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

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Augmented Reality Adds Computer Graphics to Sight

What is augmented reality?

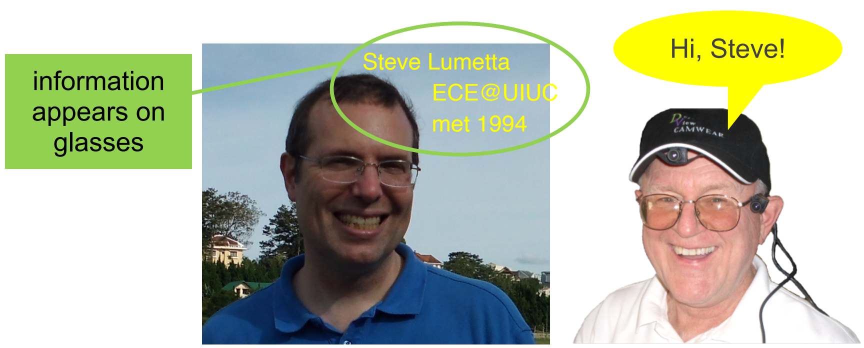
Enhancement of a person's **vision through** addition of **computer-generated imagery**.

Accomplished through projection onto glass positioned between viewer and world.

Example: after Gordon's system looked someone up in his Rolodex, how would it tell him about the person?

Gordon Bell

Let's Imagine How Augmentation Might Look



Pokemon Really Exist! (in AR phone view)

Have you ever seen a Pokemon?

You probably think they're made up.

But here's a rare photo of a wild Mew…

Instead of glass,
- one can capture reality with a camera,
- augment the scene, and
- project the merged image onto the screen.

AR Applications are Wide-Ranging

What companies use augmented reality?

Amazon, for example.

Thinking of buying a new chair?

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

Start by Building a Model of the Object

How does it work?

In advance,
- use images from many angles
- to construct a 3D model of object,
- including surface textures.

Given Model and Position from IMU, Just Graphics

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

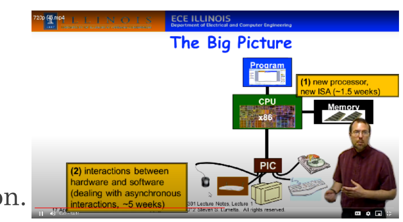
In the future,
- lighting and other environmental aspects
- can be extracted in real-time and
- composed onto the virtual object
- to better integrate them into the scene.

Another AR App: Teleconferencing

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.

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

*Founded by UIUC ECE faculty.



experiment from 2012

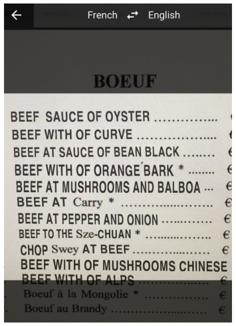
Some Other Current AR Applications

Real-time translation overlays (really useful!)

Shopping
- Tattoo preview, makeup preview, clothes preview
- Shop by pointing (Google Lens)

Games (Pokemon Go, Yu-gi-oh battles, etc.)

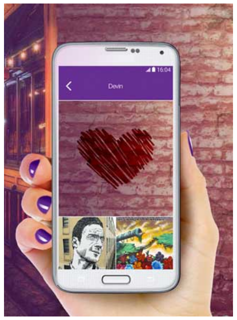
Learning languages with virtual instructors



More Current AR Applications

Art
- Invisible ink artwork … only exists in the app! (WallaMe; see to right)
- Decorations on faces and other features during video calls

Information
- Rulers, solar path, sky maps, finding your car
- Local guide highlights points of interest (wifi, coffee, bar, club, and so forth).



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!

Future AR: Your Own Application

Future AR: Open Everything All the Time!

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.

Next Topic: Sensing the Humans

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

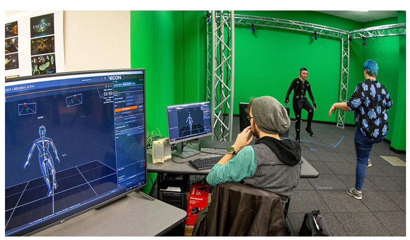
Let's take a look at sensing the humans.

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**.

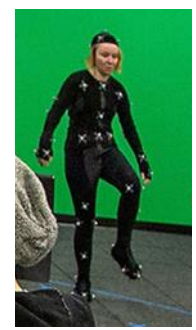


Markers Reduce Image Processing Workload

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**.

Active markers can be strobed to simplify separation in recorded video.



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
- snd 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.

Real Immersion … in a VR Cave!

In 1992, researchers at UI Chicago developed a VR cave

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

Within a year (announced 1991, previewed in 1993), virtual reality headsets emerged as an alternative approach.

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

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 come back to it.

Senses Aren't Always Strictly Physical

But the human brain has evolved in the real world, and the real world obeys certain laws.

Even natural languages reflect physics through their organization and separation of concepts, grammar, and so forth.

(See, for example, Stephen Pinker's book, "*The Stuff of Thought*")

Magic is Defined by Our Understanding of the World

"Any sufficiently advanced technology is indistinguishable from magic."

Arthur C. Clarke, "*Profiles of The Future*," 1961 (Clarke's third law)

"Magic" is often associated with phenomena that violate our intuitive understanding of physics.

For example, things don't instantly teleport from one place to another.

Sense of How the World Works is Also Important

In the real world, of course, things DO instantly teleport…that's how solid state drives work… but quantum physics is not visible to our brains.

Mimicking the real world is important to immersion, though, and some of the technologies originally developed for games are perhaps as important as providing realistic vision and sound.

Real Physics Can be Simulated

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

Haptics Simulates Touch-Related Experiences

Let's return to **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.

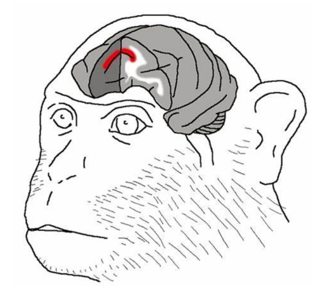
Haptics feedback includes things like vibration and arcade-game mechanical equipment that moves to simulate acceleration in the game world.

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

Signals Sent to Control Our Limbs are Easily Identified

In early 2000s,

- studies on monkeys showed that
- although nerves signals to an arm (for example) are many,
- they were also redundant,
- so processing could identify
- commands sent from the brain
- to the various muscles in the arm, hand, and so forth.



Controlling Touch is Easier: 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 added 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.

Open Question: Can We Use the Same Ideas for VR?

Do you have to lose a limb to gain an artificial one?

For now, perhaps.

But similar techniques,
- using more sophisticated sensors, signal processing, and signal generation,
- may be adapted to interact with nerve endings or even directly with your brain,
- enabling a virtual world or controls to be placed directly into your head
- … virtually, of course.

External Brain-Machine Interfaces Still a Bit Clunky

Researchers have been playing with these techniques for more than a decade, initially with fairly cumbersome electrode-based headsets sensing a small number of signals from outside the skull.

Brain plasticity may help here, too: train your brain to generate coherent controls for your game…like learning to walk?

Terminology You Should Know from These Slides

- augmented reality (AR)
- motion capture (mo-cap)
- digital twin
- virtual reality (VR)
- immersion
- VR cave
- VR headset
- haptics
- brain-machine interfaces (example: prosthetics)

Concepts You Should Know from These Slides

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