Government Polytechnic Pune -16

(An Autonomous Institute of Government of Maharashtra)

A

Seminar report

on

“Quantum Computing”

SUBMITTED BY:

Yash Sandip Mahajan

Under the Guidance of

Smt. Priya K. Zade

DEPARTMENT OF COMPUTER ENGINEERING

(Academic Year:2022-23)

Government Polytechnic Pune -16

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DEPARTMENT OF COMPUTER ENGINEERING

CERTIFICATE

This is to certify that **Mr. YASH SANDIP MAHAJAN** with Enrollment Number **2006134** of Third Year Diploma in Computer Engineering has successfully completed the seminar titled **"QUANTUM COMPUTING"** as part of his diploma curriculum in academic year 2022-2023.

Seminar guide	Head Of The Department	Principal
(Smt. Priya K. Zade)	(Mrs. M. U. Kokate)	(Dr. V. S. Bandal)

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I extend my hearty thanks to “Smt. Priya K. Zade”,who guided me to the successful completion of this project. I take this opportunity to express my deep sense of gratitude for her invaluable guidance, constant encouragement, immense motivation which has sustained my efforts at all the stages of this project work.

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ABSTRACT

This report is a seminar report submitted in partial fulfilment of requirements for the Diploma in computer engineering as per the norms of Government Polytechnic Pune. This report is based on the most exciting topic of 21^{st} century that is Quantum Computing. It is considered to be the way by which all the laws of classical physics would be fooled and then the technology would be used which would work much faster than classical computing methods and also communication of their fundamental unit would be faster than the speed of light.

This report would not cover anything else which would not be required to explain the quantum computing. It would be explaining the fundamental unit of quantum computing that is qubits and how nature of qubits is used to carry out all the operations. This is one of the most heard topic of 21^{st} century and is meant to be at least known rather than understanding it entirely. This , is the future of computing that does not follow any conventions classical rules and has an entire set of rules in its own world. It is yet to be figured out to full extent how it works.

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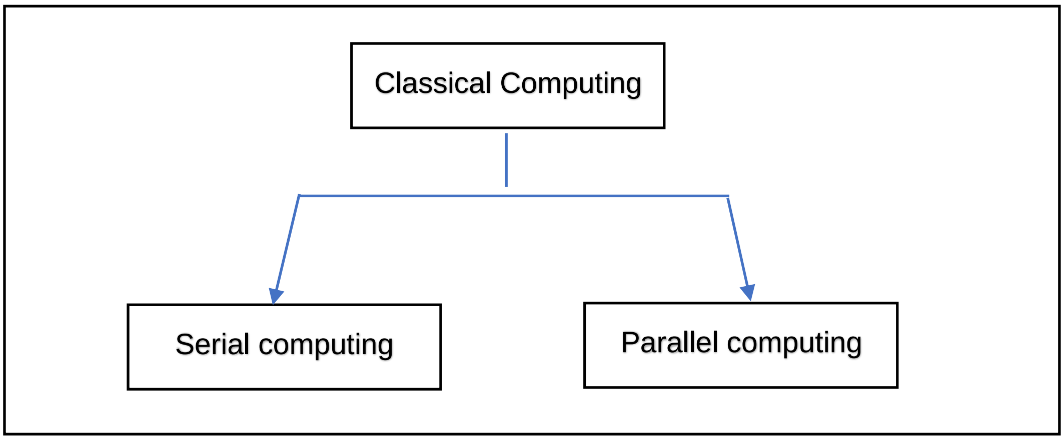
CHAPTER 1:
CLASSICAL COMPUTING

Classical Computing

Classical computing is the computation that occurs in all the present level computers be it laptop , mainframes or super-computers. From the first generation computers that were invented in 1946 to the advanced super computers used today up to the date, all these computers use the concept of classical computing.

Classical computing involves serial and parallel computing.



Classical computing has the operational and fundamental unit know as a Bit. It is also called Classical Bit.

Classical computing also supports the reversible and irreversible computing.

Classical Bits

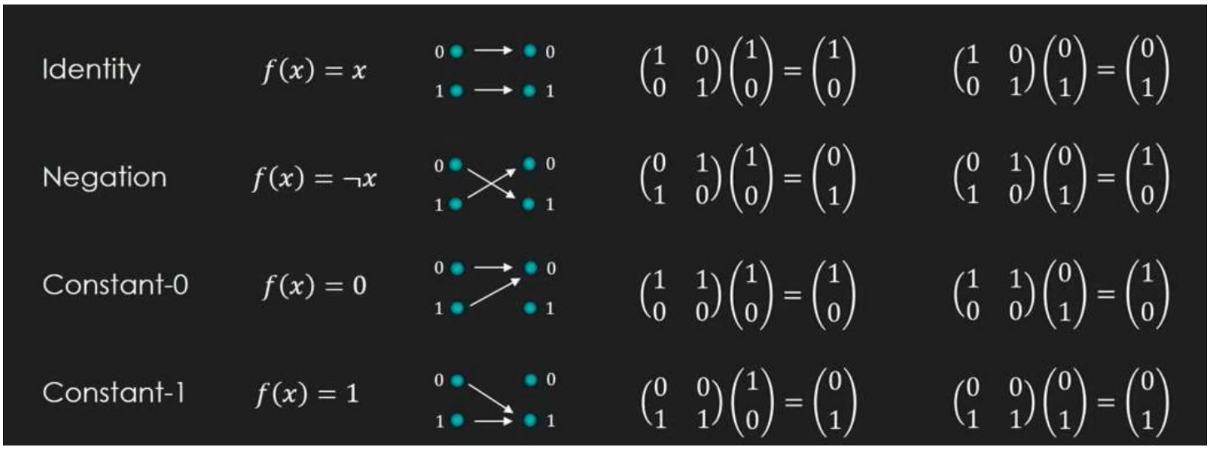
The classical bits are the bits that were invented in 1732 by Basile Bouchon and Jean Falcon. Classical bits are the state of transistor , at a time , a transistor can be on or off. For simplicity , rather than considering the on and off state of the transistor , the off is considered as 0 or “false” and on is considered as 1 or “true”.

It has following features:

1. It is state of transistor that can either be on , 1 or true , off or 0 or false.
2. If we have n bits , then the (c-bits) then there are 2^n possible states but a bit can have only and only one possible state at a time.
3. We use reversible and irreversible operations on a c-bit.

Operations on One Classical Bit

There are 4 possible operations that can be performed on the single classical bit.



1. **Identity : f(x) = x**

   It is the operation that produces output same as the input

   So ,

Input	Output
0	0
1	1

2. **Negation : f(x) = -x**

   It is the operation that produces output opposite to the input

   So,

Input	Output
0	1
1	0

3. **Constant 0 : f(x) = 0**

   It is the operation that produces output as 0 irrespective to the type of input

   So ,

Input	Output
0	0
1	0

4. **Constant 1: f(x) = 1**

   It is the operation that produces output as 1 irrespective to the type of input

   So,

Input	Output
0	1
1	1

These 4 operations are the types of reversible and irreversible operations.

1. **Reversible Operations:**

   The operations in which using the set of output we <u>can</u> determine the values of inputs are called reversible Operations.

   There are two reversible operations on 1 bit:

   1. <u>Identity</u> :

      Since both the set of inputs produce different set of output , it is reversible operation.

   2. <u>Negation</u> :

      Since both set of inputs produce output opposite to actual input, it is irreversible operation.

2. **Irreversible Operations:**

   The operations in which using the set of output we <u>cannot</u> determine the values of inputs are called reversible Operations.

   There are two reversible operations on 1 bit:

   3. <u>Constant 0 :</u>

      Since both the set of inputs would produce only 0 as output , it cannot determine input using output.

4. <u>Constant 1 :</u>

   Since both the set of inputs would produce only as output , it cannot determine input using output.

CHAPTER 2:
DRAWBACKS AND LIMITATIONS OF CLASSICAL COMPUTING

Classical computing is used in everyday life by us while we use the classical computers. But still there are drawbacks that it holds with itself as follow:

1. **Incompatible to calculate small scale values :**

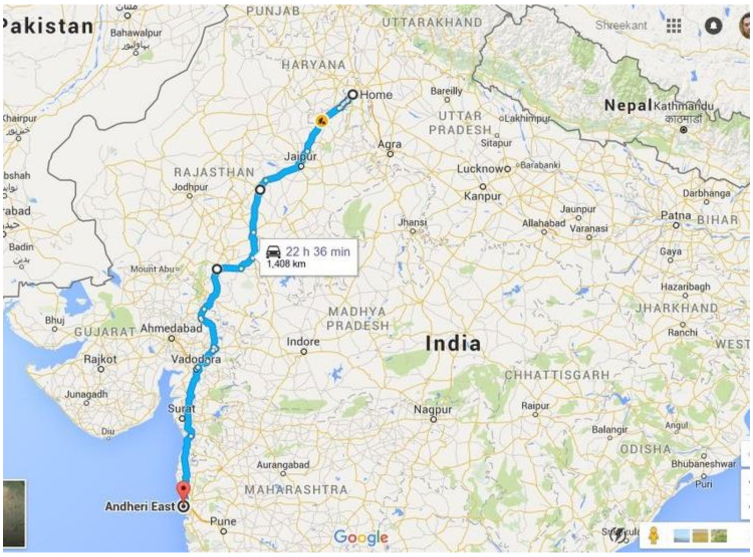
   A best supercomputer is waste while calculating the Bond length of the molecules having more than 50 electrons.

   It makes this technology look waste when the small particles are involved in it.

Species	Name	Bond Length (Å)		
		Experimental	Calculated	Difference
CaF	Calcium monofluoride	1.967	4.079	2.112
Na_2	Sodium diatomic	3.079	2.379	-0.700

2. **Impossible to calculate the operation that involves small set of inputs and outputs but very large number of possibilities in them:**

   E.g. Suppose , we have to calculate the longest distance between two cities of a Country, there is only one possible output, still, there are infinite number of possibilities for output.



Reason for incompatibility:

The nature works on the principles of quantum mechanics. The electron , molecule , nucleus of atom works on quantum mechanics.

CHAPTER 3:
INTRODUCTION TO QUANTUM COMPUTING

Quantum Computing

The computing technique that uses principles of Quantum mechanics and concepts as entanglement and superposition is called Quantum Computing.

Invention of Quantum Computing:

- Quantum computing began in 1980 when physicist Paul Benioff proposed a quantum mechanical model of the Turing machine. Richard Feynman and Yuri Manin later suggested that a quantum computer had the potential to simulate things a classical computer could not feasibly do.

- In 1986
  - Feynman introduced an early version of the quantum circuit notation.
- In 1994
  - Peter Shor developed a quantum algorithm for finding the prime factors of an integer with the potential to decrypt RSA-encrypted communications.
- In 1998
  - Isaac Chuang, Neil Gershenfeld and Mark Kubinec created the first two-qubit quantum computer that could perform computations.

Differentiator between Classical and Quantum Computing

- Quantum computing can only perform reversible operations.
  So , it cannot be operating Constant 0 and Constant 1 operation.
  But it can perform Identity and Negation operation.

- Quantum computing does not use the classical bits but has the fundamental unit of quantum computing is called Quantum bit also known as qubit.
- Quantum computing cannot perform the operations such as addition with higher speed than the Classical computing , it will even consume more resources than that.

There are three important concepts in Quantum computing that are required to be studied to understand it , as follows:

1. Qubits
2. Superposition
3. Entanglement

CHAPTER 4:
QUBITS AND HOW ARE QUBITS CREATED?

Qubits:

The fundamental unit of quantum computing is called Qubit. It is also called Quantum bit.

Components that can act as Qubit:

A bit can simply be called as state of the transistor , but quantum bit is not like any of it because it does not have just the two states, it can be 1 and 0 at same time. So , it is important to know which subatomic particles or components can be used to make the qubits. So,
Any subatomic particle that exhibits quantum behavior can be used to make the qubits.
For example, electron , nucleus , molecule etc.
Two materials that can be used are:

1. Superconducting :

   Superconducting material can be used to make the qubit but the size of qubit would be large that the required appropriate size.

2. Semiconducting:

   Semiconducting material is best suited to make the qubit as it allows to create qubit of required size.

Making of a Qubit:

A quantum bit , also known as qubit is made as follows:

1. It is made by use of outermost electron of Phosphorous atom. A phosphorous atom is embedded into the silicon , which bring the electron in special state know as a spin.
2. When a strong magnetic field is provided to the semiconducting mixture, then the electron changes its state called Spin.

3. It goes into up spin and down spin. When magnetic field that is applied is stopped , then in that case , the electron goes into state that is neither up spin , no downspin.

Issue with general silicon:

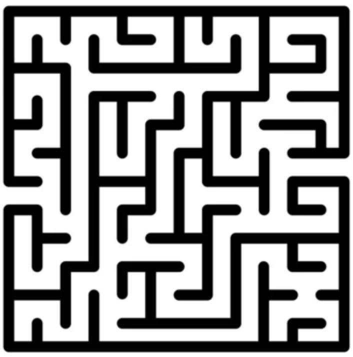
1. A general silicon has electrons that can go into up spin and down spin along with the electron of Phosphorous atom .

Solution to issue : Silicon 28 :

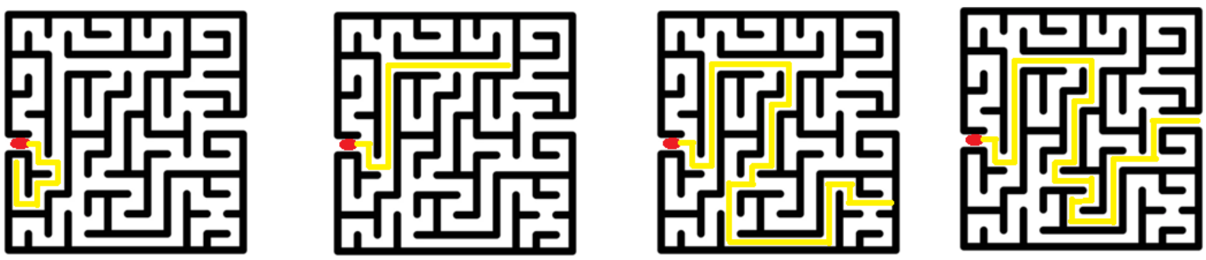
1. There is an isotope of silicon that is known as Silicon 28 which does not have any kind of magnetic spin, which makes it most suitable for being the constituent element of qubits.
2. This Silicon-28 isotope , is used for Avogadro experiment.

Analogy to understand How Quantum Computing works:

Quantum computing can be best understood by explaining the example of maze and how the classical computing would solve it and how would Quantum computing solve it.

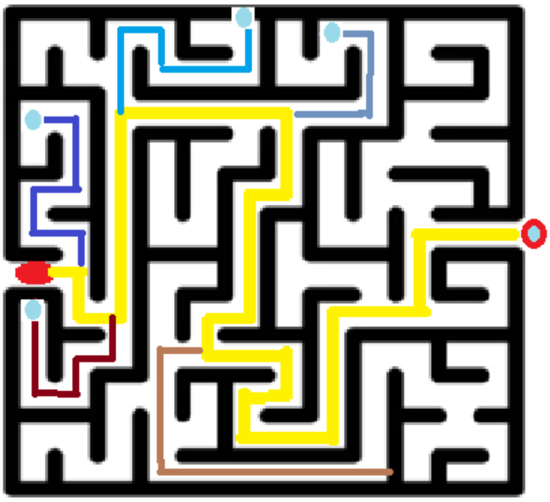


Classical computing:



Way it would be solved in Classical computing….Trial and Error Method

Quantum computing:



Qubits at single instance would take number of forms and would find the solution

CHAPTER 5:
SUPERPOSITION AND HADAMARD GATE?

Superposition:

A qubit exists in the state known as superposition which can be stated as a state in which a qubit is neither 0 nor 1 but between 0 and 1 , but when measured , gives the result in the form of 0 or 1.

Qubit can exist in superposition and it can be defined as [a b] where probability of a qubit being 0 is a^2 and being 1 is b^{2}..

It is impossible to get the state of the qubit, all we can do is , predict the state of the qubit and it is given by the above equation.

When the qubit is measured , it turns into either of the state that is 0 or 1.

Hadamard Gate:

So, we know that qubit is in superposition , but how to prove it ? How to make it a visual? Answer lies with the Hadamard gate.

Hadamard gate is used to bring the qubit in the superposition and it operates such that it creates 50% chances of a qubit being 1 and 50% for qubit being 0.

Hadamard gate when accepts a qubit , on experiment , half times result is 1 and half time the result is 0.

$$H|0\rangle = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} \end{pmatrix}$$

Output of Hadamard Gate when Input is 0

$$H|1\rangle = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} 0 \\ 1 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} \\ \frac{-1}{\sqrt{2}} \end{pmatrix}$$

Output of Hadamard Gate when Input is 1

REFERENCES :

The various sources that were used to extract knowledge from are as follows:

1. https://www.academia.edu/33402389/Quantum_physics_by_hc_verma_cmpress : Quantum Physics
2. https://www.scientificamerican.com/video/how-does-a-quantum-computer-work/ : Quantum Computing Working
3. Articles on Quantum Computing
4. ibm.com : IBM Quantum Computer

CONCLUSION:

This seminar session has covered various topics such as the classical computing and its drawbacks, quantum computing and qubits , construction of qubits and superposition , along with the states qubits can have depending upon the number of qubits we have.