CHAPTER 1

INTRODUCTION

1.1 GENERAL

This chapter describes the model updating problem faced by every initial model of a sufficiently complex system and the challenges posed by the problem. It also describes the systematic approach followed in addressing each challenge. This thesis does not assume the reader is familiar with the field of finite element models. For such a reader, the words finite element model (FEM) can be replaced by the words mathematical model without any loss of specificity. Science and specifically engineering is concerned with the understanding of natural phenomenon and or systems. To understand any system the general scientific process is measure the natural system, devise a mathematical model to describe and explain the behaviour of the said system and finally check that the model is a good approximation of this system.

To this end FEMs are a particular class of models used to mathematically describe the mechanics and dynamics of complex engineering systems like Space Vehicle Model. Besides mathematically describing such complex systems, modelling is also used to predict and analyze unforeseen behaviour of these real systems in a variety of settings. System modelling forms an important stage of many engineering design problems. The results from the model either confirm or highlight limitations of the design. An analyst is usually interested in the accuracy, confidence range and more critically the correctness of the assumed mathematical model. In this thesis the model domain is structural FEMs.
1.2 THE FINITE ELEMENT MODEL UPDATING PROBLEM (FEMUP)

FEMs are limited by definition; they are an approximation of a real system and will thus never produce dynamic results that are equal to the measured system data. The question is then what can be done to the initial model for it to better reflect the real system dynamic results? This leads to the need for automatic and intelligent methodology to improve models. This has to be attained whilst using realistic characteristic parameters of the system in question.

It is clear from the problem background that there are many ways to tackle this FEMUP. To see the problem is fundamentally about and to provide a global perspective as shown in Figure 1.1. This indicates three spaces, $S^1$, $S^2$ and $S^3$, each inscribed by an oval. The $S^1$ space is the space of all possible measurements of the real system. $S^2$ is the space of all possible initial models and $S^3$ is the space of all possible updated models. The real system of interest exists outside the space $S^1$. This is due, amongst other reasons, to the measured data being incomplete from the impracticality of capturing the full dynamics of the system at every degree over the full behaviour range. This fact is shown by the different accuracy measurement datasets possible for a particular real system. In the case shown dataset 3 is the most accurate measurement of the system because the distance between the two is smallest.
1.3 NEED FOR THE STUDY

Assume our model to be $M_C$ and measured dataset to be dataset 2. As depicted in Figure 1.1 the initial model $M_C$ is initially far from the measured dataset. The main reason for creating the model is for it to be as accurate in approximating the measured data as possible. The goal therefore is to reduce the distance between this initial model and the measured dataset. For a given model reducing this distance is achieved by improving or updating the initial model.
1.4 THE CHALLENGES OF FEM UPDATING

In practice engineers often propose a number of models for one real system for example the three models; \(M_A(\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5)\), \(M_B(\beta_1, \beta_2, \beta_3)\) and \(M_C(\lambda_1, \lambda_2, \lambda_3, \lambda_4)\) proposed in Figure 1.1. Each model has its own type and number of uncertain parameters. Before performing model updating, a number of fundamental questions need to be addressed, these are:

1.4.1 Which aspects of the model need to be updated?

Said differently, which features/parameters of the initial model are uncertain or incorrectly modelled? The above question effectively cast model updating as a system identification problem. System-identification is concerned with the development of parameterized mathematical approximations to some complex system whose features or order is unknown and is to be identified. This simply translates to which and how many model parameters are sufficient to correctly capture the dynamics of the underlying process/system. In the Finite element(FE) models of concern there are a variety of structural parameters that can be mathematically modelled. These can vary from geometric to material properties. Some of the most difficult and uncertain geometric parameters to model are points of structural variation such as joints and/or welds. Material uncertainties arise from incorrectly proposed properties due to lack of manufacturing and/or operational condition knowledge.

Given that a model can have a large number of uncertain parameters we do not want to blindly search for the parameter combination that produces a good solution. This combination parameter search can easily become a combinatorial problem. A significant constraint to such a procedure is that the updated parameters must remain physically realistic. That is when updated the values of the parameters must be within practical limits.
The first challenge therefore is to automatically identify and or select the most uncertain parameters in our proposed FE model. The next question is;

1.4.2 How can the chosen model be efficiently updated?

Ideally as straight a line as possible is required to move from the initial model in space $S^2$ to the optimal model position in Figure 1.1. Realistically this trajectory will not be straight but will be determined by the form of the initial model, the model parameter set and the mechanics of the proposed updating procedure. Since each FE model is different the challenge here is to design an updating procedure independent of any particular FE model. In this context of multiple models this is our efficiency criterion.

The final question to be considered in model updating should be;

1.4.3 Is the final updated model the best one?

It is difficult to compare and decide on the best model in a set of competing models of one system. This question essentially requires some form of proof that the updated model is the best. All models, constrained by the practicality clause, will attain certain optimal positions once updated. One can then simply calculate the distances between these positions and measured data and determine the closest model. In Figure 1.1 the updated model $M_C$ achieves the smallest distance while $M_B$ the largest. This does not strictly mean $M_C$ is the best updated model. Perhaps $M_C$ is not significantly better than $M_A$ and or $M_A$ may require less adjustments to achieve a position close to $M_C$ even though it is more complex than $M_C$. Therefore the challenge here is to develop an evaluation criterion for which model is the best in a given set.
1.5 FLOW CHART DESCRIBING THE METHODOLOGY

The step-by-step procedure of the finite element model updating scheme is clearly shown in the following flow chart as Figure 1.2
1.6 RESEARCH WORK OBJECTIVES

The thesis objectives are as follows:

1. Propose and implement an automatic procedure to identify and select the most uncertain parameters in any FEM. The aim is to propose a generic method that can be used on any space vehicle model. The attraction of such a proposal would be that anyone can plug their model onto this algorithm and it will automatically produce the model most uncertain parameter(s). Furthermore the optimal parameter selection will be reproducible.

2. Design and implement an efficient FEM updating procedure in the context of multiple competing models. The aim here is to be able to update multiple FE models in one procedure and to determine which model is the best. Updating one model in isolation is not that informative given that someone else can propose a different model for the same system.

3. Propose and evaluate a relative goodness measure for the updated FEM. After developing a model goodness measure, quantify why a particular model is better than another. This is fundamental to FE updating especially in the multi-model context.

1.7 LIMITATION OF EXISTING WORK

In our Country, in spite of much research in FEM updating, application of these methods in aerospace industrial regions are not properly established. The reason for this is lack of easy access to finite element model updating procedure for complex structure. The shortcoming in complex algorithm used for model updating would be overcome by a simple and cost effective procedure by using orthogonal array techniques that can employed in any space craft and air craft manufacturing of complex parts. The policy and strategy perspectives of the programmes planned by Indian Space Research
Organization reports that there will be a substantially increased usage of this recent techniques in space structure by 2020 including launching of vehicle. Some of the major limitations in the existing literature with regards to finite element model updating procedure are given below.

1. The use of FEMUP procedure in space vehicle, aircraft and other spacecraft application were not studied.

2. In spite of much research in model updating procedure, it is implemented for simple structures over the past 15 years, very few researchers have studied a method for increasing the accuracy of the complex structure, but they are not implementing the specific algorithm based generalized software for updating the structures.

3. Aerospace industry and Space vehicle organization has not yet used this FEMUP based neural network programmable software for a complex structure.

1.8 SUMMARY

Model updating techniques are intended to “fine tune” physical parameters of the model, looking for a better match between analytical and experimental results. They differ from parameter/system identification techniques in the sense that they need a good initial model of the system being studied. Because the model is corrected based on experimental data, every effort should be made to obtain clean and accurate data. When modal data can be obtained with high accuracy one should update the model using either direct techniques or iterative techniques based on modal data. The choice between these two approaches depends mainly on whether or not the updated model will be used to modify the physical system. Direct methods produce updated models that do not obey the FEM formulation, while iterative techniques do. Other factors are computational cost and convergence issues associated with iterative techniques. When modal data cannot be accurately obtained from experimental
data, the choice is to use iterative methods based on frequency domain data. In this case one should be aware of the high computational cost and convergence issues associated with these techniques. The choice of parameters to be updated should be based on the results of parameter updation techniques. These techniques determine which substructures contribute the most from the discrepancy between analytical and experimental data.