Quantum Computing Research Center

Vision

The vision of our Quantum Computing Research Lab is to pioneer breakthroughs in quantum computing, pushing the boundaries of what is possible in computation, communication, and cryptography. We aim to develop scalable quantum technologies that will revolutionize industries, empower scientific discovery, and shape the future of computing.

Mission

Our mission at the Quantum Computing Research Lab is to advance quantum computing research through cutting-edge exploration, innovation, and collaboration. We strive to develop practical quantum technologies, algorithms, and applications that address pressing challenges and unlock new opportunities for computation and beyond.

Objectives

- Fundamental Research: Conducting fundamental research to deepen our understanding of quantum mechanics, quantum algorithms, quantum error correction, and other key concepts underlying quantum computing. This research may involve theoretical investigations, mathematical modeling, and experimental validations.
- Algorithm Development: Developing new quantum algorithms and protocols for solving computational problems more efficiently than classical algorithms. This could involve designing algorithms for specific application domains, as well as general-purpose algorithms with broad applicability.

- Quantum Hardware Development: Designing, building, and testing novel quantum computing hardware platforms, including quantum processors, qubit architectures, control systems, and quantum memory devices. This objective aims to improve the scalability, reliability, and performance of quantum hardware for practical applications.
- Error Correction and Mitigation: Developing error correction codes and error mitigation techniques to address noise, decoherence, and other sources of error in quantum computations. This research is critical for improving the reliability and accuracy of quantum algorithms and hardware implementations.
- Software and Tools Development: Creating software libraries, programming frameworks, and simulation tools for quantum computing. These tools enable researchers and developers to design, simulate, and analyze quantum algorithms, as well as to experiment with quantum programming languages and quantum circuit optimization techniques.
- Applications Research: Exploring and developing applications of quantum computing in various fields, such as optimization, cryptography, machine learning, materials science, and quantum chemistry. This objective aims to identify promising use cases for quantum computing and demonstrate its potential for solving real-world problems.
- Collaborations and Partnerships: Collaborating with academic institutions, industry partners, and government agencies to leverage expertise, resources, and funding for advancing quantum computing research. This includes participating in joint research projects, technology transfer initiatives, and knowledge exchange programs.
- Education and Outreach: Educating the broader community about quantum computing through workshops, seminars, online courses, and educational materials. This objective aims to foster interest in quantum computing, train the next generation of quantum scientists and engineers, and promote awareness of its potential impact on society.
- Technology Transfer and Commercialization: Facilitating the transition of quantum computing research outcomes from the laboratory to practical applications in industry and government. This may involve licensing intellectual property, forming spin-off companies, and collaborating with industry partners to commercialize quantum technologies.
- Ethical and Societal Implications: Considering the ethical, legal, and societal implications of quantum computing research and its potential applications. This objective involves addressing issues such as data privacy, security risks, algorithmic bias, and the impact of quantum computing on employment and inequality.

Principal Investigator : - Dr. Kolla Bhanu Prakash, Professor, CSE Department

Projects currently working:- Optimize Quantum Machine Learning Parameters to Solve Differential Equations, Meity QCAL Lab, 32000 USD worth AWS Quantum bracket credits

Other funds received:- 1.5 lakhs for conducting Quantum computing workshop from DST SERB

1.5 lakhs for conducting International Conference from DST SERB

Deliverables of Research lab:-

- Research Papers and Publications: Scientific papers detailing novel discoveries, algorithms, methodologies, and experimental results in quantum computing, published in peer-reviewed journals and conference proceedings.
- Quantum Algorithms and Protocols: Development of new quantum algorithms, protocols, and techniques for solving computational problems more efficiently than classical methods, along with open-source implementations and software libraries.

- Quantum Hardware Innovations: Design, fabrication, and testing of novel quantum computing hardware components, architectures, and systems aimed at improving qubit coherence, gate fidelity, scalability, and fault tolerance.
- Error Correction and Mitigation Techniques: Creation of error correction codes, error mitigation algorithms, and fault-tolerant schemes to address noise, decoherence, and other sources of error in quantum computations.
- Applications Demonstrations: Exploration and demonstration of practical applications of quantum computing in fields such as optimization, cryptography, machine learning, materials science, quantum chemistry, and finance.
- Technology Transfer and Commercialization: Transfer of research outcomes and intellectual property to industry partners for commercialization, including licensing agreements, spin-off companies, and collaborative projects.
- Educational Resources: Development of educational materials, courses, workshops, and online resources to educate students, researchers, and the public about quantum computing concepts, algorithms, and applications.
- Collaborative Partnerships: Collaboration with academic institutions, industry partners, government agencies, and international organizations to leverage expertise, resources, and funding for advancing quantum computing research and technology development.
- Public Engagement and Outreach: Engagement with the broader community through outreach activities, public lectures, media appearances, and participation in science festivals and events to raise awareness and foster interest in quantum computing.
- Policy Recommendations and Ethical Guidance: Contribution to policy discussions and ethical debates surrounding quantum computing, including recommendations for regulatory frameworks, standards development, and societal impact assessments.

Other Lab members: - 1. Mr. Alhajie Mohamed Sesay

2. Mr. Aditya

3. Mr. Talluri Siva Ramakrishna

<u>Optimization of QML parameters to solve Partial Differential Equation</u>

Kolla Bhanu Prakash, Rut Lineswala

Dear Sir/Madam,

I am happy to share that we have completed project phase 1.

As part of our project, we published 2 papers in IEEE conference.

Links to the full papers are given below

https://ieeexplore.ieee.org/document/10091029

https://ieeexplore.ieee.org/document/10091087

As part of 2nd Phase, we are working on in-depth literature survey in solving Partial Differential Equations and work carried out till date is reported in conferences given below.

- 2 Papers Accepted for IEEE Conference - SmartTechCon2023, Singapore, papers presented in conference, waiting for publication in IEEE xplore.

1. Quantum Machine Learning Approach for Eigen Solving and Fourier Series Analysis

2. The Quantum Graph Recurrent Neural Network

- 2 Papers Accepted in Springer Conference - IEQIP2023, papers presented in conference, waiting for publication in Springer Lecture Notes in Networks and Systems.

1. Quantum Many-body Problems: Quantum Machine Learning Applications

2. Graph Optimization Studies with QAOA using Pennylane

<u>Planning and roadmap for 2nd and 3rd phase of project is described in Steps given below</u>

1. Literature Review of PINN & Quantum PINN

2. Development of Quantum PINN

3. Implementation of Quantum PINN for 1D - advection equation

4. Implementation of Quantum PINN for 1D - diffusion equation

5. Implementation of Quantum PINN for 1D - Burgers' equation

6. Implementation of Quantum PINN for 2D - Burgers' equation

7. Implementation of Quantum PINN for 2D - Euler's equation (Simplified Navier-Stokes Equations)

Implementing a PDE is a complex task that involves combining quantum computing principles, neural networks, and physical modeling. First defining the 2D Burgers' equation and formulating the PINN Approach. A neural network is used to approximate the solution to the differential equation in the Quantum PINN method. The neural network parameters are trained to minimize the discrepancy between the expected and actual solutions while accounting for the physics of the situation via the equation considered. We intend to use a quantum-inspired neural network architecture to include quantum concepts for solving PDE. This may entail incorporating quantum gates or quantum layers into the neural network framework. The data relevant to the PDE problem is then encoded in quantum states or quantum circuits, depending on the quantum-inspired neural network architecture used. So that we can define the loss function and begin training and quantum computing integration. Later, the quantum PINN will be trained by optimizing the neural network parameters with a gradient-based optimization technique. Back-propagation through the neural network and potentially through quantum layers is involved in this process.

We will incorporate quantum elements with PINN after creating an appropriate neural network architecture for Quantum PINN in order to provide a better optimal solution using Quantum bracket. We will validate the Quantum PINN's performance after training by testing it on unseen data and comparing the findings to known solutions or experimental data. The next phase is to optimize hyper-parameters such as learning rate, neural network design, and quantum layer configuration. After that, evaluate Quantum PINN's correctness, convergence, and computing efficiency in solving the 2D Burgers' equation and PDE. Finally, we must iterate and fine-tune the Quantum PINN implementation, possibly including more advanced quantum techniques or optimizations to improve speed.