HARVESTING TECHNICAL NOTE

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An On-board Machine Stability Information System

Summary

New Zealand's forest harvest is increasingly sourced from steep broken terrain, so providing accurate terrain information to harvest machine operators in real time has potential safety benefits, and may also improve machine productivity. A newly developed custom software application takes advantage of advances in LiDAR technology to produce a highly detailed and accurate digital terrain model of the harvest area in which the machine is operating. This development has been facilitated by improvements in GIS technology and reduction in the cost of mobile computing. The software application provides a real-time display of the position of the machine on digital terrain and slope models, displays important spatial information to the operator such as boundaries, roads and watercourses, projects the terrain profile to show topographical features ahead of the machine, and includes an operator warning system. The current application will be developed into a commercial version for industry testing by mid-2013.

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Introduction

Future Forests Research Limited and a local New Zealand engineering company, Trinder Engineers Ltd of Nelson, are making significant investments in the development of a winch-assisted felling and bunching machine for harvesting forests on steep terrain (Figure 1). The successful development and commercialisation of this machine will enable mechanical felling and bunching of wood on steeper terrain than has been possible in the past.

Figure 1: The beta prototype ClimbMAX Steep Slope Harvester operating in Nelson.

The main concerns with ground-based machines operating on slopes are the health and safety of the operator and the stability of tracked machines as their uses are extended on to steeper terrain. The Approved Code of Practice for Safety and Health in Forest Operations states "as a guide, subject to weather and ground conditions…feller bunchers and excavators…should not operate on slopes that exceed 40% (22^0)". The ClimbMAX steep slope harvester has been designed for much steeper terrain, and both the manufacturer and current practice show that the machine (in the right soil conditions) can handle 45^0 slopes. Potentially these health and safety and machine stability issues could be mitigated by providing operators of steep slope machines with real-time information about the terrain on which they are operating.

Development Concept

The idea of developing an on-board custom-designed software application to provide harvest machine operators with a decision support system (DSS) arose from the availability of better terrain information using Light Detection and Ranging (LiDAR) technology (Marshall, 2011).

The detail of the digital terrain models (DTM) derived from the LiDAR data reveals topographical features such as historic stream crossings and old roads, unstable soils and difficult side-slopes, that often cannot be seen on the ground, especially in forest terrain with slash and undergrowth (Krogstad and Schiess, 2004).

The main purpose of this system was to provide the operator of a steep slope harvester, such as the ClimbMAX, with real time information about the terrain not only that the machine is currently on but also the immediate terrain in front of the machine. The operator can then make an informed decision regarding where the machine can operate safely on

the landscape. In this way this type of decision support system can become an important hazard identification tool for the operator and improve the health and safety features of the machine.

It must be stressed that using LiDAR-derived topographical maps with the high level of topographic detail can lead to a false confidence in the data (Krogstad and Schiess 2004). A decision support tool such as this does not replace operator observation and skills in avoiding obstructions such as stumps and fallen trees which will not be featured on the DTM. The software will operate on an on-board computer mounted in the cab of the harvester. Information will be provided in both a graphical and text based format. This report details the development of the beta version of the software.

System Components

Input Data

The software will require a range of terrain information as well as the current location of the machine. In this version of software the terrain surfaces have to be pre-calculated, but in future the number of inputs could be reduced, with the software itself calculating these surfaces. The spatial information that can be imported into the application includes surfaces-based inputs, vector-based inputs and real-time position inputs.

Surfaces-Based Inputs:

A spatial parameter such as elevation is best represented as a raster (grid) data file where the earth surface is broken into squares (grids of x metres by x metres). The value stored represents some aspect of the earth surface, for example elevation (metres above sea level). The main two raster surfaces required by the application are:

1. Digital Elevation Model (DEM).

The digital elevation model (DEM) is the most important input surface, as all the other surfaces are derived from the DEM. The resolution, vertical and horizontal accuracy is critical to the success of this software application, and therefore the highest possible quality digital elevation model should be used. Although a minimum quality standard for the digital elevation model is yet to be determined, it is suggested that if possible the DEM used in this system should be derived using LiDAR (Light Detection and Range). A LiDAR point cloud collected from an aircraft can be converted into a DEM. First the LiDAR points that hit the ground are extracted and then rasterised into a grid; there are numerous LiDAR analysis software products that can perform this task.

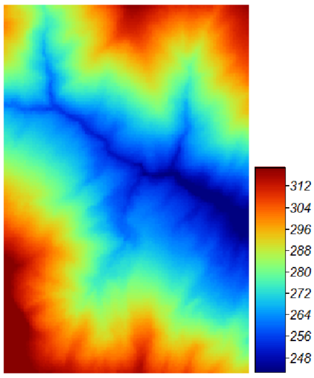

Figure 2: Example digital elevation model (DEM) generated from LiDAR (units in metres above sea level)

2. Slope Model Surface

Although not required by the application, a slope surface can be loaded. If this surface is loaded then the slope warning system is activated. This surface can be derived from a digital elevation model externally using a GIS software product such as ArcGIS[1], or for those without access to ArcGIS, a number of freely available GIS such as QGIS[2] and Saga[3] have the functionality to derive slope surfaces.

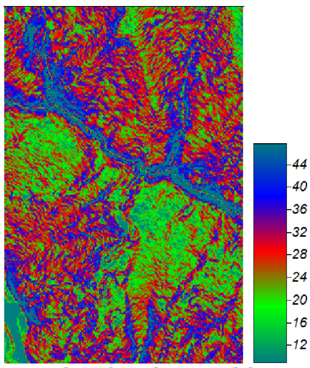

Figure 3: Example of a slope grid generated from LiDAR (units in degrees slope)

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1 www.esri.com

2 www.qgis.org

3 www.saga-gis.org

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The slope surface gives that maximum rate of change in any direction. The application also allows aerial photographs to be loaded as a base layer.

Vector Based Inputs:

Although not required by the application, users can load several different types of the vector layers (shape files) and display them on the map. The beta version allows the following layers to be loaded:

1. harvesting boundaries (polygon feature type)
2. stand boundaries (polygon feature type)
3. water courses (line feature type)
4. exclusion zones (polygon feature)
5. roads (line feature type).

The exclusion zone layer is used in the operator warning system. When the location of the machine is determined to be within an exclusion zone the operator is notified through the warning system.

Real-Time Position Information:

The application is capable of interfacing with a GPS unit, allowing the current location of the machine to be determined in real time. The accuracy of that location is affected by a number of factors including the GPS unit being used, the number of satellites available, local topography and forest canopy conditions. Once the application has been connected to the GPS, the track is displayed on the map canvas of the user interface. The track is stored as a shape file once tracking is turned off. The Beta application has been tested with the Garmin 60csx and Garmin 62c. The application requests the coordinates from the GPS at set time intervals with the location of the machine shown on the application map (Figure 4) in real time.

User Interface

Figure ~~Figure~~ 4 shows the beta user interface for the application. The user interface displays important information to the operator in both graphical form (i.e. maps and profile) and text form in real time. The user interface was developed for a touch screen platform with buttons large enough to make the application navigable using the operator's finger.

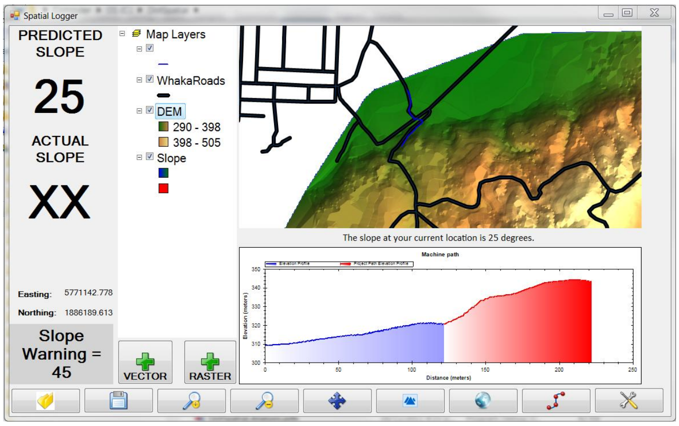

Figure 4: The screenshot of the beta version of the Spatial Logger application

The interface is made up of the following elements:

Information Panel

The information panel shows textual information on:

- Predicted Slope for the slope surface;
- Actual Slope (not implemented in beta version);
- Current Easting;
- Current Northing;
- Slope Warning.

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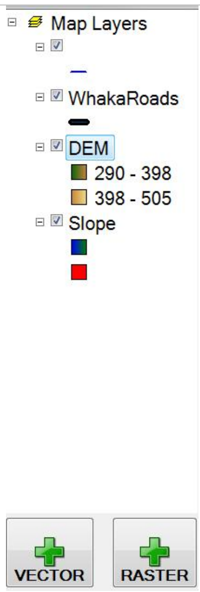
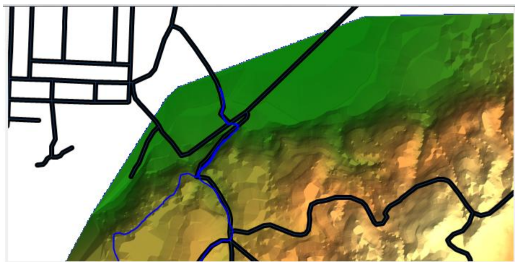
Spatial Legend Panel

The spatial legend panel shows the spatial layers that are currently loaded. This panel also contains the add vector and raster layer buttons. Right clicking on the layer opens a menu with a range of standard GIS functionality such as changing the symbology of the layer and zoom to layer extent.

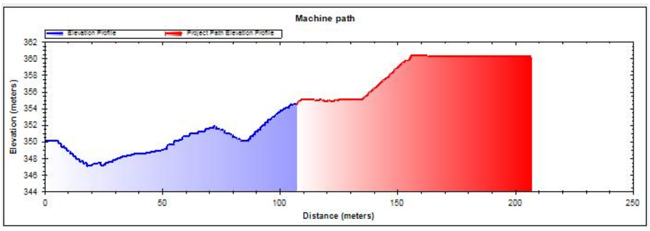


Map Canvas Panel



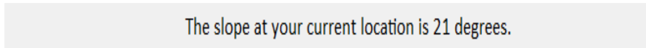
The map canvas displays the spatial information to the operator. The display order of these layers can be adjusted in the spatial legend panel.

Terrain Profile Panel



The terrain profile panel shows the profile graph of the past approximate 100 metres that the machine has travelled, as well as a projection of the next 100 metres using the machine's current bearing.

Scrolling Message Bar



The scrolling message bar shows messages to the operator. The colour of the scroll bar changes depending on the type of message; grey for normal, yellow for warning and red for danger. In the beta version the message bar shows messages detailing the current slope, and whether the machine has entered an exclusion zone.

The Tool Bar

The tool bar contains the buttons for all the important tools to operate the software.

Key Functionality

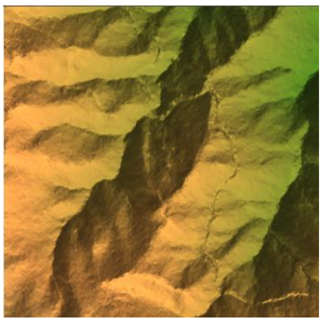
Zoom/Pan

The application contains the standard GIS zoom and pan functionality. This functionality will enable an operator to focus in on an area of interest.

Hill Shading

The application allows an operator to switch between a standard raster display of the digital elevation model and hill shading view. Figure 5 shows the extra topographic detail that is visible using hill shading.

Digital Elevation Model



Hill Shaded Digital Elevation Model

Figure 5: The effect of applying hill shading to digital elevation model.

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Profiling

The past and future terrain profile is calculated using the last 100 metres of the GPS track. The future profile is projected 100 metres ahead of the last recorded heading the machine was on. The combined profile is then displayed in the profile graph. The profile is updated with each request for new location from the GPS.

Warning Systems

The application warning system displays a textual warning using the scrolling message bar to the operator under the following conditions:

- The machine occupies a terrain with a slope which exceeds a predefined level.
- The machine has entered an exclusion zone as defined by the exclusion zone polygon layer.

As the functionality of this application grows the number of warnings will be extended.

Hardware and Software

The application was developed to run under the Windows operating system using the .Net 4 framework. The programming language C# was used. It relies heavily on an open source geographic information system library DotSpatial[4]. The DotSpatial library allows spatial data, analysis and mapping functionality to be incorporated in custom applications such as those described above.

The key components of the on-board hardware required to run this system would be a computer, GPS and possible a device that can measure actual machine slope. There are numerous platforms that could be used to run the software; the key desirable specifications would be:

- semi-ruggedised;
- 12v-24v power supply;
- touch screen;
- back light screen; and
- Windows Operating System.

[4] http://dotspatial.codeplex.com/

Future Development Plans

This report describes the development of a software application designed to operate on a timber harvesting machine to give an operator information in real time about the terrain on which the machine is operating.

The current beta version of the application provides a framework for implementing a range of potentially useful functionality to machine operators. The base functionality of the Beta release has been field tested using a road vehicle to test the real time GPS tracking and profile projection.

Although this application was designed for use in the winch-assisted steep slope harvester developed by Trinder Engineers Ltd, there is no reason why it could not be used in a wider range of forest harvesting equipment. Many additional functions could be added to the framework.

Over the next year this application will be further developed into a full release version. During this period further field testing will be carried out. The full version will be released for general use by June 2013.

References

Krogstad, F., and Schiess, P. (2004). The allure and pitfalls of using LiDAR topography in harvest and road design. Joint Conference of IUFRO 3.06: Forest Operations under Mountainous Conditions and the 12th International Mountain Logging Conference, June 13-16, 2004 Vancouver, B.C.

Marshall, H. (2011) The Potential of LiDAR in New Zealand Forest Engineering. Harvesting Technical Note HTN04-02, Future Forests Research Limited, Rotorua, New Zealand.