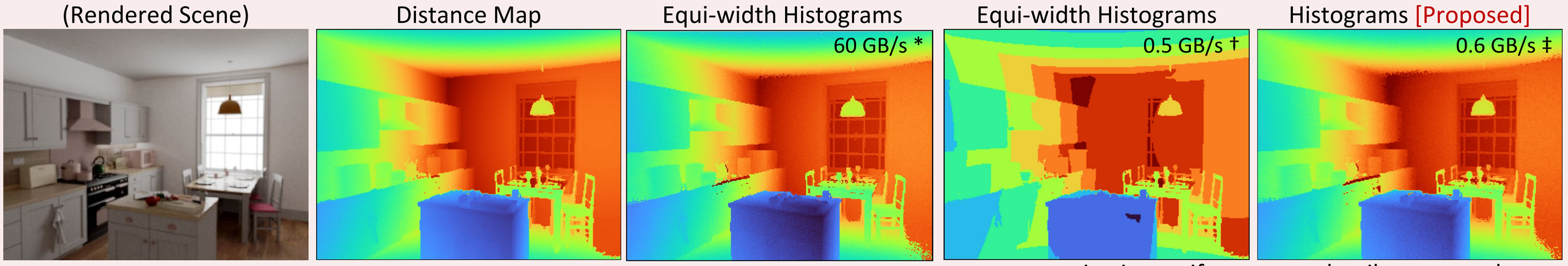
P1.15

Count-Free Single-Photon LiDAR with Equi-Depth Histograms: An FPGA Implementation

Hayden Galante*,1, Tommaso Milanese[2], Kaustubh Sadekar[1],
Claudio Bruschini[2], Edoardo Charbon[2], David Maier[1], David Burnett[1], Atul Ingle[1]
[1] Portland State University, USA [2] EPFL, Switzerland
* Email: galante@pdx.edu Webpage: www.computational.camera

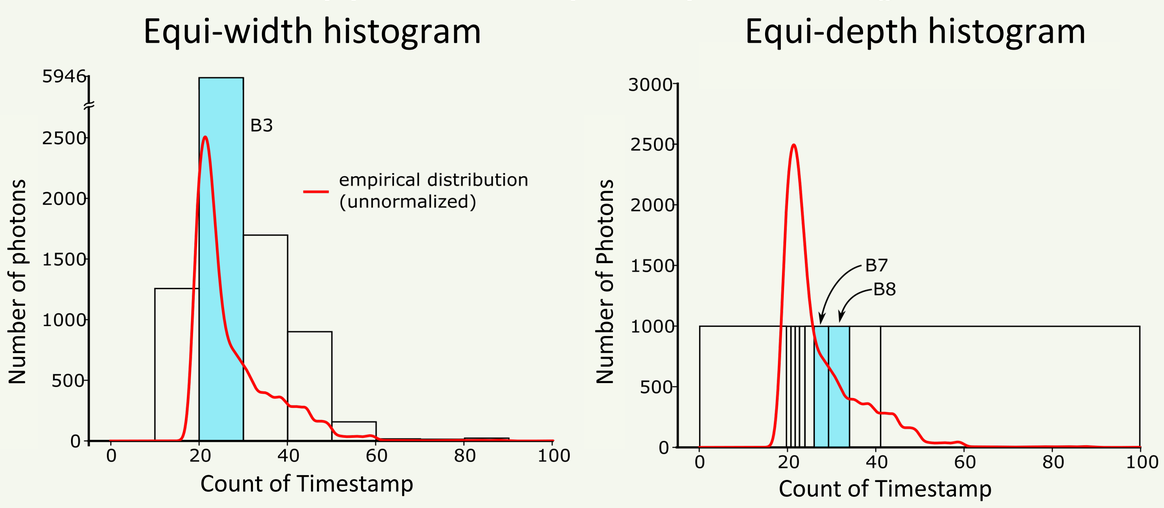
Single-Photon LiDAR at 100x Lower Bandwidth (Simulated Results)



*1 Mpix SPAD, 8 bits/bin, 30 fps
†1 Mpix SPAD, 8 bits/bin, 30 fps
‡ 1Mpix SPAD, 10 bits/bin, 30 fps

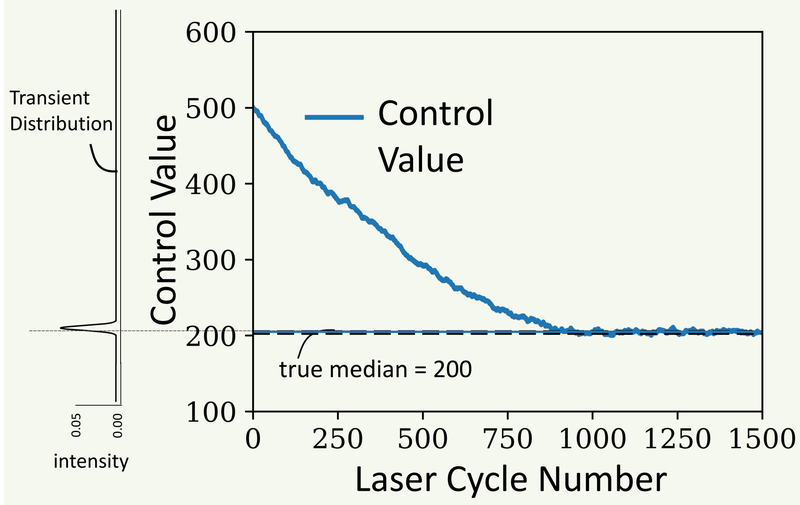
Equi-depth photon histograms: 100x lower bandwidth while maintaining distance resolution

Our Approach: Equi-depth Histograms



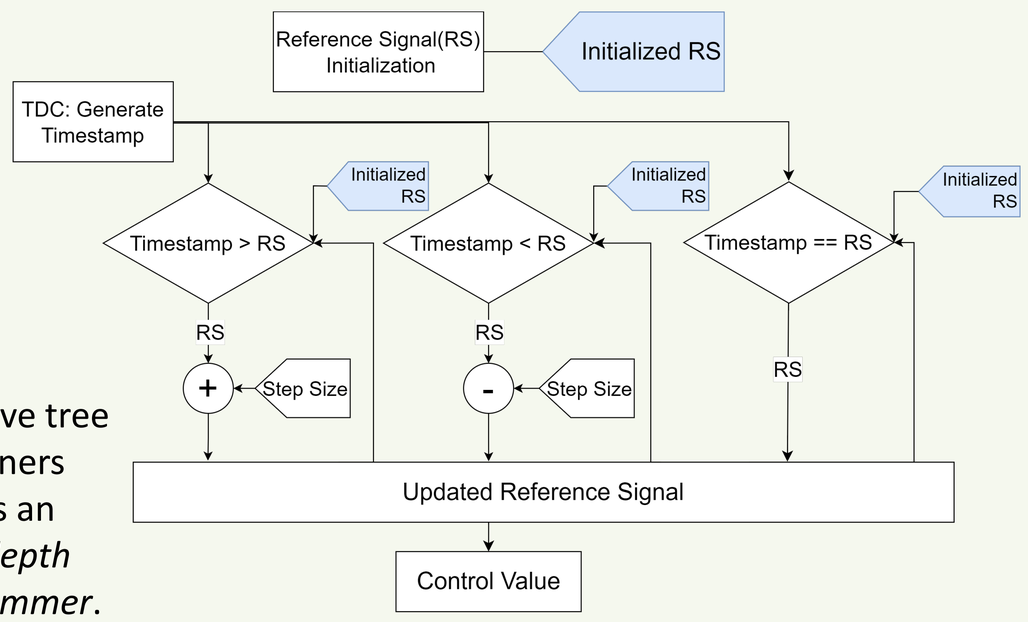
Equi-depth histograms adaptively capture “peaky” distributions.

“Binner Circuit”: A Two-bin Equi-depth Histogram



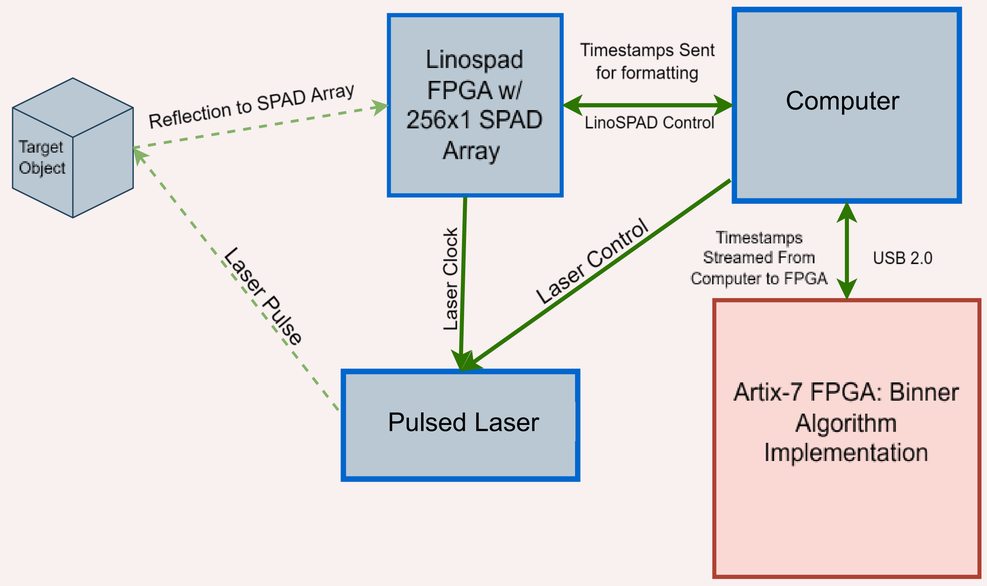
- A binner circuit updates its *control value* to track the overall median.
- At each laser cycle the control value is updated in the direction of more photon arrivals.

FPGA Binner Implementation

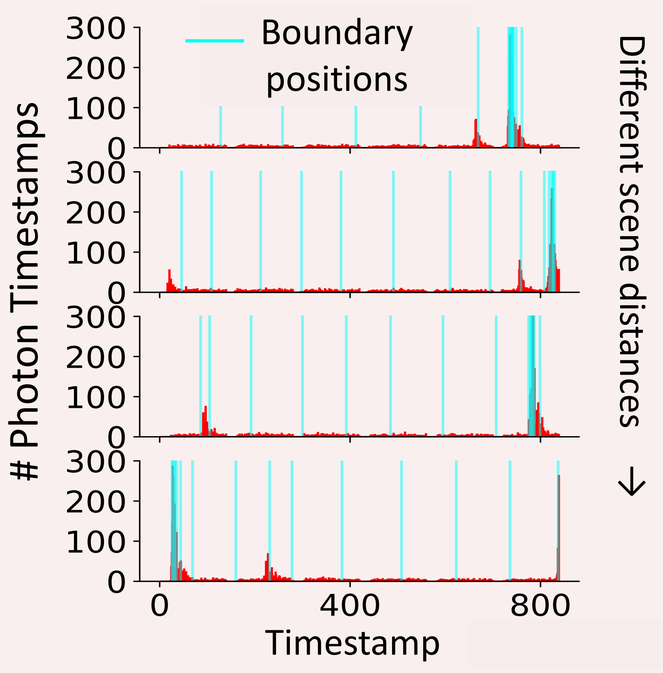


A recursive tree of binners forms an *equi-depth histogrammer*.

Experiment Setup



Results from FPGA Implementation



- We capture data at varying distances, and stream timestamps through a binner tree on the FPGA.
- FPGA output shows 15 bin boundaries with a cluster of bins around the main peak.
- We also see a second cluster around the secondary multipath peak.

Advantages

- Will enable larger image sensors by reducing bandwidth and lowering power consumption
- Does not need to store the complete history of photon timestamps or photon counts
- Modest circuit complexity compared to high resolution TDCs
- Can capture complex return distributions (e.g., multiple returns, interreflections, and multipath)

Ongoing Activities

- Create a 256x256 distance map using a scanning setup with the LinoSPAD camera
- Implement adaptive stepping strategies for improved convergence and accuracy
- Design TDC-less binners without explicit timestamping

Funding: NSF Award # 2138471