Computers and Electronics in Agriculture 141 (2017) 109–117

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Tango in forests – An initial experience of the use of the new Google technology in connection with forest inventory tasks

Julián Tomaštík *, Šimon Saloň, Daniel Tunák, František Chudý, Miroslav Kardoš

Faculty of Forestry, Technical University in Zvolen, T.G. Masaryka 24, 96053 Zvolen, Slovakia

ARTICLE INFO

Article history:
Received 31 March 2017
Received in revised form 30 June 2017
Accepted 17 July 2017

Keywords:
Google Tango
Point cloud accuracy
Forest inventory
Simultaneous Localisation and Mapping (SLAM)
RGB-D (depth) sensors

ABSTRACT

This study focuses on the evaluation of the accuracy and feasibility of the use of the new Google Tango technology for outdoor measurements in forest inventory tasks. The technology uses RGB-D and inertial sensors and visual Simultaneous Localization and Mapping (SLAM) and combines them with compact mobile devices. Three circular test plots, established using forest inventory methodology, were used for the testing. Tree position references were measured using a total station; reference diameters at breast height (DBH) were acquired using callipers. Close-range photogrammetry and Field-Map measurements were conducted for comparison. Root mean square errors (RMSE) of the DBHs acquired using the Tango device were up to two centimetres. The positional accuracy was highly dependent on scanning methods. Two patterns of scanning were designed for the testing – "Spiral" and "Sun". RMSE of positions were over one metre for the Spiral pattern and 0.20 m for the Sun pattern. These results are comparable with some earlier reported results of other technologies, which provide 3D point clouds (photogrammetry, laser scanning). Field experiences related to the use of the hardware and software are also reported. With the further development of hardware and dedicated software, the Google Tango platform could provide a feasible, sufficiently accurate, and cost-effective solution for various measurements in forests where point clouds are applicable.

1. Introduction

Methods capable of providing 3D models and point clouds of environment are already in common use for various tasks. In forestry, laser scanning and photogrammetric methods (both airborne and terrestrial) provide valuable information usable in forest management. In addition to the data determined by "classical" inventory methods (diameters, heights of trees, etc.) the 3D reconstruction enables wider areas of application, from monitoring of short- and long-term changes in forests (Korpela, 2006; Hakala et al., 2015; Koreň et al., 2015) to the navigation of autonomous vehicles (Hellström et al., 2009; Hussein et al., 2015). In terms of terrestrial measurements, both laser scanning and photogrammetry can achieve accuracy close to one centimetre or within a few centimetres (e.g. Liang et al., 2016; Mikita et al., 2016). However, the relatively high price of the devices or the complicated methodology of measurements and processing often hinders a wider application at the level of field staff (e.g. field foresters).

In 2014, Google released the first developer versions of devices related to "Project Tango". The technology is mainly promoted as a platform for augmented reality, indoor navigation and measurements, but it could provide useful data for a much wider area of applications. The technology combines three core technologies (Google, 2017):

1. Depth perception – measurement of distances between the device and objects in its surroundings. Current devices use RGB-D (RGB + depth) sensors including infrared (IR) depth sensors, which use Structured Light or the Time of Flight principle (Sarbolandi et al., 2015). The depth perception provides point clouds of scanned objects in real time.
2. Motion tracking – Tango technology implements visual-inertial odometry to estimate a trajectory of the device, i.e. its position relative to where it started. Visual odometry is supplemented with inertial sensors, which provide data related to the device's acceleration and rotation. The combination of position and rotation in six degrees of freedom is referred as the device's "pose".
3. Area learning – the motion tracking alone is affected by "drift" originating in the application of inertial sensors, which increases with distance and time. Area learning is therefore used to record visual features of the area. If the device returns to an already recorded area and these features are recognised, drift corrections (also referred as "loop closures") can be

* Corresponding author.
E-mail address: tomastik@tuzvo.sk (J. Tomaštík).

http://dx.doi.org/10.1016/j.compag.2017.07.015

performed. This also allows localization of the device in a previously saved area.

Overall, the Tango technology currently combines known approaches of Simultaneous Localisation and Mapping (SLAM, e.g. Bailey and Durrant-Whyte, 2006; Engelhard et al., 2011) with the application of RGB-D sensors (stereo cameras are also supported, but not used currently). However, a compact design and user-friendly applications could bring the Tango technology to a wider range of users compared to other systems.

The main aim of the testing was to provide initial results of the accuracy of point clouds generated by the Tango technology. Forest inventory tasks were used as examples in this case. "Object-related" accuracy was tested using diameters of trees, relying mostly on the depth perception. To assess "area-related" accuracy, the positions of the trees were determined as well as their distances from the centre of the test plot. All three core technologies were applied. The creation and test of reliable scanning methodology were also part of the experiment.

2. Methodology

2.1. Test plots and reference measurements

2.1.1. Test plots

Three circular test plots (TP) were established in forests near Sielnica village, Slovakia (Fig. 1, coordinates ~48°38′N, 19°05′E).

The test plots differ in age and tree species composition as can be seen in Table 1.

The radius of the test plots was set at 12.62 m, resulting into 500 m^2 areas. This corresponds with methodology used in some national forest inventories (e.g. Šmelko and Merganič, 2008). The central points of the test plots were fixed using 10 × 10 × 5 cm survey marks fixed to the ground with a 0.5 m steel stake. Four other points were fixed using wooden stakes ~8 m from the central point, forming a cross. These were used as ground control points (GCPs) for georeferencing.

2.1.2. Total station and DBH measurements

Reference measurements were conducted in October and November 2016 even before the Tango device came into market. The positions of trees at a height of 1.3 m were determined using a Topcon 3000 total station. All measurements were conducted using a local coordinate system with its origin at the central point (X = 0, Y = 0) and the Y-axis lying north-south. The diameters at breast height (DBH) of the trees were measured in two perpendicular directions using a calliper, averaged and rounded to 0.5 cm. The place of the position and DBH measurements on the trees was marked using a 5 cm wide textile tape to avoid differences when using different methods of measurement.

2.2. Alternative data – Field-Map and close range photogrammetry

2.2.1. Field-Map

Two other methods were used to acquire data, which were then compared to the Tango device data. The Field-Map technology (www.fieldmap.cz) is used for national forest inventories and other projects in many countries. It is based on compass measurements in combination with electronically measured distances. The set applied consisted of the Impulse LR 200 laser range-finder, the LTI MapStar compass module, a field computer and a monopod. The set was used to measure the trees' positions, which were automatically saved into a database.

2.2.2. Close-range photogrammetry

The second method – close-range photogrammetry (CRP) applied with Structure from Motion (SfM) and Multi-View Stereopsis (MVS) techniques – was used in comparing the positional as well as DBH accuracy. The Canon EOS 5D Mark II camera with EF 16–35 mm f/2.8 L II USM lens was used on a tripod. The central point and GCPs were marked using yellow 20 × 30 cm PVC foil and two-metre high red-white pole. Pictures were taken using two circles. The outer circle had a radius approximately three metres wider than the test plot itself, i.e.~ 15.5 m. The distance between observation points was approximately 2.5 m; the pictures aimed inward approximately at the central point. Two pictures

Fig. 1. Experimental area and location of test plots.