USE OF 'BLACK BOX' CFD PACKAGES: SCIENCE OR BLACK MAGIC?

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'To lure many away from the herd - that is why I have come' - Nietzsche

INTRODUCTION

CFD research groups in Australia are having to make critical decisions about the way that they provide a service to industry, government and the public. One option involves emphasis on the long term investment in the development of local expertise at the cutting edge. Another option involves the implementation of packages, usually imported and often with closed architecture. This paper seeks to open up discussion on the advantages and disadvantages associated with the two different approaches.

FLUID DYNAMICS: A COMPLEX FIELD WORTHY OF RESPECT

The field of fluid dynamics has a long and noble history that has attracted the attention of some of the finest intellects. It continually provides new challenges that require ever-increasing sophistication and ingenuity. Even in the simplest small sub-area of flows that are single phase, incompressible and isentropic, one of the great mysteries of the universe, turbulence, is manifest. Lurking in the Navier-Stokes equations are a myriad of flow instabilities, singularities, cascading energy distributions and unsteady, non-periodic states that are sensitive to infinitesimal changes in initial conditions. Unlocking even a fraction of the secrets requires intense high-level investigation with cooperation between analysis and numerical and physical experiments. The complexity of the fluid dynamics increases many times as flows of industrial relevance are considered. The inclusion of magnetic fields, multiphases, acoustic effects, combustion, structural interactions, etc., present significant challenges.

Historically, knowledge and experience in fluid dynamics far beyond that contained in the published literature has been accumulated in particular research centres through the sustained pursuit of excellence and research coordination e.g. GALCIT at Caltech, Mechanical Engineering at Stanford University. A key factor in the success of these research centres is the development of in-house expertise working at the cutting edge, whether it be on the experimental or numerical aspects. The question arises therefore why any self-respecting research group would turn to the almost exclusive use of imported general purpose CFD packages instead of fostering the development of its own expertise.

THE PACKAGED CFD APPROACH

Nietzsche [1] has observed that the truth resides only in the laps of a small elite. By the time that knowledge has spread to the general populace, a new truth has been found by the elite. This is certainly true in the area of CFD and computer hardware. The development of computational techniques, computer processing power, and graphics display has been staggering over the past decade. The time taken for a commercial software firm to code, test, make user friendly, guarantee convergence, market and supply is of this time-scale. By the time the product reaches the consumer in a reliable form, the techniques it offers are usually obsolete. By the time the consumer has familiarised herself with the code, another few years have elapsed and she has become uncompetitive. Nevertheless, ill-informed or inexperienced managers are insisting in increasing numbers that their researchers stop thinking and crank the handle with these packages. Compounding the problem is the trend for University departments to forgo solid CFD teaching for hands-on package usage. This presentation seeks to show that package mentality is counterproductive.

Checklist of advantages/disadvantages of CFD packages

Advantages

- Easy to obtain.
- No numeracy or fluid dynamics expertise required.
- Researchers can impress boss with glossy output and get promoted.
- Managers can establish research activity quickly in any area and get promoted.

Disadvantages

- Redirection of research activity from innovative techniques to handle-cranking.
- Decline in ability to handle new phenomena.
- Decline in ability to serve industry who can also buy the same package and use it equally incompetently.
- Encouragement of an uncritical GIGO mode of operation.
- Package use does not attract good new staff; package teaching decreases the supply of good researchers.

AN ALTERNATIVE CFD APPROACH

A second option is for CFD researchers to rigorously learn the skills of their trade through basic principles of numerical methods and stability and fluid dynamics theory as students. Later, as scientists, development of algorithms appropriate to particular problems can take place in an environment where experience with physical flows is gained. Presently, a range of techniques is available to solve specific problems well. Boundary layer stability and turbulence modelling are handled well by spectral methods. Finite elements with adaptive unstructured grids can be used to predict complex flows and structural problems. Simple geometries with large gradients are handled well by finite-difference methods with adaptive gridding. Vortex methods using fast Poisson solvers are very efficient at solving unsteady 2-D separated flows. Boundary element methods are appropriate for a range of radiation problems. Smoothed particle hydrodynamics methods are well suited to jets and unbounded problems. Encouragement of a diversity of techniques can lead to a stimulating research environment. Conversely, imposition by management (who can be out of touch with the latest developments) of the use of general purpose packages can lead to mediocrity. Which option will you choose?

For those who choose the route of self-enlightenment, good quality software in source form is readily available to provide a starting point for CFD researchers. For example, Zienkewicz and Taylor [2] provide an efficient finite-element code and Fletcher [3] provides a number of elegant CFD algorithms. A wide range of numerical methods algorithms is available in [4]. Various other avenues such as the ACM journal and NASA technical reports provide worthwhile computer codes. These codes can be tailored to the individual taste and can incorporate the latest numerical algorithms.

REFERENCES

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