UNIVERSITÀ DEGLI STUDI DI PADOVA

High-fidelity Simulations of Sprays Using Artificial Intelligence Models

Xiang’en Kong - 38th Cycle

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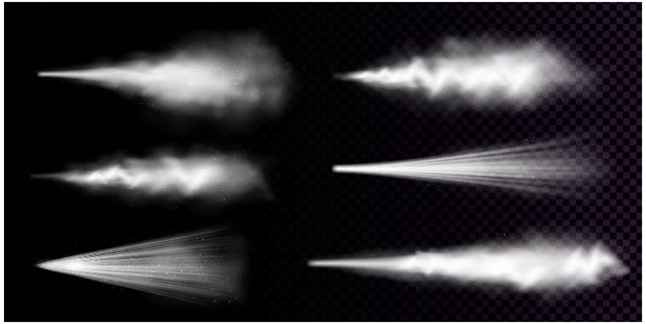
Co-supervisor: Dr. Federico Dalla Barba

Meeting - 09/11/2022

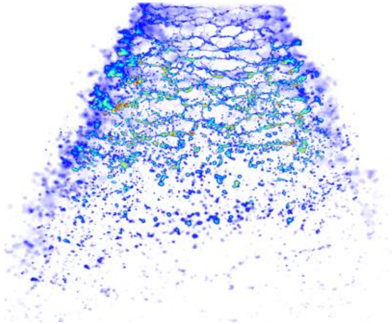
What is Spray?

A spray is a two-phase flow which involves a liquid as dispersed or discrete phase in the form of droplets or ligaments and a gas as the continuous phase.

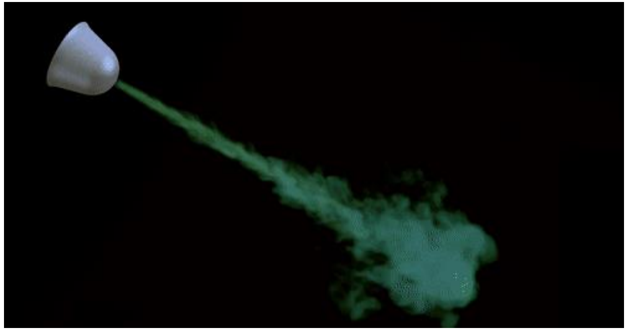
Important and challenging fluid-dynamic and transport phenomena can occur in many different ways within sprays.



https://www.freepik.com/free-vector/white-dust-spray-isolated-transparent-background-realistic-set-smoke-powder-with-particles-splash-from-aerosol-stream-spraying-cosmetic-fragrance-deodorant_10308169.htm



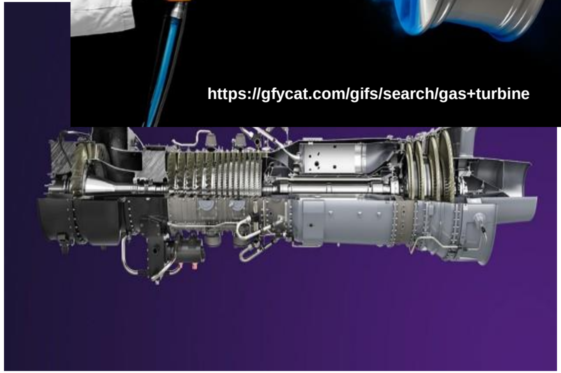
https://spray-imaging.com/



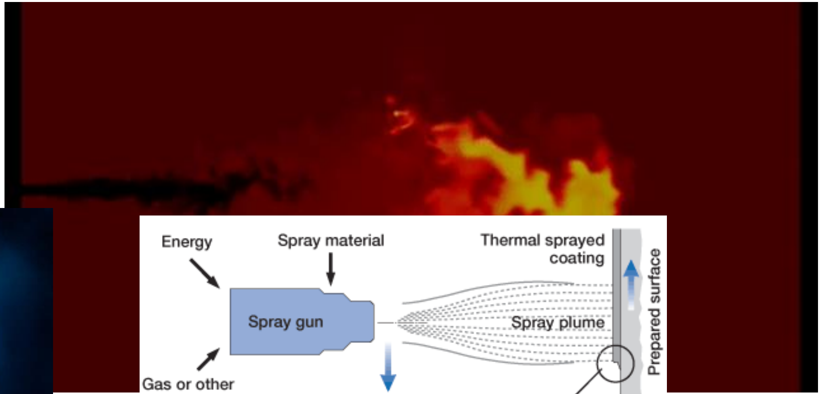
https://gfycat.com/impartialminoramericanbobtail-flamelet-generated-manifolds-large-eddy-simulation

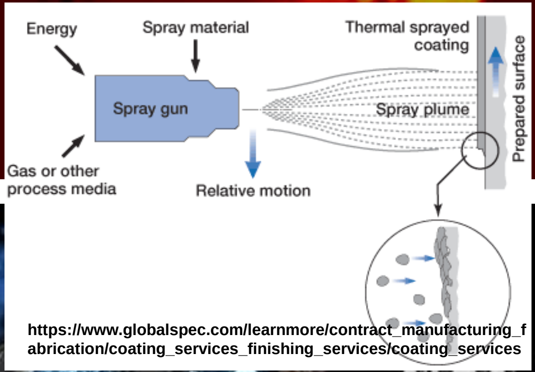
Why Spray is important?

https://gfycat.com/gifs/search/gas+turbine

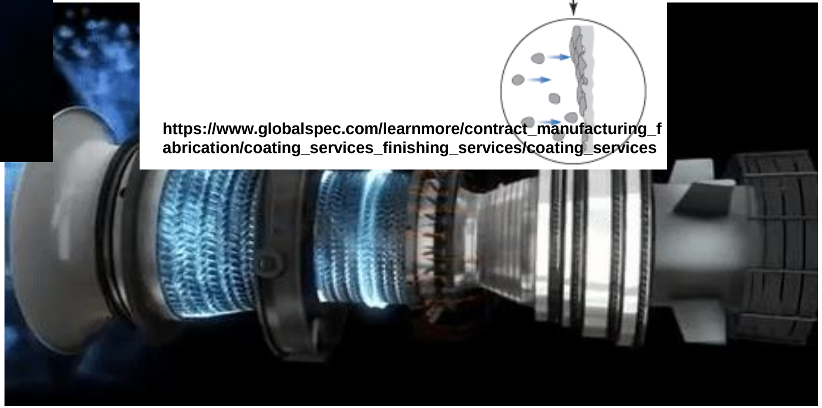


https://www.siemens-energy.com/global/en/offerings/power-generation/gas-turbines.html





https://www.globalspec.com/learnmore/contract_manufacturing_fabrication/coating_services_finishing_services/coating_services



https://gfycat.com/gifs/search/gas+turbine

Applications:

- Internal combustion engines
- Gas-turbine Engine
- Manufacturing technologies
- etc…

Why Spray modeling is important?

Traditional methods to study spray and their advantages and disadvantages:

- **Theoretical analysis**

  Advantage: The results of theoretical analysis can reveal the internal law of flow and have universal applicability
  Disadvantage: The analytical scope of this approach is limited

- **Experiments**

  Advantage: The experimental results can reflect the actual flow law in engineering, discover new phenomena and test the theoretical results
  Disadvantage: The universality of the experimental results is poor

- **CFD**

  Advantage: This method can calculate the mathematical equations which cannot be solved by the theoretical analysis method, and it saves time and money than the experimental method. It is most suitable for engineering applications.
  Disadvantage: Its scope of application is limited by the correctness of mathematical models and the performance of computers

How to further optimize spray modeling?

Limitations of spray modeling by CFD:

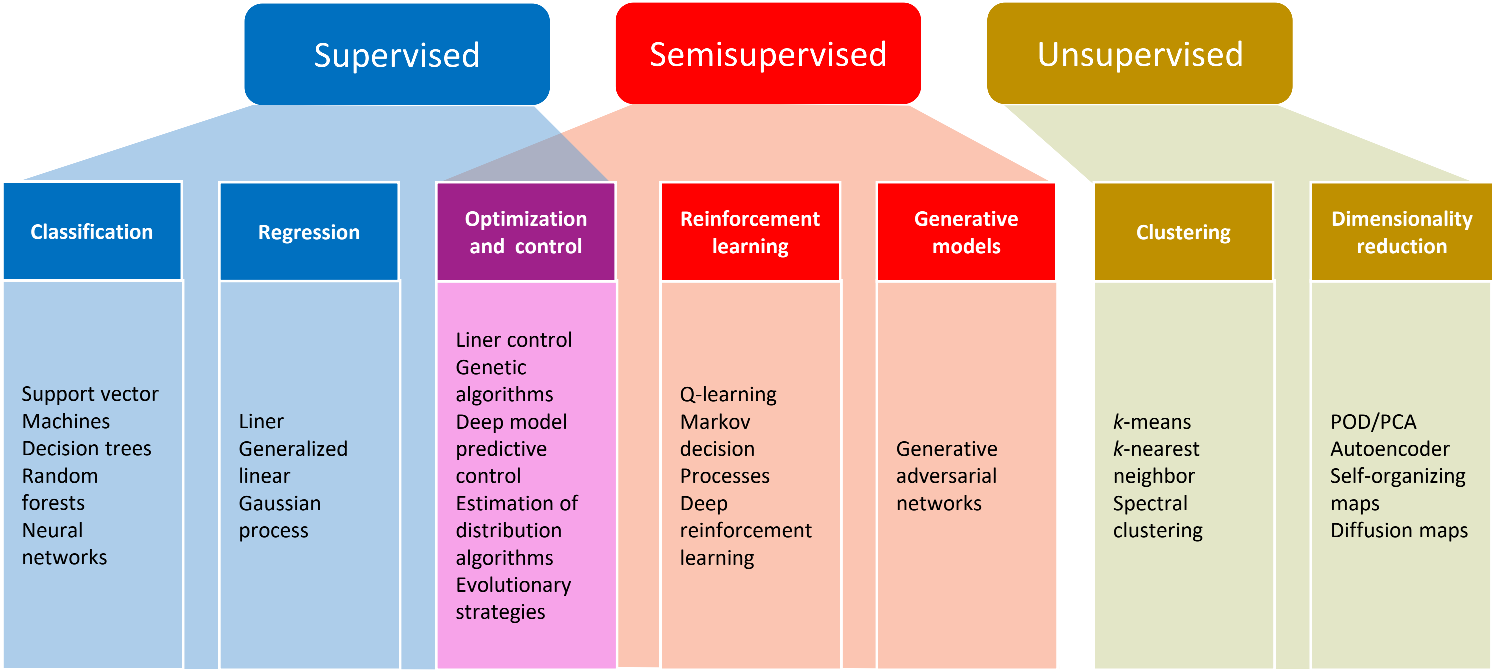
- Limitation from the correctness of mathematical models
- High computational costs

What is the solution?

AI is a promising solution!

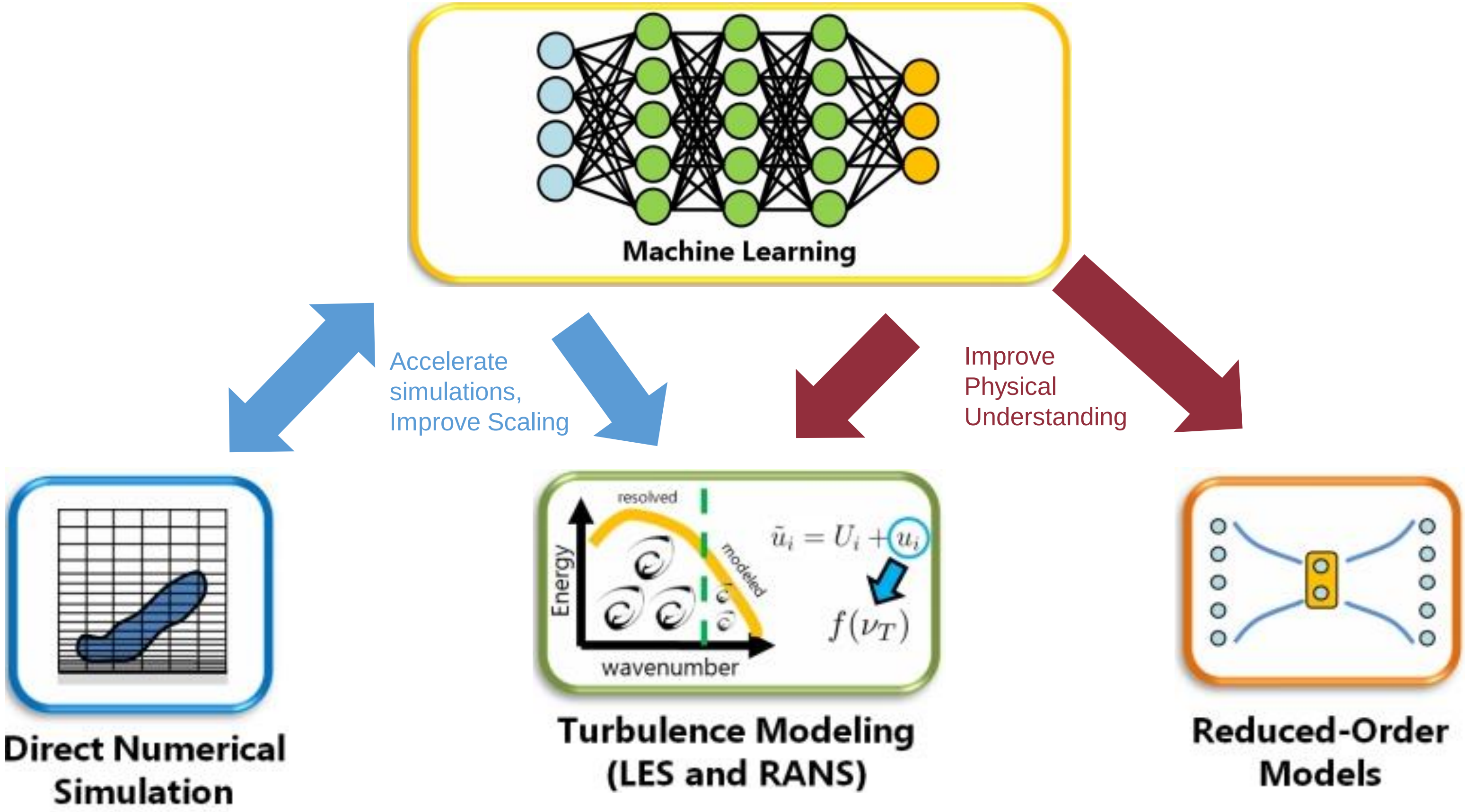
With the development of deep learning and machine learning, artificial intelligence is bringing many changes to CFD by improving gridding friendliness, reducing manual intervention, improving turbulence prediction accuracy, and fast data visualization analysis

Machine learning algorithms



Annu. Rev. Fluid Mech. 2020. 52:477–508

Summary of some of the most relevant areas where machine learning can enhance CFD



Nature Computational Science volume 2, pages358–366 (2022)

Research plan

01 Theoretical Knowledge Preparation

02 OpenFOAM simulation of Non-reactive and reactive sprays using LES standard models

03 Training Machine-learning models using datasets from step 2

04 Low-order simulations using Machine-learning models

Research plan for Year I

Bibliographical Research
- Fluid Mechanics
- Turbulent Flows Theory
- Turbulent Spray Dynamics

OpenFOAM Simulation
- Training for OpenFOAM
- Non-reactive Spray Simulation in LES Standard
- Reactive Spray Simulation in LES Standard

Research plan for Year II

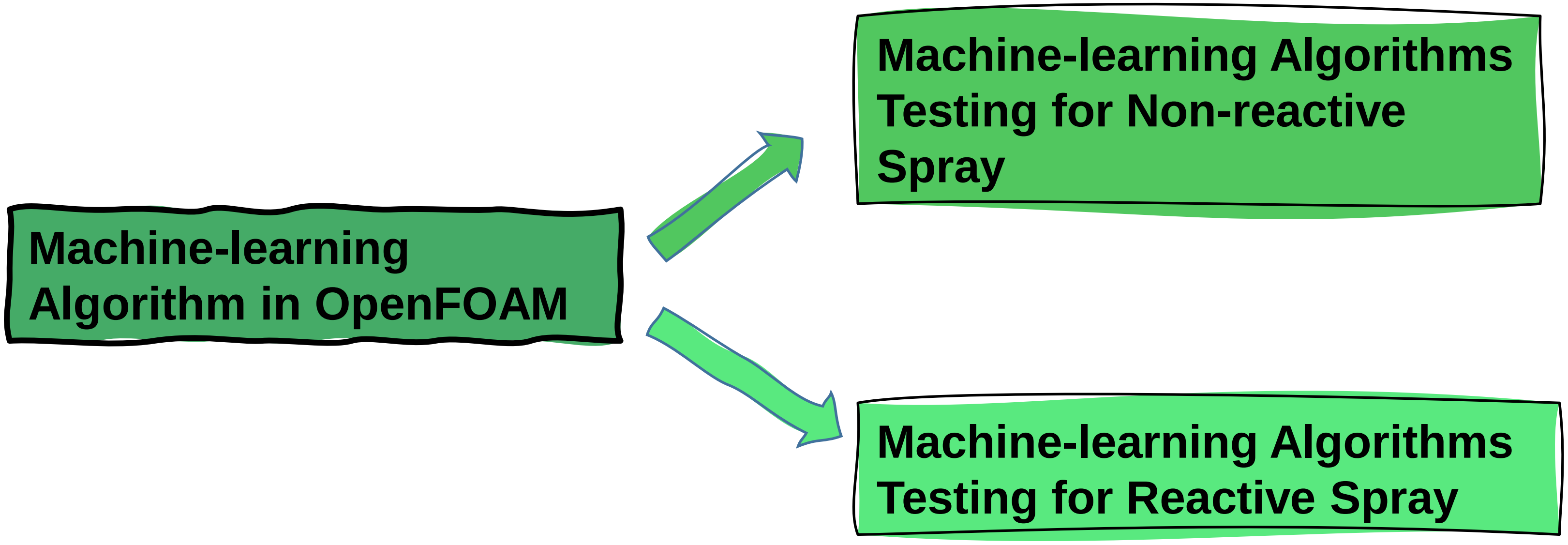
Definition of Machine-learning Algorithm for Droplets Transport

→ Machine-learning Algorithms trained on datasets of Non-reactive Spray Simulation

→ Machine-learning Algorithms trained on datasets of Reactive Spray Simulation

→ Implementation of New Algorithms in OpenFOAM

Research plan for Year Ⅲ



Gantt Chart

FIRST YEAR (T1: O N D; T2: J F M; T3: A M J; T4: J A S) — SECOND YEAR (T1: O N D; T2: J F M; T3: A M J; T4: J A S) — THIRD YEAR (T1: O N D; T2: J F M; T3: A M J; T4: J A S)

WBS NUMBER	TASK TITLE	% OF TASK COMPLETE
1	Bibliographical Research	
1.1	Learning fluid mechanics and the turbulent flows theory	30%
1.2	Literature reviews on turbulent spray dynamics	0%
2	OpenFOAM Simulation	
2.1	Training for OpenFOAM	0%
2.2	Non-reactive spary simulation in LES standard	0%
2.3	Reactive spary simulation in LES standard	0%
EVENT	**Admission to Year Ⅱ**	
3	Definition of Machine-learning Algorithm for Droplets Transport	
3.1	Machine-learning algorithms trained on dataset of 2.2	0%
3.2	Machine-learning algorithms trained on dataset of 2.3	0%
3.3	Application new algorithms in OpenFOAM	0%
EVENT	**Admission to Year Ⅲ**	0%
4	Machine-learning Algorithm in OpenFOAM	
4.1	Machine-learning algorithms testing for non-reactive spray	0%
4.2	Machine-learning algorithms testing for reactive spray	0%
EVENT	**Admission to Final Examination**	
5	Writing Thesis and Reports	0%

Thanks for the attention