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The Next Generation NATO Reference mobility model development ☆

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Abstract

The NATO Reference Mobility Model (NRMM) is a simulation tool aimed at predicting the capability of a vehicle to move over specified terrain conditions. NRMM was developed and validated by the U.S. Army Tank Automotive Research, Development, and Engineering Center (TARDEC) and Engineer Research and Development Center (ERDC) in the 1960s and '70s, and has been revised and updated through the years, resulting in the most recent version, NRMM v2.8.2b. It was originally used to facilitate comparison between vehicle design candidates by assessing the mobility of existing vehicles under specific terrain scenarios, but has subsequently and most recently found expanded use in support of complex decision analyses associated with vehicle acquisition and operational planning support. This paper summarizes recent efforts initiated under a NATO Exploratory Team (ET) and its follow-on Research Task Group (RTG) to upgrade this key modeling and simulation tool and the planned path forward toward implementing the recommendations of that team.

Keywords: NATO; NRMM; Mobility model; Operational planning; Multibody dynamics; Intelligent vehicles; Vehicle-terrain interaction; Stochastics; Verification and validation; Geographic information systems

Contents

Abbreviations: AI, artificial intelligence; AVT, Applied Vehicle Technology; CM, Configuration Management; ET, Exploratory Team; GIS, Geographic Information Systems; HPC, High Performance Computing; MBD, Multi-Body Dynamics; M&S, Modeling and Simulation; NRMM, NATO Reference Mobility Model; NG-NRMM, Next Generation NRMM; NTU, iNdividual Terrain Unit; OBSDP, collectively, NRMM's legacy and current OBStacle crossing Development Programs; RTG, Research Task Group; STANAG, NATO STANdardization AGreement; STANREC, NATO STANdardization RECommendation; VEHDYN, collectively, NRMM's legacy and current VEHicle DYNamics programs; VI, Vehicle intelligence; VTI, Vehicle Terrain Interaction

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1. Introduction

Although NRMM has proven to be of great practical utility to the NATO forces, it has several inherent limitations, particularly when compared to modern multibody dynamic (MBD) modeling and simulation (M&S) capabilities. Many of the off-road mobility algorithms are based on empirical observations, and therefore extrapolation outside of test conditions is impossible. It is heavily dependent on Cone Index (CI) based soil strength measurements and steady state analysis of various other mobility performance metrics. Turning performance and lateral vehicle dynamics are not considered. Vehicle dynamic effects are limited to pitch plane for ride quality and all obstacle crossing models were forced to conform to an equivalent walking beam formulation for tracked vehicle suspensions systems. Due to its age and intermittent ad hoc development history and reliance on empirical performance data collected at the vehicle level, NRMM's software and data architectures do not easily support evolutionary development in terramechanics or vehicle terrain interaction (VTI) models such as the fundamental extension to 3D models that support vehicle turning mechanics and more complete obstacle crossing metrics. The means for expansion of the analysis techniques to include intelligent vehicles, custom mobility metrics, stochastic knowledge of terrain, and metrics for urban areas are additional pressing needs for a Next Generation NRMM (NG-NRMM).

While an effort to update NRMM was initiated in 2002 (McClelland) resulting in some specific advances summarized in a 2011 report (Jones et al.), this effort did not lay the organizational and architectural foundations required for sustained growth and evolution of the model in a way that opens the model architecture up to multi-scale mechanics solutions, continuous future improvement, non-preferential use of commercial software capabilities and also promotes inclusion of all NATO nations preferred mobility modeling solutions. Thus in 2014, a NATO Applied Vehicle Technology (AVT) Exploratory Team 148 (ET-148) (Dasch and Jayakumar, 2016) was formed to consider the development of a truly Next-Generation NRMM (NG-NRMM). ET-148 identified seven themes with the following goals:

(1) *Requirements:* Capture, consolidate, and summarize desired capabilities (Priddy and Bradbury, 2016).
(2) *Methodologies:* Develop a plan for deriving a ground vehicle mobility modeling and simulation (M&S) architectural specification for the NG-NRMM (McCullough, 2016).
(3) *Stochastics:* Describe a framework for a stochastic approach for vehicle mobility prediction over large regions for integration into a NG-NRMM (Iagnemma and Gonzalez, 2016).
(4) *Intelligent vehicles:* Define a NG-NRMM approach and requirements for mobility assessment for intelligent vehicles (Jain, 2016a,b).
(5) *Tool choices:* Identify the state of the art for NG-NRMM enabling simulation technologies as claimed by the technical community of software developers, suppliers, and user nations (Hodges, 2016).
(6) *Input data and output metrics:* To define the input/output data requirements that will inform the Next-Generation NRMM tool development/selection processes and tool recommendations for advanced mapping tools including the means for analysis of remotely sensed Geographical Information System (GIS) data (Wojtysiak, 2016).
(7) *Verification and Validation (V&V):* Develop a plan to provide benchmarks for conducting successful simulation tool V&V with respect to the NG-NRMM specification (Letherwood, 2016).

The NATO ET-148 committee consisted of 38 persons from 13 nations (Canada, Czech Republic, Denmark, Estonia, Germany, Italy, Poland, Romania, Slovakia, Spain, Turkey, United Kingdom, and United States) each of whom participated in the detailed research and development goals through membership on one or more of the teams formed to focus on each of the seven goals.

2. NRMM overview

NRMM is one of the first and few enduring models that comprehensively and realistically quantifies ground vehicle mobility based on terrain accessibility and maximum attainable speeds for comparative force projection assessments of

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