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A GIS-based simulation model for terrain tractability

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Abstract

The paper describes a concept for a GIS-based terrain tractability model and an optimal off-road routing. The general structure of the model is based on an object model which uses the cost surface technique to describe actual conditions in the terrain. The cost surface is a kind of mobility index and it is based, e.g., on vehicle, wheel, terrain, tree coverage, road and weather objects. Different cost surface alternatives can be generated according to changing information in objects. A regular raster analysis is used to determine alternative routes in different conditions. It has been shown that the adequate number of useful parameters can be found from national level digital maps to support off-road analyses.

Keywords: Terrain tractability; Terrain trafficability; Vehicle mobility; GIS; Routing

1. Introduction

Terrain trafficability means the ability of terrain to support the passage of vehicles [1]. Vehicle mobility in turn means the overall capability of a vehicle to move from place to place while retaining its ability to perform its primary mission [1]. Rounsevell [2] uses the term tractability to cover trafficability, mobility and their interaction (and workability). Tractability is an important part of logging, as haulage in the

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forest is an aggregate form of off-road transportation [3]. Harvesters also operate on the forest floor.

There are a lot of studies and articles in existence that deal with components related to tractability, but very few of them handle it as a comprehensive system which can be managed by computer techniques. Also, off-road routing for forestry purposes is in most cases not computerized, although existing digital maps and GPS systems could support such routing methods. Hintze [4,5], Rounsevell [2] and Earl [6], for example, have set out to predict soil strength with the aid of climatic data, and Davis and Laut [7], Matthies [8] and Saarilahti [9] have created expert systems to estimate terrain trafficability and soil strength. Birkel [10] also took into account the interaction between the terrain and the vehicle. This interaction is the template of his simulation models for terrain trafficability. GIS techniques have been applied to logging operations in several studies, e.g. [11–14], while Davis et al. [15] and Cuddy et al. [16] used them together with expert systems to predict environmental damage during army training exercises. Orava [17] used raster analysis to determine terrain trafficability as needed for planning military activities, but his application included only terrain parameters and did not contained the attributes of the vehicle, and therefore it could not be used to solve routing problems. Rummukainen and Ala-Ilomäki [18] presented a theoretical structure for an object-oriented GIS system for modelling terrain tractability conditions and routing problems in logging operations, but has not applied this technology in practice.

Traditionally information on terrain tractability and elements affecting it can be gathered by field measurements, and information on all the components which have an effect on terrain tractability can be handled using GIS techniques. This can reduce the need for field measurements, but the technique also has its limitations. Not all terrain tractability models are usable for this purpose, as they have to be compatible with the available GIS data. In other words, the input data for these models already have to be available in GIS form. On the other hand, there is little in the way of GIS data as such that can be used directly in these models, but relevant data sets can be modified by means of mathematical models. Both these mathematical models and the GIS data entail sources of error and there is always some inaccuracy and uncertainty in GIS applications of this kind.

The objective of this study was to formulate an object-based terrain tractability model and test it with public map data sets available in Finland. Terrain tractability can be described in terms of two elements, the terrain and the vehicle [3]. The focus of this paper was on the interaction between the two, which takes place through the contact surface of the wheel. Other factors which affect terrain tractability, off-road routing and forest operations include macro and micro-topography, obstacles, vegetation, soil moisture, snow and frost. The cost surface approach is effective for solving routing problems by means of GIS techniques, with the cost being assessed in money, time, preferences [19] and resistance forces. The proposal cost surface is offered as a mobility index.