

Introduction to VVUQ | Part 2

Verification

Task Group on VVUQ Concepts in Engineering Education

ASME Codes & Standards | Committee on Verification, Validation, and Uncertainty Quantification

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V. 3, Draft, 2026

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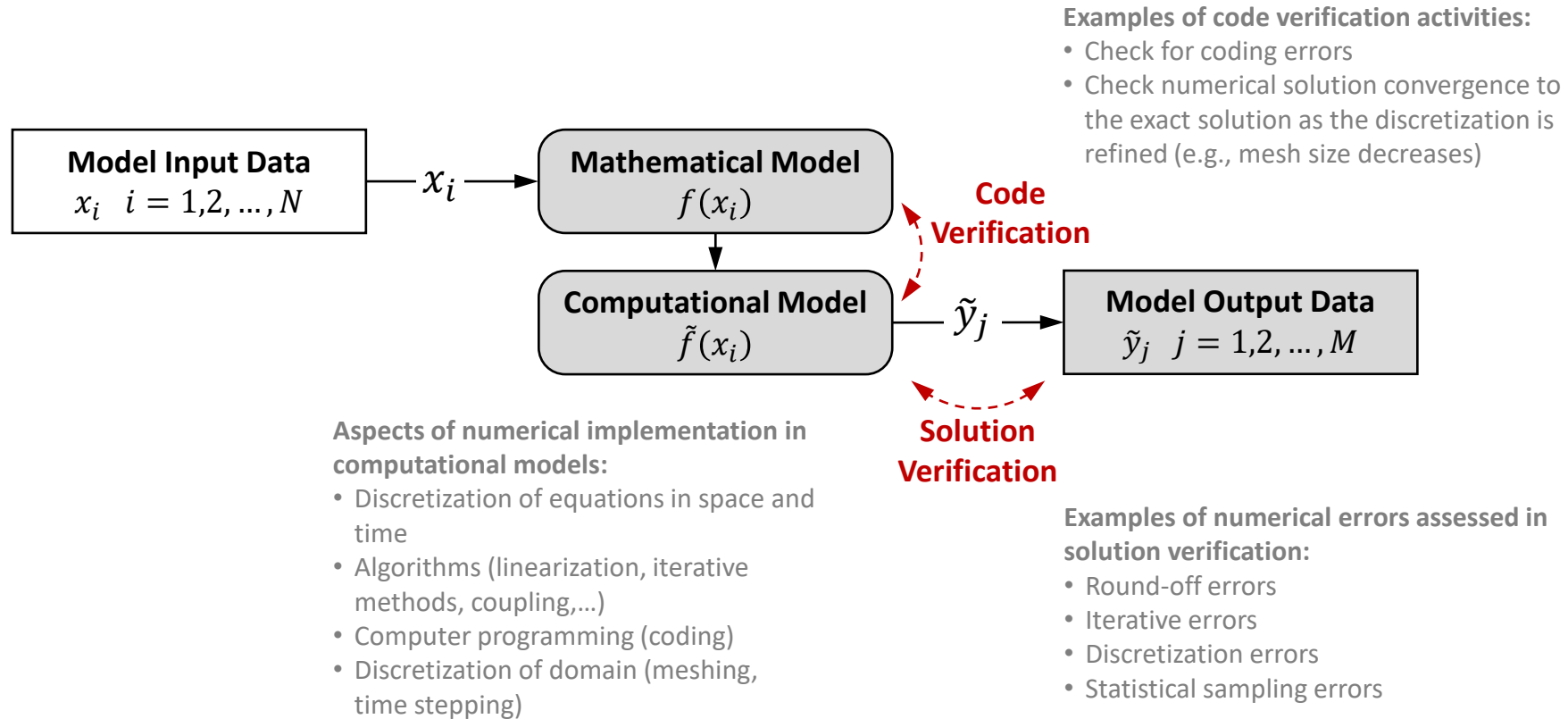
Outline

- What is verification, and why do we care?
- Verification activities: code and solution verification
- How is code verification performed?
- How is solution verification performed?

What is verification and why do we care?

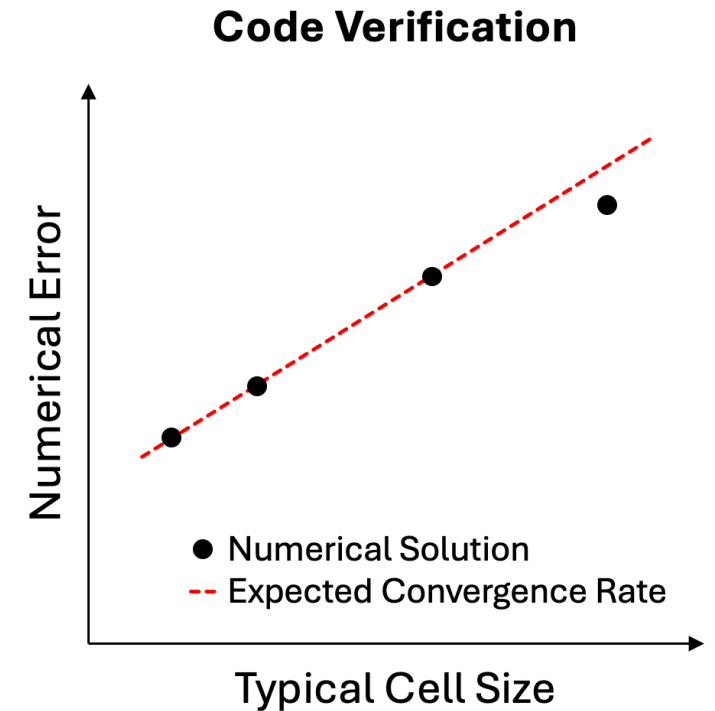
- Verification is the process that establishing the *mathematical correctness* of the computational model and determining the *accuracy* of a particular numerical solution.
- Verification includes two different activities:
 1. **Code verification** is the process of determining that the mathematical model and its numerical solution is correctly implemented in the computer code. Code verification *evaluates* the numerical error using a known reference solution.
 2. **Solution verification** is the process of estimating the *numerical accuracy* of output quantities of the computational model for the application conditions of interest. Solution verification *estimates* the numerical error of the output quantities of interest.

Verification activities



How is it code verification performed?

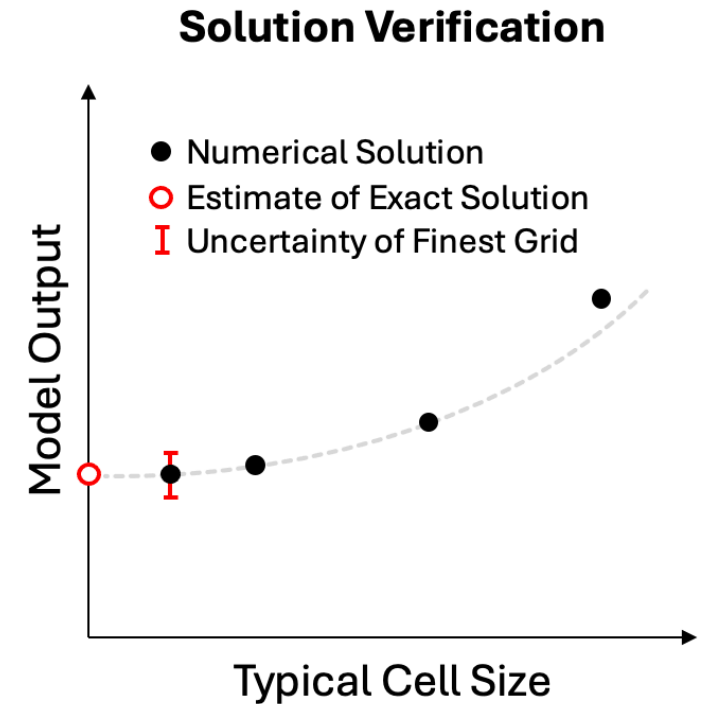
- Code verification requires a *known solution* to a problem that is solved with the same mathematical model. For example, a problem that uses the same terms for the transport of mass, momentum, and energy as the application of interest.
- Known reference solutions can come from:
 - Classical analytical solutions
 - Manufactured solutions
 - Highly accurate numerical solutions
- Numerical solutions are computed and the error is *evaluated* on a series of refined grids and time steps to determine the numerical order of accuracy.
- Code verification is a *software testing procedure*.



How is it solution verification performed?

- Solution verification is the process of estimating the numerical solution error in the model outputs ϕ for the application of interest. Since the exact solution ϕ_{exact} is unknown, there will be uncertainty $U(\phi)$ in the model outputs of interest ϕ .
- Similar to code verification, computing solutions on a series of refined grids and time steps is a common technique for estimating the numerical uncertainty $U(\phi)$.
- Since the sign of the numerical uncertainty is not known, the estimated bound on the numerical uncertainty is written as

$$\phi_{\text{exact}} - \phi = \pm U(\phi)$$



References

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