Thoughts on Computational Photography

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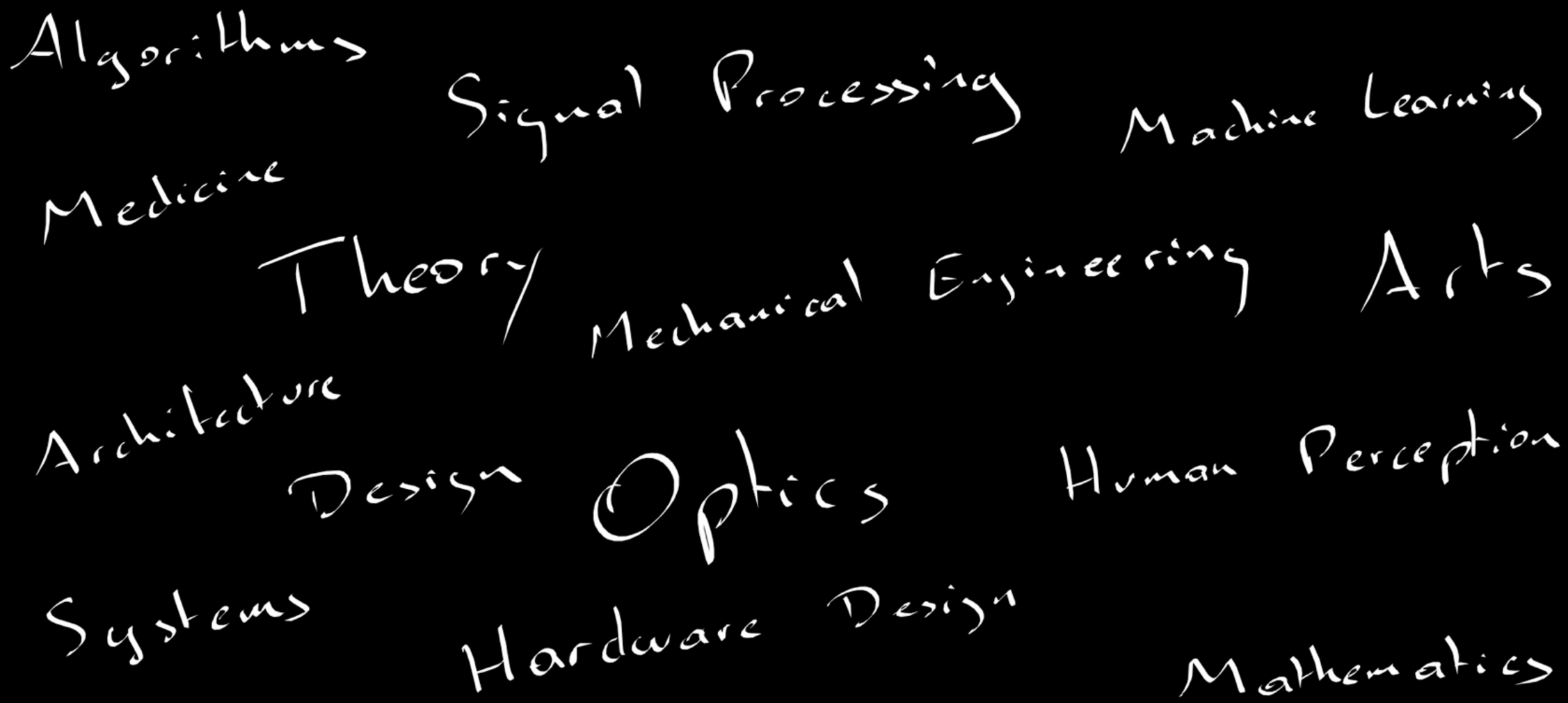
Computational Photography

Computation is a central component of image formation

The final image is not a mere projection of light onto a sensor but results from deep calculation

I love how interdisciplinary computational photography is



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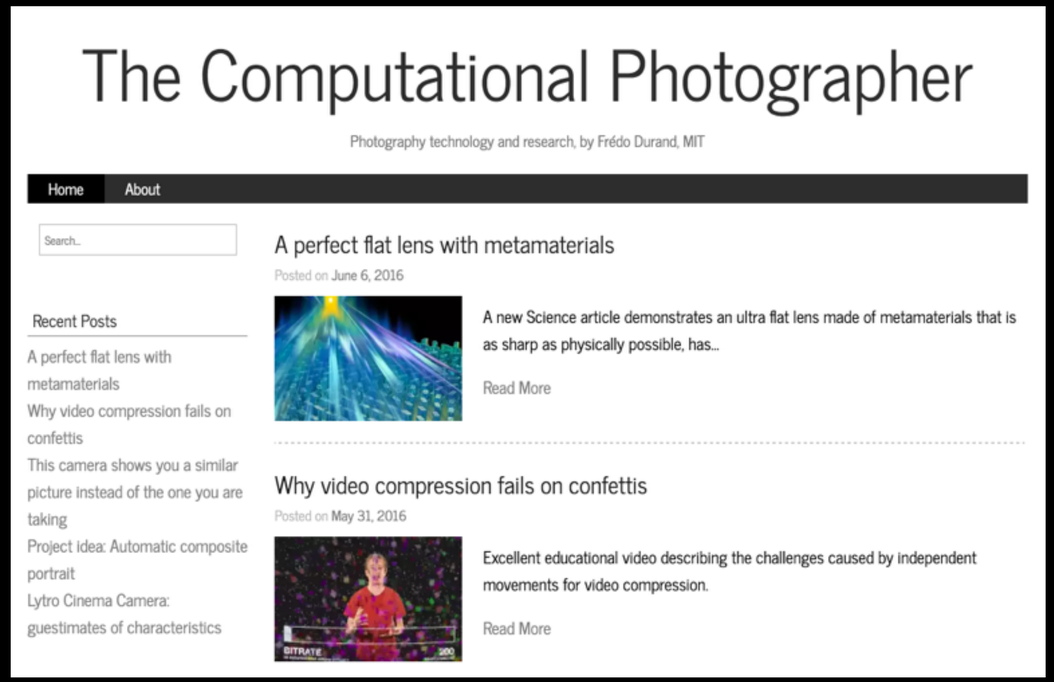
Read my blog!

- http://thecomputationalphotographer.com
- I will post these slides there



Computational photography has great successes

Basic camera pipeline
(demosaicking, denoising, compression)

Panorama stitching

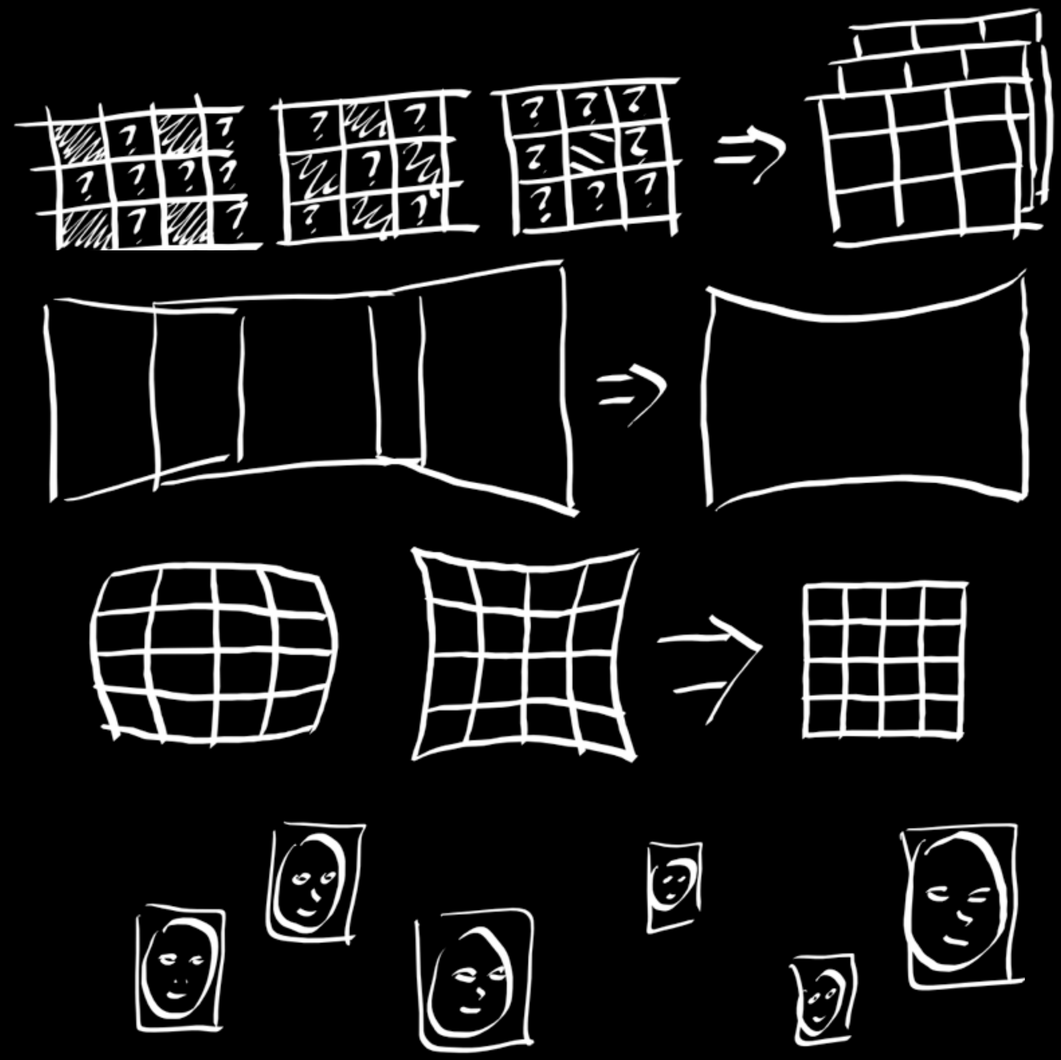
HDR, tone mapping

Correction of optical aberrations

Face detection & recognition

Video stabilization

Gradient editing, patch match, warps



But some ideas have remained mostly academic

Computational optics

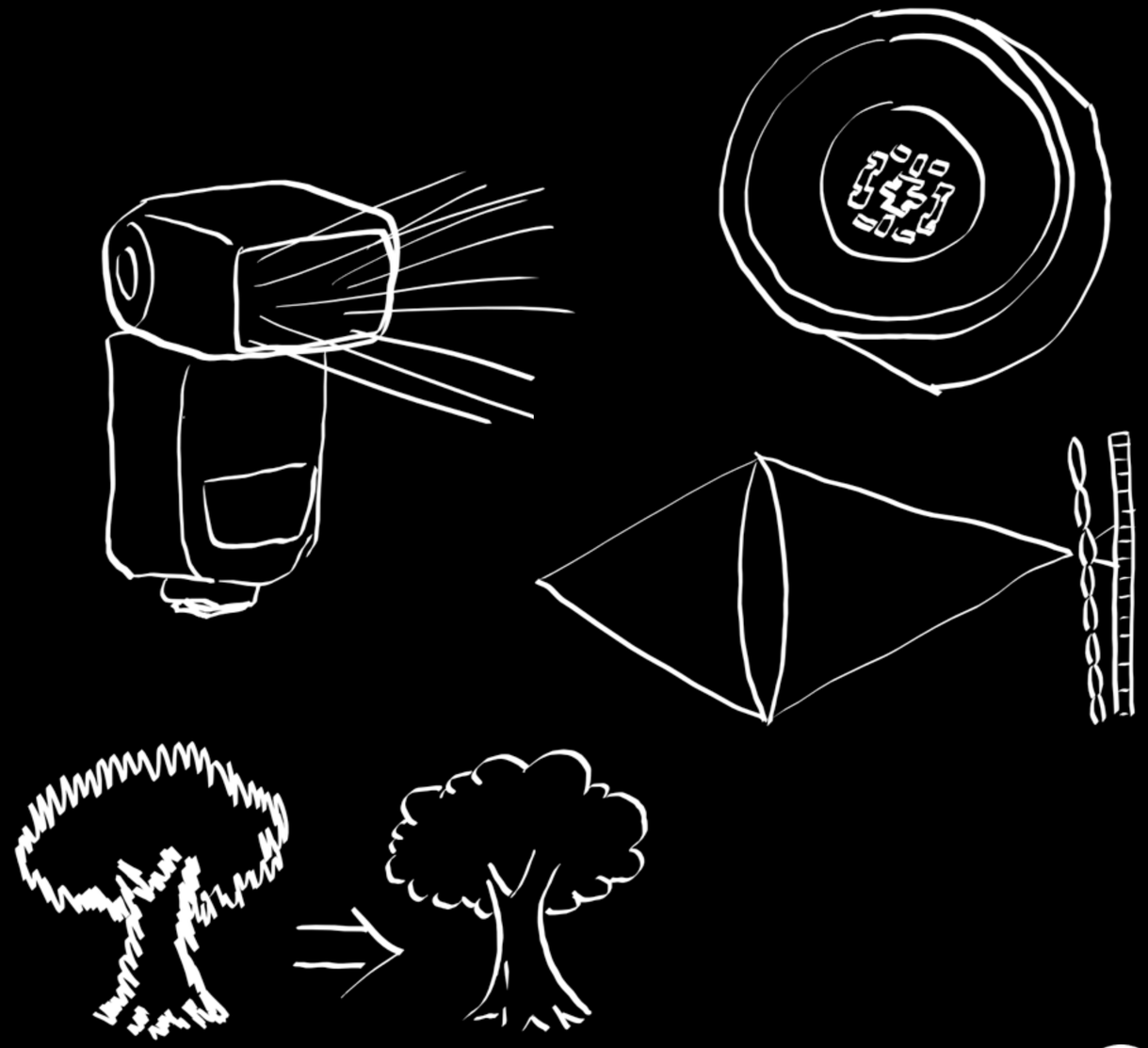
Flash no-flash, multi-flash,

Light fields

Deblurring

Superresolution

Most work on image collections

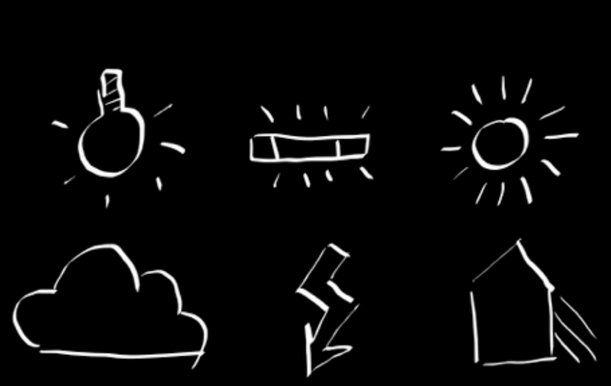


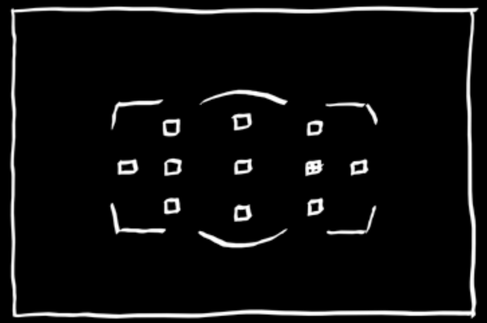
Some basic camera functions are still open problems

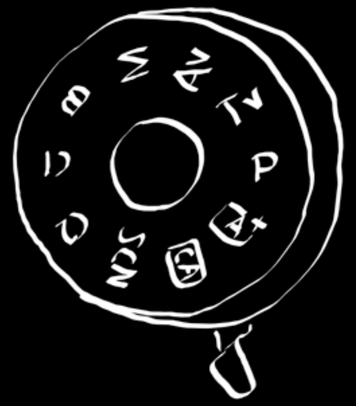
White balance (especially with mixed lighting)

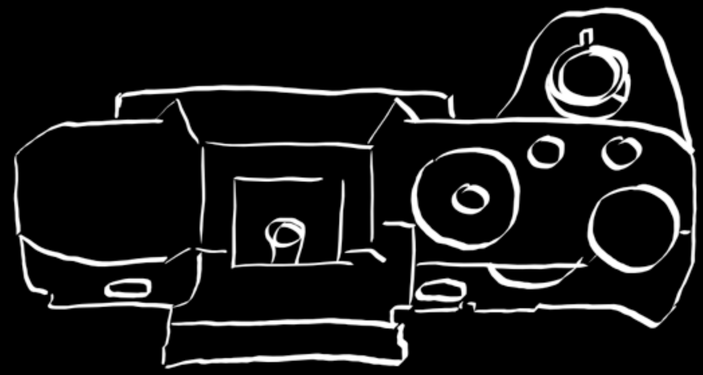
Focusing , auto-exposure (especially for video)

User Interface









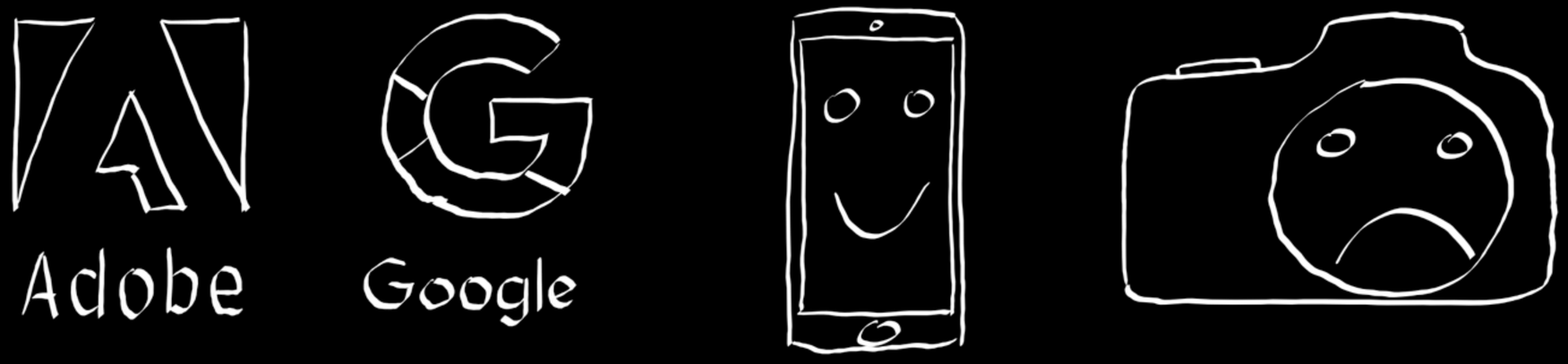
We do not have enough synergy with industry

Adobe and Google do great tech transfer

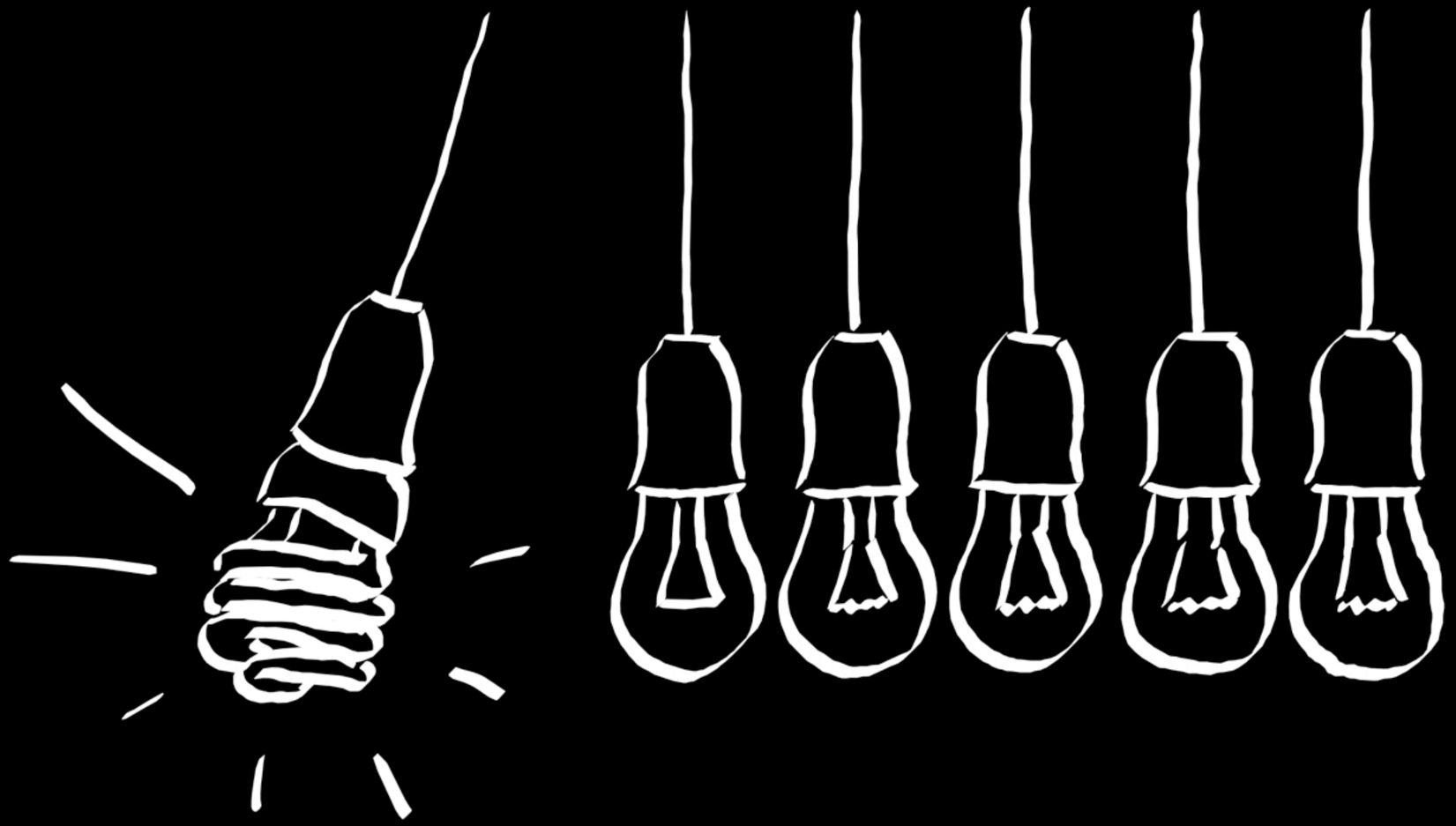
Other software companies do great research but transfer is not as strong

Cell phones are an open platforms for computational photography

Camera manufacturers are not thinking computationally

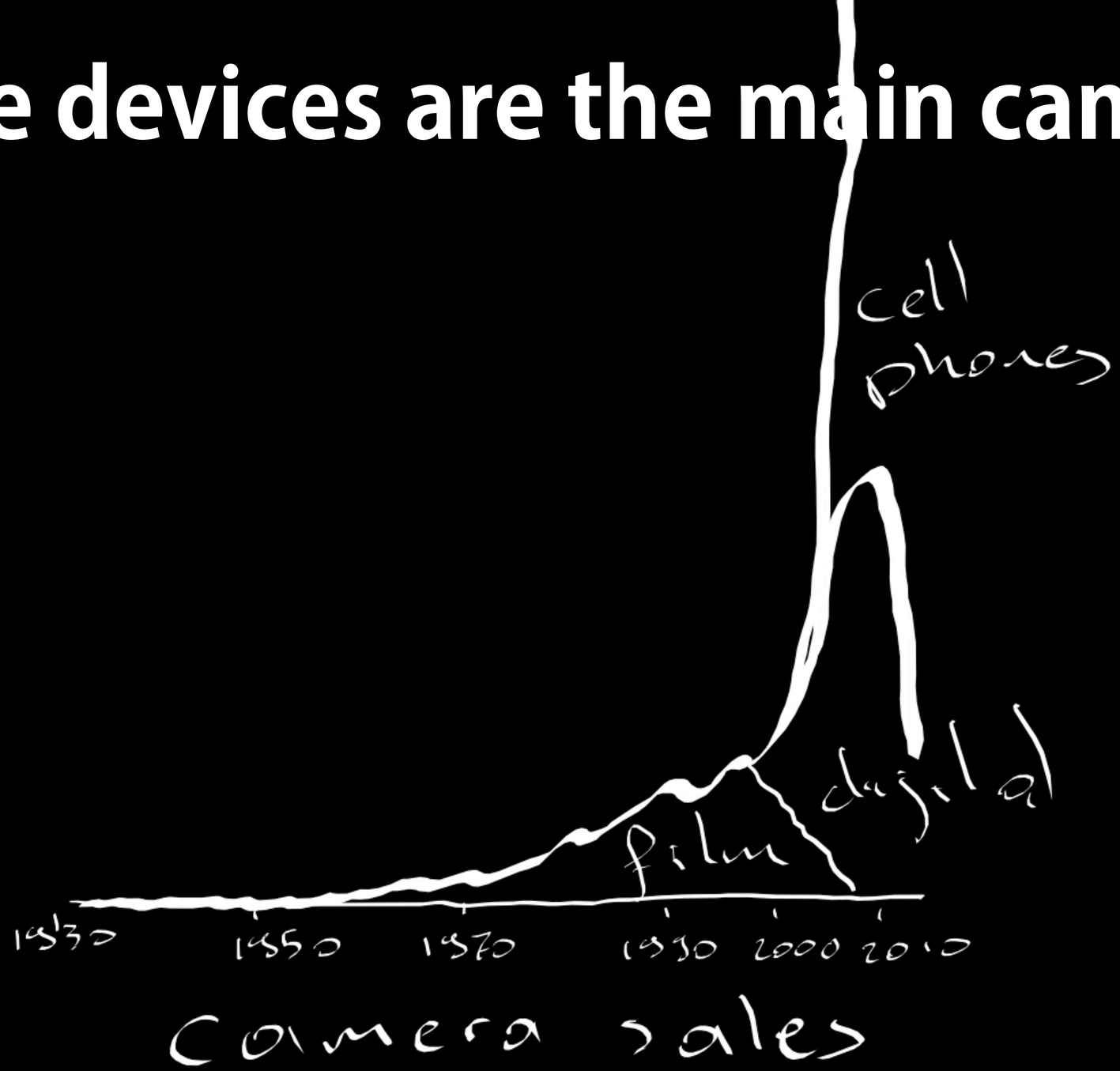


Can we sustain and improve our impact?



After https://researchimpactnetwork.wordpress.com/

Mobile devices are the main cameras

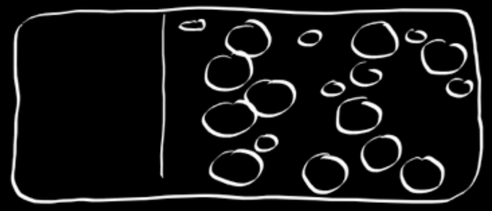


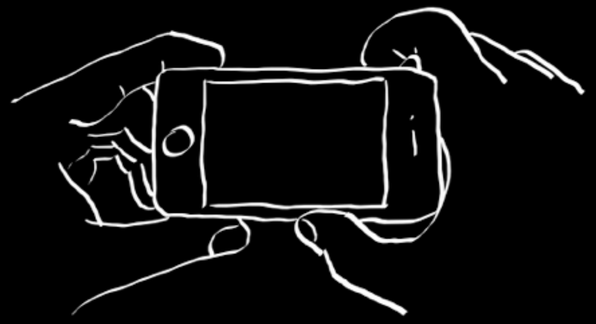
Mobile devices are the main cameras

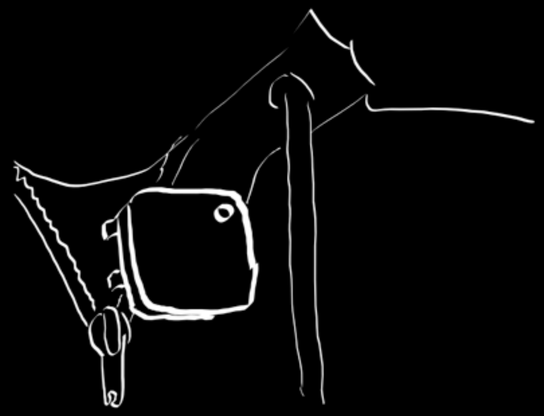
Form factor and power create harsh constraints

Connectivity offers challenges and opportunity:
people expect all their data on all devices with similar software

Wearable, always-on imaging and life logging compounds these issues







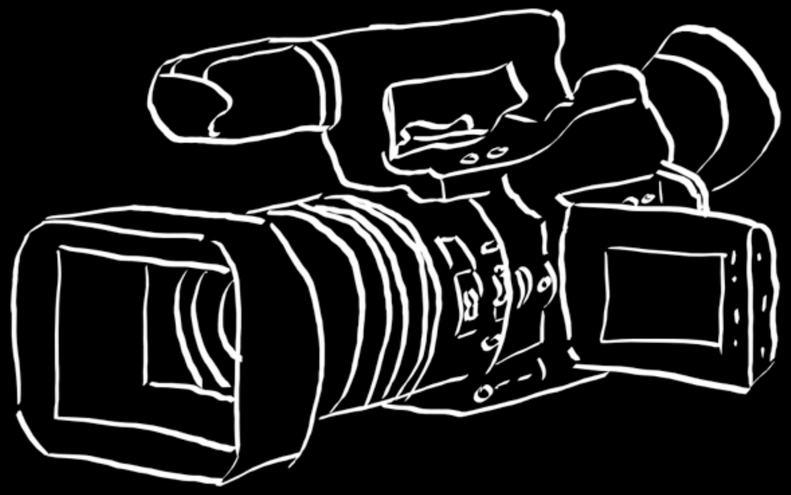
Video is still in its infancy

The gap between amateurs and pros is much larger than for still

Focus, autoexposure are hard and must be temporally coherent

Good and stable framing is a challenge

Editing and selection are painstaking and tools are complex



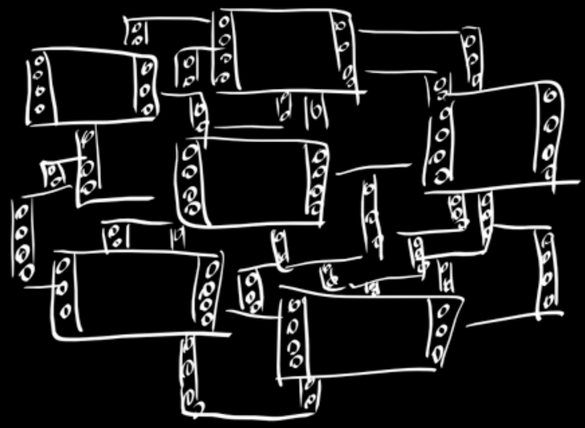
Scale is an opportunity and a challenge

How can we find the needle in gazillion photos and videos?

We need search and selection algorithms, interfaces, visualizations.

How can we get enough data to train deep learning?

We have systems challenges with scale, especially on mobiles and across devices



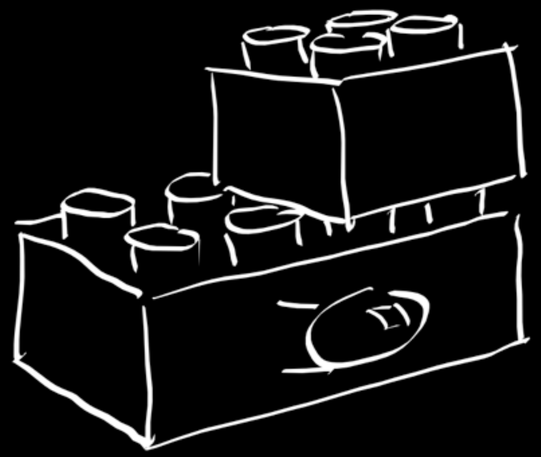
We need more Systems research

Users expect their data everywhere on heterogenous devices

New compilers and hardware are needed for performance

Software and hardware should be modular

What are data structures for metadata and new types of data?

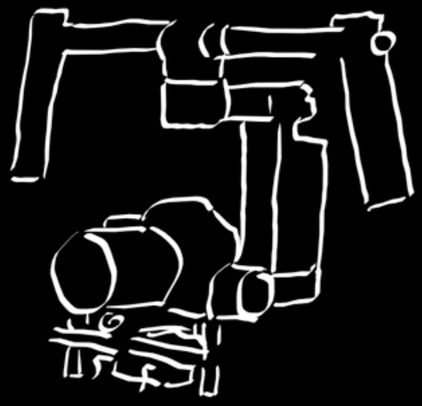


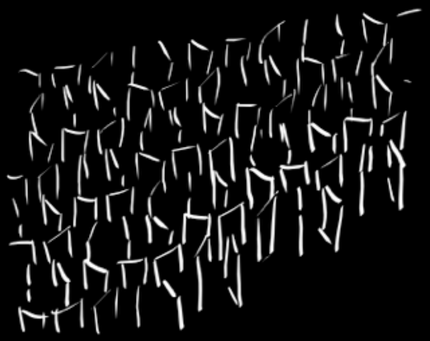
We need more research on hardware

Sensors should evolve for light fields, depth, other information, and on-board processing

Actuators and drones can move or stabilize cameras and lights

Computational fabrication and metamaterials can customize optics, sensors and lighting





We need more research on human factors

New UI is needed for traditional and computational photography

Visual perception must be studied and incorporated

We need better image metrics and priors

We need more theory

We must derive fundamental limits and scaling laws

We should unify time of flight and linear imaging

Light field and computational illumination need more theory

$$SNR(\Phi^2) = \frac{\Phi^2}{var(\Phi)} = \sum_{i,j} m_{ij} \frac{\Phi^2 t_i^2 [I_{ij} \angle 1_{m \times n}]}{\Phi t_i + \sigma_r^2 + \sigma_{dc}^2 \sigma^2}$$

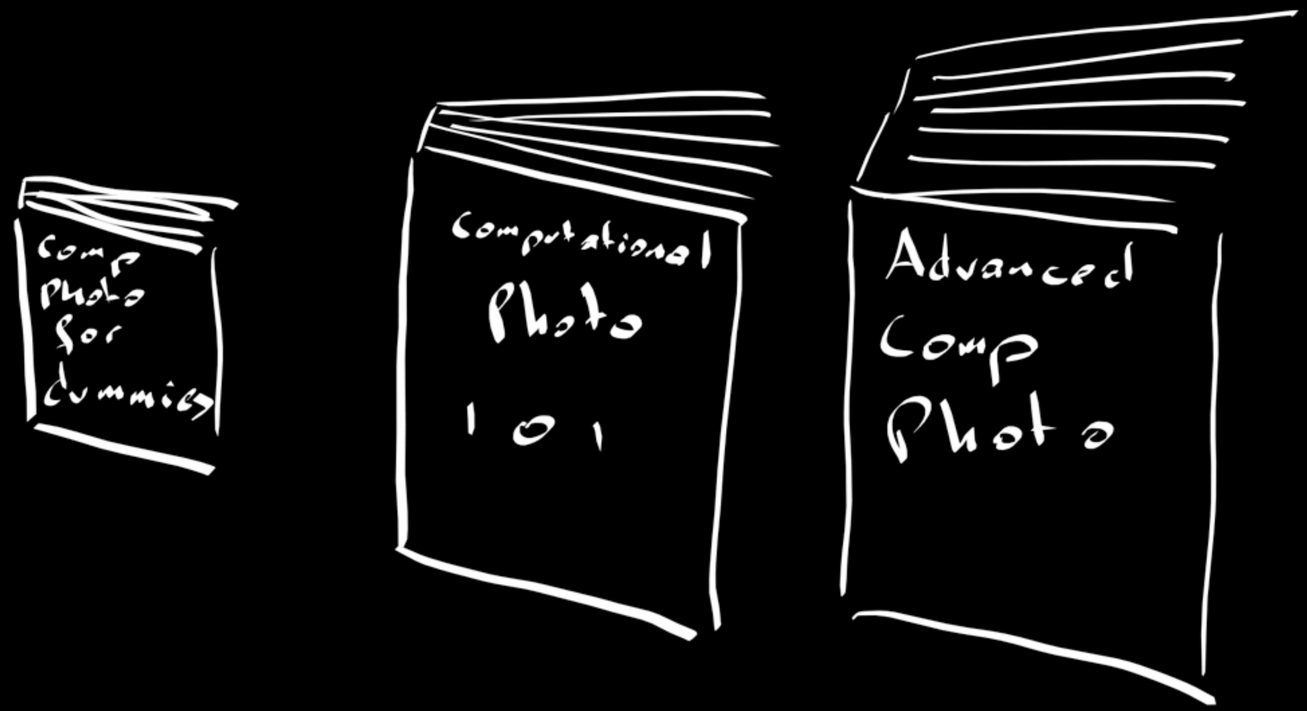
$$\frac{1}{\alpha^2 F^2} \iint L_f(u(1-1/\alpha) + x/\alpha, v(1-1/\alpha) + y/\alpha, u, v) \, du \, dv$$

$$\int \left| \iiint k(x, y, v, v) e^{-2i\pi(\omega_x x + \omega_y y)} \, dx \, dy \, dv \right| du \leq A^3$$

We need textbooks

We must put all we do into a coherent intellectual framework.

Systems and theory help with this too.



We should Reveal the invisible

a.k.a. super-hero vision

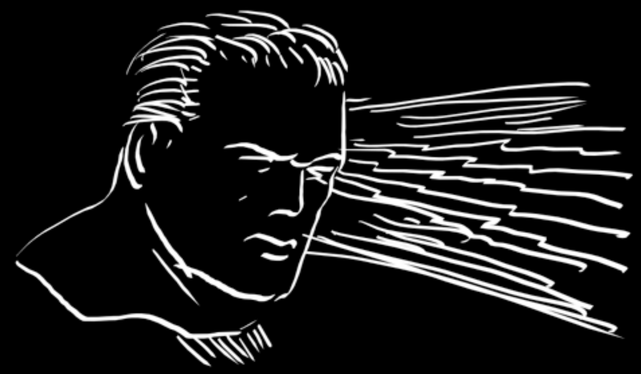
See beyond occlusion

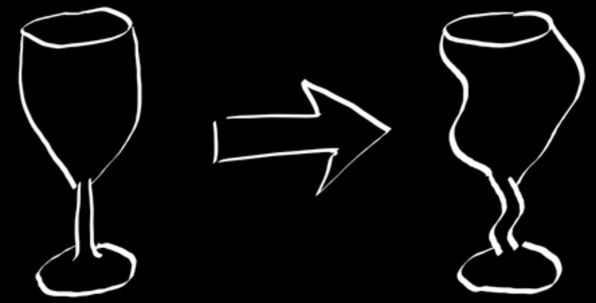
Video magnification and video comparison

Reveal non-visible properties and effects

Leverage augmented reality to overlay new info

cf. my slides on the topic





We must explore applications beyond photo

Computer Vision, inverse rendering

Virtual Reality, Augmented Reality

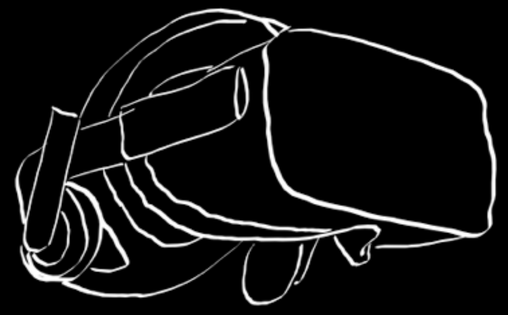
Automotive, robotics

Scientific & medical imaging

Various inputs, e.g. barcode reader

HCI, depth sensors, Kinect

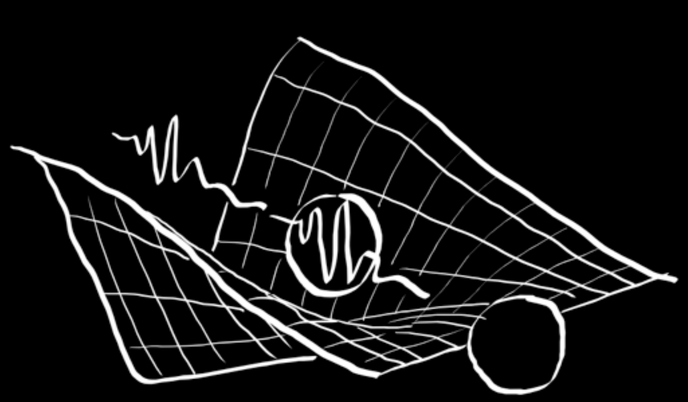
Wireless networks and communication

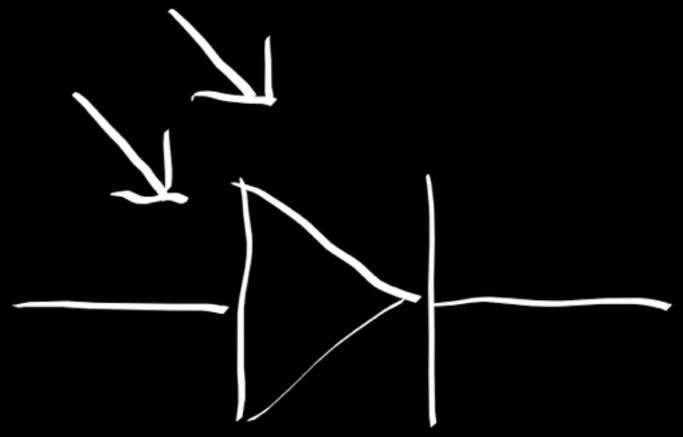


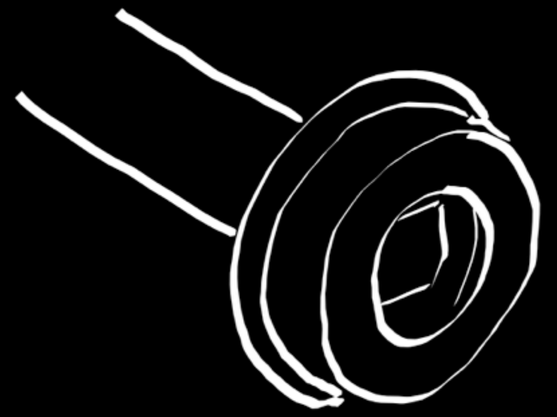
Most sensing is optical

We mostly know how to measure photons and electrons

Whatever you are measuring (bio, chemistry, medical, etc.),
make it have a visible effect (fluorescent dye, diffracting bead, etc.)







Thank You

Computation has revolutionized photography

Challenges and opportunity still abound

Computational photography should revolutionize other fields as well

Thank you

My PhD advisors: George Drettakis, Claude Puech

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