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Accuracy and Efficiency of the Laser-camera

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Timo Melkas[1], Mikko Vastaranta[2] & Markus Holopainen[2]

[1]Metsäteho Ltd, Finland,
timo.melkas@metsateho.fi
[2]University of Helsinki, Department of Forest Resource Management, Finland,
mikko.vastaranta@helsinki.fi,
markus.holopainen@helsinki.fi

The aim of the study

- to develop a device for the measurement of growing stock variables (diameters, tree heights, locations of trees and quality variables) from the centre of a sample plot, without having to visit the trees
- to test the Laser-camera under forest conditions
- to improve the accuracy of the diameter measurements

Laser-relascope (I prototype)

- a laser rangefinder
- a variable-width slot with a fixed length arm
- an electronic altimeter
- a data collection/processing unit
- GPS

Kalliovirta, J, Laasasenaho, J. & Kangas, A. 2005. Evaluation of the Laser-relascope

Laser-camera (II prototype)

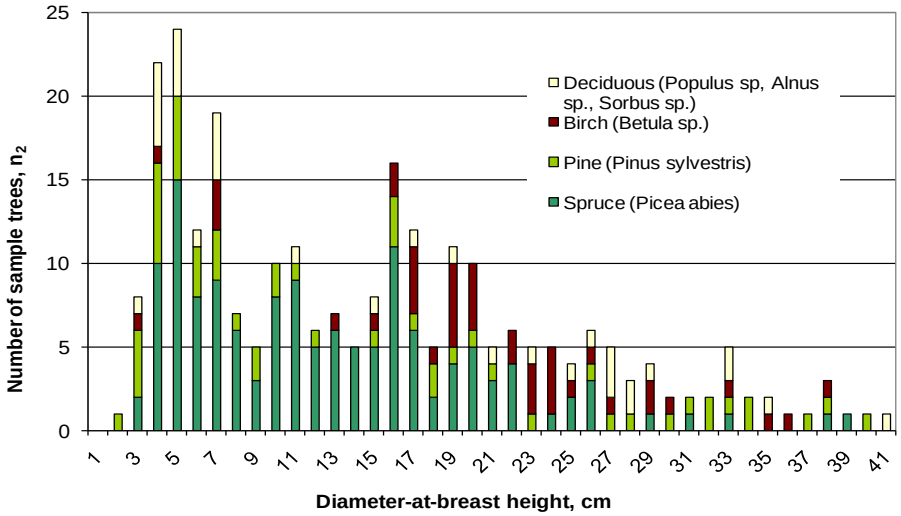
Laser-camera

- Consists of a Canon EOS 400D digital reflex camera, with an integrated Mitsubishi ML101J27 –laser line generator.
- The measurement of tree diameter is performed by using the length and relative position of the laser line on the image.
- Measurements are based on a laser line and a laser point. The device enables the measurement of tree diameter from any desired height.
- Image interpretation is performed with specifically designed computer software in a data collection/processing unit.

Study material

- Study material was gathered during the turn of the year 2007-2008 from 13 circle sample plots (r = 7.98-10.0 m) from a group of 728 diameter observations, and from 265 trees in total (pine, spruce, birch, aspen)
- The diameters were measured both semi-automatically[1] and fully automatically.

1) When using the semi-automatic method, digital images are checked afterwards. If errors are located, markers that define the outline of a tree stem can be set manually.



	n_1	n_2	minimum	maximum	average	S.D.
Pine (Pinus sylvestris)	153	53	4.4	46.5	15.7	11.7
Spruce (Picea abies)	386	137	5.2	40.9	14.8	7.8
Birch (Betula sp.)	108	42	5.0	40.4	22.8	7.7
Deciduous[1]	81	33	4.7	47.8	20.9	11.7
All observations	**728**	**265**	**4.4**	**47.8**	**16.9**	**9.7**

1) aspen (n_1 = 51), rowan (n_1 = 17), alder (n_1 = 13)

New picture

Select right or left marker

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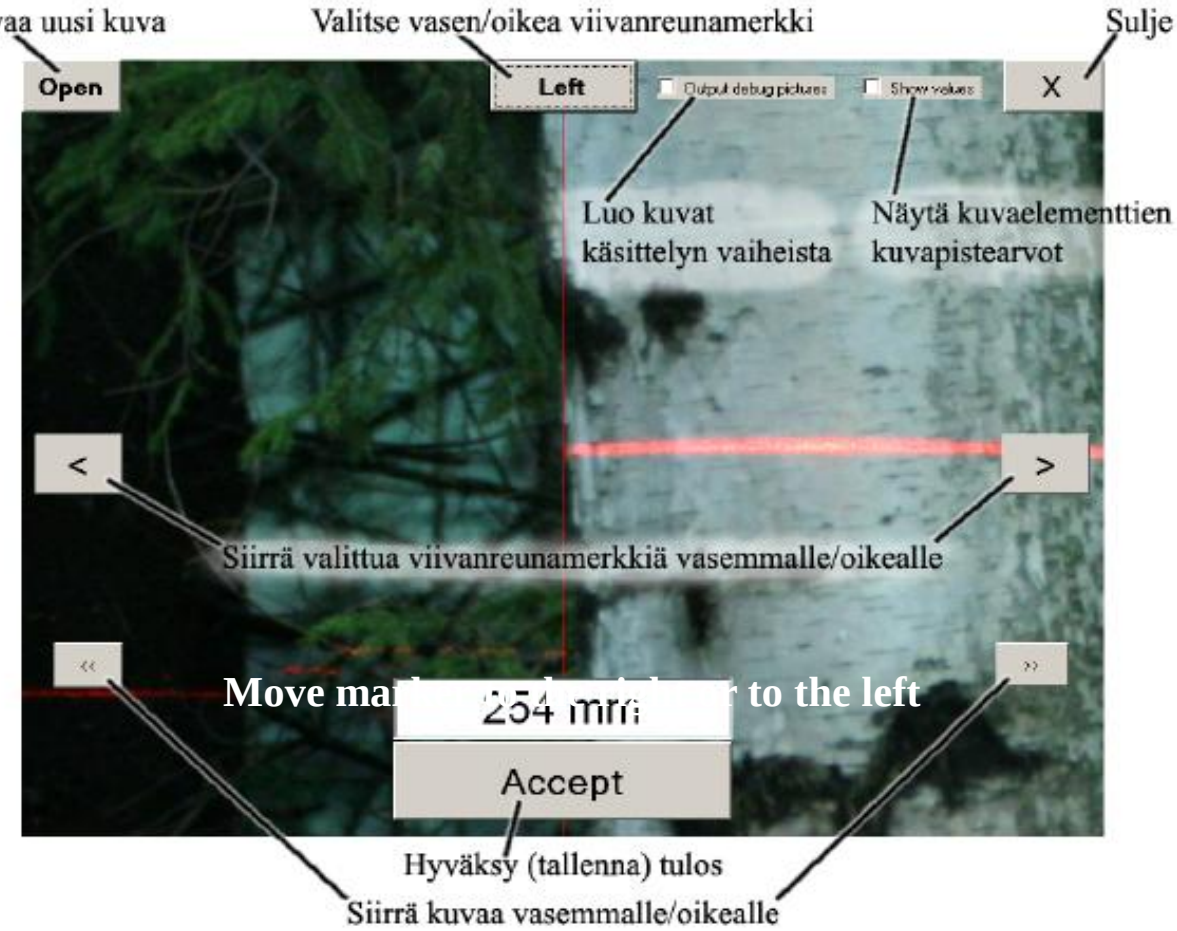

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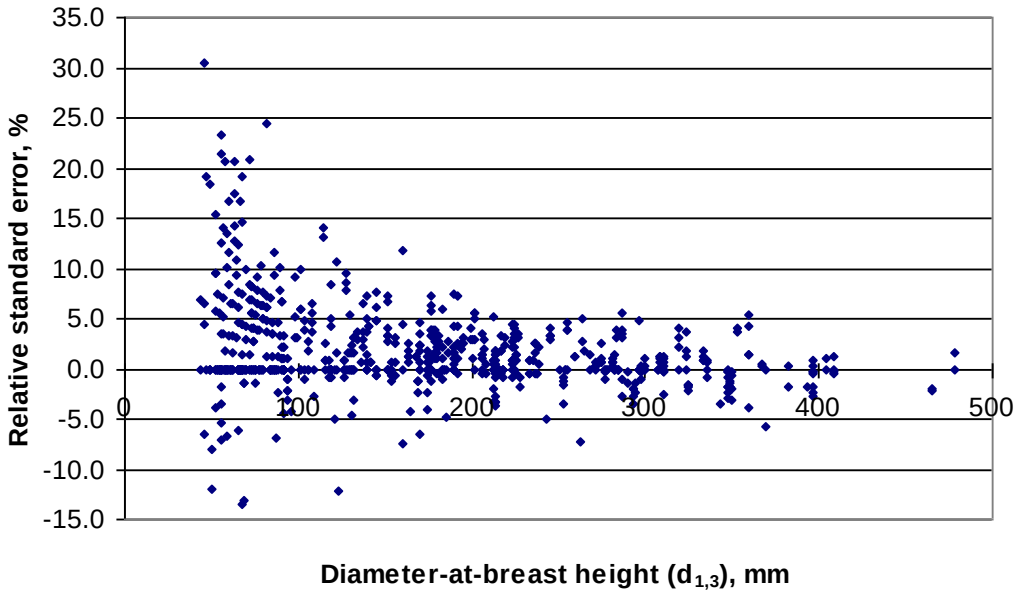
The accuracy of Laser-camera

- The accuracy of diameter measurements using the semi-automatic method was 6 mm (S. E.) and bias 2.5 mm, throughout the research data.
- The precision of diameter measurements was most successful with spruce 5.0 mm (4.4 %), then birch 6.4 mm (3.3 %), and finally with pine 7.6 mm (7.6 %).
- Using the fully automatic image interpretation method, measurement accuracy of tree diameter was 12.7 mm.



Precision of diameter measurements on the basis of tree species and measurement success

	n	$d_{1.3}$	bias, mm	bias, %	S.D, mm	S.D., %	S.E., mm	S.E., %
Pine (*Pinus sylvestris*)	124	17.2	**4.6**	4.8	**6.0**	5.8	**7.6**	7.6
Spruce (*Picea abies*)	272	16.9	**2.2**	1.8	**4.5**	4.0	**5.0**	4.4
Birch (*Betula sp.*)	88	22.8	**2.5**	1.0	**5.9**	3.1	**6.4**	3.3
Deciduous[1]	68	21.9	**-0.6**	1.5	**6.1**	5.8	**6.1**	6.0
All observations	552	18.5	**2.5**	2.3	**5.5**	4.8	**6.0**	5.3

1) aspen (n_1 = 51), rowan (n_1 = 17), alder (n_1 = 13)

Table 1. The precision of diameter measurements using a laser camera and semi-automatically interpreted diameter observations.

	Automatic method	Semiautomatic method
Pine (Pinus sylvestris)	51.6	81.0
Spruce (Picea abies)	58.0	70.5
Birch (Betula sp.)	80.6	81.5
Deciduous[1]	60.5	84.0
All observations	**57.4**	**75.8**

Table 2. Measurement success on the basis of tree species and throughout the study material (automatic/semi-automatic image interpretation).

Efficiency of a laser camera and major sources of error

- Diameter measurements were successful in 60 % of observations, when using the automatic image interpretation method.
- When using the semi-automatic method, the level of success was 70,5 % with spruce, 81,5 % with birch, and 81 % with pine.
- Measurements are obtained quickly with the device (10 s / tree) and the accuracy of tree diameter measurements are able to compete with results obtained with traditional measuring methods.
- It took approximately 7.5 minutes to measure one sample plot.
- Major sources of error are caused by the following:

1. The camera calculation algorithm does not work, when the laser point does not hit the tree stem.
2. Branches in front of the trunk are hampering visibility
3. Measurement height or direction is erroneous.

Major sources of error

1) Camera calculation algorithm non-functioning, when the laser point doesn't hit the tree stem

2) Branches in front of tree trunk

3) Measurement height or direction is defined incorrectly

4) Strong sunlight causes the laser line to break

Functionality of a Laser-camera in field conditions

- Measurements of tree diameter can be obtained quite reliably with a Laser-camera, and at a fast speed (10 s / tree) and high efficiency.
- The observer or measuring distance has no impact on measurement results.
- Measurements are always documented and one can always refer to the obtained results later on, if something out of line comes up when interpreting the results.
- Automatic image interpretation requires manual checking of images either during field measurements or afterwards.
- Tree diameter can be measured from any height, if an inclinometer is added to the Laser-camera. In that case, tree volume measurements can utilize a group of diameter measurements from different stem heights and improve the volume estimate by 5-8 % (taper curves).

Future development requirements

- By adding an electronic inclinometer, a laser rangefinder, an electronic compass and a GPS receiver to the device, tree height, location and other quality attributes can be measured very efficiently from sample plots.
- The device technology can be integrated with a water/weather proof camera that includes all necessary calculation software.

- The accuracy of Laser-camera is compared with other laser-based methods (TSL, Laser-camera, Laser-relascope, caliper) to measure stem diameter in the following study:

  Comparison of different Laser-based methods to measure stem diameter. 2008. Vastaranta, M., Melkas, T., Holopainen, M., Kaartinen, H., Hyyppä, J. & Hyyppä, H.SilviLaser 2008. Sept. 17-19, 2008 – Edinburgh, UK - poster presentation

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