Feature Selective Validation

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Abstract—The paper is aimed towards developing an algorithm and converting it to a C++ program that will enable us in offering an objective stance while comparing data values of given variables from two different sources. The code is designed to run across multiple platforms by utilizing only the standard C++ library functions. It is inspired by the paper titled "IEEE Standard for Validation of Computational Electromagnetics Computer Modeling and Simulations" and implements the method elucidated there by inputting data values from the two sources as independent text files. The technique employed is called the Feature Selective Validation (FSV).

Keywords-Validation, objective.

I. INTRODUCTION

URRENT aerospace engineers are far better placed than their predecessors in at least one respect. They have ample resources to analyze their designs. They get data faster and in multiple sets than their counter parts of olden days. It is therefore quite inevitable that their concern may shift from merely getting the data to identifying it with lesser uncertainty. This looks pretty simple when data sets are small and are required to be used manually or in discussions. But then, what about the case when data sets are large and are required to be used in automated design process such as Multidisciplinary design optimization (MDO)? Secondly, for simulations such as CFD, CEM, FEM, to be reliable, the designer may demand inter-code validation even before such data is used. Even with a single discipline, there may be multiple implementations and since such disciplines make progress from time-to-time, it becomes imperative that only validated solutions are accepted for design.

The purpose of the FSV is to mimic a visual comparison. The actual comparison is based on decomposing the original data into trend and feature information. This is done by applying 2D Fourier Transform to the data and to window the transformed data to separate out the lower and higher portions. The high and low portions are then inverse transformed back into the original domain. Combinations of these filtered data sets and their derivatives are used to compute the Amplitude Difference Measure (ADM) and the Feature Difference Measure (FDM), which can be combined into the Global Difference Measure (GDM).

II. APPLICATIONS

A. CFD Transonic Store Separation

The technique has massive applications throughout the aerospace ecosystem. For instance, the critical issues associated with store separation in aerospace vehicles can be ironed out by achieving accuracy through this technique. The system will go a long way in ensuring that the store is released and steered clear of the parent aircraft without endangering the aircraft or the pilot.



Fig. 1 Store separation events with ejectors at Mach 1.2 for 0 and 5 deg angle of attacks, respectively (Side view)



Fig. 2 Surface pressure profile for phi = 5 deg.

While Figure 1 illustrates the store separation event visually at different time instants, Figure 2 provides a graphical comparison of the simulation data with the experimental surface pressure data from the wind tunnel tests. It underscores the importance of an objective validation technique with a universal acceptance.

B. Radar Cross Section (RCS)

Another critical application of the technique lies in the area of Radar Cross Section (RCS).Radar cross section is used to

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detect planes in a wide variation of ranges. For example, a stealth aircraft (which is designed to have low detectability) will have design features that give it a low RCS (such as absorbent paint, smooth surfaces, surfaces specifically angled to reflect signal somewhere other than towards the source), as opposed to a passenger airliner that will have a high RCS (bare metal, rounded surfaces effectively guaranteed to reflect some signal back to the source, lots of bumps like the engines, antennae, etc.). RCS is integral to the development of radar stealth technology, particularly in applications involving aircraft and ballistic missiles. Figure 3 illustrates the measured response as a solid line and the calculated one by a dashed line with all values calibrated in dBsm.



Fig. 3 H-plane RCS pattern comparison for the 36 long ogive at 4GHz. Solidmeasured, Dashed-calculated

III. MOTIVATION

Whenever we are faced with competition, comparisons are iminent. For many problems in the scientific world, multiple implementations get proposed from time to time. It's imperative that we uncover the best solution to the problem and charter a meticulous plan of course in achieving this. Though it's natural and useful to make assertions based on visual comparisons guided by experience and expectation, this also lets subjectivity across observers creep into our decisions.

Quite a number of different techniques have been used in the past to compare two sets of data. Simple subtraction of one data set from the second data set will show the differences, but is very limited as a true indication of the overall agreement between the two data sets if there is a slight offset between the data sets. Similarly, cross-correlation has been used, but it is difficult to relate the results from cross-correlation to what the human expert would decide with a visual inspection of the data sets. Statistical approaches to quantifying comparison using non-parametric tests such as the Kolmogarov-Smirnov test have found application in some areas, but statistical approaches generally fail for various reasons, such as failing to account for a likely group response of a number of users and failing to show whether that "good enough" is governed by broad agreement across much of the data or detailed agreement over all the data.



Fig. 4 A graphical comparison

This therefore calls for a need of an objective measure of similarity which would foster neat and intelligent comparisons of datasets and help us all move on. Feature Selective Validation (FSV) does exactly that to a very good part by combining an amplitude-based comparison with a featurebased comparison to give an overall better indication of the agreement between two sets of data. The FSV has been calibrated to match human expert comparison for decisions that are somewhat subjective, but will attach labels describing the agreement such as excellent, very good, good, poor, etc.

To summarize, these are some of the reasons motivating the project:

- The need to control variations between visual assessment results.
- The reduction of cost (a skilled engineer is an expensive commodity).
- The desire to reduce ambiguities.
- The inability of humans to process and cache extremely large volumes of data.

IV. INTRODUCTION TO FSV

The FSV theory was conceived as a technique to quantify the comparison of data sets by mirroring engineers' visual perceptions. Furthermore, FSV allows automated comparisons of large volumes of complex data whilst reliably categorising the results into a common set of quality bands.

The FSV offers three figures of merit for the comparison of two data sets:

- ADM (Amplitude Difference Measure) and FDM (Feature Difference Measure): These are available as numerical values and can be converted to a natural language descriptor in a six level scale: excellent, very good, good, fair, poor, Very Poor. These combine to give the GDM.
- GDM (Global Difference Measure): An overall single figure goodness-of-fit between the two data sets being compared. This allows a simple decision to be made

about the quality of a comparison. This may be numerical or converted to a natural language descriptor.



These figures of merit can be further represented in three different ways in order to quantify the quality of the comparison performed:

- GDMi, ADMi and FDMi: These are point-by-point comparisons of the amplitude differences, the feature differences and the global differences. This allows a user to analyze the resulting data in some detail, probably with the aim of understanding the origin of the contributors to poor comparisons.
- GDMc, ADMc and FDMc: These give probability density functions which show the proportion of the point-by-point analyses of each of the components that falls into the six natural language descriptor categories. This provides a measure of confidence in the single figure comparisons.
- GDMtot, ADMtot, FDMtot, GDMcon f, ADMcon f, FDMcon f, GDMpw, ADMpw, FDMpw. These are more synthetic figures of merits of the comparison and stem from an elaboration of the variables described in the previous points. They are described later. Based on these figures of merit, the comparison of two data sets can be ranked.

V.CONCLUSION

The use of FSV has largely remained limited to electromagnetics when it houses potential of great applications in many other fields, fluid mechanics for example. The vast solutions offered by scientists and students worldwide to shock problems can, for instance be objectively validated using the FSV technique. After all this, FSV is still a technique in development and quantified validation for CEM is still a very young subject. It provides information that is essential for the formal validation of numerical modeling data in a way that appears to provide a good approximation to the group response of visual assessment. However, there are a number of pressing challenges to be overcome in order to extend the reach of FSV. These include a better mathematical representation and implementation of FSV, developing a better understanding of how humans approach the comparison of multiple dimension data, the effects of zero crossing data and an appreciation of the cumulative effects of numerical noise on the comparison.

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