EPFL

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

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

RGB Image (Rendered Scene)	Ground Truth Distance Map	Conventional 2000-bin Equi-width Histograms	Coarse 16-bin Equi-width Histograms	16-bin Equi-depth Histograms [Proposed]
		60 GB/s *	0.5 GB/s +	0.6 GB/s ‡

strong quantization artifacts details preserved

*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-width histogram Equi-depth histogram 5946₁ 3000-**B**3 2500 2500 Number of photons 12000 12000 1000 500 empirical distribution of Photons (unnormalized) 2000 1500 Number 1000 500 500 40 60 80 20 100 0 80 40 20 60 100 Count of Timestamp **Count of Timestamp**

Equi-depth histograms adaptively capture "peaky" distributions.

FPGA Binner Implementation

"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.

Experiment Setup





Results from FPGA Implementation

- 300
200
0Boundary
positionsDifference
Ference001000
 - We capture data at varying distances, and stream

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)



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.

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



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