Cloud and Quantum Computing

Cloud computing (CC) is the delivery of different services through the Internet. These resources include tools and applications like data storage, servers, databases, networking, and software. The National Institute of Standards and Technology (NIST) defines general characteristics of Cloud Computing as follows:

- **On-Demand Self-Service –** It is one of the significant and essential features of Cloud Computing. It enables the client to constantly monitor the server uptime, abilities, and allotted network storage. Users can run and configure their own computing resources without human help. In other words, a manufacturing organization can provision additional computing resources as needed without going through the cloud service provider. This can be a storage space, virtual machine instances, database instances, and so on.
- **Broad Network Access:** Cloud Computing resources are available over the network and can be accessed by diverse customer platforms. In other words, cloud services are available over a network – ideally high broadband communication link – such as the Internet, or in the case of private clouds, it could be a local area network (LAN).
- **Resource Pooling –** It means that multiple customers are serviced from the same physical resources. It is a multi-client strategy that can be applied to data storage services, processing services, and bandwidth-provided services. The administration process of allocating resources in real-time doesn't conflict with the client's experience. Providers' resource pool should be very large and flexible enough to service multiple client requirements and to provide economy of scale. When it comes to resource pooling, resource allocation must not impact performances of critical manufacturing applications.
- **Rapid Elasticity and Scalability:** One of the great things about cloud computing is the ability to quickly provision resources in the cloud as manufacturing organizations need them. And then to remove them when they don't need them. Cloud computing resources can scale up or down rapidly and, in some cases, automatically, in response to business demands. It is a key feature of cloud computing. The usage, capacity, and therefore cost, can be scaled up or down with no additional contract or penalties. This cloud characteristic enables the cost-effective running of workloads that require a vast number of servers but only for a short period.
- **Measured Service:** The utilization of resources is tracked, monitored, controlled, and reported for each occupant. This gives transparency to both the service provider and the consumer. The cloud system has a metering capability, which is leveraged to monitor billing, use of resources, and pay only for what has been used. For instance, the user pays only for the storage or bandwidth consumed, and not for potential bandwidth.

Technological Enablers

Cloud Computing is essentially a combination of many preexisting technologies. The key technological enablers for CC include the following:

- **Virtualization:** The key feature of CC is the idea of virtualization, which enables an operating system to run on several hardware deployments. It is one of the technologies that enable elasticity. Virtualization decouples the software from the hardware. It is the technology that uses a physical resource such as a server and divides it into virtual resources known as virtual machines. Several cloud infrastructures are built with virtual servers and virtual machines. Within a virtualized environment, some networking functionalities can stay on a physical server. CC lowers cost of operation by employing virtual machines, which are managed by the hypervisor. The hypervisor allocates resources to every virtual machine.
- **Grid computing –** It refers to a distributed architecture of a large number of computers connected to solve a complex problem. It allows the computers on the network to work on a task together, behaving like a supercomputer. Grid technologies leverage the computational power of the available computers by managing them in the grid infrastructure. Grid or distributed computing is a special type of parallel computing that relies on complete computers connected to a computer network. CC is regarded as an evolution of grid computing. It provides scalable computing resources on a payment basis
- **Distributed Computing:** Cloud computing is distributed computing paradigm, which allows for a highly elastic resource pool. Clouds are built to share computing, memory, storage, and other resources. Load balancing establishes an algorithm for assigning tasks to the cloud nodes. All computers in distributed systems are quite independent and do not share resources. Each computer has its own responsibility.

- **Multitenancy –** This involves sharing a single set of infrastructure across several customers and stakeholders. Virtualization helps to deliver infrastructure multitenant capability. Multitenancy implies that multiple tenants share computational resources, storage, database, services, computing, memory, and other resources with other tenants. This sharing violates the confidentiality of tenants. For secure multitenancy, there should be a degree of isolation among tenant data.
- **Elasticity –** This refers to the ability to automatically scale up and handle high volumes of traffic or scale down and use less resources when needed, maximizing the use of resources. It implies that users can grow or shrink infrastructure resources dynamically based on the current demand. When automated, elasticity allows a cloud provider to continuously monitor a customer's infrastructure and scale it on-demand.

Cloud Service Models

Cloud computing is not a single product or piece of technology. Rather, it is a system, primarily providing three different services. The services provided by Cloud Computing are:

- **Infrastructure-as-a-Service (IaaS)** – This is the simplest of cloud computing offerings. It involves the delivery of huge computing resources such as the capacity of storage, processing, operating systems, servers, computing power, firewalls, bandwidth, and network, which form the underlying cloud infrastructure. It allows users to rent any form of hardware and software and remotely access computing resources on a pay-per-use basis. aaS enables end-users to scale and shrink resources on an as-needed basis, reducing the need for high, up-front capital expenditures or unnecessary on-premises or 'owned' infrastructure and for overbuying resources to accommodate periodic spikes in usage. The major advantages of IaaS are pay per use, security, and reliability. Popular examples of the IaaS system include IBM Cloud and Microsoft Azure.
- **Platform-as-a-Service (PaaS)** – This supports the development of web applications quickly and easily. The customer can build his own applications, which run on the cloud provider's infrastructure. With PaaS, the cloud provider hosts everything — servers, networks, storage, operating system software, middleware, databases — at their data center.
- **Software-as-a-Service (SaaS) –** It is the delivery of applications-as-a-service, probably the version of cloud computing that most people are used to on a day-to-day basis. SaaS is application software that's hosted in the cloud and that you access and use via a web browser, a dedicated desktop client, or an API that integrates with your desktop or mobile operating system. It involves the licensure of a software application to customers. Licenses are typically provided through a pay-as-you-go model or on-demand. In most cases, SaaS users pay a monthly or annual subscription fee; some may offer 'pay-as-you-go' pricing based on your actual usage.

Cloud Deployment Models

The **Cloud Deployment Model** identifies the specific type of cloud environment based on ownership, scale, and access, as well as the cloud's nature and purpose. Different types of cloud computing deployment models are:

- **Public Cloud:** The public cloud makes it possible for anybody to access systems and services. It allows users to access the cloud through interfaces using web browsers. The public cloud is one in which cloud infrastructure services are provided over the Internet to the general people or major industry groups. The infrastructure in this cloud model is owned by the entity that delivers the cloud services, not by the consumer. It is a type of cloud hosting that allows customers and users to easily access systems and services. This form of cloud computing is an excellent example of cloud hosting, in which service providers supply services to a variety of customers. The most common uses of public clouds are for application development and testing, non-mission-critical tasks such as file-sharing, and e-mail service.
- **Private Cloud –** It is the exact opposite of the public cloud deployment model. It is a one-on-one environment for a single user (customer). There is no need to share your hardware with anyone else. It is also called the "internal cloud" & it refers to the ability to access systems and services within a given border or organization. The private cloud gives the greater flexibility of control over cloud resources. A private cloud is especially suitable for companies that seek to safeguard their mission-critical operations or for businesses with constantly changing requirements. The private cloud offers bigger opportunities that help meet specific organizations' requirements when it comes to customization.

- **Hybrid Cloud –** It is the combination of a public and private cloud. Creating a hybrid cloud means that a company is using the public cloud but also owns on-premises systems, and there is a connection between the two. This is a very useful model that allows for a smooth transition into the public cloud over a longer period of time. Due to security requirements or data protection, some companies can't operate only in the public cloud, so they may choose the hybrid cloud to combine the requirements with the benefits of a public cloud. With a hybrid cloud, you may host the app in a safe environment while taking advantage of the public cloud's cost savings.
- **Community Cloud –** It allows systems and services to be accessible by a group of organizations. It is a distributed system that is created by integrating the services of different clouds to address the specific needs of a community, industry, or business. The infrastructure of the community could be shared between the organization which has shared concerns or tasks. It is generally managed by a third party or by the combination of one or more organizations in the community.

Quantum Computing

Quantum computing is an area of computing focused on developing computer technology based on the principles of quantum theory (which explains the behavior of energy and material on the atomic and subatomic levels). In quantum computing, operations instead use the quantum state of an object to produce what's known as a qubit. A ***qubit*** is the basic unit of information in quantum computing. Classical bits are binary and can hold only a position of 0 or 1, but qubits can hold a superposition of all possible states.

Quantum refers to the quantum mechanics that the system uses to calculate outputs. In physics, a quantum is the smallest possible discrete unit of any physical property. It usually refers to properties of atomic or subatomic particles, such as electrons, neutrinos, and photons.

Quantum computers perform calculations based on the probability of an object's state before it is measured - instead of just 1s or 0s - which means they have the potential to process exponentially more data compared to classical computers. The power of quantum computers grows exponentially with more qubits.

Application Areas of Quantum Computing

A quantum computer can't do everything faster than a classical computer, but there are a few areas where quantum computers have the potential to make a big impact.

- **Quantum Simulation:** Quantum computers work exceptionally well for modeling other quantum systems because they use quantum phenomena in their computation. This means that they can handle the complexity and ambiguity of systems that would overload classical computers. Examples of quantum systems that we can model include photosynthesis, superconductivity, and complex molecular formations.
- **Cyber Security:** The online security space currently has been quite vulnerable due to the increasing number of cyber-attacks occurring across the globe on a daily basis. Although companies are establishing necessary security frameworks in their organizations, the process becomes daunting and impractical for classical digital computers. And, therefore, cybersecurity has continued to be an essential concern around the world. Quantum computing with the help of machine learning can help in developing various techniques to combat these cybersecurity threats. Additionally, quantum computing can help in creating encryption methods, also known as quantum cryptography. With quantum computing, cracking encryption becomes much easier, which poses a threat to data security.
- **Optimization –** It is s the process of finding the best solution to a problem given its desired outcome and constraints. In science and industry, critical decisions are made based on factors such as cost, quality, and production time – all of which can be optimized. By running quantum-inspired optimization algorithms on classical computers, we can find solutions that were previously impossible. This helps us find better ways to manage complex systems such as traffic flows, airplane gate assignments, package deliveries, and energy storage.
- **Quantum Machine Learning**: Machine learning on classical computers is revolutionizing the world of science and business. However, training machine learning models comes with a high computational cost, and that has hindered the scope and development of the field. To speed up progress in this area, we're exploring ways to devise and implement quantum software that enables faster machine learning.

Virtual, Augmented and Mixed Reality

Virtual Reality (VR) is the use of computer technology to create a simulated environment. Unlike traditional user interfaces, VR places the user inside an experience. Instead of viewing a screen in front of them, users are immersed and able to interact with 3D worlds. By simulating as many senses as possible, such as vision, hearing, touch, even smell, the computer is transformed into a gatekeeper to this artificial world. To get a better understanding of how the technology is used, let's break down the different types of VR:

- **Non-Immersive Virtual Reality** – It refers to a virtual experience through a computer where a user can control some characters or activities within the software, but the environment is not directly interacting with them. Non-immersive virtual experiences are often overlooked as a virtual reality category because it's already so commonly used in everyday life. This technology provides a computer-generated environment, but allows the user to stay aware of and keep control of their physical environment. Non-immersive virtual reality systems rely on a computer or video game console, display, and input devices like keyboards, mice, and controllers. A video game is a great example of a non-immersive VR experience. All actions or features are rather interacting with the characters within. These types of experiences have become more advanced in recent years with video games like Wii Sports, where the system actually detects your motion and translates it on screen.
- **Fully Immersive Virtual Reality** – It is the opposite of non-immersive reality. Fully-immersive simulations give users the most realistic simulation experience, complete with sight and sound. It would feel as if the user is physically present in the virtual world and the events occurring there are happening to them. This is an expensive form of virtual reality that involves helmets, gloves, and body connectors with sense detectors. These are connected to a powerful computer. To experience and interact with fully-immersive virtual reality, the user needs the proper VR glasses or a head mount display (HMD). VR headsets provide high-resolution content with a wide field of view. The display typically splits between the user's eyes, creating a stereoscopic 3D effect, and combines with input tracking to establish an immersive, believable experience. This type of VR has been commonly adopted for gaming and other entertainment purposes, but usage in other sectors, namely education, is increasing now as well.
- **Semi-Immersive Virtual Reality** – It is a mixture of non-immersive and fully immersive virtual reality. Semi-immersive virtual experiences provide users with a partially virtual environment. It will still give users the perception of being in a different reality when they focus on the digital image, but also allows users to remain connected to their physical surroundings. Semi-immersive technology provides realism through 3D graphics, a term known as vertical reality depth. More detailed graphics result in a more immersive feeling. This category of VR is used often for educational or training purposes and relies on high-resolution displays, powerful computers, projectors, or hard simulators that partially replicate the design and functionality of functional real-world mechanisms. Semi-immersive virtual reality is the most cost-effective and commonly used among all forms of virtual reality.

Augmented Reality (AR) is the deploying of interactive digital elements over the surrounding real-world objects. This technology is all about enhancing the real world with the use of virtual elements through a visual device. This technology allows to visualize the real-life environment with a digital augmentation overlay, being a highly visual and interactive method with digital content such as sounds, videos, graphics and GPS in real working environments through cameras. The different types of augmented reality are:

- **Marker-based AR –** It is tied to a specific physical image pattern marker in a real-world environment to superimpose the virtual 3D object, text, or animation on top of it. The cameras continuously scan the input and put a mark for image pattern recognition to create its geometry. When the camera is not focused on a particular spot, the virtual 3D object is not shown properly. Marker-based AR image recognition system consists of several modules such as camera, image capturing, image processing, rendering as well as marker tracking. It is easy and budget-friendly to implement on the filters through a custom app for recognizing specific patterns using its camera feed. An example of this type of augmented reality is used by Instagram and Snapchat through filters and games.
- **Markerless AR –** It refers to the software application that does not require any camera to put a mark for image pattern recognition. Markerless AR places virtual 3D objects in the real-life environment by examining the features present in the real-time data. It relies on the hardware of any smartphone, including the camera, GPS, digital compass, and accelerometer, for the AR software to complete the

work efficiently. There is no need for an object tracking system due to the advancement in cameras, sensors, and AI algorithms. It merges the digital data with input from real-time data that are registered to a physical space. This is a technology that is characterized by its association with the visual effect of combining computer graphics with real-world images. There are four different categories of markerless AR such as:

- **Location-based AR –** It ties the augmentation to a specific place by reading the real-time data from a smartphone camera, GPS, digital compass as well as an accelerometer. Location-based AR does not require any cue from an image or object to deploy as it can predict the user's focus as a trigger to pair the real-time data with the present location. It also allows developers to attach interactive and useful digital content to geographical points of interest. It is beneficial to travelers to have a clear understanding of the whereabouts of a specific area through virtual 3D objects, videos, texts, links, and audio.
- **Projection-based AR –** It is a method of delivering digital data within a stationary context as projection-based AR focuses on rendering virtual 3D objects within or on a user's physical space. The user can freely move around the environment within a specified zone where the fixed projector and a camera for tracking are placed. It is used to create illusions on the depth, position, and orientation of an object by projecting artificial light onto the real flat surfaces. It eliminates the need for computers and screens as the instructions can be placed on a particular task space.
- **Superimposition AR –** It is used either for partial or full replacement of the original view of an object with an updated, augmented view of that object for the human eye. Superimposition AR provides multiple views of a target object with the option of showing extra relevant information on that object.
- **Outlining AR:** Special cameras are built for human eyes to perform outlining of the specified objects like boundaries and lines to help in certain situations. Outlining AR utilizes object recognition for a better understanding of the current environment. It is specially used in-car navigation systems for safe driving after sunset.

Their umbrella term, **Mixed Reality**, referred to any point in the middle, any hybrid of the physical and virtual. Mixed Reality is a blend of physical and digital worlds, unlocking natural and intuitive 3D human, computer, and environment interactions. This new reality is based on advancements in computer vision, graphical processing, display technologies, input systems, and cloud computing.

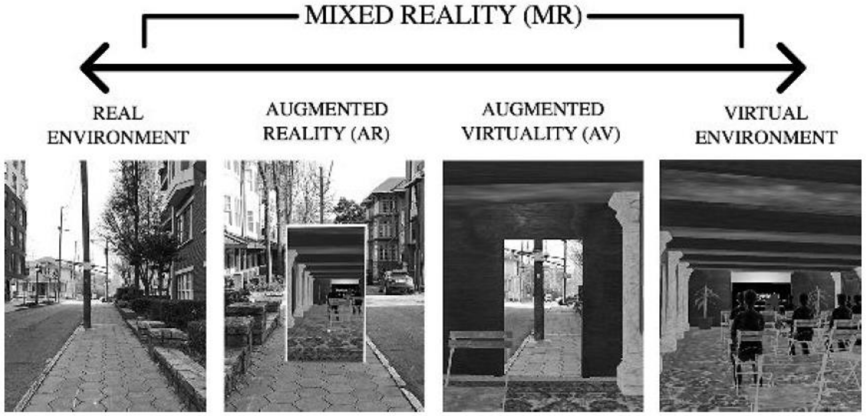

Figure 1. Reality Landscapes

Additive Manufacturing (3D Printing)

Additive Manufacturing (AM) is the formalized term for what used to be called Rapid Prototyping and what is popularly called 3D Printing. The term ***Rapid Prototyping (RP)*** is used in a variety of industries to describe a process for rapidly creating a system or part representation before final release or commercialization. The basic principle of this technology is that a model, initially generated using a *Three-dimensional Computer-Aided Design (3D CAD)* system, can be fabricated directly without the need for process planning.

AM Modeling Parameters

- **Form:** The initial models were used to help fully appreciate the shape and general purpose of a design.
- **Fit:** Improved accuracy in the process meant that components were capable of being built to the tolerances required for assembly purposes.
- **Function:** Improved material properties meant that parts could be properly handled so that they could be assessed according to how they would eventually work.

Additive Manufacturing Process

Step 1: CAD & Conceptualization

- All AM parts must start from a software model that fully describes the external geometry. This can involve the use of almost any professional CAD solid modeling software, but the output must be a 3D solid or surface representation.
- Conceptualization, sometimes referred to as ideation, can take many forms, from textual and narrative descriptions to sketches and representative models.

Step 2: Conversion to STL

- Every AM machine accepts the STL file format, which has become a de facto standard, and nowadays, nearly every CAD system can output such a file format.
- ***STL files*** are an unordered collection of triangle vertices and surface normal vectors. This file describes the external closed surfaces of the original CAD model and forms the basis for calculation of the slices.

Step 3: File Transfer to Machine

- Once the STL file has been created and repaired, it can be sent directly to the target AM machine. The STL file describing the part must be transferred to the AM machine. There may be some general manipulation of the file so that it is the correct size, position, and orientation for building.

Step 4: Machine Setup

- The AM machine must be properly set up prior to the build process. All AM machines will have at least some setup parameters that are specific to that machine or process. Some machines are only designed to run a few specific materials and give the user few options to vary layer thickness or other build parameters.
- Such settings would relate to the build parameters like the material constraints, energy source, layer thickness, timings, etc.

Step 5: Building

- Building the part is mainly an automated process, and the machine can largely carry on without supervision.
- Only superficial monitoring of the machine needs to take place at this time to ensure no errors have taken place like running out of material, power or software glitches, etc.

Step 6: Removal & Cleanup

- Once the AM machine has completed the build, the parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure, for example, that the operating temperatures are sufficiently low or that there are no actively moving parts.
- In all cases, the part must be either separated from a build platform on which the part was produced or removed from excess build material surrounding the part.

Step 7: Post Process

- Parts may be weak at this stage, or they may have supporting features that must be removed. Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use.
- ***Post-processing*** refers to the (usually manual) stages of finishing the parts for application purposes. This may involve abrasive finishing, like polishing and sandpapering, or the application of coatings.
- They may require priming and painting to give an acceptable surface texture and finish. This step may also involve heat treatment.

Step 8: Application

- Parts are now ready for use. This may require them to be assembled together with other mechanical or electronic components to form a final model or product.
- It should be noted that, although parts may be made from similar materials to those available from other manufacturing processes (like molding and casting), parts may not behave according to standard material specifications.
- AM processes inherently create parts with small voids trapped inside them, which could be the source for part failure under mechanical stress

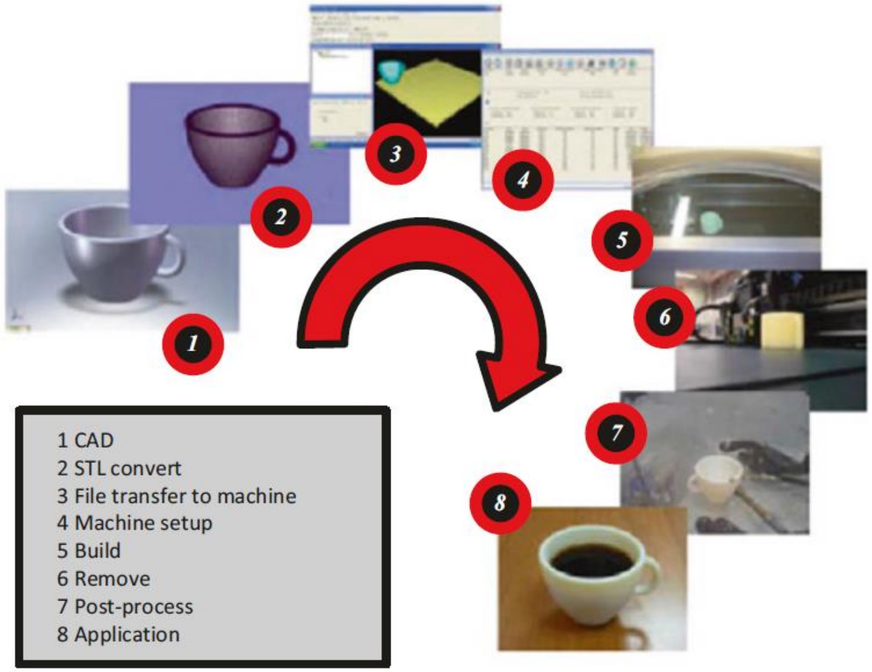

Figure 2. Additive Manufacturing Process.

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