SIMULATIONS OF MECHANIZED PLANTING – MODELLING TERRAIN AND CRANE-MOUNTED PLANTING DEVICES

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When reforesting clearcuts in southern Sweden, the Bracke Planter has shown to plant seedlings with better planting quality than operational manual tree planting (Ersson and Petersson 2011). Consequently, there is an increasing demand for intermittently advancing tree planting machines with crane-mounted planting devices in southern Sweden.

Nevertheless, regardless of using one- (Bracke Planter) or two-headed planting devices (M-Planter), today's average planting machine productivity is still too low (Rantala and Laine 2010, Ersson *et al.* 2011) for planting machines to cost-wise compete with manual tree planting in southern Sweden (Ersson 2010). There is, therefore, a need to develop new planting machines concepts that are significantly more productive on Nordic terrain, i.e. clearcuts on moraine soils with varying prevalences of stones and stumps where the slash has been harvested for bioenergy.

For over 40 years, simulation studies have proven useful for testing prospective forest machine concepts (e.g. Sjunnesson 1970), including different types of planting heads (Andersson *et al.* 1977). In particular, simulations studies can nowadays help to cost-efficiently evaluate new ideas before real world implementation (Jundén 2011). However, previous forest machine simulations simplified terrain characteristics like stumps, roots and stones to the extent that these models are too simplistic for meaningful planting machine simulations. For this reason, we have built several terrain, base machine and planting device models for use in discrete-event simulations to test potential solutions that realistically might increase Nordic planting machine productivity. These simulations were performed using a simulator programmed in Python on top of the SimPy discrete-event library (Jundén 2011).

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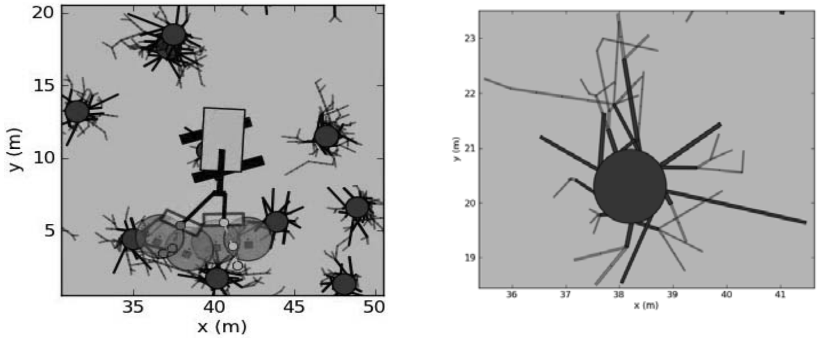

Figure 1. Visualization feature of the planting machine simulator (left) with a close-up view of a modelled stump comprising the root plate and roots over two cm in diameter (right).

TERRAIN MODELS

Presently, our terrain models encompass stumps, roots and underground stones. To delineate the clearcuts, we used Herlitz’s (1975) type stands for clearcutting. These type stands also provided the input data necessary for sizing and spatially allocating the stumps. To all stumps, we attached a root plate according to the deterministic data from Björkhem *et al.* (1975) and a stochastic root architecture inspired by Kalliokoski *et al.’s* (2010) root models.

As concluded already during the 1960s, it is the presence of non-visible, underground stones and boulders which makes mechanized reforestation on moraine soils so difficult (Bäckström 1978). To model this difficulty, we used parameter values from Andersson *et al.* (1977) to define incidences of stones and boulders (i.e. boulder quota or stoniness) and mean stone sizes. Then, we chose an exponential distribution to link stone frequency to stone diameter. In accordance with Eriksson and Holmgren (1996), our modelled stones are spherical in shape and are spatially allocated in a random manner.

BASE MACHINE MODELS

Today’s planting machines use excavators as base machines. If using standard components, it might be techno-economically feasible to add another arm to the excavator; thereby creating two- (Fig. 2) or four-headed planting machines where planting head interdependence is minimized. We hypothesized that the productivity of two-armed planting machines, compared to normal one-armed machines, might especially be higher on obstacle-rich terrain since one arm could be free to move while the other arm is busy working. Moreover, two-armed machines might particularly benefit from additional task automation. Preliminary results, however, show that this productivity increase might not be high enough to warrant further development of our two-armed planting machine concept.

Figure 2. The two-armed excavator base machine model.

PLANTING DEVICE MODELS

We modelled today's two most common crane-mounted planting devices, the one-headed Bracke Planter and the two-headed M-Planter. During simulation, the planting machine operator searches sequentially for microsites free from visible obstacles (stumps and main lateral roots). However, both devices can be impeded by underground roots or stones during mounding, and by stones during the planting phase. Striking obstacles with the M-Planter can result in delays for one or both heads.

FURTHER DEVELOPMENT

We are currently expanding the terrain models to include humus layers and surface boulders, on which new multi-headed planting device concepts (with two to four planting heads) with obstacle-avoiding capabilities are being tested. Those simulation results will provide guidance as to how future crane-mounted planting devices should behave and be designed in order to increase planting machine productivity.

Keywords: *terrain model, tree planting machine, boom-tip planting head, Discrete-event simulation, mounding, root architecture, SimPy*

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