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Method to improve tree volume measurement

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Introduction

Biomass has the highest proportion of total energy production in Finland than in any other industrialized country. Most of the biomass that is used for energy production in Finland is wood (2014). [1] The usage of biomass for energy production has increased and therefore it is important to be able to measure how much biomass is stored in the forests. Another interesting future prospect is carbon storage in forests. In order to estimate the carbon storage capacity of the forest, accurate estimate of the biomass needs to be known. [2]

Accurate measurement system for tree volume is needed, because the volume estimation is currently done by using mathematical models. These mathematical models do not take branches into account, even though their volume is significant. [2] Accurate estimation of the volume is also necessary to determine the density of a tree. Many structural properties of the tree depends on its density. Pine tree's tensile strength varies between 34-192 MPa, when it is being pulled along the grains of the tree. [3] This means that the applicability of a tree is determined by its density.

Volume measurement can be done by using terrestrial laser scanning (TLS). This method allows tree volume measurement without cutting the tree into pieces. With this method, the tree is first digitized by TLS. Then the TLS data is processed by geometric fitting algorithms which can compute the total volume of the measured tree. This method does not take into account branches that are smaller than 7 cm in diameter, which leads to ±30 % error in

branch volume measurement. This error is significant and the results do not include the density of the tree. [4]

University of Helsinki has a volume measuring device in Hyytiälä forestry field station, which has been developed in collaboration with Aalto university. The device measures volume of desired part by plunging it in water. Force sensor registers the buoyancy and determines the volume by using archimedes principle. [2] Drawback of the machine is that it does not take into account that the buoyancy depends on the temperature of the water [5]. The device has been upgraded with an ultrasonic sensor, for measuring the volume by determining how much the water level rises when the object is plunged into the water. The device can now measure the volume by measuring buoyancy and water level. Our goal is to determine which method is more suitable for this purpose by building a similar device as the original.

Tree volume measurement

- General information about tree volume measurement
- Why measuring the biomass volume is important
- Existing solutions and methods

Sensors in volume measurements

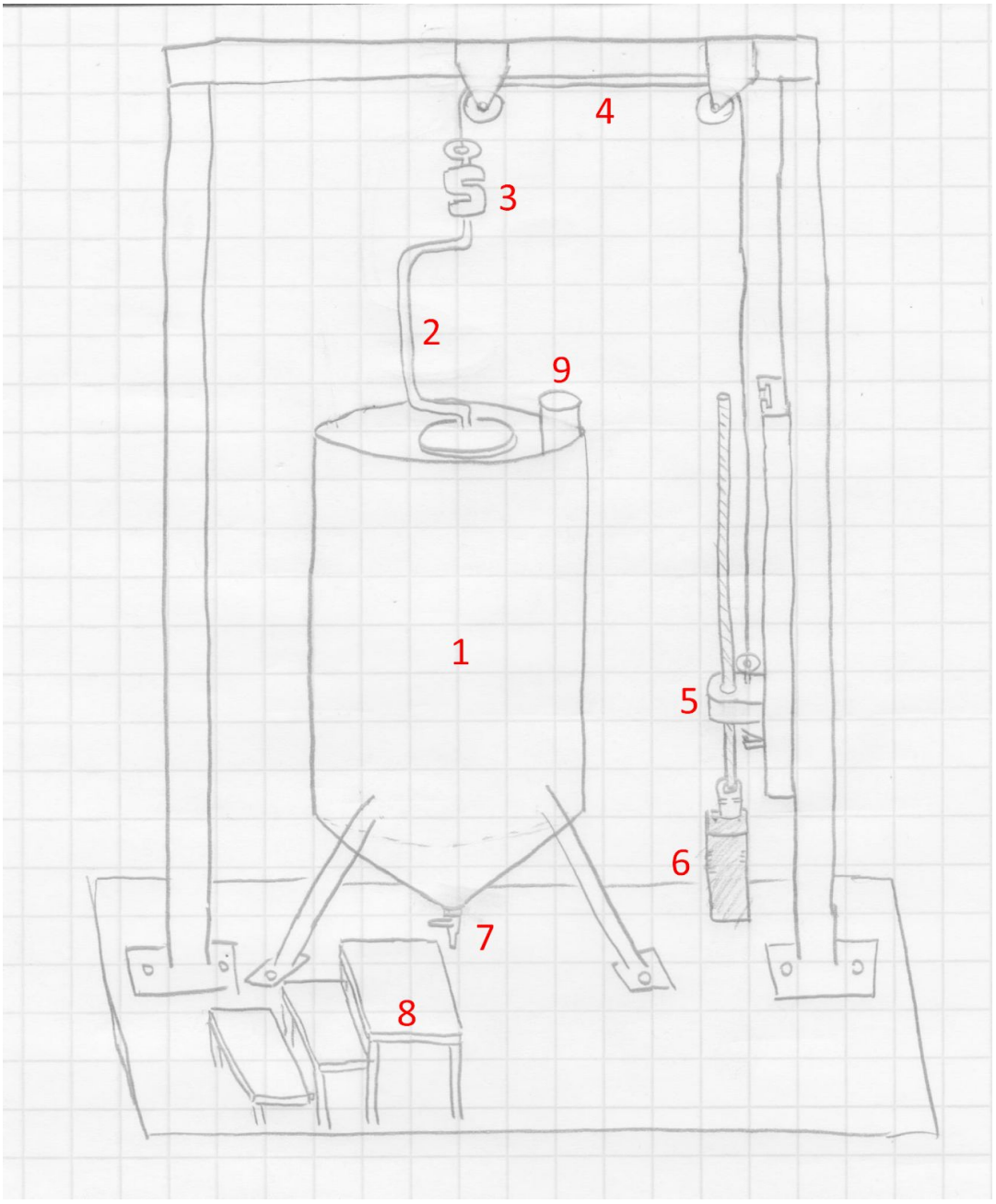
- Comparison of different sensor options for measuring the tree volume

Load cell for buoyancy measurement

Distance sensor for liquid level measurement

Dimensiometer

Mechanical concept



Volume measurement is started by filling the water tank (1) and powering up the system. Operator of the machine climbs on the platform (8) and attaches the specimen to a holder (2). Measurement cycle is started by the operator. The machine starts to lower the holder by

rotating a stepper motor (6), which is connected to a screw. Rotation of the screw allows a sled (5) to move. Rotation of the sled is prevented by a rail. Cable (4) pulls the sled upwards and the force is measured with a force transducer (3). Volume of the measured part can be calculated from the buoyancy effect (change in force readings). Calculations take into account that the immersion depth depends on the water level. Water level is measured with ultrasonic sensor (9), which is placed inside a tube. Volume can be also calculated by measuring the rise of the water level. After the measurement, operator can drain the water tank with a valve (7).

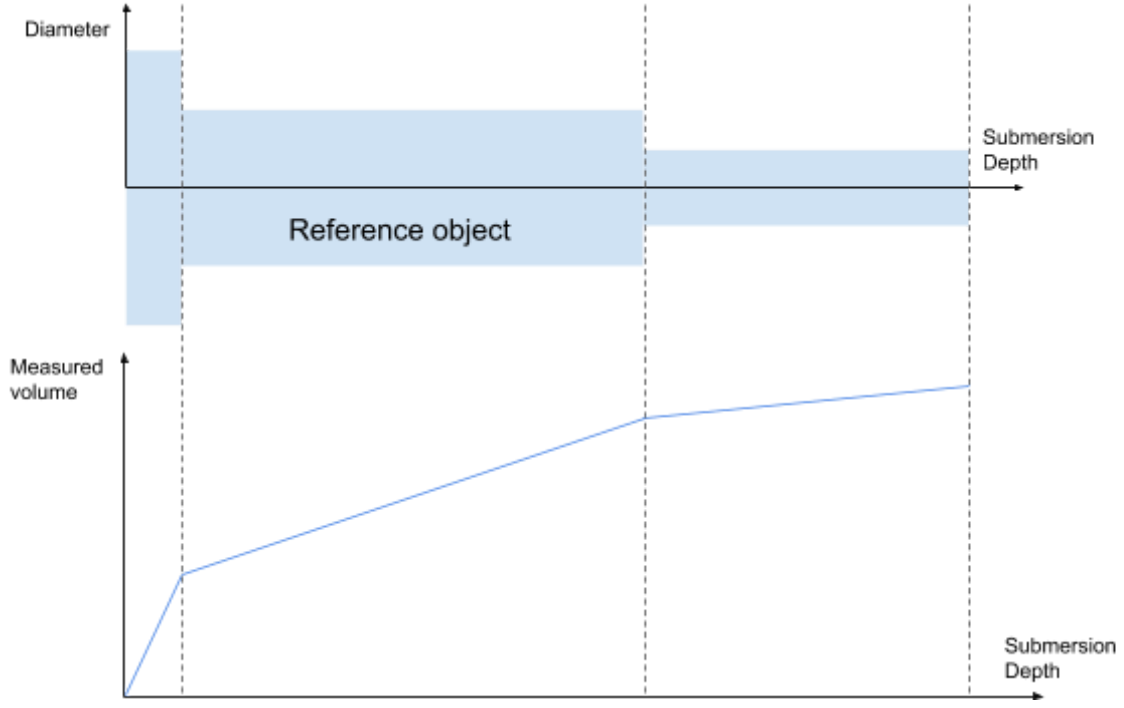
Component choices

Component	Selected part	Reason
Tank	270 liter air tank, 54 x 195 cm	Tall and narrow, mounting feet, price vs. custom made stainless steel tank.
Lifting mechanism	Trapezoidal screw driven by a stepper motor. The screw drives a sled that is sliding on a linear guide. The lifting mechanism is mounted beside the tank so that it does not add additional height to the system. Lifting force is transmitted with a steel cable which is supported by two rollers.	Screw is not back-driven by gravity. This ensures that the measurement device does not fall down to the tank when the motor is de-energized. Open-loop control is sufficient so the lowering height does not have to measured.
Water level measurement	Ultrasonic sensor MB7369	Does not need a float to sense the water surface.
Load cell and amplifier	PSD-S1 50 kg S-type load cell and Sparkfun HX711 amplifier	Price, suitable for measuring tension. Sparkfun version of the HX711 has better power filtering than other versions.
Temperature measurement	DS18B20 digital thermometer	Easy to use 1-Wire interface, ±0.5°C Accuracy
Software	Python, possibly interactive IPython shell with a Jupyter notebook interface that can be used with a browser.	No licensing costs, easy development
Computer hardware	Raspberry Pi 3B+	GPIO enables easy attachment of sensors, price

Testing measurement accuracy

The accuracy and repeatability of the dimensiometer was tested with a reference object whose dimensions and weight are known. Comparing the measured volume against a calculated value at different submersion heights shows the measurement error of the system. Comparing the results between multiple measurements makes it possible to evaluate the repeatability of the measurement system.

The reference object was turned on a lathe. It consists of straight sections that should show a steady increase in volume/height in the measurements. In addition to the straight parts the object has steps of different diameters that show up as changes of the volume/height slope in the measurements. These can be used to evaluate the accuracy of the submersion depth measurement.



Conclusion

- Are the results as expected
- Analysis of the results
- Further improvement ideas

References

We found 12 articles, thesis patents and books to begin with [1]–[12].

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