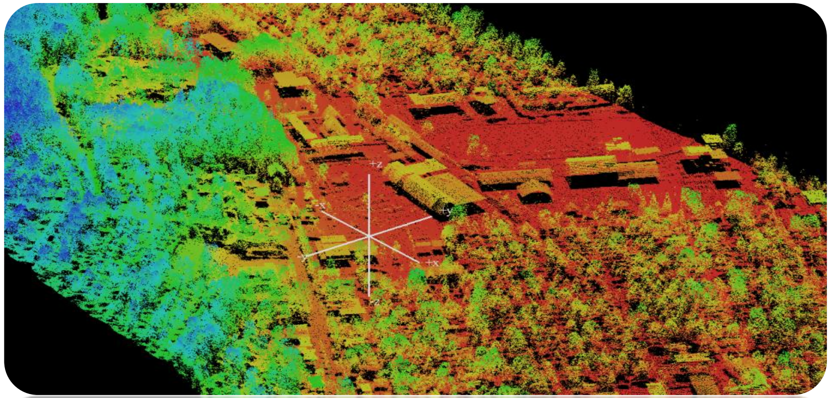
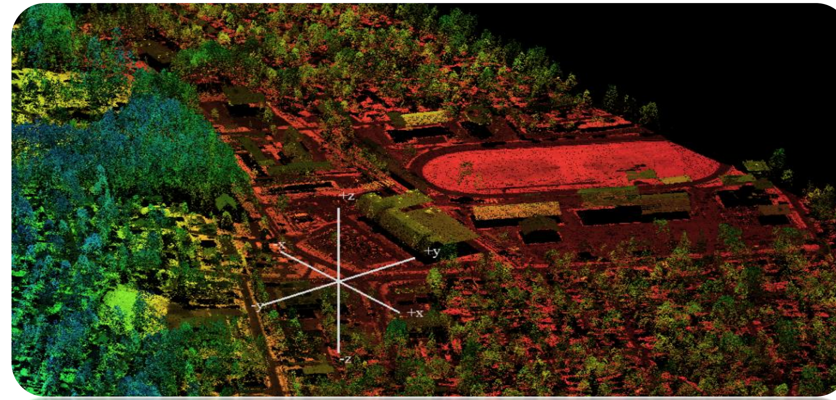




Effects of LiDAR mapping errors
- user-side analysis -

Presenter: Patrick Adda, PhD, P.Eng.

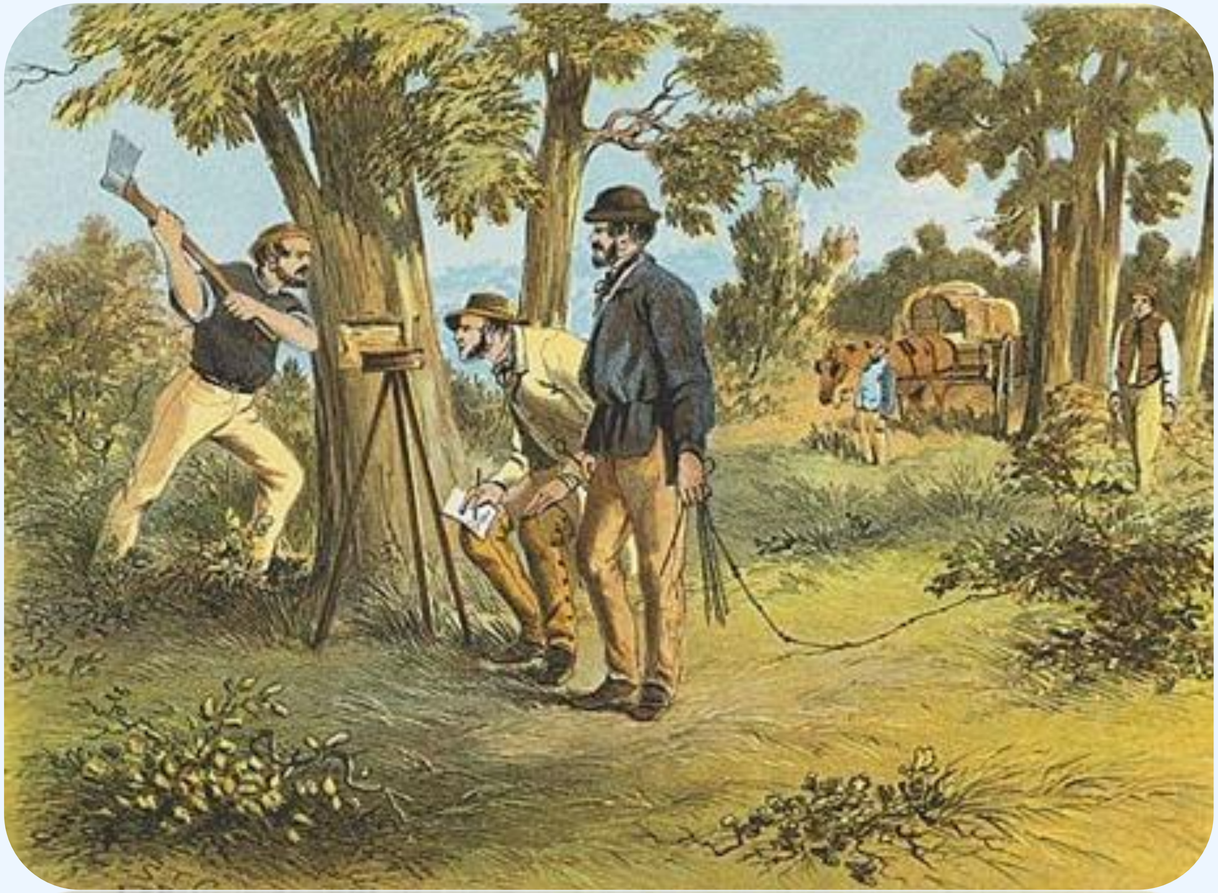
University of New Brunswick.
Email: padda@unb.ca or addapat@yahoo.com

The University of Lethbridge Airborne LiDAR stakeholder Forum, 8-10 July 2013

Intro.
Why ?
How ?
Lessons
Summary

Introduction

Evolution of positioning – modest equipment / methods

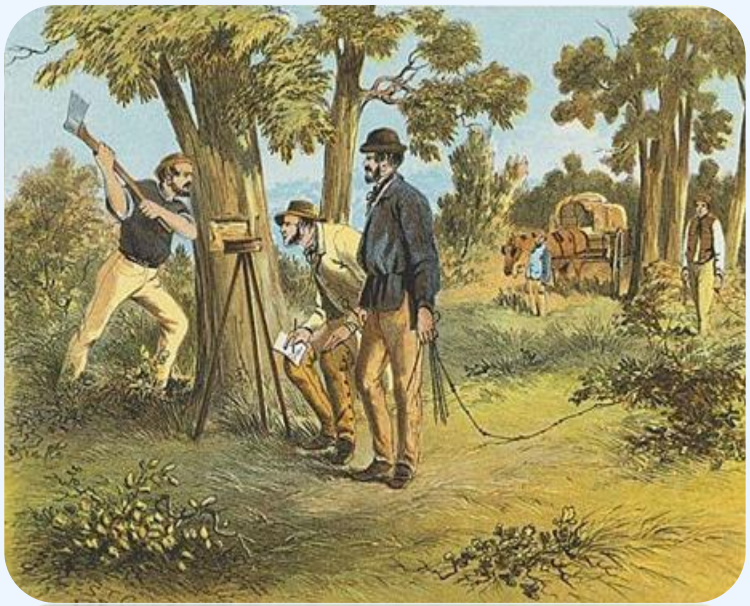


A 1865 field survey using Circumferentor and Gunter's Chain *(from The Australian sketchbook)*

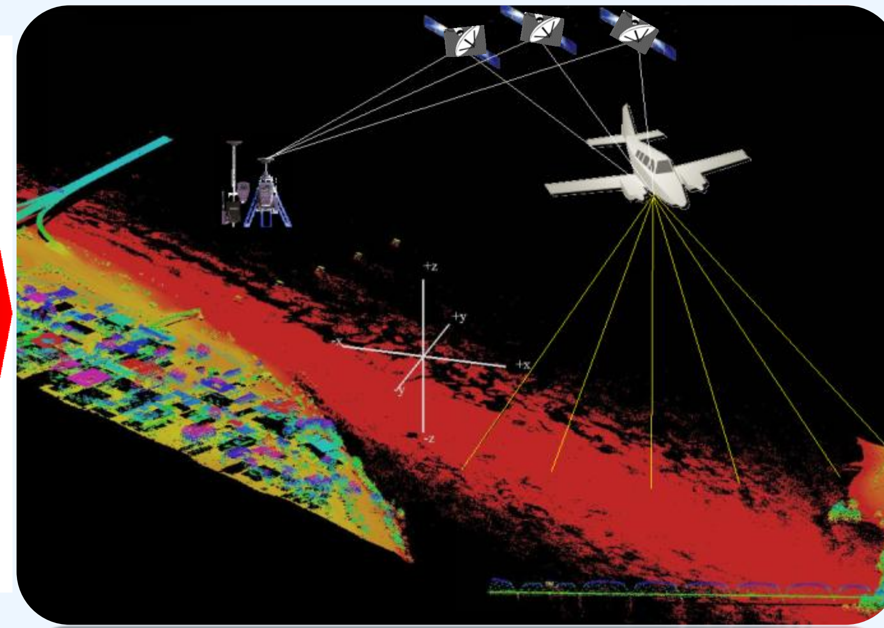
- Equipment parts more transparent and easier to understand
- Survey methods can be replicated to validate process and data

Introduction

Things get complex => independent validation gap created



A 1865 field survey using Circumferentor and Gunter's Chain *(from The Australian sketchbook)*



Satellite altimetry, GNSS, LiDAR, Remote Sensing, Photogrammetry

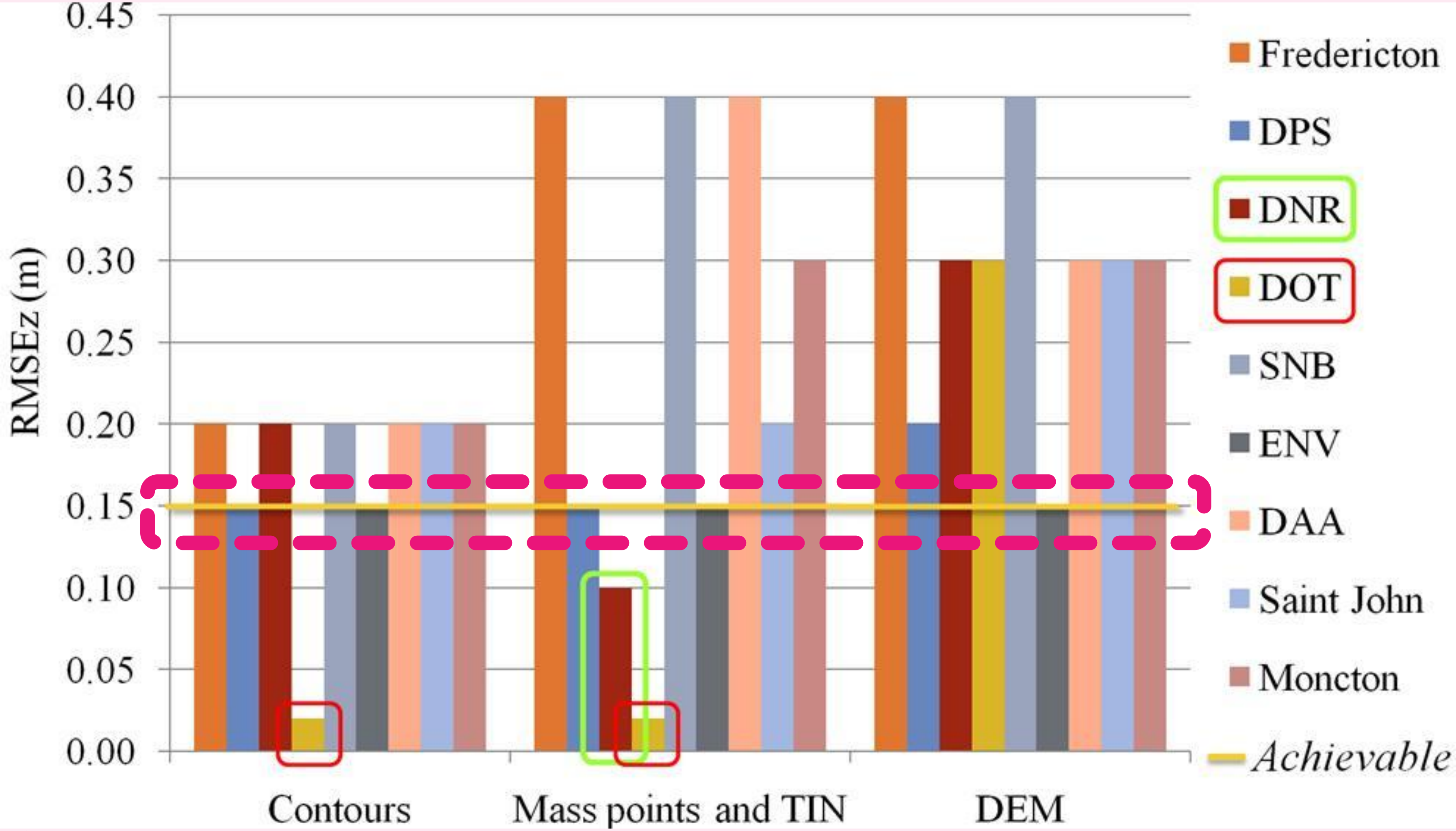
Why user-side error analysis?

- No matter how complex things get, it is STILL OUR PRIMARY MANDATE is to provide our clients and the public with accurate spatial information

- There CAN BE blunders from acquired airborne LiDAR data

- YOU CAN INCLUDE BLUNDERS in the dataset during the field validation exercise. There is no one process for all data validation tasks

How? Start with specifications

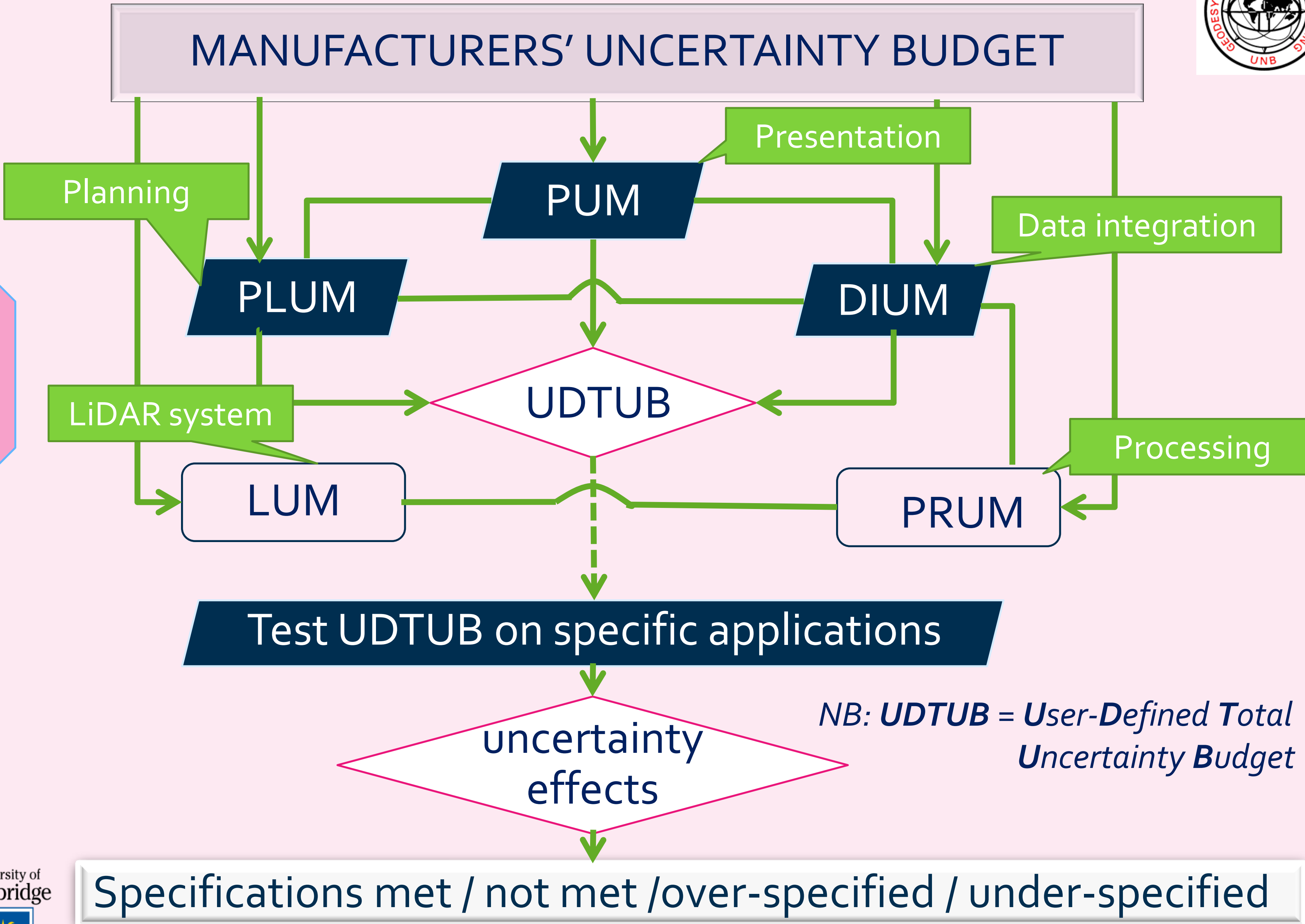


Different Applications , Different Accuracy Requirements

Intro. | Why ? | How ? | Lessons | Summary

Table 3.3. Confusing specification terminology as used in the LiDAR industry supposing to describe the same characteristics (Ussyshkin and Smith [2006, p.2]).

Characteristic	Confusing Terminology	
Laser Pulse Frequency	Pulse repetition rate	Data collection rate
Laser Beam Divergence	1/e or $1/e^2$	Full angle or Half angle
Footprint Size on the Ground from Reference Altitude	Footprint diameter, 1/e	Ground spot diameter $1/e^2$
Maximum Scan Angle	±Half-angle	Full-angle or full FOV
Scanning Rate	Scan rate	Scan speed
Survey Altitude	Operational altitude	Slant range or max. scan angle
Vertical Accuracy	Vertical (elevation) accuracy for the max. scan angle	Vertical (elevation) accuracy versus scan angle
Horizontal (Planimetric) Accuracy	Horizontal accuracy for the max scan angle	Planimetric accuracy for scan angle



*NB: **UDTUB** = **U**ser-**D**efined **T**otal **U**ncertainty **B**udget*

University of Lethbridge

Intro. | Why ? | How ? | Lessons | Summary

The Checkpatching Approach

...Field validation of accuracy

- The patch validation process [by Merrett Survey Partnership, UK and US] adopted for field validation
  - employs conventional land surveys over a well defined test area

- The method was modified to cover :
  - varying terrain morphologies
  - Obstructions to ground cover

  for five test areas

Obstruction (%)	Description
0-32	Light
33-65	Medium
66 - 100	Dense

...from Martin et al. [2001]

University of Lethbridge

Intro.
Why ?
How ?
Lessons
Summary

The Checkpatching Approach

- Sampling is necessary in validating big data
  - e.g. for LiDAR as it is practically impossible to validate each point in a project area by comparing it with a surveyed checkpoint.
- The sampled data must have the following properties to represent the entire population:
  - Unbiasedness – not deviate systematically;
  - efficiency – i.e. small in variance;
  - sufficiency – enough to represent population; and
  - consistency [from Kothari, 1985]

The Checkpatching Approach

…Field validation of accuracy

- Use superior datasets to validate LiDAR
  - The superior dataset should be at least three times more accurate than the data to be tested.
    [Hodgson and Bresnahan 2004; Flood 2004; Chrzanowski 1977]

- For checkpoint [i], the vertical error [Ve_i]

  $$Ve_i = \{ Zdata[i] – Zcheck[i] \}$$

- Sampled points are employed since it is it is practically impossible to validate each point

Intro. | Why ? | How ? | Lessons | Summary

The Checkpatching Approach

Example of the process adopted for this study:

1. Chose five random checkpatches (with varying terrain morphologies and obstructions to ground cover) in the LiDAR survey area.

2. Each checkpatch contained a set of checkpoints whose coordinates were determined.

3. A TIN is created for each of the checkpatches from clipped LiDAR ground points.

4. The checkpoints are used to derive their corresponding LiDAR elevations from the TIN.

5. Finally, the difference between the checkpoint elevations and their corresponding LiDAR elevations are determined.

… LET'S LOOK AT A PRACTICAL EXAMPLE

our study area will have varying degrees of terrain cover and topography…

University of Lethbridge

(a) High Obstruction: Built-up area.

(b) Flat open terrain

(c) Dense forest

(d) Steep slope with 5° slope angle

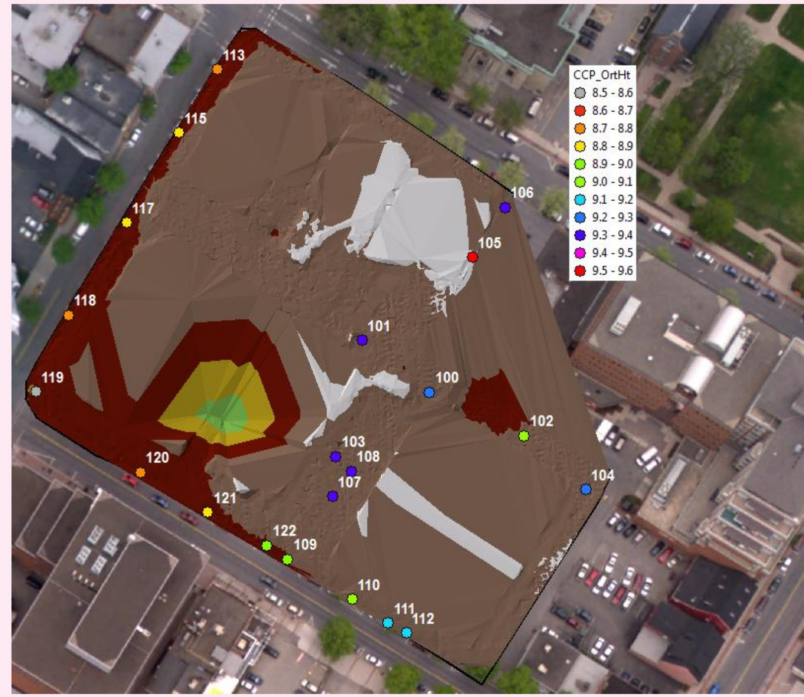
(e) Low obstruction - less denses

(f) All controlled checkpoints

University of Lethbridge

The Checkpatching Approach

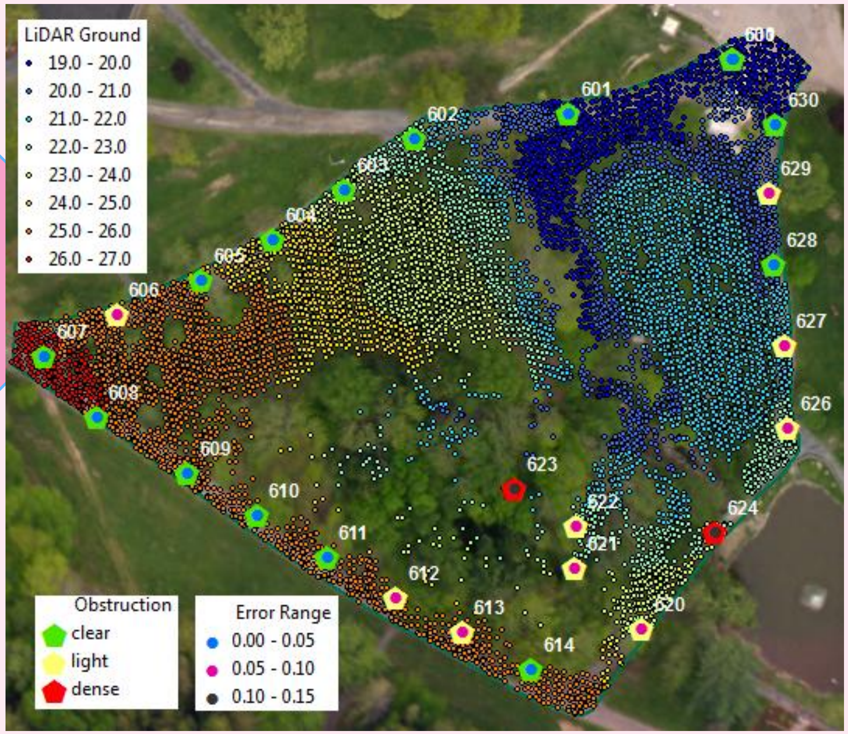
LiDAR ground points of downtown Fredericton



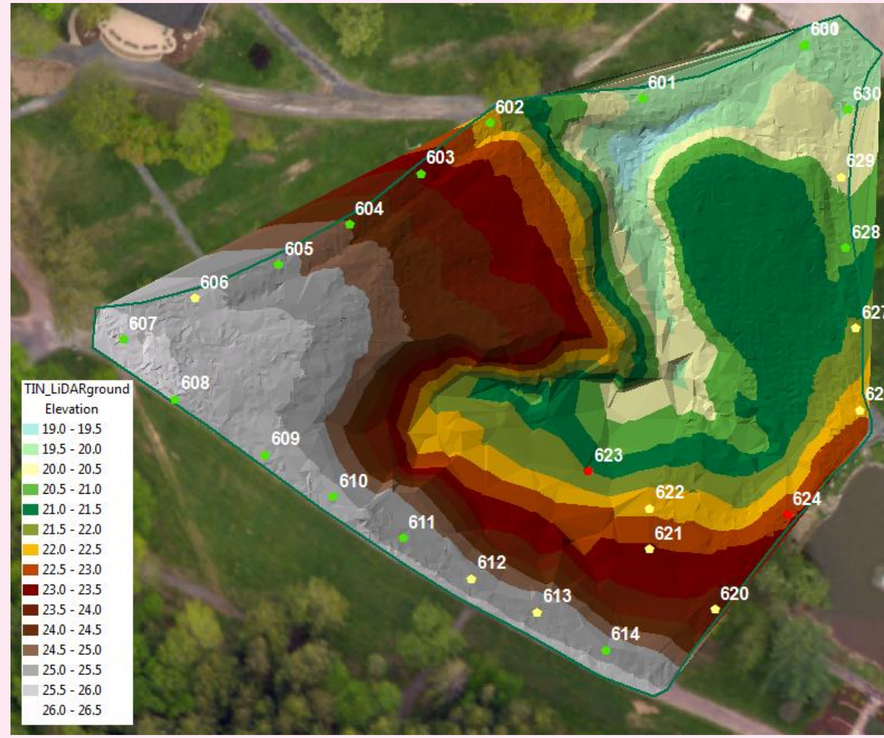
TIN from LiDAR ground points in downtown Fredericton

Terrain morphologies and obstruction to ground cover information is extracted for each checkpoint. Elevation (and x,y) variations between the surveyed checkpoint and corresponding x,y location is determined to RMSE reporting.

The Checkpatching Approach



Controlled Checkpoints and sampled LiDAR ground points

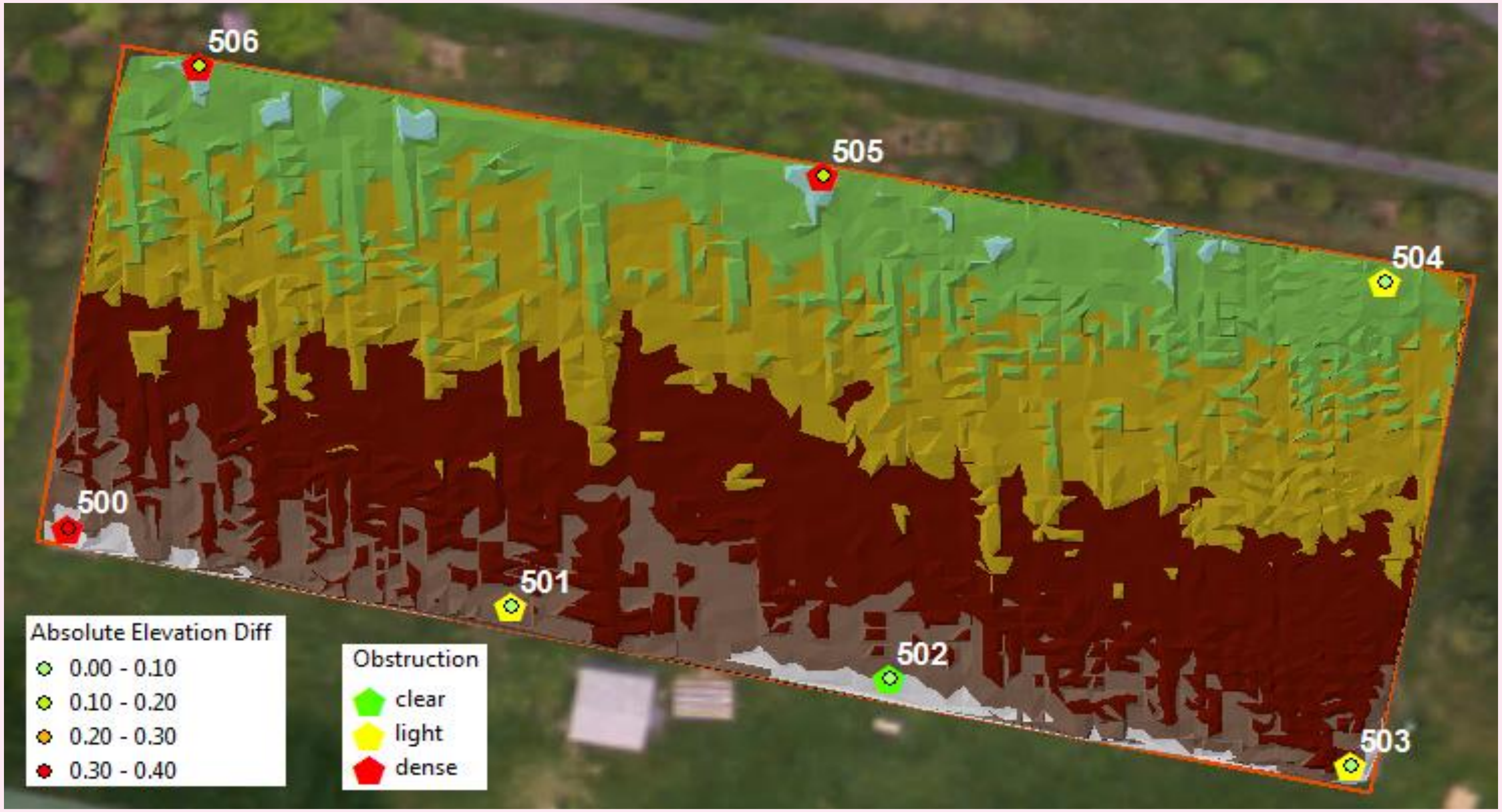


TIN from the sampled LiDAR ground points in Odell Park

University of Lethbridge

Terrain morphologies and obstruction to ground cover information is extracted for each checkpoint. Elevation (and x,y) variations between the surveyed checkpoint and corresponding x,y location is determined to RMSE reporting.

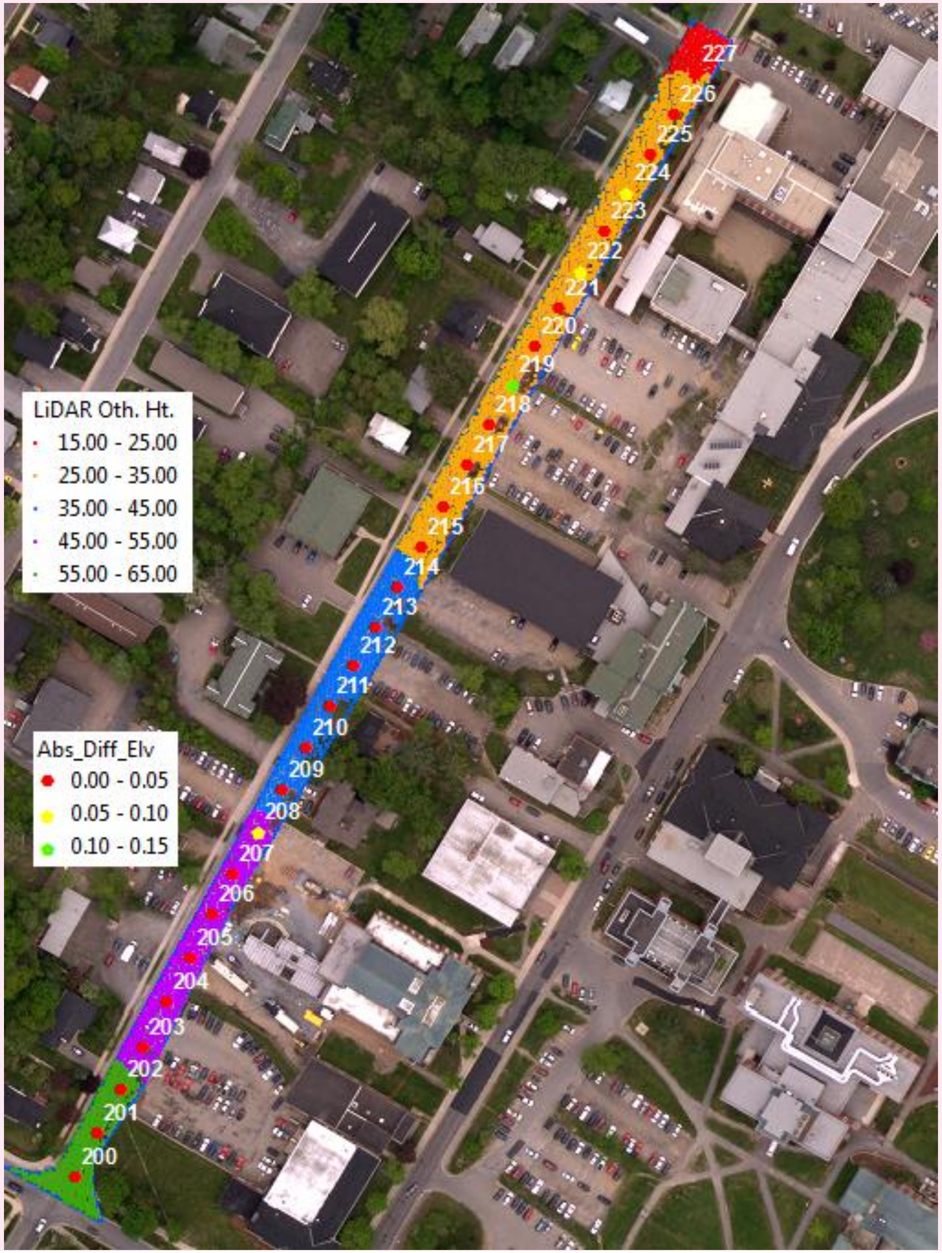
The Checkpatching Approach



A TIN created from sampled points in sparsely dense areas

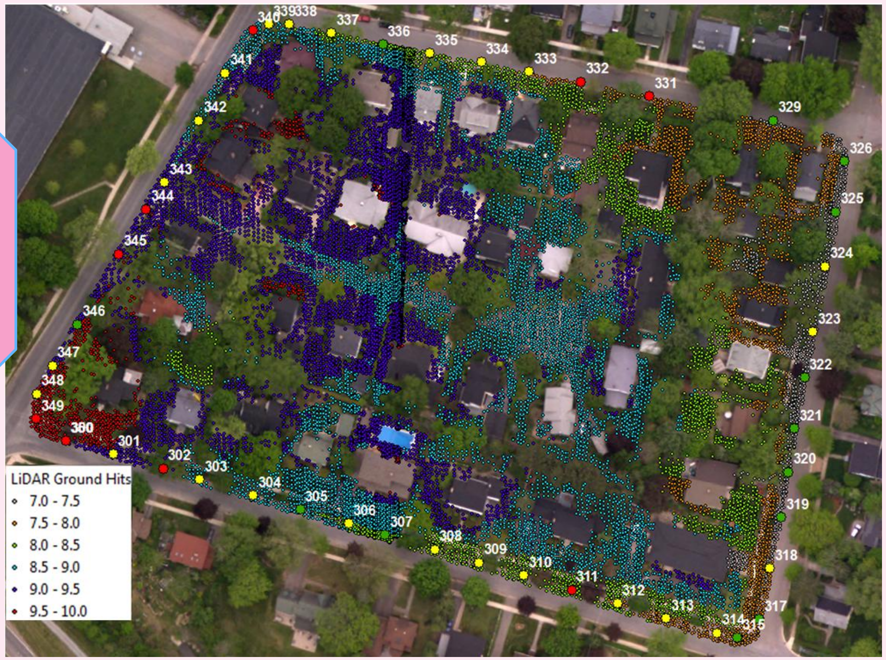
Terrain morphologies and obstruction to ground cover information is extracted for each checkpoint. Elevation (and x,y) variations between the surveyed checkpoint and corresponding x,y location is determined to RMSE reporting.

University of Lethbridge

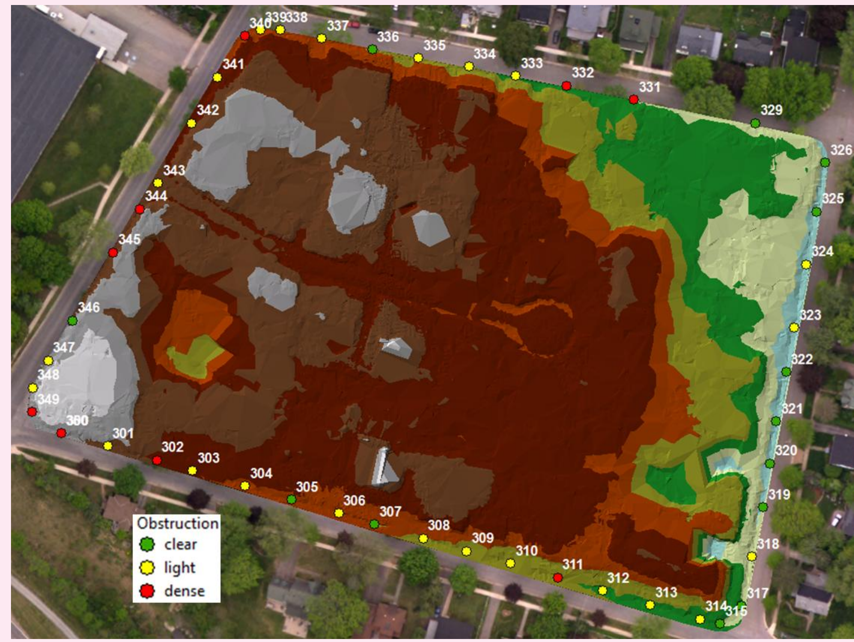


LiDAR data along the Windsor street.

The Checkpatching Approach



Ground LiDAR points in areas with light obstructions.



Obstruction and TIN of ground Hits in light obstructions.

Terrain morphologies and obstruction to ground cover information is extracted for each checkpoint. Elevation (and x,y) variations between the surveyed checkpoint and corresponding x,y location is determined to RMSE reporting.

University of Lethbridge

Intro. | Why ? | How ? | Lessons | Summary

Lessons learned

The vendor is typical suspect for erroneous data.

E.g. Parts of 2007 LiDAR data of Fredericton for flood mapping:

- had errors due to flight problems

A Digital Terrain Model (DTM) contained elevation errors between 0.5 cm and 2 m;

- as a result, some houses could potentially be announced as flood prone when they are not

Lessons learned

However, the field validation process can yield errors a well – user side blunders!!! Here is proof!

Two survey methods were experimented using:

1. Post Processing Kinematic (PPK)
   - obviously was an incorrect procedure to employ for the whole area
   - but was used as a possible alternative to RTK when radio between base and rover was broken

2. Network Real Time Kinematic (NRTK) and total station (TS) survey methods.

Intro. | Why ? | How ? | Lessons | Summary

Checkpatches in the test area and their amounts of obstruction		RMSE (±) m			RMSE (±) m differences
		PPK	NRTK	TS	
Areas clear of obstructions	Vegetation	0.14	0.03	-	0.11
	Open flat area	0.06	0.01	-	0.05
	Steep slope street	0.24	0.04	-	0.2
	Sparsely dense area	0.11	0.04	-	0.07
	Mean error	0.14	0.03		0.11
Areas with light obstructions	Vegetation	0.47	0.07	-	0.4
	Open flat area	0.97	0.1	-	0.87
	Sparsely dense area	0.58	0.07	-	0.51
	Built-up area	1.3	-	0.1	1.21
	Mean error	0.83	0.08		0.75
Areas with dense obstructions	Vegetation	1.16	0.21	-	0.95
	Open flat area	1.27	0.27	-	1
	Sparsely dense area	1.29	0.16	-	1.13
	Built-up area	1.45	-	0.2	1.28
	Mean	1.29	0.20		1.09

University of Lethbridge

FIAT LUX

Intro. Why ? How ? Lessons Summary

Summary

Sources of blunders in large datasets like the LiDAR data can be due to the :

- **data capture process (or vendor side blunders)**
- **differences in accuracies of the survey tools and methods employed**
  - **can introduce errors up to a few metres if right tools and processes are not employed**
- **limiting technology in interpolating checkpoints and corresponding LiDAR elevations**
- **choice and/or configuration of checkpoints**

Summary

There are several ways to mitigate this:

- employing Quality Control Points (QCPs) with accuracies three times better than the required accuracy.
- rigorous equipment testing before validation surveys.
- not enough to just spread QCPs randomly
  - important to consider varying terrain morphology and ground cover when choosing sites for validation to avoid bias.

Acknowledgements

Special thanks to Dr. David Coleman, Dr. Peter Dare and Dr. Mark Masry for their direction during this research

The University of New Brunswick
Fredericton / Saint John

caris

Leading Edge Geomatics

merrett survey partnership
topographic survey services

MITACS

Service New Brunswick Nouveau

University of Lethbridge

References used

- Chrzanowski, A. (1977). "Design and error analysis of surveying projects". Selected papers and lecture notes. Department of Surveying Engineering. University of New Brunswick, NB, Canada. Lecture Notes N. 47, pp. I-1-IV-13.
- Flood, M. (Editor) (2004). ASPRS Guidelines Vertical Accuracy Reporting for Lidar Data V1.0. [On-line] Accessed on February 3, 2010 from http://www.asprs.org/society/committees/lidar/Downloads/Vertical_Accuracy_Reporting_for_Lidar_Data.pdf.
- Hodgson, M and P. Bresnahan (2004). "Accuracy of Airborne LiDAR-Derived Elevation: Empirical Assessment and Error Budget" Photogrammetric Engineering and Remote Sensing, 70(3), pp. 331- 339.
- Kothari, C. R. (1985). Research Methodology, Methods & Techniques. New Age International (P) Ltd. New Delhi, India. ISBN: 81-224-152-9, pp. 152-188, Figure 9.1.
- Martin A. A., N. M. Holden, P. M. Owende, S. M. Ward (2001). "The Effects of Peripheral Canopy on DGPS Performance on Forest Roads". International Journal of Forest Engineering. 12(1). pp.1-9.
- Ussyshkin, R. V., B. Smith (2006). "Performance analysis of ALTM 3100EA: Instrument specifications and accuracy of LiDAR data." ISPRS Conference Proceedings (Part B), Paris, France. 1-4 July. pp.1-7.

Thank you

Bounce all enquires and comments to addapat@yahoo.com

Keep being spatially responsible; because your work affects lots of lives than you can ever imagine!

if it does not make spatial sense then it does not make sense ☺