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Design and Implementation of Quantum half Adder and Full adder Using IBM Quantum Experience

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ABSTRACT

Quantum machine learning is the combination of quantum computing and classical machine learning. It helps in solving the problems of one field to another field. Quantum computational power can be advantageous in handling huge data at a faster rate.In this regard, quantum computational power can be advantageous in handling such huge data at a faster rate. Classical machine learning is about trying to find patterns in data and using those patterns to predict future events. Quantum systems, on the other hand, produces typical patterns which are not producible by classical systems, thereby postulating that quantum computers may overtake classical computers on machine learning tasks. Hence the whole motivation in this work is on understanding and analysing the half adder and full adder circuit design using Quantum mechanics.

Key words : Quantum, IBMQ

I. INTRODUCTION

Quantum machine learning is the intersection of classical machine learning and quantum computation. Quantum objects can be present at two places in the same time.These can be more complex in nature and executed faster with the assistance of quantum devices. Quantum algorithms can be used to analyse quantum states instead of classical data.

Quantum computers are known to solve problems that cannot be solved using a classical computer. If classical and quantum computers are simultaneously utilized for the same purpose, cases can exist in which quantum algorithms prove to be more efficient. Quantum technologies have three main specializations: quantum computing, quantum information and quantum cryptography.

Quantum computer is used to perform calculations based on the probability of an object state before it is measured. Quantum computers usesqubits or quantum bits to store the information. By using this we can encode the information as 0s, 1s or both at the same time. It has more potential to process data exponentially. The basic principle of quantum computation is that quantum properties are used to represent and structure the data and quantum mechanisms can be devised and built to perform operations with this data. The classical computers tasks, process & store everything in only 2 states: 0 and 1. It can only be 0 or 1 at a time, not both. This is exactly where quantum computers differ from classical computers. Quantum computers use Qubits instead of Bits. It means that they run 0 & 1 at the same time this is called as the principle of superposition.

II. LITERATURE SURVEY

To contribute in any field it is very important to be aware of the works that are currently in progress. In this regard during this mini project, a thorough review of various works carried out in the field of quantum mechanics was carried out. A brief description of the same is presented here.

In “On quantum methods for machine learning problems part I: Quantum tools” [1] the authorsFaridAblayev et al. have presented preliminary work on quantum computing, including qubits, quantum registers, quantum states, basic transformations, quantum circuits, and information extraction. The authors focus on two main problems of machine learning, namely the classification problem and the clustering problem. Classification as the process by which algorithms group data based on predefined characteristics which is known as supervised learning. Clustering is the process of grouping data without predefined characteristics, which is known as unsupervised learning.

The authors FaridAblayev et al. of “Quantum Methods for Machine Learning Problems Part II: Quantum Classification Algorithms”[2] have discussed about binary classification of quantum algorithms. They have analysed the advantages of quantum nearest neighbour algorithms, for their quadratic speed-up over classical algorithms. They also have intensively researched and thereby presented variants of Nearest Neighbour (NN) algorithms for classification problems and two more algorithms for binary classification.

In “Quantum Algebraic Machine Learning” [3] the author DmitriiMalov have discussed about the optimization problems and in particular non-convex optimization problems that can be hardly solved on classical digital computers, but can be naturally solved on a quantum computer. He has implemented the facial recognition system based on the proposed combination of the algebraic machine learning and the QBoost algorithm.

The authors Zi-AngRen et al. of “Implementation of Machine Learning in Quantum Key Distributions” [4] they have discussed about the Quantum key distribution (QKD) thereby providing an information-theoretic secure way for distant parties to transmit information. In the quick optimal QKD protocol classifier after comparing the behaviours of different machine learning models among all these classifiers, RF classifier shows its overwhelming advantages in preciseness, robustness, and efficiency. It can literally handle all scenarios no matter it is long or short distance. The accuracy of 98.2% on the testing set, as well as its strong generalization ability ensures that it is capable of providing customized and credible suggestion for users with different demands.

In "Challenges and Opportunities: Quantum Computing in Machine Learning" [5] the authors Shubham et al. have explained the principles of quantum mechanics. These principles are stated for quantum particles, the quantum particles are very small in size and their behaviour is very difficult to predict, thus making it more complex and tedious task to control and manipulate them to get desired results. Superposition is the mixing of two or more states to combine and form a single state. Entanglement explains the correlation between quantum states. These two properties are the basis of quantum computing and the working of a quantum computer is more complex than a classical one.

The authors Yangyang Li et al. of "Quantum Optimization and Quantum Learning" [6] they have summarized the existing quantum algorithms from two aspects: quantum optimization and quantum learning. Firstly, the related concepts and development history of quantum optimization and quantum learning are introduced. Then, classical algorithms are described in detail, and their development is summarized. They have analysed quantum intelligent algorithms to combine the high efficiency of global search with high parallelism, powerful storage and computing advantages of quantum computing, which can effectively avoid the shortcomings of intelligent algorithms and improves the efficiency.

III. METHODOLOGY

To implement Quantum half adder and full adder circuit using IBM quantum experience. The procedure is as shown below

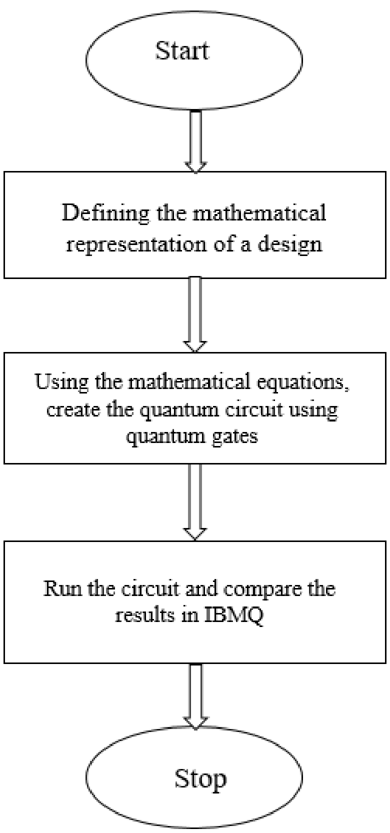

Fig.1 Flow chart

A. Quantum half adder

Quantum half-adder built from a Toffoli gate followed by a controlled-NOT (CNOT) gate.

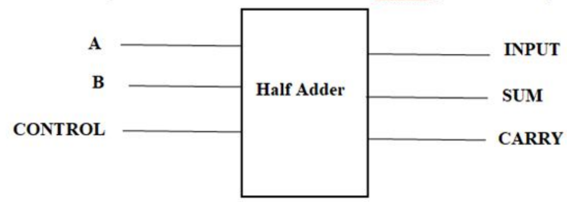

Fig 2: Block diagram of Quantum half adder

One possible implementation of a 2-bit Half adder, using CNOT gates and Toffoli gates is the following:

Inputs: q0 = A; q1 = B

Outputs: q0 = A; q1= Sum Out; q2 = Carry Out

Table 1: Truth table of Quantum half adder

	Q2	Q1	Q0	-	Q2	Q1	Q0
T1	0	0	0	-	0	0	0
T2	0	1	0	-	0	1	0
T3	0	0	1	-	0	1	1
T4	0	1	1	-	1	0	1
T5	1	0	0	-	1	0	0
T6	1	1	0	-	1	1	0
T7	1	0	1	-	1	1	1
T8	1	1	1	-	0	0	1

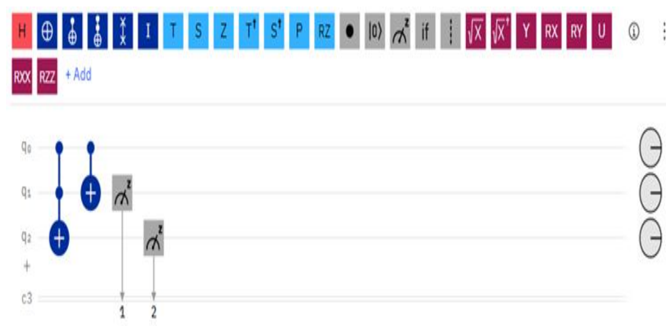

Fig 3: Circuit of Quantum Half Adder

B. Quantum Full adder

A,B and control are the three inputs of the full adder and sum and carry are the outputs.Since quantum circuits are reversible, they have an equal amount of input and output qubits, therefore we define a 4-qubit function, where the input qubits are A,B, Carry In and (zero) and the output qubits are A,B, Sum and Carry Out, see the figure below.

Table 2: Truth table of Quantum full adder

	Q 3	Q2	Q1	Q0	Q3	Q2	Q1	Q0
T1	0	0	0	0	0	0	0	0
T2	0	1	0	0	0	1	0	0
T3	0	0	1	0	0	1	1	0
T4	0	1	1	0	1	0	1	0
T5	0	0	0	1	0	1	0	1
T6	0	1	0	1	1	0	0	1
T7	0	0	1	1	1	0	1	1
T8	0	1	1	1	1	1	1	1

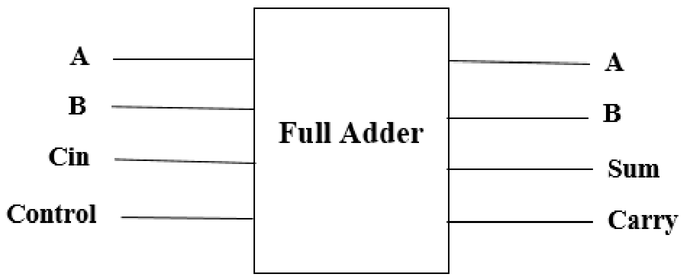

Fig 4: Block diagram of Quantum full adder

One of the possible implementation of full adder using Toffoli gates and CNOT gates is the following:

Inputs: q0 = A; q1 = B; q2= Carry In

Outputs: q0 = A; q1 = B; q2= Sum Out; q3 = Carry Out

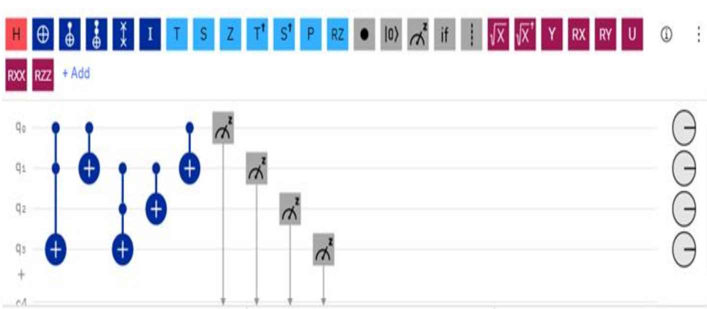

Fig 5: Circuit of Quantum full adder

IV. RESULTS

Quantum Half adder and Full adder is designed and implemented using IBMQ and results are verified with respect to probabilities.

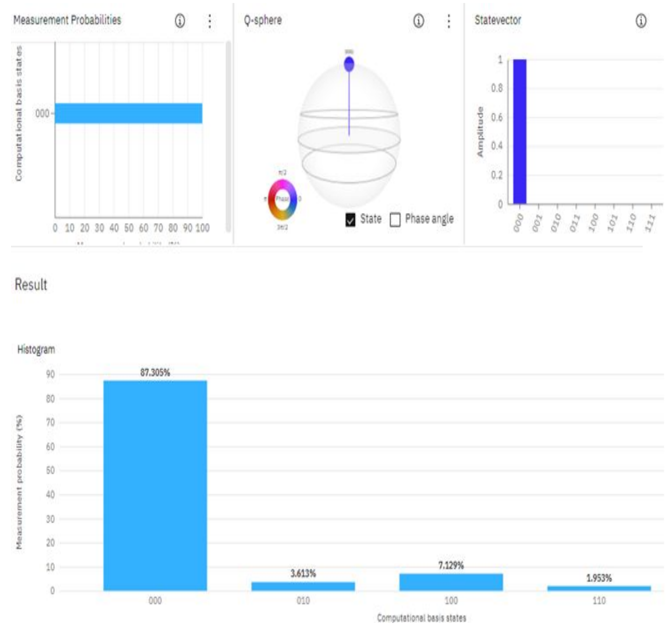

Fig 6: Result of Quantum Half Adder

Fig 7: Result of Quantum Full Adder

V. CONCLUSIONS

Quantum systems produces typical patterns which simplifies and enhances the computational power that can be advantageous in handling huge data at a faster rate. Hence the whole motivation in this work was in understanding and analysing the circuit design using Quantum mechanics. First a thorough study was carried out to understand the basics of quantum mechanics.Two circuits i.e. half adder and full adder were designed and implemented on IBMQ and thoroughly analysed for the results. It was observed that, in quantum computing results are based on probabilities for all the possible input combination at one go. Due to this there as an enormous reduction in the time to obtain the outputs when compared to classical computation wherein we need to force all the input combinations one by one.

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