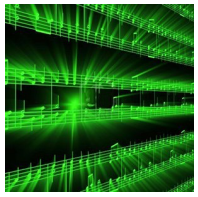
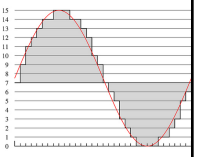
Penn Engineering

ESE





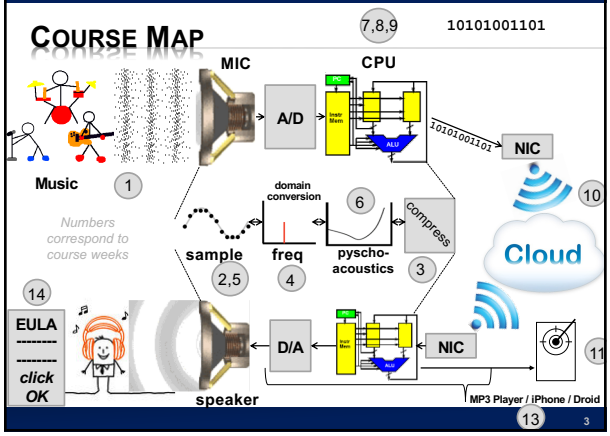
Lecture #26– Wrap Up!

ESE 150 – Digital Audio Basics

Lecture Topics

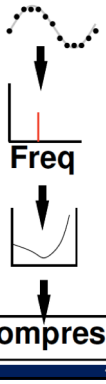
- Course map review
- Generalize
- Final
- Engineering Disciplines
- What's Next?

Course Map



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

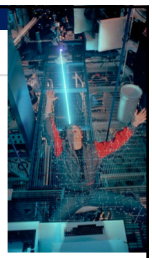


In the Process

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

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

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

7

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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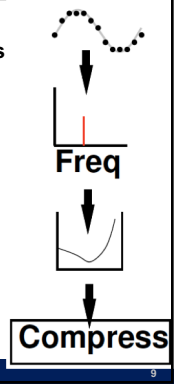
Image Processing One Slide

- **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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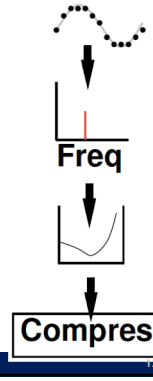
Video Processing One Slide

- **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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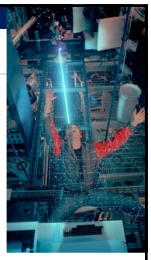
Virtualization of the World

- **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

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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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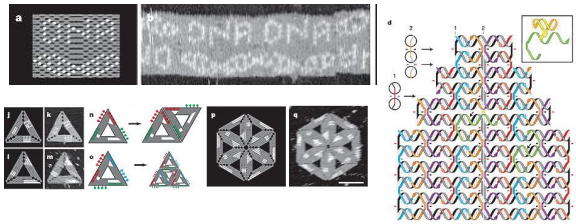
Programming the Physical World (DNA)



[Winfree & Rothemund, CALTECH]

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

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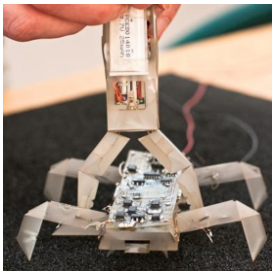
Printable Programmable Robots (Machines)



- Print out mechanisms
- With integrated
  - Mechanics
  - Sensing, actuation
  - Electronics
  - Computation

http://ppm.csail.mit.edu

MIT, Penn, Harvard

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It Gets Easier

- **3D Printing, contract manufacturing**
  - Low volume production, mechanical things
- **Processors – deploy code**
- **FPGAs, FPAA, PSoC – deploy circuits**
- **Internet – transfer designs, orders, advertise**
- **FedEx – global shipment**
- **Lowering Barriers**
  - Production, distribution, deployment

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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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Administrative Interlude: Final

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FINAL

- **Final Office Hours: (see piazza)**
  - Sunday 5/2, Monday 5/3, Tuesday 5/4
- **Final: Wednesday (5/5) Online**
  - Regulations posted
    - Like Midterm
    - 12 hour window
  - 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

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

ENGINEERING DISCIPLINES

UNDERSTANDING

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

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

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 by CMPEs
- **Enables**
  - Autonomous Vehicles, Robots, Assistance, Business, Science, Engineering, ….

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	SSE
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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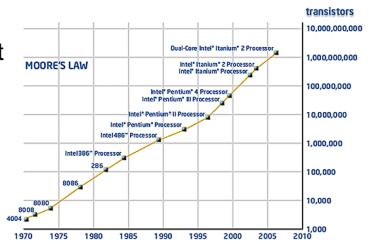
"Moore's Law" Today

- 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
- 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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Lab Due

- Note: Lab due Thursday (by midnight)
  - Last day of classes (not have due during reading period)
- Remember Lecture and Lab feedback form

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