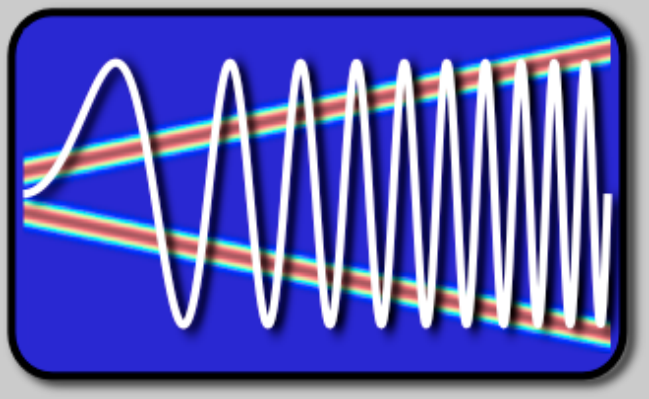
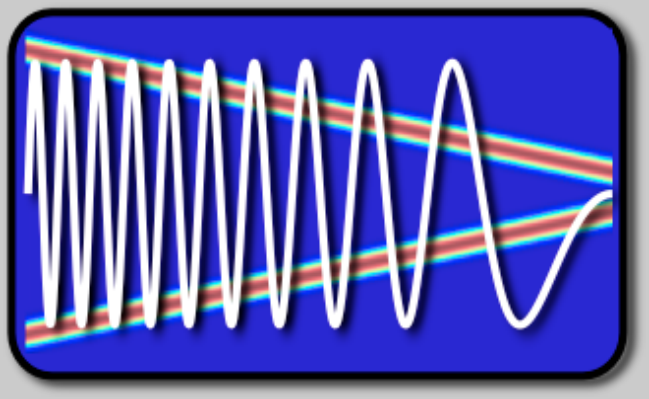


EE123 Digital Signal Processing



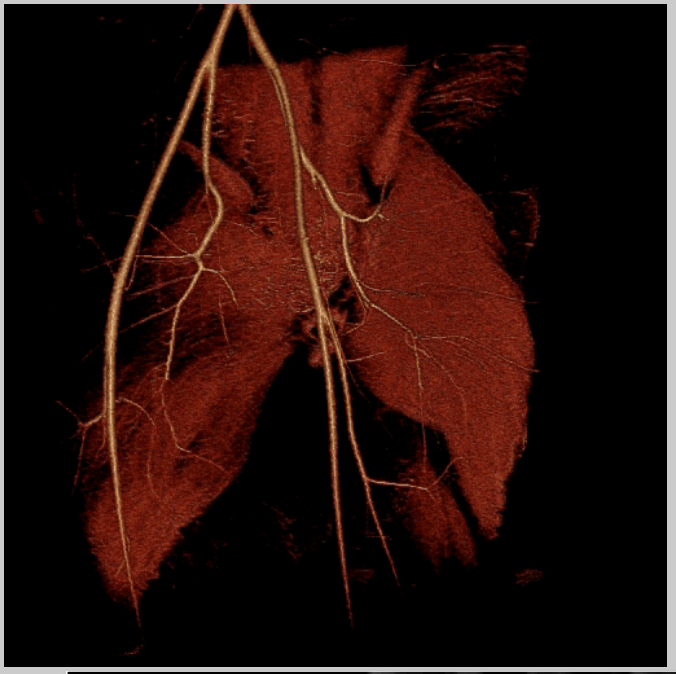
Miki Lustig

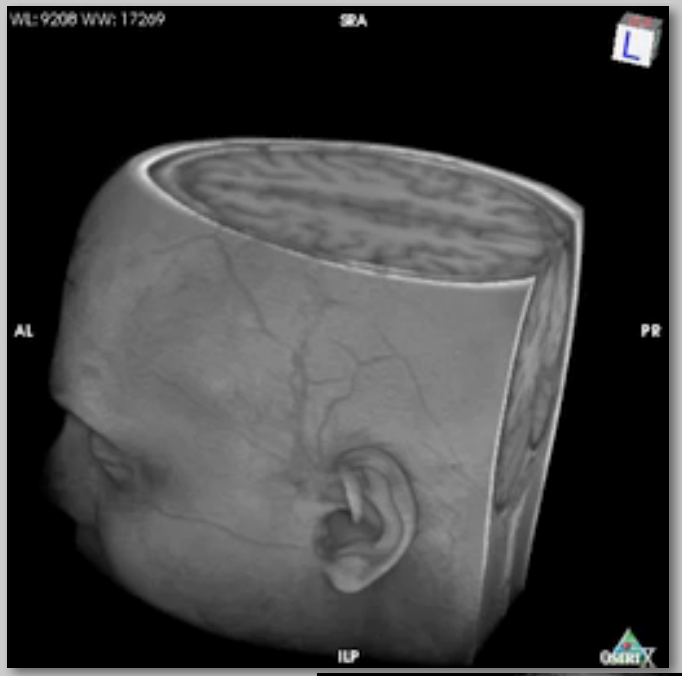
Electrical Engineering and Computer Science, UC Berkeley, CA

Information

- Class webpage:
  - https://inst.eecs.berkeley.edu/~ee123/sp16/
- Self grading
- Labs and check-offs
- EE198-13 -- please register to get credit for studying for ham exam
  - Wednesdays 6:30-8:30pm (not today!)

My Research

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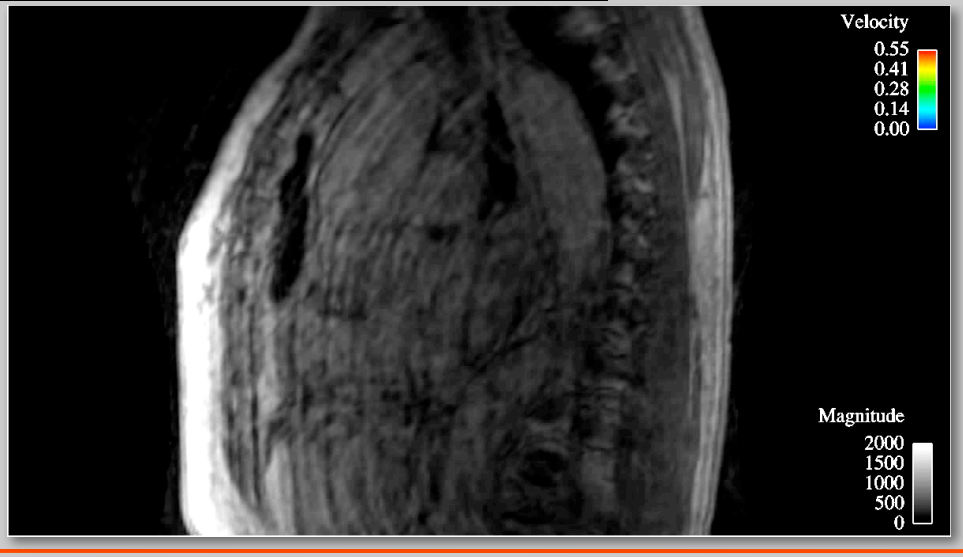
SRA
AL
PR
ILP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0.28
0.14
0.00
Magnitude
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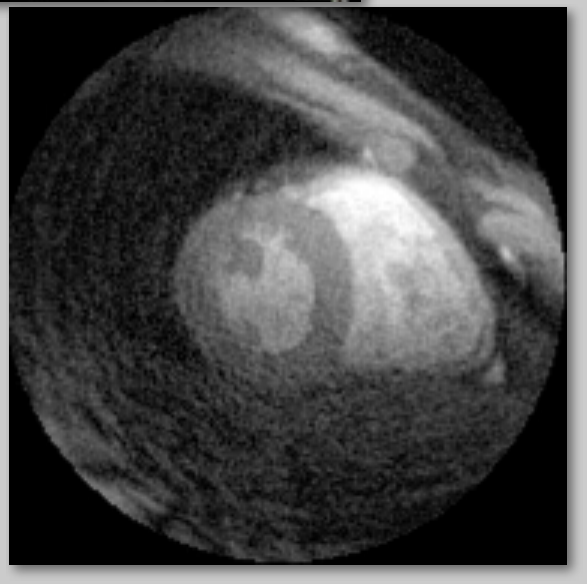
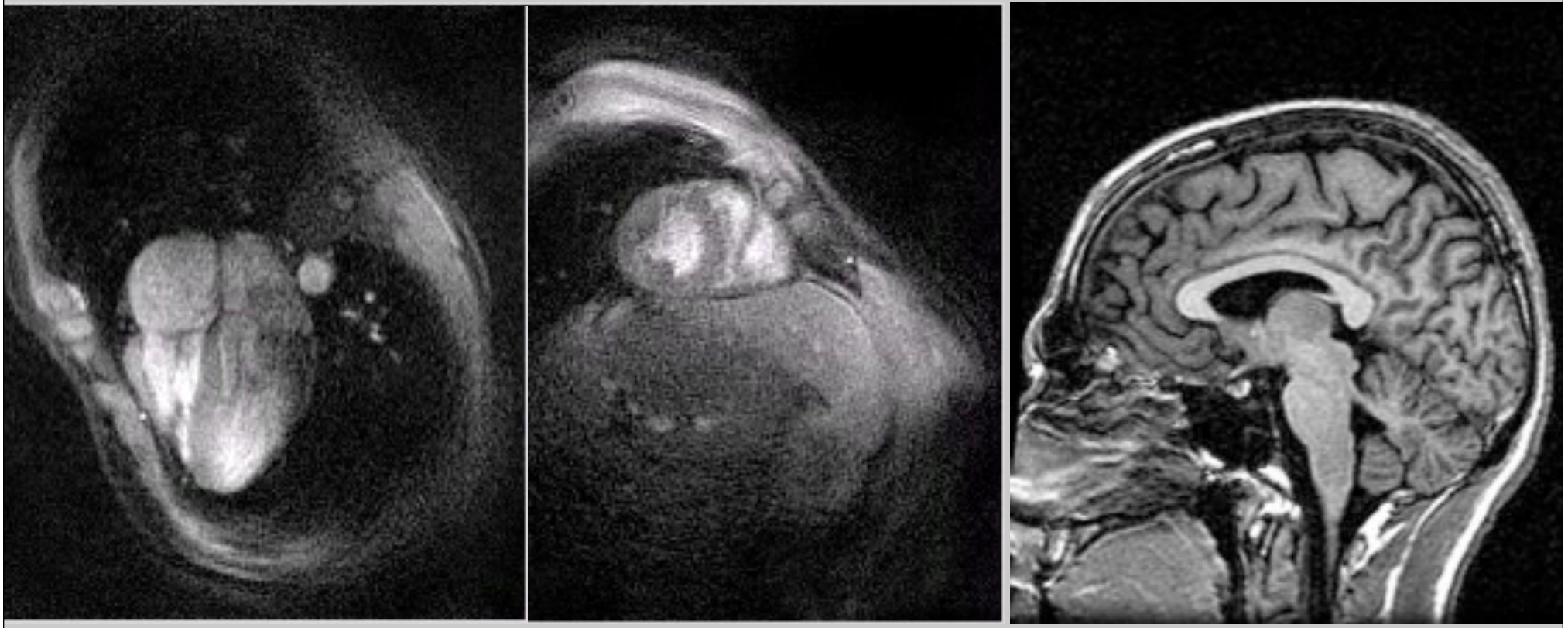
1500
1000
500
0



Me - Exposed



Signal Processing in General

- Convert one signal to another
  (e.g. filter, generate control command, etc.)
- Interpretation and information extraction
  (e.g. speech recognition, machine learning)

Digital Signal Processing

- Discrete Samples
- Discrete Representation (on a computer)

- Can be samples of a Continuous-Time signal: $x[n] = X(nT)$
- Inherently discrete (example?)

Why Learn DSP?

- Swiss-Army-Knife of modern EE
- Impacts all aspects of modern life
  - –Communications (wireless, internet, GPS...)
  - –Control and monitoring (cars, machines...)
  - –Multimedia (mp3, cameras, videos, restoration ...)
  - –Health (medical devices, imaging....)
  - –Economy (stock market, prediction)
  - –More....

Advantages of DSP

- Flexibility
- System/implementation does not age
- “Easy” implementation
- Reusable hardware
- Sophisticated processing
- Process on a computer
- (Today) Computation is cheaper and better

Example I: Audio Compression

- Compress audio by 10x without perceptual loss of quality.
- Sophisticated processing based on models of human perception
- 3MB files instead of 30MB -
  Entire industry changed in less than 10 years!

CD mp3 Error x10

Historical Forms of Compression

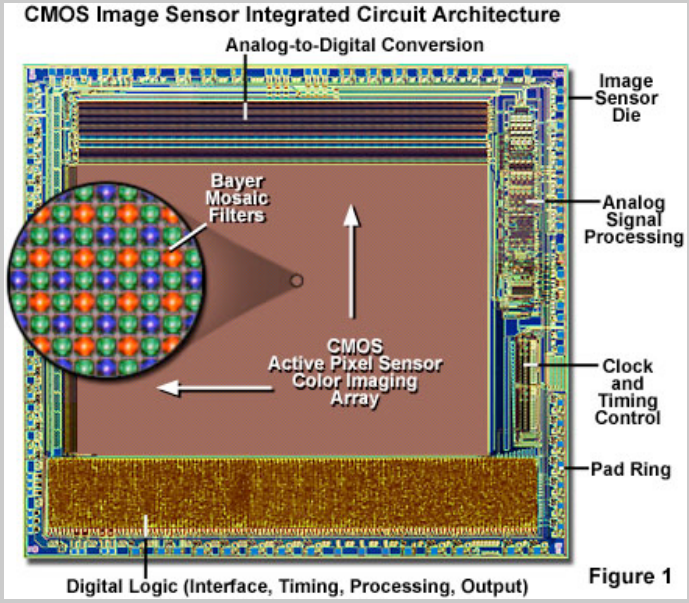
- Morse code: dots (1 unit) Dashes (3 units)
  - –Code Length inversely proportional to frequency
    E (12.7%) = . (1 unit) Q (0.1%) = --.- (10 units)

- "92 Code" - Used by Western-Union in 1859 to reduce BW on telegraph lines by numerical codes for frequently used phrases
  - –1 = wait a minute
  - –73 = Best Regards
  - –88 = Loves and Kisses

73 --... ...-- (19units)

Best -... . ... - / Regards .-. . --. .- .-. -.. ... (59units)

Example II: Digital Imaging Camera

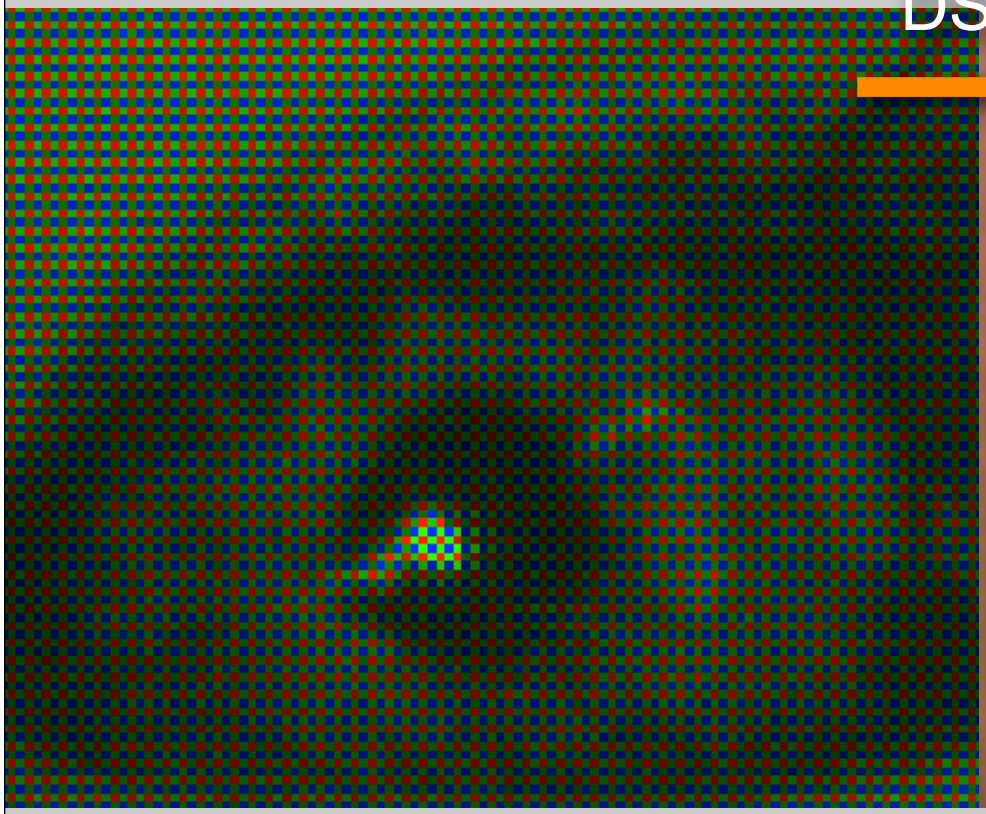


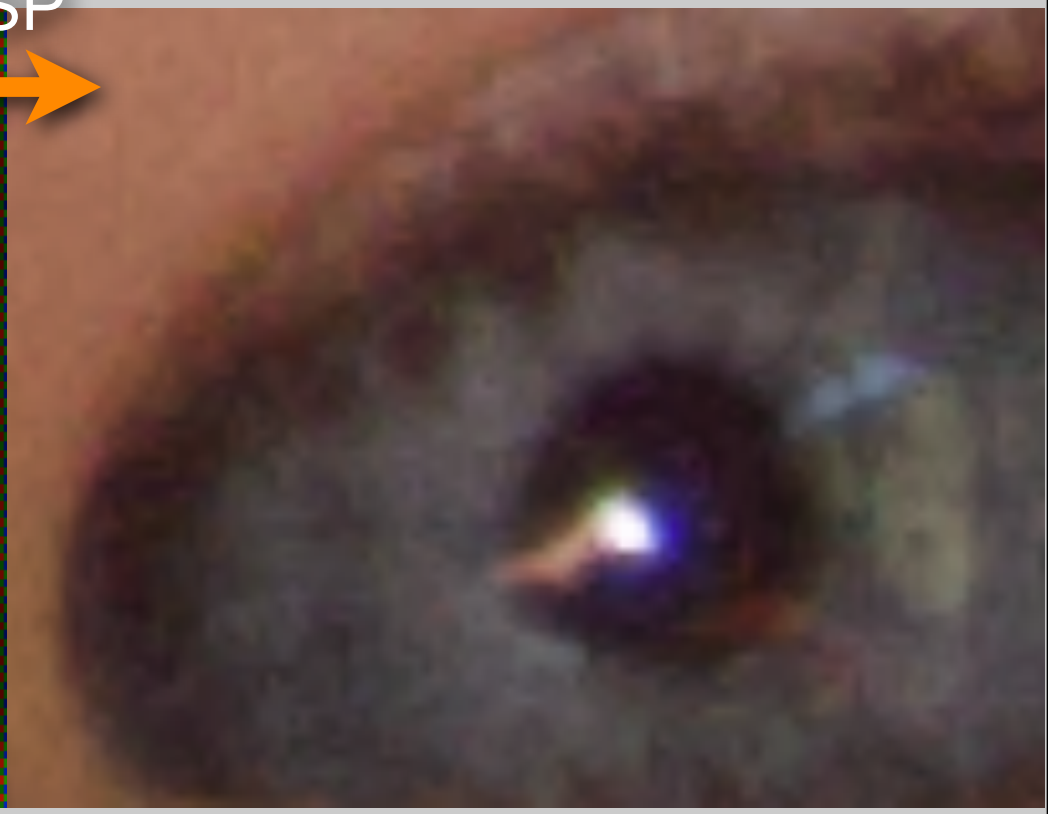
Focus/exposure Control → preprocessing → white-balancing → demosaic → Color transform → Post-processing → Compression

http://micro.magnet.fsu.edu/primer/digitalimaging/cmosimagesensors.html

Example II: Digital Camera

DSP





Example II: Digital Camera

- Compression of 40x without perceptual loss of quality.

- Example of slight overcompression: difference enables x60 compression!

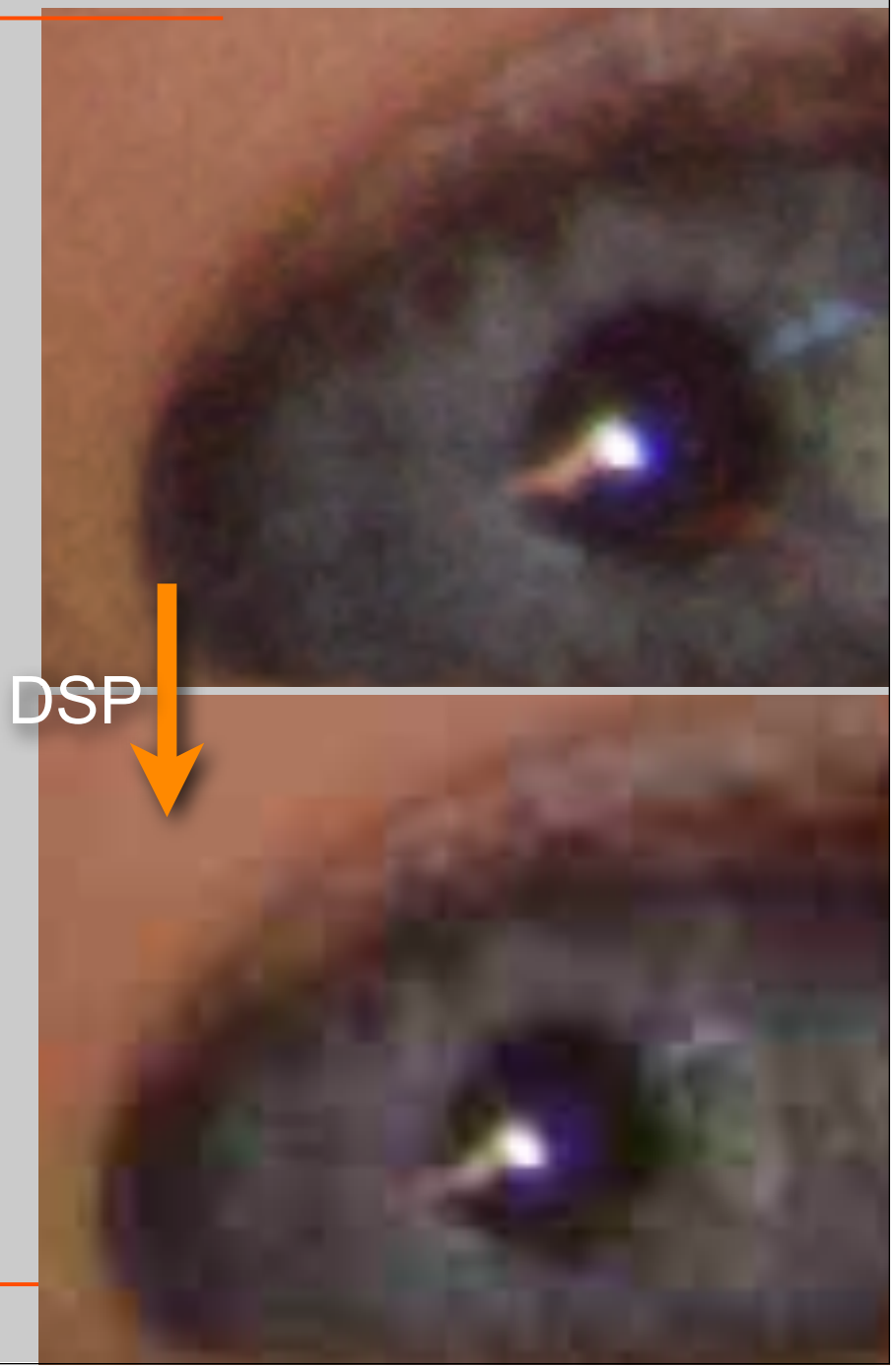


Image Processing - Saves Children

Canadian 'swirl face' pedophile jailed in Thailand

August 15, 2008

Images released by Interpol in 2007 show the 'unswirling' of the internet pictures that led to the capture of Christopher Paul Neil.

Computational Photography

DSP

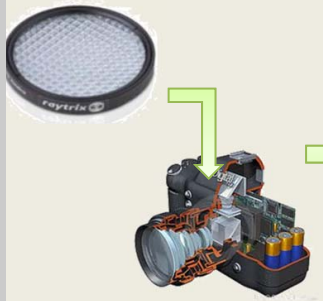
Now implemented in smart phones (HDR)

*www.hdrsoft.com

The light field camera

Link

1) Add lenslet array



2) Take picture
(looks like a lot of little pictures)

3) **Computation**

4) Final result

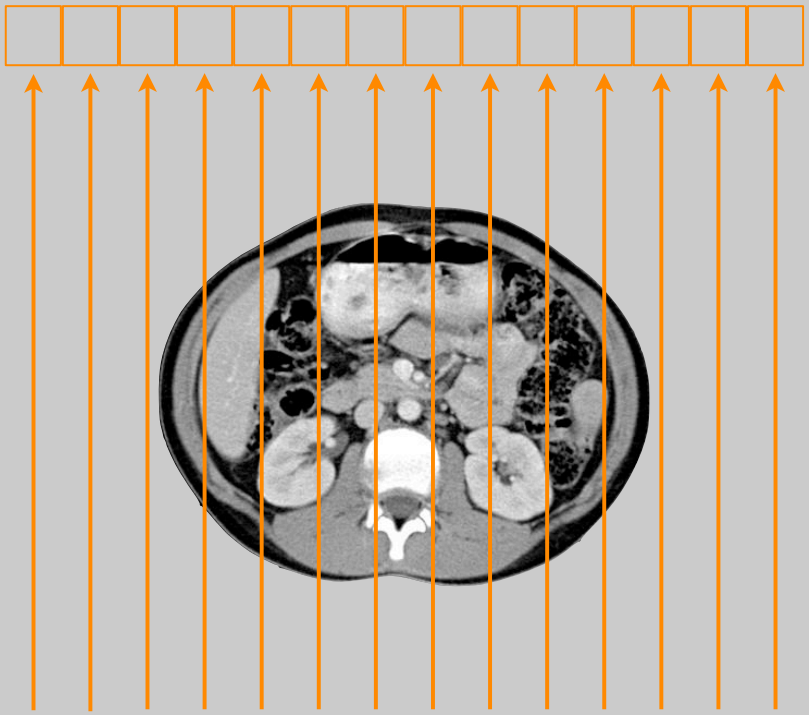
5) Start company

LYTRO
Picture Revolution

Pelican Imaging

Raytrix Gmbh

Example III: Computed Tomography

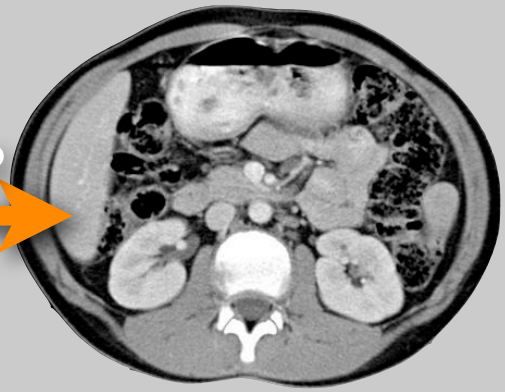


x-ray source

Sinogram

DSP

cross-section

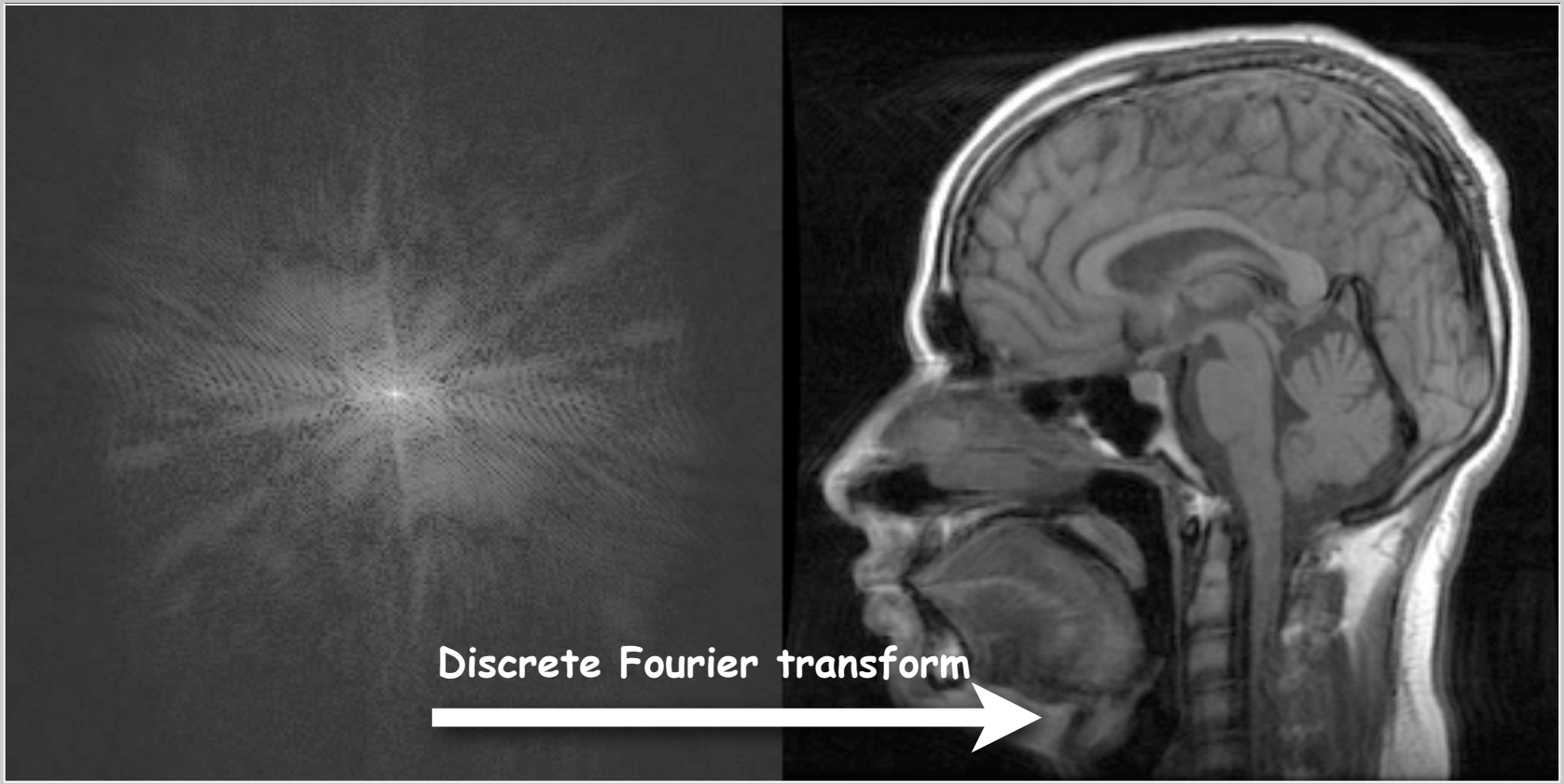


Example IV: MRI (again!)

Fourier

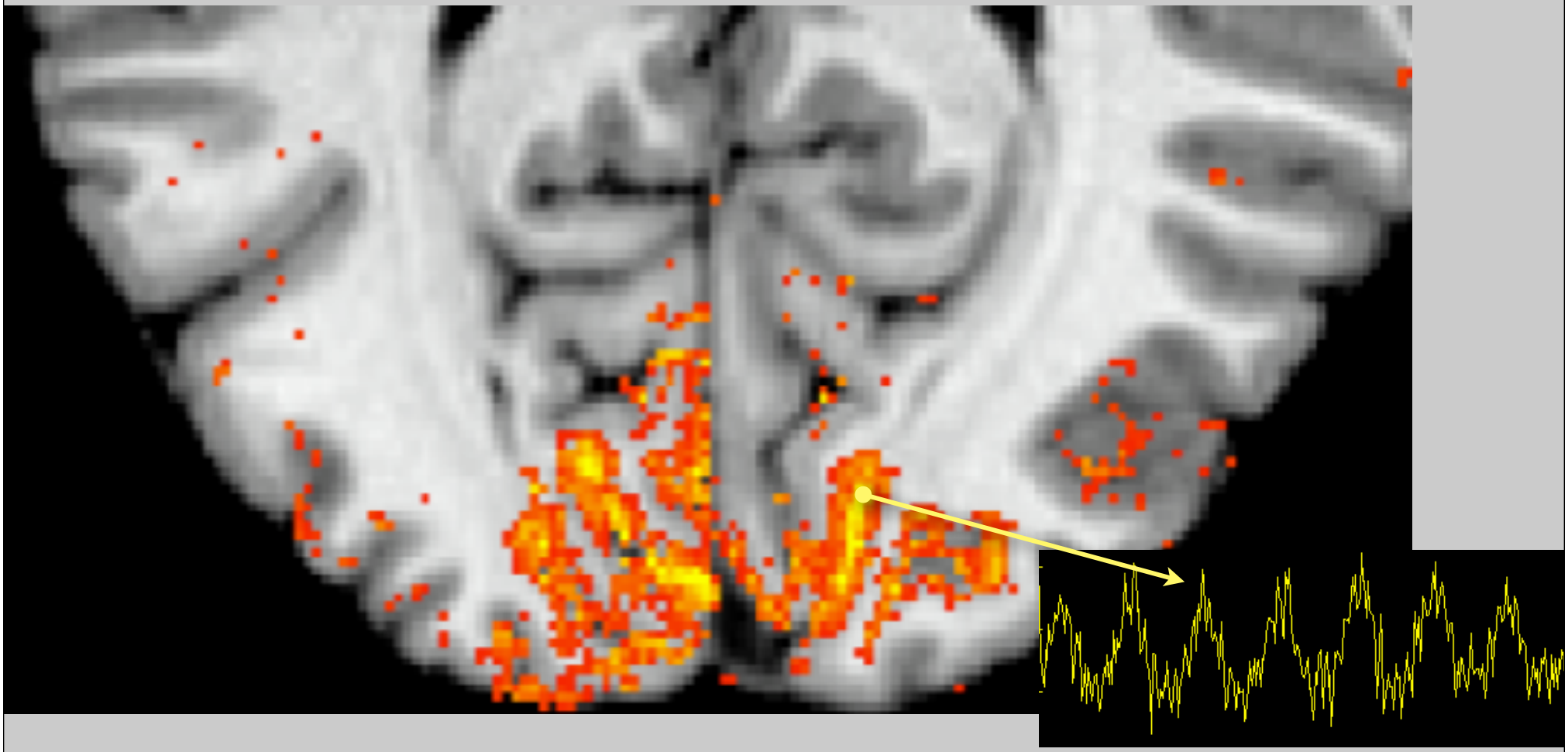
k-space (Raw Data)

Image



Functional MRI Example

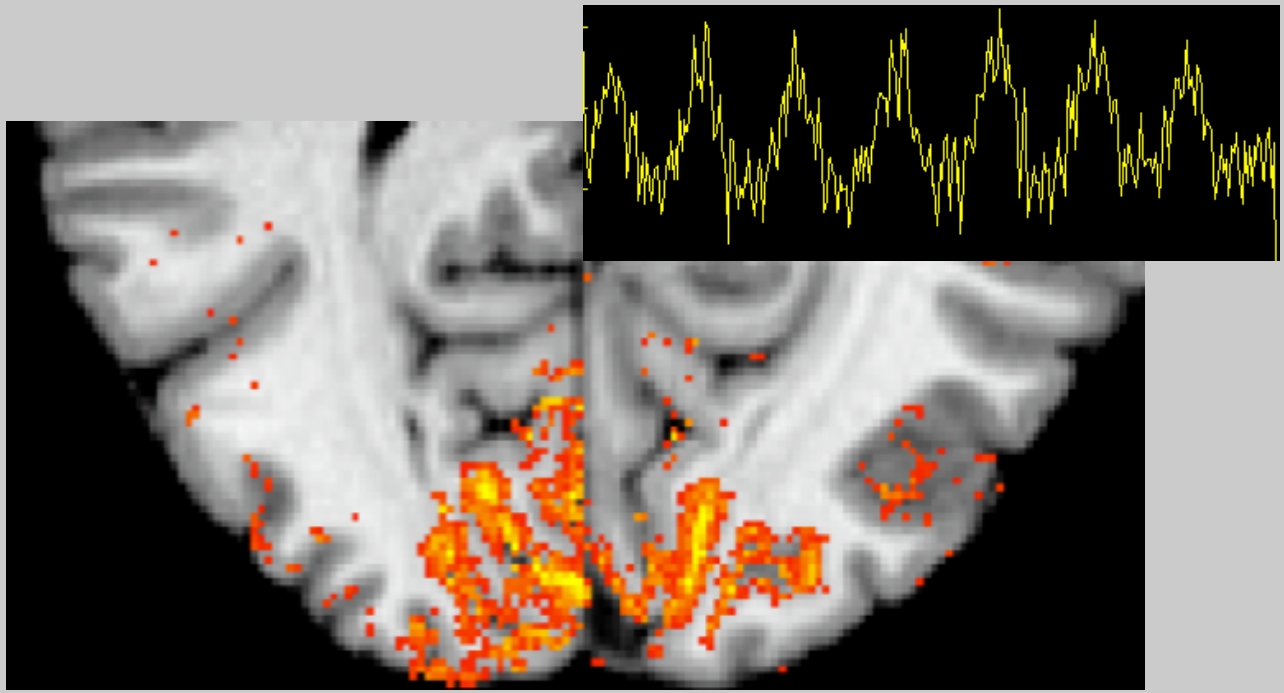
Sensitivity to blood oxygenation - response to brain activity
Convert from one signal to another

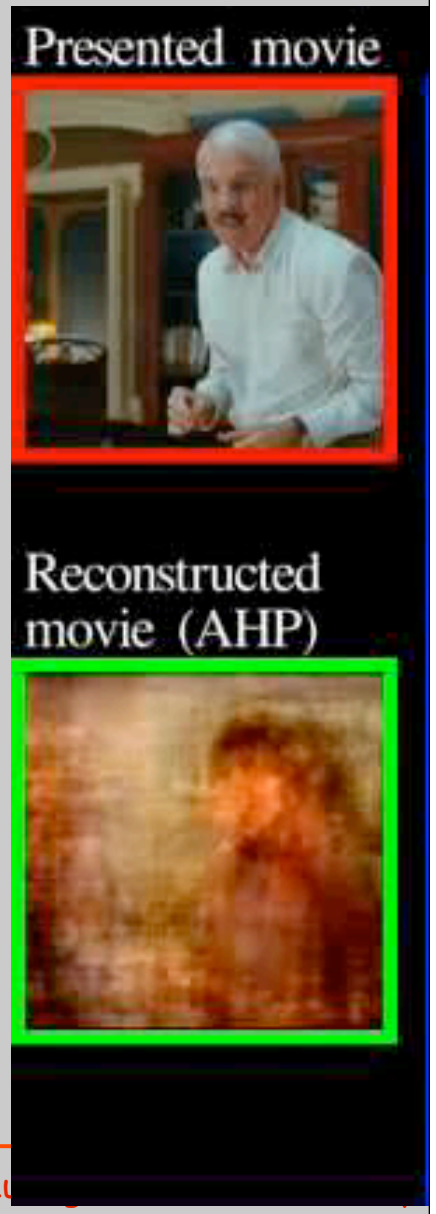


*Karla Miller, Oxford
*Brian Wandell, Stanford

Taking fMRI further

- fMRI decoding : “Mind Reading” Gallant Lab, UC Berkeley
- Interpretation of signals

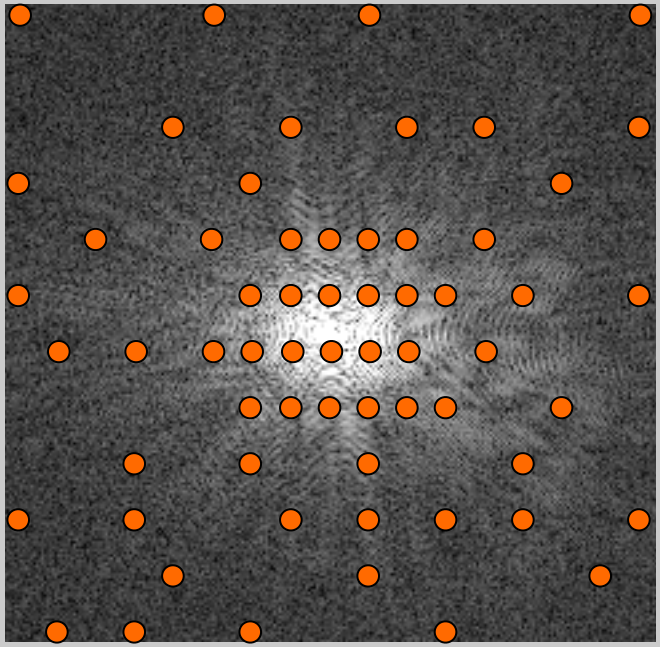




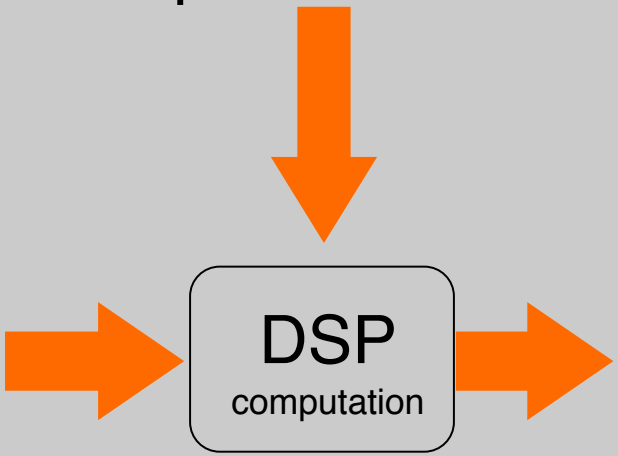
Compressive Sampling

- Compression meets Sampling

Don't collect all data to save time



prior information



Example V: Software Defined Radio

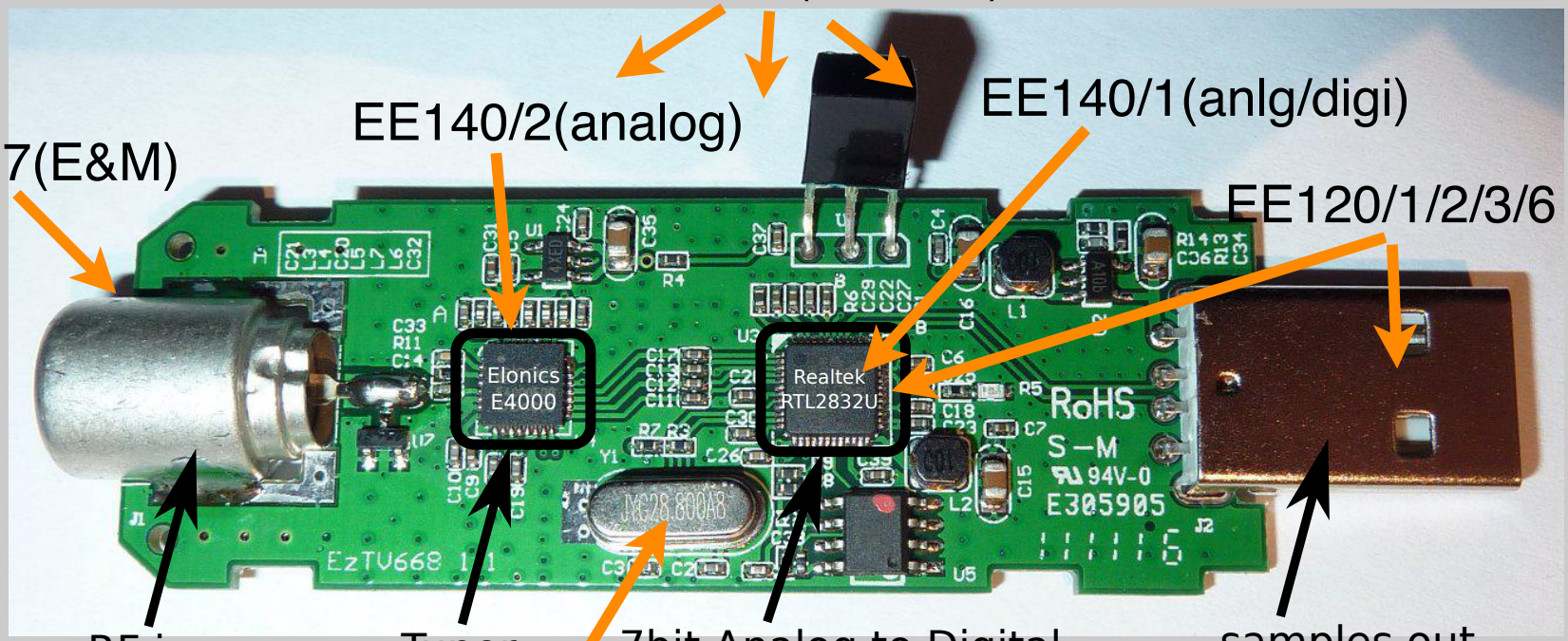
- Traditional radio:
  - Hardware receiver/demodulators/filtering
  - Outputs analog signals or digital bits
- Software Defined Radio:
  - Uses RF font end for baseband signal
  - High speed ADC digitizes samples
  - All processing chain done in software

Software Defined Radio

- Advantages:
  - Flexibility
  - Upgradable
  - Sophisticated processing
  - Ideal Processing chain - not approximate like in analog hardware
- Already used in consumer electronics
  - Cellphone baseband processors
  - Wifi, GPS, etc....

RTL-SDR

- Inexpensive TV dongle based on RTL2832U and E4000 /820T chipset can be used as SDR



SDR & You

- Will provide easy interface to Python
  - Each student will be given a device
  - Homeworks/Labs based on the device
  - Final Project could use SDR

```
> sdr = RtlSdr()
> sdr.sample_rate = 240000
> sdr.center_freq = 94.1e6
> sdr.gain = 36
> samples = sdr.read_samples(480000)
```

SDR Demo

Promotion

- If you are interested in how Analog to digital converters, amplifiers etc...work and how to make them
- Take EE140!
- Good engineers know both sides of the system

Ham Radio

- All students will get FCC license in class
- Each student will get a Handheld radio
- Radios will be used for Digital Signal Process and communication Labs and Project.

- HAM is a wonderful way to learn about more complex EE/CS topics -- play with hardware, software, processing, E&M with a broad diverse community
- Mark your calendar March 12 ham licensing exam