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Analysis of vehicle platoon movement and speed-spacing relationships during military exercises

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Abstract

In this study a method that identifies off-road vehicle column movement was developed and evaluated. Previous studies have revealed that multiple vehicle passes produce detrimental soil and terrain impacts. Identifying the frequency and location of this type of multi-pass impact during military maneuvers is difficult. This method will aid in the assessment of environmental impacts of off-road military vehicles by allowing land managers to characterize vehicle movement patterns, especially column movement, at military training installations during maneuvers. GPS units mounted on military vehicles collected on and off-road tracking data during a reconnaissance maneuver at Fort Lewis Military Installation, Washington. A set of data utilizing a Stryker platoon of four vehicles was used to evaluate this method. The GPS coordinates, speed, and direction of travel of each vehicle was collected at each second. A criteria to identify platoon column movement was developed based on vehicle proximity, speed and direction of travel. The results of this study show that the method can correctly identify off-road column movement for the purpose of evaluating the multi-pass impacts on the terrain. In addition, using this approach the vehicle movement patterns associated with on- and off-road platoon movement (i.e. vehicle speeds and spacing) were evaluated.

Keywords: Platoon; Multi-pass; Column; Military vehicle; GPS; GIS

1. Introduction

Off-road military vehicles can disturb soil and cause damage to the terrain in a number of ways. Webb and Wilshire (1983) found that off-road vehicle movement can cause soil compaction, rutting, and vegetation removal. Off-road military vehicles decrease vegetative cover, which can increase soil erosion. Land managers at military bases must manage the military lands in a way that sustains the land for future use and training maneuvers. Land managers at these military bases use a standard method known as the U.S. Army Training and Testing Area Carrying Capacity (ATTACC) model to predict the amount of soil and vegetative damage that will be caused by the military vehicles during a maneuver (U.S. AEC., 1999). The purpose of utilizing the ATTACC model is to minimize non-sustainable erosion and accelerated degradation of the land.

The amount of disturbance caused by each vehicle is a function of vehicle wheel and track dimensions, soil conditions, type and amount of vegetative cover present, and vehicle dynamic properties (velocity and turning radius). The amount of damage is also a function of vehicle platoon movement patterns (i.e. multi-pass). Many studies have shown that repeated traffic (column movement) causes more severe damage to the terrain than dispersed traffic. Pearson et al. (1990) found that the soil disturbance caused by vehicle traffic was a function of the characteristics, timing, and intensity of the traffic, thus it was maneuver specific. Braunack (1986) reported that additional passes of

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the tracked vehicle resulted in increased cone penetrometer resistance and increased rut depths. A study by Goran et al. (1983) observed military vehicle impacts at 12 different training installations. They found that environmental impacts and magnitude of disturbances vary between installations, but in general, single-pass traffic produces minor damage and only light surface disruption with minimal vegetation loss, while frequent and repeated use of an area resulted in degradation of flora, fauna, and soils. Grantham et al. (2001) and Abele et al. (1984) evaluated the effects of multiple straight passes of tracked vehicles on the environment. Grantham et al. (2001) found that an increase in vehicle passes resulted in significant damage to vertical vegetation structure, increased erosion, and decreased soil surface stability. Abele et al. (1984) found that multiple passes with Rolligon vehicles caused disturbance that lasted longer than light tracked vehicles. This was likely due to the high tire pressure and wider area of disturbance. Fuchs et al. (2003) conducted a study to determine the amount of sediment loss from runoff and the effects on surface plant cover and surface microtopography as a result of tracked vehicles maneuvering in a desert military training environment. They studied both single and triple passes with the tracked vehicles under both wet and dry seasonal conditions. It was found that the intense rainfall conditions under the wet seasonal conditions generated significantly greater sediment losses for the triple passes. Kane et al. (2013) developed multi-pass terrain impact coefficients for a variety of vehicles operating at different turning conditions. Multipass coefficients increased with heavy, tracked vehicles operating in turns.

Studies by Ayers et al. (2000) and Haugen et al. (2000) evaluated the use of GPS for tracking vehicles and determining their dynamic properties such as velocity, turning radius, and acceleration. Similar methods were incorporated in this study while tracking maneuvers conducted at Fort Lewis Military Installation. Ayers et al. (2004) tested a variety of GPS and DGPS receivers to evaluate the feasibility of using GPS to determine vehicle column movement (multi-pass vs. multi-track).

Vehicle platoon (and column) movements and geometries, and speed-spacing relationships have been investigated by several researchers. Dafflon et al. (2013) developed a local platoon control approach with obstacle avoidance. El-Zahier et al. (2012) explored multi-configuration vehicle platoon geometries analyzing follower vehicle positioning. Factors affecting multi-vehicle convoy mobility were addressed by Gray and Vantsevich (2015). Analysis of leader tracking and speed-spacing relationships are important for motion planning for determining column movement pattern (or convoy behavior) (Beck, 2016). By utilizing operator controlled speed-spacing relationships, machine learning techniques can be used to define and implement vehicle separation distances (intervehicle spacing). These behaviors can be integrated into drive by wire autonomous convoys (Beck, 2016).

Kim and Park (2000) used ArcView to recognize military vehicle formations during tactical situations. The authors developed algorithms in ArcView to recognize six types of formations. Their method was developed for use by commanders in managing platoon formations. For this study a similar method was developed and evaluated to recognize column movement for the assessment of environmental impacts. A reliable and accurate method to identify vehicle column movement would aid in identifying multi-pass traffic (column movement), which is believed to have negative effects on the environment. The vehicle movement patterns (i.e. how the vehicles are moving with respect to each other) influence the amount of damage done to the terrain. A maneuver that involves significant off-road column movement would have a high event severity factor. A method that identifies the frequency vehicles are traveling in a platoon and the type of platoon movement would aid in evaluating the event severity factors for different types of maneuvers in the ATTACC model. The method developed in this study will be useful in characterizing how frequently column movement is occurring during training maneuvers, and whether or not this should be a concern to land managers.

More detailed analysis of vehicle movement patterns during maneuvers would greatly benefit the training area land managers. A GIS method to identify vehicle column movement would greatly benefit training area land managers, because it is known that this type of vehicle movement pattern causes the most severe type of damage to the soil and vegetation. The method would also identify areas where this type of movement has occurred. The identified areas could then be visually inspected and rehabilitated if needed.

The objective of this project was to develop and evaluate a method to identify off-road vehicle column movement using GPS tracking data. Vehicle column movement is a platoon movement pattern where multi-pass traffic is occurring. The vehicles are said to be traveling in a ***platoon*** when all four vehicles in the troop are traveling at a similar speed, in a similar direction, and are within a specified distance of each other. The vehicles are considered to be traveling in a ***column*** when all four vehicles are traveling in a platoon and are one behind the other, following the same track. To identify column movement, it is necessary to identify movements where the support vehicles are following the same path as the platoon leader (multi-pass traffic). Once the method has been developed, on and off-road column was analyzed to evaluate vehicle movement patterns. Just because column movement (multi-pass) is occurring, it does not mean the vehicle wheels are following in the same track (multi-track), it just indicates that multi-track traffic is more likely.

2. GPS tracking of military vehicle maneuvers

A vehicle tracking study was conducted at Fort Lewis Military Installation, Washington from October 17, 2005 through October 24, 2005. Nineteen Strykers were tracked for up to eight days using GPS units during a military