulation analysis.

The shape optimization problem can be similar to the parameter identification problem if the shape to be optimized is defined by a finite number of parameters. Therefore, both problems can be solved by the same approach.

The minimization of the cost function, defined as the difference between experimental and numerical results, can be a hard task. The function of a set of arguments (the material parameters) may have many isolated local minima, non-isolated minimum hypersurfaces, or even more complex topologies. No finite minimization method can guarantee to locate the unique, global, minimum of the parameter set without supplying additional information about the cost function by the user (Birkinshaw, 1998).

There is no best algorithm for finding the minimum of a cost function. Several approaches and optimization methods can be used to solve the mentioned non-linear optimization problems

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