Why Should I Believe My Code?
The Quest for Verification & Validation*

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Abstract

An integral component of scientific inquiry is skepticism of our own work as well as that of others. Presumably, computer simulations should receive the same degree of scrutiny as any experiment or theory. The nomenclature and methodologies of verification and validation have been developed to facilitate this process.

Verification and validation examples from the computational fluid dynamics (CFD) community or the Accelerated Strategic Computing Initiative (ASCI) typically involve much more manpower and expense than a fusion code development team can afford. Nonetheless, good or even adequate testing can be carried out with reasonable resources. As an illustration, I will describe some of the procedures and benchmarks that have been used to verify and validate the DEGAS 2[1] Monte Carlo neutral transport code. We should keep in mind that since codes are being continually improved and applied to new problems, verification and validation are both ongoing activities.

Verification essentially involves establishing that the code correctly solves the equations upon which it is based. Oberkampf[2] further subdivides it into code verification and solution verification. The former deals primarily with finding and preventing errors in the source code and numerical algorithms. Among the techniques we use in DEGAS 2 to achieve this end are documenting the code thoroughly and maintaining a version history with the CVS utility. As suggestions for how we might go beyond these basic steps, I will discuss static analysis tools and dynamic testing programs.

Solution verification consists of establishing correctness of input data and quantifying the accuracy of code results. DEGAS 2 features several stand-alone programs designed explicitly to test input data structures, such as the problem geometry. Benchmarks against analytic solutions and other codes, such as EIRENE, allow us to determine the accuracy of solutions. One near term goal for the fusion community might be to identify or manufacture solutions suitable for testing our principal code types. Note that such solutions need not be physically realistic!

The objective of validation is to determine whether or not the code and its underlying model represent a physically reasonable description of reality. The effort to validate DEGAS 2 has thus far been based on four experiments, with each being closer than the last to the ideal validation test in which the code is run in a predictive mode, with no adjustable parameters, and its results are quantitatively compared with those obtained from the experiment. Although this "improvement" was obtained by seeking experiments with progressively simpler physics content, all yielded some insight into the utility of the DEGAS 2 model.

A useful subject for further discussion is how to design future experiments suitable for validating specific code(s). Experimentalists and code authors should collaborate to identify experiments that can be (1) executed, with all essential diagnostics, at modest cost, and (2) operated in a parameter regime consistent with the known limitations of the simulation code.

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[1] D. P. Stotler and C. F. F. Karney, Contrib. Plasma Phys. **34**, 392 (1994); see also `http://w3.pppl.gov/degas2`.

[2] W. L. Oberkampf and T. G. Trucano, Prog. Aero. Sci. **38**, 209 (2002).