LIDAR and Compressive Sensing

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Outline

• Provide an introductory discussion of LIDAR
  – LIDAR 101
  – Key capabilities
  – Geiger-mode detectors and unique challenges

• Discuss objectives and challenges

• Solicit ideas from Compressive Sensing community
LIDAR

• Principle of LIDAR
  – A laser (pulse or continuous wave) is fired from a transmitter and reflected energy is captured (see illustration below)
  – Used to measure distance, velocity, chemical composition, etc.

• Nomenclature
  – “LIDAR” – light detection and ranging
  – “LADAR” – laser detection and ranging
  – “Laser radar”
  – These terms are almost always used interchangeably

\[ T_L = \text{Time of travel} \]
Range and Intensity Products

LIDAR Range Reveals 3D Structure

Data from Optech Lynx system

LIDAR Intensity Supports Image Interpretation
Multiple Returns

Can collect multiple returns per pulse along z-axis within the beam width (footprint)

First Returns

Last Returns
Multiple Looks with Gimbaled LIDAR

Elkhorn Lake, Single Pass, No Gimbal, 66k points

Single Pass w/Gimbal, 461k points

Data from NGA ILAP system

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Foliage Removal

Before Foliage Removal

Mingo Knob, WV – 0.5m GSD

“Bare Earth” reveals roads, trails, etc.

Data from NGA ILAP system

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THE UNITED STATES OF AMERICA
Vertical Obstructions

LIDAR Point Cloud

Data from Optech Lynx system
Geiger-mode Detectors

• A linear-mode avalanche photo-diode (APD) is a photodetector that is biased at close-to but below the breakdown voltage of the semiconductor, so a single photon in is multiplied to produce at most a few hundred electrons.

• A Geiger-mode APD (GmAPD), also called a Single Photon Avalanche Diode (SPAD), operates at a bias voltage above breakdown, so a single photon in sets off an avalanche, triggering the timing register.

• GmAPD LIDAR data can include points due to dark current and background light as well as surfaces of interest.

• Range histogram is built up over many pulses.
  – Each pulse contributes either (1) a “1” to a single range bin or (2) a null result.

• Photon counting methods are employed to determine which points to retain.
GmAPD Benefits and Challenges

• Benefits
  – Highly sensitive detectors support lower power, longer ranges
  – Multiple-pixel APD arrays support increased area rates of coverage

• Challenges
  – Additional processing (and time) required to remove noise
  – Greater amount of raw data collected for GmAPD compared to conventional LIDAR
  – Noise in raw data poses additional challenges for compression
Objectives and Challenges

• Explore methods to efficiently manage large volumes of data
  – Processing
  – Exploitation / visualization
  – Dissemination / storage

• Retain fidelity of datasets
Conclusions

• LIDAR provides key capabilities
  – 3D structure
  – Intensity information
  – Foliage penetration
  – Bare earth and vertical obstruction extraction

• Geiger-mode detectors present unique benefits and challenges
  – Lower power, longer ranges, increased area rates of coverage compared to linear mode sensors
  – More data, noisier data

• Goals
  – Investigate methods to efficiently manage large volumes of data
  – Retain fidelity of data