Geographical Data and Algorithms Usable for Decision-Making Process

Dana Kristalova(✉), Martin Vogel, Jan Mazal, Petra Dohnalova, Tomas Parik, Adam Macurak, and Katerina Fialova

University of Defence, Brno, Czech Republic
{dana.kristalova,martin.vogel,jan.mazal,petra.dohnalova,tomas.parik,adam.macurak,katerina.fialova}@unob.cz

Abstract. The traffic-ability of military vehicles in the terrain outside of communication is not trivial matter. The article deals with the application of different types of geographic data sources within the decision-making process. The Commanders of the military or rescue units are participated in this decision-making process especially in the field. The key role is offered for the use of geographic information systems and application of geographical-tactical analyses, the methods of mathematical modelling, simulation and optimization for the purpose of scheduling the appropriate routes of movements of military vehicles in the operating environment. The special algorithms for searching of optimal path have to satisfy the criteria that are set of for solution of tactical tasks in autonomous systems. It is possible the time and speed limits and safety of peoples to determine. The geographical conditions, tactical conditions and types of vehicles are the most important factors for estimation of time of movement in the different types of terrain. Lots of experiments in military area in the Czech Republic have been performed and unmanned ground vehicle TAROS for gathering of the data was used and method of laser-scanning was tested. The measurement has been evaluated by mathematical statistics and computer sciences. Solution of these tests it is possible to use also in crisis management for emergency systems in case of natural disasters such as floods, fires etc.

Keywords: Geographical data · Geographic factors · Movement of vehicles · Pass ability of an area · Cross-country movement · Movement in terrain · Decision-making process · Crisis management · Unmanned ground vehicle

1 Introduction

Analogue map products are the primary basis for the decision-making process in the selection of the optimal variants of the route. Choosing the right documents, selection of the appropriate methodology for the evaluation of the different geographical factors in a cartographical measurement and a research and also a creation of suitable algorithms to determine of the final route of movement is necessary for a successful decision. Last but not least the influence of tactical factors and a consideration of the possibility of the vehicles due to their tactical-technical data are important. The use of

J. Hodicky (Ed.): MESAS 2016, LNCS 9991, pp. 226–241, 2016.
DOI: 10.1007/978-3-319-47605-6_19

this evaluated data must conform to the manners of the military units according to the doctrine, due to the preferred tactics and due to identify of HVT (High Value Target - it is the means or ability, that the enemy needs to complete the task).

Simultaneously, the evaluation of terrain that is suitable for further activity is controlled by the STANAGs (Standardization Agreement) – see [1]. See Fig. 1. An analysis of geographic products is thus one of the steps within the IPB, and generally it is given by the publications [2]. The methodology is united for all states of NATO (North Atlantic Treaty Organization), however, the article deals with the possibilities of analogue geographic documents available in the Czech Republic - both the military and civilian resources.

A decision making process can be understood, in civil (managerial) terms, as a process of solving decision-making problems, i.e. problems with more (at least two) solution options where a manager achieves a desired state by means of that decision. Whether it involves strategic or operational decision making, its quality has an influence on efficiency and effectiveness of follow-up operations. It is necessary to consider a fact that a majority of decisions is related to problem solving. Managerial (or commanding) decisions may concern common, reoccurring problems as well as unusual and complicated ones. In relation to a subject of work we can talk about decision making of specific character, as a rule, requiring a creative approach, great knowledge and experience, often even intuition, which, in its nature, deals with ill-structured problems.

However, there is a potential here, that by means of appropriate development in technological computing apparatus, along with gradual integration into a current way of decision making, the decision-making activities will gradually acquire character of well-structured problems in the future. Nowadays, when the world is dramatically changing, the ability to find, correctly identify and effectively solve a problem is becoming really critical. The role of managers (commanders) is, in relation to problems, irreplaceable since they remove obstacles on the way to better results [3].

The decision-making process within a military field is related to a fairly specified area, which is not, by its fundamental aspects, too different from a concept applied in a

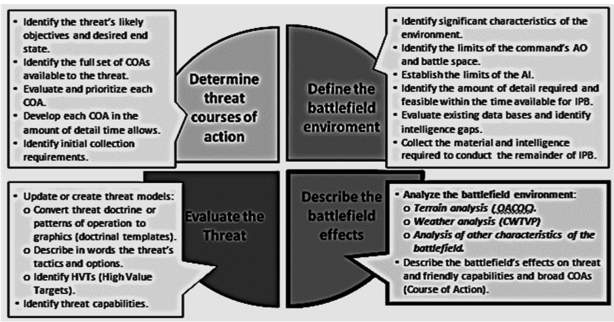


Fig. 1. The diagram shows several steps to the evaluation of the intelligence preparation of battlefield (IPB). This schema is relevant to the decision-making process of commander. The second step describes the effect of the terrain and weather conditions on military units. The success of this analysis corresponds to the amount and quality of input geographical information.

civil environment. However, its specific environment, where the decision-making process is executed, is especially typical for a degree of a risk that can be brought about by a wrong decision. When making military decisions there are factors, coming to the fore much more explicitly than in a civil sphere, such as time (decision-making speed), issues of available resources (material, human), unknown areas (terrain, enemy, population), a degree of uncertainty, and especially a factor of possible losses of personnel and materiel. We cannot omit a factor of the operational environment and requirements for speed and quality of decision making [4, 14].

Under combat conditions a commander is usually forced to decide explicitly without delay, having a lack of relevant (needed) information. The decision-making results in pronouncing a decision in terms of a commander's combat order or directly an order or fire task that is unambiguously obligatory for all subordinates. Therefore it is necessary to pay utmost attention to this process because wrong decisions may have fatal consequences, even at the lowest command levels, which is the feature highlighting or properly distinguishing the decision making in the military practice [3]. The lack of information or failure of the communication means might be overcome by the use of simulation techniques [15, 16].

2 Cross-Country Movement

The issue of capability of the terrain (Cross-Country Movement, Traffic Ability of a Terrain) is still a current topic, despite the fact that for a long time the new approaches are developed. These approaches could contribute to optimizing the search paths [5]. Finding of the relevant algorithms is not a trivial matter, because the selection of the most appropriate routes and the estimate of the time that is needed for the move is a function of the quantity various factors: geographical, tactical, technical and the influences that are predetermined by the human manners.

Analysis of the Cross-Country Movement (abr. CCM) means the assessment of several geographical and tactical factors together, i.e. that it is complex multi-field analysis [6–8]. Apart from these geographical factors (abr. GF) and their parameters that affect the choice of routes, it includes:

- Relief (a parameter is a gradient).
- Micro-relief – i.e. embankments, excavations, holes, terrain steps, rock cliffs, terraces, rock groups, boulders, stone fields or rows of stones, etc. (parameters are height or depth, length, slope gradient, width).
- Vegetation – structure of partial forests, vineyards or hop-gardens (dimension, shape, orientation), structure and specific characteristic of woody plants (spacing between trunks, thickness of trunks measured at height 1.3 m over terrain, vegetation height, sort of plants).
- Soils – a sort of soil (depends on soil granulation), a type of soil at factual weather conditions, a vegetation cover of soils, a roughness of terrain surface.
- Waters – rivers, streams, lakes, dams, etc. (their parameters are width, depth, water flow rate and flow speed, characteristics of banks and of bottom, overall covering of terrain by drainage and mutual position of drainage and other subjects).

- Weather conditions – precipitation, fogs, temperatures, humidity, speed of wind, light conditions.
- Settlements - built-up of given territory by settlements, location, structure, shape and orientation in regard of troop movement, construction material, height of buildings, (in)flammability of buildings.
- Communications - railways (number of tracks, traction – the kind of drive, track gauge, transportation significance) and roads (width or number of traffic lanes, quality of roadway wear course, transportation significance).

The impact of all factors should be expressed by "Coefficient of the deceleration" (abr. CoD). The value of the coefficient of the slowdown (C_i, $C_i \in \langle 0, 1 \rangle$ or ($C_i \in \langle 100\,\%, 0\,\% \rangle$) is assigned to each geographical factor Fi, which is located in the section of the ground, and that affects the speed of the vehicle. The value of this coefficient indicates how many times (how much percent) the factor to slow down the vehicle. The coefficients of the slowdown (according to the Table 1) define the degree of Cross-Country movement.

Table 1. Determination of the levels of Cross-Country Movement (Pass-ability of the Terrain)

Pass-ability of the section	C_i
NO GO section	0
SLOW GO section	0,5
GO section	1
Section without information	1

The common impact of GF on the deceleration of vehicle movement at given section of route can be expressed by the following algorithm [7, 8]:

$$v_j = f(v_{\max}, c_1, c_2, \ldots c_n) \tag{1}$$

where:

v_j = vehicle speed at j-section of vehicle path,
v_{max} = maximum road speed,
c_i = i-coefficient of deceleration due to geographical factor F_i computed for j-section with invariable values c_i,
n = number of geographical factors effecting at given section of the terrain,
k = number of section on vehicle path.

The total CoD depends on the partial CoD of the different GF and is given by this formula [7, 8]:

$$C = \prod_{i=1}^{8} c_i \tag{2}$$

where, C = total CoD, c_i = partial CoD (C_1 is CoD of the relief, C_2 CoD of the soils, C_3 CoD of the vegetation,..).

These basic algorithms were particularized by a huge number of measurements, data processing and calculations. The authors tried to depict all the important links of the GF. A large number of field tests were realized, and thus, it was possible to include real (not only laboratory or theoretical) measurement.

The resulting effect of all the geographic factors on the deceleration of the vehicle in a given section of track shall be expressed in the following formula:

$$v_j = v_{max} * \prod_{i=1}^{n} C_i, \quad \mathrm{i} = 1 \ldots \mathrm{n}, \; \mathrm{j} = 1 \ldots \mathrm{k} \tag{3}$$

where:

v_j [km/h] … is the speed of the vehicle in the j-th section of track vehicles,
v_{max} [km/h] …is the maximum speed of the vehicle for communication,
C_i …is the i-th coefficient of a slowdown,
n …is the number of geographic factors operating in the given section of the terrain,
k …is the number of sections of the vehicle on the track.

These factors and their parameters determine 3 levels of Cross-Country Movement – GO, SLOW GO and NO GO. The level called “GO” means the movement without a loss of speed the level “SLOW GO” means partial deceleration of the speed of the movement and the last level “NO GO” signifies that the movement is not possible. These terms are given in [6–8]. But the purpose of the analysis is very important.

The analysis is different according to the type of military (or civilian) unit and the meteorological conditions.

From the point of view of means of transport (used for movement) following basic types of terrain are determined: terrain passable for full track vehicles, terrain passable for wheeled vehicles, terrain passable for other means of transport, terrain passable for infantry troops only.

3 Analogue and Digital Geographical Data

The scheduling of movement routes may take place in an office, often far from the real battlefield. At this point we can use all the available sources as maps, plans, aerial photos, scenes (obtained by RS – Remote sensing of Earth). The overview of existing digital data and GIS used in the Army of the Czech Republic and their possible use in tactical-geographic analysis is described in [9].

In real time the soldier often has only an analogue map or evaluation of the supporting documents, which due to the devastating effects of war need not be current. The determining of the correct routes of a movement or suitable visible or hidden areas may not be easy.

That is why it is calculated with the introduction of the “System of the 21th century Soldier” or some similar system in the future. This system is developing, verifying and applying in similar versions in many advanced armies all over the world. If the soldier will have the appropriate analogue or digital data, its decision-making process will be easier and faster. Commonly available sources are topographic maps and aerial photos, very good source would be the forestry maps and, in particular, their conversion into digital format. The new, highly current and accurate source of data is the acquisition of the field by the method of laser scanning, which can currently assess the most appropriate route for the movement of the vehicle.

3.1 Topographical Maps

Topographic maps (abr. TM) are designed for a security of defence of the Czech Republic and primarily for an orientation in the terrain and for a study of geographical factors. On topographic maps, important positional and altitude elements of terrain are recorded (greatly in detail).

Topographic maps allow you to evaluate the spatial relationships, evaluate the visibility between objects, determine the coordinates, determine the altitude and the azimuths and determine the slopes of the terrain. The contents of the maps are divided into the planimetry and altimetry. Another division according to the character of the objects: points, line, aerial. This is one way how to convert selected analogue data to the digital form and these digitalized data it is possible use to simulation of movement of vehicles in terrain (Fig. 2).

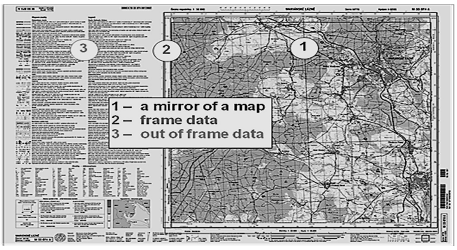


Fig. 2. The mirror of the map displays the cartographic projection of a terrain, its shapes and objects. Frame data include geodetic coordinates and its division, rectangular coordinate network UTM, Point "P" to determination of the direction of magnetic north and lots of labels. Out of frame data include different type of the map scale, the name of the map sheet, marking a series of maps, the issue number and marking sheet maps, data about geodetic and altitude system, interval of recta-angle network, contour interval and units for altitude, data about grivation and meridian convergence, magnetic azimuth and bearing, diagram of the administrative division, overview of neighbour map sheets, military designation of the map sheet, codename maps, legend and abbreviations, diagram of the UTM and diagram of elevation guide.

3.2 Forestry Maps

Forestry maps are very interesting source of data on the vegetation and paths. For each analogue or digital map there is a digital file. In this file there are the following: 8 classes according to the age of the trees, a species of trees, the approximate height of the trees according to the tables of speed of growth, and other information about the type of forest. Further maps contain detailed drawings of paved and unpaved paths, trails and footpaths, the boundaries of the individual areas, protected areas and a large number of map markers for the various landmarks (e.g. high seat, apiary, waste dump, the cottage, bushes). These points are very useful and can help with orientation in difficult conditions and the subsequent decision-making process.

Unfortunately, these maps are not publicly accessible. The above mentioned data in topographic maps are missing, or are not recorded in such detail. However, when comparing the topographic maps and forestry maps, it was found a large amount of new information. A unit of soldiers, which had detailed information source about paths and landmarks, was guided much better, than a unit only having topographic maps.

3.3 Aerial Surveying Photos

Aerial photos are the common product, which is easily accessible from public sources. Due to the fact that the majority of the movements of military reconnaissance units takes place in the woods and on the slide, there are not many paths through the forest cover can be seen, the aerial imageries are used only as a suitable complement of topographical or forest maps.

3.4 New Sources

Given the above positives and drawbacks of basic data sources, and given the trend to use new means, methods and simulation technology this year the experimental measurements with robotic means TAROS v2 hold in military area Libavá (in the Czech Republic). TAROS v2, which develops the national company VOP CZ in cooperation with the University of Defence, is an autonomous unmanned ground vehicle designed primarily for combat support units and reconnaissance purposes. It is a way to get the digital current data about the surrounding area and take advantage of the laser scanning method.

4 The Applied Methods

Thanks to the joint consideration of these factors and their standards indicating the degree of continuity, it would be possible to determine the correct route transfers and calculate the time estimates for the movements of various military or ambulance units. Speeds are relevant not only to the type of terrain, but also the type of (military) equipment. To devise a methodology for estimating the speed of movement of the influence of the terrain surface is necessary to establish a method of obtaining the relevant data (inclination of slopes, the frequency of the micro-relief shapes, types of surface soil conditions, terrain and weather conditions), to analyze data, identify ways to evaluate the data and build the algorithms for the calculation of time limits movements. It would be possible to modify the algorithms and other aspects (in terms of security, economic, or the shortest distance).

The use of environmental variability and the typical characteristics of each type of terrain with regard to the availability of these spaces as well as on the available types of military vehicles is most important when testing the polygons are drawn. Straight and sloping spaces, flat and rough were tested. The surfaces of a grassy, rocky, sandy, clay, asphalt and snowy were investigated. For the preparation and implementation of these tests a large number of calls with the appropriate personnel is necessary and ensuring these areas is not easy. It is possible to use different methods for obtaining and evaluating these data, it is the right to choose the most practical.

5 The Calculations and Results

Several methodologies (in particular assessing the impact of geographical factors on the movement) were created at the Department of Military geography and Meteorology in the course of carrying out the tasks relevant to the specific research [10, 11]. Several effects, which had a majority influence on the ride of vehicles in the terrain, and which were still relatively neglected were evaluated during the research. Influence of micro-relief on the movement of military vehicles was the first [6], the influence of human reactions and of the surrounding environment was the second. New approaches for a comprehensive evaluation of the operating factors and their parameters, it has also been described in some articles [12].

The result of the research, which takes place in the present, should be used to design a digital interface for collecting, managing, and redistribution of geographic data relevant to a given issue. Documents containing database tactical-technical data of vehicles and their traction diagrams (on whose basis it is possible to define the maximum possible speed attainable on exit or descent of the concrete slopes), detailed geographic data, algorithms for the determination of the coefficient of the slowdown on the basis of the frequency and the size of the micro-relief shapes, the coefficients of a deceleration defined on the basis of adhesive factors for the main types of surfaces and the coefficients of deceleration determined on the basis of meteorological characteristics would have been necessary for the new information system. These coefficients slowdown associated with each field types, however, interact and, therefore, it is not easy to quantify the impact of elementary.

One way for calculating of the total CoD depends on the partial CoD of the different GF and is given by formulas (1–3) and [4–6] and an overview of the models for determining the speed of the vehicles is given below.

5.1 The Summary of the Various Models of Paths Optimization

The algorithms of the route optimization (for communication and outside of them) may not be intended only for the war purposes because finding optimal routes outside the communication may be relevant also in civilian crisis situations, or the provision of assistance when natural disasters such as floods, fires, storms etc.

The Model of the Micro-relief. Micro-relief is a neglected factor in optimizing route. There are several reasons:

- The absence of country-wide mapping of this factor (the maps, which provided the input data, are TM in scale 1:10 000, these maps are not in using today (the date of editing was between years 1958–1964!). Unfortunately, other map resources for these measurements were not available at the time of the creation of models. Today, it is possible to use civilian product ZABAGED in scale 1:10 000 or one of the products of ALS (aerial laser scanning), especially DSM 1G (Digital Surface Model the 1st Generation).
- The apparent "small size" of these shapes, and thus, in the context of generalization of maps, totally inaccurate data on maps.

The input data were obtained by the map measurement research (the length of the micro-relief shapes, their numbers in the squares of 10 by 10 km and the average height of these shapes). The route optimization model due to micro-relief can be solved by different ways. The model was created and the values of the average length, numbers and height of the micro-relief shapes were accepted.

Model "Matlab". The coefficients of the vehicle deceleration due to one obstacle and due to the influence of a probable number of obstacles in real morpho-metric type of total length of a route have been obtained by calculation of many simulations transits. The average elongation of route, then the average size of an obstacle and the fact that a driver sees the obstacle in distance d/2 and bypasses it by angle 45° is accepted and the probability that the obstacle is met in ¼ of size is accepted too, for one obstacle it is given by coefficient $\rho = 1.0155$ (see [6], p. 68).

Model "3D Terrain". The composition and calculation of this model of routes optimization of the vehicle in the field is based on the data and equations and application of the programming language C++. The table that was created from the values of the map measurement research has been accepted as input values for a model of the micro-relief. For the calculation of the elongation of the route it is appropriate to consider, for which vehicle the simulation is created. It is assumed that ambulances or other operational vehicles are equipped with GPS devices. The total elongation for a vehicle equipped with GPS devices searching the direct route is about 5–8 % (depending on the morpho-metric type). See Fig. 3. This model can be optimized by

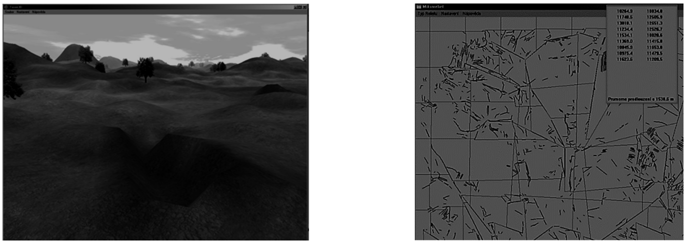


Fig. 3. There is a type of terrain that is created based on the values of the map measurement research on the left, on the right this is the evaluation of the 1000 transits by the terrain (The lengthening is 119 m to 1 km.) These models and algorithms are built in C++ programming language.

modifying the algorithm, where the route leads only over the apexes of the obstacles that occur on the route. The vehicle is still oriented by using GPS to the target point. Here the value of the elongation of the route is 1–1.4 %, compared to 5–8 %.

Unfortunately, not all vehicles have a GPS or other navigation instruments. The crew knows only the coordinates of the starting and destination point and a bypassing of obstacles leads to change of the azimuth to the target point. Here the average value of the elongation of the route is 12–15 %.

Model "Real Map". Input data for the next models of optimization were gathered using digitalization of layers of micro-relief, waters and railways from the TM 1:10 000. The obstacles were selected carefully, the limits for CCM were considered. The first simulation model was for influence of micro-relief only but the second was for an influence of micro-relief, waters and railways together. The values of elongation of routes for micro-relief only were 7.4 % for non optimized route and 1.2 % for optimized route, for joint model it was 14.9 % and 3.8 %.

Model of the Optimization of Routes. This model offers a solution to the optimization of routes generally valid for any terrain or for influence of any geographical factor. Some of other ideas, how to optimize routes are quoted from [5–8]. The general solution for this issue (optimizing routes for communication or outside of them) can be expressed as two processing stage:

- To construct a graph, the emphasis is on the correct determination of values of weight coefficients for links of individual nodes. The starting model is represented by a mathematical chart of a traffic network, which represents initiatory data model for solving given tasks. During the solution, the initial data model is being gradually modified based on influence of individual elements and their anticipated (calculated) path, where the time of appearance in individual (calculated) segments of optimum path is extrapolated.
- **To implement the algorithm** for searching of the shortest, fastest, safest or cheapest route. Another separate part is effective searching for optimum path of individual element. The key element in this part is effectiveness of the algorithm finding optimum (usually the shortest) path in a large not-oriented weighted chart (millions of nodes and dozens of millions of links). A searching has to be quickly enough to enable the solution "in the real time" for a large number of moving elements. A solution for each element depends on previous calculation of the optimum path (for the previous element).

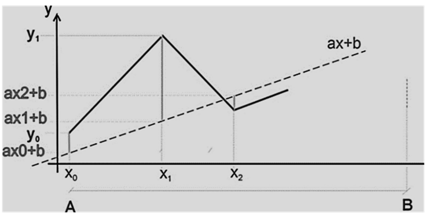
Solution of both problems has the same basic principles, but with different data models and process of its construction. More detailed information on this issue you can see in this publication [8].

5.2 Model "Variation of the Function"

For the evaluation of the dependency of the shape of the surface and the driving speed math function "variation feature" (variations) has been selected. A numerical expression of the influence of the micro-shapes could be characterised by other features, used in the engineering fields and for determining the roughness of surfaces. See [6].

The calculation of the curve that defines the estimate this dependency can be divided into three steps:

- How to calculate the "roughness of routes" (x axis)? See Fig. 4 (on the left).
- How to calculate vehicle speed (y values)? The measured values of speed relevant to the types of surfaces have been used and a comprehensive table of speed from the huge number of rides in terrain was drawn up.
- How to establish a curve? An example of the calculation of the variation is based on the use of tabular data relevant to the length of elementary sections and elevation coordinates of the beginning and end of the connecting line See Fig. 4 (on the right).



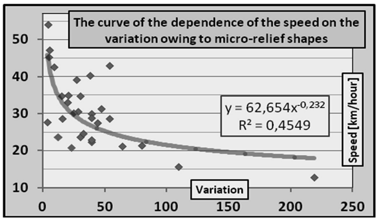


Fig. 4. On the left there is the principle of variation of function is the expression of the roughness of the terrain on the basis of the summaries of the products of the values of the tangents directives and the lengths of elementary sections. The absolute value of the tangent (this is the quotient of the differences of heights or elevation differences of extreme points to the horizontal length of the section) is multiplied by the length of a section (also in absolute value) and by the summarization of these products the value of the variations of the function between the starting and final point is calculated. It was not very precise, therefore variations were converted to the reference "zero" level, i.e. to a linear trend-line (broken line). The dependence curve of the speed on the variation (it is conditional on the roughness of the terrain) is on the right.

5.3 Regression Model

One of the way, how to evaluate the speed of vehicles in terrain, is the use of mathematical-statistical calculations in a form of a regression model. [6]. The Program "R" (the sophistic software for regression analysis) was used to evaluate the speed of vehicles depending on many factors. A simple regression model was built, which describes the dependence of the speed of the drive based on the numerical representation of categorical variables. The input data was compiled into a table about 1872 records with 13 parameters (type of vehicle, driver experience, the practice of the use of the vehicle, type of surface – grass, silt, mud…, lit by the sun, etc.) and then the regression equation, which approximately describes the real speed of the vehicles, was established. On the basis of the carried out calculations the equation of regression was established.

The regression equation has the form:

$$Speed\ of\ vehicle = 5.9170 + 1.2999^{*}vehicle + 4.8573^{*}driver + 4.9551^{*}primary\ vehicle + 1.1451^{*}surface + 2.7789^{*}ride\ category - 0.1066^{*}variation\ of\ micro - \text{relief shape} - 0.0270^{*}slope\ variation - 0.2917^{*}slope + 0.9476^{*}meteorological\ condition - 5.4804^{*}sunshine \quad (4)$$

5.4 Evaluation of the Influence of the Surface Using a Programming Environment in the Language "C++" in Vector Format

Model simulating the ride vehicles in the field has been created in the programming language C++ [6, 13]. Input data are defined by the curve of terrain profile and were obtained by two methods – by terrestrial laser scanning (measurement of the coordinates of the profile was targeted with step 10 cm) and by total station Leica (characteristic fracture points of terrain shapes in the same profile were targeted on the basis of a subjective selection of surveyor). Length and height coordinates were used. Several algorithms have been built. Their purpose was: to retrieve data, to display the off-road curve, refining the methodology of the rolling wheel after the terrain and the final output was the determination of the value of the time needed to complete the profile. Other input data were maximum vehicle speed, wheel diameter, the maximum speed of the vibrations the wheels – always relevant to a given type of vehicle. These data were calculated in models at the software ADAMS.

The author recommends use this model in particular in conjunction with the air laser scanning and use of UAV (Unmanned Aerial Vehicle).

5.5 Unmanned Ground Vehicle TAROS

Research of the autonomous movement of the vehicle in the real terrain takes place in the context of development. The measurement was focused on the acquisition, training, validation, and processing data in the framework of the development of the model of optimal manoeuvre the robotic device on the battlefield in the area of operations. Data was gathered from sensory systems, and on the basis of these data the vehicle reconstructs the surrounding space (Fig. 5).

Fig. 5. Unmanned Ground Vehicle TAROS v2. The scanned data is used as a starting basis for the calculation of throughput analysis in complex terrain.

It consists of:

- The 3D laser scanner (LIDAR);
- The differential GPS device for the localization of the device to the nearest hundredths metres;
- The inertial unit for determining angles of rotation of the vehicle in the space.

The optimal model of manoeuvre which is a part of the long-term research decision support for ACR Commander on the University of Defence is built on a complex mathematical model. The basic entry to this model there are the data about vehicle surroundings that are getting by the laser scanner and from the information about the current position, and the rotation of the vehicle in the area. The obtained data are used as input to the Simulator. The Simulator is a key element of the verification of the correctness of the design and operation of the model. Verification takes the form of mathematical simulation, in which the proposed model is verified as in the experiment. The next stage of the verification is verification of the model in the real environment, which is the next stage in the planned project. When measuring 6 independent experiments were carried out. Each experiment was focused on a separate key area, which was necessary to verify.

These are the following areas:

- The movement of vehicle on the road.
- The movement of vehicle outside of the communication with a significant change of elevation of the terrain.
- The movement of the vehicle around the near negative obstacle.
- The movement of the resource in the area with higher grass and shrubs.
- The movement of the resource in the tunnel.
- The endurance test of the engine when the vehicle is moving in difficult terrain.

From each experiment a comprehensive set of data was obtained. It was subjected to a thorough analysis, on the basis that the proposed model has been verified. The results of the analysis are also used for adjusting the input parameters of the model. A total of more than 6 GB of data was obtained in the context of all the experiments and stored. This data will be analyzed in the context of the other phases of the research component of the project.

6 Map Outcomes

The potential graphic outputs should be maps of optimal paths from the start to the final points (with a time calculation for the move), secondary data could be used for the creation of the current flow maps of the terrain, which would have been over existing products as well as from the standpoint of the methodology of determining how the terrain, so from the standpoint of data bases (especially during the use of products produced by the method of laser scanning) (Fig. 6).

Aspect of the database data bases were open to question, however, is given to the development of methods and means for the collection of data, it is assumed that in the future the current ignorance of the field will not be a problem.

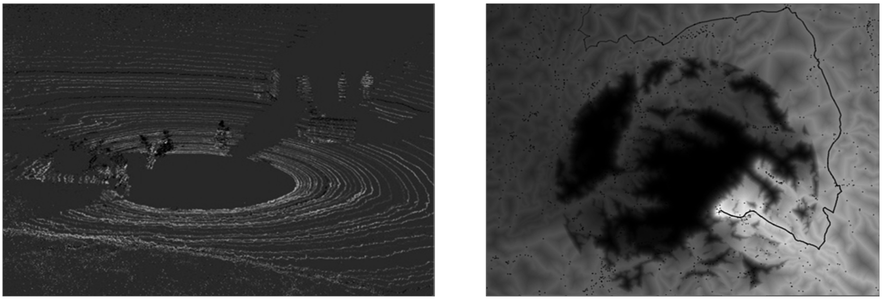


Fig. 6. On the left there is the scanner records the "point cloud" as a result of the 3D measurement. Concentrated points show a shape characterising the barrier (figures people are back - this is a simple example, but the multi-objective analysis is required to assess more complex shapes). Robotic device using laser scanner detects obstacles while trying to optimize the manoeuvre. It is looking for the best route through the space in such a way that the manoeuvre to satisfy certain criteria in terms of fluidity, speed, options of device, etc. (on the right).

7 Conclusion

The available analogue data documents are the primary source for the evaluation of the situation on the battlefield. Topographic maps produced by the VGHMÚř Dobruška (Military Geography and Meteorology Service Department), forestry maps ("map of growing forest units") and images of the terrain (whether the air surveying the slides or the slides from Web browsers) and the older topographic maps of micro-relief units were included among these data documents. All of these products have their advantage and disadvantage and it is appropriate, in the context of the decision-making process and optimization-use these facts. It is possible to get a very detailed idea of the area by combining the information from the particular products. The current topographic maps contain unfortunately much less data than maps created from the previous mark guide. In these maps the basic information about the forest units (e.g. fraction, which expresses the height of trees, their spacing and thickness of the tribes–including the type of crop) are not mentioned, or are mentioned only sporadically. Missing data can be found in the above mentioned forest maps and similarly, so data that are not in the current topographic maps must be obtained from other analogue map resources.

On the basis of the products mentioned above, the dates of the individual elements (which have an impact on the potential route of movement of military units) were obtained by methods of cartographic metric investigation. The movement of military units is a basic tactical activity and the process of planning and decision-making is usually subject to just map the elements, whether analogue or digital. Cartographic investigation methods help obtain data so that at first glance may not be obvious, and the evaluated data are used as input data for the optimization algorithms.

That is why it is calculated with the introduction of the "System of the 21th century Soldier" in the future. This system is developing, verifying and applying in similar versions in many advanced armies all over the world.

The decision-making process has its own rules however it is conditional on the explanatory value of up-to-date geographic data. This data is becoming an essential part of the decision-making process when planning of a successful movement (for peace and for war) is one of the fundamental questions. For its creation it is necessary to know the impact of geographical factors on the manoeuvre, and if it is possible to use algorithms to find optimal routes. “The optimization of the routes” means not only finding the shortest route, but also to ensuring the safety of movement, or at least limitation of risk factors and so the compliance with time limits or acceptance of the economic aspects of the movement can play an important role.

The optimization of the route may be useful for ambulances or other operational vehicles for a solution of crises or natural disasters. These vehicles are equipped with GPS devices, which can maintain the direction to the target point in the current time and the issue of optimization of a movement can be calculated and used for a movement over the communication or outside of them. Here is a great space for the use of the UGV and new methods, therefore the vehicle TAROS was tested.

Another solution is the use of math-static models and model based on simulations of rides in terrain. The database, which is used for calculations, is created from the vast amount of data measured in the field. Capture the dependencies between individual factors is not a trivial matter, and therefore, the implementation of field tests is very beneficial. The scientific team is gradually getting to still more specific conclusions.

Acknowledgements. The work presented in this paper has been supported by the Ministry of Education (project of specific research SV15-FVL-K110-10-KRI) and by the Ministry of Defence the Czech Republic (research project DZRO K-110).

References

1. NATO Standardization Agency: AJP 2 (A) SD1, Allied Joint Doctrine for Intelligence; Counter Intelligence and Security. Edition A Version 1 Ratification Draft, Brussel (2013)
2. Headquarters Departement of the US Army, FM 2-01.3, Inteligence Preparation of the Battlefield/Battlespace. Washington, DC (2009)
3. Košťan, P., Bělohlávek, F., Šuleř, O.: Management. Business Books (Computer Press). Computer Press, Brno (c2006). ISBN 80-251-0396-X. Bělohlávek, F.: Decision-Making Process, Incomia, Praha (2006)
4. Mokrá, I.: A model approach to the decision-making process. In: Conference Proceedings 3, Applied Technical Sciences and Advanced Military Technologies, vol. 3, no. 1, pp. 278–281 (2012). ISSN: 1843-6722
5. Mazal, J.: Real time maneuver optimization in general environment. In: Brezina, T., Jablonski, R. (eds.) Recent Advances in Mechatronics, pp. 191–196. Springer, Heidelberg (2010). ISBN 978-3-642-05021-3
6. Kristalova, D.: Vliv povrchu terénu na pohyb vojenských vozidel (The Effect of the Terrain Cover on the Movement of Military Vehicles), The Ph.D. thesis (in Czech). The Univerzity of Defence, Brno, The Czech Republic, 318 p. (2013)
7. Rybanský, M.: Cross-Country Movement - The Impact and Evaluation of Geographical Factors, The Czech Republic, Brno, 114 p. (2009). ISBN: 978-80-7204-661-4

8. Zelinková, D.: Analýza získávání a využitelnosti informací pro vyhodnocení průchodnosti území (The Analyse of Collecting and Applicability of Information for the Cross-Country Movement), The Diploma thesis (in Czech). VA Brno, The Czech Republic, Brno, 118 p. (2002)
9. Kristalova, D.: The overview of existing digital data and GIS used in the army of the Czech Republic and their possible use in tactical-geographic analysis. In: The Conference Paper, MMK 2011, The Czech Republic. 8 p. (2011). ISBN: 978-80-904877-7-2
10. Rybansky, M., Zikmund, J., Kristalova, D., Rydel, M.: Metodika vyhodnocování vlivu mikroreliéfu a terénních překážek na průchodnost vojenských vozidel – kolová vozidla (The Metodologhy of the Evaluation of the Micro-Relief and the Terrain Obstacles on the Movement of the Military Wheeled Vehicles), Identification Number J-4-720/74, The Czech Republic, Vyškov, 30 p. (2010)
11. Rybansky, M., Zikmund, J., Kristalova, D.: Metodika určování vlivu povrchu terénu na pohyb vojenských kolových vozidel dle AVTP-1/01-80 a FMS-33 (The Metodologhy of the Determination of the Effect of the Terrain Cover on the Movement of the Military Wheeled Vehicles), Identification Number J-4-720/75, The Czech Republic, Vyškov, 45 p. (2011)
12. Křišťálová, D.: Nové datové trendy pro stanovení průchodnosti území (The New Data Trends for the Determination of the Levels of Cross-Country Movement). The Conference Paper, The Czech Republic, Taktika 2012, 8 p. (2012). (in Czech). ISBN 978-80-7231-887-2
13. Kristalova, D.: An effect of sandy soils on the movement in the terrain. In: Hodicky, J. (ed.) MESAS 2014. LNCS, vol. 8906, pp. 262–273. Springer, Heidelberg (2014). ISBN 978-3-319-13823-7
14. Hodicky, J., Frantis, P.: Decision support system for a commander at the operational level. In: Dietz, J.L.G. (ed.) Proceedings of the International Conference on Knowledge Engineering and Ontology Development, KEOD 2009, October 2009, Funchal, Madeira, pp. 359–362. INSTICC Press (2009). ISBN: 978-989-674-012-2
15. Hodicky, J., Frantis, P.: Online versus offline critical geographic information system. In: Proceedings of the Informatics, Wireless Applications and Computing and Telecommunications, Networks and Systems 2011. Part of the IADIS Multi Conference on Computer Science and Information Systems 2011, July 2011, Roma, pp. 127–131. IADIS Press (2011). ISBN: 978-972-8939-39-7
16. Hodicky, J., Frantis, P.: Using simulation for prediction of units movements in case of communication failure. World Acad. Sci. Eng. Technol, Int. J. Electr. Comput. Energ. Electron. Commun. Eng. **5**(7), 796–798 (2011)