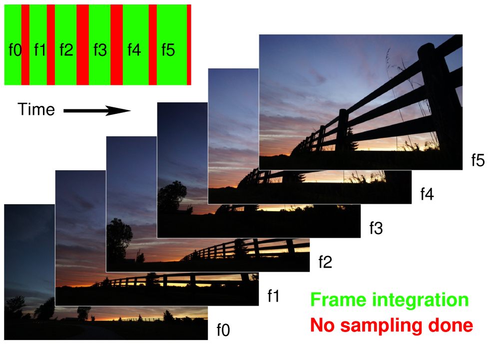
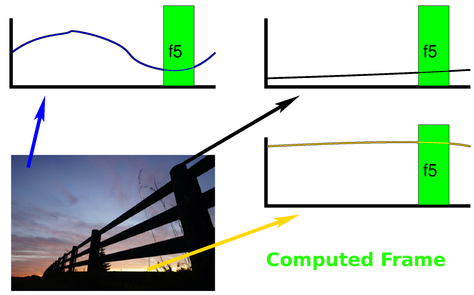
Time Domain Continuous Imaging



Traditional Image Capture



Time Domain Continuous Imaging

TIME DOMAIN CONTINUOUS IMAGING doesn't sound like supercomputing. It is about a new type of imaging sensor and processing – processing that ideally would use *millions* to *billions* of processing elements on the sensor chip.

Exposing Like Film: With film, there was no choice but to expose all points in the frame for the same photon integration (shutter speed or Tv) period. Physically moving the film to the next frame also forces temporal gaps between frames. Why should digital cameras mimic that behavior?

Massively Parallel Sensel Processing: Since 2003, we've been quietly working on a better approach called TIME DOMAIN CONTINUOUS IMAGING:

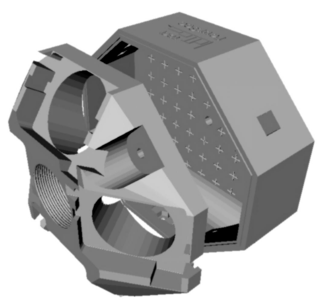
- Use different integration (exposure) periods for sensels, ideally directly obtaining a digital value for the time taken to collect enough photons to achieve the target accuracy in the presence of (e.g., photon shot) noise
- If possible, deliberately skew sampling of individual sensels in time to allow improved temporal interpolation
- For each pixel, computationally derive a smooth function for how light intensity varies over time and output the (compressed) waveform

The digitized and computationally compressed waveforms for all pixels are output.

Benefits: Why bother with TDCI? Because it can do things no frame-based still or video imager can:

- HDR (High Dynamic Range) with integration period <, =, or > exposure interval: never lose data to overexposure, temporally interpolate underexposed pixels
- Exposure interval can be smoothly adjusted after capture: virtual shutter speed is independent of exposure, can nudge exposure interval forward/backward to get the precise moment with zero "shutter lag"
- Framerate-independent movies: no more "stutter" in displaying at cinematic (24FPS), PAL (25FPS), and NTSC (59.94 fields/s) framerates
- Artifact-free movie pans and motion in general: computationally integrating means no temporal gaps between frames (e.g., no "jumping" objects in movie pans)

Current work: Funded in part by NSF Award #1422811, we are exploring algorithms for TDCI processing. Although our ideal implementation would place a programmable NANOCONTROLLER under each pixel in the sensor, we are currently synthesizing TDCI streams using either a single high-framerate camera (e.g., *Sony RX100 IV*) or multiple conventional cameras with skewed timing and exposure settings. Our 3D-printed **FOURSEE** array camera coordinates four *Canon PowerShot N* cameras (programmed using *CHDK*, the *Canon Hack Development Kit*) to sample the image projected by a 135mm *f*/4.5 Rogonar-S lens.



For More Information: There have been papers on TDCI in *IS&T/SPIE Electronic Imaging* 2014, 2015, and will be another at 2016. See **Aggregate.Org** for the latest information, open hardware designs, and open source software.

This document should be cited as:

```
@techreport{sc15tdci,
author={Henry Dietz and John Fike},
title={{Time Domain Continuous Imaging}},
institution={University of Kentucky},
address={http://aggregate.org/WHITE/sc15tdci.pdf},
month={Nov}, year={2015}}
```