Computer Science Future

15-110 – Wednesday 12/03

Quizlet9

Learning Goals

- Recognize and describe the impact of key future computing ideas, including:
  - **Cryptocurrencies**
  - **Generative AI**
  - **Deepfakes**
  - **Quantum computing**

Cryptocurrencies

How does money work?

A dollar bill does not have any intrinsic value; it's only worth $1 because we all agree it should be, and we all trust it will continue to hold that value.

This is how all currencies work! Usually we trust currencies because they are backed by a powerful system (a country or government), and we trust that system to not start printing a lot more money.

Cryptocurrencies are just like normal currencies, except that they are **independent** and **decentralized** – they are not backed by a country. So how can we trust in their value?

Collective Accounting

In most cryptocurrencies, the value of the currency is protected by the **collective** that uses the currency. Every person in the collective keeps track of the financial record of the system **independently**.

Whenever someone makes a transaction, they send that information as a message to the rest of the collective. Everyone in the collective can contribute computing power to verify the transaction on their own personal record. This is called **mining**. Occasionally, miners receive a bit of bonus currency for successful verification; this helps incentivize the distributed work.

If a majority of people (weighted by computing power) accept a transaction, it becomes official and is added to the public record.

Everything is public, but you can only spend money from an account if you have that account's **private key** – it uses asymmetric encryption!

Example Transaction

Suppose Soren wants to send Ariana 0.05 coin.

Soren posts a transaction to the collective (using his **private key** to encode) saying he wants to send 0.05 coin to Ariana's account (using her **public key**).

Individuals among the collective use computing power to verify that both account numbers are legitimate and that Soren has enough money to make the transaction.

When 50% of the collective has verified the transaction, it becomes part of the official record.

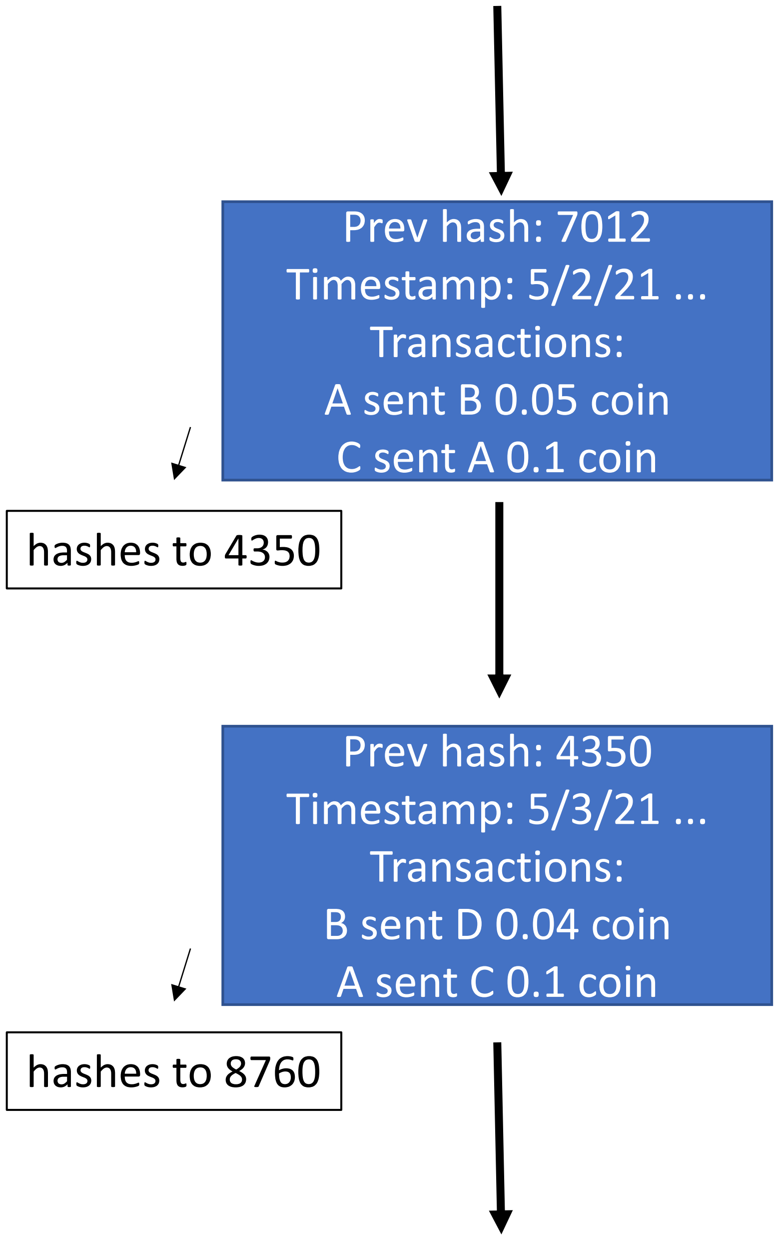
Discuss: What happens if an individual controls more than 50% of mining?

Blockchain

The collective ensures that no one spends more money than they have through a transaction, but how does it ensure that no one modifies the record? They use a **blockchain**.

A blockchain is just a data structure used to store records over time. It is literally a chain (list!) of **blocks**, where each block contains information about the state of the financial system at that point in time (by listing transactions that have been made).

The blockchain is **secure** because every block contains a hash of the block that came before it. This means that no one can go back into the blockchain and edit one of the older records to give themselves money; this would break the hashes on all the subsequent blocks, and people would notice.



Bitcoin

Bitcoin is a specific type of cryptocurrency. It was created by a mysterious individual(s) called Satoshi Nakamoto in 2008. To this day, no one knows who this is...

The code was made open-source in 2009. Link here: github.com/bitcoin/bitcoin

Bitcoin started out as worth a few cents per bitcoin. It has gone up and down a great deal over time and is currently worth [$91k per bitcoin](#).

Learn more here [start at 2:41] :
www.npr.org/sections/money/2011/07/13/137795648/the-tuesday-podcast-bitcoin

Generative AI

Generative AI

Some AI models classify or cluster data (we’ve talked a bit about those). Others create new data – we call those **generative** models.

How is it possible for a model to generate new data? It can be trained over time to recognize the patterns that make a piece of generated data look 'real'.

We'll talk about a common approach for generating data: generative adversarial networks (GANs).

GANs

GANs have two pieces:

- A **generator**, which creates new images
- A **discriminator**, which classifies images as real or fake

GANs are an example of an **adversarial** algorithm. The two parts learn from each other because each part is constantly trying to fool the other.

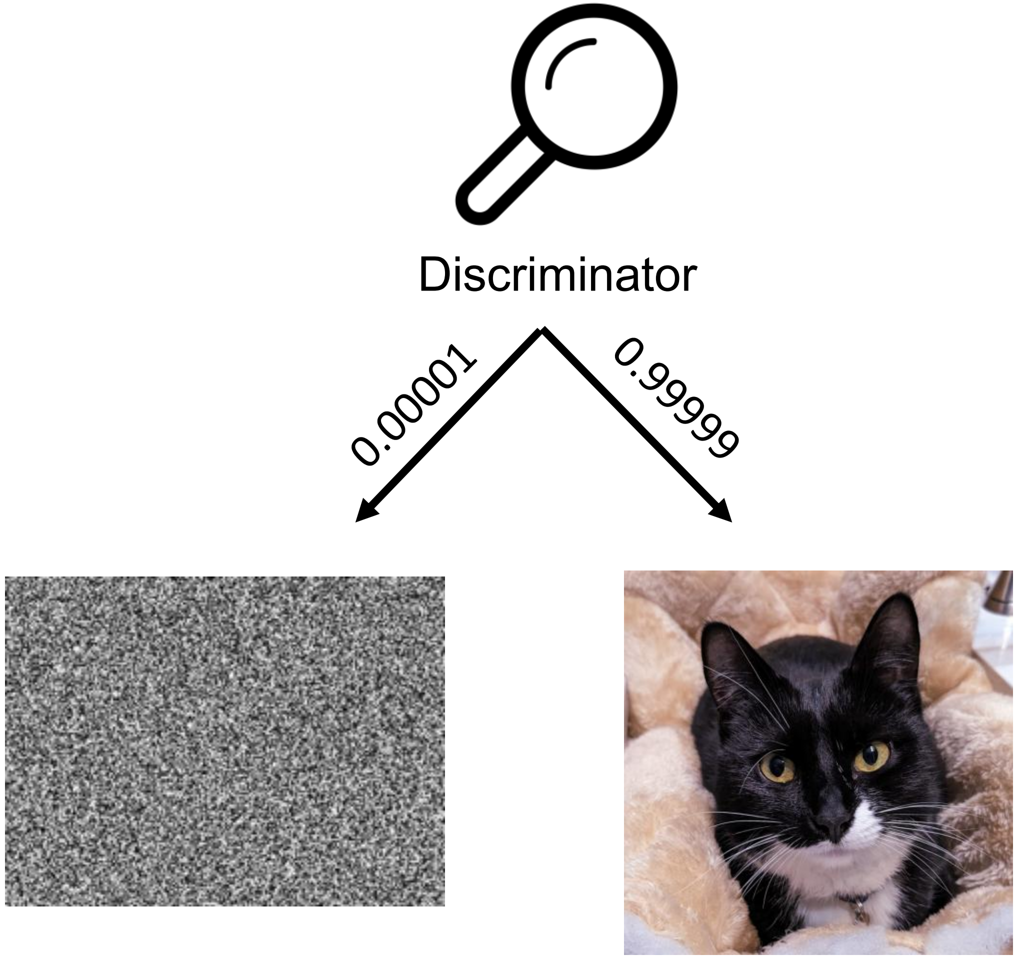
Let's use a GAN for generating images of cats as an example.

Discriminator

The **discriminator** is just a classification model. It takes an image as input and outputs the probability that the image is real or fake (a number between 0 and 1).

We train the discriminator by giving it a dataset with a mix of real and fake images, all labeled. Perhaps the fake images are all random noise.

Distinguishing cats from random noise is easy, so the discriminator does well at first.

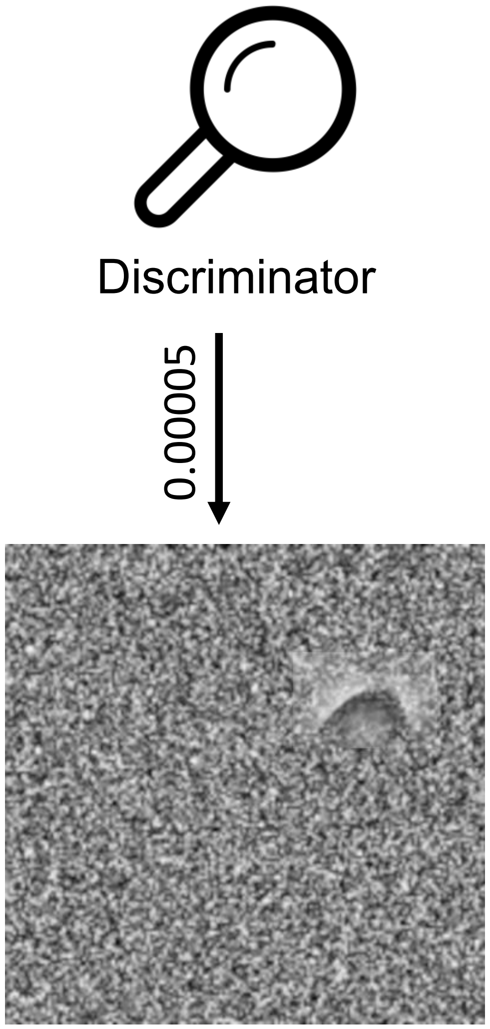


Generator

The **generator** is supposed to create new images (fake images) that fool the discriminator into thinking that they are real images.

At first, it has no idea how to do this. It generates lots of nonsense images that are just random noise and gets scores from the discriminator that are mostly terrible.

But some of those images are slightly closer to being cats than others and get slightly higher scores. The generator changes its settings to make more images like those and slowly gets better over time.



Back and Forth

Eventually the generator gets so good at generating images that it can reliably fool the discriminator. But we're not done yet!

Now we can use the *generator* to train the *discriminator*. Use a set of images created by the generator as the fake images in the training dataset for the discriminator and retrain it.

After the discriminator has been updated, we go back to updating the generator again. Each time one model improves, the other is trained until it catches up: they are adversaries, each working to be better than the other. This continues until the person training the model is satisfied with the results.

Learn more: https://machinelearningmastery.com/how-to-develop-a-generative-adversarial-network-for-an-mnist-handwritten-digits-from-scratch-in-keras/

Deepfakes

Deepfake Definition

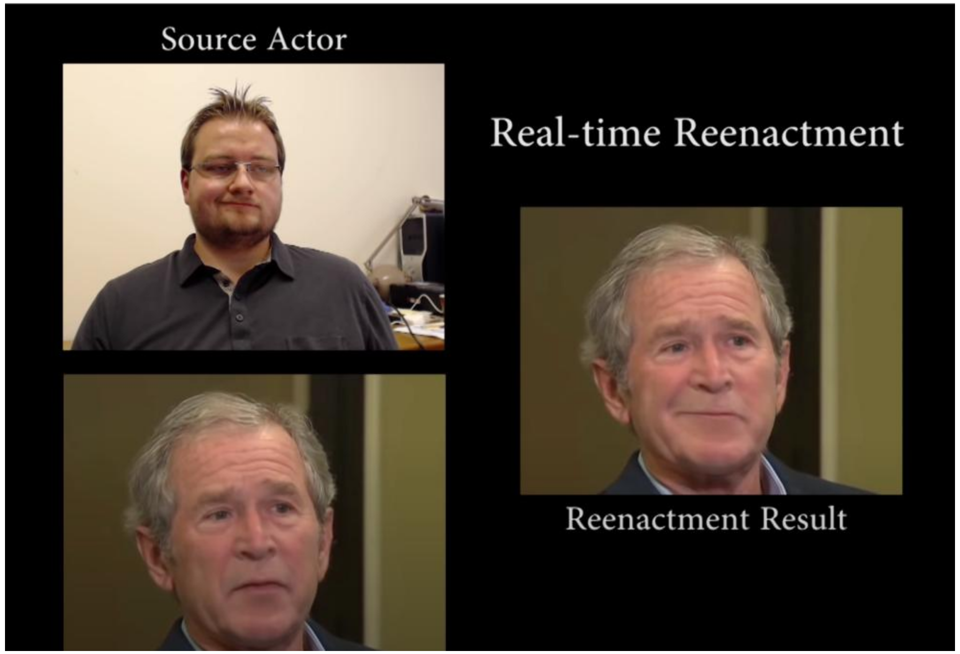
A **deepfake** is a piece of media that has been edited or created using machine learning. Deepfakes can be images, videos, or audio.

Images can be created using GANs, as described before. Here's an example of generated images: https://www.whichfaceisreal.com/

How can an algorithm generate video or audio?

Video Editing – Modifying Video

One approach to editing video is to modify an existing video by mapping the facial motions of an actor onto the target's face.



How it works:
www.youtube.com/watch?v=ohmajJTcpNk

Videos can also be generated using techniques like GANs. These tools have gotten pretty effective recently:
https://www.threads.com/@christopherdemers/post/DQpk1eDkrIf/video-ive-never-been-prouder-of-the-nypd-bye-bye-ice

Audio Editing

Adobe (the company that created Photoshop) also showcased research on a system that could edit audio, Project VoCo:

www.youtube.com/watch?v=I3l4XLZ59iw&t=58

Again, this technology is intended for post-production use, but could obviously be put to other purposes as well.

Intention vs. Potential Use

This technology is intended for post-production editing in film. For example, Disney has used deepfakes in several recent Star Wars movies to bring back actors who have aged a great deal or passed away since their original appearance.

Some people also use this technology for fun, turning all movies into Nicholas Cage movies or having Dr. Phil interview Dr. Phil.

There are lots of concerns about the potential repercussions of deepfakes when used for more serious purposes, like spreading fake news. This can be done by editing real footage or creating non-existent people to spread propaganda.

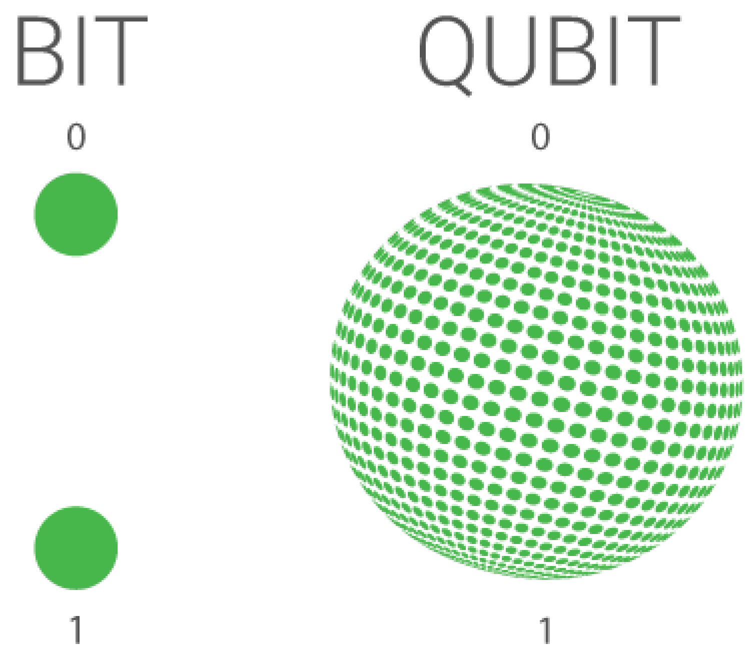
Quantum Computing

Quantum Physics vs Quantum Computing

Quantum physics states that particles are not limited to being in only one state at a time. A particle can also be in a **superposition** of states.

For example, a particle that could be in the "spin up" or "spin down" states could also have those two states superimposed; then it would be in some mixture of both states at the same time.

This same idea is used in **quantum computing**. A classical bit can be in one of two states (0 or 1); a quantum bit, or a **qubit**, can be 0, 1, or a mixture of 0 and 1. The mixture percentage is a real number, not a binary value.



Entanglement

When qubits are represented by physical phenomena such as particle spin, it's possible to connect the states of several qubits together. This is called **entanglement**.

If a system of N qubits is fully entangled, we can represent $\mathbf{2^N}$ possible data values **simultaneously** instead of just representing one value. For example, two entangled qubits can have a state that is a mixture of 00, 01, 10, and 11.

This is what makes quantum computers so powerful – they rapidly speed up **efficiency** by playing by non-classical rules.

Quantum Algorithms

When we represent data using qubits, we can process that data using **quantum algorithms** that operate on all the possible states of the data at the same time.

This produces a quantum result, which we then need to translate back into a classical (non-quantum) answer. This is done probabilistically, but certain translation algorithms (like Grover's Algorithm) have a high likelihood of success.

If this translation can be done quickly, it can lead to **huge efficiency gains**. For example, Grover's algorithm can take a O(N) algorithm and solve it in O($\sqrt{N}$) time.

Quantum Implications

Quantum computing may seem very theoretical, but it can have real impacts on the computing we do today.

For example, consider **integer factorization**. This is an intractable problem for classical machines, but Shor's Algorithm can solve it in $O((\log N)^2)$ time, if N is the size of the integer. This has been successfully implemented only for tiny integers so far - up to the number 21.

Why does this matter? RSA – the algorithm that provides encryption on the internet – depends on integer factorization being hard to do!

Quantum Breakthroughs

In October 2019, Google announced that it had created a quantum processor, called Sycamore, that could represent 53 qubits.

This processor could solve a task that would take a classical computer thousands of years in only 200 seconds. IBM later claimed that it would only take a classical computer a few days, but this is still a huge improvement.

Paper here: www.nature.com/articles/s41586-019-1666-5

Learn more here: www.youtube.com/watch?v=lypnkNm0B4A

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Other Future Topics

Bonus slides – material will not be tested on the final exam

Virtual Reality

Virtual Reality is Embodied Simulation

Virtual reality (VR) is a technology that lets you experience a virtual space as if you're actually there. You can see the world, hear your surroundings, and sometimes move around and interact with different parts.

At its most basic, VR maps your senses to computer representations. It uses a headset with many sensors to change what you see based on your movements, speakers to change what you hear, and controllers to let you interact with the virtual world around you.

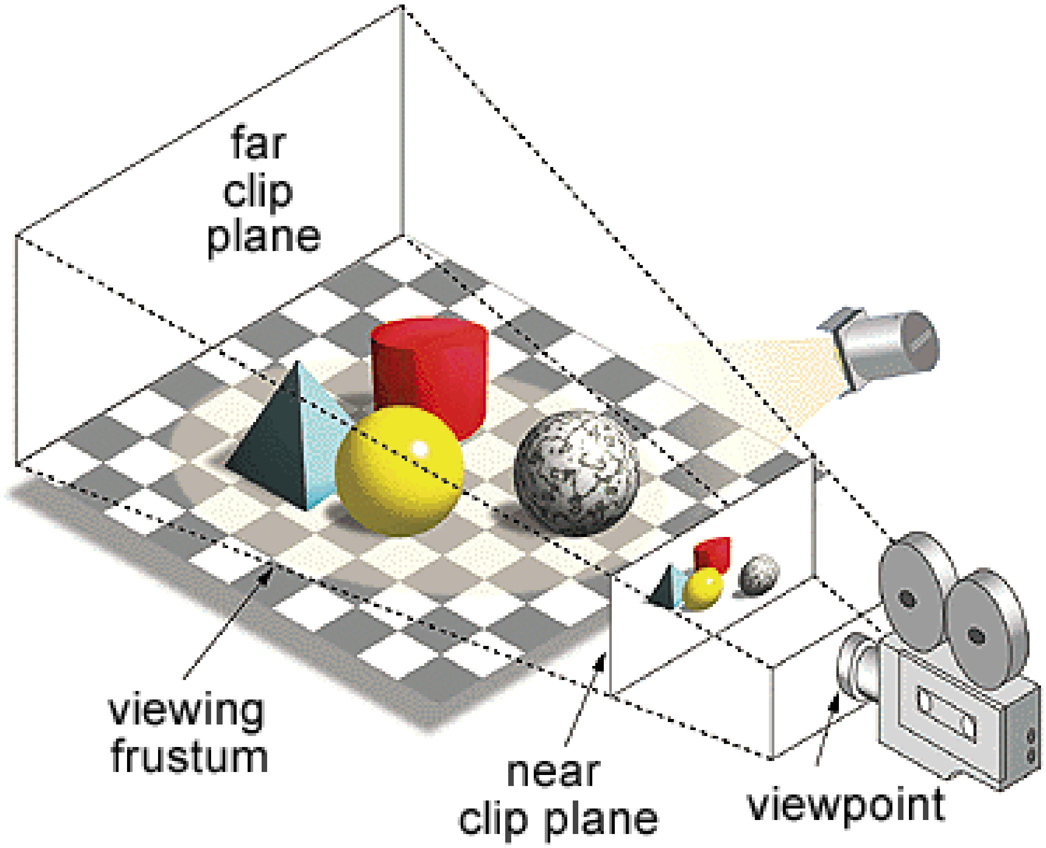
VR has been explored widely in pop culture and is available commercially in several game consoles. But what can it actually do?

3D Rendering Translate a Space

We've shown how to draw two-dimensional images on a canvas to make pictures and simulations algorithmically. What changes when we move to three dimensions?

In three dimensions our view is based on a **camera** situated within a space. That camera has a position and a viewing angle that determine what it sees.

The world is then generated by taking the model of the 3D space and drawing each object in that space based on the geometry of how the object would appear to the camera.



Virtual Reality Adds Complications

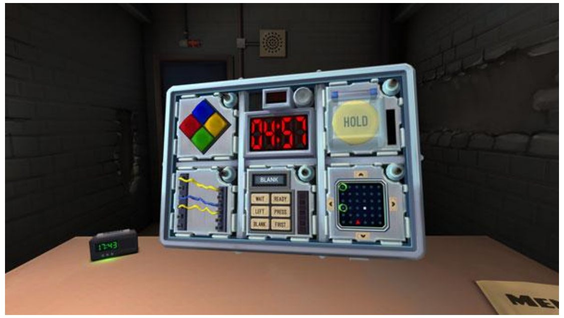
How is VR different from 3D rendering? The main difference is the **distance from your eyes**.

Most VR systems have a headset that puts a screen very close to your eyes. This makes it harder to trick your brain into believing that it is perceiving the world.

This disconnect can cause motion sickness, especially when there is a low refresh rate, or when the visual display does not track head movements perfectly. Companies are still trying to figure out how to reduce motion sickness to make these technologies more widespread.

Virtual Reality Capabilities

Most VR kits available for commercial purposes today focus on the headset. That means that common VR applications are mostly focused on the visual and auditory.



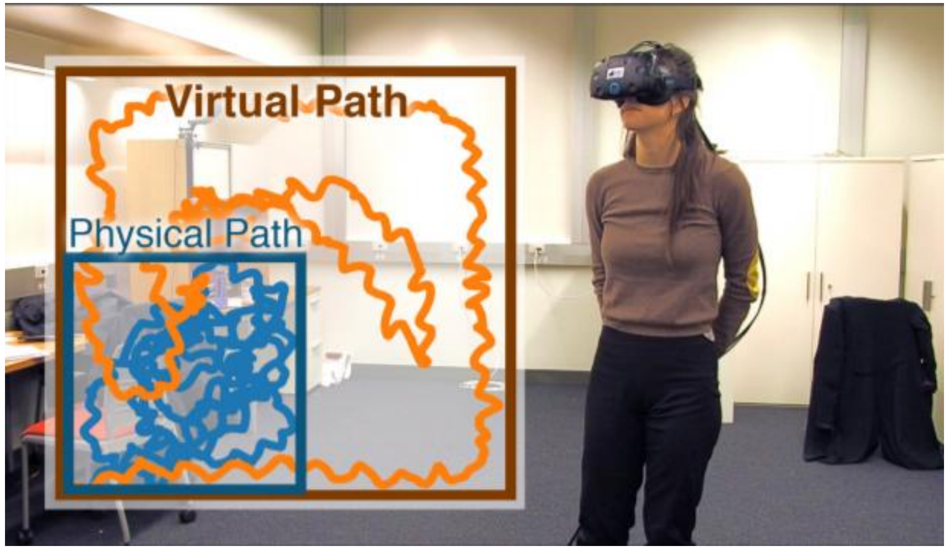
Recent developments have used hand tracking (with controllers) and head tracking to allow basic **interaction** with the VR environment.

Currently you can play games, watch documentaries, and participate in social experiments through VR.

Virtual Reality Limitations

Though you can see, hear, and interact with objects in a virtual reality, other senses – touch, smell, taste – are much more limited. Controllers may be able to vibrate, but they cannot replicate most touch sensations.

Additionally, any simulation that involves moving across space has a simple limitation- the size of the room. Developers can use clever design tricks to make a virtual space seem bigger than the physical equivalent, but design only goes so far.



Sidebar: Augmented Reality

You may also have heard of **augmented reality (AR)**. This is like virtual reality, except that the virtual components are **overlaid** on the real world instead of taking the real world's place.

AR is also used in widely, in games and applications.