**Quantum Bootcamp (Week 1- Virtual) - Quantum Algorithms, Quantum Advantage and Applications**

Dates: 5th, 6th and 7th March 2024

Venue: Online

**Week 1:** Quantum Algorithms, Quantum Advantage and Applications

For this set of workshops, we provide an overview of the different types of quantum algorithms that have played a significant role in shaping the landscape for the field of quantum computing. Through the lens of these algorithms, you will learn how the field has developed over the past few decades and what potential changes that might bring to the world of computing, while learning the basics of how to implement them in AWS Braket.

Goals for Week 1

1. Learn the various Quantum Algorithmic techniques that are historically significant and currently in popular discussion.
2. Discuss the potential advantages Quantum Computing has and when these advantages might be realized.
3. Identify the types of problems these algorithmic techniques might be applicable to.

**Day 1: AWS Braket Fundamentals / The Classic Quantum Algorithms Part 1**

Overview: When the idea of Quantum Computing and information was first pitched, it inspired a new avenue of research, but did not take the world by storm. That came later when the first Quantum Computing algorithms were pitched, with Shor's algorithm and Grover's algorithm being among the forerunners and the most famous. Over the sessions in the next two days, you will be learning two main topics: the basics of these algorithms, how they provide an advantage, and why they caused the storm they did; and a brief introduction to the capabilities of AWS Braket so that you can learn how to apply these algorithms.

| Time | Activity | Remarks | Presenter |
|---|---|---|---|
| 0845 - 0900 | Registration | | |
| 0900 - 0915 | Welcome and Introduction of Organizer and Instructor Team | | Pawsey, Softserve, AWS representatives and course instructors |

| | | | |
|---|---|---|---|
| 0915 – 1115 | Introduction to AWS Braket | Objective:<br>Introduction to Amazon Braket<br>(optionally including a brief recap of quantum circuit building blocks)<br>Enabling participant access to the AWSprovided workshop environment (including temporary AWS accounts)<br>Tutorial: How to run quantum tasks on simulators and QPUs (participants may follow along at their own pace to acquire hands-on experience) | Brajesh Gupt, Quantum Applied Scientist at AWS |
| 1115 - 1130 | Introduction to the workshops | Objective:<br>- Briefly explain the agenda for the next few days | Jonas Tan, SoftServe R&D |

| | | | |
|---|---|---|---|
| | | | Quantum Team Lead |
| 1130 - 1300 | Lunch | | |

| | | | |
|---|---|---|---|
| 1300 - 1445 | A Brief History of Quantum Computing and Introduction of Important Concepts | Objective:<br>To start with a broader view of<br>Quantum computing leading to the creation of the classic Quantum algorithms<br>Set the framework for the next two days.<br>To do a brief recap of some of the basic notions of Quantum Computing<br>Participants will learn (or relearn) about qubits, quantum operations in the form of quantum gates, quantum circuits<br>Go through important notation (like linear algebra notation) for<br>Quantum<br>Computing | Jonas Tan, SoftServe R&D Quantum Team Lead |
| 1445 - 1500 | Break | | |
| 1500 - 1630 | Deutsch-Jozsa Algorithm | Objective:<br>To introduce the theory behind the DJ Algorithm<br>To show how a simple quantum algorithm looks like<br>Introduce the basic concept of oracle that is present for | Dikshant Dulal, SoftServe R&D Quantum Research Engineer |
| | | many quantum algorithms | |

**Day 2: AWS Braket Fundamentals / The Classic Quantum Algorithms Part 2**

| Time | Activity | Remarks | Presenter |
|---|---|---|---|
| 0845 - 0900 | Registration | | |
| 0900 - 0945 | Introduction to Quantum Fourier Transform | Objective:<br>To introduce the theory behind QFT<br>Discuss the pros and cons between QFT and other implementations like FFT | Dikshant Dulal, SoftServe R&D Quantum Research Engineer |
| 0945 - 1045 | Quantum Fourier Transform Hands-on | Objective:<br>To implement the Quantum Fourier Transform<br>Start with the 3 qubit QFT, and progress to the general QFT on AWS Braket | |
| 1045 - 1100 | Break | | |
| 1100 - 1230 | Introduction to Quantum Phase Estimation and Shor's Algorithm | Objective:<br>To introduce the theory behind QPE<br>To show how to access it through AWS Braket<br>Briefly describe the applications of QPE, including Shor's Algorithm | Jonas Tan, SoftServe R&D Quantum Team Lead |
| 1230 - 1400 | Lunch | | |

| | | | |
|---|---|---|---|
| 1400 - 1600 | Introduction to Amazon Braket Hybrid Jobs | Objective:<br>Tutorial: How to run a hybrid job (participants may follow along at their own pace to acquire hands-on experience)<br>Review an exemplary hybrid quantum-classical algorithm: QAOA<br>Tutorial: How to run QAOA on Braket Hybrid Jobs (participants may follow along at their own pace to acquire hands-on experience) | Sebastian Stern, Quantum Solutions Architect at AWS |
| 1600 - 1615 | Break | | |
| 1615 - 1700 | Quantum Advantage | Objective:<br>Why should we look at quantum advantage, and where should we look?<br>Brief intro to different computational complexity classes with quantum<br>Discussions of quantum advantage beyond computational complexity classes, and whether they are valid | Jonas Tan, SoftServe R&D Quantum Team Lead<br><br>Dikshant Dulal, SoftServe R&D Quantum Research Engineer |

**Day 3: Variational Quantum Algorithms**

Overview: Although the classic quantum algorithms inspired people to take notice of the field, it soon became clear that in the short term these algorithms were not going to change anything as the required hardware was just too far away. While engineers started working on quantum hardware, another question was raised: “could we do anything with the current noisy smaller scale quantum

computers?" You will learn about one of the answers to that question, variational quantum algorithms, and the ingenious ways people are pairing quantum computing with classical computing.

| Time | Activity | Remarks | Presenter |
|---|---|---|---|
| 0845 - 0900 | Registration | | |
| 0900 - 0945 | Introduction to Grover's Algorithm | Objective:<br>- To introduce the theory behind<br>Grover's Algorithm | Jonas Tan, SoftServe R&D Quantum Team Lead |
| 0945 - 1045 | Grover's Algorithm Hands-on | Objective:<br>To implement a Grover's search algorithm for a<br>simple, small-scale problem<br>To learn how to access the general purpose one by AWS Braket<br>To demonstrate how many qubits and gates we need to use before we have a useful Grover's algorithm | |
| 1045 - 1100 | Break | | |
| 1100 - 1200 | Current Problems and how the Field<br>moved Forward | Objective:<br>To describe the problems faced by the classic Quantum Algorithms<br>Briefly describe efforts in Quantum Error Correction | Jonas Tan, SoftServe R&D Quantum Team Lead |

| | | | |
|---|---|---|---|
| | | - Lead into today's agenda for variational quantum<br>computing | |
| 1200 - 1330 | Lunch | | |

| | | | |
|---|---|---|---|
| 1330 - 1430 | Introduction to VQE and QAOA | Objective:<br>- To introduce the theory behind VQE and QAOA | Dikshant Dulal, SoftServe R&D Quantum Research Engineer |
| 1430 - 1515 | VQE Hands-on | Objective:<br>To implement a simple VQE algorithm<br>To learn how to access the general purpose one by AWS Braket | |
| 1515 - 1530 | Break | | |
| 1530 - 1615 | Quantum Neural Network Introduction Hands-on | Objective:<br>To show other forms of variational algorithms<br>Brief look into QML<br>To teach how to implement a simple Quantum Neural Network<br>We will use Amazon Braket to do a hybrid job with Pennylane for this. | Dikshant Dulal, SoftServe R&D Quantum Research Engineer |
| 1615 - 1700 | QC and Industry | Objective:<br>Discussion of the current landscape of Quantum Computing<br>Go through who is looking at QC, and why they are interested in it | Jonas Tan, SoftServe R&D Quantum Team Lead |
| | | | |