Programmable Cameras and IoT

EE599-001/EE699-001, Spring 2024

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http://aggregate.org/hankd/

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Course Overview

- Materials will be on Canvas or at:
  `http://aggregate.org/PCIOT`

- This is an embedded systems course with a heavy emphasis on digital cameras; C/C++/Arduino exposure as prerequisite

- Two exam/lab-practical things, 15% each
- Class participation, 10%
- Projects, 60%

What You'll Learn Here

- User-level camera operation
- Thinking like a photographer
- Camera hardware & lenses
- Camera algorithms (e.g., autofocus)
- Canon PowerShot reprogramming via CHDK
- ESP32-CAM programming via Arduino
- Understand image data formats and basic computational processing

Topics

- Introduction, overview of digital camera terminology and basic operation
- Basic photographic concepts and techniques; thinking like a photographer
- Introduction to CHDK, the Canon Hack Development Kit
- CHDK Lua scripting (camera apps)
- Control of camera operation (bracketing, motion detection, scripting, tethering, etc.)

Topics

- Image data (raw formats, EXIF, JPEG, etc.) and processing
- Introduction to the ESP32-CAM IoT and Arduino environment
- IoT camera applications
- Design of camera subsystems and lenses
- Camera algorithms (e.g., autofocus) and postprocessing (e.g., using OpenCV)
- Graduate project presentations and discussions

Projects

- Basic photography, critique of photos
- CHDK making PowerShot do something odd
- CHDK automating a common photographic task
- ESP32-CAM as a camera
- ESP32-CAM as a sensor & control
- Graduate students get bigger projects and are expected to present their work

Schedule Note

- January 23-24 I will be presenting research at the Electronic Imaging 2023 conference…

Class January 23 will be made-up later

Me

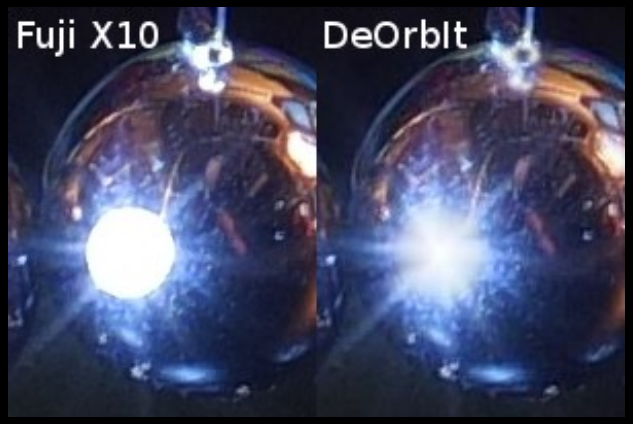
- Hank Dietz, ECE Professor and
  James F. Hardymon Chair in Networking
- Office: 203 Marksbury
- Photography background
  - High school paper & yearbook photo editor
  - Photo editor Columbia Broadway Magazine
  - Commerial photographer
  - Computational photography researcher:
    http://aggregate.org/DIT/
- Lab: 108/108A Marksbury – I have **TOYS**!

Computational Photography

Cameras as computing systems;
using computation to enhance camera abilities
and / or to process the data captured

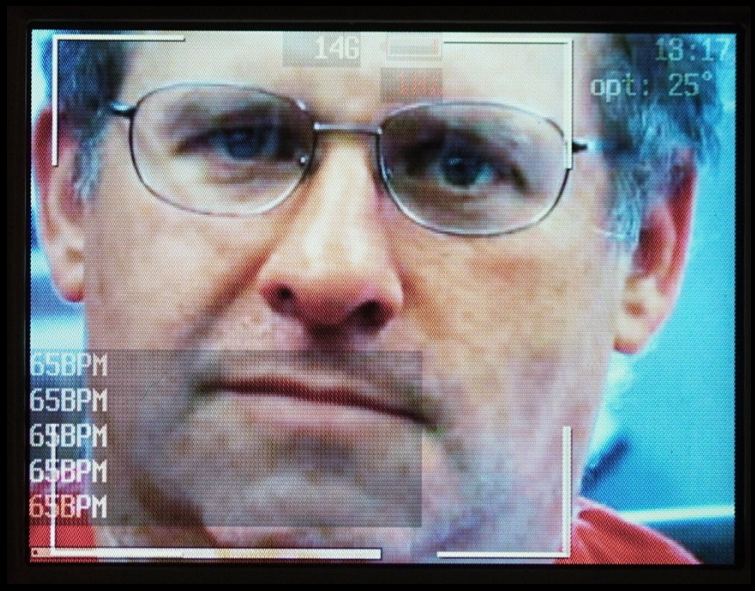
- New camera / sensor / processing models
- Intelligent computer control of capture
- Detection / manipulation of image properties

“Raw” Repair



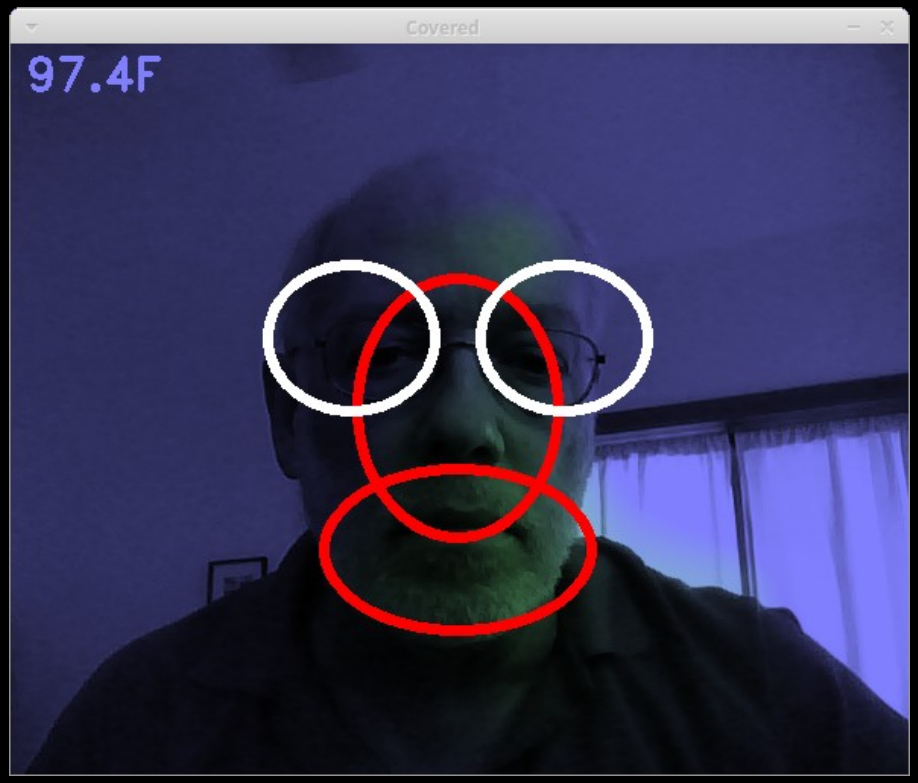
- “Raw” means “uncooked” or “unprocessed”
- Can *credibly* **repair** corrupted data
  - Fuji X10 “white orbs” blooming ⇒ **DeOrbIt**
  - Sony ARW compression artifacts ⇒ **KARWY**
  - Sony ARW PDAF artifacts ⇒ **KARWY-SR**

Photoplethysmography



- Reprogrammed a $100 camera to detect heartbeats by detecting color change

Covered Safe Entry Scanner



- Detect when a mask is being properly worn
- Also thermal imager & contact tracing

TDCI: Time Domain Continuous Imaging

- TDCI representation: a continuous waveform per pixel, compressed (mostly) in time domain
- TDCI processing enables:
  - High dynamic range (HDR), improved SNR
  - Rendering a virtual exposure for any time interval (start time, shutter speed)
  - Rendering a conventional video at any FPS and shutter angle (temporal weighting)

FourSee TDCI Camera

- Syncs four reprogrammed PowerShots
- 3D-printed structure for alignment, etc.

Some of our recent work...

For EI2024: Parsek

Probabilistic Alignment Raw
Sticher Experiment from Kentucky