Yang Liu, Ph.D.

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Assistant Professor, Department of Nuclear Engineering, Texas A&M University

3133 TAMU, College Station, TX 77843

EDUCATION

Ph.D. North Carolina State University, Raleigh, NC   2018
Advisor: Professor Nam Dinh, Department of Nuclear Engineering
Thesis:"Development of a Data-Driven Analysis Framework for Boiling Problems
with Multiphase-CFD Solver"

M.S. China Institute of Atomic Energy, Beijing, China   2013

B.S. Tsinghua University, Beijing, China   2010
Department of Engineering Physics

RESEARCH EXPERTISE AND INTERESTS

- Reactor thermal-hydraulics
- Model validation, uncertainty and sensitivity analysis
- Data-driven modeling, data assimilation, physics-informed machine learning
- Digital twin and AI-Agents for nuclear engineering applications

EXPERIENCE

Texas A&M University, Department of Nuclear Engineering
Assistant Professor   8/2023-
- Multi-scale M&S for thermal-fluid systems using physics-informed machine learning
- Uncertainty quantification on M&S for advanced nuclear systems
- Intelligent modeling, optimization, and control for advanced nuclear systems

Argonne National Laboratory, Nuclear Science and Engineering Division
Nuclear Engineer   6/2020-7/2023
Postdoctoral Appointee, Supervisor: Dr. Rui Hu   7/2019-5/2020
- Code development for machine learning enhanced SAM (SAM-ML)
- Methodology development for physics-informed machine learning
- Application of SAM for advanced reactor safety analysis

University of Michigan, Nuclear Engineering and Radiological Sciences   4/2018-7/2019
Postdoctoral Research Fellow, Supervisor: Professor Xiaodong Sun
- Data-driven modeling and uncertainty quantification for two-phase flow systems
- High-resolution experimental study of two-phase flow systems

Oak Ridge National Laboratory, Reactor and Nuclear Systems Division   5-7/2015
Summer Intern, Supervisor: Dr. David Pointer
- Analysis of flow and heat transfer in helically-coiled tubes using STAR-CCM+

North Carolina State University, Department of Nuclear Engineering   1/2014-3/2018
Research Assistant, Supervisor: Professor Nam Dinh
- Data-driven modeling for boiling heat transfer through deep learning
- Validation and uncertainty quantification for Multiphase-CFD solver

- Data analysis for high-resolution boiling images using machine learning methods

GRANT EXPERIENCE

- PI of FY24 DOE-NE Distinguished Early Career Program: "Integrating Thermal Hydraulic Simulation and Experimentation with Data-Driven Methods to Support Molten Salt Reactors Development". Funding level: $625,000.
- Co-PI of FY22 ANL Program Development Grant: "Deep learning-based multiphysics online simulator to support autonomous operations in advanced reactors". Funding level: $150,000.
- Co-PI of FY21 ANL LDRD Grant: "Artificial Intelligence Assisted Safety Modeling and Analysis of Advanced Nuclear Reactors". Funding level: $280,000.

HONORS AND AWARDS

- DOE-NE Distinguished Early Career Award   2024
- BEPU-2018 Best Student Paper Award   2018
- Alpha Nu Sigma Honor Society   2018
- Tau Beta Pi Engineering Honor Society   2016
- Phi Kappa Phi Honor Society   2016
- CIAE Outstanding Master Thesis   2013

INVITED TALKS

1. "Supporting Advanced Reactor Development through Improved Modeling & Simulation in the Age of Data". Seminar, Department of Nuclear Engineering, Texas A&M University, August, 2022.

2. "SAM-ML: integrating data-driven closure with nuclear system code SAM for improved modeling capability". Panel, Advanced in Thermal Hydraulics (ATH 2022), June, 2022.

3. "Advancing Nuclear Thermal-Hydraulic Modeling in the Age of Data: Applications on Uncertainty Quantification and Data-driven Modeling". Seminar, School of Nuclear Engineering, Purdue University, February, 2022.

4. "Physics-Informed Machine Learning". Scientific Machine Learning for Nuclear Engineering Workshop, M&C 2021, October 3, 2021.

5. "Improving Advanced Reactor Safety Analysis by Integrating Scientific Machine Learning with System Analysis Code". Seminar, Department of Engineering Physics, University of Wisconsin-Madison, July 13, 2021.

6. "Advanced Reactor Safety Analysis Assisted by Physics-Informed Machine Learning". Seminar, Department of Mechanical and Nuclear Engineering, Virginia Commonwealth University, February 12, 2021.

7. "Modeling of Advanced Reactors Assisted by Physics-Informed Machine Learning: Applications on Coarse Mesh Turbulence Modeling and Model Uncertainty Quantification". Argonne National Laboratory, November 11, 2020.

8. "Physics-Informed Machine Learning". Guest Lecture of NE-795: Scientific Machine Learning. Department of Nuclear Engineering, North Carolina State University, October 1, 2020.

9. "Modeling of Advanced Reactors Assisted by Physics-Informed Machine Learning: an Open-Box Approach". Seminar, Department of Nuclear Engineering, North Carolina State University, September 10, 2020.

10. "Validation and Uncertainty Quantification for Advanced Thermal-Hydraulic Tools: Approaches, Achievements, and Challenges". NRC-DOE Workshop on VVUQ of Advanced Codes, Raleigh, January 9, 2020.

11. "Improving Predictive Capability of T-H M&S Tools with Physics-Informed Machine Learning". Seminar, Department of Nuclear Engineering, University of New Mexico, November 12, 2019.

12. "Improving Predictive Capability of T-H M&S Tools with Physics-Informed Machine Learning". Seminar, Department of Nuclear, Plasma and Radiological Engineering, University of Illinois at Urbana-Champaign, October 1, 2019.

13. "Development of a Validation and Uncertainty Quantification Framework for Closure Models in Multiphase CFD Solver". Multi-Physics Model Validation Workshop, Raleigh, June 28, 2017.

PUBLICATIONS

Book Chapter

1. **Liu, Y.**, and Dinh, N. (2018). "Flow Boiling in Tubes". In Kulacki F., editors, *Handbook of Thermal Science and Engineering*. Springer, Cham.

Journal Articles

1. **Liu, Y.**, Alsafadi, F., Mui, T., O'Grandy, D., and Hu, R. "Development of whole system digital twins for advanced reactors: leveraging graph neural networks and SAM simulations".*(Under review)*.

2. **Liu, Y.**, Dinh, N., Sun, X., and Hu R., "Uncertainty Quantification for Multiphase-CFD Closure Relations with a Physics-Informed Bayesian Approach". *Nuclear Technology*,1-14.

3. Liu, Q., **Liu, Y.**, Burak, A., Kelly, J., Bajorek, S., and Sun, X., (2023) "Tree-based Ensemble Learning Models for Wall Temperature Predictions in Post-CHF Flow Regimes". *ASME Journal of Heat and Mass Transfer*,145:1-34.

4. **Liu, Y.**, Hu, R., Zou, L., and Nunez, D., (2022) "SAM-ML: Integrating Data-Driven Closure with Nuclear System Code SAM for Improved Modeling Capability". *Nuclear Engineering and Design*, 400:112059.

5. **Liu, Y.**, Hu, R., Balaprakash, P., Kraus, A., Obabko, A.,(2022) "Data-Driven Modeling of Coarse Mesh Turbulence for Reactor Transient Analysis Using Convolutional Recurrent Neural Networks". *Nuclear Engineering and Design*, 390:111716.

6. **Liu, Y.**, Wang, D., Sun, X., Liu, Y., Dinh, N., and Hu, R.,(2021). "Uncertainty Quantification for Multiphase-CFD Simulations of Bubbly Flows: a Machine Learning-Based Bayesian Approach Supported by High-Resolution Experiments". *Reliability Engineering and System Safety*, 212: 107636.

7. Liu, Q., Sun, H., **Liu, Y.**, Sun, X., and Kelly, J., (2021). "Experimental Study of Post-CHF Heat Transfer in a Vertical Tubular Test Section". *International Journal of Heat and Mass Transfer*, 166:120697.

8. Wang, C., **Liu, Y.**, Sun, X., Sabharwall, P., (2021). "A Hybrid Porous Model for Full Reactor Scale CFD Investigation of a Prismatic HTGR". *Annals of Nuclear Energy*, 151:107916.

9. **Liu, Y.**, Wang, C., Qian, Y., Sun, X., and Liu, Y., (2020). "Uncertainty Analysis of PIV Measurements in Bubbly Flows Considering Sampling and Bubble Effects with Ray Optics Modeling". *Nuclear Engineering and Design*, 364:110677.

10. Wu, X., **Liu, Y.**, Kearfott, K., and Sun, X., (2020). "Evaluation of Public Dose from FHR Tritium Release with Consideration of Meteorological Uncertainties". *Science of the Total Environment*, 709:136085.

11. **Liu, Y.**, Sun, X., and Dinh, N.,(2019). "Validation and Uncertainty Quantification of Multiphase-CFD Solvers: A Data-Driven Bayesian Framework Supported by High-Resolution Experiments". *Nuclear Engineering and Design*, 354:110200.

12. **Liu, Y.**, Dinh, N., Smith, R.C. and Sun, X., (2019). "Uncertainty Quantification of Two-Phase Flow and Boiling Heat Transfer Simulations Through a Data-Driven Modular Bayesian Approach". *International Journal of Heat and Mass Transfer*, 138:1096-1116.

13. **Liu, Y.** and Dinh N., (2019). "Validation and Uncertainty Quantification for Wall Boiling Closure Relations in Multiphase-CFD Solver". *Nuclear Science and Engineering*, 193:81-99.

14. **Liu, Y.**, Dinh N., Sato Y., and Niceno, B., (2018). "Data-Driven Modeling for Boiling Heat Transfer: Using Deep Neural Networks and High-Fidelity Simulation Results". *Applied Thermal Engineering*, 144:305-320.

15. **Liu, Y.** and Dinh N., (2016). "Analysis of Heat Transfer under High Heat Flux Nucleate Boiling Conditions". *Kerntechnik*. 81:308-314.

16. **Liu, Y.**, Yu H., and Liu Y., (2014). "Investigation on Flow and Convective Heat Transfer Phenomena of Fast Reactor Fuel Bundle". *Atomic Energy Science and Technology*. 48: 61-66. (*in Chinese*)

17. **Liu, Y.**, Yu H., and Zhou Z., (2014). "Numerical Analysis of Thermal Hydraulic Behavior of the Wire-Wrapped Fuel Assembly of Sodium Cooled Fast Reactor". *Atomic Energy Science and Technology*. 48: 1790-1796. (*in Chinese*)

Conference Proceedings

1. **Liu, Y.**, Alsafadi, F., Mui, T., O'Grandy, D., and Hu, R. "Digital Twin Development for Advanced Reactor System Based on Graph Neural Networks Using SAM Code Simulation".In *Proceedings of the 20th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-20)*. Washington DC, August 2023.

2. Liu, Q., **Liu, Y.** , Sun, X. , Wang, D. , Liu, Y., Buchanan, J. R., and Worosz, T. "Experimental Study and CFD Simulation of Air-Water Bubbly Flow in a Rectan-

gular Channel".In *Proceedings of the 20th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-20)*. Washington DC, August 2023.

3. Wang, D., Fu, Y., Sun, H., Liu, Y. , Liu, Q., **Liu, Y.**, Sun, X., Worosz, T., and Buchanan, J. "A Comprehensive Measurement of Bubbly Flow in a 30 mm x 10 mm Rectangular Channel".In *Proceedings of the 20th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-20)*. Washington DC, August 2023.

4. **Liu, Y.**, Alsafadi, F., Mui, T., O'Grandy, D., and Hu, R. "Digital Twin Development as a Holistic Representation for Advanced Reactor Systems Using Graph Neural Networks".In *Proceedings of the 13th Nuclear Plant Instrumentation, Control & Human-Machine Interface Technologies (NPIC&HMIT 2023)*. Knoxville, TN, July 2023.

5. **Liu, Y.**, Dinh, N., Sun, X., and Hu, R. "Quantifying Model Form Uncertainty in MCFD Simulations of Bubbly Flows with Physics-Informed Machine Learning". *12th Japan-U.S. Seminar on Two-Phase Flow Dynamics*. Virtual, May 2022.

6. **Liu, Y.**, Hu, R., Zou, L., Hu, G., and Nunez, D. "SAM-ML: Machine Learning Enhanced System Analysis Module for Thermal Stratification Analysis". In *Proceedings of the 19th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-19)*. Virtual, March 2022.

7. **Liu, Y.**, Hu, G., and Hu, R. "Benchmark Simulation of the FFTF LOFWOS Test #13 Using SAM". In *Proceedings of the 19th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-19)*. Virtual, March 2022.

8. Vegendla, P., **Liu, Y.**, Zou, L., and Hu, R. "Development of Wall Heat Transfer Correlation for Laminar Flow in a Cylindrical Tube". In *Proceedings of the 19th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-18)*. Virtual, March 2022.

9. Wang, C., Sun, X., **Liu, Y.**, Shabharwall, P. "CFD Study of the Effects of Bypass Gaps on MHTGR Thermal Flow". In *Proceedings of the 19th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-18)*. Virtual, March 2022.

10. **Liu, Y.**, Hu, R., Balaprakash, P., Brunett, A., Obabko, A. "Application of Deep Neural Networks to Support Coarse Mesh Turbulence Modeling of Reactor Transients". In *Proceedings of the International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering (M&C-2021)*, Raleigh, North Carolina, USA, October 2021.

11. **Liu, Y.**, Hu, R., and Balaprakash, P. "Uncertainty Quantification of Deep Neural Network-based Turbulence Model for Reactor Transient Analysis". In *Proceedings of the ASME-Verification and Validation Symposium 2021*, Virtual, May 2021.

12. **Liu, Y.**, Hu, R., Balaprakash, P., Brunett, A., Obabko, A. "Coarse Mesh CFD Turbulence Prediction for Reactor Transient using Densely Connected Convolutional Networks". In *Transactions of the ANS Winter Meeting*, Virtual, November 2020.

13. **Liu, Y.**, Sun, X., Liu, Y., and Dinh, N. "Uncertainty Quantification and Reduction

For Multiphase-CFD Solvers: a Data-Driven Bayesian Approach Supported By High-Resolution Local Measurements". In *Proceedings of the 18th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-18)*. Portland, Oregon, USA, August 2019.

14. **Liu, Y.**, Qian, Y., Wang, C., and Sun, X. "Uncertainty Analysis of PIV Measurements for Liquid Velocity in Two-Phase Bubbly Flows". In *Proceedings of the 18th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-18)*. Portland, Oregon, USA, August 2019.

15. **Liu, Y.**, Shi, S., Qian, Y., Sun, X., and Dinh, N. "Inverse Uncertainty Quantification of Turbulence Modeling in Multiphase-CFD Solver Using High-Resolution Data from Particle Image Velocimetry". In *Proceedings of the Advances in Thermal Hydraulics (ATH-2018)*. Orlando, FL, USA, November 2018.

16. Zhang, X., **Liu, Y.**, Sun, X., and Dinh, N., "Design of Validation Experiments for Model Improvement of Dispersed Flow Film Boiling in COBRA-TF". In *Transactions of the American Nuclear Society*. Orlando, FL, USA, November 2018.

17. **Liu, Y.**, Dinh, N., Sato, Y., and Bojan, N., "Validation and Uncertainty Quantification of DNB Closures in MCFD Solver Using Inverse Bayesian Inference Method". In *Proceedings of the ANS Best Estimate Plus Uncertainty International Conference (BEPU-2018)*. Lucca, Italy, May 2018.

18. **Liu, Y.** and Dinh, N., "Development of A VUQ Framework for Wall Boiling Model in MCFD Solver". In *Proceedings of the 17th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-17)*. Xi'an, China, September 2017.

19. Pointer, W.D. and **Liu, Y.**, "Eulerian Two-Fluid RANS-based CFD Simulations of a Helical Coil Steam Generator Boiling Tube". In *Proceedings of the 17th International Topical Meeting on Nuclear Reactor Thermal Hydraulics(NURETH-17)*. Xi'an, China, September 2017.

20. **Liu, Y.**, Rollins, C., Dinh, N., and Luo, H., "Sensitivity Analysis of Interfacial Momentum Closure Terms in Two Phase Flow and Boiling Simulations Using MCFD Solver". In *Proceedings of the ASME 2017 Heat Transfer Summer Conference (HT-2017)*. Bellevue, Washington, USA, July 2017.

21. **Liu, Y.** and Dinh, N., "Analysis of Heat Transfer under High Heat Flux Nucleate Boiling Conditions". In *Proceedings of the Second International Seminar on Subchannel Analysis (ISSCA-2)*. Shenzhen, China, December 2015.

22. **Liu, Y.** and Dinh, N., "Treatment of Nucleation and Bubble Dynamics in High Heat Flux Boiling". In *Proceedings of the 16th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-16)*. Chicago, IL, USA, September 2015.

23. **Liu, Y.**, Yu, H., and Liu, Y., 2013, "Thermal Hydraulic Study of Wire Wrapped Blanket Assembly of CEFR". In *Proceedings of the 21st International Conference on Nuclear Engineering (ICONE-21)*. Chengdu, China, August 2013.

Technical Reports

1. **Liu, Y.**, Hu, R., Dai, D., Balaprakash, P., and Obabko, A.(2021). "Machine Learning Assisted Safety Modeling and Analysis of Advanced Reactors". ANL/NSE-21/82.

2. **Liu, Y.** and Hu, R. (2020). "Benchmark Modeling and Simulation of the FFTF LOFWOS Test #13 Using SAM". ANL/NSE-20/8.

3. Vegendla, P., **Liu, Y.**, Zou, L., and Hu, R. (2020). "3D CFD Model Validation Using Benchmark Data of 1/16th Scaled VHTR Upper Plenum and Development of Wall Heat-Transfer Correlation For Laminar Flow". ANL/NSE-20/11.

4. Liu, Y., Wang, D., Fu, Y., Song K., Sun, X., Shi, S., **Liu, Y.**, Liu, Q., Tentner, A., Vegendla, P., and Sung, Y., (2020). "Development of a Comprehensive Two-Phase Flow Database for the Validation of NEK-2P". VT/MFTL-20-04, Final Technical Report for NEUP Project.

5. Wang, D., Fu, Y., Liu, Q., **Liu, Y.**, Liu, Y.,and Sun, X., (2019). "Two-Phase CFD Validation Experiment in a 30 mm 10 mm Rectangular Channel, Task 2: Initial Scoping Tests". VT/MFTL-19-02, Report to Naval Nuclear Laboratory.

6. Wang, D., Fu, Y., **Liu, Y.**, Liu, Y.,and Sun, X., (2019). "Two-Phase CFD Validation Experiment in a 30 mm 10 mm Rectangular Channel, Task 1: Demonstration of Local Measurement Approach". VT/MFTL-19-01, Report to Naval Nuclear Laboratory.

7. Zhang, X., **Liu, Y.**, and Sun, X., (2019). "System Thermal-Hydraulics Model Validation Experiment". M3NU-16-NC-NCSU-030401-1511, NEUP Integrated Research Project.

8. **Liu, Y.** and Dinh, N., (2018). "Application of Machine Learning in Thermo-Fluid Closure Model Development". CASL-L3:THM.UQ.P17.01, Consortium of Advanced Simulation of LWRs.

9. **Liu, Y.** and Dinh, N., (2017). "Development of a Data-driven Analysis Framework for Pool Boiling and Subcooled Flow Boiling Problems". CASL-THM.CLS.P13.07, Consortium of Advanced Simulation of LWRs.

10. Pointer, W.D., Shaver, D., **Liu, Y.**, Vegendla, P., Tentner, A., (2016). "Evaluation of CFD Methods for Simulation of Two-Phase Boiling Flow Phenomena in a Helical Coil Steam Generator". ORNL/TM-2016/612, Oak Ridge National Laboratory, Oak Ridge, TN, USA.

11. **Liu, Y.** and Dinh, N., 2016. "Data-Driven DNB Advancements". CASL-THM.CLS.P13.07, Consortium of Advanced Simulation of LWRs.

12. Rollins, C., Pandare, A., Wang, C., Luo, H., **Liu, Y.**, and Dinh, N., (2016). "boilEulerFOAM Multi-phase CFD Solver : Milestone Report". CASL-THM.CLS.P13.02, Consortium of Advanced Simulation of LWRs.

13. **Liu, Y.**, Srivastava, M., Dinh, N., (2014). "Micro-hydrodynamics in High Heat Flux Boiling and Burnout: Experimental Data and Model Development". CASL-U-2014-0211-000, Consortium of Advanced Simulation of LWRs.

PROFESSIONAL SERVICE

Journal Guest Editor
- Special Issue "Artificial Intelligence Applications in Nuclear Energy" on *Frontiers on Energy Research*
- Special Issue "Advanced Modeling and Simulation of Nuclear Reactors" on *Frontiers on Energy Research*

Reviewer for Proposals
- US DOE Office of Nuclear Energy Consolidated Innovative Nuclear Research (CINR)
- US DOE Office of Science Small Business Innovation Research (SBIR)

Reviewer for Journals
- Annals of Nuclear Energy
- Nuclear Engineering and Design
- Nuclear Technology and Engineering
- Nuclear Science and Engineering
- Nuclear Technology
- Progress in Nuclear Energy
- Scientific Reports
- International Journal of Heat and Mass Transfer
- Applied Thermal Engineering
- Experimental Thermal and Fluid Science
- Mathematical Problems in Engineering
- ASME Journal of Verification, Validation and Uncertainty Quantification
- Heat Transfer Engineering
- Entropy
- Fluid Dynamics Research

Reviewer for Conferences
- NURETH: International Topical Meeting on Nuclear Reactor Thermal Hydraulics
- NUTHOS: International Topical Meeting on Nuclear Reactor Thermal Hydraulics, Operation and Safety
- SHTC: ASME Heat Transfer Summer Conference
- ICAPP: International Congress on Advances in Nuclear Power Plants
- BEPU: Best Estimate Plus Uncertainty International Conference
- ICONE:ASME International Conference on Nuclear Engineering

Conference Session Organizer
- NURETH-20 Panel Session *"Machine Learning for Reactor Thermal Hydraulics"*
- ATH-2022 Panel Session *"Machine Learning for Reactor Thermal Hydraulics: Progresses, Challenges, and Opportunities"*

Conference Session Chair
- ATH-2022
- NURETH-18
- ATH-2018
- NURETH-17

Membership
- American Nuclear Society (ANS)
- American Society of Mechanical Engineers (ASME)

PROFESSIONAL DEVELOPMENT

- **ALCF Simulation, Data, and Learning Workshop**
  Argonne National Laboratory   10/2021

- **Data-Driven Modeling and Machine Learning for Engineering Applications**
  Illinois Institute of Technology/Argonne National Laboratory   8/2021

- **ALCF Computational Performance Workshop**
  Argonne National Laboratory   4/2020

- **Workshop of Turbulence Modeling in Nuclear Energy Systems**
  NURETH-18, Portland   8/2019

- **Center of Excellence for Thermal-Fluids Applications in Nuclear Energy**
  Argonne National Laboratory   6/2019

- **Multi-Physics Model Validation workshop**
  North Carolina State University   6/2017

- **RAVEN Workshop**
  North Carolina State University   3/2017

- **Severe Accident Workshop**
  North Carolina State University   8/2016

- **CASL Summer Student Workshop**
  Oak Ridge National Laboratory   6/2015

- **Modeling, Experimentation and Validation (MeV) Summer School**
  Idaho National Laboratory   7/2014