Fundamentals of Computer Engineering

Module II - Unit 8
New Trends I

Teachers: Moisés Martínez (1ºA English)

Year: 2022 - 2023

Universidad Francisco de Vitoria
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Grado en Ingeniería Informática
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What is a trend technology?

Trend technologies

A **trend** is a change or development towards something new or different.

This means that trend technology will change our future.

- Artificial Intelligence (AI).
- Machine Learning (ML).
- Computer Vision.
- Computation.
- Control systems.
- Internet of Things (IoT).
- Blockchain.

Trend technologies - The digital transformation

Technology is changing our behaviours.

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Trend technologies - The digital transformation

Technology is changing our behaviours.

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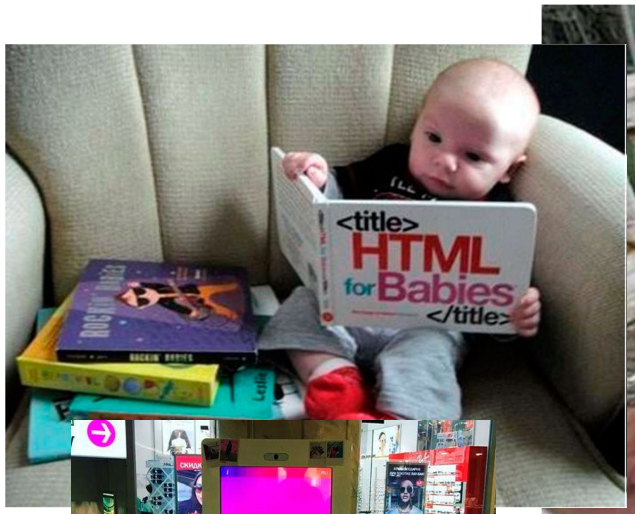
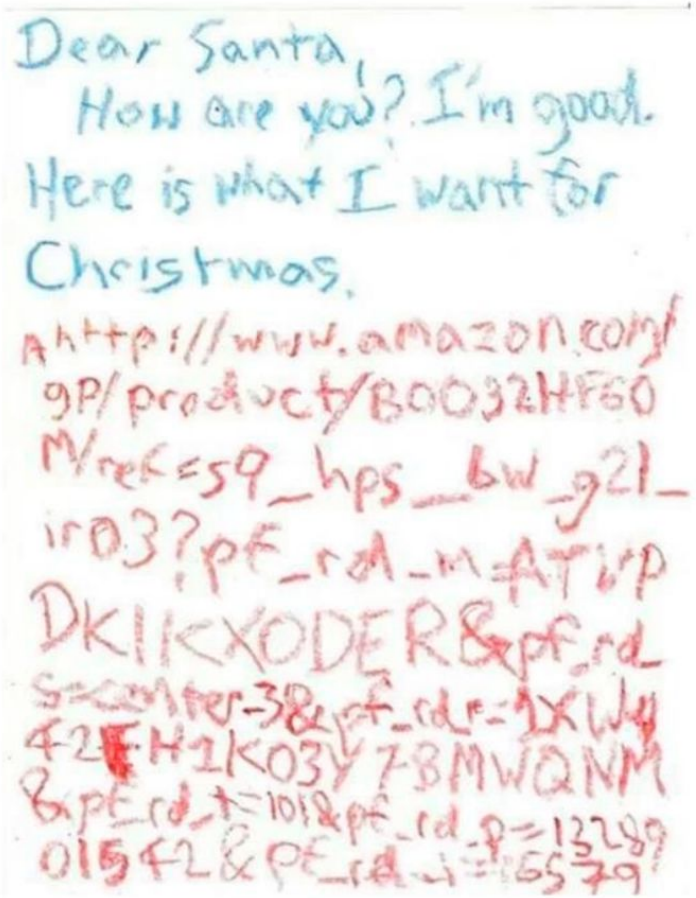
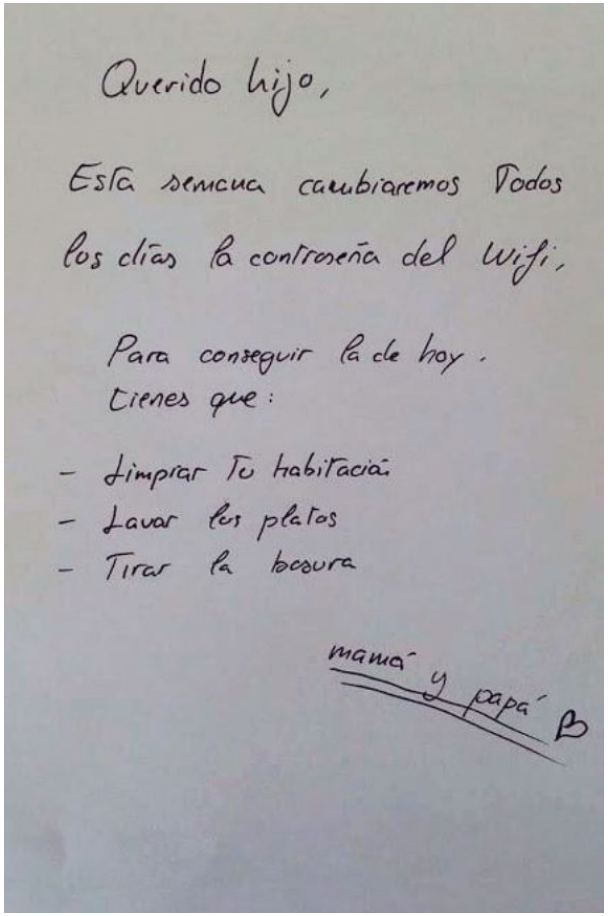


Trend technologies - The digital transformation

Technology is changing our behaviours.





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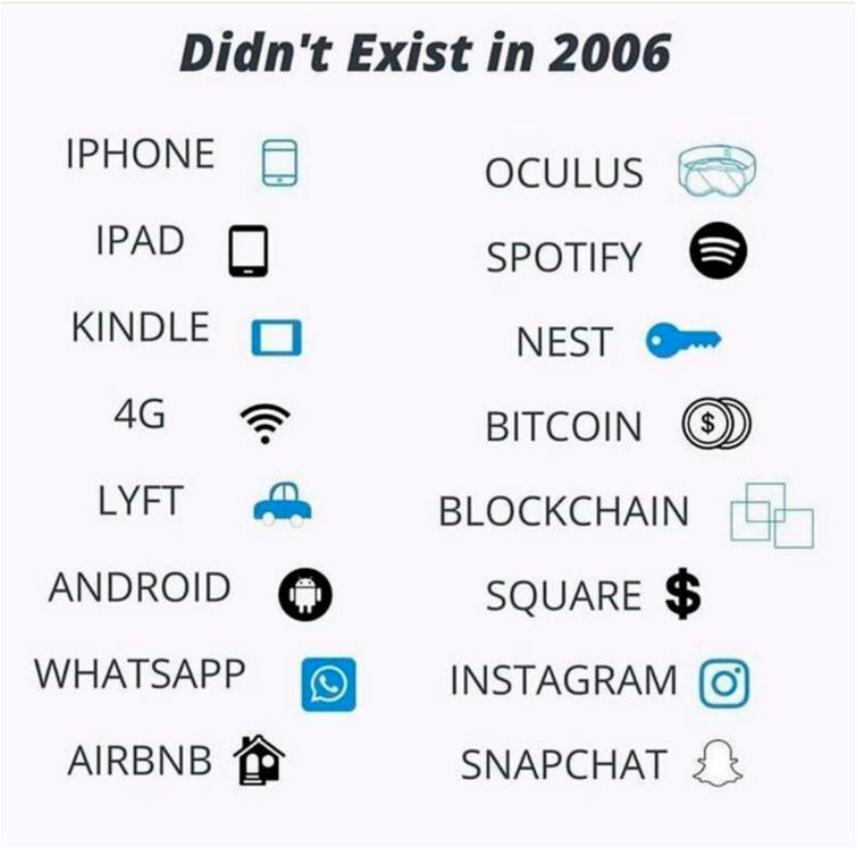
Trend technologies - The digital transformation



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Trend technologies

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- **Artificial Intelligence (AI).**
- **Machine Learning (ML).**
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Artificial Intelligence

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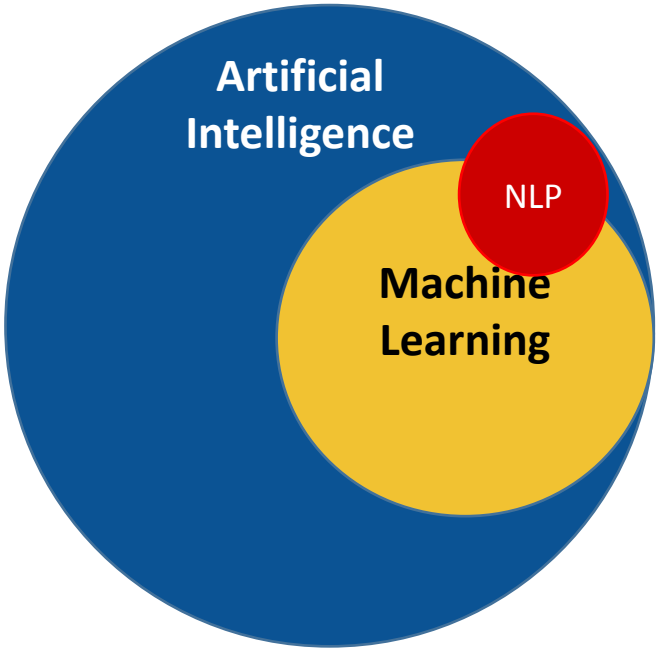
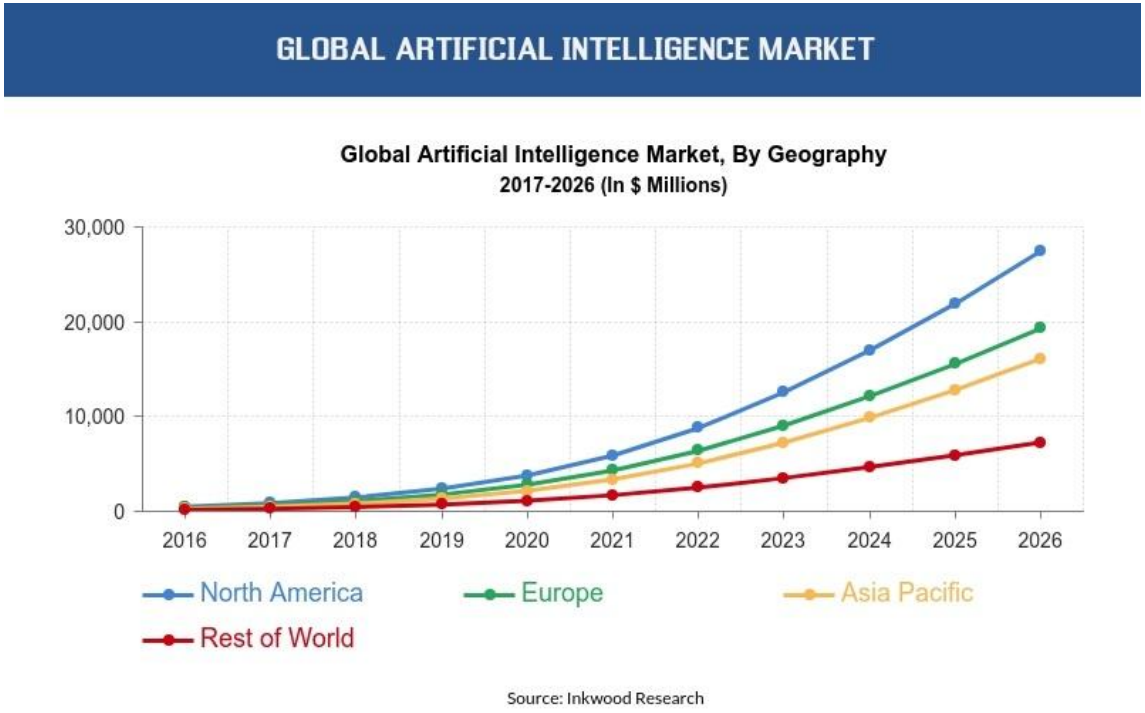
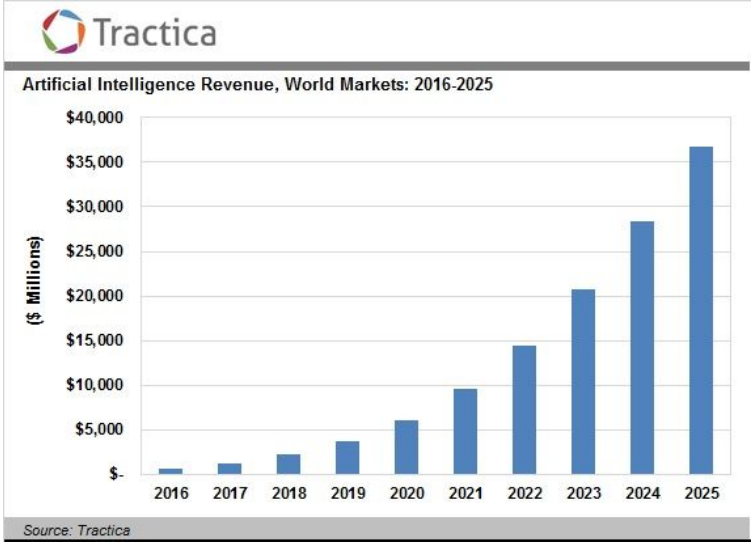
Artificial Intelligence (AI)



Artificial Intelligence (AI)

Artificial intelligence (AI) is intelligence demonstrated by machines, as opposed to the natural intelligence displayed by animals and humans.





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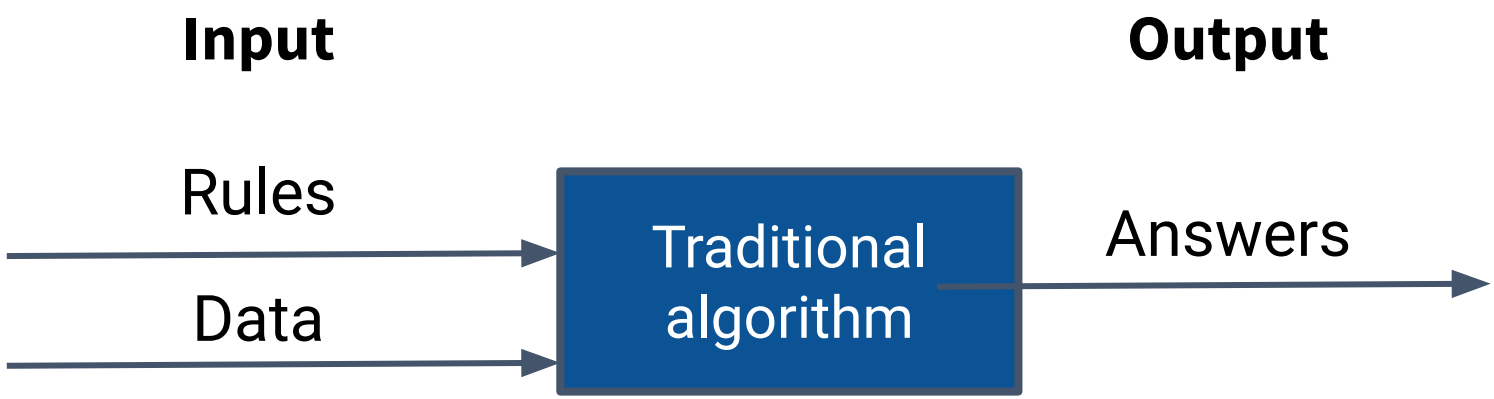
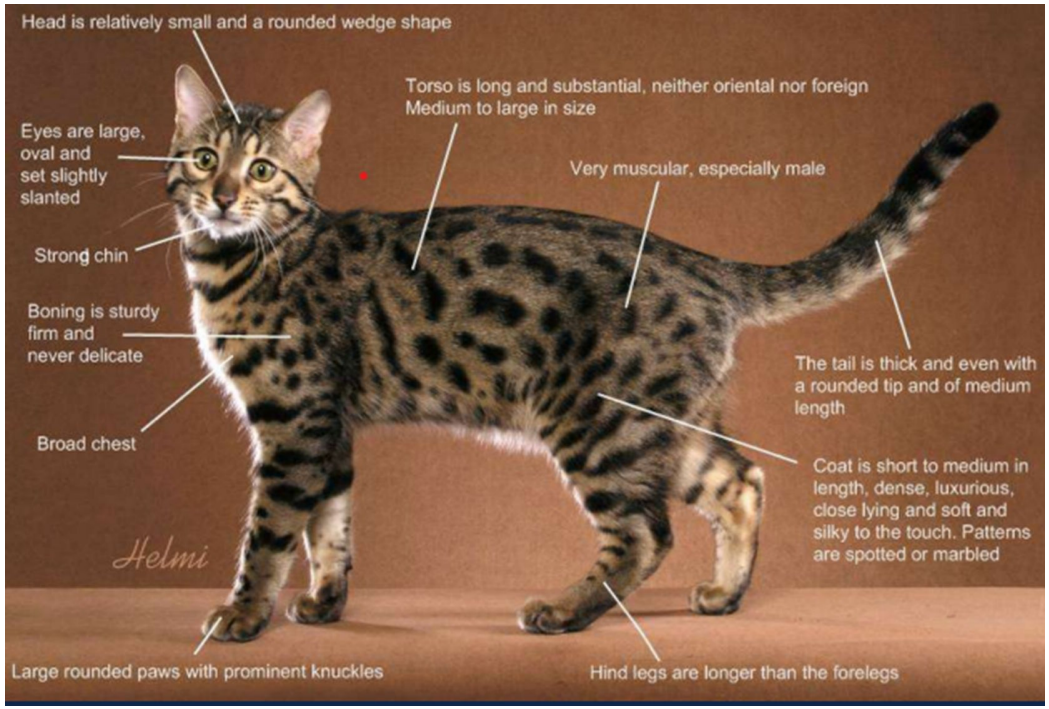
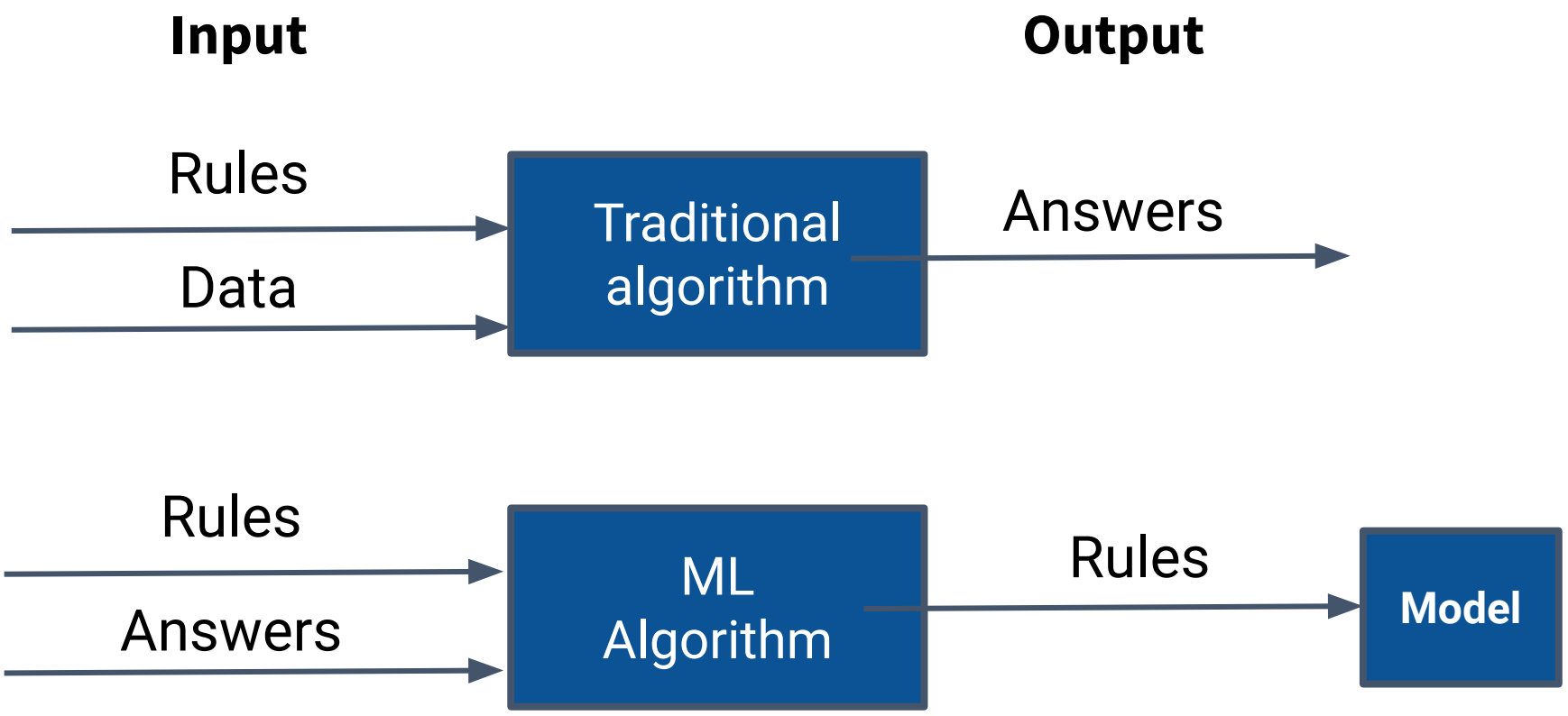

Input
Output
Rules
Data
Traditional algorithm
Answers

Artificial Intelligence - Machine Learning

Traditional algorithms work by using rules defined by an expert.

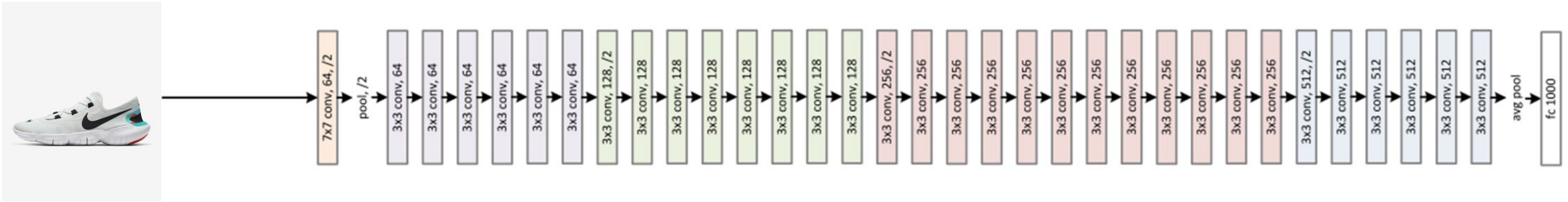


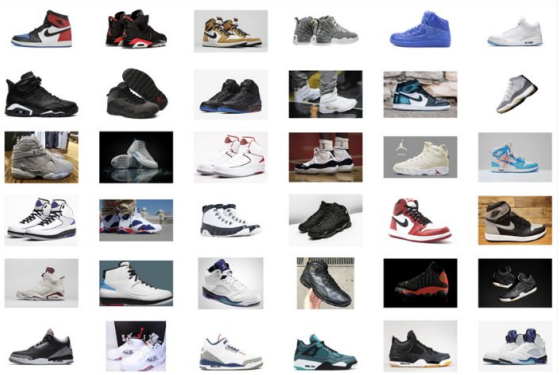
Artificial Intelligence - Machine Learning



Artificial Intelligence - Machine Learning

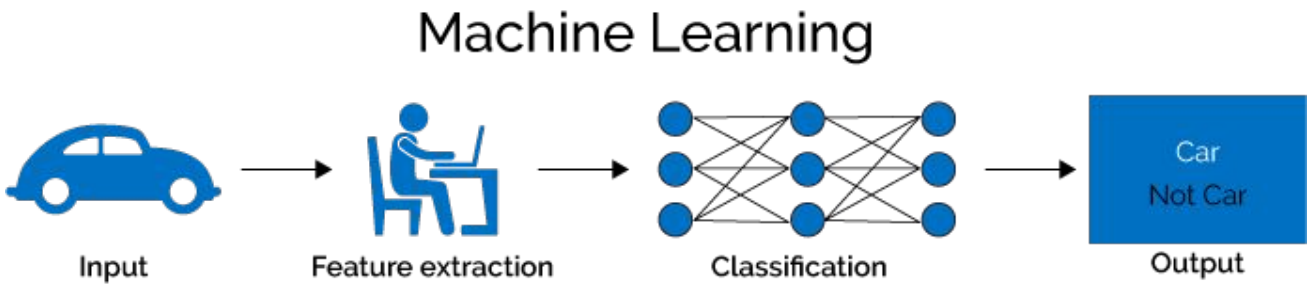
ML algorithms work by using examples that attempt to capture the knowledge that resides within them.





Artificial Intelligence - Machine Learning

Machine learning (ML) is the study of computer algorithms that improve automatically through experience (data examples).



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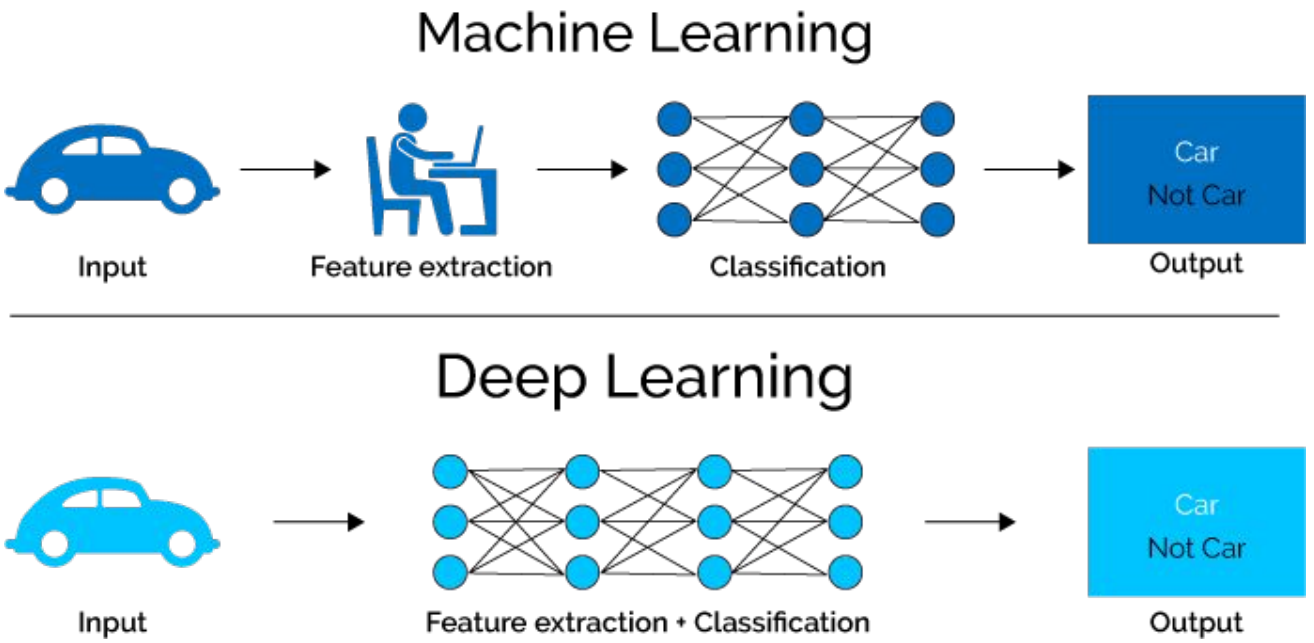
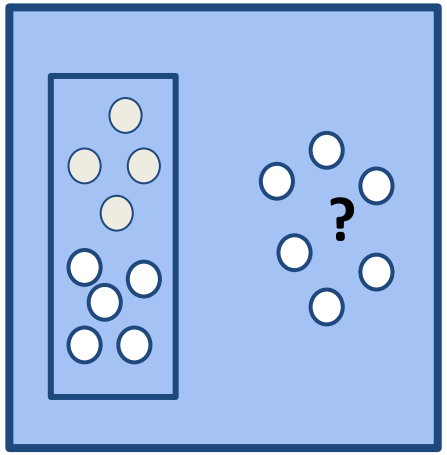


Supervised

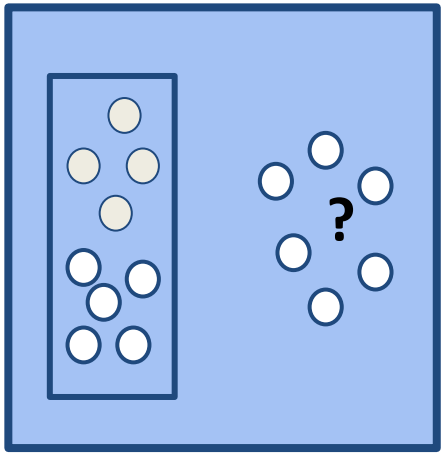


Data + Answers

Supervised learning is the machine learning task of learning a function that maps an input to an output based on example data-answer pairs. It infers a function from labelled training data consisting of a set of training examples.

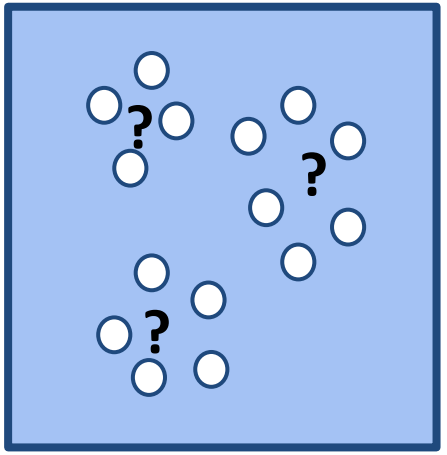
Artificial Intelligence - Machine Learning

Supervised



Data + Answers

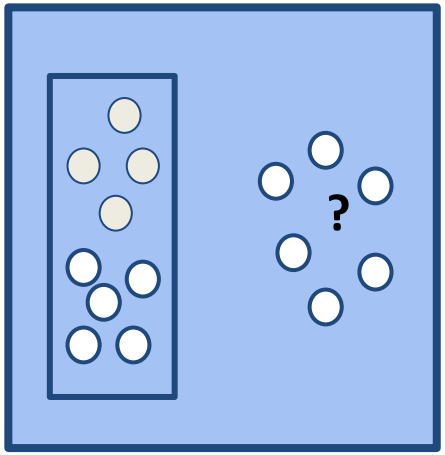
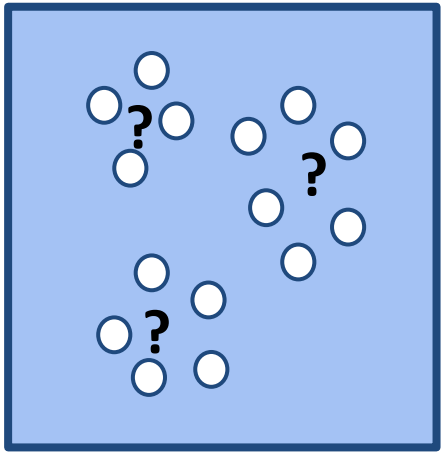
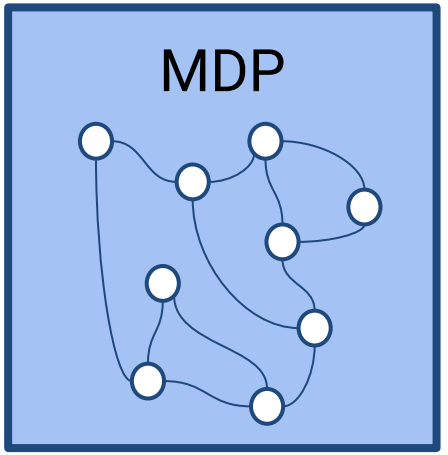
Unsupervised



Data

Unsupervised learning is a machine learning task of learning patterns from unlabelled data. The hope is that through mimicry, the machine is forced to build a compact internal representation of its world.

Artificial Intelligence - Machine Learning

Supervised	Unsupervised	Reinforcement
		
Data + Answers	Data	Actions$^{\text{Reward}}$ + State

Reinforcement learning (RL) is an area of machine learning concerned with how intelligent agents ought to take actions (data) in an environment, defined by states, in order to maximize the notion of cumulative reward.

AlphaGo

AlphaGo is the first player to defeat a human professional Go player, **the first to defeat a world Go champion**, and is possibly the strongest Go player in the world.

- Two players who play in turns.
- Black and white stones.
- Models based on human-machine interaction.

The player combines an advanced search tree with deep neural networks. These networks take a description of the board as input and process it through several different layers which contains millions of neuron.

There are **10 to 170 possible board configurations** in Go, far more than the number of atoms in the known universe.

OFF-EXAM CONTENT

ALPHAGO

TRIBECA FILM FESTIVAL 2017

BFI LONDON FILM FESTIVAL

WINNER

MILL VALLEY FILM FESTIVAL

Official Selection

VIFF

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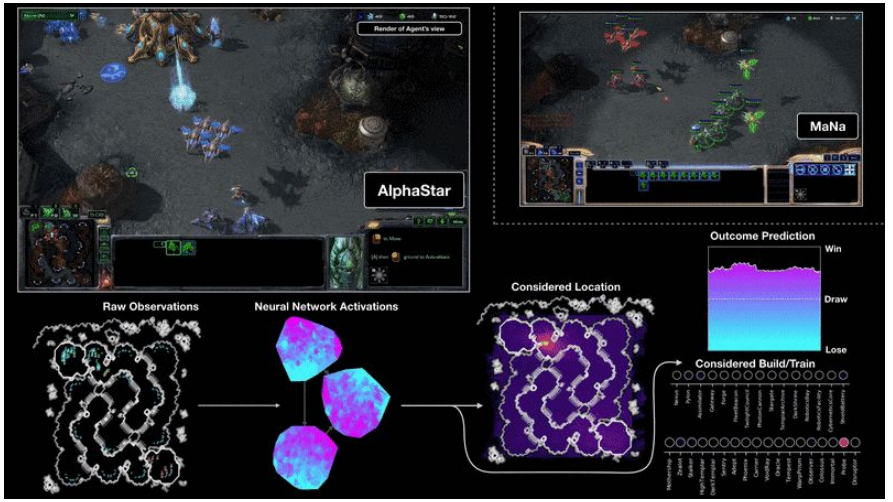
AlphaStar

AlphaStar is a reinforcement learning agent for tackling the game of Starcraft II. AlphaStar uses numerous types of architecture to incorporate different types of features:

- Observations of player and enemy units are processed with a Transformer.
- Scatter connections are used to integrate spatial and non-spatial information.
- The temporal sequence of observations is processed by a core LSTM.
- Minimap features are extracted with a Residual Network.



It is not possible to compute the maximum number actions in a Starcraft II game.

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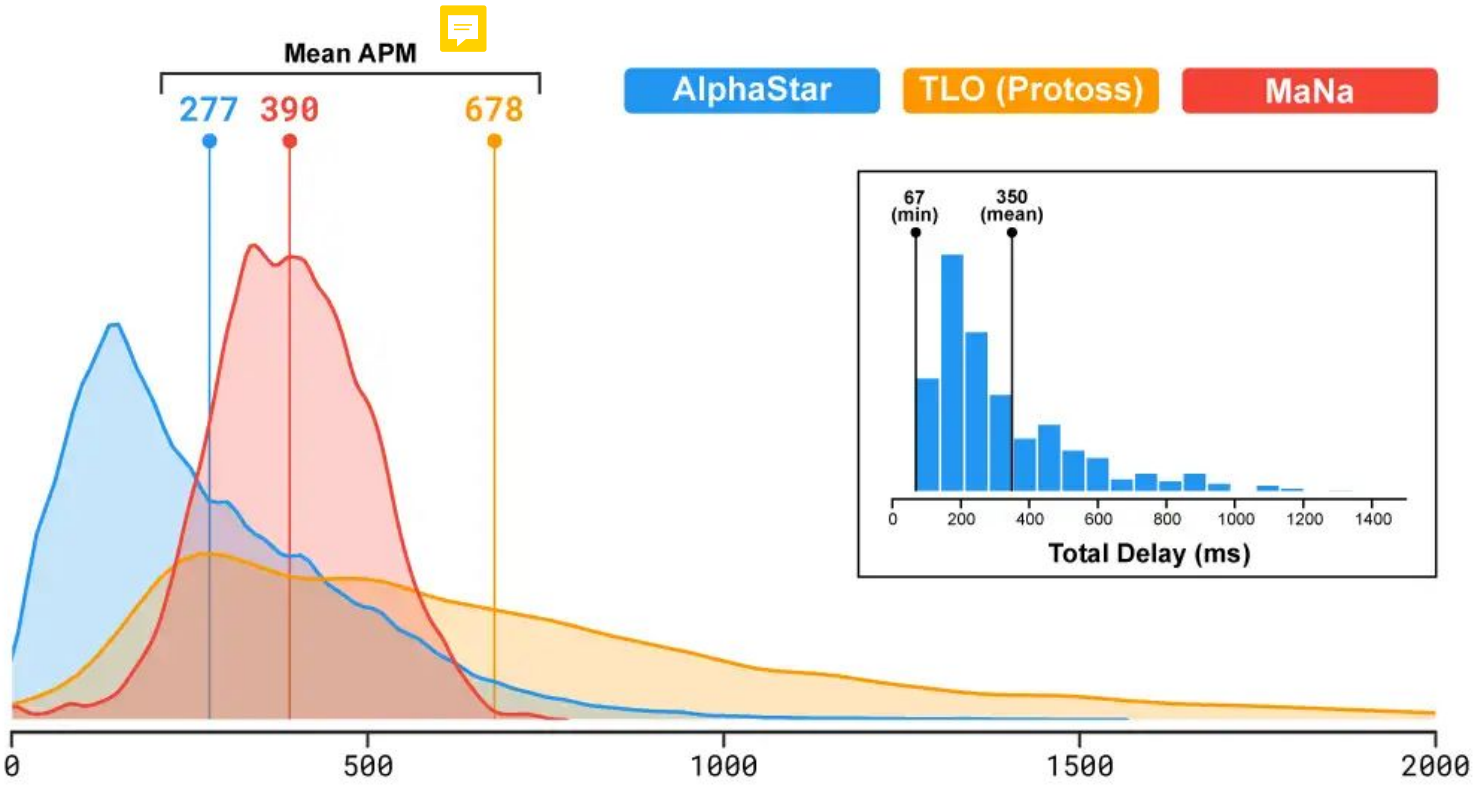
Machines are slower than humans.



Mean APM: Actions per minute on average.

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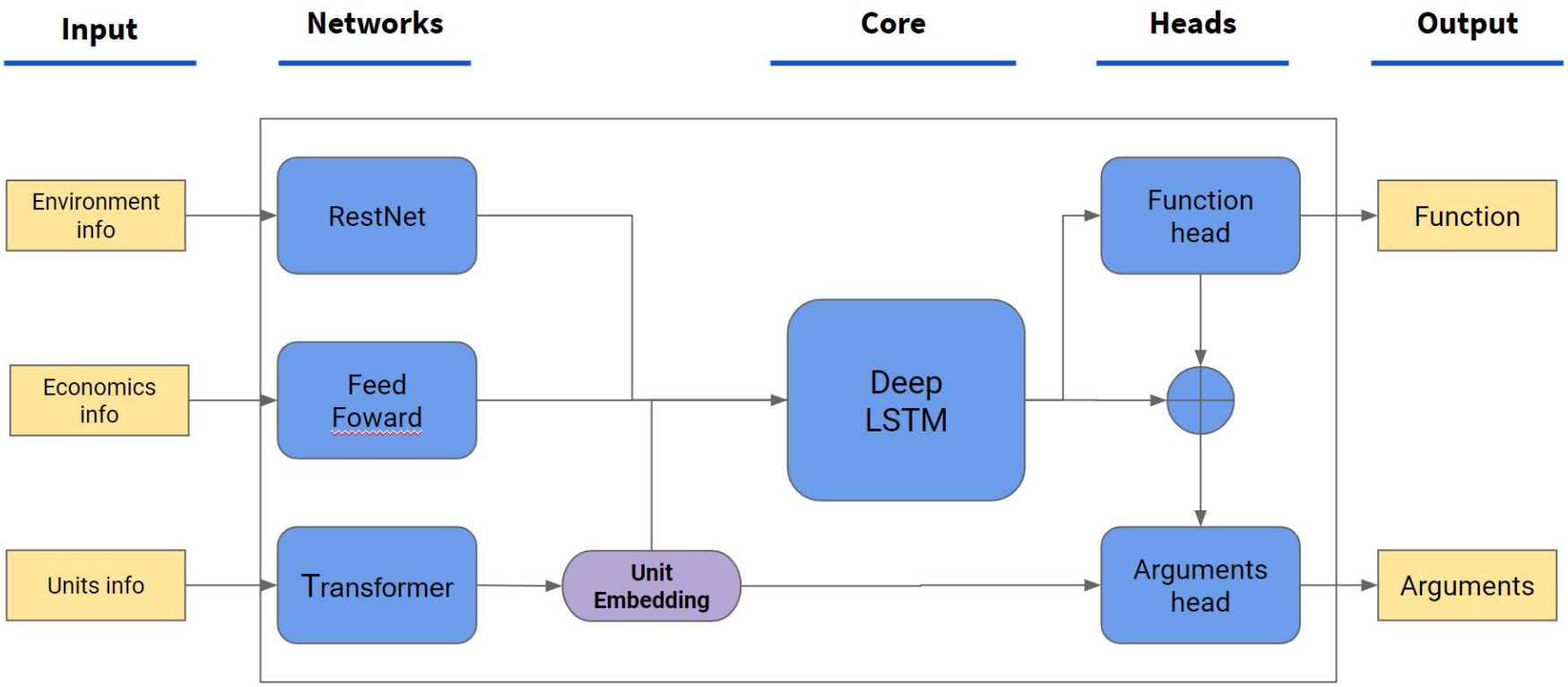
Artificial Intelligence - Machine Learning



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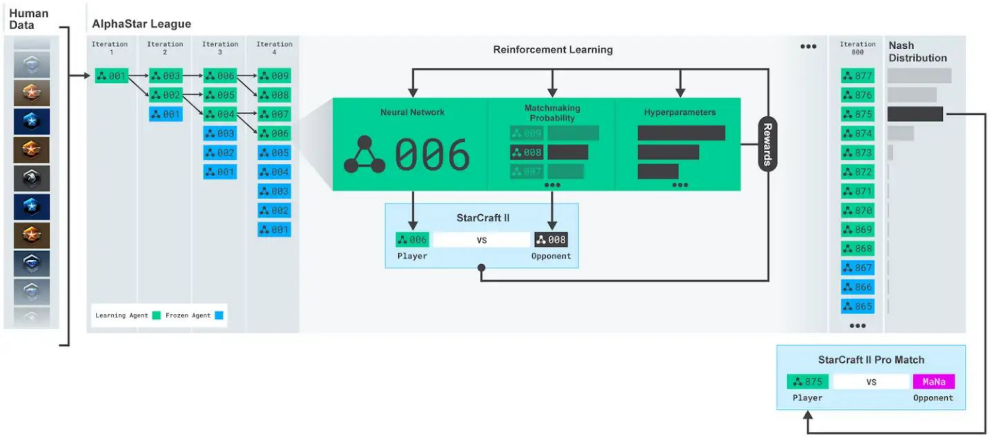
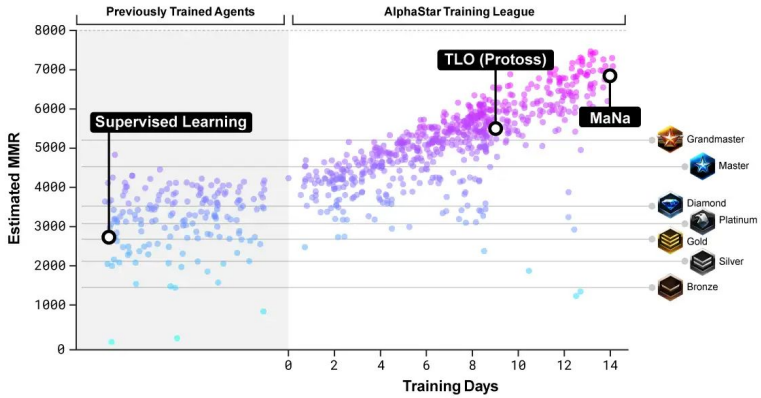
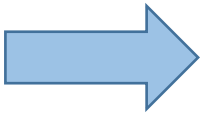
Artificial Intelligence - Machine Learning





AlphaStar League was trained based on next configuration:

- 14 days
- 16 TPUs for each agent



200 full years playing StarCraft

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OFF-EXAM CONTENT


FALL OF AIUR
HOW DEEPMIND'S
ALPHASTAR
BECAME A STARCRAFT
GRANDMASTER

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Computer Vision

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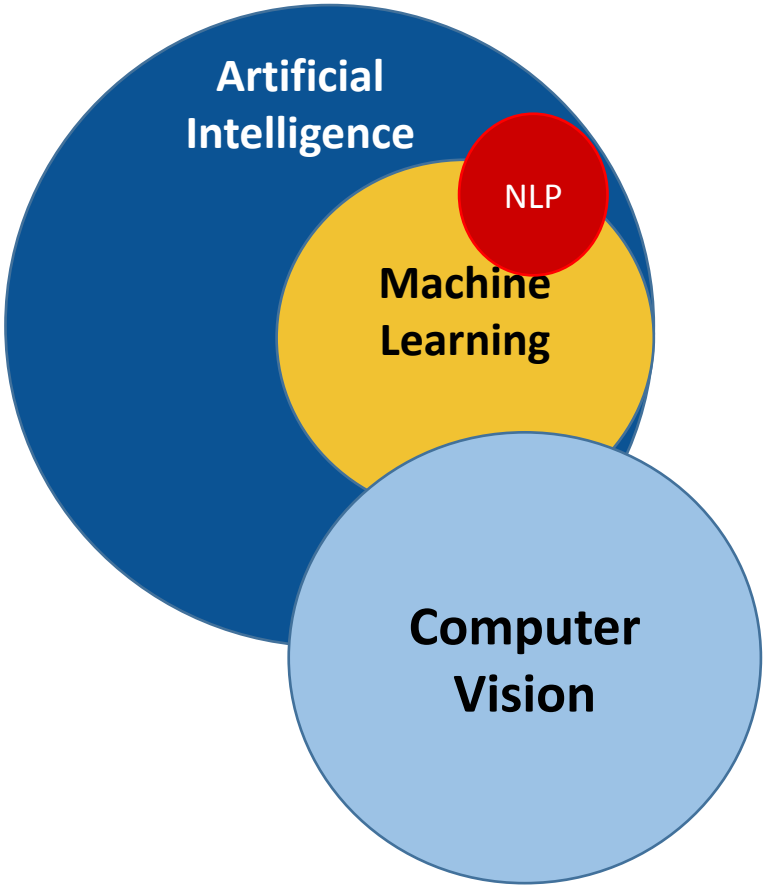
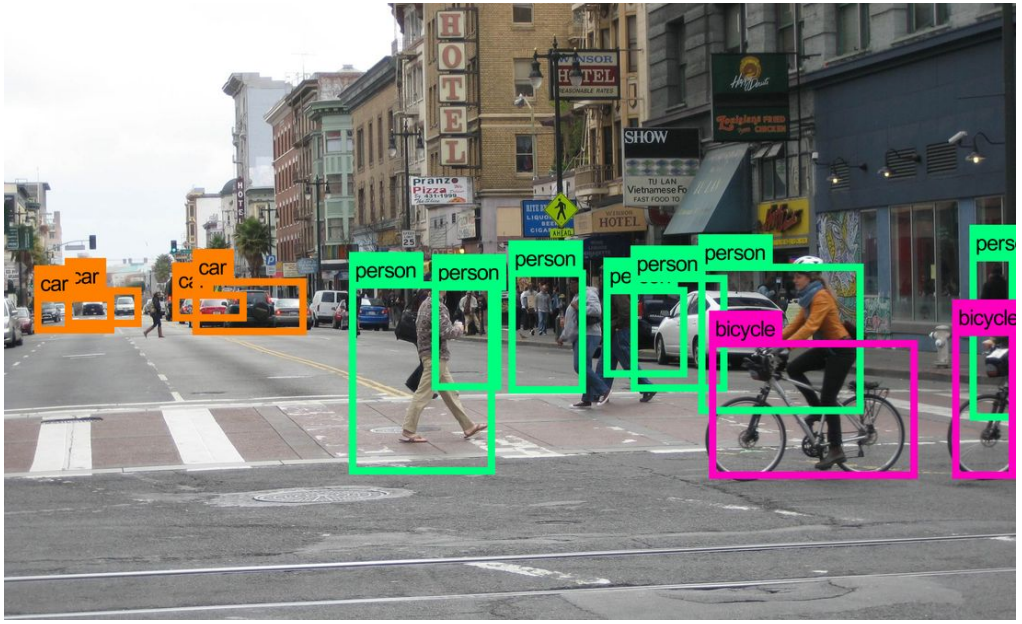
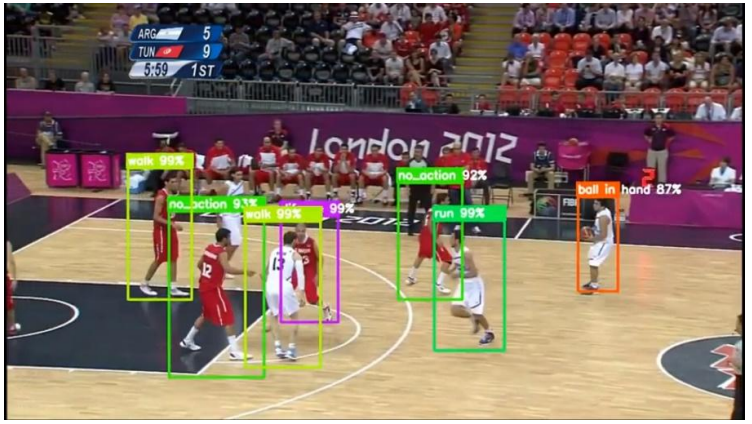
Computer Vision



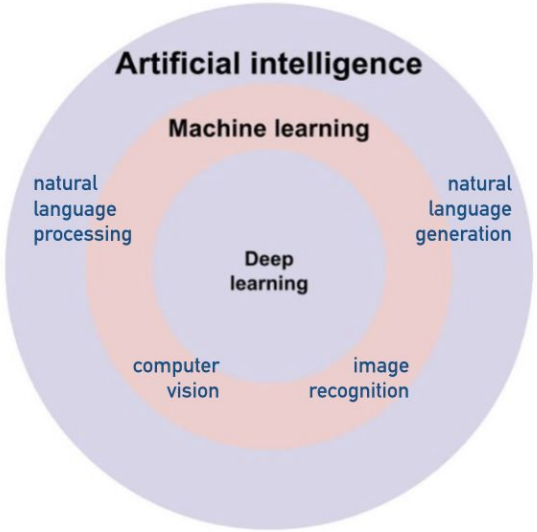
Computer Vision

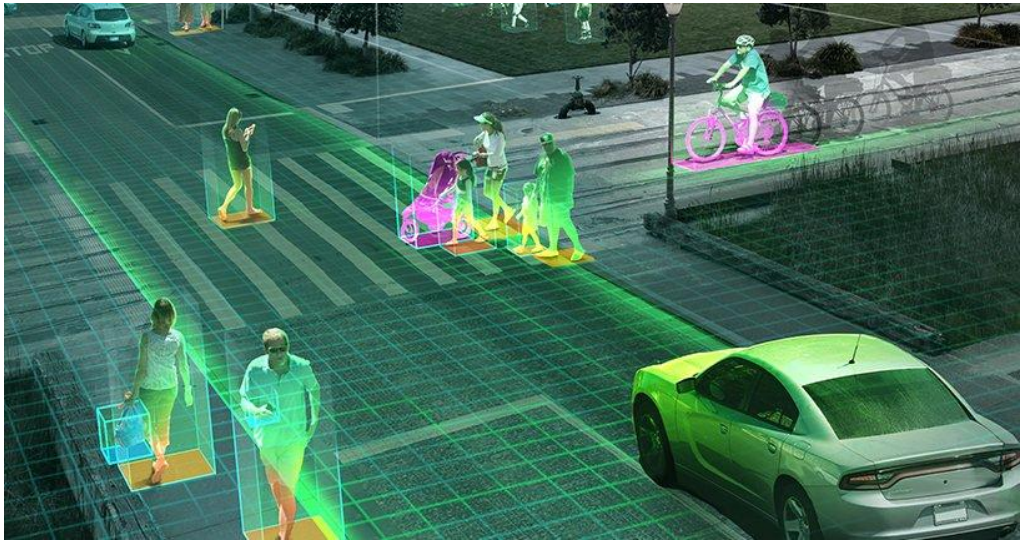
Computer vision is a field of artificial intelligence that trains computers to interpret and understand the visual world by using images and videos from cameras.





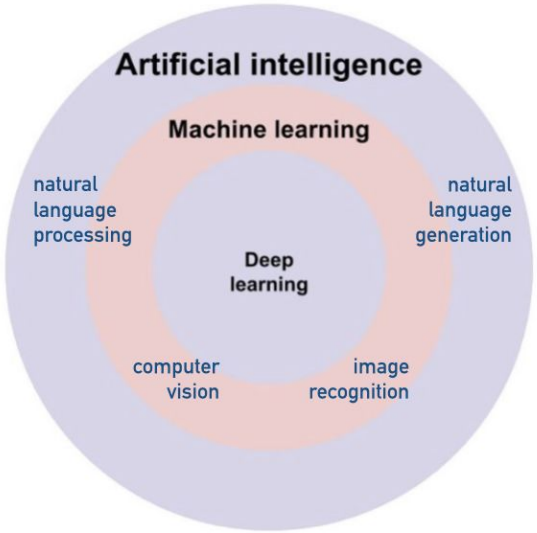
Computer Vision





Computer vision, in the context of computer vision, is the ability of machines to understand (including being able to infer something about it) the input image and its contents. Computer vision uses image processing algorithms to solve some of its tasks.

Computer Vision



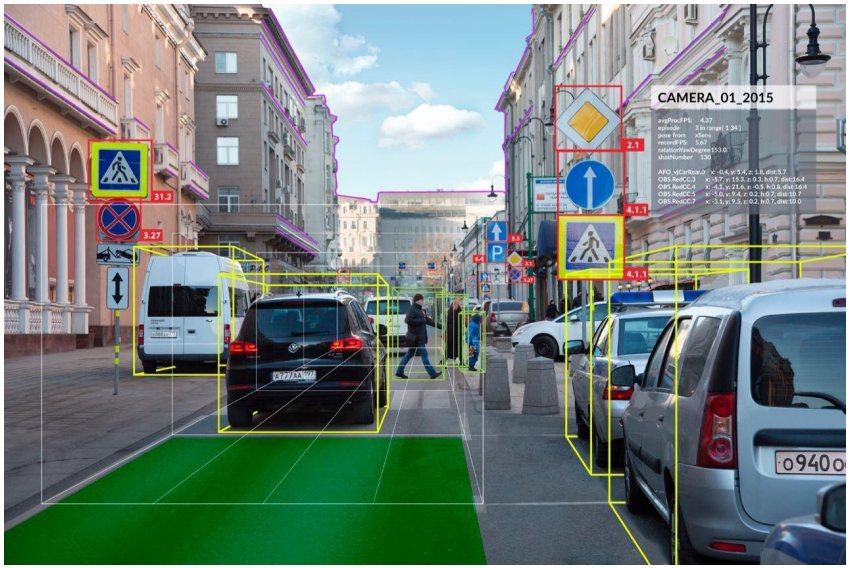
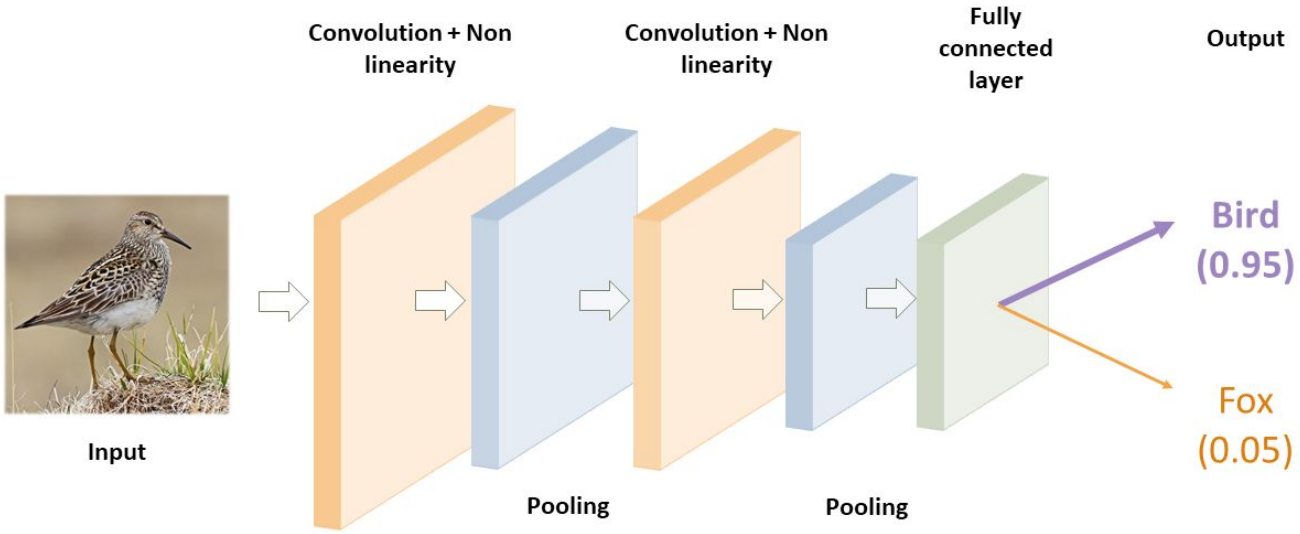


Image recognition, in the context of computer vision, is the ability of machines to identify objects, places, people, ..., anything which is in the input image. Image recognition uses image processing algorithms to solve some of its tasks.

Computer Vision

A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning algorithm which can take in an input image, assign importance (learnable features and biases) to various aspects/objects in the image and be able to differentiate one from the other.



Computer Vision

was it done by a human?

Computer Vision

real picture

Input picture

Deep Neural Network

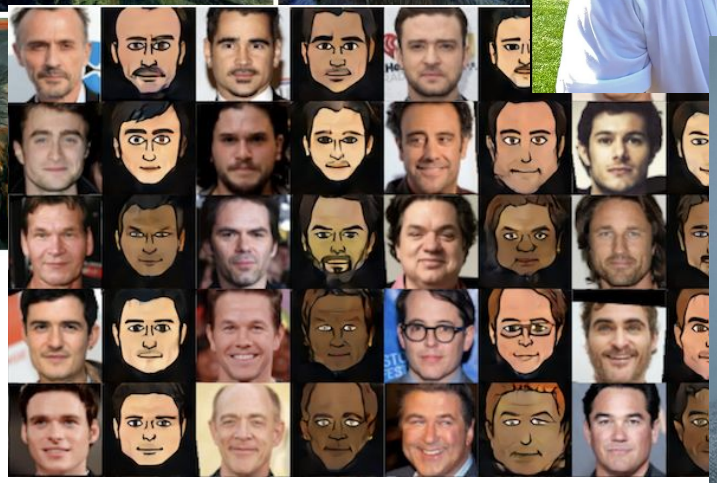
was it done by a human? NO

Computer Vision

What more can we do using Computer vision?

Art generation

Deep fake



Emoji Generation

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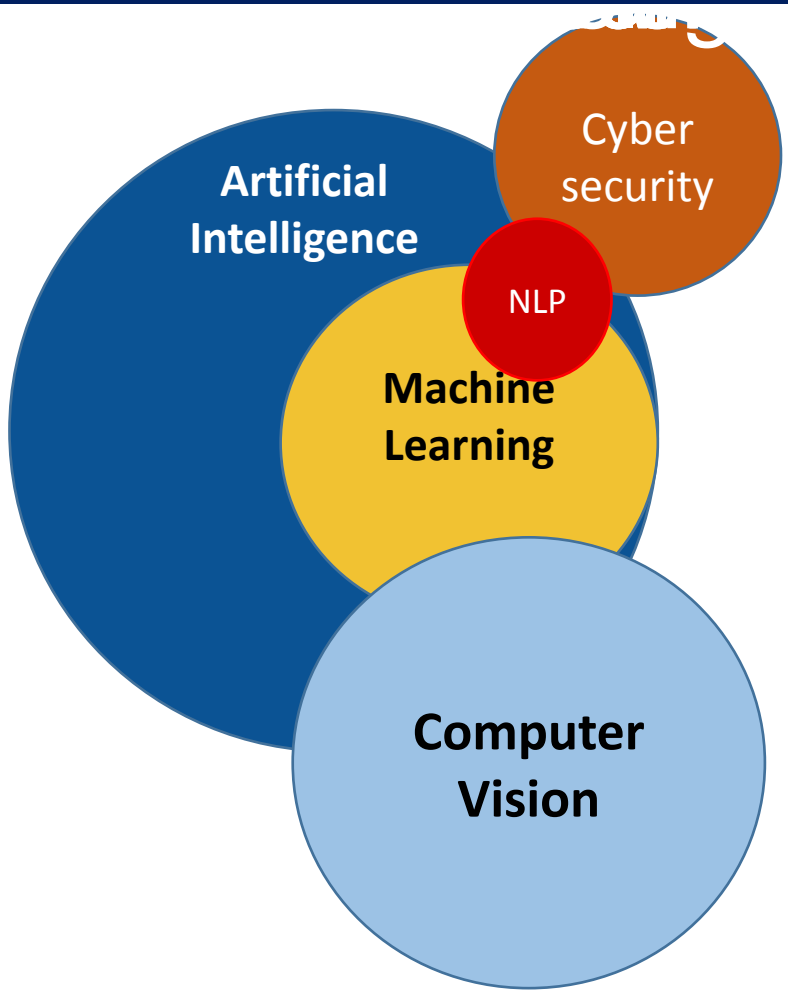
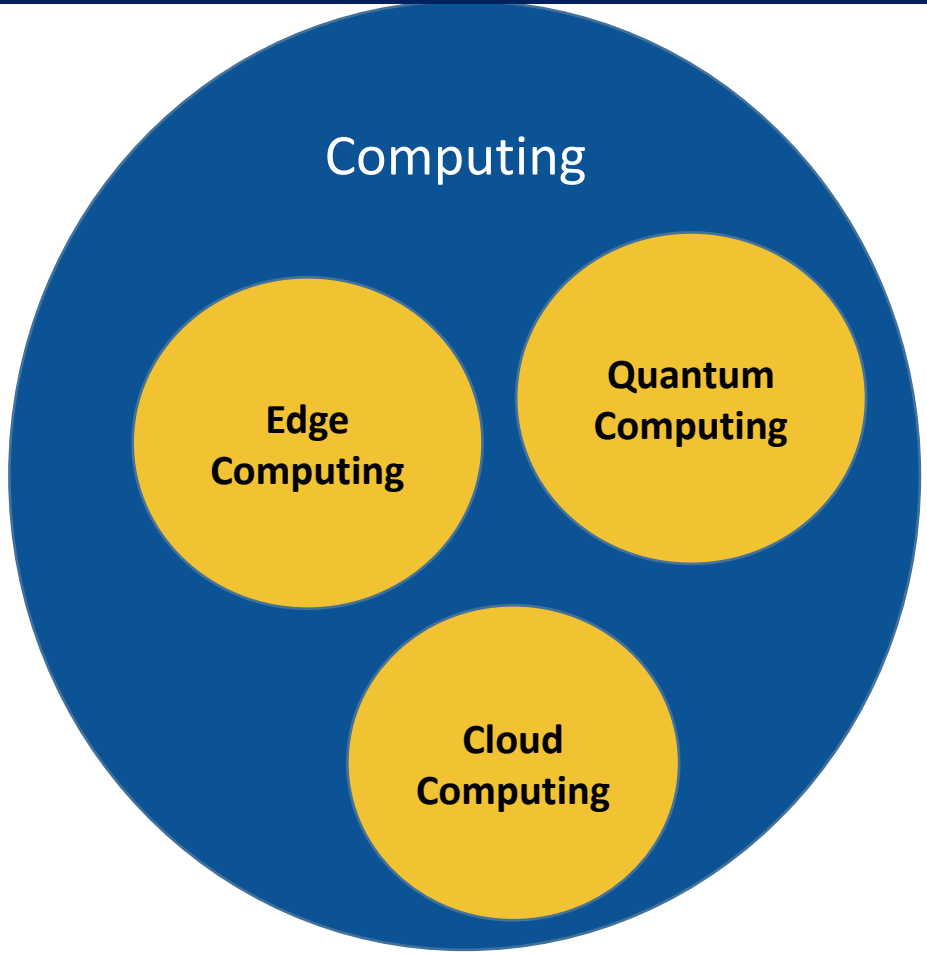
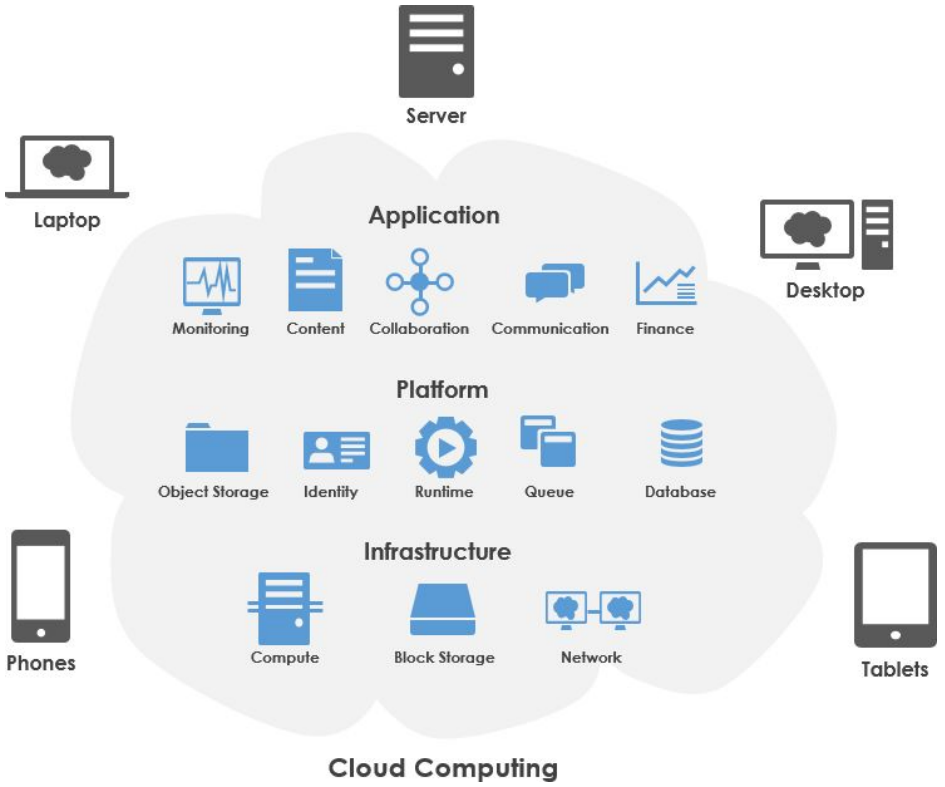
Computation - Cloud

Computation





Computation - Cloud computing



IBM Cloud

Alibaba Cloud

Azure

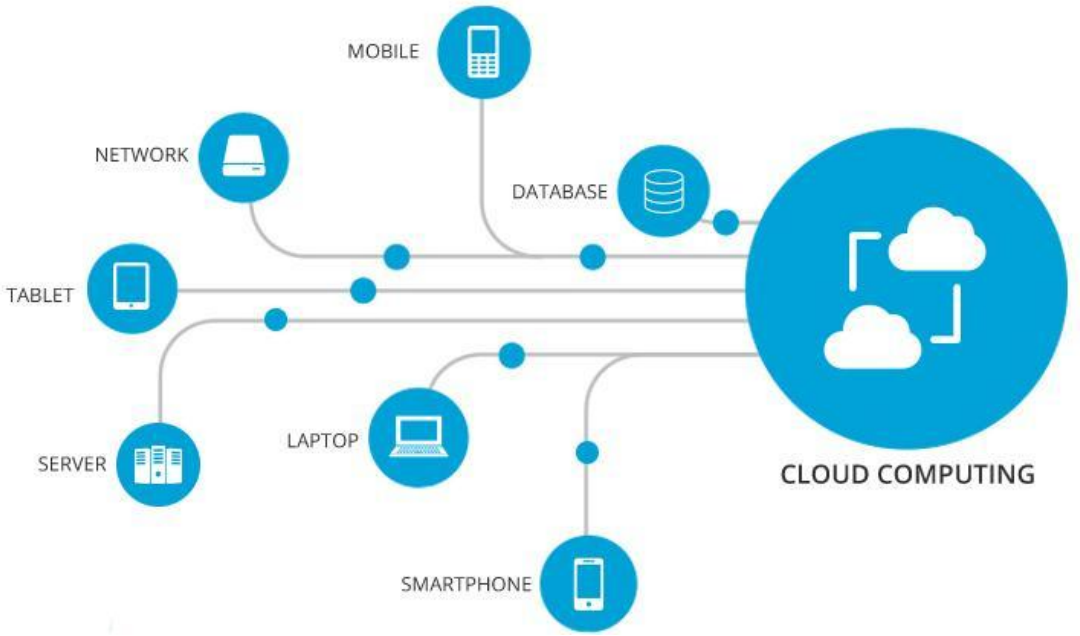
aws

ORACLE CLOUD

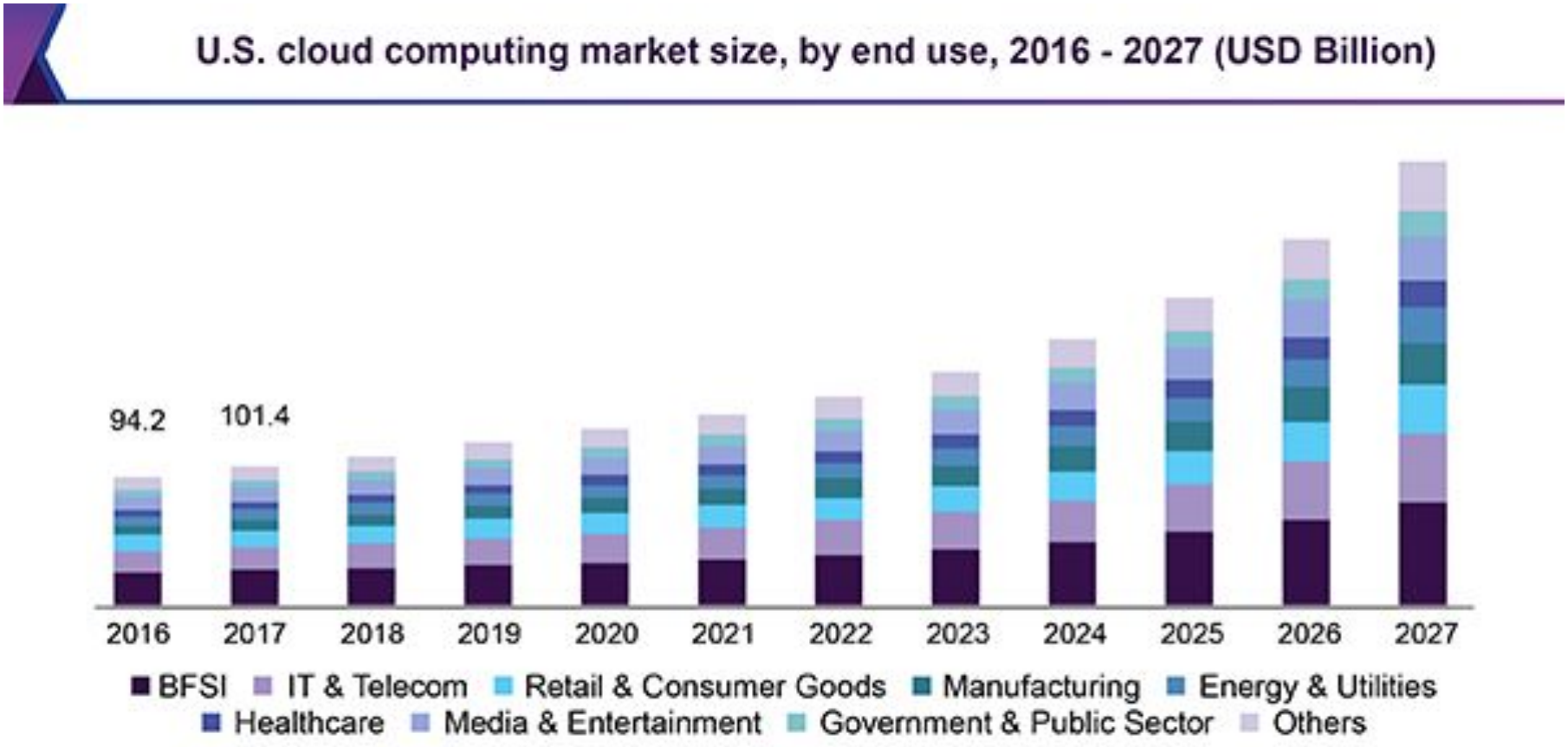
Computation - Cloud computing

Cloud computing is the **on-demand** availability of computer system resources, especially data storage and computing power, without direct active management by the user.

- Pay for use as needed.
- Global scale.
- Big Performance.



Computation - Cloud computing



Source: www.grandviewresearch.com

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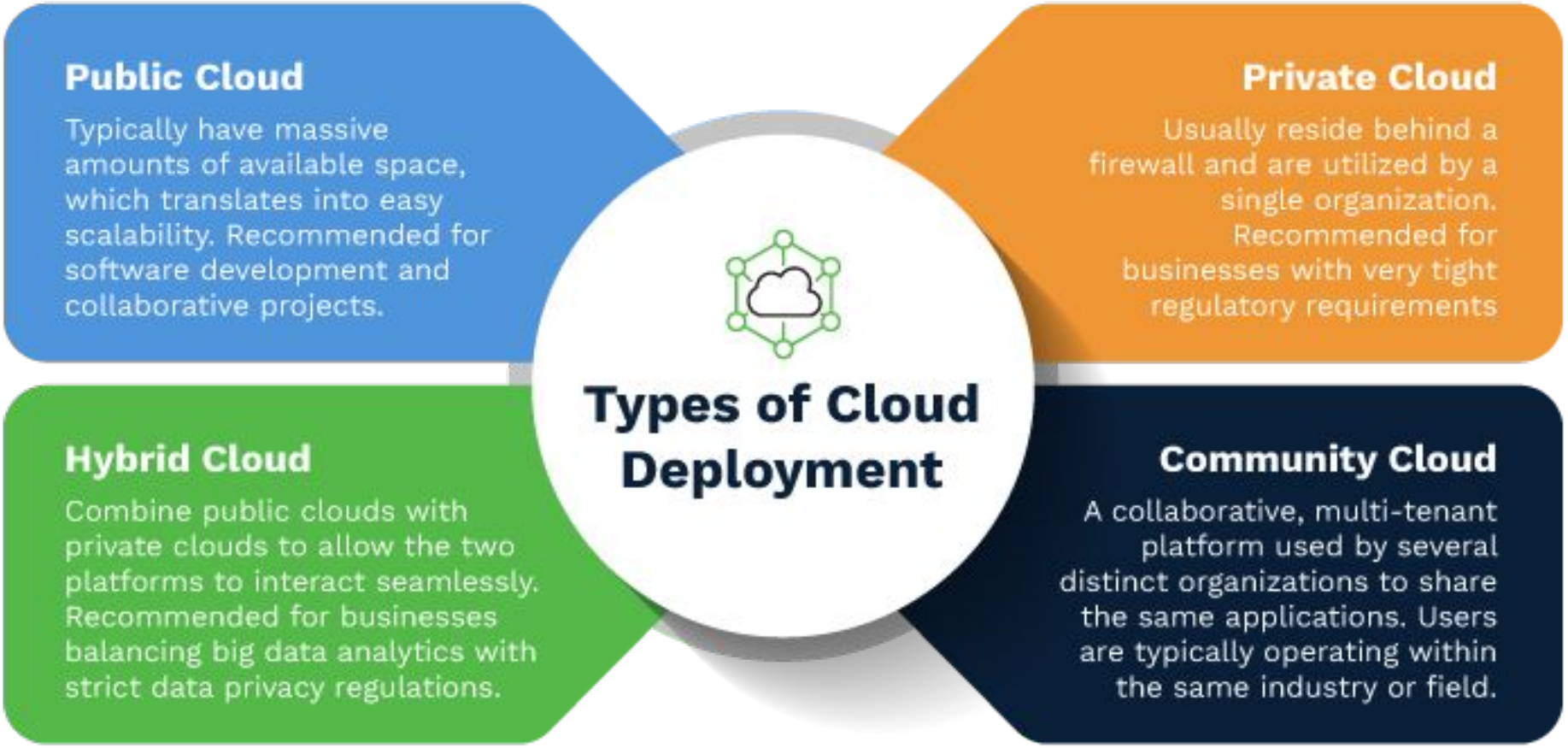
Computation - Cloud computing



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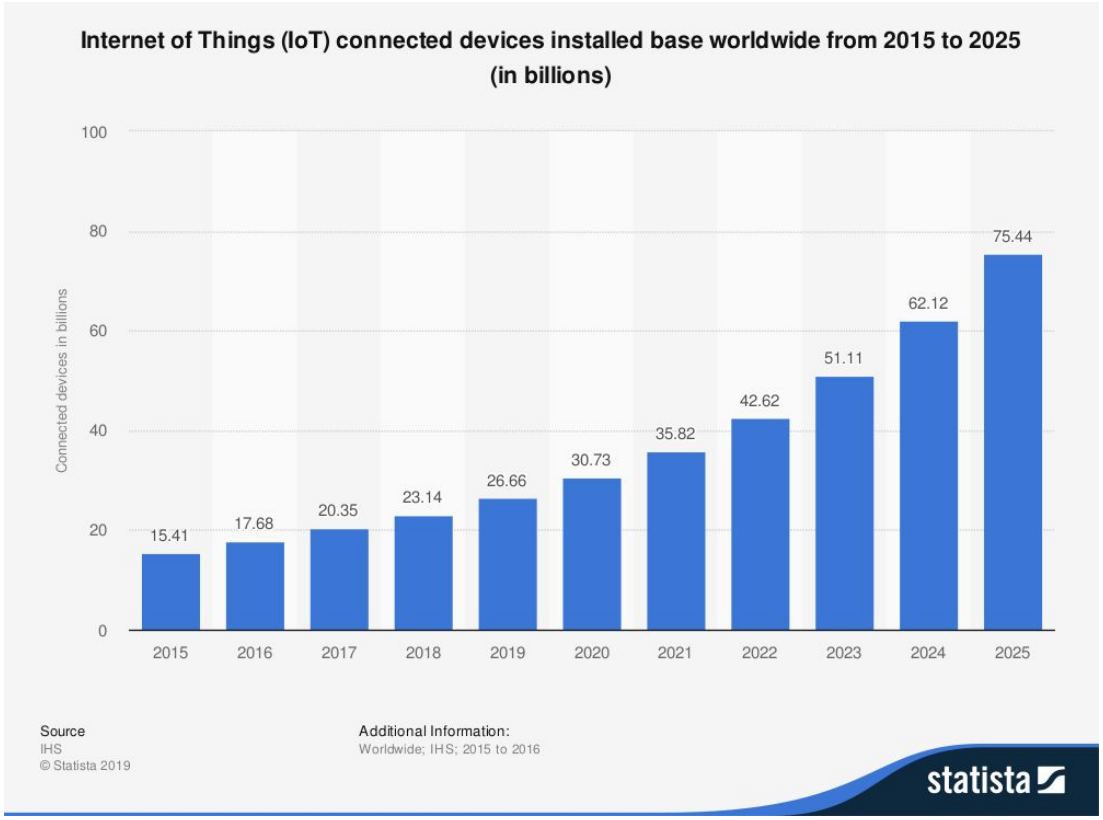
Computation - Edge

Computation - Edge computing



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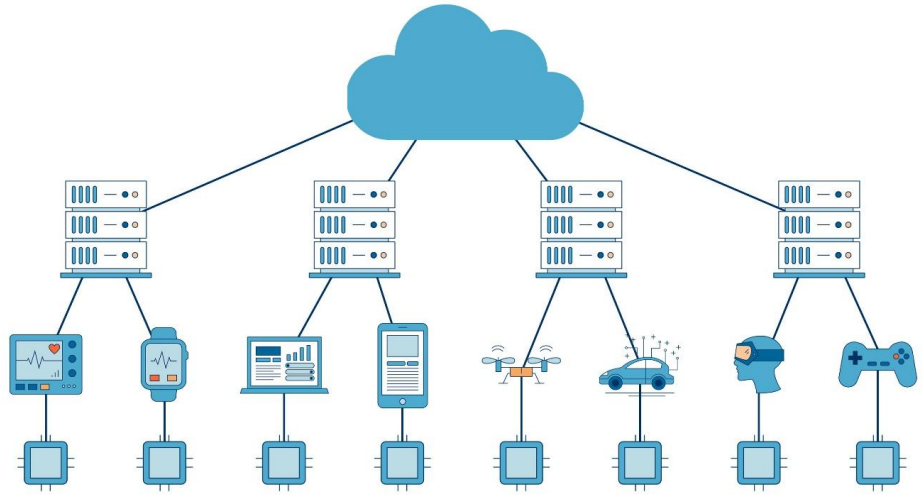
Computation - Edge computing

Edge computing is a distributed computing paradigm that brings computation and data storage closer to the location where it is needed, to **decrease response times**, **save bandwidth** and **keep privacy**.



Computation - Edge computing

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Intel NCS 2

Price: $79.99

Coral Edge TPU Accelerator

Price: $74.99

Jetson Nano Nvidia

Price: $99.00

Coral Edge TPU Board

Price: $140.99

New cheap devices to run Machine Learning Inference on the edge

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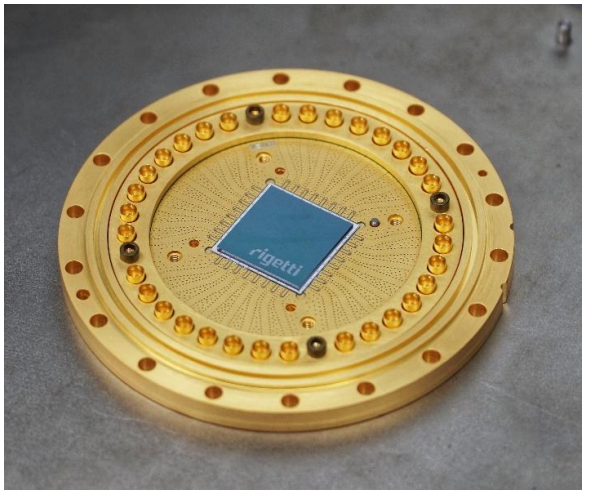
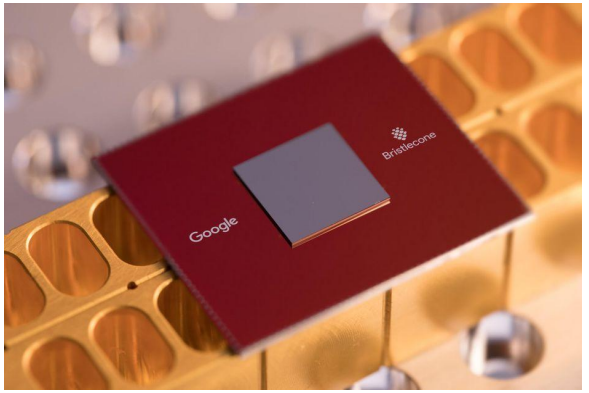
Computation - Quamtum

Computation - Quantum computing

Quantum computers are machines that use the properties of **quantum physics** to store data and perform computations.





The basic unit of memory in quantum computers is a quantum bit or **qubit**.

Computation - Quantum computing

Quantum computing is the use of quantum phenomena such as superposition and entanglement to perform computation.

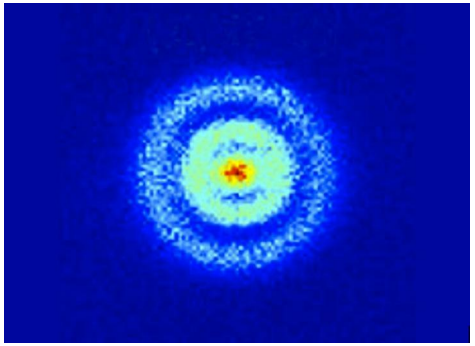
- **Quantum Superposition** is a property of quantum systems to be in multiple states at the same time until it is measured.

- **Quantum entanglement** is a physical phenomenon that occurs when a pair or a group of particles is generated, interact, or share spatial proximity in a way such that the quantum state of each particle of the pair or group cannot be described independently of the state of the others, including when the particles are separated by an enormous distance.

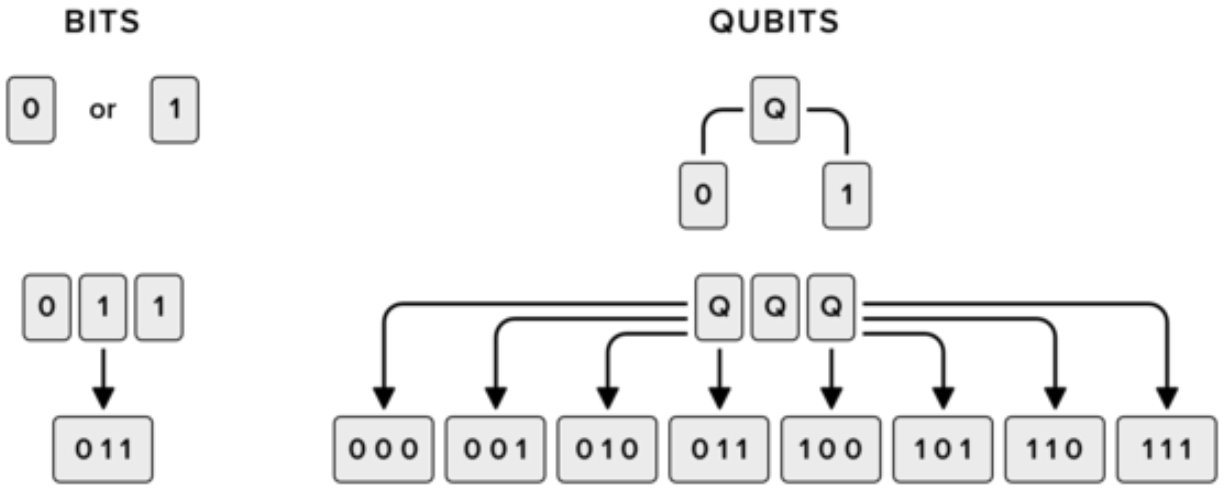
Computation - Quantum computing

Qubits are made using physical systems, such as the spin of an electron or the orientation of a photon.

- A traditional computer needs three bits to represent any integer number between 0 and 8
- A quantum computer of three qubits can represent every number between 0 and 8 at the same time.



Hydrogen Atom



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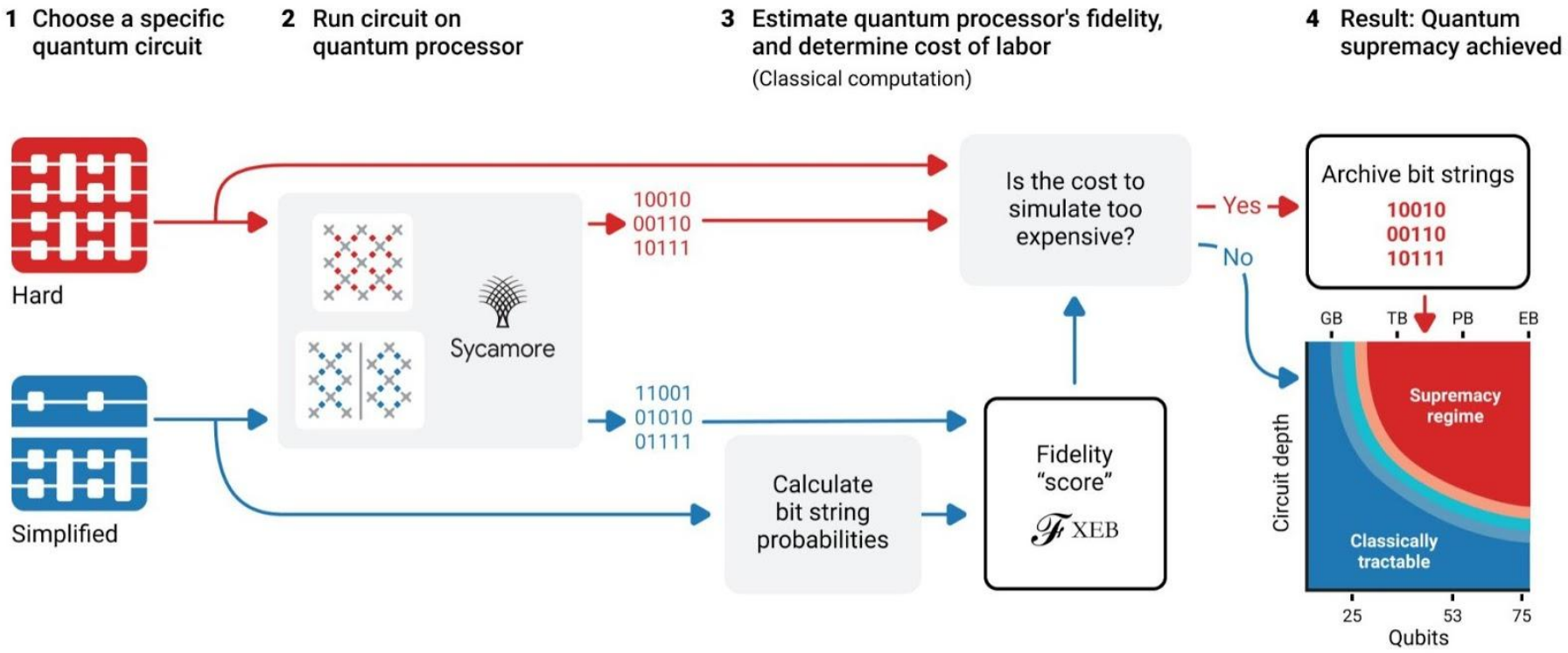
The challenge is in placing and then addressing that single atom.

Computation - Quantum computing

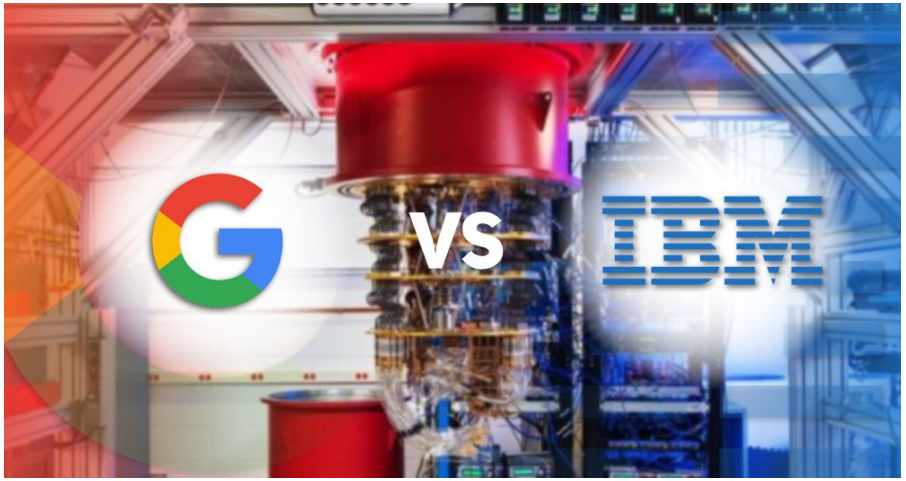
Operations on qubits are performed using a mix of Matrix Multiplication, Complex Numbers, and Quantum Logic Operators rather than the simple truth-functional operators of Boolean Algebra.



OFF-EXAM CONTENT

Computation - Quantum computing

Quantum supremacy or Quantum advantage is the goal of demonstrating that a programmable quantum device (quantum computer) can solve a problem that no classical computer can solve in any feasible amount of time.



Quantum Supremacy: A Test on the IBM Quantum Computer

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The news of achieving quantum supremacy by Google AI has received critical acclaim by a number of researchers in the field of quantum computing. Here, we implement cross entropy bench marking procedure on the IBM quantum computer and report the results obtained. The backend used for this purpose is IBM Qurense. Through this experiment, we observe an exponential decay in the fidelity. Noticing that the observations are similar to ones obtained by Google AI, we conclude that by increasing the number of qubits, it is possible to achieve quantum supremacy on IBM's quantum computer.

I. INTRODUCTION

Ever since Deutsch's proposal about a quantum Turing machine, the idea of quantum computation was made concrete. This sparked an interest in the community to search for possible methods of building such devices as well as raising practical issues like decoherence and fault tolerance of such a device. Hence, the birth of the field of Quantum Information and Computation took place. Over the years, many advances in this field, in both theoretical and experimental areas, have taken place. In the theoretical arena, ideas like quantum teleportation[12] and quantum superdense coding[13] increased the possibilities that could be explored in practical quantum computation as well as posing experimental challenges.

Many approaches have been undertaken for the creation of a working quantum computer. People have tried quantum computation using trapped cold atoms in a periodic potential. The advantage of such a system is that there is very low decoherence[7]. Another proposal consisted of using optics for creation of a quantum computer[8]. Other possibilities included topological quantum computer[9], NMR based quantum computation[11], quantum computation using quantum dots[10,19] and many others. The present day quantum computer at IBM is made up of superconducting qubits[17] with as much as 53 qubits. Hence, a landmark was achieved in development of physically realizable quantum computer.

The birth of the idea of quantum supremacy lies in the paper published by Shor titled "Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer"[15]. In this paper, he outlined the now famously known Shor's algorithm for prime factorization. Here, we see one of the first instances where a quantum computer is able to provide a speedup when compared to the best classical algorithms. In fact, this algorithm is able to provide an exponential speedup when compared to the best classical algorithm. On a similar line is the Grover's search algorithm[14], which also provides a square root speedup in comparison to the best classical search algorithm. These, along with other algorithms indicated to the possibility that quantum computers might be better than classical computers in terms of the problems that can be solved on it. Quantum supremacy is said to be achieved when a quantum computer is said to have solved a problem which cannot be solved by a classical computer (keeping practical considerations in mind). The term was first coined by Preskill.

In the paper published by Google AI titled "Quantum supremacy using a programmable superconducting processor", it was claimed that quantum supremacy had been reached. The method used by them is called random circuit sampling. The idea is to use randomized non commuting gates and see the sample's probability distribution. In the experiment conducted by Google on Sycamore, 53 qubits arranged in a square lattice with a depth of 14 random gates was used. It was estimated that sampling the output probability distribution would require more than one petabyte of storage as well as high computation time. They have demonstrated that despite having a large amount of errors, they are able to sample the distribution in 5 hours, which a supercomputer would require at least 2.5 days.

Also, along with practical importance, establishing quantum supremacy also has theoretical importance. Supremacy experiments directly refute the "Extended-Church-Turing thesis" which states that classical computers have the ability to simulate any physical process with a polynomial overhead[4].

In this paper, we perform cross entropy benchmarking technique on the IBM quantum computer. This is done by calculation of the fidelity and plotting its variation with number of qubits and the depth of the circuit. By depth, we refer to the number of times the circuit is repeated. Using this we verify that the results obtained by Google AI and also show that a similar pattern is followed by the IBM quantum computer. Hence, we can conclude, that for 53 qubits or higher, quantum supremacy can be achieved even by the IBM quantum computer.

The outline for the paper is as follows: in Section 2, we arrive at the equation for cross entropy fidelity which is used for benchmarking purpose. In section 3,

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