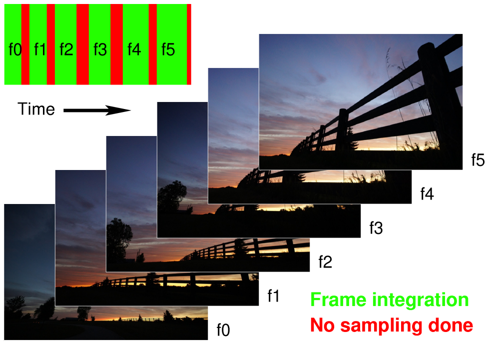
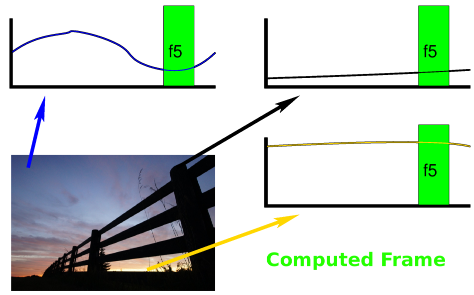
Time Domain Continuous Imaging



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:

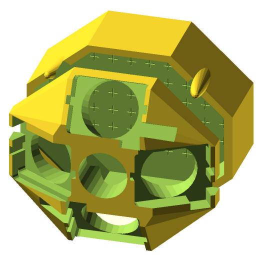
- Use different integration (exposure) periods for sensels, ideally directly obtaining a digital value for the time taken to collect enough photons to achieve the target accuracy in the presence of (e.g., photon shot) noise
- If possible, deliberately skew sampling of individual sensels in time to allow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

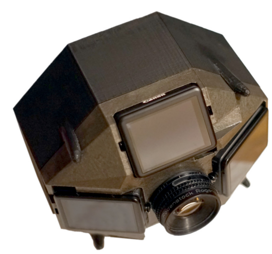
The digitized and computationally compressed waveforms for all pixels are output.

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: Our NSF funding centers on exploring algorithms for TDCI processing. Thus, although our ideal implementation would place a programmable nanocontroller under each pixel in the sensor, we are currently synthesizing TDCI streams using multiple conventional cameras to sample the scene with skewed timing and exposure settings. Our 3D-printed array camera at SC14 coordinates four Canon PowerShot N cameras (programmed using CHDK) to sample the image projected by a 135mm *f*/4.5 Rogonar-S lens. The resulting sub-$1000 system, shown below, is capable of up to 960 FPS.





For More Information: Our first publication giving details about TDCI was presented at the IS&T/SPIE Electronic Imaging conference in February 2014. We are seeking collaborators and support to further develop and bring this technology to market.

This document should be cited as:

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title={{Time Domain Continuous Imaging}},
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