Computational Aerosciences Laboratory
2018 Highlights

New projects started in CASLAB:

Data-Driven Modeling for Turbulence Transition in Mixing:

Accurate prediction of the scalar mass fraction variance is important for the closure of the average thermonuclear reaction rate in variable density turbulent mixing problems. The goal of the present work, funded by Lawrence Livermore National Labs, is to utilize statistical inference and machine learning to learn and embed a RANS model correction for improved prediction of the mass fraction variance in a Rayleigh Taylor mixing layer during transition to turbulence.

Physics Inspired Learning and Learning the Order and Structure Of Physics:

This project is funded by DARPA to develop novel machine learning algorithms that are capable of learning and enforcing physics principles and constraints. Using modern sparse and low-multilinear-rank regression architectures and neural networks, a number of critical tasks can be enacted from data alone: (i) the discovery of first principles models, (ii) the identification of physical constraints and conservation laws, and (iii) improved models using known physics and enforcing known constraints. These architectures allow us to develop black box and gray box modeling strategies for complex systems where physics is unknown or only partially known. This project is in collaboration with Profs. Alex Gorodetsky (Michigan), Nathan Kutz (Washington) & Steve Brunton (Washington).

Deep learning and Reduced order modeling for Vehicle Aerodynamics

This is a 3-year project funded by General Motors. We are investigating the use of convolutional neural networks to augment (and under the right circumstance, to replace) detailed CFD solutions of aerodynamic flowfields. We will also develop projection-based reduced order models to assess the impact of parameterized design modifications.

Center Updates:

Airforce Center of Excellence on Multi-fidelity Modeling of Rocket Combustor Dynamics

The Center[1] which was initiated in April 2017[2] had a very productive year. We had a workshop in Ann Arbor in March, and two reviews - with the Space Propulsion and Computational Mathematics programs in August. A list of publications can be found here[3]. The following are some highlights:

1. A multi-fidelity framework was established and demonstrated for the prediction of combustion instabilities in rocket engines. Since we will not have access to the full order simulations of the entire engine, the traditional geometry-specific training is replaced by the response generated by perturbing the characteristics at the boundary of the truncated component domains. The sub-component ROMs are then integrated as part of a multi-fidelity full system ROM.

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[1] https://afcoe.engin.umich.edu/
[2] http://umich.edu/~caslab/docs/CASLAB_Newsletter_2017.pdf
[3] https://afcoe.engin.umich.edu/publications

2. We established a hierarchy of rocket relevant problems for ROM explorations. Based on a thorough examination of the impact of the loss of conservation, lack of artificial dissipation and spurious local phenomena, we were able to devise a local constraint to augment global stability guarantees, thus resulting in robust ROMs.

3. We improved efficiency, accuracy and robustness of ROMs by adapting the basis and sampling on-the-fly.

4. We examined the prospects of developing non-intrusive ROMs by combining the ideas of lifting with POD and Operator inference. The resulting ROMs will be structured, easier to reduce, and amenable for analysis.

Center for Data-driven Computational Physics

The center for data-driven computational physics had a great year in terms of publications and scope. We added some exciting new projects and welcomed new members to the team. A full list of projects can be found here[4]. Our supercomputing facility Conflux was used for interactive demos at the Michigan Cardiovascular Innovation Translation (M-CRIT) workshop.

Awards

1. Eric Parish won the big one - *The John von Neumann Fellowship* from Sandia National Laboratories. This is a highly competitive fellowship and one of the most prestigious for computational science. Sandia selects one recipient from 100+ applications (open to everyone within 3- years of completing a PhD degree) after several interviews. This offers Eric the opportunity to establish his own program at SNL and to collaborate with other groups.

2. Eric Parish's thesis was also nominated for the *Proquest distinguished dissertation award* as the representative from the Aerospace Department. Thus, we will count this as the most distinguished dissertation from the Aerospace department. The result of the Proquest award at the university level will be known in 2019.

3. Shaowu Pan won the *MICDE fellowship*, which is a competitive fellowship for students pursuing computational science research at the University of Michigan. This fellowship offers funding augmentations to existing funding.

Visitors to/from CASLAB

1. Prof. Traian Illescu (Virginia Tech) spent time with us collaborating on closure modeling for reduced order models.

2. Ms. Elizabeth Qian (PhD student at MIT with Prof. Karen Willcox) spent time with us working on operator inference.

3. Dr. Qian Wang (Post doctoral fellow at EPFL with Prof. Jan Hesthaven) spent time with us working on combustion modeling.

4. Mr. Saakaar Bhatnagar (Bachelor's student at IIT Kanpur) visited us over the summer to work on machine learning of aerodynamic flowfields.

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[4]http://cddcp.sites.uofmhosting.net/index.php/current-projects/

5. Ayoub spent the summer at NASA Ames research center, working with Scott Murman's group on Entropy stable methods.

New members

1. Aniruddhe Pradhan (PhD student) : Aniruddhe has a Bachelor's in Mechanical Engineering from IIT Kharagpur and has a good background of research in turbulence simulations and lattice Boltzmann Methods. Currently, he is focused on large eddy simulation modeling.

2. Mohit Tekriwal (PhD student): Mohit has a Bachelor's in Aerospace Engineering from IIT Kanpur and will be working on computational verification. He is jointly advised with Prof. Jean-Baptiste Jeannin.

3. Alex Sun (Masters student): Alex Sun has a Bachelor's in Mechanical Engineering from Shanghai Jiao Tong University and a Bachelor's in Aerospace Engineering from the University of Michigan. Alex is working on data-driven dynamical systems modeling.

On the move

1. Anand Pratap Singh (Post-doctoral fellow): Anand took up a position as the principal engineer at the startup called Geminus.AI, working on digital twins.

2. Eric Parish (PhD student): Eric defended his PhD & joined Sandia National Labs, Livermore as a John von Neumann post doctoral fellow, working on multiscale modeling and machine learning.

3. Adam Comer (Research Scientist): Adam decided to pursue a Masters in Applied Mathematics (but will still continue in his current role).

4. Helen Zhang graduated with a Masters degree in Aerospace Engineering.

5. Chris Wentland became a PhD candidate in Aerospace Engineering.

6. Aniruddhe Pradhan became a PhD candidate in Mechanical Engineering.

Conferences

1. At the *AIAA Scitech* conference in Orlando, we had three presentations on robust design, adaptive control and data-driven modeling.

2. The next big venue was the *SIAM Uncertainty Quantification Conference* conference in Orange County, where we had five presentations.

3. At the *AIAA Aviation* conference in Atlanta, we had two presentations.

4. Ayoub presented his work at the *International Conference on Hyperbolic Problems* at Penn State.

5. At the *World Congress of Computational Mechanics* in New York City, we had five presentations in data-driven and reduced order modeling.

6. At the *AIAA/SAE/ASEE Joint Propulsion Conference* in Cincinnati, Cheng and David presented their papers on reduced order models.

7. Karthik was a keynote speaker at the High Fidelity LES conference in Brussels, Belgium in November.

Workshops/Meetings/Courses

1. Karthik was an invited speaker at the Future CFD Technologies Workshop in Orlando in January.

2. Karthik was an invited speaker at the Physics Informed Machine Learning Workshop in Santa Fe in January.

3. CASLAB organized a workshop for the Air force on reduced order modeling in Ann Arbor in March.

4. Karthik was an invited speaker at the Digital Twins workshop in IMA, Minnesota in March.

5. Karthik participated in and reviewed NASA's revolutionary computational aerosciences program in March.

6. Karthik was an invited speaker at the US/Japan Data science and fluid mechanics workshop in Tokyo, Japan in March.

7. Nick attended the Princeton summer school on Combustion in June

8. Karthik was an invited speaker at UTRC's digital threads workshop in Hartford in August.

9. Karthik gave talks at the University of Kansas, University of California (Berkeley), NASA Ames, Army Research Office and ANSYS (Pittsburgh).

Teaching

AEROSP 495: Fundamentals of Aerospace Computing (Joint with Prof. Jean-Baptiste Jeannin), Fall 2018.

AEROSP 729: Data-driven Analysis and Modeling of Complex Systems, Fall 2018.

Short course on 'Machine Learning for Fluid Dynamic Modeling' in Daejeon, South Korea.

Entrepreneurship

Karthik co-founded (with Hive ventures) a startup called Geminus.AI[5], located in University Avenue, Palo Alto, California. The focus is on an industrial process centric digital twin product that delivers self-optimized design, predictive operational intelligence and asset performance enhancement to operators and engineering service providers. The product leverages physics-constrained artificial intelligence to deliver high-fidelity operational & maintenance intelligence and to continuously optimize the designs of assets & processes. Anand joined the company as the principal engineer.

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[5]https://geminus.ai/

CASLAB team in 2018

Research Scientists: Cheng Huang, Adam Comer.

Post Doctoral Fellows: Daniel Foti, Yaser Afshar, Anand Pratap Singh.

PhD Students: Helen Zhang, Eric Parish, Nicholas Arnold-Medabalimi, Ayoub Gouasmi, David Xu, Behdad Davoudi, Shaowu Pan, Vishal Srivastava, Christopher Wentland, Aniruddhe Pradhan, Mohit Tekriwal.

Masters Students: Alex Sun.

Bachelors Students: Saakaar Bhatnagar.

Lead: Karthik Duraisamy.

Visit us at `https://caslab.engin.umich.edu/`.