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

ECE 101: Computing Technologies and the Internet of Things

Introduction and Landscape

The World Has Undergone a Digital Convergence

Many alumni across many disciplines
- inside and outside of engineering
- **are now computer people**.

Most solutions are digital technology.

Understanding the basics and implications provides **a critical set of skills**.

These skills will enable you
- to **go further faster**, and
- to **make sound decisions** as a voter.

What is our Class About?

Two key concepts lie at the core of technology.
- **information**: data, statistics, or knowledge about something or someone
- **computation**: the act of mathematical computation …

… according to one dictionary

What is technology?

Use of computation and distribution of information to improve people's lives.

What Does the Class Cover?

An **under-the-hood view of important technologies** that will impact your daily life in the next decade.

For each technology, **we will explain**
- the core technical **challenges**,
- the **solutions** to these challenges,
- How the technology translates to **business and revenue**, and
- What the technology implies in areas such as **privacy, fairness, policy, ethics**, and other paradigm shifts.

What are We Hoping that You will Learn?

Give you **insight as to** who does what, how it all fits together, and what **the future** might hold.

But also to give you a basis for **computational thinking:** what is possible?

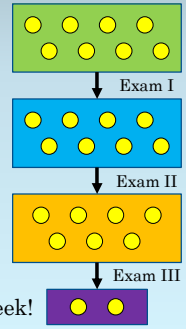
Help you as a citizen in a democracy **to make the best choices** about what is allowable.

What's the Overall Structure?

Weekly structure: two lectures and a lab

Format of class
- **Three parts**: past & present, intelligence, and future technologies.
- Each part **about five weeks**.
- Within each part, **roughly eight topics**.
- After **each part**, **an exam** on that part.

(**no final** exam)



What Happens at Our Meetings?

In each lecture:
- What's **the problem** being solved?
- Where's **the computation**?
- What are **the key technologies and companies**?
- What are the **benefits, pitfalls, and issues**?

In the labs, **we'll use Google Colab to let you explore** and play with the ideas and solutions.

Who are We?

Romit Roy Choudhury
Prof. ECE, CS, CSL
At UIUC since 2013
(MS, PhD from UIUC)
Research: Wireless networking, Signal processing, Sensing, Internet of Things
Education: Networking & mobile computing
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Steve Lumetta
Assoc. Prof. ECE, CS, CSL
At UIUC since 1998
(BS, MS, PhD Berkeley)
Research: Networks, Processors, Accelerators, High-Performance Computing, Genomics
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Who are We?

Viraj Shah

Ph.D. Candidate in Electrical & Computer Engineering

Research Interests:
Machine Learning and Computer Vision

Passionate about motivating people to understand science and technology

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How Does the Grading Work?

- Participation … 10%
  (6 absences allowed)
- Weekly labs … 30%
  (lowest 2 dropped)
- Three exams … 60% (20% each)

Administrivia

Where to find information?

http://go.illinois.edu/ece101

Will take you to the class web page with…
- all kinds of info,
- slides, and
- links to everything below…

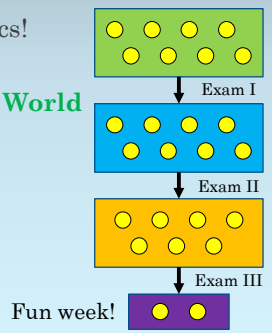
CampusWire for Q/A (http://campuswire.com)—please join our class if you haven't already.

Grade data (only) will be kept in Canvas.

Video recordings will be available in MediaSpace.

First Part of the Course Covers Past and Present

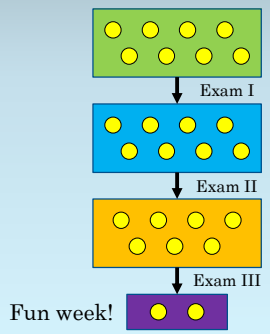
Let's look a bit more closely at the topics!



Part I: Past & Present—Connecting the World
- Week 1: landscape, history, & terminology
- Week 2: communication: WiFi and Cell
- Week 3: how the Internet works
- Week 4: web services and social networks
- Week 5: distributed systems and storage

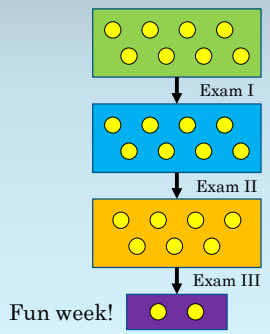
Second Part of the Course Covers Intelligence

Part II: Intelligence & Implications
- Week 6: web search (& Part I exam)
- Week 7: recommendations and gaming
- Week 8: machine learning and AI
- Week 9: ethics, privacy, and security



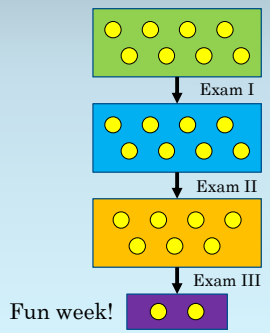
Third Part of the Course Covers the Future

Part III: Future
- Week 10: fairness (& Part II exam)
- Week 11: sense-compute-communicate, voice assistants, and wearables
- Week 12: automated speech, language, and vision
- Week 13: AR/VR and automated driving



Last Couple of Weeks Just for Fun!

Wrap-up
- Week 14: Part III exam
- Week 15: fun week



Summary of Exam Dates

Exams are all in-class, so please let us know (ASAP) if you need other accommodations.

Exam date summary:
- Exam on Part I: **Wednesday 28 September**
- Exam on Part II: **Wednesday 26 October**
- Exam on Part III: **Wednesday 30 November**

(no final exam)

What's Your Favorite Color?

Time for a break.

What's your favorite color?

This one, perhaps? CRIMSON

Answers and Choices Represent Information

If we ask everyone here,

but limit the answers to …

RED	ORANGE	YELLOW	GREEN	BLUE	PURPLE	BROWN	BLACK	WHITE
1	2	3	4	5	6	7	8	9

Each answer is then a number from 1 to 9.

(We decide together which number means which color.)

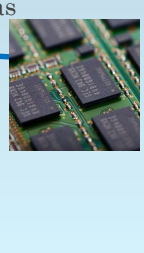
The answers are **information** about us.

Information is Stored Physically

How do we measure information?

In a digital system, information is stored **using physical quantities** such as

- voltage,
- crystal structure, or
- magnetic field.



Information Stored Using Binary Digits (Bits)

Such systems **typically** have **two states**, which we call **0 and 1**.

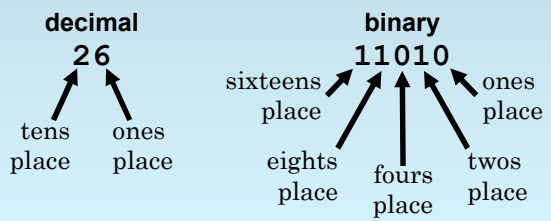
That gives us **a binary digit**, or **bit**.

Information is then **measured by** how many **bits** are needed.

Physical Locations Enable Place Value

Each bit is stored somewhere.

So using positional / **place value** is natural.



Answers and Choices Represent Information

We **could** instead **name** the **colors with bits**

(base 2 / binary):

RED	ORANGE	YELLOW	GREEN	BLUE	PURPLE	BROWN	BLACK	WHITE
0001	0010	0011	0100	0101	0110	0111	1000	1001

Then **to store one** person's favorite **color**,
we need **4 bits**.

A Question for You: How Many Bits do We Need?

How many bits do we need to represent a
whole number in the range…

- from **0 to 31**?
  - 32 different integers
  - so **we need 5 bits** (2^5 = 32 bit patterns)
- from **0 to 100**?
  - 101 different integers
  - so **we need 7 bits** (2^7 = 128 bit patterns)

We Need One Bit Pattern for Each Possible Thing

Trick question: How many bits do we need
to represent two "books"?

- **The Collected Works of Shakespeare**
- **ECE101 slides by Roy Choudhury & Lumetta**

  - 2 different books
  - so **we need only 1 bit!** (2^1 = 2 bit patterns)

What matters is the **number of things**,
not what those things are.

How Many Bits Do We Need to Represent N Things?

Let's test your understanding (and generalize)!
How many bits do we need to represent…

- a whole number from **1000 to 1100**?
  101 different integers, so **7 bits** ($2^7 = 128$)
- one of **199 flavors of ice cream**?
  199 different flavors, so **8 bits** ($2^8 = 256$)
- **a living person**?
  7-8 billion people, so **33 bits** ($2^{33} > 8$ billion)
- **N things**?
  $\lceil \log_2 N \rceil$ (ceiling / integer at least as large as log base 2 of N)

But Some Patterns May Represent Nothing

Since most things require a lot of bits, we have another unit called a byte, which is just 8 bits

1 Byte = 8 bits

1 B = 8 b

An Image Contains a Lot of Information

In practice, modern systems often use **24 bits (3 B)** to **specify one** of 16,777,216 (2^{24}) possible **color**s.

What if I give you one 1920×1080 picture for your computer desktop background?

That requires
1920×1080×24
= 49,766,400 bits
= **6,220,800 Bytes**.

Computer Units are Based on Powers of 2

That's a big number, so we usually use bigger units. For example…

k	**kilo**	**2^{10} = 1,024**
M	**mega**	**2^{20} = 1,048,576**
G	**giga**	**2^{30} = 1,073,741,824**
T	**tera**	**2^{40} = 1,099,511,627,776**

Almost but not quite the metric system…

One Video Contains a Huge Amount of Information

So one image requires **6,220,800 Bytes = 5.9 MB**.

What about a one-hour recorded lecture with 24 images every second?

3600 seconds × **24** images / second × **5.9** MB / image

= **501 GB!!!**

That's why we don't usually send videos through e-mail: it's a lot of information!

(And why I don't include a video example in these slides: the slides are only a few MB!)

Humans are Good at Conveying Information

Human languages use a trick to **reduce** the effective **size** of ideas.

In particular, **frequently used ideas use short words**.

Uncommon ideas require long words.

Compression is Useful for Most Types of Information

Modern technologies use **compression** a lot:

- **common ideas require fewer bits** (like shorter words); usually a few GB for a one-hour video
- **uncommon videos require more bits** (like longer words)

If we consider all possible images/videos, nothing changes.

Computation Used to Solve Problems

The second key concept?

computation

Given some information, answer a question, or make a decision.

Humans are good at such things.

So are computers.

Let's consider some examples.

Shortest Path is a Straight Line!

In January, I drove to Atlanta.

What's the shortest way to Atlanta?

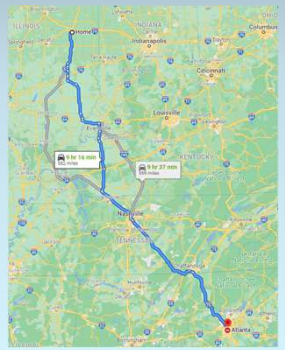
A great circle!
(A straight line on a sphere.)

Stick to the Roads when Driving

I prefer to drive on roads, though, so I asked Google.

That's a lot longer.

But it's not the fastest!

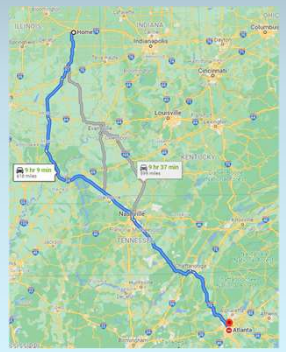


Don't Speed on the Freeway!

Speed limits matter…

Staying on the Interstates shaves 7 minutes off the time!

(Speeding saves an hour or more, but no one does that!)



Catssification of Photos

Sometimes I like to earn some extra money.

So I classify images on the Internet.

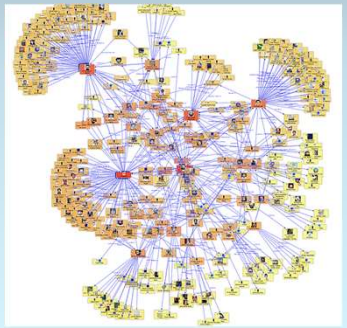
Help me out here: which photos contain cats?

Counting Hops in a Social Network

One more question for you:

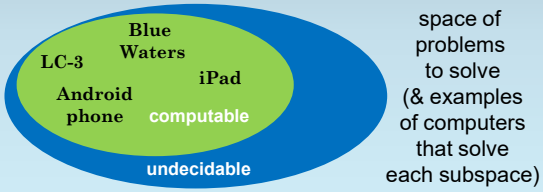
In Facebook, how many friends' friends do I have to meet to get to know…

- Rihanna
- Angelina Jolie
- Jackie Chan



Computers are Universal Computation Devices

Described by Alan Turing in 1936



Church-Turing Hypothesis: Computers and humans can compute the same things.

Terminology You Should Know from These Slides

- information
- computation
- technology
- bit (BInary digiT) and Byte (8 bits)
- kilo, Mega, Giga, Tera, (Peta, Exa)
- compression

Concepts You Should Know from These Slides

- information is stored as bits (0s and 1s) using physical quantities
- how to find the number of bits needed to represent one thing from a group
- compression is used to reduce the number of bits needed for more common things in a group
- humans and computers are (in theory) equally capable of computation, given sufficient memory and time (the Church-Turing hypothesis)

More Neurons than Transistors?

"The apparatus they [animals] use for timing their movements has more in common with an electronic computer, although it is strictly different in fundamental operation. The basic unit of biological computers, the nerve cell or neurone, is really nothing like a transistor in its internal workings. Certainly the code in which neurones communicate with each other seems to be a little bit like the pulse codes of digital computers, but the individual neurone is a much more sophisticated data-processing unit than the transistor. Instead of just three connections with other components, a single neurone may have tens of thousands. The neurone is slower than the transistor, but it has gone much further in the direction of miniaturization, a trend which has dominated the electronics industry over the past two decades. This is brought home by the fact that there are some ten thousand million neurons in a human brain: you could pack only a few hundred transistors into a skull."

--Richard Dawkins, "The Selfish Gene," Oxford University Press, New York and Oxford, 1976, p. 51

Today: Billions of Transistors

Dawkins was writing in 1976.

Moore's Law continued.

1997: Pentium released, **4.5 million** transistors

Today: **21.1 billion** transistors on **815mm^2**

(NVIDIA GV100 GPU – https://devblogs.nvidia.com/inside-volta/)

Smaller than neurons!

… still only 3 terminals

