Dr. **Aritra** Sarkar

Personal Data

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Birth : 7 July 1991, Purulia, India
Nationality : Indian

Professional Experience

QuTech — Delft, The Netherlands

Postdoctoral Researcher — *Jul'22 - present*

Quantum Machine Learning research group

Delft University of Technology — Delft, The Netherlands

Doctoral Candidate — *Nov'18 - Jul'22*

Department of Quantum & Computer Engineering

TCS Research and Innovation — Kolkata, India

Research Intern — *Jul'17 - Sep'18*

Embedded Devices and Intelligent Systems research team

Indian Space Research Organisation — Bengaluru, India

Scientist — *Oct'13 - Jul'16*

ISRO Satellite Centre (now U R Rao Satellite Centre), Controls and Digital Area

Research Keywords

Explainable Quantum Artificial Intelligence; Quantum Software Design Automation; Quantum Computer Architecture
Automated Science; Neuro-Symbolic and Neuro-Evolution Approaches; Algorithmic Information Theory
Artificial General Intelligence; Causal Inference; Computational Genomics; Reinforcement Learning

Education

Delft University of Technology — Delft, The Netherlands

Doctorate — *Nov'18 - Jul'22*

Dissertation: Applications of Quantum Computation and Algorithmic Information for Causal Modeling in Genomics and Reinforcement Learning

Master of Science in Computer Engineering, *cum laude* — *Sep'16 - Jun'18*

Thesis: Quantum Algorithms for Pattern-Matching in Genomic Sequences

Indian Institute of Space Science and Technology — Thiruvananthapuram, India

Bachelor of Technology in Avionics — *Aug'09 - May'13*

Thesis: Elevation Mapping using Stereo Vision enabled Heterogeneous Multi-Agent Network

Professional Affiliations

IEEE International Conference on Quantum Computing and Engineering

QCE 2023 Workshop Organizer *Sep'23*
Quantum Algorithm Design Automation

QCE 2023 Poster Program Committee *Sep'23*

QCE 2022 Tutorial Organizer *Sep'22*
Machine Learning for Full-Stack Quantum Computation

IEEE International Conference on Quantum Software

QSW Publicity Chair *Nov'22 – present*

QSW Symposium Organizing Committee *Dec'23 – present*

QWorld Association

Member, QBoard *Jul'22 – present*

Coordinator, QResearch *Oct'21 – present*

QIndia

Member, Steering Committee *Apr'21 – present*

ISRO Satellite Centre

Project Manager, SSR subsystem, HySIS *Jul'15 – Jul'16*

Team Leader, SSR firmware standardisation *Oct'14 – Jul'16*

FPGA Design Review Committee *Mar'14 – Mar'15*

Delft Aerospace Rocket Engineering

Electronics team member, Project Stratos *Jan'17 – Jan'18*

Certifications

Wolfram Summer School : Metamodeling Metamathematical Observers *(Jul'22)*

edX : Understanding Artificial Intelligence through Algorithmic Information Theory *(Dec'21)*
Quantum Machine Learning *(Apr'19)*
Introduction to Genomic Data Science *(Nov'18)*
The Quantum Internet and Quantum Computers *(May'18)*

Santa Fe Institute : Introduction to Complexity *(Oct'19)*

IBM Cognitive Class : Hadoop 101, MapReduce and YARN, Apache Pig 101, Watson Analytics 101, Big Data 101, R 101, Bitcoin 101, Build Your Own Chatbot *(Sep'16 – Jun'18)*

Coursera : Quantum Mechanics and Quantum Computation *(Dec'12)*

Udacity : Artificial Intelligence for Robotics *(Apr'14)*

Stanford Online : Machine Learning *(Dec'11)*, Introduction to Artificial Intelligence *(Dec'11)*

Language Skills

English : Full professional proficiency
Bengali : Native proficiency
Hindi : Bilingual proficiency
Dutch : Basic proficiency

Computer Skills

Quantum Programming : IBM Qiskit, OpenQL, cQASM, OpenQASM, Quantum Inspire, Rigetti Forest, D-Wave Ocean, Xanadu PennyLane, pyGSTi

Softwares : MS Office, Git, VS Code, LaTeX, Discord, Anaconda, Virtual Box, GPT

Programming (frequent) : Python (SciPy, NumPy, SymPy, Matplotlib, Jupyter Notebook), Shell Scripting

Programming (past) : Assembly, MATLAB, Java, C++, C, ADA, VHDL, OpenCL, CUDA, AWS, ROS, Libero IDE, ModelSim, Docker, AFL, KLEE, Android Studio, Camtasia

Hardware : Intel 8086, Actel 54SX32 FPGA, Raspberry Pi, Arduino, AVR Atmel

Publications

Google Scholar : Qo84iBgAAAAJ
ORCID : 0000-0002-3026-6892

Patents

- S. Dey, A. Mukherjee, A. Sarkar, "Context based path planning for vector navigation in hexagonal spatial maps," Priority number: IN201821007023 20180223

Preprints

- A. Sarkar, "Automated Quantum Software Engineering: why? what? how?," arXiv:2212.00619 [quant-ph]
- T. Acharya, A. Kundu, A. Sarkar, "Quantum Accelerated Causal Tomography: circuit considerations towards applications," arXiv:2209.02016 [quant-ph] (in peer-review)
- A. Sarkar, Z. Al-Ars, H. Gandhi, K. Bertels, "QKSA: Quantum Knowledge Seeking Agent – resource-optimized reinforcement learning using quantum process tomography," arXiv:2112.03643 [quant-ph]
- A. Sarkar, Z. Al-Ars, K. Bertels, "Quantum circuit design for universal distribution using a superposition of classical automata," arXiv:2006.00987v2 [quant-ph]

Journals

- B.G. Bach, A. Kundu, T. Acharya, A. Sarkar, "Visualizing quantum circuit probability: estimating quantum state complexity for quantum program synthesis," Entropy 2023, 25(5), 763.
- A.M. Krol, A. Sarkar, I. Ashraf, Z. Al-Ars, K. Bertels, "Efficient Decomposition of Unitary Matrices in Quantum Circuit Compilers," Applied Sciences. 2022; 12(2):759.
- K. Bertels, A. Sarkar, I. Ashraf, "Quantum Computing - From NISQ to PISQ," IEEE Micro, vol. 41, no. 05, pp. 24-32, 2021.
- A. Sarkar, Z. Al-Ars, C.G. Almudever, K. Bertels, "QiBAM: Approximate Sub-String Index Search on Quantum Accelerators Applied to DNA Read Alignment," Electronics. 2021; 10(19):2433.
- A. Sarkar, Z. Al-Ars, K. Bertels, "QuASeR: Quantum Accelerated de novo DNA sequence reconstruction," PLoS ONE 16(4): e0249850.
- A. Sarkar, Z. Al-Ars, K. Bertels, "Estimating Algorithmic Information Using Quantum Computing for Genomics Applications," Applied Sciences. 2021; 11(6):2696.

Conferences

- A.M. Krol, K. Mesman, A. Sarkar, M. Möller, Z. Al-Ars, "Efficient parameterised compilation for hybrid quantum programming," Third International Workshop on Integrating High-Performance and Quantum Computing (WIHPQC 2023) (accepted)
- A. Sarkar, Z. Al-Ars, K. Bertels, "QKSA: Quantum Knowledge Seeking Agent," 15th International Conference on Artificial General Intelligence (AGI), Seattle, WA, USA, August 2022.
- T. Hubregtsen, C. Segler, J. Pichlmeier, A. Sarkar, T. Gabor, K. Bertels, "Integration and Evaluation of Quantum Accelerators for Data-Driven User Functions," 2020 21st International Symposium on Quality Electronic Design (ISQED), Santa Clara, CA, USA, 2020, pp. 329-334.
- K. Bertels, A. Sarkar, T. Hubregtsen, M. Serrao, A.A. Mouedenne, A. Yadav, A. Krol, I. Ashraf, "Quantum Computer Architecture: Towards Full-Stack Quantum Accelerators," 2020 Design, Automation & Test in Europe Conference & Exhibition (DATE), Grenoble, France, 2020, pp. 1-6.
- S. Dey, A. Sarkar, A. Mukherjee, "A Brain-inspired Approach to Robotic Mapping and Navigation," 2019 IEEE RO-MAN, Workshop on Cognitive and Interactive Robotics, New Delhi, India, 2019.
- A. Sarkar, R. Srividhya, J. Soman, S. Udupa, "Approaches towards standardization of software for on-board storage systems in space programs," Proceedings of Enabling Spacecraft Systems Realization through Industries Conference, ESSRI-16, June 2016.
- A. Sarkar, E.J. Jafi, R. Srividhya, J. Soman, S. Udupa, N. Valarmathi, "On-board payload data store and forward design for remote sensing satellites," Proceedings of National Conference on Recent Trends in Microsystems, IINC-15, October 2015.
- A. Sarkar, S. Srivastava, B.S. Manoj, "Elevation mapping using stereo vision enabled heterogenous multi-agent robotic network," 2013 IEEE Global Humanitarian Technology Conference: South Asia Satellite (GHTC-SAS), Trivandrum, 2013, pp. 340-345.
- S. Srivastava, A. Sarkar, B.S. Manoj, "Hazard control algorithms for heterogenous multi-agent cloud-enabled robotic network," 2013 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS), Kattankulathur, 2013, pp. 1-6.

Posters

- T. Acharya, A. Kundu, A. Sarkar, "Quantum Accelerated Causal Tomography: circuit considerations towards applications," Causalworlds conference, ETH Zürich, September 2022

Teaching Experience

Delft University of Technology — *Apr'19 - present*

Quantum Computing Architecture and Electronics

Delivered lectures involving quantum compilation, error-correction, quantum algorithms, and simulators. I was responsible for preparing and evaluating the assignments and exams.

Modelling, Algorithms and Data Structures

Delivered lectures on scientific modelling and graph theory, was responsible for conducting exercise sessions, and preparation of the exams.

Electronics and Computer Engineering for QIST

Planned course content and prepared lectures on number systems, memory architecture, microprocessors, and assembly language.

Supercomputing for Big Data

Prepared projects involving Scala, Spark, Hadoop, AWS, Docker, Open Street Map, ALOS and Kafka. Responsible for the final evaluation of the projects and oral examinations.

Technical University of Munich — *Nov'20 - Jul'21*

Quantum Entrepreneurship Laboratory

Technical project assistant for quantum algorithms and quantum computer architecture. Guided student teams on the quantum computation viability of the project proposals and algorithmic formulations.

University of Porto — *Sep'20 - Dec'20*

Advanced Computer Architectures

Delivered lectures on quantum computing applications and algorithm development.

edX, University of Toronto — *May'19 - Oct'19*

Quantum Machine Learning

Aided Dr. P. Wittek in moderating the community discussions on quantum machine learning algorithms, IBM Qiskit, Rigetti Forest and D-Wave Ocean.

Outreach talks and Tutorials

- 'Machine Learning for Quantum Computation' - Tutorial at IEEE Quantum Week (IEEE QCE'22), Broomfield, USA *(21 Sep'22)*
- 'Quantum Technologies' - Expert Talk on Quantum Computing: Emerging Areas, Bennett University *(30 May'22)*
- 'Quantum Computing: naam toh suna hi hoga?' - IEEE Thakur college of Engineering and Technology *(8 Apr'22)*
- 'Quantum Computation: past - now - future, an interdisciplinary introduction' - Qoffee o'Clock at QIndia *(19 Jun'21)*
- 'Introduction to Quantum Computing' - Seminar on Quantum Technologies: Towards the Second Revolution at IISTAA Outreach *(9 Jan'21)*
- 'Quantum-accelerated genomics' - Panel Discussion at Quantum4HealthCare, UK *(14 Jul'20)*
- 'Search and optimization on quantum accelerators' - Guest Seminar at Amsterdam University of Applied Sciences, Amsterdam *(23 May'19)*
- 'Search and optimisation algorithms for genomics on quantum accelerators' Meetup at Munich Quantum Technologies, Munich, Germany *(4 Apr'19)*
- 'Quantum algorithms on the QX Simulator' - Tutorial on Quantum Computer Architecture at HiPEAC Conference 2019, Valencia, Spain *(23 Jan'19)*
- 'Quantum algorithms for accelerating DNA sequence reconstruction' - Software/Theory werkbespreking at QuTech *(12 Jun'18)*
- 'Exploring quantum algorithms for genomics' - Mini-Symposium on Quantum Computing organised by TU Delft's Micro-Electronic Systems & Technology Association *(24 May'18)*

Supervision and Mentoring

Doctoral research guidance

- "Holographic quantum error correction codes," M. Steinberg, TU Delft, *(ongoing)*
- "Libraries for high-level quantum programming on OpenQL," A.M. Krol, TU Delft, *(ongoing)*
- "Machine learning approaches to quantum gate set tomography," K.K. Yu, TU Delft, *(ongoing)*
- "Design space exploration of spin qubit architectures and compilation," N. Paraskevopoulos, TU Delft, *(ongoing)*
- "Algorithm and device aware quantum circuit mapping," M. Bandic, TU Delft, *(ongoing)*

Master's theses supervision

- "Resource theory of quantum algorithmic complexity," S. Mishra, TU Delft, *(ongoing)*
- "Energy-optimized pulse based universal quantum optimal control," S. Fauquenot, TU Delft, *(ongoing)*
- "Agent-based concept discovery of quantum error correction codes," D. Rajan, IIST, *(ongoing)*
- "Automated design space evaluation of spin qubit architecture," D. Hamel, TU Delft, *(ongoing)*
- "Hardware-aware quantum circuit mapping using reinforcement learning," J. Henstra, TU Delft, *(ongoing)*
- "Transformer-based quantum circuit generator for benchmark dataset synthesis," B. Apak, TU Delft, *(ongoing)*
- "Determining minimal SWAP operations for the qubit-mapping problem using quantum information theory," S. Szkudlarek, TU Delft, *(Jul'23)*
- "Scalable parallelization of quantum computing simulations," L.R.M. Mendes, University of Porto, *(Jul'22)*
- "Quantum algorithms for portfolio management," D. Frazão, University of Porto, *(Jul'21)*
- "A Generic micro-architecture for quantum accelerators," J.L.T. Vieira, University of Porto, *(Jul'21)*
- "QuantumSim - a memory efficient quantum computing simulator," R. Budhrani, TU Delft, *(Oct'20)*
- "Unitary decomposition - implemented in the OpenQL programming language for quantum computation," A.M. Krol, TU Delft, *(Sep'19)*

Bachelor's theses supervision

- "Quantum algorithms for RNA design," E. Larroque, Ecole Normale Supérieur Paris-Saclay, *(Aug'23)*
- "Quantum state tomography and quantum assisted quantum compilation on OpenQL," N. Eelman, Drexel University, *(Sep'19)*

Research project mentoring (QWorld)

- "Gymnasium environment for quantum circuit optimization," K. Knopp, *(ongoing)*
- "Estimating the thermodynamic cost of quantum programs," S. Gosavi, *(ongoing)*
- "Algorithmic probability of quantum circuits for program synthesis," B.G. Bach, *(Mar'23)*
- "Quantum accelerated causal hypothesis testing for gene regulatory networks," T. Acharya, *(Sep'22)*
- "Reinforcement learning agent for quantum foundations," Mentor for QIntern 2021, with 18 interns, *(Aug'21)*
  Won 3rd prize for Best Projects

Internship supervision

- "Methods of implementing intelligent agents in quantum environments" H. Gandhi, Guru Gobind Singh Indraprastha University, *(Dec'21)*
- "Distributed quantum circuit simulation," K. Krishnakumar, Birla Institute of Technology and Science, Goa, *(Dec'20)*

Master's theses guidance and evaluation

- "QPack: A cross-platform quantum benchmark-suite: quantitative performance metrics for application-oriented quantum computer benchmarking," H. Donkers, TU Delft, *(Jul'22)*
- "QPack: QAOA as scalable application-level quantum benchmark," K. Mesman, TU Delft, *(Sep'21)*
- "Resource optimal executable quantum circuit generation using approximate computing," S. Adarsh, TU Delft, *(Jul'21)*

Interests and Activities

Gamification, Esolangs, Fractals, Brain Computer Interface, Gesture-based control, Crowdsourcing

Second-Order Cybernetics, Metaphysics (participatory epistemology, finitism), Causal Set Theory

Singing, Musical instruments (keyboard, harmonium, santoor), Poetry, Cooking, Archery

Sculpting (kirigami, impossible architectures), Art (oil painting, tessellations), Photography (long exposure)

Research Projects

GitHub : prince-ph0en1x

- YAQQ: Novelty search on quantum gate sets *(QuTech, ongoing)*
- AME-state based spin qubit processor benchmarking *(QuTech, ongoing)*
- Algorithmic probability guided quantum geometric machine learning *(QuTech, ongoing)*
- Logic programming and circuit interpretability for quantum accelerators *(QuTech, ongoing)*
- Automated thought experiments for quantum foundations concept discovery *(QuTech, ongoing)*

- Quantum algorithms for mRNA codon optimization and RNA design *(QBee, QuTech, ongoing)*
- Quantum neural networks for satellite image classification *(QBee, ongoing)*

- Evolutionary resource-bounded universal reinforcement learning in quantum environments *(Ph.D. research '22)*
- Gate based quantum automata for estimation of algorithmic information *(Ph.D. research '21)*
- De novo DNA read assembly using QAOA and quantum annealing *(Ph.D. research '20)*
- Design of quantum algorithms for accelerating DNA read alignment *(M.Sc. thesis '18)*
- Quantum Innovation Environment (QuInE), a PyQT based IDE for visual quantum programming *(TU Delft '18)*

- Spiking neural network based associative memory evolution for context-based navigation *(TCSRI '18)*
- Brain-inspired robotic mapping and navigation using time-series of hexagonal grid and place cells *(TCSRI '17)*
- System design of warehouse automation using multi-agent collaborative box-pushing strategies *(TCSRI '17)*

- Human brain simulation in GPU with Inferior Olive model in OpenCL and CUDA *(TU Delft '17)*
- GATK based human genome sequencing for distributed Spark platform in Scala *(TU Delft '17)*
- Fuzzing and concolic execution on RERS-2016 problems using AFL and KLEE *(TU Delft '17)*
- Optimizing a SoC using ρ-VEX VLIW processors *(TU Delft '17)*
- Enhancing the Plasma processor IP core *(TU Delft '17)*
- Accelerating object tracking in OMAP3530 application processor *(TU Delft '17)*
- Solar energy forecasting using ORCA system *(TU Delft '17)*
- Earthquake occurrence analysis and aftershock prediction using MATLAB and Tableau *(TU Delft '17)*

- Technology demonstrator of satellite firmware update via telecommands *(ISRO '16)*
- Software design of onboard memory management subsystem for Chandrayaan-2 orbiter *(ISRO '16)*
- Project management of onboard memory management subsystem for HySIS satellite *(ISRO '16)*
- Software design of onboard memory management subsystem for Resourcesat satellites *(ISRO '15)*
- Hardware design of onboard memory management subsystem for ScatSat-1 *(ISRO '15)*
- Software design and implementation of onboard memory management subsystem for Cartosat-2C *(ISRO '15)*
- Software design and implementation of onboard memory management subsystem for Astrosat *(ISRO '14)*

- Elevation mapping using stereo vision enabled heterogeneous multi-agent network *(B.Tech. thesis '13)*
- Self-configuring classical logic gate circuits using genetic programming in Java *(IIST '12)*
- Multi-vehicle path planning in dynamically changing environments using genetic optimised TSP *(IIST '12)*
- Computer vision based centralized multi-agent system on MATLAB and Arduino *(IIST '11)*

RESEARCH STATEMENT

Over the course of my academic pursuits, I have been training myself to incorporate an interdisciplinary perspective in my research. I am specifically **passionate about the amalgamation of concepts within computer science, physics, and biology**. These three subjects have substantially influenced my career path from the start.

My **childhood dream of being a space scientist** translated into me joining the **Bachelor of Technology program in Avionics**, with a **full scholarship from the Government of India, at the Indian Institute of Space Science and Technology**. My outstanding grades within the **computer science track** allowed me to opt for a **minor in robotics**, to hone my theoretical knowledge, in a subject I was passionate about. Equipped with this multidisciplinary background, I was able to effectuate **artificial intelligence algorithms on embedded electronic platforms**.

After my bachelor's graduation, I **joined ISRO, the national space agency of India, as a scientist**. My major contribution was towards designing a **standardized operating firmware for satellite** on-board computer systems. These were successfully implemented and deployed for all ongoing remote-sensing and deep-space missions since 2015. It was overwhelmingly gratifying to play an active role in these engineering frontiers, partake in the joy of my codes helping in the **discovery of one of the earliest galaxies** (via Astrosat), and affirm the **detection of water on the moon** (via Chandrayaan-2). The various hardware and software platforms involved, made me realize the significance of **comprehensive system design**, to harness the full potential of a system where one does not become the design bottleneck for the other. Working in **low-level real-time programming platforms for FPGAs and micro-controllers** with data and program memory limitations helped me discern **algorithmic and computational complexity concepts in practice**. Besides, I came in association with many veteran scientists, from whom I learned not only the technicalities of intricate engineering but also, the modus operandi of **effective project management**.

In days when computers were being strapped to spectacles and voyages of landing on asteroids making news, I realized both had their limitations. Space exploration is strangled by the speed of spacecraft and, more fundamentally, by light speed. **Computer technology is limited by transistor miniaturization limits of Moore's law and NP-hard algorithms** alike. I was in search of a very concrete inkling to relinquish my job in favor of an academic research career. Besides my curriculum, I love constantly staying updated on the latest technological directions through online courses from leading scientists and institutes. It is via these that I acquired a good background in **artificial intelligence, machine learning, and evolutionary algorithms**. What stood out, however, was an **online course in 2012** by Dr. Umesh Vazirani on **quantum mechanics and quantum computation**. The world of Dirac notations and Hilbert spaces opened up a new vista for me.

The theme on quantum computing (QC) at **TU Delft's Department of Quantum & Computer Engineering** was a perfect synergy given my experience and interests. The two years of my **master's program** were an amazing learning experience, both in being acquainted with an **international environment** and having access to incredible educational resources. Courses like **quantum information; quantum communication and cryptography; quantum programming and micro-electronics** enabled a comprehensive understanding of the **full-stack architecture of a quantum accelerator**.

My graduate research career started under the guidance of Dr. Koen Bertels, Dr. Zaid Al-Ars and Dr. Carmen Almudever. My thesis focused on the topmost layer of the computing stack, which takes a mathematical description of an algorithm and implements a **hardware-aware yet agnostic quantum implementation** for gate-based qubit processors at **QuTech**. The objective was to explore quantum computation **applications in relevant societal problems** within bioinformatics. Starting from the quantum primitives of Grover search, associative memory, and distributed queries, I **designed and implemented a first-of-its-kind quantum-accelerated genomics algorithm** (QiBAM) for the case of approximate reference alignment for noisy DNA sequences. The **M.Sc. thesis** was accessed with a **grade of 9.5** by the committee, earning me a **cum laude** in my master's. I was also offered a **doctoral position** to continue my line of research on **quantum algorithms**.

The core principles of quantum computing, as well as the first useful algorithms, were already theorized back in the 1990s. The recent unanticipated industrial thrust in developing quantum accelerators is rather motivated by the slowdown of Moore's law. However, the **technology readiness level of physical qubits**, in both quality and quantity, is currently a substantial **bottleneck** for developing applications for fault-tolerant quantum computing (FTQC). Thus, the current noisy intermediate-scale quantum **(NISQ) era advocates a hardware-software integrated co-design approach** to extract as much computing power as possible. The workhorse of this is the **variational approach** that uses a low-depth quantum ansatz circuit in tandem with a classical parameter optimizer. I witnessed this transformation of focus first-hand during my master's. Thus, in my Ph.D., the first topic I explored is the hybrid quantum optimization techniques (using gate-based **QAOA** as well as **quantum annealing)**. I designed a pipeline (QuASeR) for

QUBO-based **de novo DNA sequence assembly** using these approaches.

My research experience at this stage taught me the subtleties of quantum algorithm development. These convictions prompted that instead of sequence reconstruction, genome data analysis would more likely be the processing bottleneck in the timeline when large-scale QC will be realized. The research in **DNA sequence analysis involves understanding the generative causal models in the biological world**. Diving into the underlying logic of these approaches led me to **algorithmic information theory** (AIT). Looking back, this tryst with AIT eventually became the **most significant milestone in my research career**. Understanding the **applications of AIT for QC** (e.g., in resource-efficient quantum optimal control), **and QC for AIT** (e.g., in interpretable quantum machine learning), forms the **core of my research interest**.

Techniques based on AIT, like universal induction and algorithmic probability are often the most **optimal causal modeling** technique given unlimited computing power. Approximations from resource-limited algorithms still require supercomputers months of computing time. Quantum algorithms for AIT naturally fall in the **small-data-big-compute** space, which we believe to be promising for quantum acceleration. After studying corresponding quantum automata models, I precisely **defined, constructed, and simulated a quantum universal Turing machine using quantum gates**. The application framework, QEAIT, developed over this was **demonstrated for understanding properties of self-replication**, which is a very important biological characteristic of all living organisms. I cherish this **balance** between the **foundational theories** of physics and computer science, applied in the context of a **real-world use case**.

Artificial intelligence (AI) has long been an interesting avenue for me. The link between AI and QC revealed itself with the aid of AIT. Human intelligence can **induce quantum mechanical laws using classical observables**, while QC simulators implement quantum logic; both share the same Turing degree with quantum processors. To automate this, I worked on a classical agent formulation that can model quantum environments. AIXI is a well-studied classical **universal reinforcement learning** (URL) agent for artificial general intelligence that uses an active formulation of AIT. As its generalization, I defined a Quantum Knowledge Seeking Agent (QKSA), based on process tomography, as an active URL model of the recently proposed formulation of quantum mechanics using AIT. Beyond foundational implications, this framework is specifically suited for **automated causal inference and optimizing NISQ algorithms**. Recently, the thrust in machine learning is in looking beyond data-driven correlations, toward causal generative modeling. While this domain is still in its infancy, I am invested in building the groundwork for **using quantum computation for symbolic reasoning** and cognitive architectures.

Most algorithms of the current digital revolution, from stock markets to medical diagnostics, from logistics in transportation to entertainment media, are increasingly reliant on automation. This level of automation is **no longer programmed explicitly but rather learns an acceptable approximate transformation by training on data** or by symbolic regression. **Quantum algorithm design** has long been reliant on precise **circuit-level logic design**. State-of-the-art quantum processors would have thousands of qubits within a few years, making them **infeasible** to be programmed at the quantum assembly level. In my current postdoctoral research, I am developing and valorizing tools to **bridge the gap between high-level problem specification and quantum circuit-level resource allocation**. These projects **span across the quantum stack layers**, spanning **computational complexity theory, high-level programming constructs, efficient gate synthesis, circuit routing and error correction, device characterization, and optimal control**.

Looking ahead, I would like to nurture an **interdisciplinary research team** in the interface between **quantum computer architecture** (QCA) and **artificial general intelligence** (AGI). **Quantum computation**, in its theoretical and pragmatic considerations, provides us with the **best possible hardware** compatible with the laws of physics. **Algorithmic information theory**, in turn, provides the **best understanding of software** in theoretical computer science, while adhering to being programmable, controllable, and explainable. Via my projects, I am interested in exploring the **trade-off between sub-symbolic computational efficiency and symbolic interpretability**, for both QC and AI. Some of the projects I supervise **exploit this trade-off for the automated design of QCA**. These projects involve assessing and suggesting a discrete set of gates for **quantum computation optimized for control** (via pulse programming), **energy** (via compression of circuits and pulse), **fidelity** (via reachability analysis of gate sets), and automated **characterization** (via machine learning based control and tomography). The assessment involves **concept discovery** of quantum computation using state-of-the-art techniques like **language models**, **algorithmic information**, **causal inference** and **communication theory**. The suggestion involves developing **efficient compilation** techniques that incorporate these modalities and **bridge the quantum software and hardware** layers, making them more **efficient and easier to use**.