Combat unmanned ground vehicles: Perspectives for implementation into operational application

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Abstract: *Combat Unmanned Ground Vehicles (UGV´s) are platforms designed for the replacement of the human element on the battlefield. Their autonomy depends on their respective level of technical development. Many armies invest varying levels of effort into the development of prototypes and solutions of UGV´s. They have various abilities and limits. This article uses open sources while identifying the current global state of perspectives in the short term. The authors are convinced that artificial intelligence, military robotics, and its implementation into operational structures can disrupt the process of conflict and will have a strong impact on the ratio of forces in regions throughout the world.*

Keywords*: AUTONOMY, ARTIFICIAL INTELLIGENCE, DISRUPTIVE TECHNOLOGY, MILITARY ROBOTICS, UNMANNED GROUND VEHICLE.*

1. Introduction, methodology and a means for solving the problem

Robotic systems and applied military robots are characterized by their ability to perform tasks in an autonomous or any other mode, as applicable. Thus, they carry out operations vicariously for humans. Weapons and weapon systems like this are called hybrid man-machine systems in the context of this operational research. In recent years, we have seen massive development in the field of robotics in both military and civilian spheres. In the military sphere, this mainly includes its deployment in military operations, where it performs a diverse spectrum of tasks. These systems and their subsystems are developed and tested intensively by military science.

The effort of leaders in the field of military robotics and autonomous systems is aimed at gaining the upper hand on the battlefield, which is to be greatly aided by the aforesaid means. Disruptive technologies are disruptive because they are able to significantly reverse the force ratio using quite unique features such as extreme speed of information processing and decision making, accuracy, or low cost when compared to the use of traditional man-machine systems. [1] Ultimately, they represent an option that gives soldiers a better chance of surviving on the battlefield. Further, these means enhance C4I capabilities, sustainability and mobility in military operations. So, they favour the side of the conflict that has these systems in place more broadly. On the other hand, it is necessary to ensure the resilience of the entire system in which the robotic system operates, because its disruption can cause the collapse of the entire system. Typically, this would involve cyber-attacks or operating in an electromagnetic spectrum. This issue has been evolving very dynamically, and every year we can observe significant technical changes, innovations as well as resulting changes in the possibilities of application.

Military robotics is an area supported within NATO, but so far more effective work has been done by development teams and experts at the national level than by alliance teams and working groups both within NATO (e.g. USA) and outside (Israel, Russia, China, India). This is demonstrated by output in the form of the means themselves and their capabilities.

The authors' long-term work deals with the tactical level of a conflict on land, with a focus on tactical task forces. The objective of this article (review article) is to identify and describe the current state applicable to the categories of UGVs operating at the tactical level and, based on the state and trends, to present an estimate of prospective developments for the short and the medium terms.

To reach the widest possible readership, the authors will apply the following divisions and definitions of the subject matter of investigation.

The robotic systems can be divided (categorised) according to a number of various aspects. In regard to the content of this article, we will deal with the breakdown by operational domain according to [2]. Depending on the environment in which the robotic (remotely controlled/unmanned) systems are used, we can divide them as follows:

- Air domain – Unmanned Aircraft Systems, UAS;
- Land domain – Unmanned Ground Systems, UGS;
- Sea domain – Unmanned Maritime Systems;
- Space domain – Unmanned Aerospace Systems;
- Cyberspace domain – Self-acting Software.

According to the manner of controlling each system, the machines are divided as follows:

- Directly controlled machine – it is operated on the basis of direct control by the operator, without its own decision-making capability; except for the human interface, it does not need any interaction with the environment (e.g. driving a car without ABS, ESP functions, direct control of a 1st generation machine tool), because this interaction is fully ensured by the human operator;
- Controlled machine – it is operated based on immediate instructions given by the operator, has a simple logical decision-making capability like a finite-state machine (e.g. an elevator stops only on the pre-set floor, an intelligence with one-bit memory, a door hold button, a semi-automatic car transmission, 2nd generation machine tools, etc.);
- Regulated machine – basically, it is a controlled machine that achieves goals in a predetermined way, i.e. it achieves the goal under different conditions, in different ways, including an analogue resolution of the degree of phenomenon intensity (e.g. when a new target station is suddenly selected during the elevator ride just before such level is reached, the elevator will prefer to pass the level and will return without stopping immediately; or driving a modern car equipped with an automatic transmission and with ABS, ASR, ESP functions, etc.);
- Remotely controlled/regulated machine – it is operated on the basis of the instructions given by the operator who is located separately from the machine. The operation of such a machine is then strongly dependent on the operator-machine transmission route. In all cases above,

the human operator is a part of the control loop of the machine (system);

- A semi-autonomous machine, also referred to as a machine with some autonomous functions, achieves the goal in the manner it chooses (however, the methods that can be used for selecting are still prescribed, e.g. by a software with defined algorithms). Although the machine can still follow the most direct path assumed, it does not foresee such paths in any way, it always verifies the path again and again; and in case of sudden obstacles, the machine itself even searches (based on the human-predefined algorithms) for the optimal path to achieve the goal, without limiting the distance from the original straight direction. The human operator is no longer part of the machine's (system's) control loop, but still gives a specific task to the machine, i.e. a goal that the machine is supposed to achieve, and checks its achievement or corrects its goals;
- A fully autonomous machine chooses its own goals and ways to achieve them (based on algorithms) itself; its operation no longer requires humans, it is a robotic system with artificial intelligence.

The robotic autonomous system (RAS), in this case UGV, in the autonomous vehicle variant will have the following capabilities and properties [3]:

- to collect information about the environment (e.g. creating maps of building interiors);
- to detect objects of interest such as people and vehicles;
- to move between waypoints without assistance from human navigation;
- to operate without human intervention for an extended period of time;
- to avoid situations that are harmful to people, property or itself unless they are part of its design specifications;
- to search for or remove explosives;
- to repair itself without external assistance;
- the robot can also learn independently. Autonomous learning involves the ability to learn or acquire new functions without external assistance, to adjust the process of performing a task depending on the surrounding environment, to adapt to the environment without external assistance, to develop an ethical sense of achieving mission goals.

In addition, it will consist of the following (general) components:

- platform;
- sensors;
- control systems;
- guidance interface;
- communication links;
- system integration functions;
- combat (or another specialized) superstructure, or a power system (e.g. a weapon).

The methodology for the compiling of this article was based on open-source literary research. After obtaining the source base, the information was sorted and categorized. Subsequently, comparisons were made, and penetrations or differences were identified. Based on the broad overview obtained, the selected examples were used to demonstrate the representatives of those means that typically present the given problem or issue in question.

2. Description of the current state of military robotics

The first area and contradiction is the categorisation by size or weight. A variety of divisions exists. Many countries profiling themselves in the area of military robotics have their own classification system. In the USA, for example, the Navy and Army apply a different classification method. India [4], China, and Israel have established their own systems. The common element is the division in categories, but quite often both the number of categories and the respective weight differ. The authors have tried to find a common intersection:

- micro (in the order of hundreds of grams to kilograms)
- mini (kilograms, a few tens of kilograms)
- small (hundreds of kilograms)
- medium (units of tons)
- big (over 10 tons)

The aforementioned fact does not have a very significant impact on the development and use of UGVs.

There are several directions or approaches to combat UGVs that have been more or less successful.

A part of the UGV design is based on the platform of a vehicle originally operated by humans (off-road, combat), either with a wheeled or tracked chassis. An example of such a design is the Wingman vehicle (within the US Army Robotic Combat Vehicle project) with the chassis of an HMMWV vehicle or a Wiesel tracked vehicle [5] by Rheinmetal. Another example is the Black Knight UGV from Great Britain that uses vehicle components by Bradley.

Other UGVs come with their own platforms, whether using wheels or tracks. Most of them fall into the category ´mini´ or ´small´. An example is the W-MUTT from the USA. [6].

In addition to the lethal function itself, the UGVs can integrate sensor or carrier functions.

All types of UGVs, if equipped with a weapon station and a sensory system, are based on already proven weapon solutions. Again, there are several approaches. The combination of blowback and a vehicle's centre of gravity in unstable terrain (typical for a battlefield) represents a significant limiting factor. As a result, there are 2 principal solutions; the use of weapons without blowback (missiles), or weapons with blowback. This in turn places demands on the vehicle stability and, proportionally, on the weight and size. Therefore, manufacturers and users alike, when required to reduce the size, must take into account the need to use missiles or smaller-calibre weapons, as applicable. On the other hand, this gives the possibility of using various less common types of ammunition, e.g. loitering ammunition, sub-calibre or otherwise specific types of projectiles.

Russia applies its own approach, which the authors consider as one of the best. It has a number of UGV prototypes, some of which have been tested in modern conflicts with varying levels of success. The “family” of Kungas UGVs [7], which includes all categories of UGVs, is worth noting.

The miniature UGVs, referred to as micro-UGVs [8], which due to their size can support certain types of tactical tasks performed, e.g. by special forces or light infantry, can be considered a separate area. They are very small (similar to a remotely controlled toy car) and equipped with a weapon of smaller calibre and power (e.g. a 9mm pistol barrel with one or several projectiles in the magazine). They are able to approach the target undetected and eliminate it at short range.

Summarizing the results of the research, the following findings can be made:

- Over the past five years, the area of military robotics has made a major shift, particularly towards the application of RAS;
- The operational deployment of the UGVs has taken place; so far, the Russian deployment in the Syrian conflict is known [9], and a number of problems corresponding to the bullets below have been encountered. Robotic systems are deployed in Israel [10], and more advanced systems are gradually being used [11]. But their more extended deployment in different parts of the world, in different types of conflicts as well as the use of robotic systems of different levels and different origins [12] can be expected;
- Weapon systems are decisive for vehicle robustness;
- The autonomy of movement in rugged terrain is not fully resolved, or rather a human being is still more efficient than a machine in this regard [13];
- Currently, most UGVs are not yet technically prepared for fully automatic operation, especially with regard to decision-making processes and the sensory system [14], [15];
- Localization, self-localization and terrain evaluation (e.g. building damage, GPS signal failure in a built-up area) limit manoeuvring [16];
- In the context of artificial intelligence, we are currently discussing so-called "weak" artificial intelligence, where a robot - UGV responds, based on predefined algorithms, in a machine-like manner but does not actually understand the problem;
- Combat Identification [17] needs to be refined in order to have at least the same level of confidence as a human operator to eliminate every potential target. This goes hand in hand with the target prioritization that is not yet fully mastered by current robots;
- The robot is not prepared for performing the tasks of escalation of force depending on different types of signals, so far this is inherent only to humans. In particular, biomimetics and bioacoustics are not at such a level that would enable it to replace a human operator by a robot in this respect [17], including emotional states and intuitive responses.
- The ethical level [18] needs to be resolved, i.e. to what extent the machine should perform the task autonomously and at what point should it be controlled by a human operator;

From the aforesaid results, which are based on freely available technical and scientific articles, it is clear that the implementation into structures of land forces is a broader problem than simple inclusion into a unit formation. From the point of view of military theory, this is a major milestone.

3. Perspectives for implementation, discussion

The robots, including UGVs, will operate in autonomous mode using AI and based on pre-planned missions. These missions will be planned by humans themselves or by humans with computer support (AI). In any case, the humans must authorize the mission, including the knowledge of the UGV´s behaviour in autonomous mode. This places not only high technical and tactical demands on the humans, but also on the ability of a holistic approach for fulfilling the tasks and missions.

The humans will be able to control and interfere with the UGV operation using virtual reality. Similarly, they will only be able to monitor the operation of the UGV. Another qualitative step forward will include the use of augmented reality to control or monitor the robot's activities. Inputs and data (e.g. a base map, a common operational picture, an anticipated manoeuvre of friendly or hostile forces, etc.) will be displayed in the real environment. Augmented reality will be able to use multiple inputs and sensors, over time even those that come from different levels of command and control.

An option will include "tele-presence", i.e. inducing a feeling of presence and experiencing such states as if the operator or the observer were present on the battlefield.

Human-robot collaboration is already in place, for example, when a human operator marks a target and the robot destroys it. Fire control will also be performed in a more sophisticated way, with human-robot collaboration in the field.

Weak artificial intelligence will be improved, and in the medium term, there is a potential to create "strong artificial intelligence" where the robot understands the problem. Unlike the current situation, the robot will be able to perform a large part of the tasks completely on its own.

Gradual steps will be taken to introduce UGVs into standard unit structures. Realistically, and having regard to several factors (safety, preparation of a new generation of operators, more technologically advanced systems), it seems appropriate to implement small semi-autonomous systems. These can function as firing modules (e.g. replacing the profitable sets of antitank missiles). Once successfully implemented, the semi-autonomous vehicles can be introduced as a permanent item of the equipment of units.

The aforesaid systems will be interconnected and will increasingly interact with other 21st century means, e.g. loitering ammunition that will become a standard item of combat unit equipment. Subsequently, the autonomy of UGV-based entities will be increasingly enhanced. Based on the current results and experience from the so-called "swarming", the swarms of UGVs cooperating with UAVs will be used in combat. The UAVs (drones) will be an integral part of such a unit.

The above development will be assisted by gaining the capability of multispectral data fusion and by sharing the data from remote sensory systems that may originate from other domains.

4. Conclusion

Military robotics has been undergoing a rapid evolution. It can be assumed that the side of the conflict possessing new, modern and resilient technology will have a significant technological advantage on the modern battlefield. This superiority is likely to ensure victory in the physical component of the conflict.

Support of the development and implementation into unit structures, including operational deployment, is a means for introducing such systems. Operational deployment enables the ability to gain non-transferable experience and accelerate further development. The sooner this process occurs, the more prepared such sides will be for a new type of war.

A response in the form of an approach to the education of future commanders is also an integral part of military science and the development of applied military robotics. It is the upcoming generation that will apply the theses presented in this article.

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