Quantum Computers Industrial Applications

Annarita Giani
GE Research

December 15th 2022

A little about me

- Research and development division of General Electric.

  We collaborates with the GE businesses – Aviation, Healthcare, Power, Renewable Energy, and others – to deliver mission-critical, next generation technology
- Los Alamos National Laboratory with focus on energy, power grid, cybersecurity
- Univ. California at Berkeley, sensor network
- Ph.D, Dartmouth College
- IIT CNR, Pisa
- Laurea, Università di Pisa

European effort: an example

https://www.qutac.de/

Quantum Technology and Application Consortium – QUTAC et al. *EPJ Quantum Technology*
https://doi.org/10.1140/epjqt/s40507-021-00114-x
EPJ Quantum Technology
a SpringerOpen Journal
EPJ.org
RESEARCH Open Access

Industry quantum computing applications

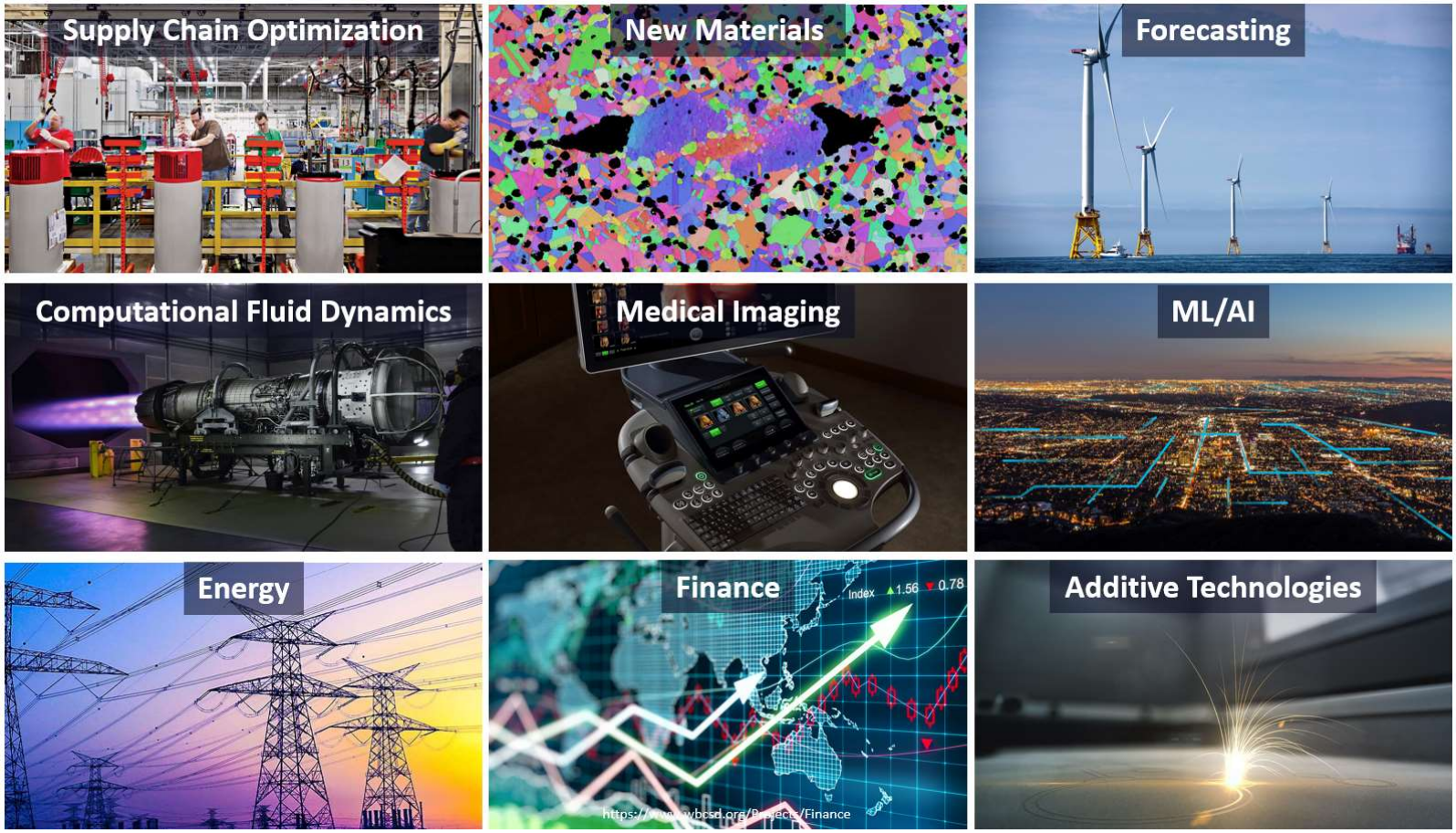
Quantum Technology and Application Consortium – QUTAC[1*], Andreas Bayerstadler[8], Guillaume Becquin[8], Julia Binder[8], Thierry Botter[12], Hans Ehm[6], Thomas Ehmer[7], Marvin Erdmann[3], Norbert Gaus[10], Philipp Harbach[7], Maximilian Hess[6], Johannes Klepsch[3], Martin Leib[11], Sebastian Luber[6], Andre Luckow[3], Maximilian Mansky[7], Wolfgang Mauerer[10], Florian Neukart[11], Christoph Niedermeier[10], Lilly Palackal[6], Ruben Pfeiffer[6], Carsten Polenz[9], Johanna Sepulveda[12], Tammo Sievers[6], Brian Standen[2], Michael Streif[4], Thomas Strohm[5], Clemens Utschig-Utschig[4], Daniel Volz[2], Horst Weiss[2] and Fabian Winter[8]

Quantum Technology and Application Consortium (QUTAC) goal is to establish and advance the quantum computing ecosystem, supporting the ambitious goals of the German government and various research programs. Members represent different industries, in particular automotive manufacturing, chemical and pharmaceutical production, insurance, and technology. Among others Bosch, Merck, Siemens, Volkswagen, Airbus, SAP, Lufthansa Industry Solutions

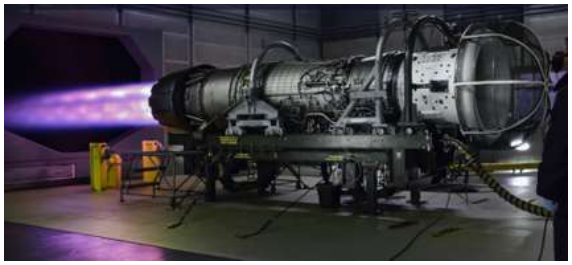
Table 3 Initial Use Case Portfolio: A wide variety of optimization, simulation, and machine learning problems exist in the value-chains across the German industry. While impact in the next 5 years is low, several high-impact use cases have been identified

Challenge	Problem Domain	Company	Use Case	Impact
Engineering & Design	Machine Learning	AIRBUS	QC for Surrogate Modeling of Partial Differential Equations	High
	Optimization	AIRBUS	Wingbox Design Optimization	High
		Bosch	Software Testing and Correctness Proving	Medium
	Simulation	Bosch	Design Optimizations for Electric Drives Using Numerical Simulation and Finite Element Methods	Medium
		Merck	Identification and control of Actionable Parameters for Disease Spread Control	Unknown
Material Science	Optimization	Boehringer Ingelheim	Optimized Imaging – Quantum-Inspired Imaging Techniques	Medium
	Simulation	BASF	Quantum Chemistry – Prediction of Chemical Reactivity in Molecular Quantum Chemistry	High
		Boehringer Ingelheim	Molecular Dynamics – Simulation of the Dynamics of Molecules	High
		Merck	Development of Materials and Drugs Using Quantum Simulations	Medium
		Munich Re	Battery Cover – Performance Guarantees for eVehicle Batteries	Medium
		VW	Chemistry Calculation for Battery Research	High
Production & Logistics	Machine Learning	Siemens	QaRL – Quantum-assisted Reinforcement Learning – Applicable to many Industrial Use Cases	Medium
	Optimization	BASF	Fleet Management – On-site Truck and Machine Deployment and Routing	Medium
		BMW	Robot Production Planning – Robot path Optimization for Production Robots (e.g., PVC sealing robot)	Medium
		BMW	Vehicle Feature Testing – Optimizing Test Vehicle Option Configuration	Medium
		BMW	Shift Scheduling – Optimizing Labour Shift Assignments	Medium
		Infineon	Demand Capacity Match in Supply Chain – Decide on a Production Plan given Predicted Customer Demand	Medium
		Infineon	Using Infineon Sensors and Actuators to Optimize Supply Chain Processes on the Customer Side	Medium
		Munich Re	Transportation Cover – Insurance of Time-Critical Freight	Medium
		SAP	Logistics – Truck Loading	Medium
		SAP	Supply Chain Planning – Improved and Accelerated Sizing of Orders (Lot Sizing)	High
		Siemens	QoMP – Quantum-optimized Matrix Production – Realtime Shop Floor Optimization	Medium
		VW	Vehicle Routing Problem – Optimize Vehicle Utilization in a Transport Network	High
Post-Quantum Security	Cryptography	Munich Re	IoT Cyber Cover – Insurance of Post Quantum Cryptography	Medium

Our Interest



Fluid Dynamics



Turbulent flows are nonlinear dynamical systems call for superior computational process.
Navier–Stokes nonlinear partial differential equations, whose solution is essential to the aerospace industry, weather forecasting, plasma magnetohydrodynamics, and astrophysics.
Applications:

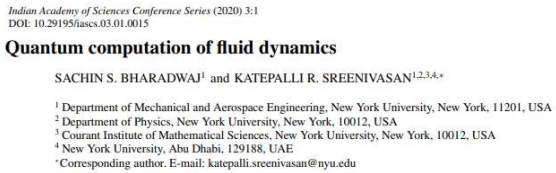
- aerospace industry
- weather-forecasting
- engineered-plasma technologies
- astrophysics

Constrained optimization is about optimizing a function's variables (e.g., trucks, SKUs, people), under constraints (e.g., cost, volume, time), for better business decision-making and efficiency.

Traveling salesperson: complexity grows geometrically with the number of stops, until it "15 destinations, the number of possible routes could exceed 87 billion"

Network design factors

Distribution logistics

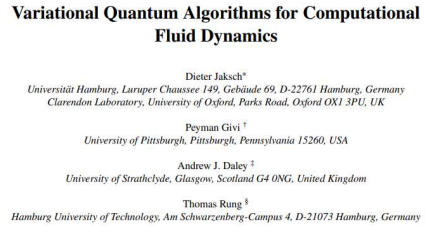


Indian Academy of Sciences Conference Series (2020) 3:1
DOI: 10.29195/iascs.03.01.0015

Quantum computation of fluid dynamics

SACHIN S. BHARADWAJ[1] and KATEPALLI R. SREENIVASAN[1,2,3,4,*]

[1] Department of Mechanical and Aerospace Engineering, New York University, New York, 11201, USA
[2] Department of Physics, New York University, New York, 10012, USA
[3] Courant Institute of Mathematical Sciences, New York University, New York, 10012, USA
[4] New York University, Abu Dhabi, 129188, UAE
*Corresponding author. E-mail: katepalli.sreenivasan@nyu.edu



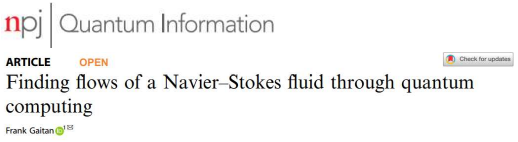
Variational Quantum Algorithms for Computational Fluid Dynamics

Dieter Jaksch*
Universität Hamburg, Luruper Chaussee 149, Gebäude 69, D-22761 Hamburg, Germany
Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK

Peyman Givi †
University of Pittsburgh, Pittsburgh, Pennsylvania 15260, USA

Andrew J. Daley ‡
University of Strathclyde, Glasgow, Scotland G4 0NG, United Kingdom

Thomas Rung §
Hamburg University of Technology, Am Schwarzenberg-Campus 4, D-21073 Hamburg, Germany

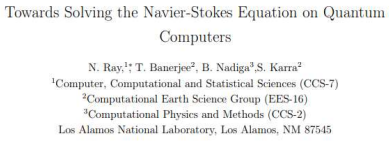


npj | Quantum Information

ARTICLE OPEN

Finding flows of a Navier–Stokes fluid through quantum computing

Frank Gaitan



Towards Solving the Navier-Stokes Equation on Quantum Computers

N. Ray,[1,†] T. Banerjee[2], B. Nadiga[3], S. Karra[2]
[1]Computer, Computational and Statistical Sciences (CCS-7)
[2]Computational Earth Science Group (EES-16)
[3]Computational Physics and Methods (CCS-2)
Los Alamos National Laboratory, Los Alamos, NM 87545

https://www.ias.ac.in/article/fulltext/conf/003/0010
https://www.nature.com/articles/s41534-020-00291-0
https://arxiv.org/pdf/2209.04915.pdf
https://arxiv.org/pdf/1904.09033.pdf

Supply Chain & Logistics

Need to constantly balance many, sometimes-conflicting variables to achieve business goals.

Running lean and mean requires optimizing supply chain and outbound logistics parameters and balancing them against **ever-changing customer demand**.

Everything needs to run like a finely-tuned machine. To **minimize the spend** on excess stock, you need to accurately forecast demand, ensure just the **right supply levels** and move supply in and product out in an agile and streamlined way.

Constrained optimization is about optimizing a function's variables (e.g., trucks, SKUs, people), under constraints (e.g., cost, volume, time), for better business decision-making and efficiency.

Traveling salesperson: complexity grows geometrically with the number of stops, until it "15 destinations, the number of possible routes could exceed 87 billion"

Network design factors

Distribution logistics

Manufacturing supply chains, from inbound components and raw materials to outbound distribution

Transportation efficiency: Small adjustments can make a big difference in the costs and productivity of the overall network.

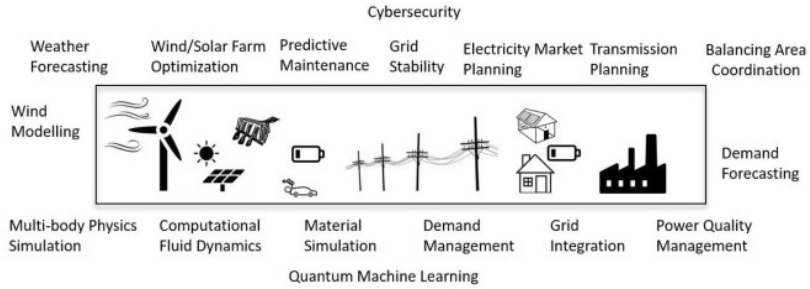
Warehouse management and **distribution services**: CO can be applied to optimize global and local shipping and loads, and warehousing and delivery for lowest cost, and highest efficiency and productivity.

Inbound logistics: From order levels to delivery to the production line, CO can drive maximum production levels at the best cost. Even one lost shipment or forgotten vendor can wreak havoc on a production line.

https://www.mhlnews.com/technology-automation/article/21171527/quantum-computing-a-new-solution-for-supply-chain-and-logistics-optimization

Energy

Circular Economy
Sostenibility
Policy
Insurance



Optimization
- Demand and generation must equal
- Different time scales, a day for Unit Commitment and 15 minutes for Optimal Power Flow
- Minimize cost to ensure security, environmental goals and reliability
- Resources allocations in time and space

Forecasting
- Uncertainty and intermittency of natural phenomenal bring challenges to optimal solutions

Chemistry
- New PB material
- Chemistry for batteries
- High temperature materials for Concentrating Solar Power

Giani, Eldredge, Quantum Computing Opportunities in Renewable Energy. *SN COMPUT. SCI.* **2**, 393

Giani, Quantum computing opportunities in renewable energy. *Nat Comput Sci* **1**, 90–91 (2021).

https://eos.org/features/how-quantum-computing-can-tackle-climate-and-energy-challenges

Final Remarks

1. Not all applications are good candidates for quantum computing
2. Need to work now to understand the potential of quantum computing for each application
3. We are at a stage where hybrid approaches can bring advantages

Thank you!