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UGVs SUPPORT TO NAVAL OPERATIONS

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Abstract: *The article is presenting actual state of the art UGVs capabilities and employment in support of naval operations. The paper provides a demanding inquiry of the Black Sea environment and, in this regard, the ways to employ UGVs in support of naval operations conducted in this basin, especially in the grey waters area. As UGVs can be employed alone, as soldiers companion or multiple vehicles, the paper underlines strong points and shortfalls regarding human-vehicle interaction, "cooperation" between multiple vehicles, and the possibility and opportunity to employ such platforms in conjunction with other manned or unmanned platforms. In the concluding section, the paper gives some directions of research necessary to improve the ability of this vehicle to support naval operations.*

Keywords: Black Sea, littoral operations, naval, UGV, robots.

1. Introduction

Nowadays, with the real technological advance, mobile robots, referred to as Unmanned Ground Vehicles (UGVs), are used in a variety of domains, such as:agriculture to enhance production; space exploration; nuclear plants; areas with harmful gases leakage; mining; search and rescue; border patrollers; shipping and many others [1-3]. Due to their feature of being capable of conducting tedious, dirty, and dangerous missions, the military domain is the perfect home for UGVs [1, 4]. On the battlefield these robots can conduct reconnaissance operations, specially look "over the hill" or "around the corner," security patrols, target acquisition and lethal or non-lethal engagement, Explosive Ordnance Disposal (EOD) tasks, investigate interior spaces in urban operations or caves and concealed areas in non-urban assignments and logistics tasks. Also, they can conduct Chemical Bacteriological Radiological and Nuclear (CBRN) reconnaissance, deceiving operations, Electronic Warfare (EW), as a communications platform, or to adjunct other unmanned, respectivelyhuman-crewed vehicles (Unmanned Aerial Vehicles - UAVs, Unmanned Underwater Vehicles - UUVs) [5-9]. In the military area, all branches and services can use UGVs, but their home seems to be in the Army and the Navy, mostly in littoral operations and the ones conducted by the marine infantry. In support of naval operations, these robots can execute reconnoitre of the beaches, mine reconnaissance and clearance on the beach, in very shallow water and surf zones (VSW/SZ), interior reconnaissance in built areas or caves, concealed areas in open spaces, base security, security patrols and communications platforms [1]. The main feature which fuelled the development of these vehicles is the augmentation of personnel life, especially in destructive

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environments such as the battlefield [3,6,7,10].

The paper presents a means by which to support naval actions by UGVs concerning the Black Sea environment. This sea basin is almost enclosed, changing waters just through the Bosporus Strait with the Marmara Sea and further with the Mediterranean Sea and through Kerch Strait with the Azov Sea. Thus, the salinity of this sea is reduced - 18‰ at the surface, almost half of the planetary ocean salinity. This low salinity is due to considerable river waters intake and weak exchange of waters. The turbidity of the Black Sea waters is high owing to river influx and low swap of waters. The bathymetry of the Black Sea (figure 1) with a broad shelf in the north-western part is the perfect home for littoral operations [11 - 14].

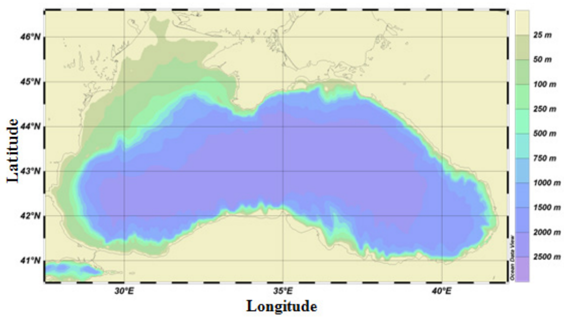

Figure 1: Black Sea bathymetry map [11]

2. UGV – system description

There are numerousfacets to consider when discussing UGVs, but this paper considers just some of them regarding classification, composition, capabilities, and the suitability of employment in the support of grey waters operations into the Black Sea basin.

2.1 Classification

Though unmanned ground vehicles are multifaceted, the current work focuses on their sizes, missions conducted, capabilities, and level of autonomy.

Regarding sizes, there are different approaches, but the majority tend to divide these systems in:

Category		Mass (tons)	
[1]	[7]	[1]	[7]
Heavy	Large	> 15	> 0.9
Medium		1-15	0.09 - 0.9
Small		0.18 - 0.9	0.0045 - 0.09
Lightweight	Micro	< 0.18	< 0.0045

Table 1 UGVs by size [1, 7]

If we analyse the level of autonomy, this can vary from wholly tele-operated to full autonomous with different levels of semi-autonomy.

Tele-operated UGVs (TUGV) – the robot is controlled by a human operator who conducts all cognitive processes based on sensor equipment onboard the vehicle indications.

Semiautonomous Proceeder / Follower (SAP/FUGV) - the requirement for proceeder is to have sufficient autonomy and reliable communication link as it is moving ahead of its controller who can be dismounted or onboard of a crewed vehicle. SAP/FUGV has enough cognitive processes to perform a simple task like choosing the best route.

Platform-centric Autonomous Ground Vehicle (PCAGV) - capable of conducting missions assigned by the controller in an aggressive environment and able to auto-protect.

Network-centric Autonomous Ground Vehicle (NCAGV) - enough autonomy to operate alone as a node in a network-centric conflict [5].

2.2 UGV composition

As a system, a UGV consists of a series of interconnected and interdependent subsystems.

The components of UGVs can organize in subsystems responsible for the interaction between human and vehicle, energy, mobility, health and maintenance, autonomous behaviour, communications,and miscellaneous (figure 2).

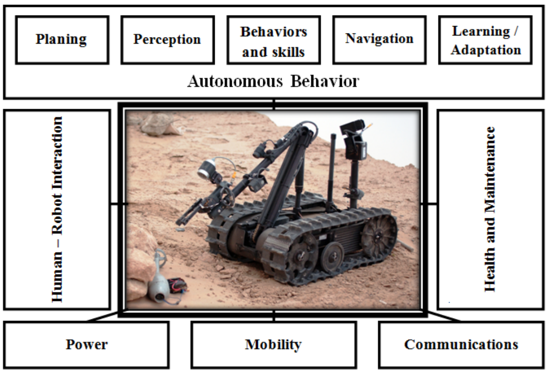

Figure 2: UGV subsystems [5, 15]

Mobility - this subsystem is responsible for the ability of the vehicle to negotiate with obstacles and rough terrain - aspect of paramount importance for terrain such as sandy, sloppy or muddy beaches or VSW/SZ.Though UGV can have a peculiar design compared with their manned counterparts,they lack human driver judgment. A high mobility vehicle meant to accomplish complex missions.

Communications - the UGVs share the same drawbacks with human-crewed systems; the difference is that thosecrewless vehicles are more communications dependant. Line of sight (LoS) can be easily lost, cooperation with other vehicles – UAVs can enhance this capability. In VSW/SZ operations, LoS communication is possible if UGVs can raise an antenna above water level - sea wave dependant. Line of sight (LoS) can be easily lost, cooperation with other vehicles - UAVs can enhance this capability.

A UGV manages to adjunct an Unmanned Underwater Vehicle - UUV, which releases a buoy or periscope for LoS communications; this is the case of the Black Sea with high turbidity water, which negatively impact on the acoustic communications.

A shared vision for both manned and unmanned vehicles is necessary and also compatibility between all assets conducting operations.

Power - energetic requirements of the small robot subsystems can be met using batteries while for large applications engines with internal combustion can accomplish their requirements but with a negative impact on acoustic and infrared (IR) signatures or the environment. Energy storage is under research; on station refuelling/recharging can be considered.

Human-Robot Interaction - military UGV require more developed interfaces compared with civil applications - yell for voice, and gestures commands input. This component also relies on the communications subsystem.

Health and maintenance - this subsystem isresponsible for monitoring robot state and reporting to an operator likely faults or alerting when the vehicle requires intervention contributing to the overall robustness of the robot [1,5].

Autonomous behaviour - consists of 5 components, namely: planning, perception, behaviours and skills, navigation, and learning/adaptation, which will be detailed below.

Planning - UGVs operation encompasses *path planning*, which is related to the trajectory to be followed by a robot to accomplish the mission, and *mission planning* - capacity of the vehicle to determine the best procedure in the tactical situation concerning adversary and friendly forces, environment and procedures. This component requires state of the art software, able and efficient processing devices.

Perception-is responsible for situational awareness and mobility of the robot. The related technology comprises processors, dedicated software, and sensors.

Behaviours and skills - this area requires more attention, especially in multiple vehicle cooperation matters. This subsystem is also responsible for individual robot behaviour generating adequate tactical response and survivability. The cooperative behaviour is essential for the success of naval operation where cooperation between crewless vehicles

(UUVs, UGVs, UAVs, and Unmanned Surface Vehicles - USVs) is essential.
Navigation - this subsystem is dependent on perception, planning, behaviours, human-machine interface, and communications. This component is responsible for providing data for updated own position, friendly and adversary assets, future position, and the waypoints to be followed. Providing sufficient data for autonomous navigation is still a challenge.
Learning/Adaptation – probably the most research demanding area. Complex and continuously changing of the tactical environment make the robot difficult to permanently adapt to new situations and changes though some progress in obstacle detection and avoidance is foreseeable [1, 5].

3. SWOT analysis

The analysis considers UGVs in general, but the focus is on the ones which are suitable to provide support to naval operations.

3.1 Strengths

Cost - generally, the cost of vehicles is proportional to their mass. As most UGVs have reduced sizes, their cost is reduced. The operation cost is also reduced, energetic requirements for small vehicles being also small.
Endurance - UGVsare capable of continuously operating longer than their manned counterparts. Their endurance can adjust in days or weeks, but this is affecting the speed of the vehicle: to increase the endurance, it has to operate at moderate speed.
Cooperative behaviour- the cooperation between a UGV and another vehicle was successfully demonstrated, though the cooperation and remote operation of many vehicles are far from reality [1, 5].
Reduction of casualties - this feature triggered, in fact, the recrudescence of

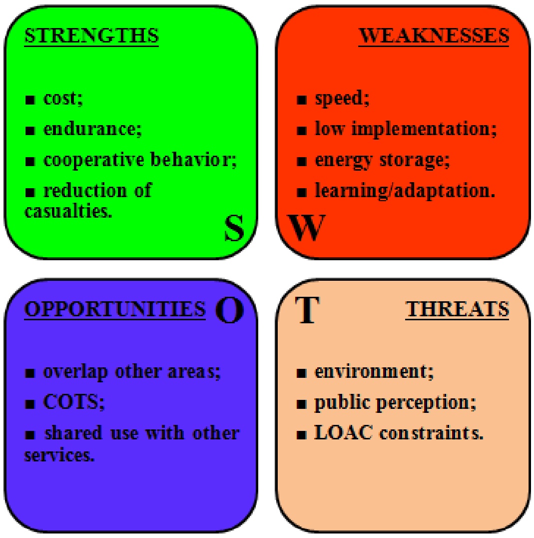

Figure 3: SWOT analysis

unmanned vehicles. The reduction of death and injuries toll on the battlefield and in dangerous environments in general. As in the past, marine mammals used to work for reconnoitring and clearance of VSW/SZ, nowadays with the availability of these vehicles, navies are encouraged to close these programmes [1, 3, 4, 8, 9].

3.2 Weaknesses

Speed - as mentioned before, the speed ability is sacrificed for the benefit of endurance. A solution to curb this shortfall could be on-station recharging/refuelling.
Low implementation -even though thatthere is a lot of research and projects regarding crewless vehicles, there are few vehicles in use. This low employment is a result of organizational resilience and competition for funding with manned programs.
Energy storage - unmanned vehicles can be designed in unusual ways compared with habited ones. Though the onboard space for batteries/fuel is not enough or a specific mission cannot just halt and wait for the vehicle to be called to the base and refuelled. Unmanned vehicles - power bank carriers for recharging batteries and crewless ground cisterns are to consider.
Learning/adaptation - this subsystem and concept, at the same time, require more in-depth research and analysis. Some steps have been completed so far, but still, issues

like data processing, navigation, sensors and algorithms are going to be further investigated and addressed [1,5,8,9].

3.3 Opportunities

Overlap other areas -as UGVs are in use on a large scale, the ones designed or equipped for support of naval operations can benefit from the availability of previous research, the similarity of components, or even conventional sensor devices or payloads.

Commercial On The Shelf - components used in the development of manned vehicles or other vehicles designed for other activities are broadly available.

Shared use with other services – to avoid funding competition, the same vehicles can be designed to fulfil a broad palette of requirements and can be commonly used by different categories of forces/services, i.e., Army and Navy.

3.4 Threats

Environment - in a VSW/SZ area, a UGV can find challenges like waves, yielding soil, rough terrain, turbid waters, and acoustic noise with a negative impact on mobility, sensors, and communications [1].

Public perception - the society and the political decision-makers are not comfortable with the idea that robots can have their conscience - autonomy resulting in disapproval of unmanned vehicle development [6].

Law of Armed Conflict (LOAC) constraints
Specialists in human rights and LOAC wow that a machine, though autonomous, is not capable of complying with all International Humanitarian Law principles. Up to now, a common legal framework regarding the development and use of UGVs is not yet enforced [6].

4. Conclusions

The features of UGVs proved that they are useful assets, especially in VSW/SZ, protecting soldiers, and conducting tedious, unsafe, and unpleasant tasks in an environment difficult to be managed by human operators.

It is required thatmore projects should be implementedand the vehicles be shared, meaning that their design and payloads are capable of responding to a broad area of requirements.

Storage of energy, learning and adaptation, and legal matters are areas that need further attention. There is also enough space for further research in the area of human-robot interaction where futuristic mimic and voice input commands interfaces require further consideration.

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