SLU

The Haglöf PosTex ultrasound instrument for the positioning of objects on forest sample plots

Tomas Lämås

Arbetsrapport 296 2010

Sveriges lantbruksuniversitet
Institutionen för skoglig resurshushållning
901 83 UMEÅ
www.srh.slu.se
Tfn: 090-786 81 00

ISSN 1401–1204
ISRN SLU–SRG–AR–296–SE

The Haglöf PosTex ultrasound instrument for the positioning of objects on forest sample plots

Tomas Lämås

Arbetsrapport 296
Skoglig resurshushållning

Sveriges lantbruksuniversitet
Institutionen för skoglig resurshushållning
Utgivningsort: Umeå
Utgivningsår: 2010

ISSN 1401–1204
ISRN SLU–SRG–AR–296–SE

Abstract

The positions of objects – typically trees and other vegetation – in forest sample plots are often of interest, e.g., as ground truth data in forest surveys in which remote sensing techniques are used, and in environmental monitoring. Laser rangefinders and measurements of bearings using electronic compasses are often used for this purpose. However, use of laser rangefinders is problematic when sighting conditions are poor. In contrast, since ultrasound passes through vegetation and around stems it also enables measurements in dense forest. Thus, the novel ultrasound-based Haglöf PosTex ® instrument provides quick measurements of positions of objects in sample plots even in dense forest with poor sighting conditions. The design of the instrument also enables measurement of positions at the same time as data are recorded for the objects, such as the diameters of trees. The instrument – developed in collaboration between the Swedish University of Agricultural Sciences (SLU) and Haglöf Sweden AB – has been used in various applications, e.g. in forest remote-sensing projects and mapping mountain vegetation, trees in burnt forests and seedlings for monitoring forest regeneration.

Introduction

Trees and other vegetation in sample plots are frequently registered in forest surveys and environmental monitoring campaigns. Often, the locations of individual trees and plants are of interest, e.g., for mapping their distribution in permanent sample plots or for acquiring ground truth data in remote sensing applications. Measurement tapes, compasses and protractors are used for measuring such objects. However, such methods typically require two persons, and mapping trees and other vegetation may still be difficult due to sighting obstructions. Alternative approaches include use of laser rangefinders in combination with electronic angle gauges or compasses (e.g. Field-Map (www.ifer.cz) (Hédl et al. 2009) and Laser-relascope (Kalliovirta et al. 2005)). However, since laser beams are stopped by obstructing vegetation (bushes, branches, stems) laser rangefinders have limited applicability in forests. For positioning individual trees mapping-grade global positioning systems (GPS) provide too low accuracy (Danskin et al. 2009) and survey-grade GPS is expensive and problematic to use under a forest canopy, to date at least (Rizos et al. 2010).

When using remote sensing techniques to detect individual trees, such as (intense) aerial-borne laser scanning (Maltamo et al. 2004) or optical 3D digital surface models (Wallerman et al. 2009) field plots including the positions of individual trees in the plots are required as ground truth data. Advances in such methods, and needs in other areas such as ecological research and environmental monitoring, have highlighted the need for convenient field instruments that provide reliable measurements of the positions of pertinent objects.

The key requirements for an instrument capable of efficiently measuring positions of objects in forest sample plots are that it must be:

- unhindered by obstructing vegetation,
- applicable by a single person in the field,
- usable at the same time that other data for objects are recorded (e.g., diameters of trees) rather than as a separate procedure,
- convenient to carry and set up on the plot,
- capable of providing quick measurements,
- usable in all weather conditions,
- capable of providing appropriate accuracy.

For ease of establishment, circular sample plots are typically used in forest surveys (typically with a 7-10 m radius in timber surveys in Nordic conditions). Since vegetation – especially stems – hamper the use of measurement tapes and laser rangefinders, an ultrasound distance measurer is highly advantageous for checking the plot radius, since ultrasound passes through non-woody vegetation and travels around stems. A transponder is placed on a pole or tripod in the plot centre and the distance is measured (using the travel time of the ultrasound) by a handheld device, e.g., when calipering trees. This technique has also been used for timber surveys based on distance sampling (recording the *n* objects closest to the sample point) with a built-in ultrasound distance measurer in an electronic caliper (Jonsson et al. 1992).

Working principle

The novel instrument – named PosTex ® – for positioning objects in sample plots uses ultrasound distance measuring technology. Three transponders are placed in an equilateral triangle, centered at the centre of the plot, and the distances between the transponders and the handheld device, located at the object of interest, are used to calculate the object's position (Fig. 1). The accuracy of the measurement depends on the error in the individual distances, which depend, inter alia, on: the distances and disturbances such as vegetation and wind, the distances between the transponders in the triangle at the plot centre and, to some extent, the position of the object relative to the transponders.

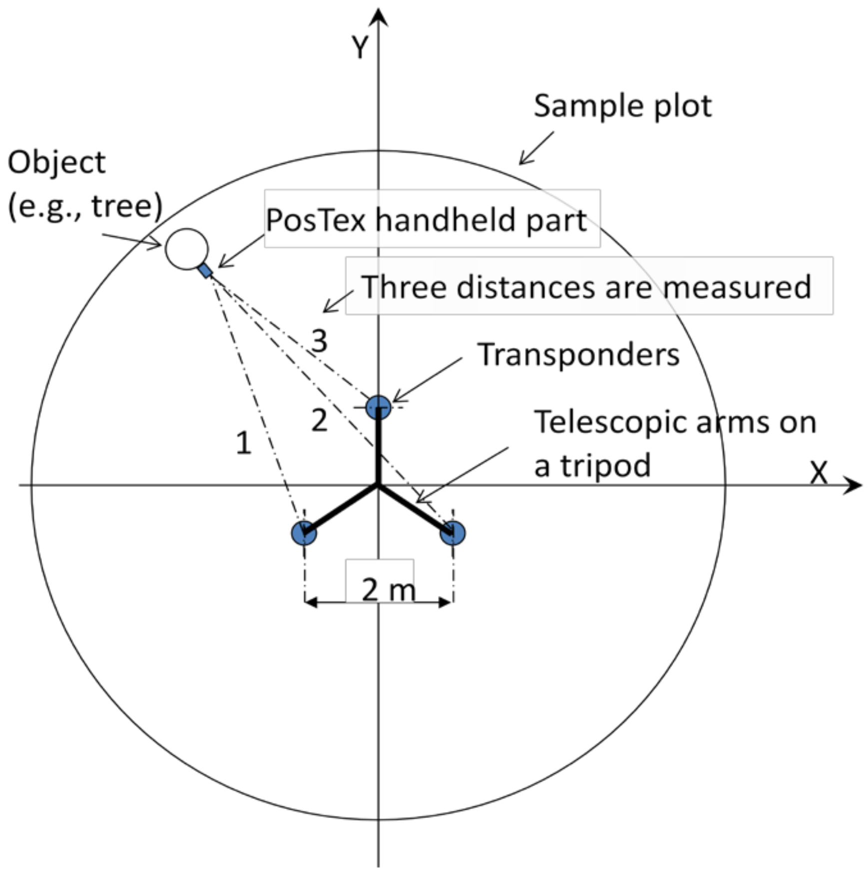


Figure 1. The working principle of the PosTex instrument for positioning objects in sample plots.

Simulations of the accuracy for given measurement errors of the distances between the hand-held unit and the three individual transponders, and tests with a prototype, have shown that the system provides reasonable accuracy with a distance of 2 m between the transponders in the equilateral triangle. Thus, it is possible to mount the transponders on telescopic arms on a tripod, making the arrangement easily operational in the field.

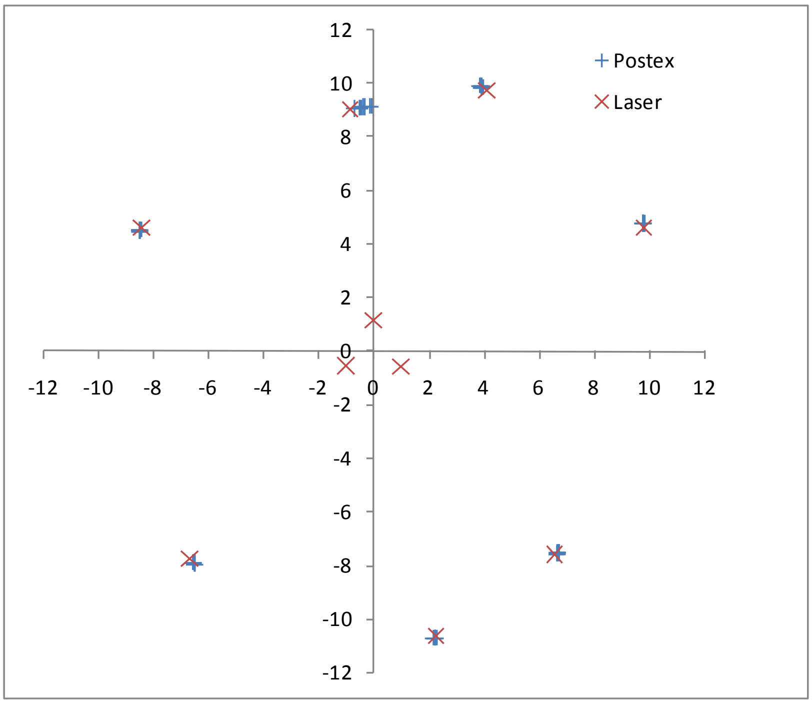
An algorithm, which has similarities with algorithms used in GPS devices, estimates the true coordinate of an object given the three measured distances and assumptions concerning the errors in the individual distance measurements.

Accuracy and coordinate system

Repeated measurements of coordinates of trees in field tests in Swedish boreal forests have been made, and compared to true coordinates measured using a total station (electronic theodolite with a laser rangefinder). For example, in an old Norwegian spruce- and Scots pine-dominated forest the positions of seven trees located between 9.1 and 10.8 m from the plot center were measured eight times, yielding 56 observations (Fig. 2). The surveyor walked around the plot repeatedly measuring the positions of the trees, thus there were several minute intervals between recordings for an individual tree. The plot contained more trees than those measured (Fig. 2). The mean and standard deviation of the PosTex measurements' divergence from the true coordinate (Euclidian distance) were 20.3 and 13.4 cm, respectively. Ninety percent of the observations were within 30.1 cm of the true coordinate. This dataset contains one tree with larger positional errors then the other trees on the plot, see the tree in the upper part of Fig. 2 close to the x-axis. On another plot in a old Scots pine-dominated forest, the positions of five trees located between 7.9 and 10 m from the plot center were measured 16 times (80 observations). The mean and standard deviation of the PosTex measurements' divergence from the true coordinate (Euclidian distance) were 4.9 and 3.2 cm, respectively. Ninety percent of the observations were within 9 cm of the true coordinate. In a dense Norwegian spruce- and Scots pine-dominated young forest (prior to pre-commercial thinning), the positions of six trees located between 6.8 and 11.3 m from the plot center were measured eight times (48 observations). The mean and standard deviation of the PosTex measurements' divergence from the true coordinate (Euclidian distance) were 14.5 and 9.6 cm, respectively. Ninety percent of the observations were within 29.3 cm of the true coordinate.

Typically the calculated positions with largest deviations from the true positions are distributed more or less along a radius of a circle with its centre at the centre of the sample plot, see the tree in the uppermost part of Fig. 2 close to the x-axis. Hence, too, the distance from the plot center, and a circular sample plot border, is estimated with higher accuracy than the abovementioned values suggest. In the examples given above the deviation between calculated and true radial distances was on average 0 - 3 cm (standard deviation 2 cm).

It is not straightforward to provide data on the accuracy of position measurements provided by instruments that have declining accuracy with increasing distance from the plot centre. The accuracy presented above is within a radius interval close to the border of a 10 m radius plot (6.8-11.3 m from the plot center, according to the data quoted above). In contrast Kalliovirta et al. (2005) presents the accuracy of the Laser-relascope as the mean accuracy for all trees on sample plots although the accuracy is clearly far higher for trees close to the plot center than for trees further from the center. As yet, the accuracy of the PosTex instrument in a range of forest conditions (hampering vegetation, variations in weather etc.) has not been assessed. However, there is an urgent need to assess its accuracy over greater distances since, for instance, ecologists need an instrument for positioning objects in larger plots, and have already used PosTex for this purpose.



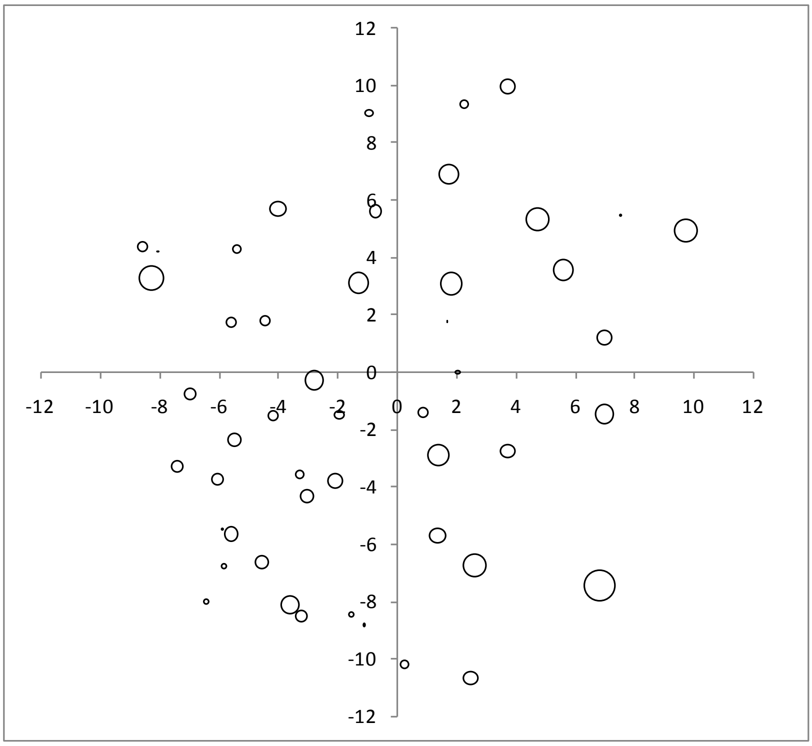


Figure 2. Results of an illustrative field test in which the positions of seven trees were measured eight times (top). The axis shows the distance from the plot center in meters. True positions (Laser) were measured with a total station. The Xs in the plot centre indicate the positions of the transponders. The plot map (bottom) shows all trees in the sample plot (the size of the circles is proportional to stem diameter, although not in scale, stem diameter 0.5 – 34.7 cm at breast height, n = 1560 ha^{-1}).

The PosTex positions are given in a local Cartesian coordinate system. When measuring, a GPS receiver is usually placed centrally on the tripod (i.e., the origin of coordinates in the local coordinate system) to acquire the global position of the sample plot, and one transponder is placed to the north to align the local coordinate system with a global one (Fig. 1). For this purpose a second position is also sometimes taken using both a GPS device and the PosTex instrument in the vicinity of the plot (preferably in a glade with good conditions for GPS measurement).

The instrument

PosTex is manufactured and marketed by Haglöf Sweden AB (www.haglofsweden.com). In its present version the handheld part is based on a modified version of the Haglöf Vertex Laser (Fig. 3). This is an electronic inclinometer, including a laser rangefinder, ultrasound distance measurer, and electronic vertical angle gauge. In the PosTex version it provides distance (e.g., as part of tree height measurement), height, slope, and position measurements. When taking positions on (considerably) sloping ground a two-step procedure is used. First, the slope from the tree to the plot centre is measured and when the subsequent position is taken the position in the horizontal plane is registered. Data from the instrument can be transmitted to a processing system, e.g. a field computer, via Blue Tooth.

Figure 3. The handheld part of the PosTex instrument, consisting of a modified version of the Haglöf Vertex Laser inclinometer and rangefinder. The display shows the calculated position in the local coordinate system – distance from plot centre (m) and angle (^{0}) – and the three measured distances to the transponders (m).

When applying the handheld part to the object the measurement of the three distances takes approximately three seconds. The transponders, one of which is the master, communicate wirelessly with each other to decide which one should be active at a given time and respond to the ultrasound signal from the handheld part. The coordinates are then calculated instantly by the handheld part (Fig. 3).

Since PosTex uses ultrasound for positioning, as indicated in the above examples it is not a high-precision instrument in comparison to laser rangefinder-based instruments (in good sighting conditions) and electronic compasses (e.g. Field-Map). However, the positional measurements it provides appear to be more accurate than those obtained by Kalliovirta et al. (2005) using the laser-relascope (by pointing the built-in laser rangefinder towards trees from the plot centre). A key, practical requirement is for sufficient accuracy to avoid individual objects (trees, plants) being mixed up in plot maps. The advantages of PosTex are that: in contrast to laser-based approaches it can be used in poor sighting conditions, such as young, dense spruce forest or vegetation-rich tropical forests; positions of objects can be measured at the same time as other variables of the objects, such as the diameters of trees; and there is no need to perform the positioning as a separate procedure.

The instrument was introduced and marketed in 2008. In that year it was used to measure and position more than 10 000 trees in several forest remote-sensing research projects undertaken by SLU and the Forestry Research Institute of Sweden, see for instance, e.g. Holmgren et al. (2010). Since then it has also been used (inter alia) for establishing permanent sample plots in burnt forests, positioning mountain vegetation in sample plots, and positioning seedlings for monitoring forest regeneration.

One way to increase its accuracy is to increase the distance between the transponders. However, if this is done the telescopic arms have to be lengthened and its application in the field may be hampered. If frequently used in sloping terrain it should be possible to eliminate the slope measurement as a separate step prior to positioning by adding a fourth transponder on a vertical telescopic pole in the centre. This allows three dimensional positioning at the same time, and the fourth transponder may increase the accuracy of the horizontal positioning.

Concluding remarks

The ultrasound-based Haglöf PosTex instrument affords quick, convenient positioning of objects in forest sample plots, with moderate accuracy up to 12 m from the plot center. It provides an alternative to options such as manual methods or laser rangefinders and electronic compasses. Compared to laser-based instruments its accuracy is moderate, but it provides positions in a few seconds, even in sites with dense, vegetation-rich forest where obstructing vegetation hinders the use of laser instruments. In contrast to laser-based instruments, which have to be placed in spots where both the plot centre and object trees can be seen, PosTex can be used at the same time that data are recorded for the objects, such as diameters of trees.

Acknowledgements

The author gratefully acknowledge the cooperation with Haglöf Sweden AB in the development of the instrument, Sören Holm, Dept of Forest Resource Management, SLU, for numerous discussions and for providing the present algorithm for calculation of positions, and staff at the Section for Forest Remote Sensing at the Swedish University of Agricultural Sciences (SLU) for fruitful discussions.

References

Danskin, S., Bettinger, P., Jordan, T., and Cieszewski, C. 2009. A comparison of GPS performance in a southern hardwood forest: Exploring low-cost solutions for forestry applications. Southern Journal of Applied Forestry **33** (1): 9-16.

Hédl, R., Svátek, M., Dančák, M., Rodzay, A.W., Salleh A.B., M., and Kamariah, A.S. 2009. A new technique for inventory of permanent plots in tropical forests: A case study from lowland dipterocarp forest in Kuala Belalong, Brunei darussalam. Blumea: Journal of Plant Taxonomy and Plant Geography **54**(1-3): 124-130.

Holmgren, J., and Barth, A., Larsson, H., and Olsson, H. 2010. Prediction of stem attributes by combining airborne laser scanning and measurements from harvesting machinery. *In* Proceedings from the Silvilaser 2010 conference, September 14th - 17th, 2010. Freiburg, Germany. Manuscript.

Jonsson, B., Holm, S., and Kallur, H. 1992. A forest inventory method based on density-adapted circular plot size. Scandinavian Journal of Forest Research **7**(3): 405-421.

Kalliovirta, J., Laasasenaho, J., and Kangas, A. 2005. Evaluation of the Laser-relascope. Forest Ecology and Management **204** (2-3): 181-194.

Maltamo, M., Eerikäinen, K., Pitkänen, J., Hyyppä, J., and Vehmas, M. 2004. Estimation of timber volume and stem density based on scanning laser altimetry and expected tree size distribution functions. Remote Sensing of Environment **90**(3): 319-330.

Rizos, C., Grejner-Brzezinska, D., Toth, C., Dempster, A., Li, Y., Politi, N., Barnes, J., Sun, H., and Li, L. 2010. Hybrid positioning. A prototype system for navigation in GPS-challanged environments. GPS World **March 2010**: 42-47.

Wallerman, J., Bohlin, J., Fransson, J., and Lundberg, K. 2009. Forest data capture using optical 3D digital surface models from the C3 Technologies system *In* Proceedings from the ASPRs/MAPPS Conference 2009 San Antonio, Texas, US, November 16-19, 2009. http://www.asprs.org/publications/proceedings/sanantonio09/Wallerman.pdf. [accessed September 20, 2010]