An Asynchronous Peak Tracking Method for dToF LiDAR Histograms

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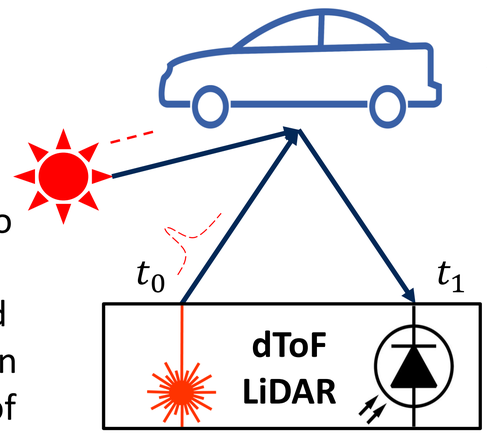
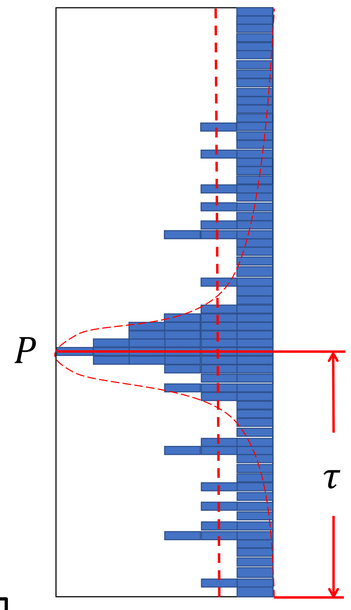
Introduction

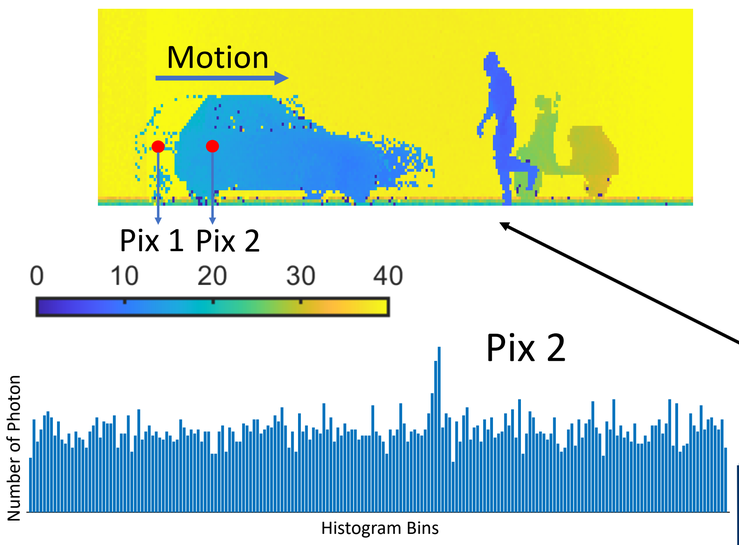
- Direct Time of Flight (dToF) Light Detection and Ranging (LiDAR) systems are used to measure the depth of an object in the scene from the LiDAR sensor.
- A laser in the system outputs a pulse of light which is reflected after hitting the object.
- Both laser and ambient photons detected by LiDAR are timestamped and stored inside a histogram, and the peak of histogram P is related to the object depth d.
- The depth of the object is calculated using the time between the emission and the reflection τ and the speed of light c.

$$d = \frac{c\tau}{2}$$





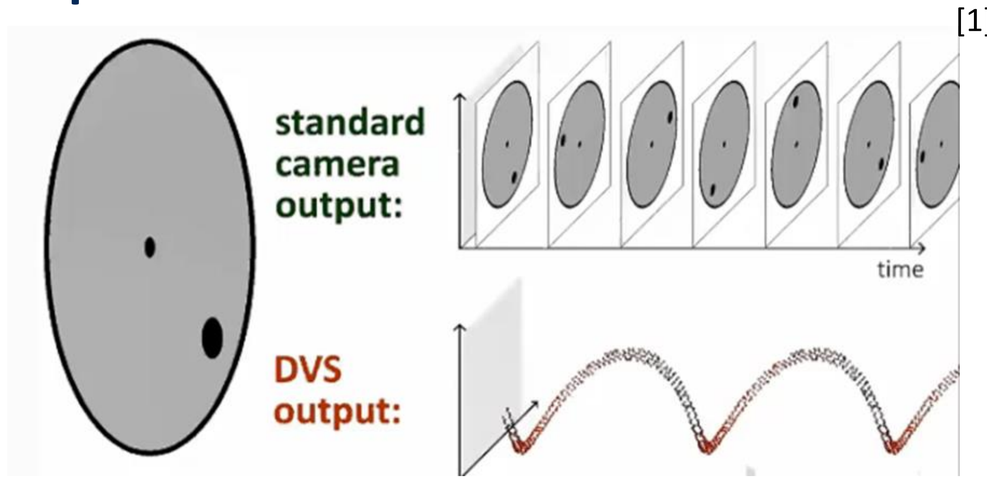
Problem Statement



- The histogram takes multiple laser pulse cycles, it requires ~1ms to build a single histogram.
- However, if any object inside the scene is moved, the histogram will have multiple laser profiles stored inside. (Pix1)
- Then during the post-processing, the peak-tracking algorithm won't be able to provide information fast enough.

Inspiration

[1]



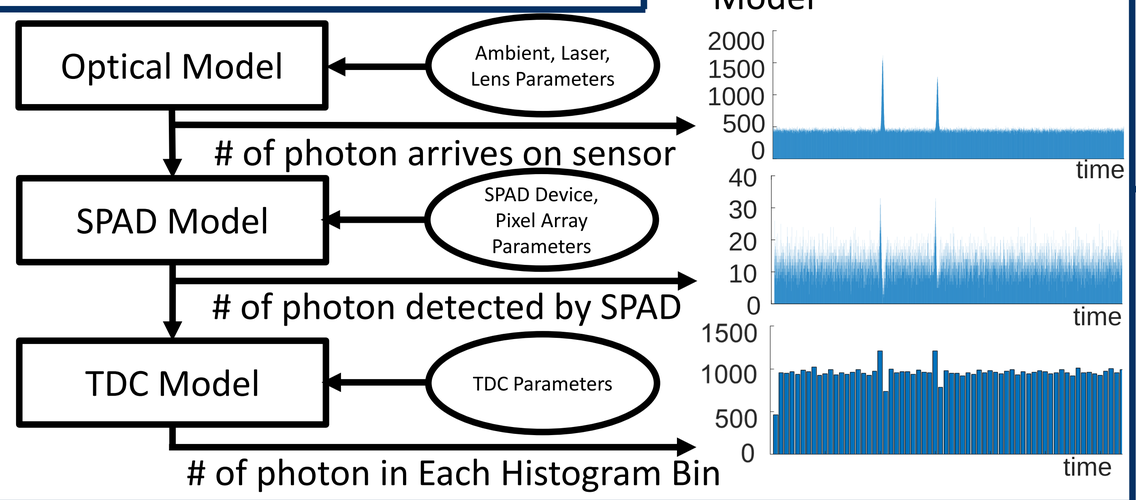
- Dynamic Vision Sensor (DVS) is a kind of imager which outputs only the change in light intensity that happens within an individual pixel.
- Instead of reading out the whole frame, DVS only reports the pixel with changes detected, thus the readout time is compressed. Therefore, it has a higher frame rate compared to standard cameras.
- Therefore, one of the usage of this kind of sensor is to **deblur images taken by standard cameras.**

Solution

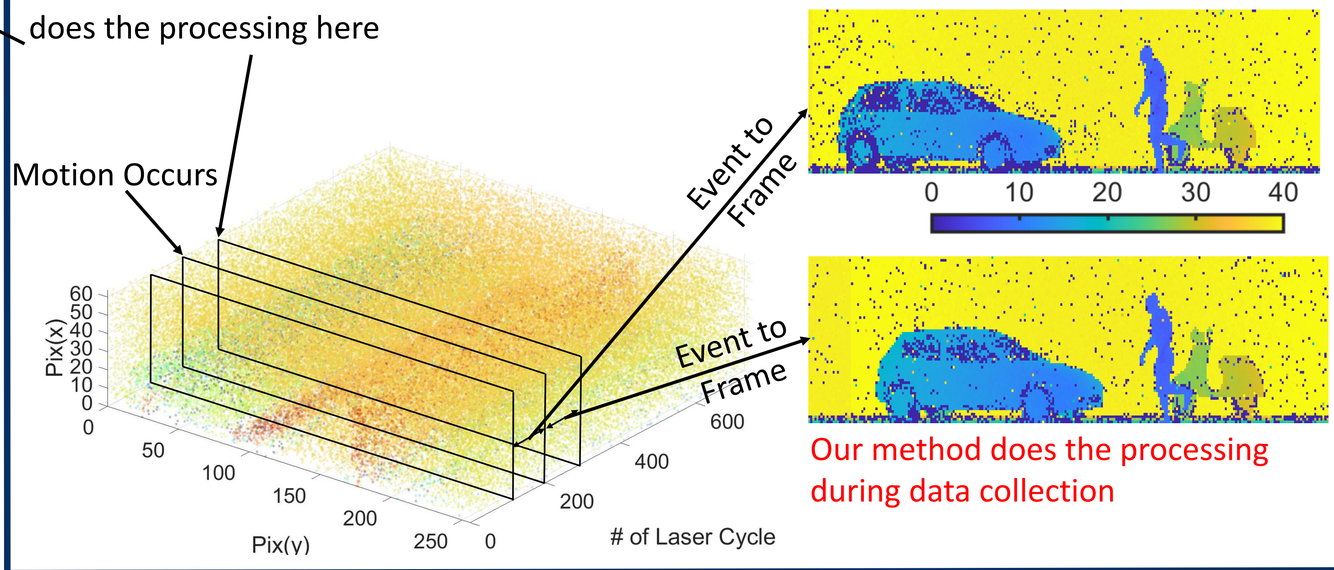
- Similar to DVS, we propose to modify LiDAR sensors' output to an event-based scheme rather than frame-based scheme.
- However, since LiDAR sensors provide depth data instead of light intensity data, the "change in light intensity" in DVS becomes "change in depth detection" in ***dynamic-LiDAR***.
- Therefore, similar to DVS, **Dynamic-LiDAR will be able to provide higher data rate to cope with motion artefacts.**

Modelling

- A dToF SPAD based LiDAR system is modelled in MATLAB to study this problem
- This Model Contains 3 parts: Optical Model, SPAD Device Model, and Peak Tracking Model



Conventional method does the processing here



Our method does the processing during data collection

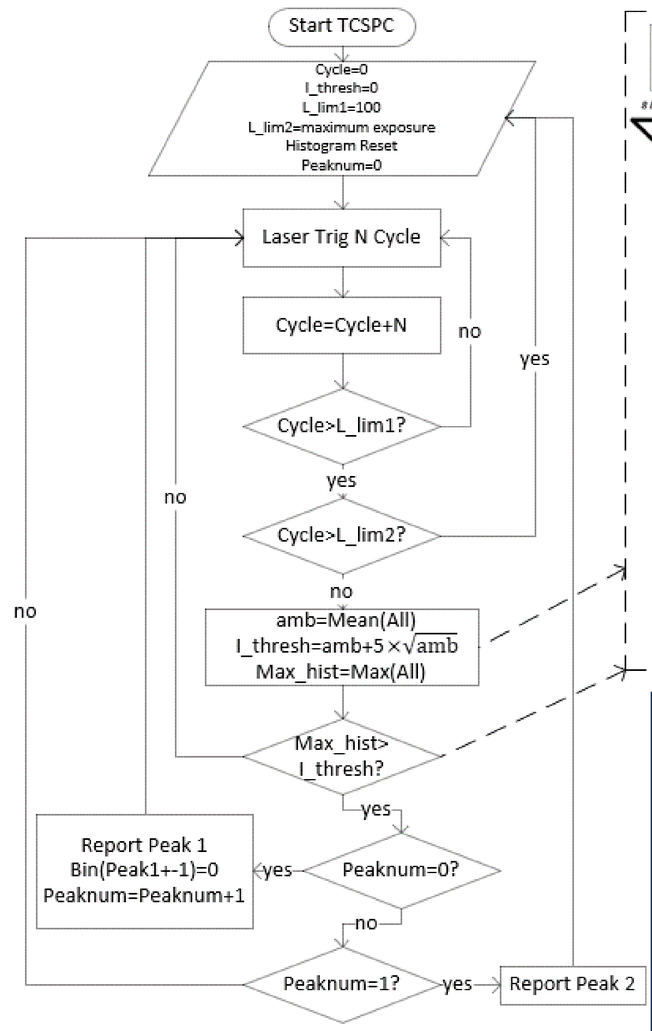
Mathematical Derivation in Peak Detection

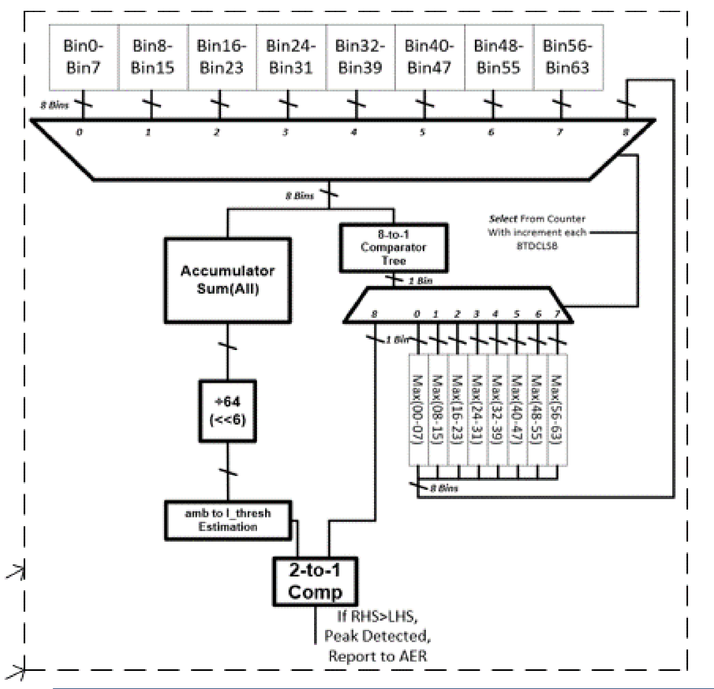
- $V(t_i) \in Amb \sim Poisson\,(BG)$
- $E\big(V(t_i)\big) = BG, D\big(V(t_i)\big) = BG$
- $V(t_i) \in Amb \sim N\big(BG, \sqrt{BG}\big)$, according to CLT

- For Effective Peaks, Peak Detected at Bin $t_i \Longleftarrow V(t_i) > BG + n \times \sqrt{BG}$

Where n is the adjustable threshold, BG means Background, and $V(t_i)$ is the photon counts in histogram bin t_i.

Proposed Dynamic Peak Detection Circuit Architecture





Next Step

- Use one of the LiDAR setups existing in the CSS group to acquire histograms.
- Implement the proposed dynamic peak detection on FPGA.
- Evaluate the proposed method and compare to the existing frame-based method.

Reference

[1] E. Mueggler, B. Huber, D. Scaramuzza, "Event-based, 6-DOF Pose Tracking for High-Speed Maneuvers", IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Chicago, 2014.