Battlespace Terrain Reasoning and Awareness

Author

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Abstract

Terrain and weather effects represent a fundamental, enabling piece of battlefield information supporting situation awareness and the decision making processes within Command and Control (C2). These effects can both enhance and constrain force tactics and behaviors, platform performance (ground and air), system performance (e.g., sensors) and the soldier. The Battlespace Terrain Reasoning and Awareness (BTRA) program focuses on the development of software analytics designed to create information and knowledge products that capture integrated terrain and weather effects and develop predictive decision tools to exploit those products. Through a Memorandum of Agreement between the U.S. Army Engineer Research and Development Center and the National Geospatial-Intelligence Agency, the Topographic Engineering Center is developing and delivering BTRA software components built upon ArcObjects to meet Analytical requirements of the Commercial Joint Mapping Toolkit Version (C/JMTK) 9. This paper will focus on the development and functionality of the BTRA Spiral 2 engines that will be transitioned to C/JMTK.

Body

BTRA's primary objective is to empower Commanders, Soldiers and systems with actionable information that allows them to understand and incorporate the effects and impacts of terrain and weather on their functional responsibilities and processes (e.g. Intelligence Preparation of the Battlefield, Command and Control (C2) planning, red and blue Course of Action (COA) Analysis. These effects can both enhance or constrain force tactics and behaviors, platform performance (ground and air), system performance (e.g. sensors) and the soldier. BTRA's focus is: 1) the development of software analytics designed to create actionable information and knowledge products that capture integrated terrain and weather effects and 2) develop interactive, predictive decision tools that can be embedded within other Command, Control, Communications, and Computers Intelligence Surveillance, and Reconnaissance (C4ISR) systems.

Military transformation is highly dependent on a common, shared understanding predicated upon both existing, shared battlefield information and predictive estimates to achieve C4ISR agility. Extension of this doctrinal tenet to geospatial information, argues that terrain and weather information should be founded in common analytics, employ common representation and employ common predictive tools. For these reasons, BTRA technology has sought the widest possible transition base to C4ISR systems through National Geospatial-Intelligence Agency's (NGA's) C/JMTK.

Mission / Overview

BTRA's developmental approach is a response to the objective of "tearing down stove-pipes" within C4ISR. Extensive requirements analysis of the Army's Future Combat System (FCS) and Distributed Common Ground Systems – Army (DCGS-A) has resulted in the identification and derivation of more than 200 C2 and nearly 175 intelligence - based requirements having significant geospatial relevance. Additional analysis, found additional requirements in the U.S. Marine Corp Topographic Production Capability (TPC) and within Time Critical Targeting elements of the U.S. Air Force Theater Battle Management Core Systems (TBMCS). All of these Programs of Record are approved to use capabilities from C/JMTK.

Capabilities

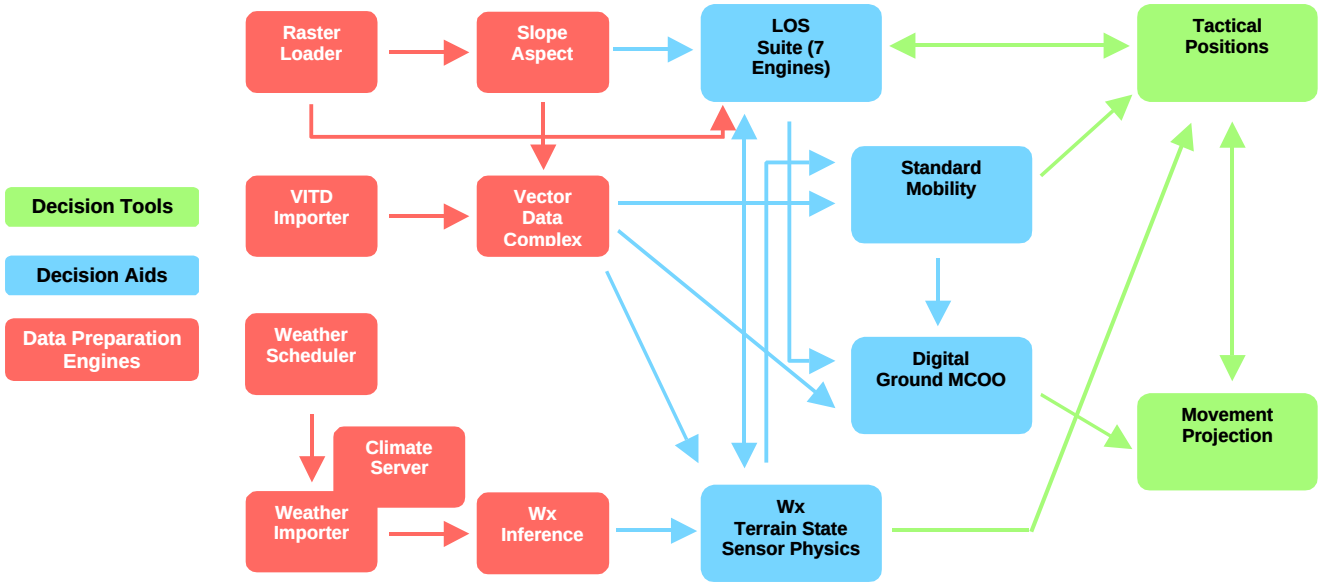
BTRA capabilities represent our best attempt to address the broadest set of requirements. BTRA focus is on the development of six (6) information generation components and four (4) decision tools addressing terrain and weather effects. Each of these components utilizes terrain feature data, digital elevation models, current and forecasted weather and information regarding tactics, techniques and system performance. BTRA analytic components generate information products addressing:

- Suite of Line-of Sight capabilities that incorporate weather attenuation
- Cover, Concealment and Obstacles
- Advanced mobility analysis
- Spatial Operational Compartment and Positions of Advantage (Key Terrain) for specific force types/tasks
- High fidelity weather/terrain effects of mobility and signature physics
- Digital ground and air Modified Combined Obstacle Overlays (MCOOs) supporting interactive route analysis

BTRA decision tools operate on BTRA information products, not the original data. These tools support:

- Predictive multi-criteria, multi-objective maneuver and logistical route analysis for ground forces
- Situation assessment
- Predictive threat assessment

The custom-developed engines augment C/JMTK to meet the requirements not totally met by the commercial package. BTRA Version 2.0 can be decomposed into 14 unique engines that fall into one of three classes: data preparation, decision aids, and decision tools. The reference implementation user interfaces are developed in Visual Basic and the engines are developed in C++. Standard interaction between the user interface and the engine is accomplished through the use of XML. All the BTRA engines will work directly with C/JMTK except the Complex Generator and the Ground and Dismounted Maneuver Network Generators which require Arc/Info Workstation. The engines have also been developed to work on both the Windows and UNIX platforms, but reference user interfaces are only provided for the Windows Platform. A test harness and input XML files are provided for the UNIX platform for integration testing.

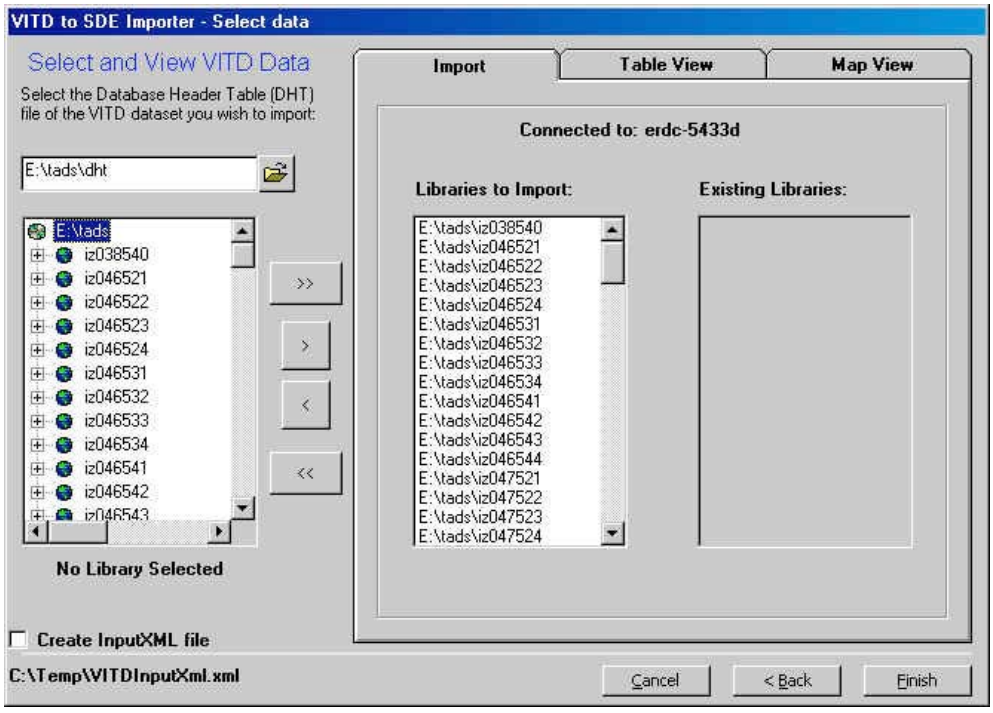


BTRA Component Engine Breakdown

Data Preparation Engines:

Vector Interim Terrain Data (VITD) Importer

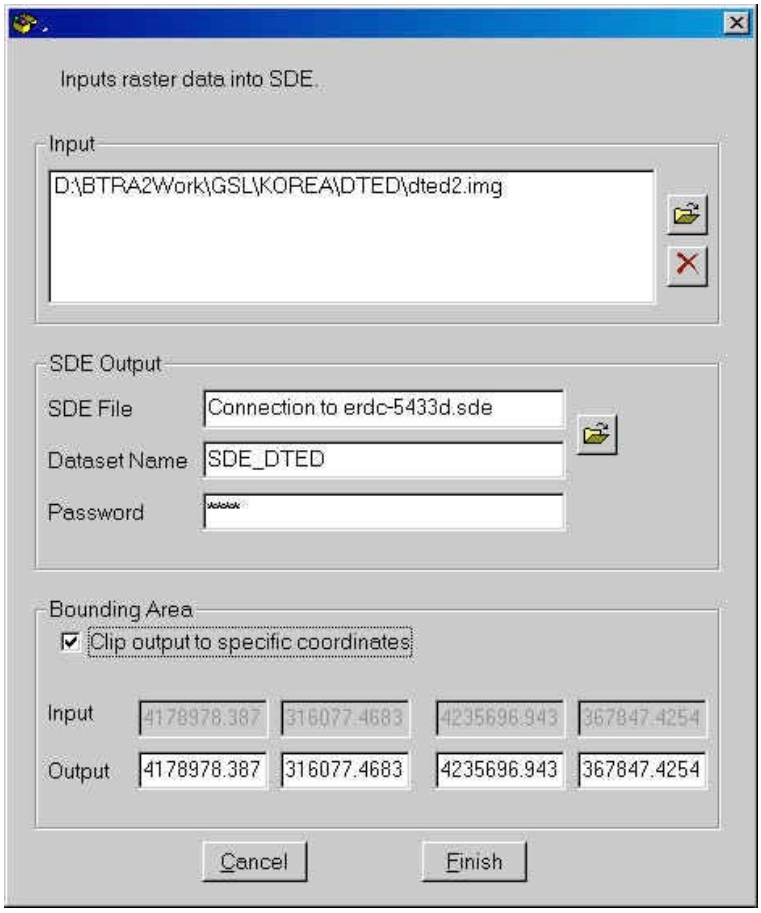
The BTRA VITD importer serves as a base data product for all geospatial tools and analysis and allows National Geospatial-Intelligence Agency (NGA) data to be imported into a Spatial Database Engine (SDE) database in a known format for use by BTRA tools. Multiple data sets can be stored to the SDE database.



VITD Importer User Interface

Raster Loader

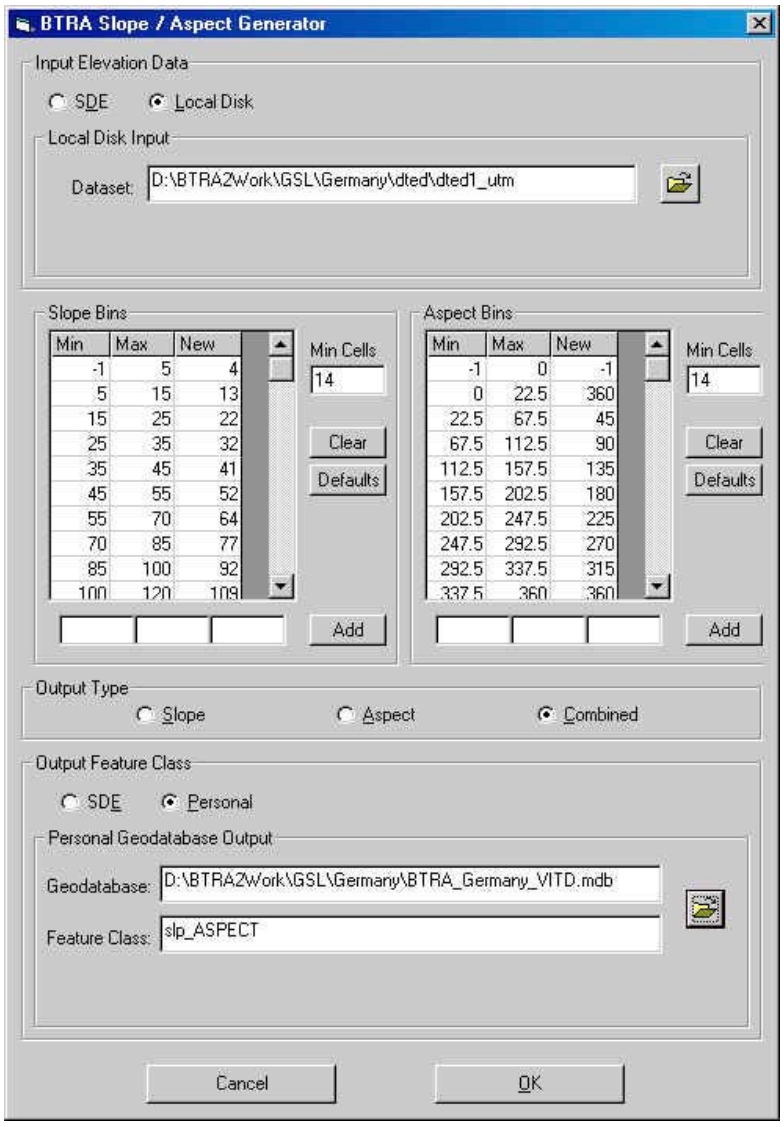
The BTRA raster loader imports elevation data in Erdas IMAGINE, ESRI Grid or NGA Digital Terrain Elevation Data format, into a SDE server and database specified by the user as an ESRI raster known format used by BTRA applications. Multiple data sets can be stitched together, and/or smaller areas can be stored to SDE. The Raster Elevation Data set is projected into the correct local Universal Transverse Mercator zone for BTRA applications requiring meters.



Raster Loader User Interface

Slope/Aspect Generator

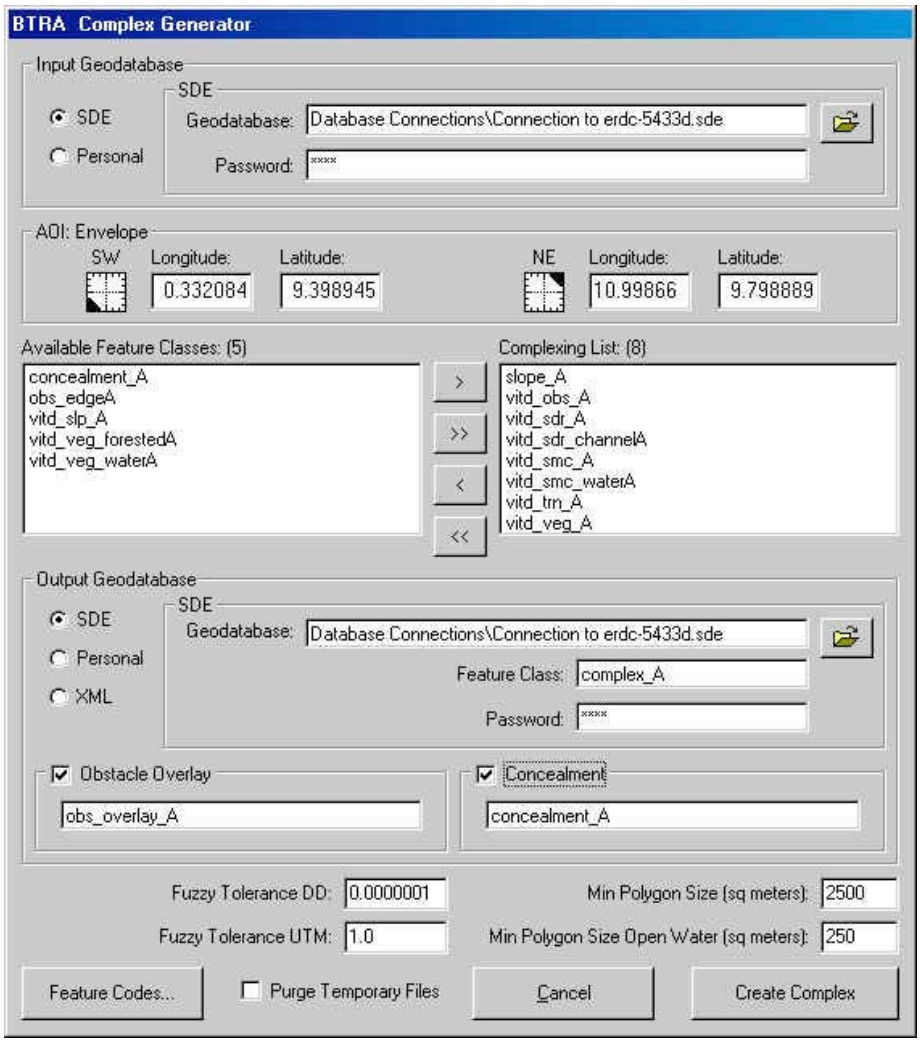
The BTRA Slope/Aspect Generator (SAG) creates a slope, aspect, or combined slope/aspect polygon layer from an elevation dataset. The product is cleaned and grouped into areas with similar slope or aspect that meets a minimum size criterion then is converted into SDE or Personal Geodatabase as a polygonal Slope_Aspect feature class. Additionally, SAG can add mean elevation information to each polygon.



Slope/Aspect User Interface

Complex Generator

The BTRA Complex Generator serves as a base data product, by unioning VITD polygon features into a single complex feature. The Generator also combines the results from the Slope/Aspect Generator and adds a weather grid to allow for the addition on real-time weather updates. The complex data set is the foundation for weather updated, mobility predictions, and ground maneuver network generation.



Complex Generator User Interface

Weather Effects Component

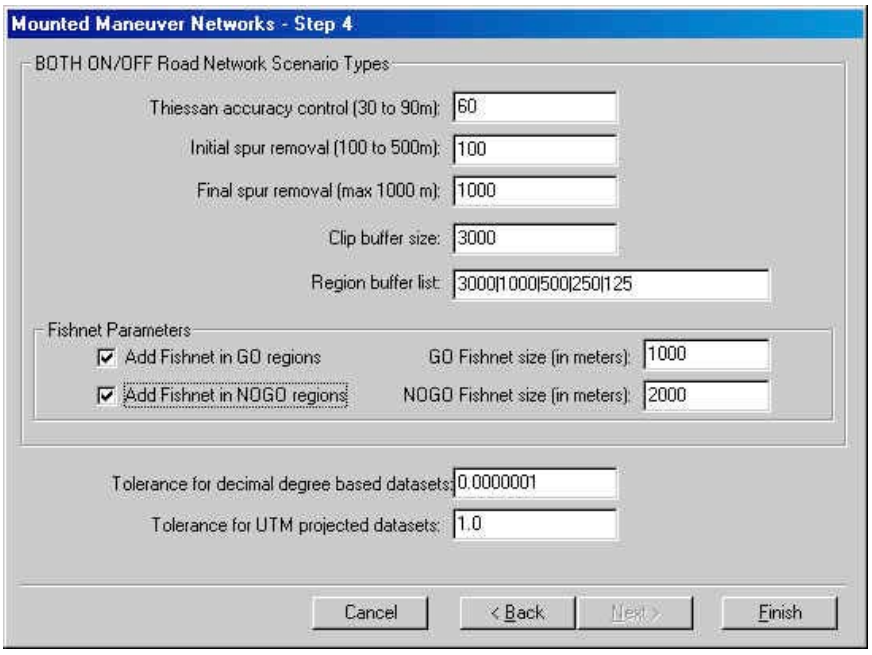
The Weather Integration component combines files received from a Cold Regions Research and Engineering Laboratory (CRREL) based Integrated Meteorological System (IMETS) site that maintains current and forecasted weather information with VITD-based terrain data contained in the BTRA Complex. After combining the data, the Fast All-season Soil STrength (FASST-C) algorithms are called to generate state -of –the- ground parameter values to be used by other BTRA tools. The BTRA weather integration contains the following components: Weather Scheduler, Weather Parser, Weather Inference, and FASST.

The weather scheduler coordinates automatic schedule for the weather importer and automatically launches FASST engine processing of raw imported data Imports IMETS weather data from CRREL weather effects (Wx) Service and stores as a local file. The weather parser parses out the required IMETS weather information to feed the FASST-C

model and the Inference engine generates the delta input data required by FASST not provided by IMETS.

Ground Maneuver Network (GMN) Generation

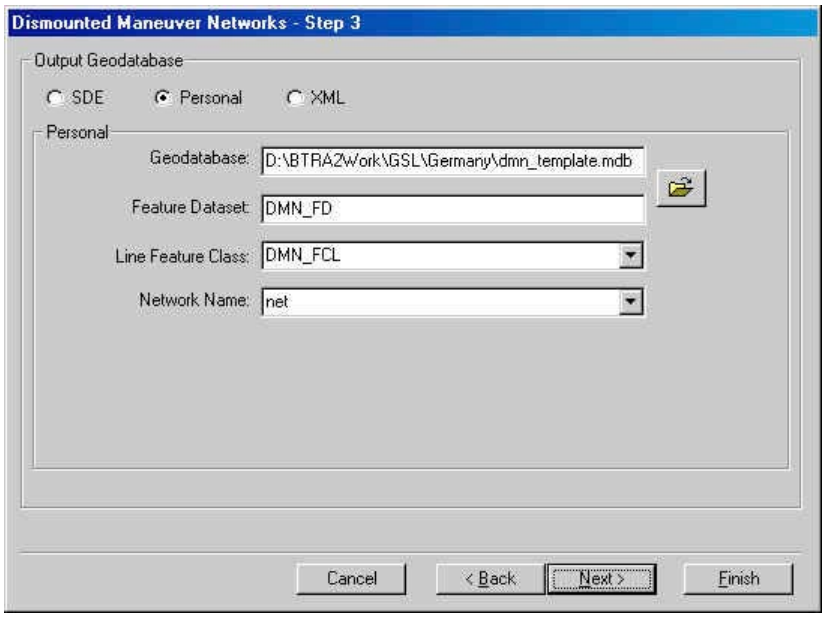
The GMN component generates an ESRI Geometric Network to perform BTRA Movement Predictions. The network is extracted from Positions of Advantage (POA) Obstacles, thins edges, adds roads, obstacles, fishnet edges, intersects the complex for speed values, assigns edge codes, calculates weights and builds the network and creates a Cross County Movement product.



Mounted Maneuver Network Generation User Interface

Dismounted Maneuver Network

The DMN component generates an ESRI Geometric Network to perform BTRA Movement Predictions. It extracts the Network from an Elevation TIN, intersects the Concealment POA, assigns edge codes, assigns speeds, calculates weights and builds the network.

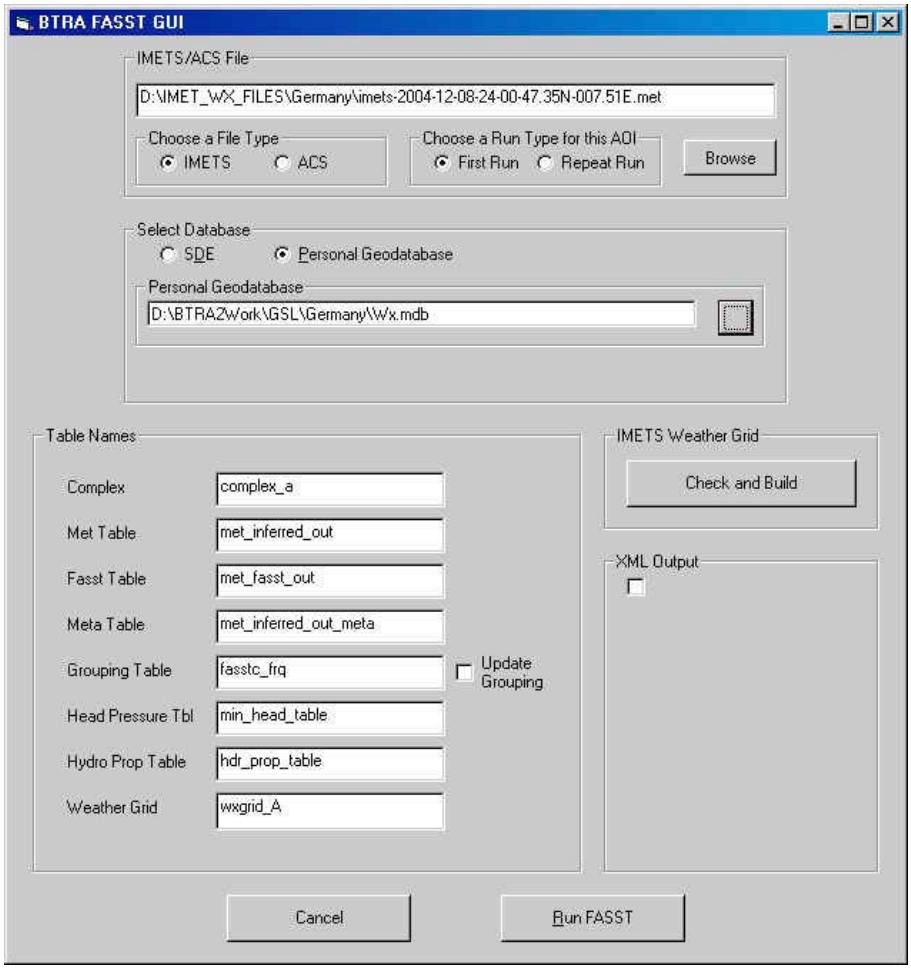


Dismounted Maneuver Network Generation User Interface

Decision Aids:

Weather Effects – Terrain State

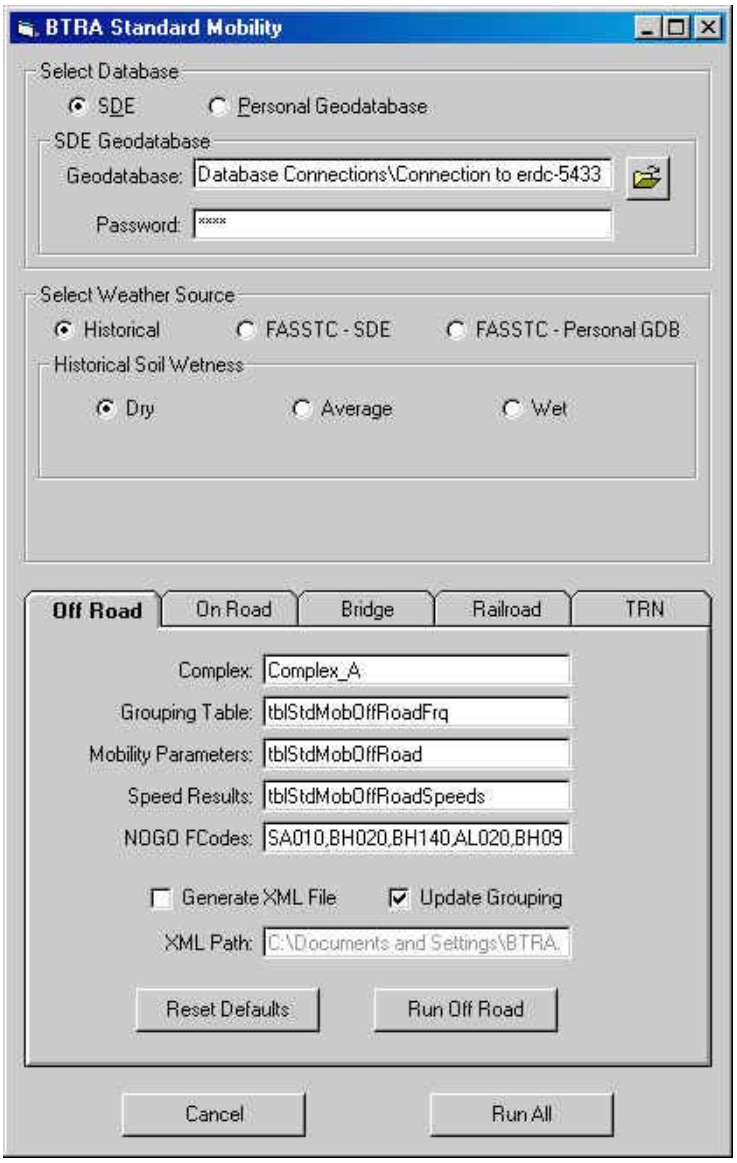
The ability to predict the state of the ground is essential to manned and unmanned vehicle mobility and personnel movement, as well as determining sensor performance for both military and civilian activities. As part of the Army's BTRA research program, the 1-D dynamic state of the ground model FASST (Fast All-season Soil STrength) was developed. It calculates the ground's moisture content, ice content, temperature, and freeze/thaw profiles, as well as soil strength and surface ice and snow accumulation/depletion. The fundamental operations of FASST are the calculation of an energy and water budget that quantifies both the flow of heat and moisture within the soil and also the exchange of heat and moisture at all interfaces (ground/air or ground/snow; snow/air) using both meteorological and terrain data. FASST is designed to accommodate a range of users, from those who have intricate knowledge of their site to those who know only the site location. It allows for 22 different terrain materials, including asphalt, concrete, bedrock, permanent snow, and the Unified Soil Classification Scheme (spell out) soil types. At a minimum, the only weather information required is air temperature.



FASST User Interface

Standard Mobility

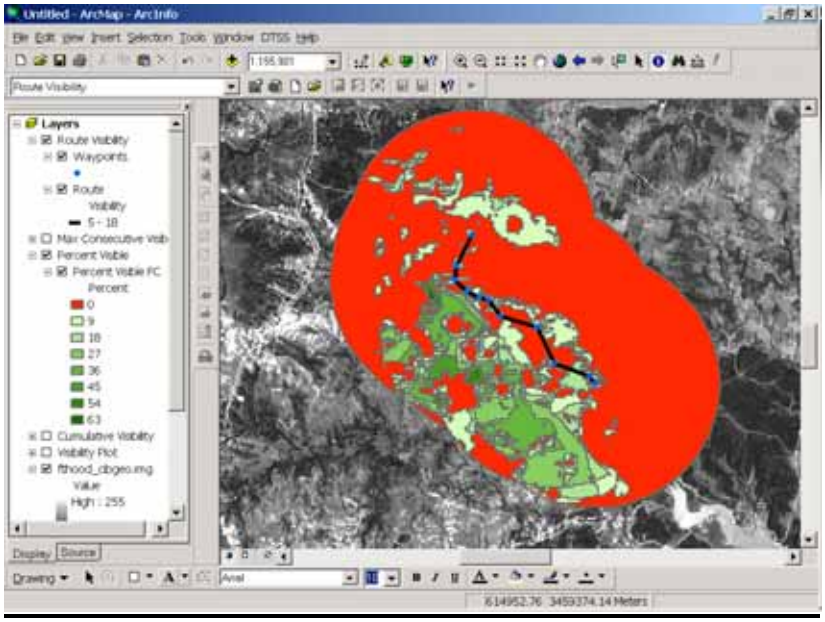
The BTRA Standard Mobility tool creates speed predictions for a specific vehicle or vehicle class, in a specific area of terrain, during specific weather conditions. StdMob infers Standard Mobility parameters from a VITD-based complex dataset. Inferred parameters are passed to Java classes, along with weather and vehicle information, to determine the maximum speed. In the absence of weather information, it can use historical soil strength values for calculations. The historical information can either be generated using inference values for dry, average, or wet conditions based on different world climatic regions or generated with the FASST model using the Automated Climatic Server (ACS) which uses the International Station Meteorological Climatic Summary (ISMCS) Data Base.



Standard Mobility GUI

Line-of-Sight:

The BTRA Line of Sight (LOS) product provides omni-directional and cover and concealment analysis to LOS while factoring weather and vegetation into the analysis. In addition to the geometric capability, the BTRA LOS component provides various LOS analyses to include view shed, omni-directional, cover and concealment, point-to-point, point-to-region, point-to-route, region-to-point, region-to-region, region-to-route, route-to-point, route-to-region, and route-to-route while factoring atmospheric extinction for weather effects and vertical visibility obstruction of vegetation. A quality metric input parameter can be set to optimize the speed vs. accuracy.



Route Visibility Line-of-Sight

Decision Tools:

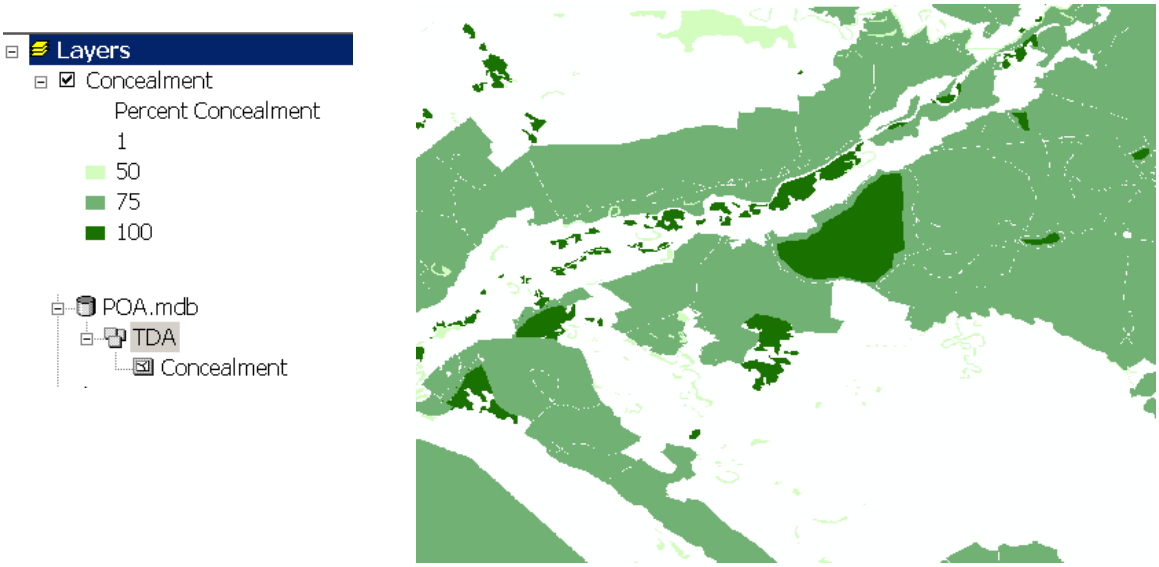
Positions of Advantage (POA)

POA is a set of tools used to produce Tactical Terrain Analysis (TTAs) products. These tools include Data Query, Suitability Calculator, and Proximity Analysis. The Data Query and Suitability Calculator provide the user with the flexibility to generate products from any geodatabase, shapefile, or coverage by letting them develop their own models based on either Boolean Queries or assigning weights (Excellent, Good, Fair, Poor) to features and their attributes.

Data Query Tool – gives the user the ability to query geospatial data and products to produce user-defined products. The User can create and save queries or edit existing queries. Any ESRI recognizable feature data or products can be queried

Suitability Calculator determines suitability of terrain to support a specific activity or task of a force or entity based on user assigning a value ranging from excellent to unsuited. The user can create and save suitability parameters models or edit existing suitability models. Any ESRI vector data file or vector products can be modeled

Proximity Analysis is a dynamic tool which allows a user to specify a spatial relation between two or more features. Spatial relations can be saved, edited or reused by the user.



POA Data Query Concealment Product

Movement Projection (MP)

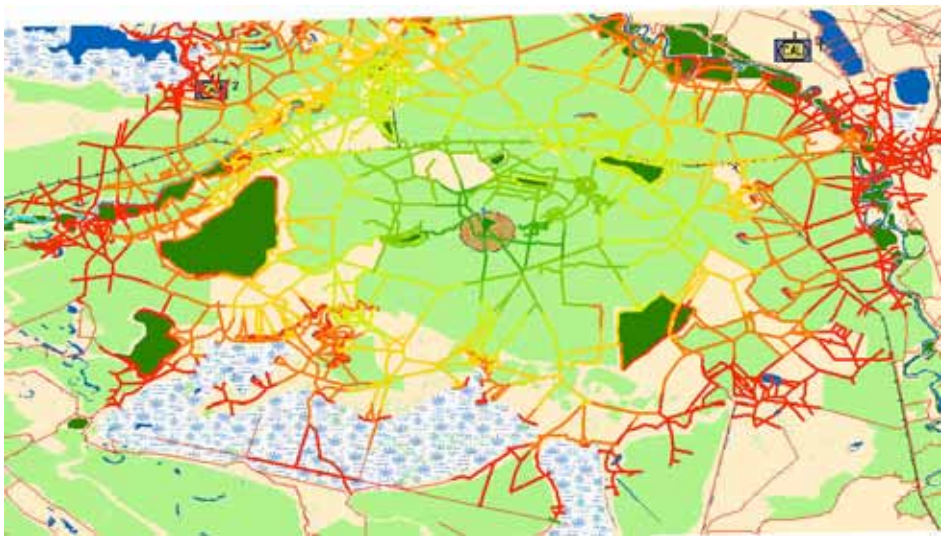
Given a set of parameters, use a maneuver network to generate one or more routes

- Determine available routes from a location given an amount of time or a distance constraint
- Best route from a location to a destination, with possible intermediate stops, with "best" being determined by selected costs (distance, time, cover and concealment, etc.)
- Two-Way Analysis – Determines the paths that can be used to get to a destination and return to the starting location in the allotted time.
- Determine "best" path to the nearest suitable area
- Capacity Flow – Determine how to move a force to a destination taking the forces size and width of roads/mobility corridors into consideration

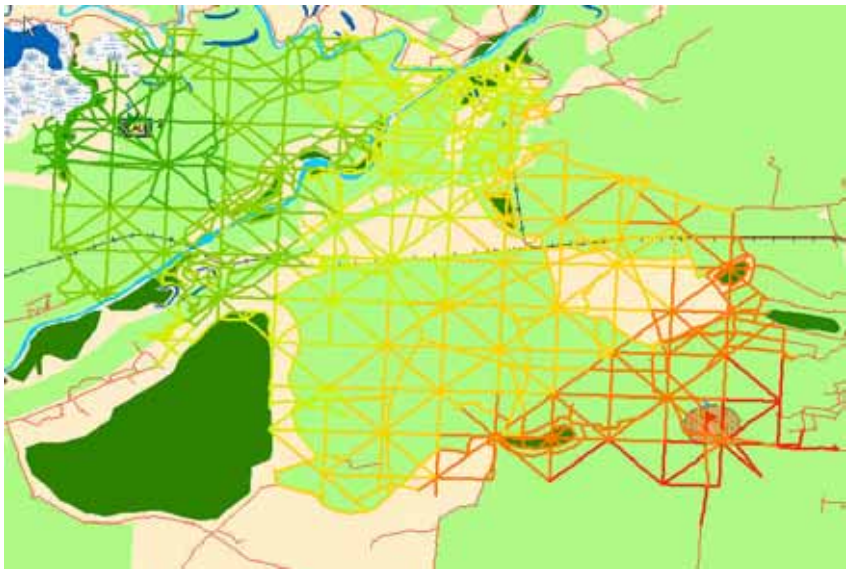
The following information is attached to the MP output depending on the product:

- Edge Length
- Width (in meters)
- Speed (kph)
- Edge Category
- Capacity (volume)
- Time (in minutes)
- Accumulated Time
- Accumulated Cost
- Accumulated Distance

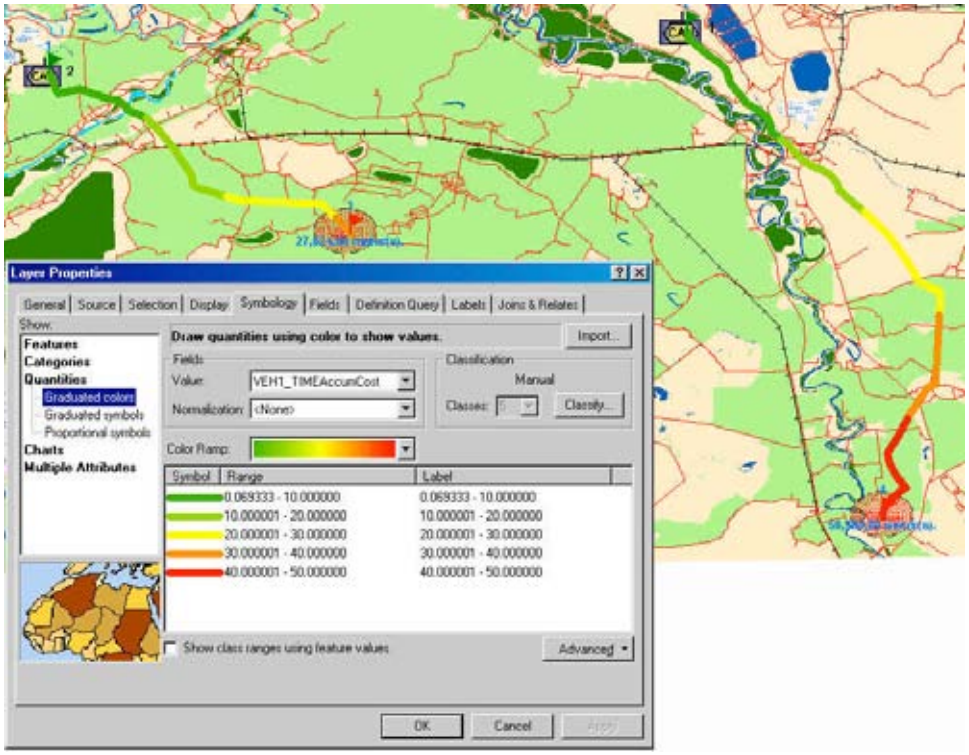
All MP output can be stored in pGDB, SDE, or XML.



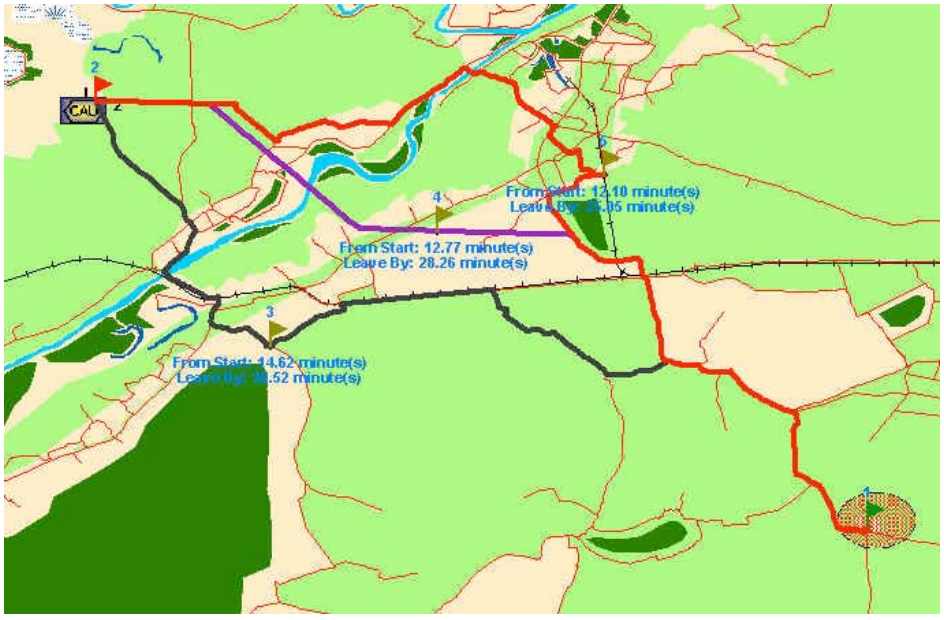
Time Constrained Movement – 30 minutes



Time and Objective Constrained Movement – 30 minutes



Weighted Movement - Accumulative Time to Two Objectives



Named Areas of Interest

Weighted Movement - Two Units Concealed to Multiple Objectives

Benefits

BTRA modular and automated capabilities provide the ability to incorporate predictive and interactive effects of the terrain and weather into C4ISR processes and systems to support real-time analysis and decision-making. BTRA tools will greatly improve Intelligence Preparation of the Battlefield and C2 processes, accelerating Course Of Action analysis and enabling interactive predictive analysis. These capabilities along with BTRA sensor performance tools have the potential to improve ISR asset management, threat detection and identification. BTRA situation and threat analysis tools provide a geospatial capability supporting improved levels 2 and 3 fusion. By design, BTRA capabilities increase situational awareness and battle management effectiveness

Summary

BTRA's decision to build upon ESRI and C/JMTK tools has allowed for rapid capability development, maturation and transition. The Engineer Research and Development Center and BTRA's partnership with NGA and C/JMTK offers the potential for common capability and tools across the force and takes the community one step closer to the elimination of information stovepipes and achieving true interoperability

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