Collecting and Processing Point Cloud Data for Snow Depth and Density Measurement

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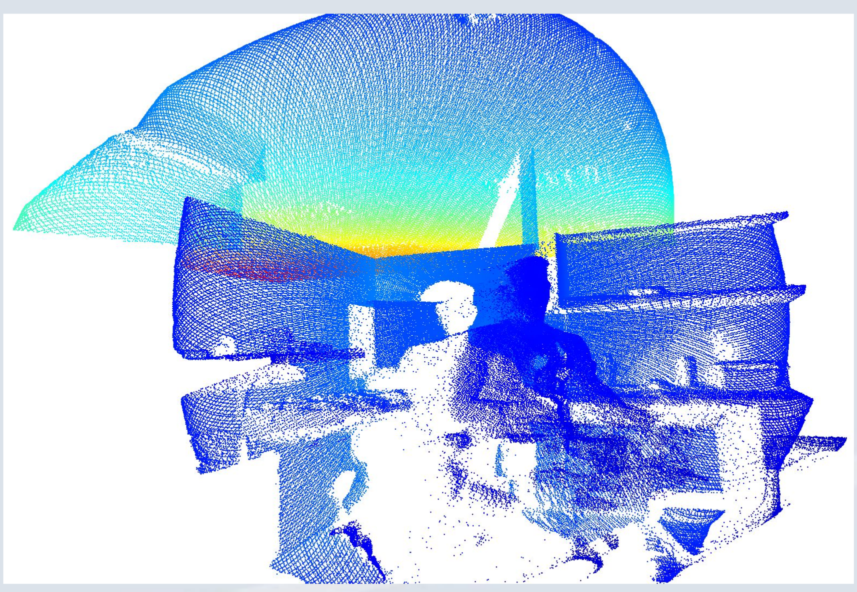
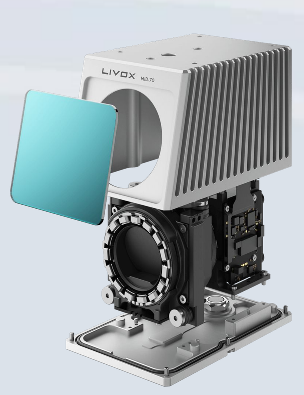
INTRODUCTION

- Accurate and low-cost snow measurements are essential for climate modeling/prediction and water management.
- Use Raspberry Pi and automotive LiDAR sensor for high-res measurements of snow depth and density.



BACKGROUND

- LiDAR sensors return point cloud data with x,y,z coordinates of each object detected, which are large and unwieldy.
- Raspberry Pi is a low-cost single board computer well suited to powerful computations in a remote embedded scenario.



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OBJECTIVES

- Reduce disk storage of data
- Parallelize point cloud collection and processing
- Develop point cloud processing algorithms

METHODS

- Data collection from LiDAR
  - Python multiprocessing and shared_memory.
  - Collect and store point cloud in shared buffer.
  - Separate process executes algorithms to downsize data.
- Snow Height Estimation
  - Find lowest elevation point in bins in 2D space
  - Calculate average of all points in each bin within threshold of lowest point
- Snowflake Density
  - Compute 3D histogram of remaining points in air.

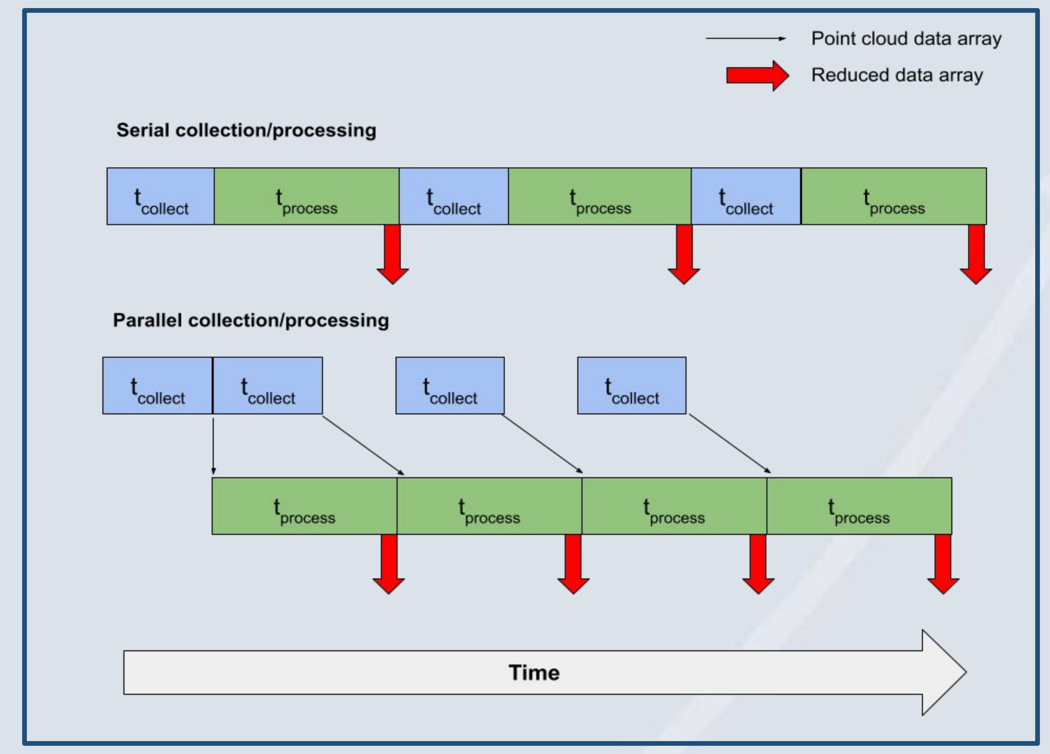

Figure 1: Timing diagram of process-level parallelism between point cloud collection and analysis.

RESULTS

	Raw point cloud storage	Snow Height Array storage	In Air Point Cloud storage	Total Storage
Without processing	12.8 MB	X	X	12.8 MB
With processing	X	1.88 MB	2.86 MB	4.74 MB

Table 1: Comparison of storage costs with and without point cloud processing. Three point clouds of three seconds each. Snow height array is fixed size such that storage savings are larger as collection duration increases.

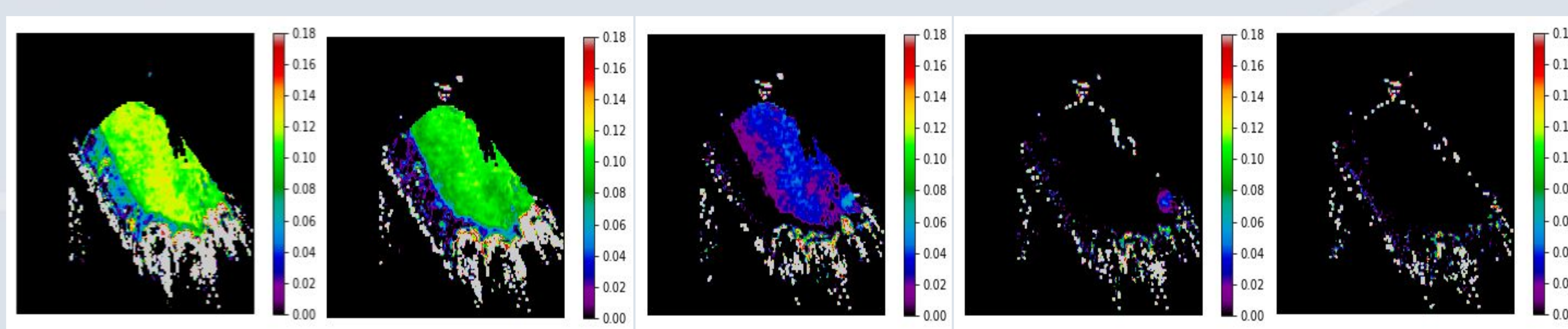

Figure 2: Time series of snowpack height estimate arrays during melting period (meters).

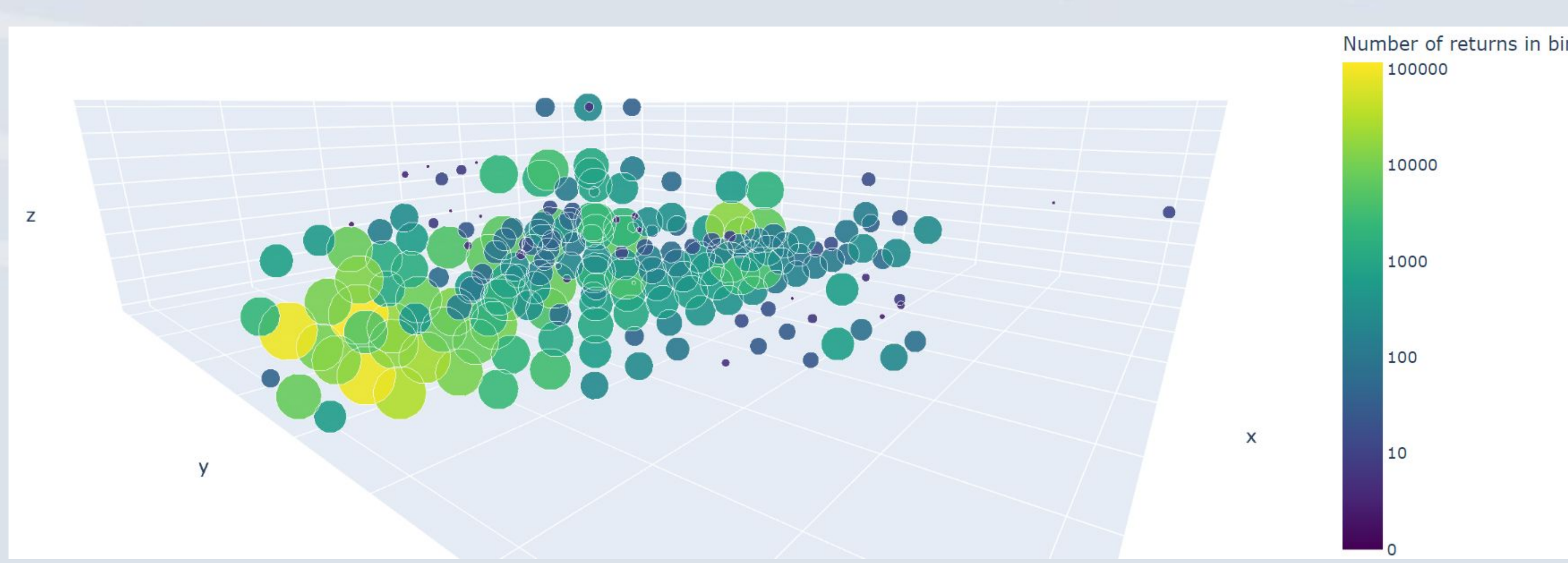

Figure 3: 3D histogram of point density over fixed volume.

Gray areas in **Fig. 2** represent static objects in environment, more filtering is necessary for tall vertical objects in measurement area. Note the shaded patch of remaining snow in the 4th image and its delayed melting.

DISCUSSION

- Process level parallelism allows parallel sensor operation and point cloud processing.
- Data disk storage requirements are largely reduced and essential data is conserved.
- Due to inefficiency of snow height estimation algorithm, parallel speedup only ~5%.
  - Evenly balanced collection and processing times would maximize throughput.
- Preliminary algorithms for snowpack volume and snowflake density developed and integrated into system.

CONCLUSION

We have proved the concept of snow data collection using Raspberry Pi and LiDAR sensor. Naive processing techniques for measuring snow volume over area and snowflake density in air have been shown tentatively successful.

Future research objectives:

- Optimization/improvement of processing algorithms.
- Extensive testing and data analysis during winter months.
- Investigation of buffering/further granularity in multiprocessing to improve collection throughput.

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