Extraction of forest roads from combined LiDAR data and optical imagery

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Outline

• Motivation and objective
• Study area and data used
• Methodology
• Results
• Conclusion and future work
Forest road inventories

• GIS data on road location and class are important for forest management and recreation.

• Existing GIS road layers may not be accurate enough for certain purposes.

  ... such as......
• Roads = ‘disturbance’
• Minimize road density
• Decommission roads

• Hundreds of legacy ‘roads’

So when is a road no longer a road ... re caribou?
So when is a road no longer a road ... re caribou?

Plan A: Take a slice of LiDAR Canopy Heights down the road line,

Correlate with ground photo and imagery

Problem #1 with Plan A: The GIS line isn’t exactly where the road is.

Problem #2 with Plan A: Lifted = different ecology, more herbaceous vegetation, a moose and wolf motel
Plan B:
• Use LiDAR to tell me where the road is *exactly* (re Problem #1)
• Use LiDAR to tell me whether the road has been ‘lifted’ (re Problem #2)

Humans can detect bush roads on LiDAR Bare Earth, so computers should be able to

Problem with Plan B:
Nobody seems to have, yet.
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Extraction of forest roads

• Existing methods and status\(^1\)
  – Manual (visual) interpretation from high resolution optical imagery
  – Automatic extraction from high resolution optical imagery
    • Roads as linear features
    • Roads with different spectral signatures from vegetation canopies
  – Significant research is needed to make automatic extraction methods operational.

\(^1\) Coops, N and C. W. Bater, 2009, Remote sensing opportunities for monitoring indicators of forest sustainability, FREP report, Government Publications, PO Box 9452, Stn Prov Govt, Victoria, BC V8W 9V7
Challenges

Vegetation covered, non-lift trails
Challenges

2-3 m, slightly lifted road
Challenges

Grass and low vegetation covered roads
Objective

• Automatically, accurately extract forest roads from the combined optical and LiDAR data
Optical imagery displayed as NIR as red, red as green, and green as blue
Methodology overview

- A progressive and adaptive approach to extract forest roads
  - Extract “Major Roads”
  - Segment the imagery at the stand level
  - Extract “Secondary Roads” or “Small Paths” in each individual segment
  - Post processing
Extraction of “Major Roads”

- Optical imagery
  - NDVI
    - threshold
    - Candidate roads
  - Contrast (texture)
    - threshold
    - Candidate roads

- LiDAR
  - DTM

NDVI: Normalized Difference Vegetation Index (NIR-RED) / (NIR+RED)
DTM: Digital Terrain Model
Extraction of “Major Roads”

NDVI

DTM

Contrast
Extraction of “Major Roads”

Candidate “Major Roads” (Yellow) from NDVI
Extraction of “Major Roads”

Candidate “Major Roads” (Purple) from Contrast of DTM
Extraction of “Major Roads”
Image segmentation

Using a region-growing segmentation method
Extraction of “Secondary Roads”

Red band → Thresholding → Hough Transform → Post Processing → “Secondary Roads”

Canopy Height Model

Line detection
Roads in individual segments

Extracted “Secondary Roads” (line features) in a segment using Hough Transform algorithm.
Extracted Roads

Note: Only one segment was analyzed
Omissions
Conclusions

• “Major Roads” can be accurately detected from the optical image and DTM, while “Secondary Roads” can not be detected.

• Obvious “Secondary Roads” can be detected from red band image or LiDAR-derived canopy height model.

• Detection of “Trails” or “Paths” in low vegetation covered, open areas are difficult.
Future improvement

• Work with smaller segments
• Exploit advanced line detection methods
• Effectively combine LiDAR/Optical imagery

• A report
Finally, to address the original problem:

- Apply the procedure to the entire roads layer (caribou zone)
- Tag segments with amount of ‘lift’ (if possible)
- Then can use road segment to slice the LiDAR canopy height model to get profile
- Then determine which aren’t roads anymore re caribou.