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Chapter

Military Factors Influencing Path Planning

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Abstract

The chapter discussed and considered the factors that influence the path planning for military purposed autonomous vehicles. The planning of movement (path planning) for autonomous vehicles is complex process influenced by many categories of factors. The complexity of autonomous vehicles path planning is dramatically increasing in military operational environment when the confrontation with enemy is expected. From operational point of view, it is necessary to considered in which military domain the autonomous vehicles will operate, for example, in Land domain, Air domain or Sea domain. From tactical point of view, there will be group of common factors for each domains and group of different factors for specific domain. As much as possible factors which will be included in consideration of path planning as the part of mathematical algorithms will increase the prerequisite for successful fulfilling of assigned tasks and missions.

Keywords: path planning, military factors, domains, operation environment

1. Introduction

Within last decade the utilization of autonomous vehicles during waged military operations significantly increased in importance. The main factor of their utilization was protection and safe lives of own soldiers or contributors. This trend will surely continue and become relevant in the future as well.

In military operations the decision support systems for utilization of autonomous vehicles have become an integral part of the commander's decision-making process [1]. One of the models of autonomous vehicles are Unmanned Aerial Systems (UAS) mainly utilize for reconnaissance which is the part of the Tactical Decision Support Systems (TDSS) developed at University of Defence, Czech Republic [2]. This system aims at supporting commanders of the Czech Army with their Military Decision-Making Process (MDMP). More detailed information about the integration of TDSS into commander's Troop Leading Procedures (TLP) can be found in [3]. Reconnaissance is one of the crucial parts of intelligence support. Intelligence support is the one of the essential part of MDMP to find a solution for a specific problem allowing to fulfil the assigned mission. It consists of models of military tactics. Each model can solve the corresponding task.

One of many important models in military tactics is the optimal cooperative reconnaissance which is a problem when an area of interest needs to be searched (observed) by multiple military elements (scouts, UAVs, UGVs) as quickly as possible [4].

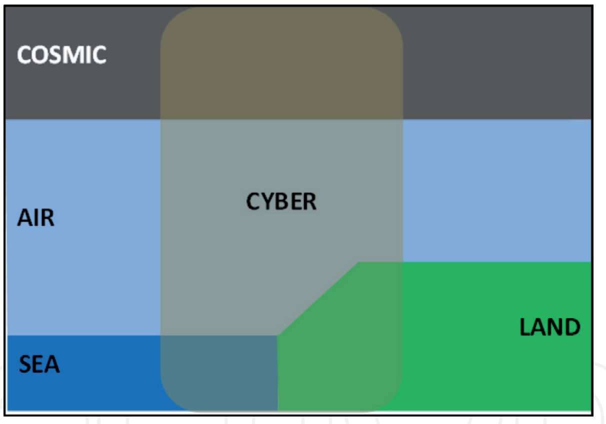

Figure 1.
Military domains in operational environment.

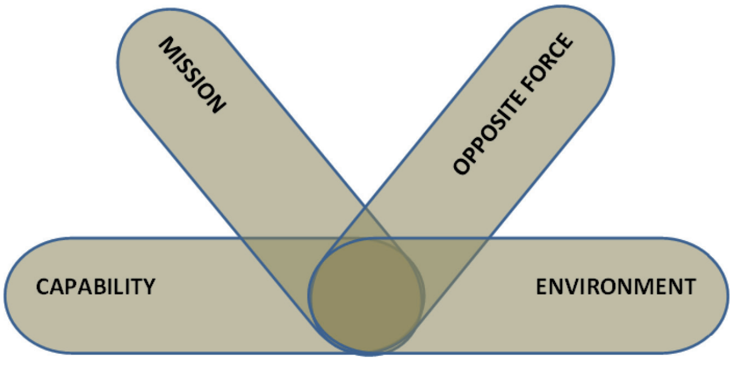

Figure 2.
Categories of factors-steps for consideration and planning.

The operational environment[1] generally consists of factors and conditions that must be understood to successfully apply military capabilities protect the force and complete the mission. It influences the completion of a single mission as well as an entire campaign and its constituent elements [5]. The operational environment includes the sea, land, air and space, the enemy, neutral, friendly and other actors, facilities, weather, terrain, electromagnetic spectrum (EMS) CBRN threats and hazards, and the information environment (e.g., **Figure 1**).

The operational environment of the armed conflicts was, is and will be very diverse and it is involving many aspects. The armed forces must be able to perform a wide range of tactical activities in different domains as Land, Air, Sea, Cosmic and Cyber [5].

Both (all) fighting parties will strive to achieve their goals in the most effective way, including minimizing their loss of life and deployed resources. One of the ways to minimize the loss of lives is the utilization of modern technical means-as autonomous vehicles could be.

Nowadays the predominant domain where fighting parties operate by soldiers is Land. But the most significant domain to gain domination by forces is Air. The multiplier of requested armed forces capabilities to effectively operate in each domain is electromagnetic spectrum.

Focusing on solving issues the Land domain is the most demanding for autonomous vehicles path planning. For ground autonomous vehicles path planning

[1] According to Allied Administrative Publication 6 (AAP-6) the operational environment is defined as: *A composite of the conditions, circumstances and influences that affect the employment of capabilities and bear on the decisions of the commander.*

is possible to apply the analogical approaches as for military units movement planning.

Movement can be understood in broad terms as relocating someone from point to point in order to create conditions for and to be capable carry out particular planned activities after the move is over.

There has to be considered amount of factors that affect the move and the goals set for it (e.g., **Figure 2**). The first step in movement consideration is capability (parameters, technical data) of the autonomous vehicle itself, the second step is the autonomous vehicles mission (recce, destroy, cooperate, transport, refuel, etc.), the third step is opposite acting force and the last step is complexity of environment (terrain, weather, temperature, visibility, etc.).

2. Capability of autonomous vehicles

Most modern armies, assessing, in particular, combat vehicles and its combat capability, evaluate four basic parameters:

1. combat power/special purpose ability,

2. protection (if applicable) of the crew (subsystems),

3. mobility,

4. signal and command.

The utilization of autonomous vehicles for military purposes can be considered in two basic missions, as lethal or non-lethal assets. Within both types of mission the opposite side tries to eliminate autonomous vehicle or to capture it. For development of autonomous vehicle to be used by military purpose should be considered the same approach as for development of the combat vehicles operated by soldiers. The parameters of autonomous vehicles have to meet maximum of factors which are influencing its movement.

According to author's long-life military experiences and deep and comprehensive analysis of the facts in the Army of the Czech Republic Lessons Learned Databases [6] the capabilities of autonomous vehicles can be considered in following ways.

The combat power of the autonomous vehicle will consist of the ability to meet the desired goal. This goal can be "only" to carry out monitoring and to find out the required information about the enemy, the task environment and their transfer to appropriate locations, detect the presence of undesirable substances in the area of operation, and warn troops about the presence of such substances until possible destruction of the enemy and its objects. Autonomous vehicle will be equipped with appropriate sensors and devices for special sub-tasks.

It is necessary to consider the degree of autonomy of the resource for the **issue of protecting** the crew of an autonomous vehicle. Fully autonomous vehicle will be equipped with an artificial intelligence that will enable him to perform the task without any human intervention (collaboration), from his deployment to the fulfilment of the task, including eventual return to assigned assembly area. Partial autonomy may consist in the necessity or only the possibility of intervening in the selected phases of the autonomous vehicle implementation by the operator. The operator may, depending on the specific conditions on the battlefield and their change over the autonomous vehicle deployment planning phase, correct and control selected functions and their interdependence.

Partly autonomous means can be considered as a means of transporting directly to this device, although some of the required functions will be automated and autonomous vehicle operators will either not influence at all or will be able to correct them. Under the declared crew protection (operator), we can understand the "only" protection of the entire device and its component components and sensors in the case of autonomous vehicle.

Like a standard combat vehicle, the autonomous vehicle should be able to withstand the effects of the environment (weather conditions, fulfillment of the task within the required temperature range, in dusty and other environments, etc.) as well as enemy effects in the form of explosive firefighting systems, enemy fire interventions to a certain caliber, contamination or ignition of autonomous vehicle area of operation, etc. An important role in the area of autonomous vehicle resilience and its ability to move and perform tasks in a particular environment will play the location of its components and sensors on the "base" of autonomous vehicle. It can be said that the autonomous vehicle as a whole will be so resistant to environmental influences (both natural and caused by human factor), how least its component, component, sensor will be resistant. Both in the profile (overlapping the sensor above the "base" of the autonomous vehicle) and attaching this sensor to the "base" of the autonomous vehicle and its cabling.

The autonomous vehicles should have the required **mobility parameters**, the ability to perform tasks in the widest possible sense of the word mobility. For most moving assets, and not only for the vehicles used by the army, the following parameters are listed:

- the average speed of the resource depending on the specific communication-on the road, on the ground, etc.,
- maximum travel speed,
- acceleration (usually from zero to desired or maximum),
- ability to overcome climb/descent (usually expressed as a percentage),
- side tilt (usually in degrees),
- crossing the obstacle and pitch,
- consumption and necessity of refueling,
- range,
- the height, width and weight,
- ability to overcome water barriers and a number of other parameters.

Mobility is also related to **terrain throughput**. A tactical view of terrain patency typically features three stages-through terrain (where no action is needed to move the device), partially through terrain (in which action must be taken towards the device or field so that it can be (although some radical measures could be taken to penetrate the terrain, but these measures would be inefficient for time or other reasons). The landing area of autonomous vehicle also relates to its undercarriage. There are terrains that are more suitable for wheeled chassis and on the contrary are terrains that can be easily overcome with tracked chassis. The ideal autonomous vehicle, which would be deployed in different terrain, could have a combined bogie (wheel and belt) where it would autonomously (based on artificial intelligence) evaluate the most suitable variant of the chassis and "deploy" itself (it would move from one platform to second, or the process could be managed by the operator. Similarly, the problem of adhesion conditions could be solved in the sense of increasing or decreasing the contact surface of the undercarriage with the terrain, or an automatic or operator controlled change of autonomous vehicle aperture. For example, in the Russian army some combat vehicles have been introduced, which can change the clearance by up to 30 cm during the movement.

If the vehicle's clearance (vehicle) changes during movement, logically this will change the position of the center of gravity of the device. Due to the generally small dimensions of autonomous vehicle compared to other combat vehicles, the change in autonomous vehicle center of gravity may radically change (as a rule reduce) some other mobility-related features such as side tilt, climb/descending, etc. But this problem is technically feasible for autonomous vehicle. It can be envisaged that by changing the autonomous vehicle's aperture and thus increasing the center of gravity of the device, the autonomous vehicle could either autonomously or by an operator's intervention modify the axle or half-axle of the undercarriage so that at one side of the bottom of the "hull" the second is lower, and the original offshore characteristics can be achieved. With mobility, the dimensions, profile and weight of the autonomous vehicle and its parts, components and sensors are logically related.

The parameters in the **area of signal and command** can be included:

- source sufficiency of the autonomous vehicle as a whole and its individual components (to fulfill their functions),
- the reach of command and control means in case the autonomous vehicle is not completely autonomous (will be operated by the operator),
- transferring data and information obtained by the autonomous vehicle in real-time tasks, various data paths, or even confidentially,
- resistance to interference with the autonomous vehicle control and information transmission system and more.

To fulfill task in any mode of autonomy, the device must be equipped with the most accurate information, parameters and programs. Ideally, autonomous vehicle would be able to "retrieve" real-world information (such as changing the terrain and the terrain, etc.) into its software and, if necessary, by the operator to correct the data and update it.

Among autonomous vehicle requirements that can be perceived as borderline between "combat power" and "mobility", views such as:

- in what environment, in terms of an unfriendly/friendly atmosphere, the autonomous vehicle will move and perform tasks;
- whether their mission will be demonstrative or will be interested in secrecy (until the possible use of lethal weapons) and some others.

3. Mission of autonomous vehicles

Autonomous vehicles (ground or air) are especially valuable in environments where immediate information feedback is needed, manned ground or air vehicles are unavailable or excessive risk or other conditions render use of manned vehicles less than deliberate. The autonomous vehicles can conduct day and night operations to support units.

The autonomous vehicle missions can include:

- Route, area, object and zone reconnaissance,
- Surveillance of named areas of interest (NAIs),
- Adjusting indirect fire weapons, close air support (CAS), and close-in fire support (CIFS),
- Support to:
    - Combat search and rescue (C-SAR),
    - Target acquisition (TA),
    - Battle damage assessment (BDA),
    - Rear area security,
    - Situation awareness (SA) development,
    - Intelligent preparation of battlefield (IPB),
    - Electronic warfare (EW),
    - Communications relay,
    - Mine and chemical detection,
    - Mine cleaning,
    - Weather surveillance,
    - Material and munition resupply,
    - Casualty evacuation.

In case of that autonomous vehicle is equipped by a weapon system (considered as a combat vehicle) it can fulfill combat missions to destroy enemy in open terrain, in vehicles or covered in shelters or in buildings.

Special consideration for mission planning is if autonomous vehicle act independently (alone) or act in cooperation with other vehicle or with units (soldiers) or act in swarming collaboration (dozens of vehicles).

4. Opposite force

The basic factor in the use of the autonomous vehicle will be the possibility of a conflict with the enemy. This factor is based on all other factors and, in particular, on autonomous vehicle technology. In the case of a high probability of a conflict with the enemy it will put demands on the protection of the autonomous vehicle, weapon system, observation systems and autonomous vehicle cloaking. The enemy's factor will further affect the mobility and speed of the autonomous vehicle, which also affects its navigation on the battlefield.

Factors affecting autonomous vehicle movement within conflict with the enemy:

- audio concealment of the enemy movement,
- thermal confidentiality of movement before the enemy,
- vulnerability to air strikes and other enemy means,
- opportunity to observe and conduct fire,
- the ability and speed of capturing advantageous lines or firing positions on the battlefield,
- way of recognizing the enemy,
- start and firing time,
- selection of an effective weapon system to destroy the enemy,
- setting elements for shooting to effectively destroy the enemy,
- possibilities of camouflage,
- the possibility of protection by using space-saving,
- ability to overcome obstacles (see below),
- ability to move at night and under reduced visibility.

5. Environment

Last but not least, the type of autonomous vehicle will influence the intent to use in a specific environment in which the autonomous vehicle fulfills and performs the desired activity. Completely different requirements for autonomous vehicle design, parameters and technology will have an urbanized, hilly and wooded environment and other desert or arctic environment.

The limitations set out help us to specify what type of autonomous vehicle is best for our purposes in order to efficiently use and meet the desired goals of the operation. The following list of factors applies without limitation to all autonomous vehicles. Which factor and level of its impact on the move depends on the choice of the type of autonomous vehicle.

5.1 Geographical factors

One of the basic groups of factors influencing autonomous vehicle movement are factors of a geographical nature. Area of operation will fundamentally affect the process of planning and executing autonomous vehicle moves. Combined with another factor such as weather, these factors are no less important as an opposite force (enemy).

For autonomous vehicle used out of the contact with the enemy for supporting and logistic operations, a set of geographic and hydro meteorological factors are more important than tactical factors.

Geographic factors affecting autonomous vehicle path planning are:

- incline of the terrain relief,
- terrain throughput,
- elevation of the terrain,
- terrain load capacity,
- hide and cover options,
- ability to evaluate key terrain for maneuver,
- frequency of roads and their type (paved, unpaved, forest, etc.)
- the width and clear height when moving along roads,
- characteristics of shores (banks) of waterways and streams,
- the width and depth of rivers, streams and waterways,
- nature of water areas,
- water flow and river flow rate,
- ability to overcome artificially created obstacles.

5.1.1 Terrain relief

The relief of the terrain is the most important element of the physical-geographic conditions at the theater (area of operation). It has an impact on the preparation and conduct of the fighting activities of the troops and especially on their mobility. The fragmentation of the terrain in specific areas of operation determines the choice of the most appropriate directions of the autonomous vehicle activities, its correct evaluation and the use of the peculiarities of the types and shapes of the relief can contribute to the surprising maneuver or to the complete concealment of the movements. The significance of the relief increases with growing fragmentation and altitude.

5.1.2 Terrain throughput

The effect on throughput (cross-country) or activity in the area of operation has obstructions that are either natural or created by human activity. The examples of effects which are obstructing movement of autonomous vehicles are mentioned in Section 5.1.5.

Another aspect of the terrain throughput when moving troops on unpaved roads and in the open terrain is the assessment of their condition, taking into account parameters of the physical condition of the subsoil, which vary depending on the season and the hydro-meteorological conditions.

In the case of forestry throughput, the main factor influencing the use of autonomous vehicle is its inclination. In the case of openness, open-air space will be influenced by the types of vegetation (shrubs, grasses or trees), their density and the space among trees.

5.1.3 Shelters and covers

Evaluating and optimizing the use of terrain shelters and covers will provide autonomous vehicle high level of protection as well as confidentiality of movement. It also makes it possible to estimate possible access routes to the mission area, and the intended gathering points or directions of action of enemy units.

Hidden access and free movement create, depending on the mission in a military operation, so-called key areas. Their knowledge provides a significant advantage in realizing the intentions of who controls the given key space.

5.1.4 Terrain load capacity

The decisive influence on the behavior of autonomous vehicle has the properties of the earth surface with which the vehicle meets its wheels (belts). This surface can be divided into "pavements" (suitably treated surface) and "terrain" (modified only partially-forest or field roads-or not modified at all).

Defining the surface type (grass, asphalt, sand, etc.) characterized by a certain degree of adhesion and rolling resistance is another sub-parameter that will affect autonomous vehicle shifts.

Soil conditions, along with current meteorological conditions (especially rainfall and air and soil temperatures) are logically another factor that cannot be overlooked when planning autonomous vehicle shifts as they greatly affect the autonomous vehicle rate of movement.

5.1.5 Obstacles

Obstacles generally prevent the maneuver from making or directing it from spaces with more favorable or disadvantageous conditions for its implementation. For autonomous vehicle needs, it is necessary to define the types of major obstacles and the autonomous vehicle activity when dealing with the obstacle. It is also necessary for each autonomous vehicle to be able to evaluate the tactical importance of the obstacle at a certain stage of the combat task and to be able to use the obstacle to its own advantage or against the enemy's activity.

Natural obstacles:

- vegetation:
  - species and types of forests and wooded areas,
  - shrubs and ravines
  - sets,
  - hop,
- water:
  - rivers,
  - streams,

  - water tanks,
  - marshes,
  - swamps,
  - wetlands.

Artificial obstacles:

- communication:
  - road,
  - railways,
  - bridges and bridges,
  - passes,
  - tunnels,
  - fords,
- utilities:
  - power lines,
  - pipelines.
- built up areas:
  - buildings and blocks of buildings,
  - power stations,
  - railway station,
- other objects:
  - chimneys,
  - masts,
  - towers,
  - lookout towers.

5.2 Hydro-meteorological factors

Hydro-meteorological conditions create advantages and disadvantages for both the enemy and the troops. Thanks to good knowledge of conditions and correct weather information, we can streamline our own troops and also minimize their adverse effects.

Weather in conjunction with the terrain forms an inseparable and mutually integrated system. The weather affects the visibility, the function of the sensors and the weapons used, the autonomous vehicle's operability, but and already mentioned terrain passage. An important aspect of the weather is that the effect of changing weather does not have to valid information recorded on maps.

In the summer season, the use of ground autonomous vehicle affects above all high air temperature, high dustiness and difficult driving conditions.

By increasing the humidity in the soil, it becomes more difficult to move the fighting techniques to such an extent that the unpaved roads become unstable. The exception is sandy soils, which are dry in the dry state, they are more solid and passable during the wet season.

In winter, the strength of the soil without the snow cover depends on the degree of freezing of the surface layer. At melting (thaw) the thickness of the thawed layer and the frozen layer below it.

Climate factors affecting autonomous vehicle:

- air temperature,
- air pressure,
- humidity and water vapor,
- cloudiness,
- visibility and visibility,
- wind conditions,
- collisions,
- sunshine and radiation.

5.2.1 Air temperatures

Temperature is one of the basic characteristics of the atmosphere. It characterizes the heat state of the air.

Low air temperature in the winter period causes a change in the physical properties of fuels, lubricants and operating materials. It also reduces the capacity of autonomous vehicle batteries. It also works the temperature of the motors, the power of the electrical triggering device and the degree of mechanical wear.

High ambient air temperature adversely affects engine operation. It also affects engine cooling, when less air is sucked into the cylinders. Water and operating fluids are also rapidly evaporating. Higher temperatures risk engine overheating.

5.2.2 Air pressure

All atmospheric objects and the Earth's surface are affected by the pressure caused by the weight of the atmosphere. Changes in pressure are closely related to the development of basic atmospheric processes. Extremely high or low air pressures can affect the autonomous vehicle control and measurement sensors, observation devices or autonomous vehicle navigation modules.

5.2.3 Humidity

Increased air humidity is manifested especially in winter. For the operation of any technique the optimum relative humidity is around 60%. The functions of all groups and subgroups into which the air is accessible are influenced by the high content of water vapor in the air. In the long run, corrosion can occur, thus rendering any part of autonomous vehicle unnecessary. From a tactical point of view, it is possible to ignite and fog the sighting devices, sighting or significant corrosion of parts of weapon systems.

5.2.4 Visibility

Visibility is the maximum distance to which the contours of the object observed in daylight under normal human eye conditions can still be distinguished. At night, it is the longest distance to which light can be distinguished by steady and dimly changing luminosity. Visibility is most affected by precipitation and fog and is therefore dependent on the presence of solid particles and water condensation products in the atmosphere.

Visibility is one of the most important meteorological elements influencing combat activity.

It has a major impact on the exploration, discovery and recognition of the enemy and its activities, the determination of landmarks, and the effective destruction of the enemy's ground and air targets.

5.2.5 Wind conditions

Wind may be a cause that will not allow the required combat tasks to be accomplished. Due to strong winds, the autonomous vehicle may be delayed. And also when it comes to the side wind to overturn the autonomous vehicle and hence the inability to continue moving. Combined with rain or snow, it may icy optical devices or sensors (sensors) and thus makes it impossible to control the autonomous vehicle or to limit its (combat) capabilities.

5.2.6 Precipitation

Precipitation (rain-fall) are a significant factor and have a great impact on soil conditions and thus the slopes of slopes, roads and terrain especially during winter (snow and deep snow). This is mainly the longest rain, after which the soil is saturated with water and thus decreases its load capacity. Long-term precipitation also causes significant changes in the nature of watercourses and surfaces.

In the case of storms, there is a risk of interference with autonomous vehicle thus the decommissioning of its electronic systems.

6. Military factors evaluation for path planning

Proposed factors were identified as the outputs of complex analysis of the facts in the Army of the Czech Republic Lessons Learned Databases [6] and compared by outputs gained from The Army of the Czech Republic Units Leaders who are using military designed autonomous vehicles for fulfilling the military missions.

Factors should not only be considered as factors that negatively affect autonomous vehicle's movement. The opposing forces (enemy) vs. our own can be stated in a general sense that if something adversely affects the activity of the enemy, it is for the own forces an advantage, a positive influence and vice versa. Positive influences must be able to use by autonomous vehicle, negatively minimize or completely suppress.

Some of the above aspects and autonomous vehicle requirements may be conceived at the same time as the factors that will movement of the autonomous vehicle both during the planning phase of the movement and during the management phase of the movement. Some aspects (factors) will be influencing ground autonomous vehicle, the same factor can affect the air autonomous vehicle in a radically different way and intensity.

The influence of this factor can be assessed by different approaches:

- has an effect-it does not affect;
- has a major influence-it has influence-it does not affect (possibly a wider range);
- weight of individual influences-percentage (or point) representation of individual influences, etc.

To more precisely the range of effects and the weight of the individual effects on the autonomous vehicle movement will be determined the better equipped autonomous vehicle could be designed (HW and SW) in order to eliminate or reduce the effects of negative influences and will ultimately be higher quality (reliable, faster, with minimizing losses, …) a combat mission is met. However, the weight of individual influences will likely be variable in relation to the specific task the autonomous vehicle has to fulfill. **The goal to be attained will always be decisive!** And the objective of the mission can be characterized primarily by time, of the type "Fulfill the task even with possible losses, but the decisive criterion is that it must be fulfilled by …" In another mission, the primary criterion may be an effect on the target area, such as "Detect the enemy and destroy it; until you do, do not return!" If necessary, "Complete the task with minimal losses on your own side!", etc. So it is important and decisive to be aware of the factors that influence the movement of autonomous vehicle in the specific situation and the specific task and then assign these factors their specific weight.

The fulfillment of the autonomous vehicle task with the acceptance of individual factors and their weight can be expressed also mathematically (1), e.g.,

$$\mathrm{P}mf = \frac{\mathrm{fpos1\,.\,kpos1 + fpos2\,.\,kpos2 + \ldots + fposn\,.\,kposn}}{\mathrm{fneg1\,.\,kneg1 + fneg2\,.\,kneg2 + \ldots + fnegn\,.\,knegn}} \tag{1}$$

where:

P*mf*, probability of mission fulfilment; fpos1 till *n*, positive factor (1/first/till n/n-th/); kpos1 till *n*, coefficient of positive factor (1/first/till n/n-th/); fneg1 till *n*, negative factor (1/first/till n/n-th/); kneg1 till *n*, coefficient of negative factor (1/first/till n/n-th/).

The coefficient is an integer from one to the value specified by the "assignor of the mission". The coefficients (both positive and negative factors) indicate the weight, the effect of these factors on the fulfillment of the given task. The larger the scale (value) of the coefficients, the more precisely their influence on the task can be defined. The scale can be set, for example, from 1 to 5 (10 and other variants). "Task designer" may even divide these factors into several groups after the factors involved in mission planning, from the point of view of the size of their impact on the task and the individual groups, and their significance separated from each other by a diverse range of coefficients. A group of the most important factors can be evaluated, for

Factors		Influence		Effect weight [number/ order]*
		Positive	Negative	
Preparation of autonomous vehicle to be put in place (time required to get ready for task start)				
Complexity/ease of operation of autonomous vehicle in all phases of task fulfillment (especially in the semi-automatic autonomous vehicle controlled by the operator)			x	
Sufficient capacity of source		x		
Functionality of all components (sensors)		x		
Interaction with "control center" at declared distance		x		
Terrain Pass Through	pass through	x		
	partially through		x	
	impassable		x	
Ability to select the axis of movement without detection by the enemy		x		
Ability to transmit information in the required ways		x		
The existence of enemy means in the transfer space, which can destroy the autonomous vehicle			x	
Autonomous vehicle ability to overtake the enemy in its destruction (to detect and destroy the enemy before he does so)		x		
Heavy detection of autonomous vehicle by enemy means (autonomous vehicle does not produce sounds, smoke, other manifestations, minimizes radiation, etc.)		x		
Easily detection of autonomous vehicle by enemy means			x	
Inapplicability of autonomous vehicle to cooperate with other vehicles in mass deployment			x	
Etc.				

**Specified by the "assignor of the mission".*

Table 1.
Example of evaluation factors influencing autonomous vehicle movement.

example, coefficients ranging from 1 to 10, a group of minor factors, coefficients in the range 1–6, and a group of least significant factors, coefficients in the range 1–3.

The result of calculating the probability of completing a task is either left in a fraction that is adjusted to the "number" on the numerator or denominator side (e.g., 1/3.8 or 2.6/1). Such a fraction shape gives a multiple predominance of the probability of fulfilling/not fulfilling the task.

The possible factors affecting the ground autonomous vehicle (as listed in **Table 1**) to which the "assignor of a particular task" has to assign a specific value before commencing (in the mission planning process).

7. Approach to the maneuver optimization

One of the approach for optimizing the autonomous vehicle maneuver in the conditions of the opposition forces is to utilize advantages of modelling combat activities. During the military decision making process, commander and his staff members use a series of models and programs to accelerate and refine decision-making and operation missions. Example of good practise is exploitation of model of cooperative reconnaissance as part of Tactical Decision Support System [7]. According to [8], the fundamental approach is based on a sequence of procedures and the weighted integration of discrete layers, where all phases converge to a maneuver optimization issued from modified versions of Floyd-Warshall algorithm. Initial C++ application was designed for a basic experiments, providing relatively fast solution (derived from path-finding algorithms used in autonomous systems), whose task was to verify theoretical approach and the time profile of solution. If it is necessary, application could find alternative routes with more-favorable movement factor.

Fundamental theoretical approach in that case was inspired by Floyd-Warshall algorithm [8]. Original algorithm was pushed throughout several modifications that make it computationally applicable even for a large data structures comprising more than 106 nodes. Basic adjustment lay in elimination of so-called reverse cycles by stopping the 82 calculation on all nodes in its root.

This process is carried out through the main field elements chosen for next phase solution. The status and verification cycle matches the bit position in the bit field with the position of the active element in the default structure. If the element belongs to a root what was modified (attribute is present), the element is excluded from the processing in the following iterative phase because it will be modified in the next steps.

This process is theoretically simple; however, the realization of this step is relatively difficult in practice, because the memory performance **P**n achieves (2):

$$\mathbf{P}\mathrm{n} = \frac{\mathbf{N}^2}{8} \tag{2}$$

where: N is the number of nodes (elements) of the graph.

It means that models which contain more than 106 nodes must allocate over 125 GB memory only for genetic structure of each element. In the case of information transfer into other elements the amount of operations raise to a level that is incompatible neither with the real time application, nor on the fastest nowadays computers. It is therefore necessary to address the sub-problem in a different way and optimize the whole process by other approach. Previously mentioned idea works well but for a wide set of nodes (more than 106) is ineffective.

For the purpose of utilizing autonomous vehicle in role as reconnaissance means is the part of MDMP to plan the reconnaissance operation of the area of interest. For optimization of using more than one air autonomous vehicle so called as Unmanned Air Vehicle (UAV) in one assigned mission was developed model for optimization of using swarm of UAV to effectively reconnaissance the area of interest [2].

The objective of the model is specified in Formula (3) which is to minimize the maximum time of flight of all routes of individual UAS in the fleet. The details of the model along with its complete mathematical formulation can be found in [8].

$$\text{minimize}\ (\max(T_1, T_2, \ldots, T_N)) \tag{3}$$

where Ti is the time of flight of i-th UAS in the fleet, N is the total number of UAS in the fleet.

The model of UAS Reconnaissance is similar to the Multi-Depot Vehicle Routing Problem (MDVRP) [9, 10]. The MDVRP is also about optimization of routes of a set of vehicles originating from multiple depots to visit a number of customers to deliver goods or services. There is, however, the significant difference between the models. While the main objective of the MDVRP is to minimize the total distance travelled by all vehicles which is expressed in Formula (4), the objective of the UAS Reconnaissance is to minimize the time of whole operation as already mentioned in Formula (1).

$$\text{minimize}\left(\sum_{i=1}^{N} Di\right) \tag{4}$$

where Di is the distance travelled by i-th vehicle, N is the total number of vehicles.

For verification of the proposed UAS Reconnaissance model there were designed two scenarios of tactical situation and applied experiments in real terrain with real UAV's [2, 11].

8. Conclusion

The information mentioned in the text of the chapter could not provide an exhaustive overview of all the factors that may influence the planning of the moving of autonomous vehicles. In the chapter there is presented a view especially on the military factors, respectively, factors from a military perspective when using autonomous vehicles in environments conducting military operations. In the case of the use of autonomous vehicles in military operations, the factory has no influence on whether an enemy will be operating in the environment in order to take measures against the effects of autonomous vehicles and to eliminate their activities to the maximum.

The chapter did not address the issue of methodology when planning the transfer of autonomous vehicles, which goes to the chapter itself.

Mentioned information can be used as a guideline in which detail to contemplate when intending to use autonomous vehicles in military operations.

Acknowledgements

For the Section 6 was utilized research outputs of academics workers of Department of Tactics Faculty of Military Leadership and one former academic worker LTC Assoc. Professor Jan Mazal, Ph.D. who is actually in duty as Head of Education and Training Department NATO Modelling & Simulation Centre of Excellence in Rome. For purposes of verification proposed models of autonomous systems path planning optimization by experiments is used synthetics and virtual environment rendered by tactical virtual simulator Virtual Battlespace [12, 13].

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