University of Illinois at Urbana-Champaign
Dept. of Electrical and Computer Engineering

ECE 101: Computing Technologies and the Internet of Things

Virtual and Augmented Reality

What comes to your mind when you hear AR/VR?

- Poll link: https://app.sli.do/event/6yRdAVzK6oYMw8YBVvRr6U

Pokemon Really Exist! (in AR phone view)

Have you seen a Pokemon?

Pokemon Go

- **Captures** reality with a **camera**,
- **Augments** the scene, and
- **Projects** the merged image onto the screen.

"It's the first mainstream case of augmented reality applied to the masses."

"… it takes commonplace technologies such as **GPS**, mapping and satellite services and combines them with location services, landmarks and Nintendo's familiar characters,… made it possible for augmented reality to blend into the background and allow the game experience to lead."

Shopping with AR

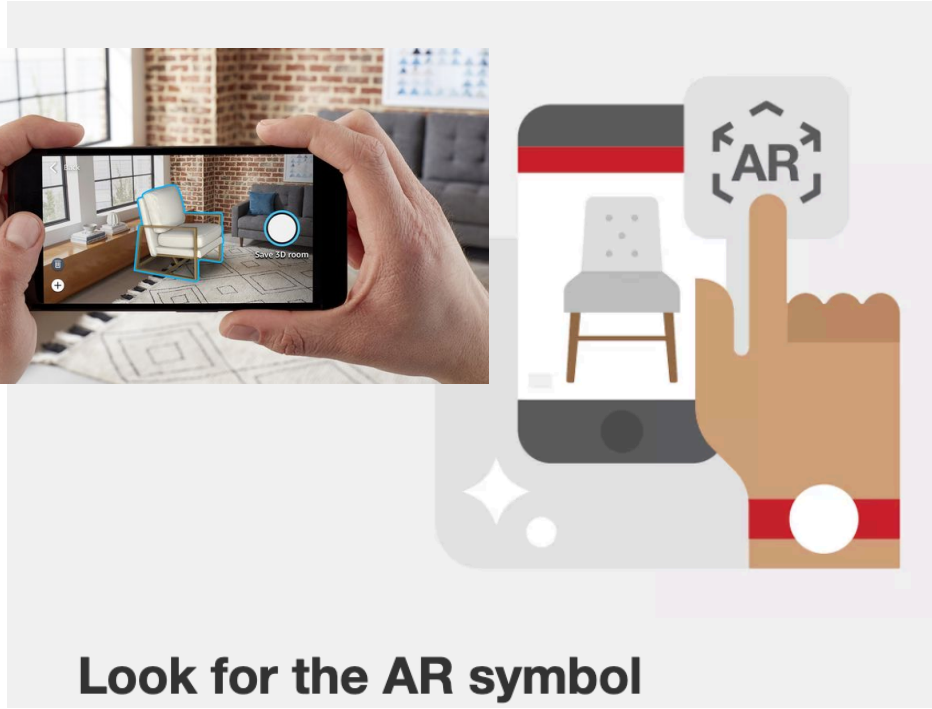
What companies use augmented reality?

Amazon, Target, Walmart,

… using AR to help customers.

Thinking of buying a new chair?

Why not see how it will look in your apartment first?



How does it Work?

Start by Building a Model of the Object

In advance,

- Take images from **many angles**
- Construct a **3D model** of object
- Including surface **textures**.

Use Position from IMU Sensors

Add in IMU readings from phone and graphics

User in home environment

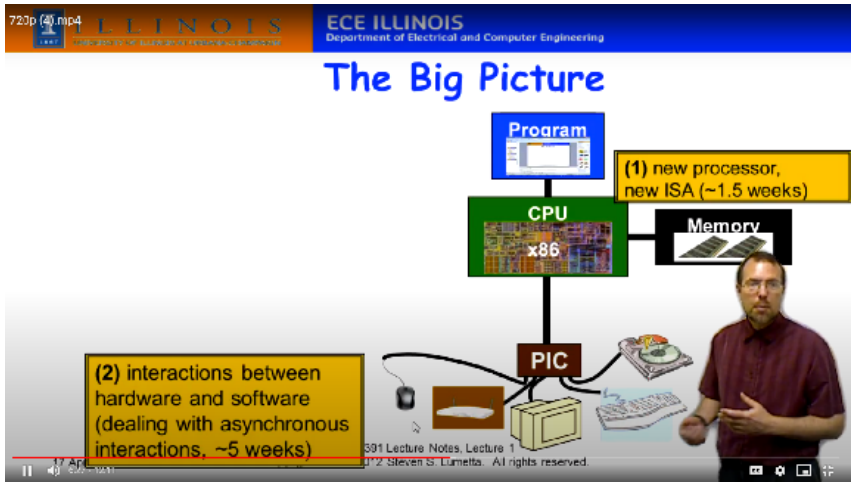
- "**places**" and **orients** object,
- then **moves around** (tracked by IMU) and
- phone **renders 3D object** to produce AR.

In the future (and in present in very advanced applications),

- **lighting** and other **environmental aspects**
- can be extracted in real-time and
- composed onto the virtual object
- to better integrate them into the scene.

Teleconferencing with AR

In 2009, **Nuvixa*** (later Personify)
- used a depth camera combined with edge detection
- to segment and extract humans from video,
- overlaying them in real-time on other video feeds, slides, and so on.



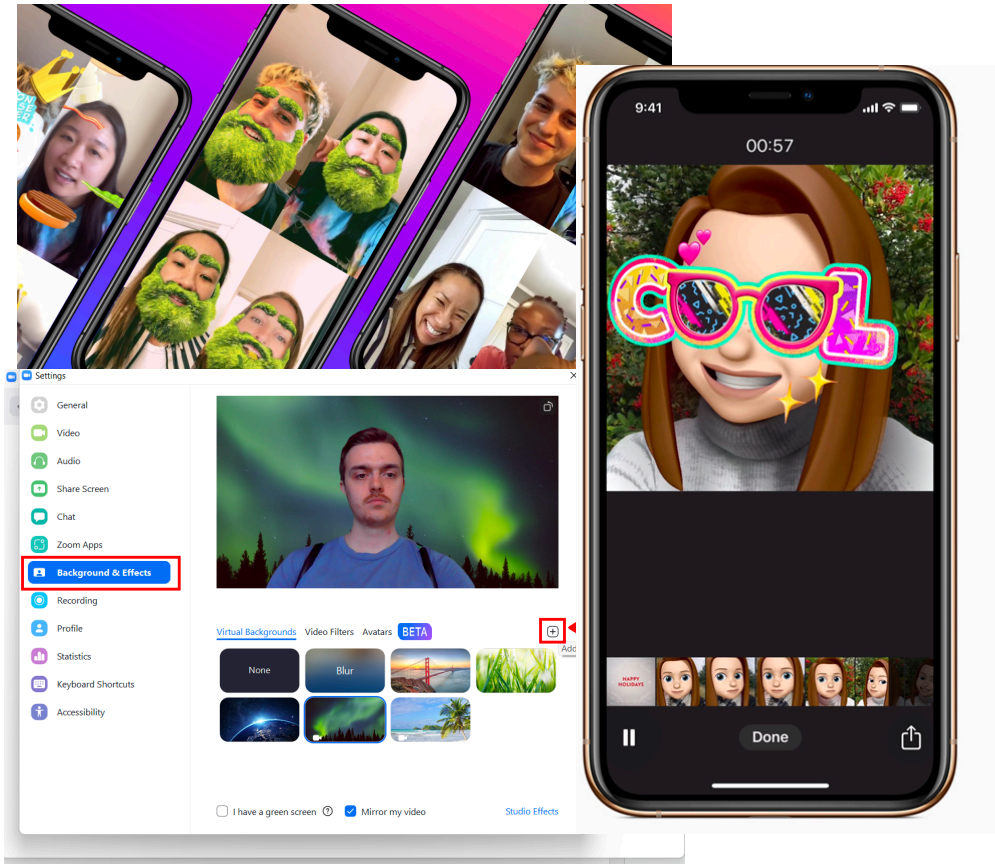
experiment from 2012

More than a decade later, such features are now common in many tools.

*Founded by UIUC ECE faculty.

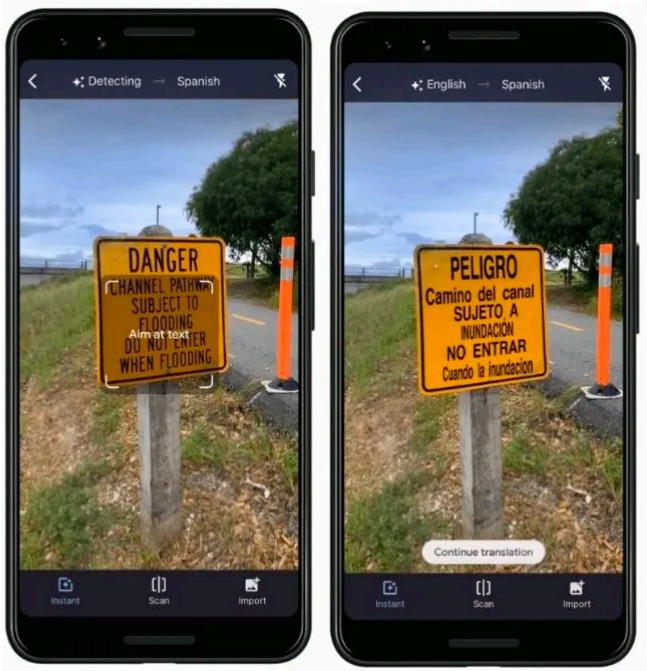
Teleconferencing with AR

- 2016 Zoom virtual backgrounds
- 2019 Facetime uses face tracking with memoji
- 2020 Skype, Google, Microsoft, Webex, and Facebook have virtual backgrounds
- 2021 Messenger introduces AR Experiences

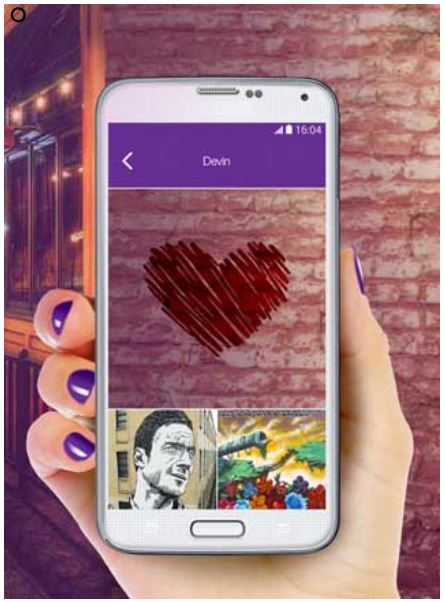


Some Other Current AR Applications

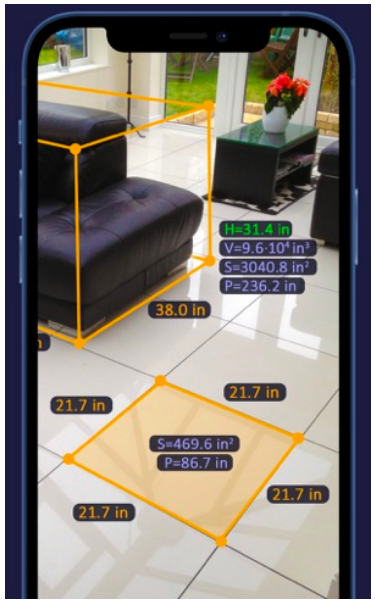
Real-time translation overlays (really useful!)



Invisible ink artwork-only exists in the app! (WallaMe)



Rulers, solar path, sky maps, finding your car



Some Future AR Applications

Enhanced view of surgical procedures
- based on previously collected patient data
- (example: shape and extent of tumor mass)
- current health indicators—heartbeat, blood pressure, and so forth.

3D preview of meals at restaurants:
- see appearance and portion size
- And how it all fits together before you order!

AR, VR, MR and ER

- **AR - Augmented reality**, designed to **add digital elements over real-world views** with limited interaction.
- **VR - Virtual reality** immersive experiences helping to **isolate users from the real world**, usually via a headset device and headphones designed for such activities.
- **MR - Mixed reality** combining AR and VR elements so that **digital objects can interact with the real world**, means businesses can design elements anchored within a real environment.
- **ER -Extended reality (XR)—** covering all types of technologies that **enhance our senses**, including the three types previously mentioned.

https://dynamics.microsoft.com/en-us/mixed-reality/guides/what-is-augmented-reality-ar/

The Future with AR/VR - the Metaverse

Virtual desktop for students:

- whether you're at your desk, in the library, or in the classroom,
- everything you've studied
- as well as the entire Internet
- is at your fingertips to peruse and connect
- while you work.

Future AR: Your Own Application

Let's hear from you

-

Future AR: Your Own Application

From previous semesters:

- Glasses: Navigation instructions, additional information on what you see, identity details of people, etc.
- Textbooks: Medical students - realistic illustrations and diagrams while you study from the textbook
- Sheet music in VR: Focus on the instrument not on the sheet music; helps with memorization,
- Learn to Play: Look at notes and replay the music, highlight parts of the instrument to play
- Engineering: Step by step process to examine parts of an engine - work/ interact with components; Better understanding of its part
- Flight simulators: Pilot experience; especially mechanical failures
- Art: Lookup piece that matches description and show how to draw/paint/make it

Future AR: Your Own Application

From the previous semester:

- Construction - what building will look like, how they will fill up the space
- Interior decor - not just looks but effective arrangement of furniture
- Travel - look at a place before you go there (VR), more information about place you visit - scan a building and learn about its history
- Surgery -
  - more information about the patient and procedure
  - Anatomical overlays on the patients real image
- Online courses (VR) - virtual classroom for people to interact in
- Communication (AR) - hologram of person you are calling
- Clothes - Check how it fits you before buying
- Beauty and cosmetics - test out products before you have to buy them
- Car shopping (VR) -Visualize interior of the car to et a better sense
- Performance (AR) - Imaging what performance venue would be like with audience (to practice)
- Car design and engineering (AR/VR) - making design decisions and testing designs

Sense-Compute-Communicate-Actuate: Sensing the Humans

With the exception of using the IMU,
most AR applications don't monitor the user.

Let's take a look at sensing the humans.

Motion Capture Records Human and Animal Motion

Motion capture, or **mo-cap**, started in the 1970s.

By the late 1980s and early 1990s, it was used heavily for **computer game animation**.

By mid- to late 1990s, movies started to make use of it for both special effects and to capture more natural **motion for animated characters**.

Markers Reduce Image Processing Workload

Historically, most systems have been **based**
on either passive or active **markers**.

Markers
- attached to full body suits
- (you can see them in the photo), and
- motion is **tracked optically**.

Mo-Cap Enables Reproduction of Human Expressions

One **difficult problem** solved with mo-cap
- is the ability to record the **relation between human emotion, speech, and facial expressions**.
- Actors are recorded, features extracted and then cast onto animated characters.

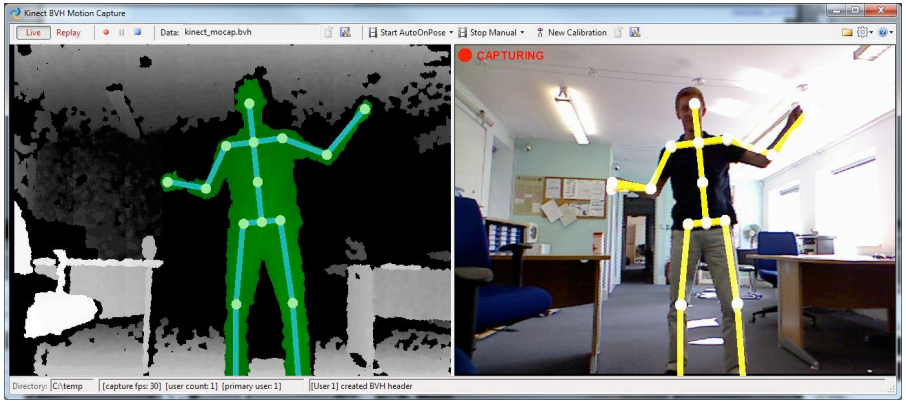
ML models are becoming able to emulate human expressions, but **perhaps not yet** to the level needed for movies.

Markerless Capture Enabled Home Use

Progress in vision enabled markerless mo-cap.

2006: Nintendo Wii (limited markers)
- fused active markers with IMUs
- to enable capture of game players.

2010: Microsoft Kinect (no markers)
- blended depth detection with feature identification
- to provide wire models (stick figures) of players.



Mo-Cap Has Many Commercial Uses

Commercial versions
- with many more cameras and
- much more computing power are
- used frequently today for movies,
- providing advice on golf swings, and so forth.

What Happens When We Combine Technologies?

Motion capture studios have
been available for decades.

So have audio recording technologies.

What can we do when we combine them?

Digital Twins Replicate Real Objects, Even People

A **digital twin is a virtual replica**, with properties based on observations of the original.

It could be **as simple**

- **as a 3D model** of an object
- captured with multiple cameras and
- constructed with image textures
- on a polygonal model.

Or it could be **as complex as a** real **person**.

Record Your Life … for a Week

Imagine that, starting tomorrow,
- you spent a week sitting in a motion capture room
- with 50 camera/speaker devices pointed at you.

An interviewer asks you questions
- about everything you've ever done or felt,
- and you answer candidly.

Your answers are all recorded,
- generating a few Terabytes of data
- (high-resolution, high-speed video!).

Big deal. It fits on a $100 drive.

Buy two in case one goes bad.

Now Add in Vision and NLP

Today, in addition to recording video and audio,

- we also have speech recognition
- and parametrized models of speech
- that allow us to capture a person's accent and speaking style
- and natural language processing to build models of how answers fit together and can be queried.

Enhance Missing Information by Mining the Internet

Recorded data about your

- background, characteristics, and personality
- can be enhanced with data mined from the Internet,
- adding depth and detail to your comments
- (as well as explanations for any outdated idioms!).

Of course, your digital twin still won't be eating outside of augmented reality.

Put It All Together and Voila! A Virtual Human!

In other words,

- if we combine a physical model
- and a mental model
- trained with data recorded in natural language,

we can create a fairly realistic virtual human!

Immersion: the Goal of Most Virtual Realities

As with some games, including computer games, one "goal" is to enable a player **to temporarily forget that the game world is not the real world**.

This property is called "**immersion**."

Traditional Gaming Has Barriers to Immersion

When a game is played on a **small display**, with **sounds coming from one or two directions**, and instructions delivered through **a keyboard, mouse, or game controller**, achieving immersion requires a significant imaginative effort on the part of the player.

Realistic VR can help!

Real Physics Can be Simulated to Help Immersion

In the mid 2000s, a startup called **Ageia** worked to develop **a chip for simulated physics**, to enable everything from more destructible environments to more realistic folding of cloth and motion of fog.

Eventually, the idea migrated into software and was acquired by NVIDIA in 2008, which provided access to game developers through the **PhysX** programming interface.

Sanjay Patel,
Professor of ECE and
Chief Architect at Ageia
https://csl.illinois.edu/news-and-media/patels-company-agrees-be-acquired-nvidia

Real Immersion … in a VR Cave!

In 1992, researchers at UI Chicago developed a VR cave (a sister installation of the original CAVE operated on the Urbana-Champaign campus from 1995 until the close of the **Illinois Simulator Lab** in 2017)

- A room covered with displays and speakers.
- A headset allowed distinct images to be delivered to each eye, providing the illusion of a 3D world surrounding the user.

Virtual Immersion—Just Wear the Headset

Between **technological challenges, cost, and other factors**, the approach did not become commercially viable until 2016, in which year three separate companies introduced products.

- Oculus Rift
- HTC Vive
- Sony Playstation VR

Virtual Reality Headsets

The top players

- Microsoft HoloLens
- Apple Vision Pro
- Meta Quest 2/3
- Sony PlayStation VR2
- HTC Vive Pro 2

Immersion and the Five Senses

Humans have **five senses**:

- **Sight** and **hearing** are covered fairly well by today's VR.
- **Smell** and **taste** are chemical in origin and (unlikely) to be handled directly in the near future.
- **Touch** … is called **haptics**.
  Let's talk about touch.

Haptics Simulates Touch-Related Experiences

Haptics: simulated touch.

Haptics has made a lot of progress, and is **used widely to control robots that need to maneuver around living things**, especially humans.

Haptics feedback includes things like **vibration and arcade-game mechanical equipment** that moves to simulate acceleration in the game world.

But most haptic interfaces for providing a touch sense to humans are still in the **research phase**.

Controlling Touch: Brain-Controlled Prosthetics

By 2013, it was possible to attach a **prosthetic arm** to a human and have the human **control** it **with** their **brain**.

In other words, **the arm acted as a real arm**.

In 2021, a high school student in Virginia produced such an arm on a 3D printer. DIY prosthetics!

Current Prosthetics Do Not Feel

These arms moved, but did not feel.

In 2020,
- researchers started adding haptics,
- placing **touch sensors** on the fingers.
- the **outputs were then fed into nerves** in the upper arm.

“Feeling” with Prosthetics Also Here Soon

The signals produced by the sensors
- are **not trained to emulate the original signals**
- sent by the absent hand

But the **human brain**
- is plastic enough (**adapts to new input**)
- such that the signals eventually “feel” like the original!

At least, once the haptics provide enough information.

In the current versions, they are fairly simplistic.

What comes to your mind when you hear AR/VR?

https://app.sli.do/event/6yRdAVzK6oYMw8YBVvRr6U

Terminology You Should Know from These Slides

- augmented reality (AR)
- virtual reality (VR)
- VR cave
- VR headset
- motion capture (mo-cap)
- digital twin
- immersion
- haptics

Concepts You Should Know from These Slides

- uses for AR
- basic operation and approaches to AR
- uses of VR
- use of markers versus feature identification for mo-cap
- use of mo-cap to capture human expressions
- how to make a digital twin
- why immersion is hard with a computer or game console
- need for realism to support immersion