Task3

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1 Task 3

Quantum Machine learning is really powerful as it merges both quantum physics and machine learning, offering us new possibilities to solve problems more efficiently and faster than Classical Computer.

One of the most important thing in Quantum Computing is that the qubit is present in both the 0 and 1 state simantaneously which makes the compuatation faster than classical computing where the bit is in either 0 or 1 state.

1.1 Features Of Quantum

1.1.1 Entanglement

Qubits can be entangled where one state is directly related to the other state. This enable us to perform complex operations in very less time that can take exponential time in Classical computers.

1.1.2 Quantum Gates

The qubits can be easily manipulated using different gates like X,Y,Z,Hamdard etc. These gates are represented using simple matrix which makes compuatation and calculation simple and faster.

1.1.3 Super Dense Coding

Quantum protocol that allows us to send 2 bits of info using 1 bit.

1.2 Deutsch Algorithm

It is one of the earliest example of Quantum Computing Algorithm which is used to predict whether a function is constant function or balanced function

1.3 Deutsch Josza Algorithm

This is an extension of above algorithm where a function takes n bit as input and we have to predict whether function is constant of balanced.

Now in case of a classical computer it will take 2^(n-1)+1 queries to determine whether it is constant or balanced.

But in case of Quantum Computer it will take only one query to determine.

This algorithm uses superpositioning principle to all the inputs rather than checking one at a time.

1.4 Bernstein-Vazirani Algorithm

It is a quantum algorithm that efficiently finds a hidden bit string encoded in a function.

$$f(x) = a * xmod2$$

We have to find out `a` hidden bit string of n bits.

In classical computer, we would have to query atleast n times ie `O(n)`

But with quantum computer we can find this in `O(1)`

1.5 Quantum Fourier Transformation

It is one of the most important and fundamental algo. It is used to apply linear transformation on state of qubits.It transforms a quantum state from the "computational basis" into a "frequency domain" basis, similar to how the classical Fourier transform converts a time-domain signal into its frequency components.

While a classical DFT takes `O(N logN)`operations for an array of `N` elements, the QFT can be performed using `O(n^2)` where `N=2^n`. This makes it exponentially faster.

I am not adding circuit and mathematical expression here because it will make it too lengthy.

1.6 Shor's Algorithm

It is my favourite algorithm and I would like to work on this and explore this algorithm further because while reading about this I realised that the whole internet can go down just by one breakthrough in this field which is scary and exciting at the same time.

It is used to factor a very large number efficiently which will break the blockchain and cryptography on which the whole internet is working.

Shor's algorithm starts by reducing the factoring problem to finding the period `r` of a function.

$$f(x) = a^x modN$$

where a is randomly chosen coprime with N

The period r is smallest positive integer such that

$$a^r = 1modN$$

The quantum part of the algorithm involves creating a superposition over possible values of `x`, and then using quantum phase estimation to determine the period `r`.

Quantum Fourier Transform (QFT) to convert the periodicity information into a measurable form. The QFT efficiently extracts the frequency (or phase) corresponding to the period.

Once `r` is known, it can be used to compute a non-trivial factor of `N` by calculating the greatest common divisor (gcd) of

$$\gcd\left(a^{\frac{r}{2}} \pm 1,\, N\right)$$

These are some of the algorithms, there are many other algorithms and concepts in quantum computing that I would like to explore and work with during my summer break.