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## OpenFOAM Dakota interface

Anjali Sandip

University of North Dakota, [anjali.sandip@und.edu](mailto:anjali.sandip@und.edu)

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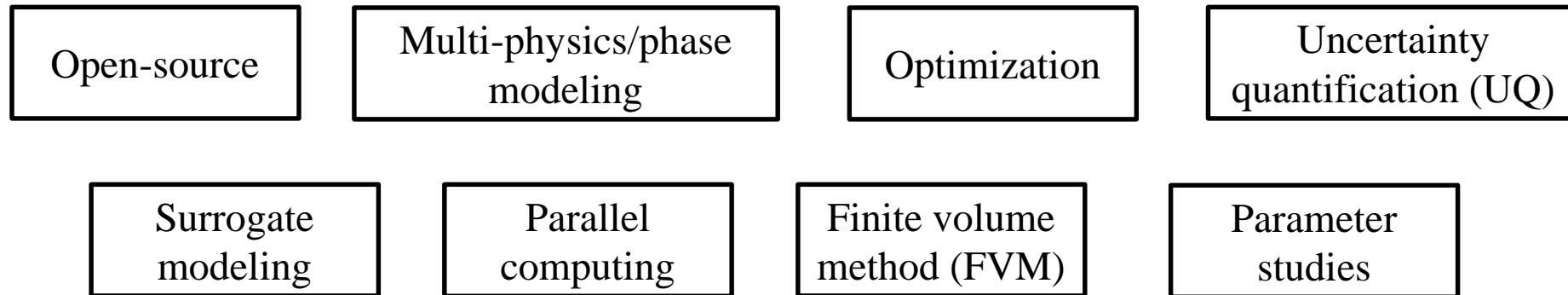
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# OpenFOAM-Dakota interface



**Anjali Sandip, Ph.D.**

Senior Lecturer

Department of Mechanical Engineering

University of North Dakota

# Scope

Traditionally, multi-physics/phase simulation software programs lack data analytics tools which can provide a richer understanding of model predictions



Growing body of research → multi-physics/phase simulation software programs + data analytics <sup>1-4</sup>



**Study objective:** Multi-physics/phase simulation program, OpenFOAM <sup>5</sup> + Data analytics toolbox, Dakota <sup>6</sup>

**Impact:** Integrating the capabilities of OpenFOAM and Sandia Dakota provides an open-source framework for multi-physics/phase simulations, uncertainty quantification, optimization, surrogate modeling, parallel computing and parameter studies.

Applications of the open-source integrated framework span several industries ranging from aerospace and energy to healthcare and manufacturing

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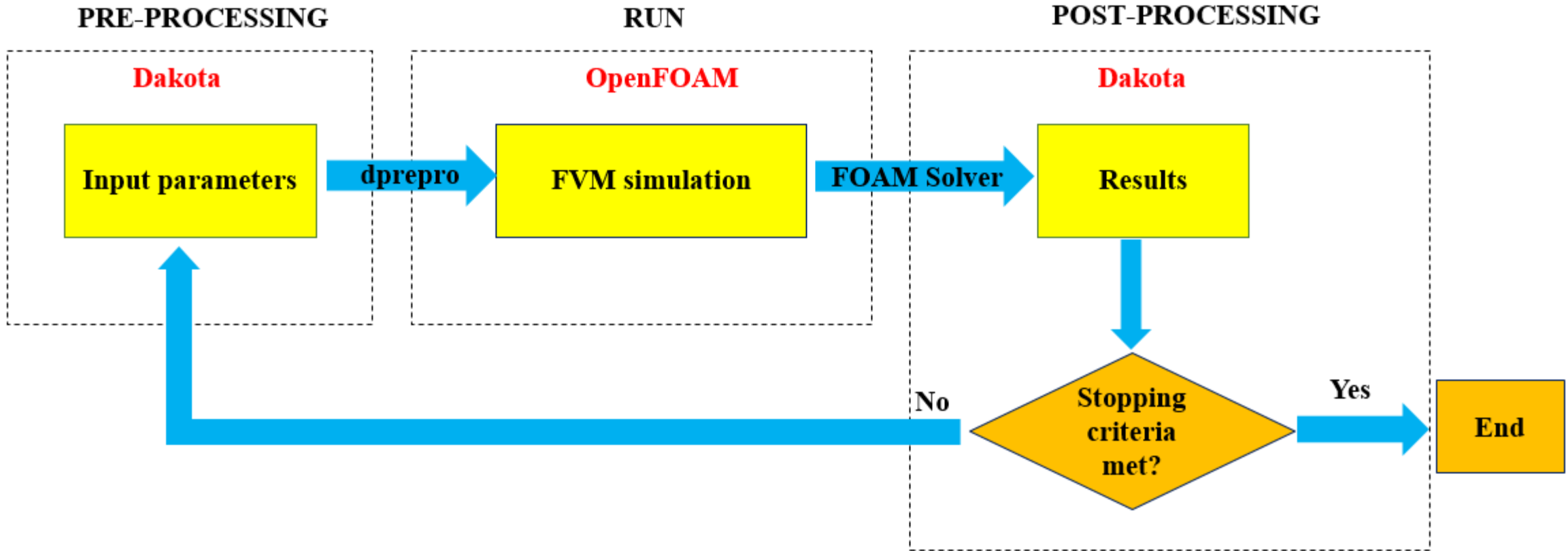
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[5]. Jasak H, Jemcov A, Tukovic Z. OpenFOAM: A C++ library for complex physics simulations. In International workshop on coupled methods in numerical dynamics 2007 Sep 19 (Vol. 1000, pp. 1-20).

# Coupling methodology



**Yellow: Changes every evaluation**

**Blue: Operations**

Source code along with test cases can be found here: <https://github.com/AnjaliSandip/OpenFoam-Dakota>

# Benchmark 1: Vortex Shedding (2D, Transient)

This is a common benchmark test in fluid-structure interaction problems <sup>7</sup>

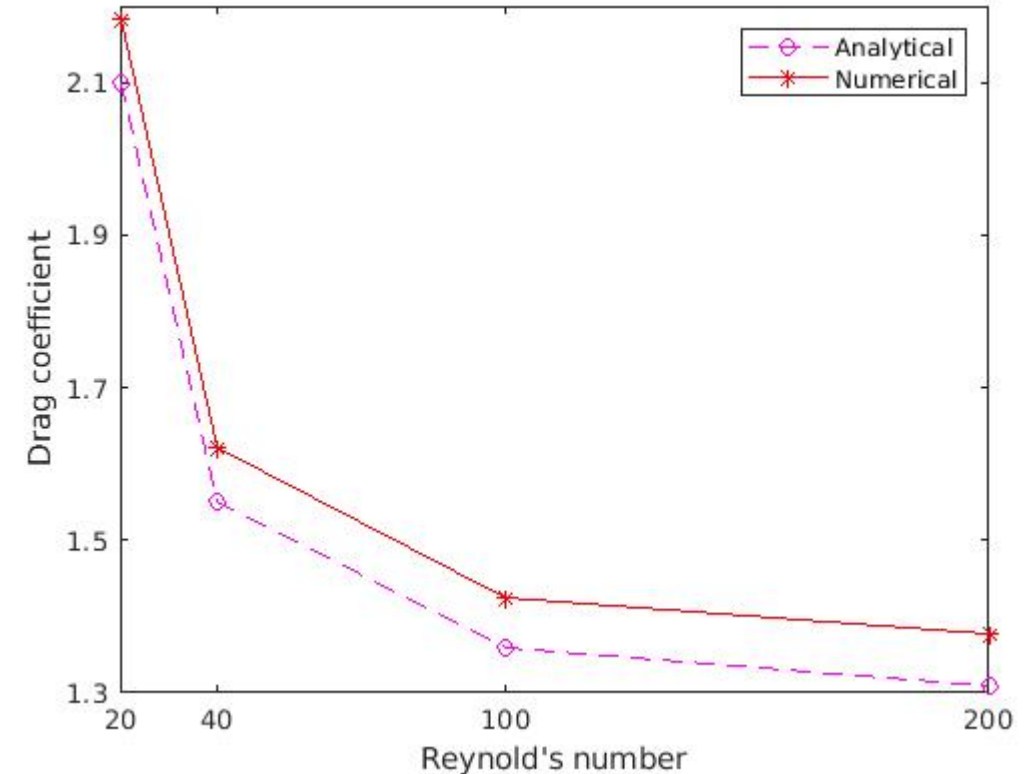
OpenFOAM solver: icoFOAM

Dakota/Data analysis: Listed parameter study <sup>6</sup>

Input parameter: Reynold's number -- between 0 and 200

Output parameter: Drag coefficient at the final time step

The results from this study were in good agreement (max. discrepancy, 5%) with literature data <sup>7-13</sup>

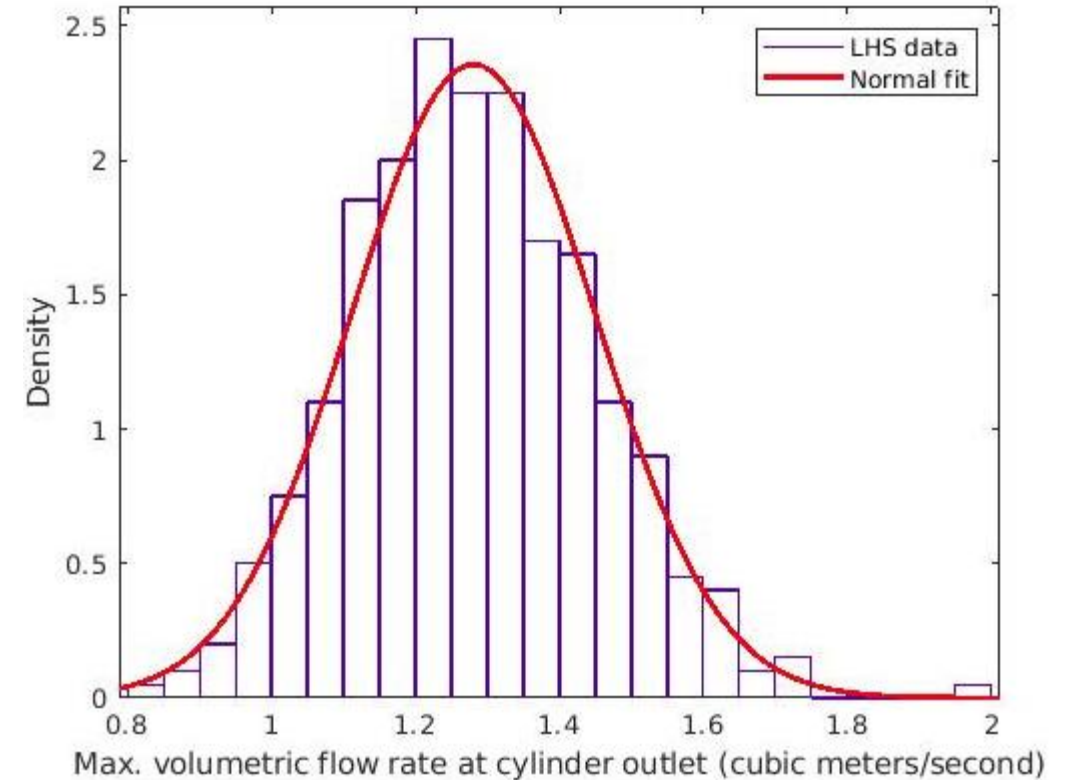


- [7] Schäfer, M., Turek, S., Durst, F., Krause, E., & Rannacher, R. (1996). Benchmark computations of laminar flow around a cylinder. In *Flow simulation with high-performance computers II* (pp. 547-566). Vieweg+ Teubner Verlag.
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- [9] Coutanceau, M., & Bouard, R. (1977). Experimental determination of the main features of the viscous flow in the wake of a circular cylinder in uniform translation. Part 1. Steady flow. *Journal of Fluid Mechanics*, 79(2), 231-256.
- [10] Russell, D., & Wang, Z. J. (2003). A Cartesian grid method for modeling multiple moving objects in 2D incompressible viscous flow. *Journal of Computational Physics*, 191(1), 177-205.
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# Benchmark 2: Hagen - Poiseuille equation (2D, Transient)

- Describes the relationship between pressure, flow rate and fluidic resistance for fluid flowing through circular tubes <sup>14</sup>
- OpenFOAM solver: icoFOAM
- Dakota/Data analysis: Latin hypercube sampling study <sup>6</sup>
- Input parameters: Length (10 +/- 0.04)m and radius (0.5 +/- 0.02)m of the cylinder
- Output parameters: Max. volumetric flow rate at the cylinder outlet (cubic meters/second)
- Numerical velocity profile at cylinder outlet agreed well with the analytical results for the same

Probability density function



# Conclusion

**Study objective:** Integrate open-source software programs, OpenFOAM for multi-physics/phase simulations and DAKOTA for optimization and uncertainty quantification, and apply it to benchmarks - *achieved*

**Impact:** Applications of this open-source framework span several industries ranging from aerospace and energy to healthcare and manufacturing.