Automated volumetric measurement of truck loads through multiview photogrammetry and 3D reconstruction software

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Outline

1. Background – Measurement of wood
2. Volumetric measurements of truckloads
3. Results from research trials AFORA/Forico – multi-view photogrammetry and 3D image reconstruction software
4. Future research
5. Summary

Why measurement of wood is important?

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- Wood is an important cost component of the supply chain costs:
  - >50% of delivered cost
  - Millions of dollars per year

- Approximate breakdown of the major costs:
  - 1/3 cost = wood
  - 1/3 cost = harvest
  - 1/3 cost = transport

Measurement methods

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Solid volume

Frame volume

Green tonnes

The unit of measurement

“The unit of quantity must be objective, reproducible, easily and cost-effectively determined, and fair to both the buyer and seller”

1. Objective: No or minimum human intervention
2. Reproducible: Quantity does not vary each time a load is measured
3. Easily and cost-effectively determined: Measurements are quick, automatic, and involve low operational and sampling costs
4. Fair: Does not create perverse incentives

Why volumetric measurements?

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The measure is related to the VALUE of the product traded

Green wood

=

Dry wood

External Characteristics

VALUE

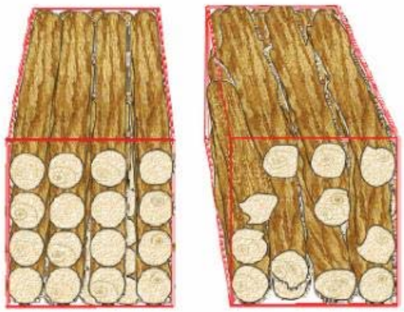
+

Water

NO VALUE

The goal is to measure only the value

Frame volume measurements



- Or gross volume, includes air spaces between logs
- Solid-to-frame volume ratio depends on product type, arrangements of logs, length and diameter distribution, taper, knots, crook and sweep

- Better than weight and can be used to estimate solid volume (factors, regression models), but

- Not the ideal measurement unit

Solid volume measurements

- Solid volume is related to fibre quantity
- Solid volume captures value
- Solid volume is fair, no perverse incentives
- Solid volume is reproducible
- Solid remains unchanged along the supply chain

Solid volume

=

Fibre

+

Water

Volumetric measurements of truckloads

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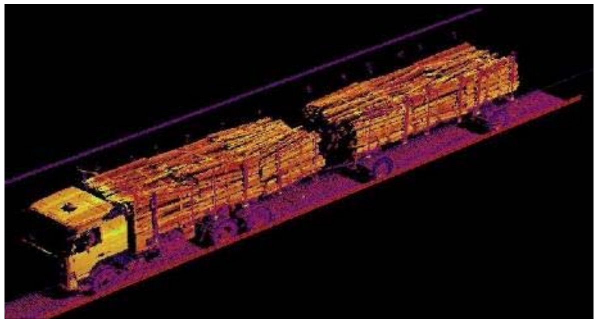
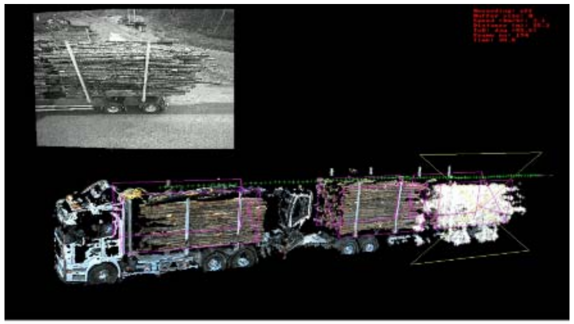
Solid volume measurements

Laser scanning



Source: Woodtech

Stereoscopic cameras



Source: Saab/Microtec

Laser scanning

Source: Mabema

Multi-view 3D reconstruction of truckloads – AFORA / Forico trial

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Objectives

1. Test multi-view photogrammetry and commercial 3D reconstruction software as an innovative and alternative method for automated volumetric measurement of truckloads
2. Determine frame and solid volume using this approach / technology
3. Determine accuracy of the approach in comparison to other measurement systems
4. Propose guidelines for the implementation of the technology in real operating conditions

Multi-view 3D reconstruction of truckloads – Steps

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1. Fly drone around 10 trucks (E. nitens, semitrailers)
2. Measuring each truckload for solid volume
3. Processing images of each truckload (35-50 photos) with 3D reconstruction software (Agisoft)
4. Generating a 3D truckload
5. Calculate frame volume (Autodesk Remake)
6. Calculate frame-to-solid vol. ratio, and predict solid vol. from frame volume vol. with regression model
7. Develop an algorithm to estimate solid volume from the 3D model developed from the images

Data collection with drone

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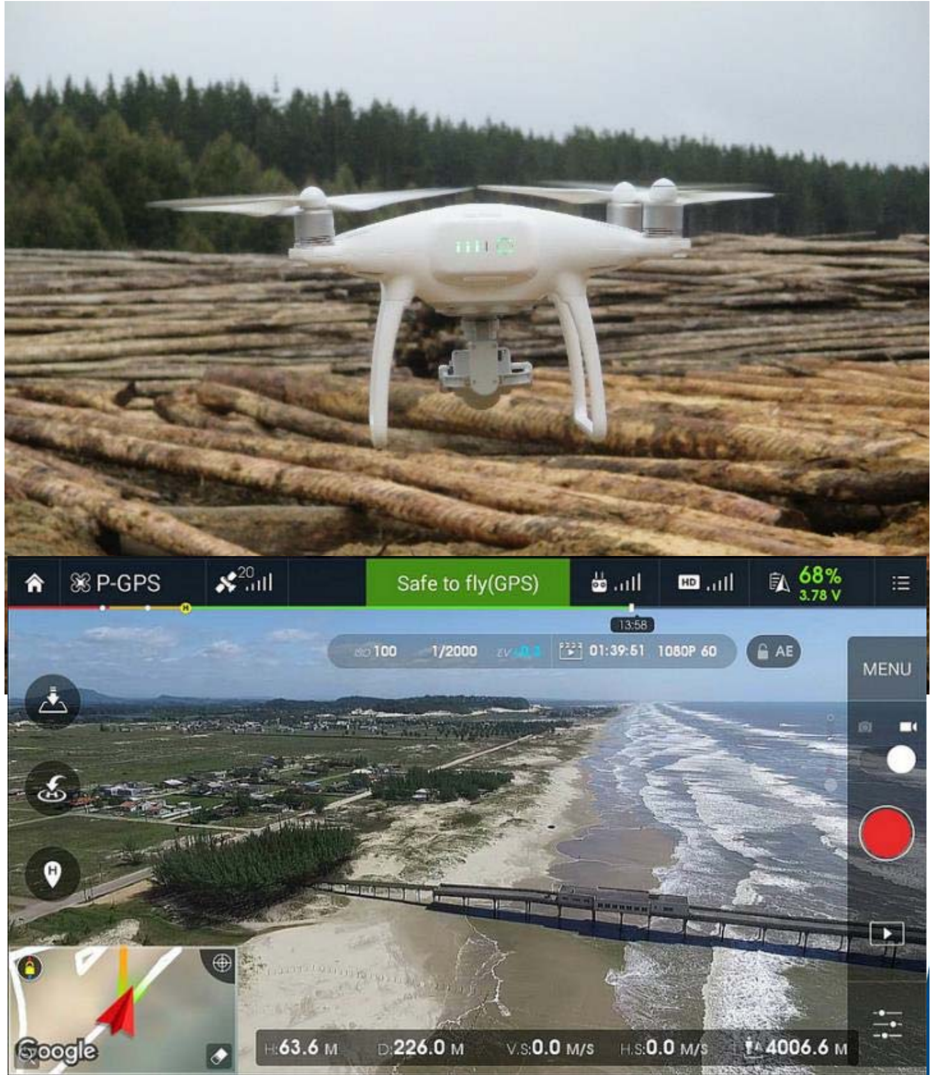
Phantom 4 Intelligent fly mode: POI



Log measurement

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10 truckloads

1,230 logs measured for solid volume using Huber

Data collection with drone

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Specification	Value
Camera model	FC 330
Effective pixels	12.4 M
Sensor	1/1.3” (6.17 x 4.55 mm) CMOS
Resolution	4000 x 3000
Focal length	3.61 mm
Pixel size	1.56 x 1.56 µm
Video recording modes	FHD: 1920×1080 24 / 25 / 30 / 48 / 50 / 60 / 120p HD: 1280×720 24 / 25 / 30 / 48 / 50 / 60p
Format photos	JPEG, DNG (raw)
Format videos	MP4, MOV

Workflow – 1. Data cloud

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Features points detection and matching procedures

26,500 data points

45 images

Processing time: 8 min

Ground resolution: 4.62 mm/pix

Workflow – 2. Dense cloud

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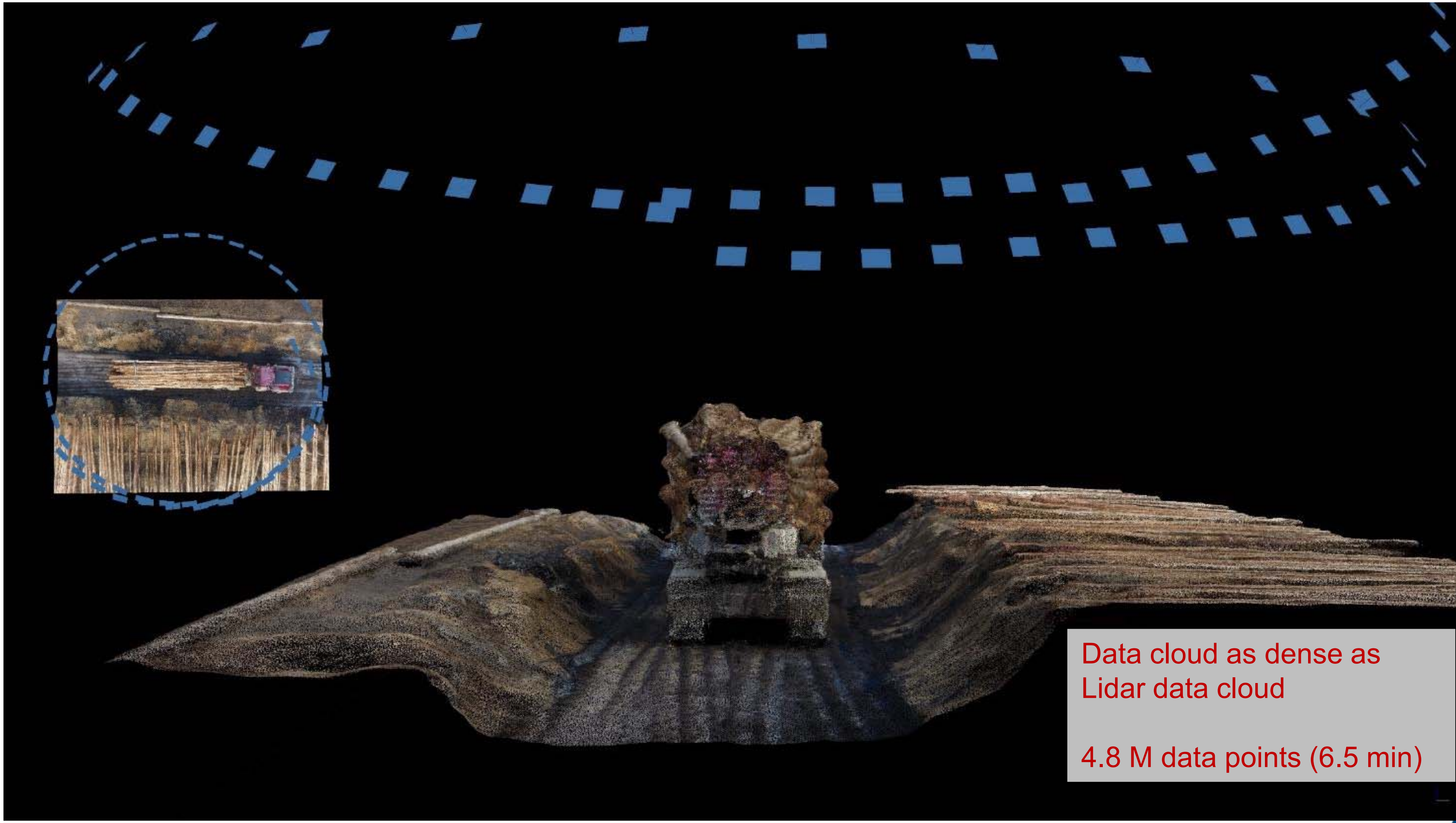
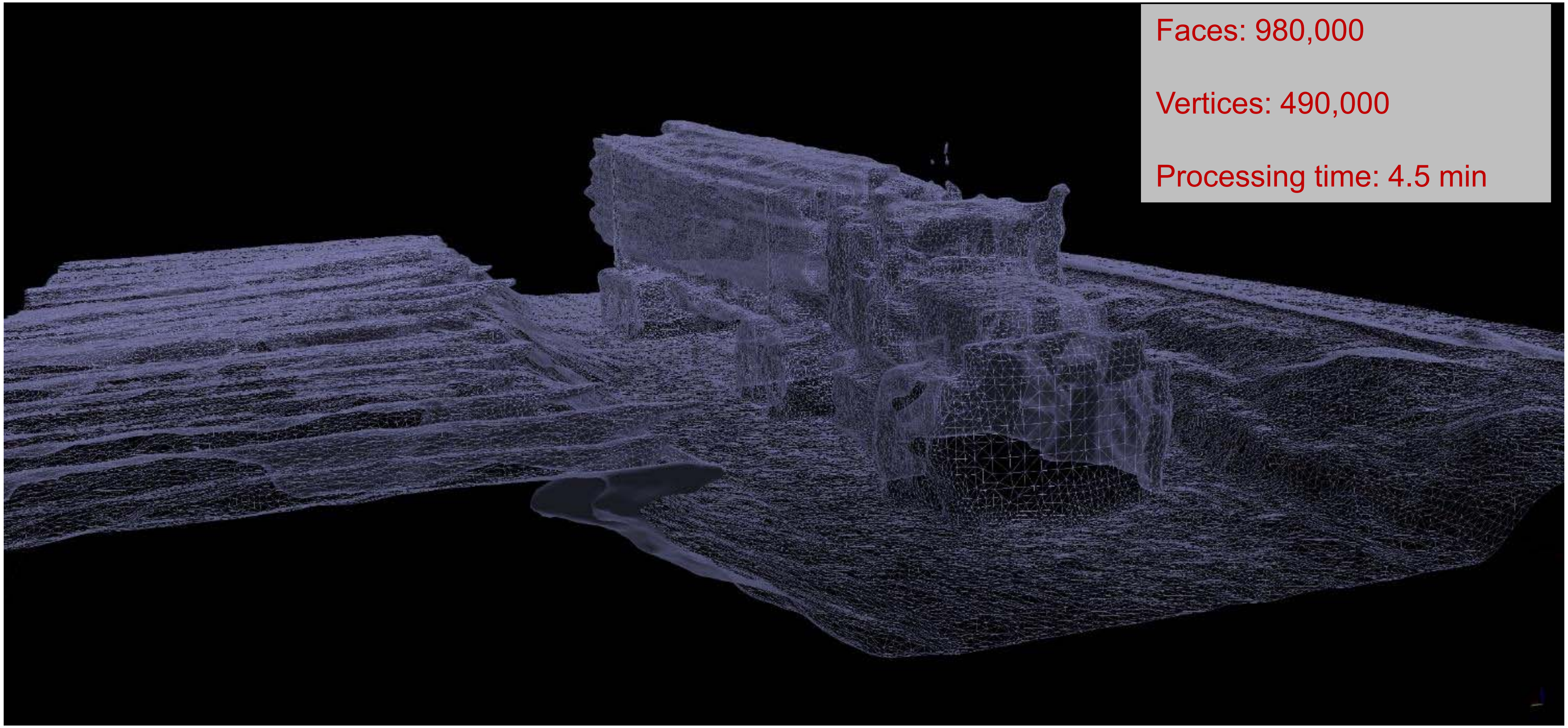


Data cloud as dense as Lidar data cloud

4.8 M data points (6.5 min)

Workflow – 3. Mesh



Faces: 980,000

Vertices: 490,000

Processing time: 4.5 min

Workflow – 4. 3D tiled model

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Processing time: 5 min & 45 secs

3D Truckload on Sketchfab

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Results

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Log measurements

		SED (mm)	LED (mm)	Log length (m)
Short logs (N = 1,943)	Min.	40.0	65.0	2.65
	Max.	335.0	392.0	6.05
	Mean	108.8	160.9	5.39
	Median	100.0	155.0	5.43
	Std. Dev.	37.3	43.2	0.19
Long logs (N = 4,837)	Min.	35.0	85.0	6.10
	Max.	353.5	575.0	12.98
	Mean	134.3	244.1	10.91
	Median	130.0	236.0	10.85
	Std. Dev.	49.2	64.9	0.87

Results from 10 truckloads

Truck #	GVM (tonnes)	Tare (tonnes)	Net payload (tonnes)	Net volume (m^3s)	Frame volume (3D reconst.) (m^3)	Net-to-Frame volume ratio
1	45.90	14.95	30.95	29.04	43.73	0.66
2	45.55	15.35	30.20	28.52	45.92	0.62
3	50.35	16.10	34.25	31.64	47.56	0.67
4	41.55	14.75	26.80	26.20	40.85	0.64
5	46.00	15.65	30.35	29.09	45.40	0.64
6	46.00	15.70	30.30	29.13	45.15	0.65
7	45.35	14.95	30.40	28.86	45.97	0.63
8	46.10	15.15	30.95	28.73	45.95	0.63
9	46.50	17.85	28.60	27.15	43.13	0.63
10	45.35	15.50	29.85	28.80	44.83	0.64
Min	41.55	14.75	26.80	26.20	40.85	0.62
Max	50.35	17.85	34.25	31.64	47.56	0.67
Average	45.88	15.78	30.09	28.54	44.85	0.64
Std. dev.	2.00	1.05	1.87	1.46	1.87	0.02

Estimating solid volume from frame volume

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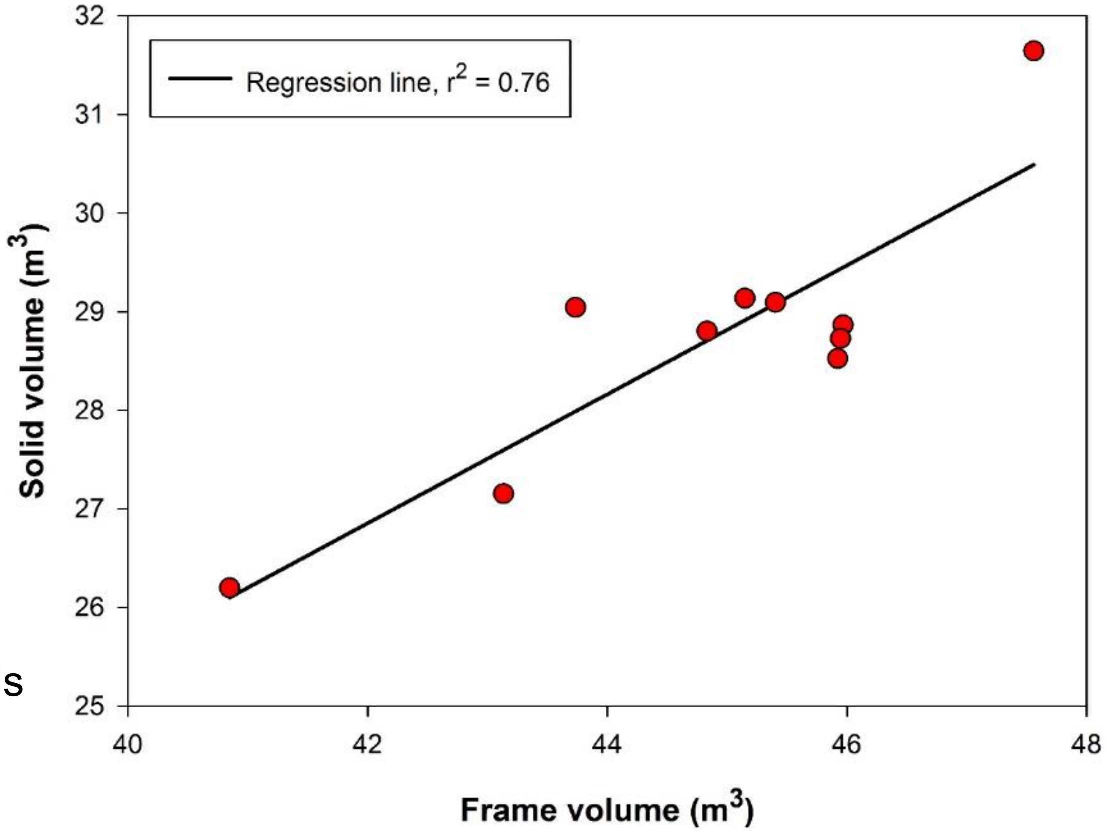
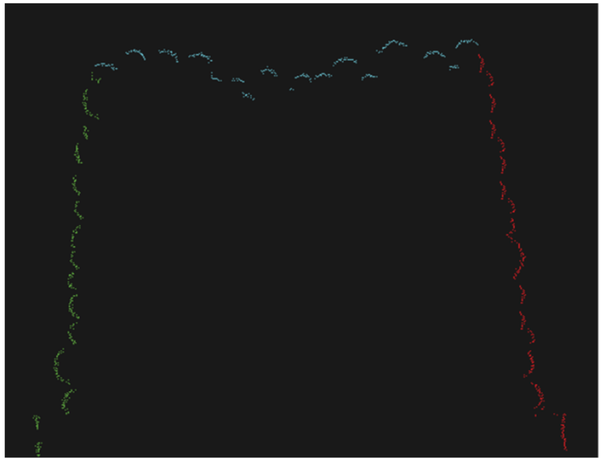
Statistics	Frame volume 1	Frame volume 2
Min	40.85	37.81
Max	47.56	47.98
Mean	44.85	44.90
Std. dev.	1.87	2.90

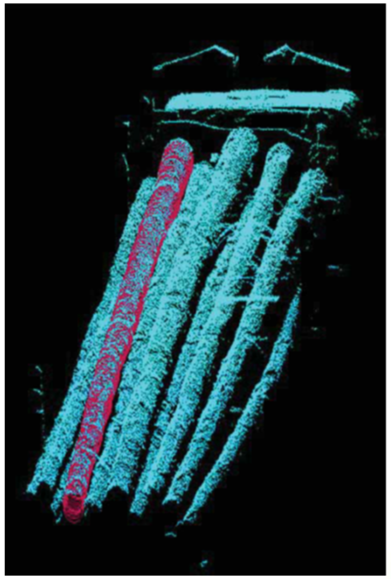
Frame volume 1: multi-view photogrammetry and 3D reconstruction
Frame volume 2: side photos of truckloads



Future research

1. Compare photogrammetry, stereoscopy and laser scanning systems for automated volumetric measurements of truckloads
2. Develop a computer vision algorithm to reconstruct the logs located in the periphery of the truckload (OpenGL, PCL)





Summary

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1. Multi-view photogrammetry and commercial 3D image reconstruction software were tested as an innovative and alternative method for automated volumetric measurement of truckloads
2. Results indicate the potential use of this approach to calculate the frame volume of truckloads
3. A high coefficient of determination ($r^2 = 0.76$) was obtained between frame volume calculated with Multi-view photogrammetry and manual solid volume
4. New algorithms will be developed for a direct calculation of solid volume from the data cloud collected with photos and laser sensors

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