Automatic clearcut obstacle identification using a time-of-flight camera

*H Lideskog[1] and M Karlberg[1]

[1] Department of Engineering Sciences and Mathematics, Luleå University of Technology, 97 187 Luleå, Sweden.
*Corresponding author: hakan.lideskog@ltu.se

Abstract

Site preparation by mounding or disc trenching preceding tree planting has in one form or another been practiced for centuries, mainly to increase seedling survival. Mounding is by many authors considered more economically and environmentally beneficial compared to disc trenching. However, mounding is particularly sensitive to clearcut obstacles since actuation can be performed over top of obstacles, resulting in poor quality or ineffectual site preparation. Hence, mounding efficiency is strongly dependent of the obstacle frequency and is inferior to disc trenching efficiency on clearcuts with high obstacle frequencies. One way to increase mounding efficiency (and mechanized planting productivity) is to automatically identify obstacles and thereby avoid them. Studies have shown that over 30% of failed mounding attempts are caused by encountered stumps. Thus, the objective of this paper was to develop and test a system for obstacle identification during mounding with focus on stump identification to enable obstacle avoidance. A time-of-flight camera was mounted in front of a forwarder to record information from a clearcut during operation, creating a virtual 3D point cloud scene. By post-processing this information, it was found that the distinct shapes of stumps (and to some extent also stones and slash) can be found automatically and be used for obstacle avoidance. Further research is needed to streamline the post-processing algorithms and to incorporate retrieval of clearcut data, post-processing and obstacle avoidance activities into a fully operational system.

Keywords: Detection, recognition, clearcut objects, remote sensing, automation, silviculture

Introduction

Site preparation preceding planting has been practiced for centuries, driven by the needs to drain the soil, increase nutrition availability, decrease competition from surrounding vegetation, reduce frost heaving, and to prevent predation by *Hylobius abietis* (Örlander et al. 1990, Sutton 1993, Petersson et al. 2005). Mounding as site preparation technique is considered more economically and environmentally beneficial compared to disc trenching (Uotila et al. 2010). Mounding, however, is particularly sensitive to clearcut obstacles since the procedure can be performed over top of e.g. stones and stumps several mounds in a row, resulting in poor site preparation. Similarly is the productivity of mechanical planting devices strongly dependent on obstacle frequency (Ersson et al. 2013). Hence, one way to increase productivity of mechanical planting devices and mounders is to automatically identify where obstacles are located on the clearcuts and avoid them. Stones, stumps and slash are particularly problematic for mounders and trenchers (Rantala et al. 2010, Larsson 2011). In Sweden, around 50% of all mounding attempts on easy to normal clearcuts fail because of encountered obstacles, and over 30% of failed attempts are caused by stumps (Larsson 2011). Thus, the main objective of this paper was to find and evaluate suitable sensing methods for obstacle identification during mounding with focus on stump identification, and a secondary objective was to find an approach to how post-processing of retrieved clearcut information could be carried out.

Materials and Methods

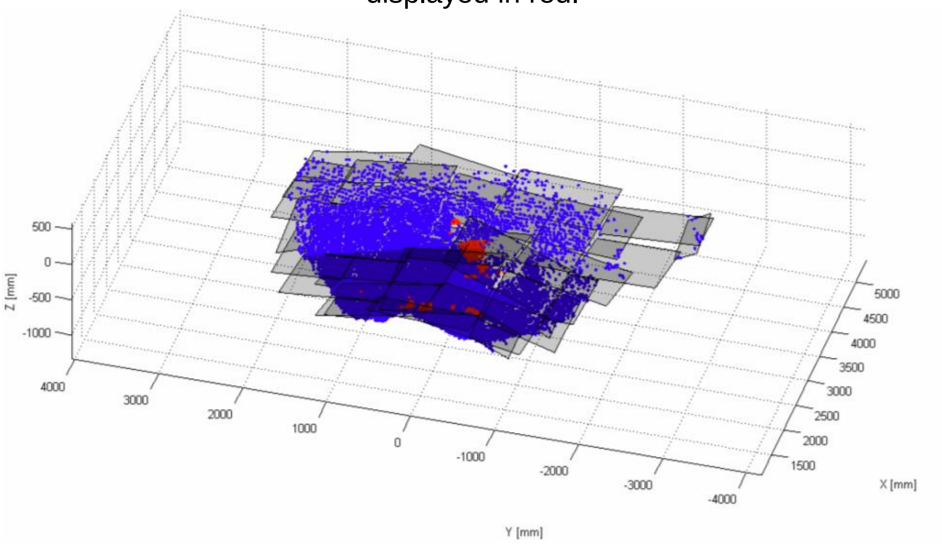
Apart from quantifiable properties such as density or moisture content that could be measured, the three dimensional (3D) shape of a stump is possible to distinguish by eyesight. Stumps usually consist of a flat rounded top with vertical sides, while no other similar object exists on clearcuts. This paper focus on identification of stumps because of their characteristic shape compared to slash and stones. Different techniques to retrieve information for stump identification was reviewed after which a time-of-flight (ToF) camera (Fotonic TOF-E70P RGBZ) for mapping the surroundings in 3D remotely was chosen. The

ToF camera sends electromagnetic energy toward the surroundings and measures the time it takes for it to return after reflection. The distance to points representing the scene is measured without any additional post-processing. The size of each depth matrix retrieved is 160x120 points with 16 bits depth per pixel.

The retrieval of clearcut information was conducted outside Umeå, Sweden on an easy classed clearcut with a snow cover of 1 cm at around 0ºC. The ToF camera was mounted in the front of a forwarder and directed at approximately a 45 degree angle so that information was retrieved at a maximum distance of 10 metres from the machine. Camera snapshots were taken at standstill and physical measurements from the camera to clearly visible obstacles were conducted to be able to compare the ToF camera identification with actual obstacle positions on the clearcut.

The raw data from the camera was represented by a 3D point cloud with x, y and z coordinates. 2D planes was placed into the 3D point cloud, fitted as mean planes to the pixels of the corresponding area, in order to compensate for ground surface changes, see Figure 1. The planes overlapped and the size was adjusted to optimize the obstacle identification. Residuals from the corresponding 2D mean plane was analysed and screened, where pixels with z values exceeding ~100 mm (above ground) was saved. Then, remaining pixels that was clustered with at least 5 pixels and comprising an area in the x-y plane of at least 5000 mm^2 were saved.

Figure 1. Point cloud with mean planes fitted in subsections. Deviating, clustered pixels are displayed in red.

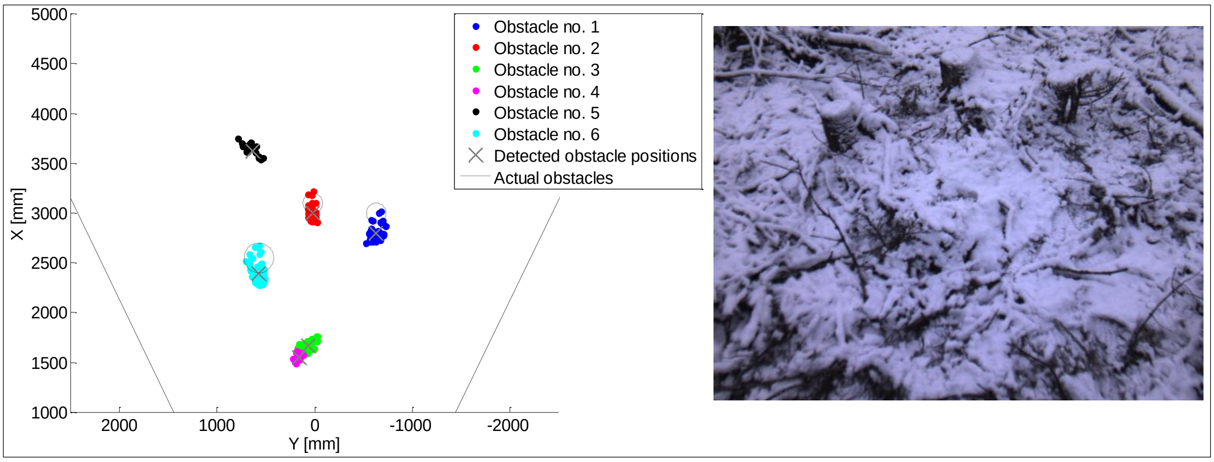


These remaining pixel clusters were considered as obstacles whereby the centre coordinate of the cluster was marked. A comparison with real measurements was conducted, and the accuracy was calculated.

Results and Conclusions

In Figure 2 an example of clustered and deviating pixels from the snapshots are depicted next to an RGB image of the same clearcut area. In this depicted area, three stump locations was measured and also found (obstacles 1, 2 and 6). In Figure 2 three other objects were identified, possibly protruding branches from slash piles which was not measured in the field (obstacles 3, 4 and 5).

Figure 2. Left: Identified obstacles in colour-coded pixels marked with 'X' and actual stumps depicted in dashed circles, seen normal to the x-y plane. Right: Angled RGB image over the same clearcut area.



The post-processing algorithm uses ~3 seconds on an office laptop @ 2.7 GHz to process each snapshot of around 5x5 metres. This gives a maximum advancement speed of 1.7 m/s, (not accounting for time delay of the actions taken by the machine given the identified obstacles) which is sufficient for many existing machines.

A comparison was made between the positions where the post-processing algorithm had found obstacles with the actual obstacle positions on the clearcut. On basis of six snapshots, the accuracy was around 90%. In order to have a reliable accuracy measure further data is needed e.g. from operation usage, alternating weather conditions, bright sunlight and darkness, different obstacle frequencies, etc. The results, nevertheless, showed that a ToF camera with sub-sequent post-processing can identify visible stumps with reasonable accuracy and that other protruding obstacles such as stones and slash piles can be found.

Further research is needed to streamline post-processing algorithms and to incorporate retrieval of clearcut data, post-processing and obstacle avoidance activities into a total system. If this setup is successfully applied on a mounder, failed mounds can be lowered by around 30%, assuming that 94% of all identified stumps can be avoided. Additional research is required to reduce failures caused by surface stones and slash. This further implies that mechanized planting directly subsequent to mounding is one step closer to realization.

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