On the determination of an:

"Efficient Geometrical Description of Perturbations to Designed Shape"

Airbus Operations Ltd

Industrial Mathematics Group Problem Statement
16th - 20th April 2012

1. INTRODUCTION AND PROBLEM STATEMENT

Manufactured artefacts such as major aircraft components (wings, fuselage, tailplane) are defined at the concept and design stages using a variety of methods, namely Computer Aided Design (CAD), NACA aerofoil definitions or purely analytical descriptions (polynomials, splines, etc.). These descriptions are used in a variety of ways for aerodynamic or structural analysis using computational (numerical) and analytical methods, as well as for physical testing.

At the end of the design, development and testing phases the final manufactured artefact can only be verified if it is measured. This measurement data is always a set of discrete points commonly described as a point cloud of data (x, y, z coordinates) describing the surface or surfaces of the component under consideration. The accuracy of these measurements is an essential part of the assessment of whether design intent has been achieved.

The types of component under consideration in this project are ones which are required to be made to a very high accuracy and precision so that extremely demanding performance requirements are met. Under these conditions there are well understood sources of error in the manufacture which will necessarily cause unwanted deviations from the intended design shape. It is these deviations that we wish to characterise and parameterise so that it becomes possible (and maybe even much simpler) to analyse them and determine their effect on component performance.

In this project it will be necessary to develop a suitable description of the geometry from the mathematical definition of shape that is then manipulated to distinguish between the overall design shape and specific types of perturbations to the nominal shape. In general there will be a global deviation from the shape and also local deviations which arise from specific assembly or manufacturing operations. In this project the intention is to focus on characterising local deviations from design shape, these are defined in the following sections below.

The other principal objective is to be able to easily make a comparison between the defined shape and the real surface of a manufactured article. This comparison should be in parametric form and it is desirable, but not essential, that the parameters are physically meaningful. In the case where the parameters are physically meaningful it might allow a parameter values to be related to actual recognisable features.

2. REQUIREMENTS FOR THE ANALYTICAL APPROACH

A primary requirement of this project is to develop an approach for characterising in a quantitative sense small cyclic or discrete perturbations. The description or characterisation should be possible with a small number of parameters (< 50) which describe the surface geometry with high fidelity. The method must be capable of being able to characterise a few specific types of geometric perturbations which are deviations from the design specification. It is highly desirable that all types of geometric definition (CAD, analytic, or discrete measured data) will be amenable to analysis by the method developed.

The approach must allow for a parametric description of a surface so that the out-of-surface perturbations from that nominal surface (where the nominal surface is defined in the design) are quantified in terms of their magnitude (out of the surface) and their extent (in the plane).

Furthermore it should be noted that the perturbations to be measured are small by comparison to the surface area being evaluated and so the method developed should be able to cope with this large difference in scale. The basic geometry being considered is a wing, empennage or fuselage.

A typical section of wing that will need to be analysed is shown in Figure 1 where the dimensions can vary from a small section approximately 0.8m wide by 1.5m long to much larger sections up to 10m long and 2m wide metres long. For the measurements, the data density will be relatively high and of the order of 100,000 points per m^2.

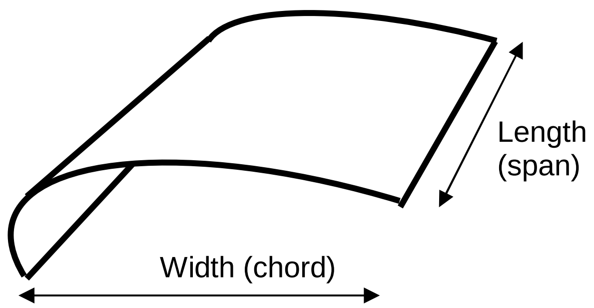

Figure 1: A section of typical geometry that might be analysed with the method developed. Only the convex surface will be visible.

3. DEFINITIONS OF PERTURBED GEOMETRY

There are three classes or types of perturbations that must be considered in this project. These are waviness, steps and discrete elements. A schematic diagram of these features is shown in Figure 2 and they are described in more detail below.

1. Waves on the surface. The wavelength and amplitude of these waves will fall within very tightly defined bounds. Waviness can occur in two main (orthogonal) directions which may or may not be aligned to the airflow. The direction of the airflow in relation to the direction of the waviness is a critical parameter. Waves can exist as singles or multiples.
2. Steps. Sudden changes in the surface height which are oriented at any angle to the airflow are considered a step. The step height will be very small in relation to the spatial extent of the surface. The edge of the step should in the first instance be defined by a straight line but it may be beneficial if a more general (curvilinear) description could be developed. The normal to this straight or curved line can be in any orientation in relation to the airflow (0 to 2π). The extent of the step is very large in relation to its height and might be the full extent of the component under consideration.
3. Discrete 3D perturbations. These are characteristically circular or elliptical (in plan view) and protrude normal to the plane of the surface. The boundary of an isolated perturbation is a step.

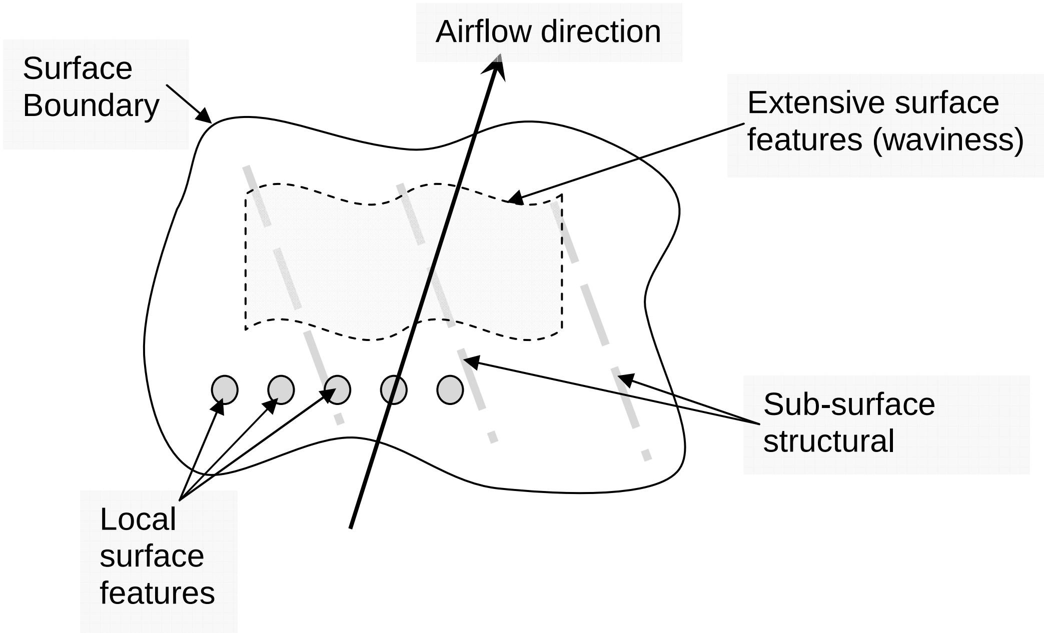

Figure 2: Schematic diagram of surface features which perturb the nominal design shape.

4. ADDITIONAL CONSIDERATIONS

It would be seen as beneficial if when considering waviness a link between steps and waves might be found in parametric form by examining the notion that a step is a single half wave of very high frequency. Isolated 3D perturbations might also be considered in this same way as a single square wave. The benefit of considering all perturbations as different manifestations of the same phenomenon might be very beneficial in allowing for a single generalised description of the surface perturbation.

Point cloud data must be amenable to a parametric description in the same way as the analytical design description so that a comparison can be made between the two. It is therefore acceptable for the discrete data to be fitted to an analytical description if necessary. The fidelity with which the analytical description fits the data must be quantified.

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30th March 2012