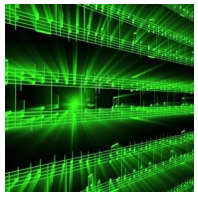
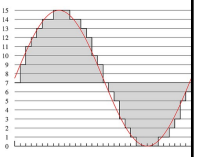
Penn Engineering

ESE





Lecture #26– Wrap Up! (final lecture)

ESE 150 – Digital Audio Basics

1

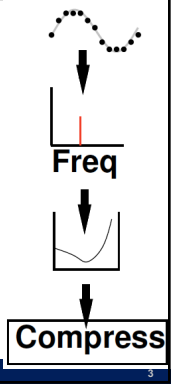
Lecture Topics

- Review
- Generalize
- Final
- Engineering Disciplines
- What's Next?

2

Class Story: One Slide

- **Sound can be converted to/from bits**
  - And compressed
  - Without loss of information
- **More information can be discarded without humans noticing → fewer bits**
- **Process this information with inexpensive machines**
- **Store it for retrieval**
- **Send it between machines**
  - Even if not directly connected



3

In the Process

- Sampling
- Signal Processing
- Frequency Domain
- Compression
- Human Hearing
- Optimization
- Processing Requirements
- Hardware (gates)
- Sharing hardware (OS)
- Networking
- Sensing and Actuation
- User Interfaces
- Intellectual Property

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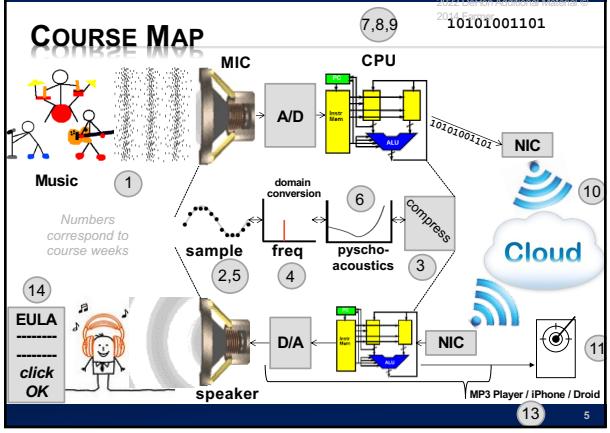
Course Map



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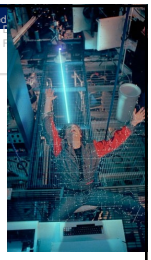
ESE150

Compression, MP3s, Psychoacoustics, and Everything

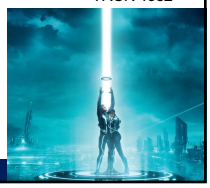
6

Virtualization of the World

- **Can represent things as bits**
  - Sound, pictures, movies
  - Location, situation, …
  - shapes, circuits, drugs, DNA
- **Cheap/powerful ways to automatically manipulate**
  - …and reproduce



TRON 1982



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Audio

- **Told detail story in terms of Audio**
- **1D signal**
- **Sample in time**
- **Quantize amplitude**
- **Quantize fine enough**
  - Lose no information that humans can perceive

8

8

Images

- **2D signal**
- **Quantize in space into pixels**
- **Quantize amplitude of pixels**
- **Quantize fine enough**
  - Lose no information human can perceive
  - 0.1 mm at 30cm (50 cycles per degree)
  - "Retina" Display 57 pixels per degree
    - 128 pixels/cm

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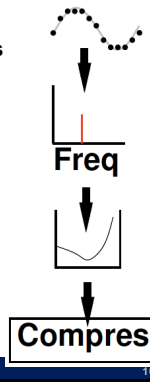
Image Processing One Slide

- **Images can be converted to/from bits**
  - And compressed
  - Without loss of information
- **More information can be discarded without humans noticing → fewer bits**
- **Process this information with inexpensive machines**
- **Store it for retrieval**
- **Send it between machines**
  - Even if not directly connected



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Compress Images

- **How do we compress images?**
  - Lossless?
  - Lossy?

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Motion Pictures

- **3D signal**
- **Sample in time**
- **Quantize in space into pixels**
- **Quantize amplitude of pixels**
- **Sample fine enough**
  - Lose no information human can perceive
  - 30 frames per second

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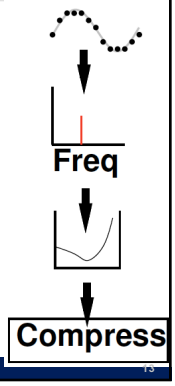
Video Processing One Slide

- Motion can be converted to/from bits
  - And compressed
  - Without loss of information
- More information can be discarded without humans noticing → fewer bits
- Process this information with inexpensive machines
- Store it for retrieval
- Send it between machines
  - Even if not directly connected



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Compress Videos

- How do we compress videos?
  - Lossless?
  - Lossy?

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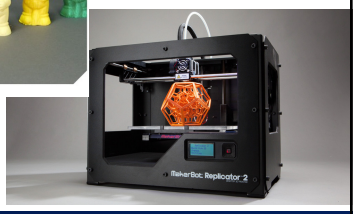
3D Object Capture and Reproduction



makerbot.com

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Virtualization of the World

- Can represent things as bits
  - Sound, pictures, movies
  - Location, situation, …
  - shapes, circuits, drugs, DNA
- Cheap/powerful ways to automatically manipulate
  - …and reproduce

TRON 1982

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World of Bits

- What else can we capture as bits?
- Reproduce from bits?

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- http://news.cnet.com/8301-27083_3-20079504-247/prosthetic-dentistry-print-your-own-teeth/
- http://phys.org/news/2011-02-3d-bio-printers-skin-body.html
- https://www.nbcnews.com/mach/science/digital-smell-technology-could-let-us-transmit-odors-online-chats-ncna940121
- https://www.makepartsfast.com/3d-printed-circuit-boards-how-theyre-made-and-why-they-matter/
- https://time.com/6162775/tiktok-3d-printed-houses/
- https://cen.acs.org/food/food-science/3D-printed-foods-enter-kitchen/100/i5
- https://www.3dnatives.com/en/3d-printed-drugs-personalized-medicine-140520204/

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DNA

- Natures bitstream
- Can read into bits
- Can reproduce from bits
- Digitize organisms….
- Those bits control behavior
- Control function of cells
  - Even what the cells manufacture and produce

http://www.astrochem.org/sci_img/dna.jpg

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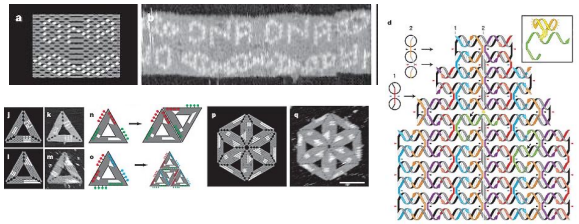
Programming the Physical World (DNA)



- How do we program DNA?
  - Self-assemble into arbitrary useful structures?
  - Perform specific functions in cells?
  - …becoming a problem of information and computation

[Winfree & Rothemund, CALTECH]

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Limits?

- What can't we capture and reproduce from bits?

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Clarke's Laws

1. When a distinguished but elderly scientist states that something is possible, he is almost certainly right.
2. When he states that something is impossible, he is very probably wrong. The only way of discovering the limits of the possible is to venture a little way past them into the impossible.
3. Any sufficiently advanced technology is indistinguishable from magic.

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Penn Engineering

ESE

Part 2

Administrative Interlude: Final

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Final

- Final Office Hours: (see piazza)
  - Sunday 5/1, Monday 5/2, Tuesday 5/3
- Final: Wednesday (5/4)
  - Like Midterm (but 2 hours, so longer)
    - Closed book; bring calculator
  - 15% of grade
  - Comprehensive (intent…does tend to weight 2nd half)
  - Last few years final and answers linked to syllabus
    - Probably mix ideas from first and second half
    - Last year was online/open-book (so less representative)

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Final Topics

Pre Midterm

- Data representation in bits
- Sounds waves
- Sampling
- Quantization
- Nyquist
- Lossy/lossless compression
- Common case
- Frequency domain
- Psychoacoustics
- Perceptual coding

Post midterm

- Combinational Logic
- Finite-State Machines
- Stored-Program Processors
- Processing Requirements
- Process Virtualization
- Networking
- Sensing, Actuation, Control
- User Interface
- Intellectual Property

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Engineering Disciplines

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Understanding

- **Computer Engineering**
- **Electrical Engineering**
- **Computer Science**
- **Systems Science and Engineering**

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Information as Unifier

- **EE**
  - Signal processing, control
  - Electrical systems to process
- **CIS**
  - Algorithms, software, strategy
- **MEAM**
  - Capture, reproduce, control
- **BE**
  - Cellular behavior, synthetic Biology
- **SSE**
  - Resuable math and information processing

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Data Science and Machine Learning

- **How do we make sense of raw data?**
- **Turn it into useful information?**
- **Use it to control things?**
- **Automate the processing and adaptation (learning)**
- **Mathematics developed in**
  - EE, Systems, Statistics, Operations Management, …
- **Implemented in**
  - Programming languages and algorithms – CIS
- **Implemented on and enabled by**
  - Computer hardware designed and optimized by CMPEs
- **Enables**
  - Autonomous Vehicles, Robots, Assistance, Business, Science, Engineering, ….

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Processing for Machine Learning

- **At core Linear Algebra**
  - Dot Products
  - Matrix Operations
    - matrix-vector multiplication, matrix-matrix multiplication
- **Same computation we have been using for Audio processing**
  - Dot Products, Fourier Transforms
- **Hardware we explored in Lab 7, 8 postlabs is a relevant starting point**
- **Learn more: ESE539**

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Topic	CSCI	CMPE	EE	ESE
Analog Circuits		**ESE215**	**ESE215**	
Compress	**CIS121**	**CIS121**		
Nyquist, Fourier			**ESE224**, ESE325	**ESE224**, ESE325
Optimization	**CIS320**	(many)		**ESE204**
Digital Logic	**CIS240**	**CIS240, ESE370,** ESE532		
Processor	CIS471	**CIS471**		
OS	CIS380	**CIS380**		
Embedded, Actuation		**ESE350** ESE421 **CIS441**	ESE350 ESE421	ESE350 ESE421
IP		EAS545	ESE545	ESE545
Networking		**ESE407** or **CIS553**	ESE407	ESE407
UI				ESE543

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(Notes for previous slide)

- **Bold – required**
- Not bold – restricted elective
- Simplified to fit on one slide
  - (e.g. should show many more analog circuits courses as restricted-electives for EE)

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Holistic/Unified Engineering

- **Today's devices and products crosscutting**
- **Fewer that fit in one silo**
- **Harder to draw boundary**

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What's Next?

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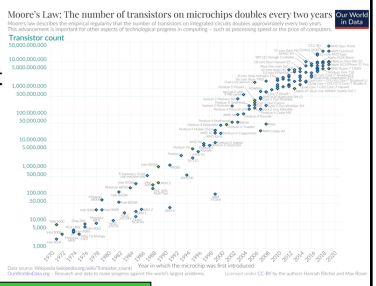
"Moore's Law" Today

- Exponential growth in Integrated Circuit (IC) capacity
- Driven by a geometric shrink in transistor feature size



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Moore's Law Enabled

- **MP3 players**
- **Smart phones and tablets**
- **Digital cameras**
- **Digital video recorders and players**
- **Realistic Games**
- **Skype, Zoom**
- **DNA sequencing**
- **Autonomous Vehicles, Drones**
- **Alexa, Siri**
- **Ubiquitous Machine Learning, Data Analytics**

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Continued Scaling

- **What will continued Moore's Law Scaling enable next?**

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Parting Thought

- **From 1st computer to PCs in 30 years**
  - Eniac 1946→ Apple 1976
- **From first PCs to iPhone next 30 years**
  - Apple 1976→iPhone 2007
- **What will next 30 years hold?**
  - Beginning of your career
- **What will you imagine, create, enable?**

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Remember

- **Lecture and Lab feedback form**
- **No lecture (or lab) Wednesday**
  - (this is last lecture)

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