Trafficability Analysis Engine

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BACKGROUND AND MOTIVATION

Detailed, thorough trafficability analysis helps tactical decision makers determine likely enemy avenues of approach and possible friendly avenues of approach. Trafficability is a measure of how easily vehicles can drive through a particular piece of terrain. Manual processing is time-consuming and coarse. The output of the manual terrain analysis process often takes days and results in a product known as the Modified Combined Obstacles Overlay (MCOO). The MCOO classifies terrain into one of three, coarse categories: "go," "slow-go," and "no-go." Many factors that affect trafficability are not considered in the manual process.

The purpose of this research was to build a trafficability analysis engine that had the following attributes:

- Predicts trafficability as a floating-point number between 0 (the cliffs at Pont du Hoc) and 1 (the salt flats of Utah).
- Considers the capabilities of individual vehicle types (e.g., M113A3), vice generalizations (e.g., tracked), with respect to slope, vegetation, and soil conditions.
- Degrades gracefully as terrain data are missing.
- Reflects the confidence in the predicted outcome.
- Performs most of the difficult computation at a server and just sends the results of the analysis to the user.
- Allows a skilled user to modify the rules by which trafficability is determined.
- Reflects the effects of weather on trafficability.

The proof-of-concept system takes into account geographic factors including location, vehicle type, off-limits terrain, water, weather, soil, land use, topography, vegetation, and roads. In addition, the system was designed to be user friendly. The goal of this work has been to build an architecture in which various trafficability modules could be inserted. If a developer has a better soil moisture evaporation module, that could easily replace the one used in this prototype.

DESIGN AND IMPLEMENTATION

The design of this system is modular, as shown in Figure 1. The overall architecture involves a terrain server above the Army division level. The user (at lower echelon units) selects an area of interest and sends that information to the trafficability engine's server. The trafficability engine's server fetches terrain data (in the form of ASCII files in the case of this proof-of-concept system) from the terrain server(s). If terrain products are unavailable for the area of interest, the engine's server may ask the user for general information about the area. For instance, the engine may query the server for recent precipitation information, such as "dry," "wet," or "very wet." Once the trafficability analysis engine has all available information, the geography modules begin processing the data.

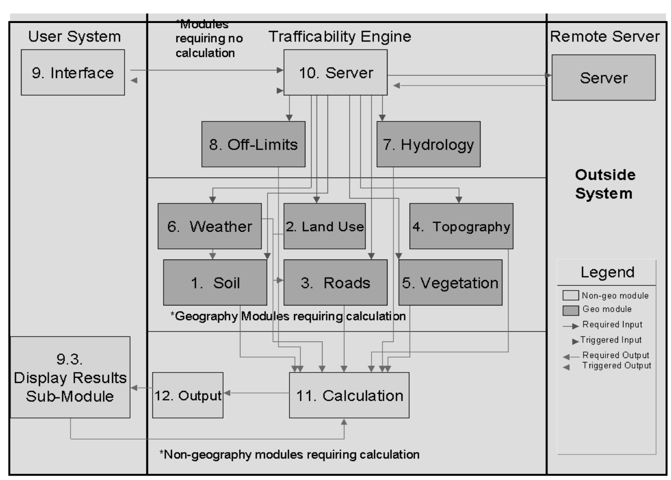

Figure 1: Architecture of the Trafficability Engine

Geography Modules

Each geography module looks at different aspects of trafficability, such as weather, topology, vegetation, land use, and soil. Some modules' output serves as input to other modules. For instance, the results of the weather module are inputs to the soil and road modules. While the actual implementation is a two-dimensional array of Java objects, one can think of each of these geography modules as filling in an "overlay," as shown in Figure 2. Each cell of an overlay includes two elements: an estimate of the trafficability of that point on the ground and a confidence in that estimate.

An advantage of the modular design is that each module can use the most appropriate mechanism to compute trafficability. The Topography Module takes the floating-point slope value at each point and compares it to the known maximum slope capability of each specific vehicle, using a formula found in FM 5-33 [1]. The result of this calculation is an estimate of trafficability as a floating-point number between 0 and 1. The Soil and Vegetation Modules query a lookup table and determine the characteristic of each different type of soil or vegetation at that specific point. That value is then used in further computations to determine trafficability based on soil or vegetation, respectively. Each module fills in values on its respective overlay, which in turn are used to perform the final trafficability computation.

Trafficability Computation

Once each module has performed its analysis, the calculation module uses an expert system to give each node an overall trafficability rating. Though often slower than compiled code, an expert system was chose for the final analysis for two reasons:

- Expert systems provide a means of explaining to the human user how a decision was reached, and
- Human experts could modify the expert system without modifying or recompiling the base program.

The expert system shell used is JESS, the Java Expert System Shell, developed at Sandia National Laboratory [2]. While the JESS project began as a port of CLIPS [3] to Java, JESS is now richer than CLIPS in many ways. The current expert system uses only crisp rules; however, support for fuzzy logic, using Matlab .fis files [4], has been implanted in Java and linked to the program.

The manner in which the expert system combines the various ratings of confidence is purely arithmetic at this point. A weighted average of the eight "overlay" means is used. If an overlay is missing day (or the overlay is missing entirely), this has a large, negative impact on confidence. In the proof-of-concept system, all overlays are weighted equally. For future work, experiments will be conducted to determine which overlays have the greatest impact on trafficability in various geographic regions. For instance in Kansas, most of which is very flat, missing the topography overlay, might have less effect on trafficability than missing the soils overlay. This "sensitivity analysis" will help determine the weights uses in the weight-average computation.

The use of a "mean" (i.e., the estimate of trafficability) and "standard deviation" (i.e., measure of confidence) allows the system to degrade gracefully when data are missing. The Engineer Research and Development Center's Topographic Engineering Center (TEC), for whom this work is being done, has indicated that in the future terrain products will come tagged with confidence in the data and that that confidence might not be uniform across the product. This technique also allows the system to adapt easily to non-homogenous input (i.e., input files in which the level of fidelity is not uniform across the whole file). As a result, the system provides the user with useful information even when some data is missing or a "best guess."

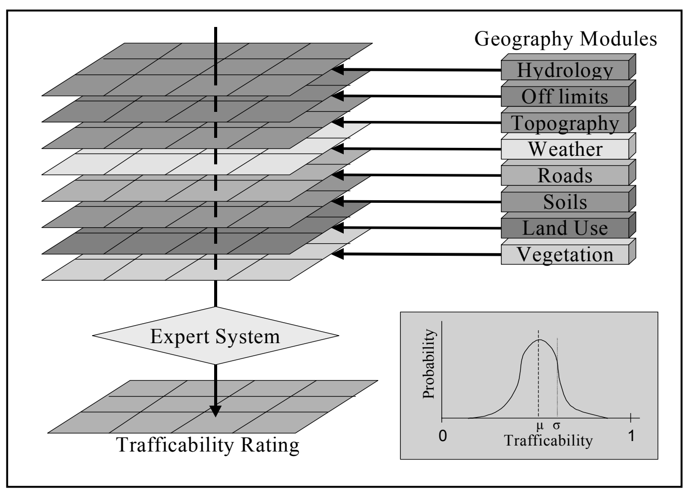

Figure 2: The output from the various Geography

Results

In the proof-of-concept system, the outcome of the analysis is a matrix rating the trafficability of each point in the area of interest. The highest resolution input file determines the size of this matrix. If the area is 10km x 10km with 10m resolution, the final matrix would be 1000 x 1000 cells. Clearly the speed of computing trafficability is based on the size of each of the overlays and is O(n), where n is the number of cells in the final matrix. (Since the area does not have to be square, complexity cannot be based on just height or just width of the area.) The slowest execution of the computation is the use of the expert system for each cell in the final matrix. Even though the computations in each of geographic modules need to be more fully developed and refined, the output of this system is very close to the results gained through detailed, manual analysis. Since the manual computation takes days, the fact that this system takes less than three minutes is a major improvement. Future work on this systems includes improving the fidelity of the geography modules, parallelizing the computation, and finding a better way to display the results of the computation.

[1] U.S. Army, *Field Manual 5-33: Terrain Analysis*. Washington, D.C.: Headquarters, Department of the Army, 1990.
[2] E. Friedman, "JESS: The Rule Engine for the Java Platform," at http://herzberg.ca.sandia.gov/jess/, 20 May 02 2002.
[3] J. Giarratano and G. Riley, *Expert Systems: Principles and Programming*. Boston, MA: PWS-Kent Publishing Co., 1989.
[4] MathWorks, "MATLAB," at http://www.mathworks.com/products/, 20 May 02 2002.