Lecture 1: Introduction and Overview

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http://yuhaozhu.com

CSC 292/572, Fall 2022 **Mobile Visual Computing**





Scope of the Course





Conventional Digital Camera







Today's Digital Camera





Today's Digital Camera: Portrait Mode

Today's Digital Camera: High Dynamic Range





Physical Scene



Physical Scene

(Objects, lights)

Human Visual System (Eye, visual cortex)



Physical Scene

(Objects, lights)

Human Visual System (Eye, visual cortex)



Physical Scene





Physical Scene



Physical Scene



Physical Scene

(Objects, lights)

Optics (Gather light)





Role of Optics in a Camera

Focus light and capture energy

At a cost of introducing "imperfections" (aberrations) • Distorting incident light signals to another form of light signals



https://www.etsy.com/hk-en/listing/275756784/camera-lens-wall-decal-camera-lens-decal











"Desired" Distortion

Shallow depth of field

Vignetting





Motion Blur







"Desired" Distortion

We even intentionally create lenses that do not mimic our eyes.



Introduce "imperfections"

Physical Scene

(Objects, lights)

Optics (Gather light)





Introduce "imperfections"

Physical Scene

(Objects, lights)

Optics (Gather light) **Image Sensing** (Optical to electrical

signal transformation)





Image Sensing

Converts optical signals (lights) to electrical signals (pixels)



Photoelectric effect



https://en.wikipedia.org/wiki/Photoelectric_effect https://www.theverge.com/circuitbreaker/2017/2/27/14749082/oppo-periscope-zoom-lens-announced-mwc-2017 https://www.zdnet.com/article/samsung-launches-first-64mp-image-sensor-for-smartphones/ 13



Convert Optical Signals to Electrical Signals

Introduces "imperfections" too, whi always unwanted.



Introduces "imperfections" too, which, unlike optical distortions, are almost



Convert Optical Signals to Electrical Signals

Introduces "imperfections" too, whi always unwanted.



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Introduce "imperfections"

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Physical Scene

(Objects, lights)

Image Sensing (Optical to electrical

Optics (Gather light)





Introduce "imperfections"

Introduce "imperfections"

Physical Scene

(Objects, lights)

Image Sensing (Optical to electrical

Optics (Gather light)





Introduce "imperfections"

Optics

(Gather light)

Physical Scene



Introduce "imperfections"	Remove "imperfections"	
Image Sensing	Image Signal	
(Optical to electrical	Processing	
signal transformation)	(Signal reconstruction)	





Introduce "imperfections"

Introd "imperfe

Physical Scene

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Optics (Gather light)

Image Se (Optical to e signal transfe



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electrical —	Processing
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Conventional cameras use complex and expensive lenses and sensors to minimize imperfections.

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Introduce "imperfections"

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Physical Scene

(Objects, lights)

Optics (Gather light)

Image Sensing (Optical to electrical signal transformation)

Conventional cameras use complex and expensive lenses and sensors to minimize imperfections.









Computational Photography

Use image signal processing algorithms to:

1. simplify optics and sensors.



Portrait mode: simulate a large aperture



HDR mode: simulate a high dynamic range sensor



Computational Photography

Use image signal processing algorithms to:

sensor, algorithm co-design.



2. do things that conventional optics/sensors alone can't do. Usually requires optics,











9
















Slides credit: Ren Ng 25



Traditional Telephoto (Long-Focus) Lens



Telephoto (Long-Focus) "Lens" in Smartphones



Telephoto lens (f = 48 mm) + computational photography algorithm for super resolution





Wide Field-of-View



https://unsplash.com/photos/Ym7NVRKgmJc 28









Cameras in Modern Smartphones







Digital Camera System

Physical Scene

(Objects, lights)

Optics (Gather light)

Image Sensing (Optical to electrical





Photorealistic Rendering

https://notrianglestudio.com/all-categories-blog/why-photorealistic-renderings-should-be-part-of-your-real-estate-marketing-strategy





Photorealistic Rendering

https://www.youtube.com/watch?v=uY4cE_nq2IY



Real-Time Photorealistic Rendering (e.g., Gaming)

https://www.digitaltrends.com/gaming/battlefield-v-dxr-ray-tracing-tested/



Why do those images look "real" to you?



Why do those images look "real" to you? Photorealism: a rendered image that looks like taken by a camera





Why do those images look "real" to you?

Photorealism: a rendered image that looks like taken by a camera





Why do those images look "real" to you?

Photorealism: a rendered image that looks like taken by a camera

transformation)

Could simulate some desired optical distortions

- Simulating the camera pipeline (assuming perfect optical to electrical signal













Parametric surface

 $x^2 + y^2 + z^2 = R^2$



Polygon mesh

Point cloud



Modeling: Mesh



https://docs.blender.org/manual/en/dev/render/introduction.html http://www.cgarena.com/freestuff/tutorials/max/thomas_highway/sergeant.html 39







Modeling: Parametric Surface



Utah teapot





Bezier surface

https://www.scratchapixel.com/lessons/advanced-rendering/bezier-curve-rendering-utah-teapot 40



Modeling: Point Cloud



Point Cloud Acquisition





Laser scanner

From Mike Jarvis, Prof. @ History Dept. Scanning Elmina Castle, a UNESCO World Heritage Site at Ghana.



Point Cloud Acquisition

Velodyne LiDAR (Light **Detection and Ranging)**



https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff?gi=78c92169e8e https://www.iftas.de/Main/VelodyneHDL64E?setlang=en 43

Uber's self-driving car equipped with LiDARs



Velodyne Lidar

Alpha PrimeTM POWERING SAFE AUTONOMY



Modeling Optics



Curvature Radius	Thickness	Index of Refraction	Aperture Diameter
35.98738	1.21638	1.54	23.716
11.69718	9.9957	1	17.996
13.08714	5.12622	1.772	12.364
-22.63294	1.76924	1.617	9.812
71.05802	0.8184	1	9.152
0	2.27766	0	8.756
-9.58584	2.43254	1.617	8.184
-11.28864	0.11506	1	9.152
-166.7765	3.09606	1.713	10.648
-7.5911	1.32682	1.805	11.44
-16.7662	3.98068	1	12.276
	1.21638	1.617	13.42
-11.97328	(depends on focus)	1	17.996







Image Signal Processing (Signal reconstruction)

Display (Generating lights) Human Visual System (Eye, visual cortex)







Modeling Light Transport









https://colinbarrebrisebois.com/2015/11/06/finding-next-gen-part-i-the-need-for-robust-and-fast-global-illumination-in-games/







https://www.tomlooman.com/lighting-with-unreal-engine-jerome/







Physics Simulation



Graphics Rendering: Not All About Photorealism







http://www.pbr-book.org/3ed-2018/Introduction/pbrt_System_Overview.html 52





https://luxcorerender.org/gallery/ 53



Computer Vision: Semantics Understanding





Computer Vision: Semantics Understanding





Computer Vision: Semantics Understanding




Not a Computer Vision Course

Computer vision is concerned with understanding scene from images.

- What this course focuses on is how images are formed from scenes.
 - Eyes, cameras, graphics rendering.

We will touch upon many computer vision topics whose solutions rely on the fundamental image formation process.







Video/Image Compression









30-second video @ 1080p resolution (1920 x 1080 pixels per frame) @ 30 frames per second (FPS) 3 colors per pixel + 1 byte per color \rightarrow 6.2 MB/frame \rightarrow 6.2 MB x 30 s x 30 FPS = 5.2 GB total size Actual H.264 video file size: 65.4 MB (80-to-1 compression ratio). Compression/encoding done in real-time without you even realizing it!

























WiFi bandwidth test at my home











Scope of the Course



Display: Transform Electrical Signals to Optical Signals

iPhone 11

Sequence filmed with 4DViews' volumetric capture technology

Sequence filmed with 4DViews' volumetric capture technology

Light-Field Display: One Way Toward Holography

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Head-Mounted Near-Eye Light Field Display Prototype

Bare Microdisplay

Near-Eye Light Field Display

Why do we see color?

Color sensation!

Why do we see color?

Why do things have colors anyways?

Why do we see color?

Why do things have colors anyways?

What is a "retina" display?

iPhone 12 Pro Max

6.7"

iPhone 12 Pro

6.1" Super Retina XDR display¹

iPhone 11 Pro Max

6.5"

iPhone 11 Pro

5.8"

Super Retina XDR display¹

Why do we see color? Why do things have colors? What is a "retina" display? What do color blind people see?

https://www.demilked.com/what-color-blind-people-see-different-types-blindness/ 69

- Why do we see color?
- Why do things have colors?
- What's the deal with a "retina" display?
- What do color blind people see?
- What about tetrachromacy?

superhuman vision?

https://www.optimax.co.uk/blog/tetrachromacy-superhuman-vision/

- Why do we see color?
- Why do things have colors?
- What's the deal with a "retina" display?
- What do color blind people see?
- What about tetrachromacy?
- What do you see during saccades?

https://www.science.org/doi/10.1126/sciadv.abf2218

Why Study Visual Computing? The most exciting applications on the horizon are visual computing applications, and they challenge the way we build computers.

TC.st

https://www.engadget.com/2018-09-14-facebook-augmented-reality-strategy.html https://en.wikipedia.org/wiki/Optical_head-mounted_display#/media/File:A_Google_Glass_wearer.jpg 73

Image Sensing: sense the environment

Computer vision: recognize table and estimate its orientation

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https://en.wikipedia.org/wiki/Optical_head-mounted_display#/media/File:A_Google_Glass_wearer.jpg 73 https://www.engadget.com/2018-09-14-facebook-augmented-reality-strategy.html

Image Sensing: sense the environment

Computer vision: recognize table and estimate its orientation

https://en.wikipedia.org/wiki/Optical_head-mounted_display#/media/File:A_Google_Glass_wearer.jpg https://www.engadget.com/2018-09-14-facebook-augmented-reality-strategy.html

Computer graphics: draw the virtual content to overlay

Image Sensing: sense the environment

Computer vision: recognize table and estimate its orientation

https://en.wikipedia.org/wiki/Optical_head-mounted_display#/media/File:A_Google_Glass_wearer.jpg https://www.engadget.com/2018-09-14-facebook-augmented-reality-strategy.html

Computer graphics: draw the virtual content to overlay

Image Sensing: sense the environment

Display: lenses, mirrors, waveguides

Virtual Reality

https://fortune.com/2016/11/15/virtual-reality-gaming-entertainment-tech/

5

360° (VR/Panoramic) Videos and Photos

https://www.cursosfotografiabarcelona.com/como-hacer-una-foto-esferica-360-grados-ref

VR Video Capturing Device

Facebook Surround 360 System (mostly open-source)

https://twitter.com/yitechnology/status/918116570559336448 https://engineering.fb.com/2016/07/26/video-engineering/surround-360-is-now-open-source/ 77

A Google Jump rig built by Yi Halo

Autonomous Machines

Cultural Heritage Preservation



https://www.imb.org/image/elmina-castle-10/ 80



Cultural Heritage Preservation



and the second states



Cultural Heritage Preservation





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The Archimedes Palimpsest

Medieval manuscript made from parchments used for other writings. The over-text is a Byzantine prayerbook (1229). The under-texts are mainly from Archimedes and Hyperides; some are unidentified.





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https://cudl.lib.cam.ac.uk/view/MS-ADD-01879-00023/2

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What Challenge?









What Challenge?

Energy Budget

Smartphone AR/(VR)

Processing Requirement

Smartphone

VR/AR

~ 4000 mAh

~ 500 mAh

~ 1 MPixel @ 30 FPS







How Do I Teach (and How You Should Learn)?

- The First-Principle approach.
- Nothing is magic.
- Things don't have to be that way.

Necessarily Inter-Disciplinary







Necessarily Inter-Disciplinary

Your goal is **NOT** to understand everything in one semester (no one does).





Necessarily Inter-Disciplinary

on your own when need to.



Your goal is **NOT** to understand everything in one semester (no one does). Your goal is to understand the basic principles so that you can learn things





Rochester is a Great Place for Visual Computing Research

Augmented/Virtual Reality Initiative

<u>https://www.rochester.edu/augmented-virtual-reality/</u>

AR/VR National Research Traineeship (NRT) Program: <u>https://www.rochester.edu/augmented-virtual-reality/education/index.html</u>

- **Digital Scholarship Library**
 - <u>https://digitalscholar.rochester.edu/</u>

Studio X:

<u>https://www.rochester.edu/advancement/studiox/</u>

Center for Visual Science

https://www.cvs.rochester.edu/



Logistics

- Course website: <u>https://www.cs.rochester.edu/courses/572/fall2022/</u>.
- We meet on Wednesdays and Fridays (11:50 13:05).
- All announcements will be made through blackboard.
- Feel free to send me emails.
- Office hours by appointment.
- TA: Abhishek Tyagi (atyagi2@cs.rochester.edu)



"Pre-requisites"

- Basic geometry (similar triangles, etc.)
- High-school physics (power, energy, etc.)
- Basic calculus (integration, derivatives, etc.)

Good to know:

- basic linear algebra (e.g., matrix multiplication, solving systems of linear equations) basic probability (e.g., random variables)
- basic computer systems (CSC 252 equivalent) could be helpful depending on what you want to get out of this course.



Reference Materials

- There is no definitive textbook. The course material is self-contained.
- The syllabus page has links to many references that I think are helpful: https://www.cs.rochester.edu/courses/572/fall2022/syllabus.html.
 - through UR digital library (login required).
- There will be readings assigned (required and recommended).

• Most of them are either PDFs online made available by the authors or are accessible



How You Will Be Evaluated

- 3%: finish the student information sheet
 - Ideally, come to my office hours to introduce yourself.
- 33%: written assignments; mostly every 2—3 weeks.
- 24%: mini programming assignments; probably 2.
- 40%: a final project of your choice that fits your interests and background; could be programming, systems, art, design, etc.
 - Need approval. Must finalize within the first 2 months. Could be team of up to 2.
 - UGs: think of it as an independent study.

