Future Robots Using in C-IED Detection

Marian Janusz ŁOPATKA[1], Tomasz MUSZYŃSKI[2]

Military University of Technology, Institute of Mechanical Engineering, 2 gen. Witolda Urbanowicza Street, 00-908, Poland
E-mails: [1] marian.lopatka@wat.edu.pl; [2] tomasz.muszynski@wat.edu.pl

Abstract
In contemporary conflicts the IED and mines threats are growing. In paper the concept of using engineer robots in counter IED operation are described. To fulfil this analyses the cooperation between varied class robots are proposed.

KEY WORDS: *mobile robot, engineer robot, Unmanned Ground Vehicle, UGV, EOD/IED tasks, C-IED.*

1. Introduction

Modern military conflicts and actions, such as the conquering of Mosul in Iraq, Rakka in Syria and operations in Donbas, provide evidence to the rising role of using mine groups, mine traps, as well as IEDs. In offensive actions IEDs and mines placed on roads and main communication routes prove to be of utmost importance, especially in cars and on roadsides (including buildings in direct proximity of streets). They are, however, the main source of losses in both combat techniques and live forces.Recent years have witnessed a rapid development of engineering platforms (also known as engineering robots) and the range of their usage. It is currently predicted that they will be exploited in asymmetrical actions, conflicts of low intensity and more classical combat actions. They are mainly used in following areas:

- engineering support of patrol actions of military subdivisions;
- engineering support of combat actions in urbanized areas;
- engineering patrol and maintenance of roads;
- realization of EOD/IED tasks.

2. Investigation Results

Engineering support for patrol activities occurs mainly during asymmetrical operations. General military units patrol the area most often using full-time, armored vehicles that provide fire protection and support. In unfavorable conditions or in the case of the need to thoroughly check the terrain, they pass into pedestrian traffic. The greatest threat to patrols are booby traps. For these reasons, these patrols are reinforcing the sapper section, whose task is to recognize suspected places and objects indicated by general military reconnaissance and neutralization of detected traps. Currently during supporting infantry teams by assigned EOD specialists, light are most commonly used robots (around 10-20 kg)- tab. 1. This is due to the limited transport possibilities (limited space) of the standard AFV (BWP) - not adapted to the transport of robots. They serve mainly as reconnaissance platforms for the optical confirmation and possibly identification of threats identified by soldiers. Under favorable conditions, they can also be used to neutralize hazards by providing a destructive load. Their low payload and low battery capacity means that they are practically not used to detect and search for IEDs. In addition, their use is limited to extremely favorable environmental conditions. They are therefore used most often in urbanized areas, inside buildings and on paved roads. Their working capabilities as carriers of detection systems should be assessed as very low. The basic robots for EOD sub units are portable robots (about 75 kg - for carrying 2 soldiers) - tab.2 Their load capacity and lifting capacity allow for more effective identification and identification of threats. They have the ability to reveal hidden elements and in favorable conditions to intervene and are also capable of transferring detection systems - e.g. magnetic detectors and mini ground penetrating radars.

They have much better terrain mobility and the ability to overcome obstacles - they can be effectively used in urbanized areas and in open areas. Larger vegetation, e.g. cereals, can however effectively limit the movement of such robots. Their effective working time is about 2 hours. Hence, due to the increased demand for energy by detection systems, the patrol capabilities are limited. For the same reasons, the width of the recognized transition and the speed / velocity of recognition are also limited. As a result, their use is effective over relatively short distances not exceeding 0.5 km.

Generally, robots to support patrols of general military units are expected to be highly transport-friendly, have a short time to prepare for operation and have an effective working range of 200-400 m (nominal range 400-800 m). As the experience indicates, it is advisable to equip the patrol with two robots - a light weighing up to 15 kg and a portable one with a weight not exceeding 75 kg. The first of these is expected to implement the tasks of rapid identification and identification of threats and support activities in a very difficult area, where the robot is carried by soldiers and used only temporarily for short-term missions. The purpose of a larger robot is to perform the task of identifying the requiring ability

Corresponding author. Tel.: 22-261-839-616
E-mail address: marian.lopatka@wat.edu.pl

to reveal hidden devices and their neutralization or transfer advanced detection and detection systems that allow for more effective protection of pedestrian patrols. The robot should have the possibility of long-lasting work enabling supporting foot patrols for a minimum of 6 h (desirable 10 h) and develop a maximum speed comparable to that of a running soldier.

Support for combat operations in the urbanized area consists mainly in detecting traps and paving passes. Portable and light robots can be used for these tasks, but their working possibilities are too small in many situations. For these reasons, it is necessary to use robots with a mass of 250-300 kg (the permissible mass is limited by the load-bearing capacity of ceilings and staircases), which have much higher lifting and thrusting forces. They are expected to be able to overcoming staircases, efficiently open doors and furniture, track, and the ability to quickly inspect rooms and warehouses. This requires a large manipulator range, high stability and high maneuverability of the robot and low energy intensity.

Currently robots adapted for military use are often used for this purpose, mainly pyrotechnic works used by police units and border guards. Due to their mass (about 300 kg) they have a considerable capacity, manipulators with complex kinematics and high degrees of freedom DOF (Degree of Freedom) - tab.3. They allow for precise diagnosis and effective IED neutralization. However, they are not adapted to fast and long-term movement and patrol operation - they are intended for intervention. Due to the mass and dimensions they are characterized by relatively low transport susceptibility - they are usually transported on special trailers. Only a few (e.g. Theodor being in the Bundeswehr's equipment) are transported inside the transporters of the EOD team.

Table 1

Light robots (about 15 kg) designed to recognize the tactical IED
on a short distance and support pedestrian sub-units

				
ROBOT	Dragon Runner 10 (QinetiQ)	MTGR (Roboteam)	AEODRS incr.1	BALSA
mass	15 kg	15 kg	15 kg	20 kg
speed	6,4 km/h	3,5 km/h	14 km/h	8 km/h
chassis load capacity	9 kg	10 kg		ok. 10 kg
width	35 cm	37 cm		50 cm
length	39 cm	45 cm		60 cm
Height (without manipulator)	15 cm	15 cm		19 cm
range of LOS teleoperation	650 m	500 m	100 m	
work time	2-3 h	2-4 h		1 h
DRIVING HEAD height of observation controlled movements magnification	on the additional mast approx. 0.3 m rotation and tilting zoom opt.	on the manipulator 0.4 m rotation and tilting zoom opt. 10x	on the additional mast approx. 0.3 m / 0.5 m on manipulation rotation and tilting zoom opt.	on the manipulator about 0.8 m rotation and tilting zoom opt.
MANIPULATOR degrees of freedom (DOF)	rotation of the boom lifting the boom raising the arm rotation of the gripper closing the gripper	lifting the boom raising the arm rotation of the gripper closing the gripper	rotation of the boom lifting the boom raising the arm rotation of the gripper closing the gripper	rotation of the boom lifting the boom raising the arm rotation of the gripper closing the gripper
range of the manipulator	approx. 0,6 m	0,49 m		approx. 0,8 m
load capacity for max. reach	approx.. 2 kg	5 kg	approx. 2 kg	approx. 2 kg

The main task of engineering patrols is to recognize the area and make transitions and clean up the area with mines and mine traps. These tasks are performed for general military units or to unlock traffic corridors. A high rate of task implementation is recommended. Used robots should be capable of detecting and quickly neutralizing road and path threats and marking safe passages. In addition, they should be able to replace sappers during land cleaning. or this purpose, they should be characterized by very high mobility, enabling access to hard-to-reach places and the ability to carry advanced detection and neutralization systems. He should be able to support the patrol for at least 10 hours (minimum 6 hours of continuous work). The desired control range is 400-800 m.The robot should be able to accompany the running soldiers. Due to the equipment being moved, the necessary working capacity and the required mobility - the total weight of the platform should be around 300-800 kg. The most complex tasks, possibly requiring whole groups of robots, are patrolling and maintaining roads – including clear-ups of mines and clearing the roads. That introduces the necessity of recognizing and neutralizing any threats on the road, the roadsides, as well as in the closest surrounding areas.

According to the conducted analyses, it is vital to be equipped with 3 types of engineering robots in the least:

- heavy engineering-recognizing robots,
- heavy engineering-intervening robots,
- light or medium-weight engineering-intervening robots of high mobility,

and UAVs (Unmanned aerial vehicle), used for scanning areas in front of motorcades and finding general hazards. The task of the heavy engineering-recognizing robots is to find and mark points which are highly probable to be mines or improvised live bombs in either the crown of the road or its surroundings. An elementary kit of sensors/detectors should allow reckoning any hazards in traffic lanes wider than 3 m. That task should be realized by integrated detection systems, using at least 2 types of mutually completing sensors, i.e. a ground penetrating radar, cooperating with a magnet detector. Finding threats on roadsides, in roadsides ditches, in culverts, under bridges or in vehicles parked off the road should be facilitated by a special manipulator equipped with suitable cameras and sensors. The area directly surrounding the road in a strip of 50-70 m width should be controlled by a special observation system. Its task is mostly finding hazardous EFPs or remote-controlled grenade-launchers. It is advised for the robot to have systems allowing for activating live bombs in front of vehicles, as well as certain elements of electronic combat, which can protect the robot from remote-controlled live bombs.

Table 2

Portable robots (about 75 kg) intended for tactical reconnaissance and support for mechanized subunits

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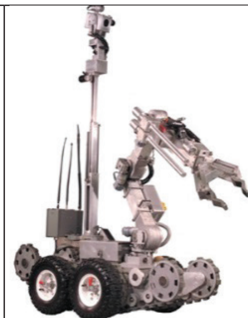
ROBOT	Packbot 510 (iRobot)	Talon IV/2 DOF (Foster-Miller)	TIGR (Roboteam)	AEODRS incr.2
mass	33 kg	52-71 kg	74 kg	75 kg
speed	9,3 km/h	8,3 km/h	-	14 km/h
bearing capacity (without manipulator)	35 kg	45 kg	150 kg	
width	52 cm	57 cm	59 cm	
length	69 / 89 cm	86 cm	91 cm	
height (without manipulator)	18 cm	28 cm	35 cm	
range of LOS teleoperation	- m	800-1200 m / 500 m	1300 m	1000 m
work time	2-3 h	2-4 h	6-8 h	
DRIVING HEAD height of observation controlled movements magnification	on the manipulator up to 2.0 m tilt zoom opt. 26x	on the additional mast approx. 0.7 m / 1.3 m on manip. rotation and tilting zoom opt. 26x	on the additional mast approx. 0.8 m / 1.5 m on manipulation rotation and tilting zoom opt. 30x	
MANIPULATOR degrees of freedom (DOF)	lifting the boom raising the arm rotation of the gripper closing the gripper	boom turnover / - lifting the boom raising the arm grapple rotation / - closing the gripper	rotation of the boom lifting the boom raising the arm lifting the gripper rotation of the gripper closing the gripper	
range of the manipulator	approx. 1,2 m	1,9 m / 1,3 m	1,5 m	
load capacity for max. reach	approx. 2 kg	- / 4,5 kg	7 kg	
maximum load capacity		30 kg / 11 kg	19 kg	

Table 3

Light robots (approx.300 kg) intended for neutralization of IED in urbanized area

				
ROBOT	Caliber Mk 4 (ICOR)	Theodor (Cobham)	Andros (AEODRS incr.3) (Northrup Grumman)	IBIS (PIAP)
mass	333 kg	375 kg	360 kg (340 kg)	300 kg
speed	3,2 km/h	3 km/h	5,6 km/h (14 km/h)	10 km/h
width	75 cm	69 cm	74 cm	88 cm
length	140 cm	130 cm	132 cm	135 cm
height	87 cm	124 cm	144 cm	125 cm
range of LOS teleoperation	1000 m	500-800 m	1000 m	1000 m
work time	5 h	-	-	ok. 4 h
bearing capacity (without manipulator)	-	350 kg	-	-
DRIVING HEAD height of observation controlled movements magnification	arm on the manipulator about 2.7 m rotation and tilting zoom opt.	on the additional mast rotation and tilting zoom opt.	on the additional mast 1.8 m rotation and tilting 72x zoom	arm on the manipulator approx. 1.7 m rotation and tilting zoom opt.
MANIPULATOR degrees of freedom (DOF)	lifting the boom raising the arm tilting the gripper rotation of the gripper closing the gripper raising the arm 2 rotation of the pyroprotor	boom turnover / - lifting the boom raising the arm grapple rotation / - closing the gripper	rotation of the boom lifting the boom raising the arm rotation of the arm lifting the gripper rotation of the gripper closing the gripper	rotation of the boom lifting the boom raising the arm arm telescope lifting the gripper rotation of the gripper closing the gripper
range of the manipulator	approx. 2,2 m	1,9 m / 1,3 m	1,4 m	1,8 m + 0,5 m telescoping
load capacity for max. reach	45 kg	- / 4,5 kg	27 kg	30 kg
maximum load capacity	90 kg	30 kg / 11 kg	73 kg	50 kg

Considering the speed and efficiency of detection systems, the robot's speed is predicted to be 5-20 k/h. A low signature of the robot is highly desirable (volume, vibrations, ground impact etc.), which will prevent from activating detonators. It is expected to allow, given favorable conditions, marking points of suspicion without the necessity of stopping the robot before a potential hazard, thus increasing the speed of tasks completion up to 15-20 km/h. Places marked by the heavy engineering-recognizing robots should then be verified by the heavy engineering-intervening robots. They should possess robotic abilities including:

- recognizing tensions (thin strings);
- recognizing antennae, cables, wires;
- recognizing mines and explosive;
- picking up or pulling out objects, using a manipulator;
- excavating objects;
- removing cars and trucks (chassis, inside, trunk);
- checking culverts and bridges;
- neutralizing IEDs, using different methods;
- wykrywanie metali zamaskowanych gruntem;
- obserwację przedmiotów nisko położonych (np. pod samochodem);
- obserwacja przedmiotów wysoko położonych nad robotem;
- odsłanianie przedmiotów w gruncie;
- podejmowanie próbek (CBRN).

Having these capabilities, a team of robots can also be successfully used as a support for the RCP, OZR and PRI group during conducting combat operations. Due to the expected high rate of action, it is advisable that the grouping has two engineering and appraisal works.

It is desirable to have 2 command vehicles to supervise such a team of robots. The dispersion of the control and control system allows to increase the effectiveness of the patrol. This gives, for example, the possibility that the mutual transfer of subordinated robots.

The command crew of each vehicle should consist of at least 5 soldiers:

commander - operator of the reconnaissance (detection and threat detection) system and UAV (unmanned aerial platform);

-the control operator of the heavy reconnaissance robot;

- operator controlling a heavy intervention robot;
- operator controlling a light intervention robot;
- driver of the command and teleoperation vehicle.

As the analysis shows, currently a number of solutions of robots of 15 kg (light), 75 kg (portable) and 300 kg (medium) robots can be found. The situation is much worse in the case of 800 kg structures. The main purpose of this size platform in these scenarios is to detect potential threats in the form of mines or IEDs and their neutralization. The most difficult task is the process of detecting a dangerous object, especially when securing the movement of troops. This is influenced by the expected high rate of action and a large area of activity. Threats should be detected on the road and in its immediate surroundings. In addition to identification, it is necessary to mark the location of suspicious objects and transfer their location to the command and control system. The detection system should enable detection of threats using a ground penetrating radar and a system confirming the high probability of finding a mine or IED. In addition, the platform should be equipped with an auxiliary detection system to detect the threat on the roadside, in roadside ditches, cars, etc. For this purpose, cameras located on the keypads are currently used. It should be assumed that the development of technology will also allow alternative, more effective systems. The reconnaissance platform should move along the road, 100-200 m before the protected group / convoy with the maximum speed and penetration detected by the system, using the ground penetrating radar of the recognized lane and if necessary checking the roadsides, road ditches and the immediate vicinity of the road. If a threat is detected, the suspect object or its hiding place should be marked. Currently, liquid sprayed by sprinklers is commonly used for this purpose. At the same time, the location information should be passed to the management and command vehicle. Regardless of the detection system, an inspection manipulator should work, which will be able to recognize and verify threats in vehicles, on roadsides, behind roadside fences, in roadside ditches, culverts, and even on trees, shelters or lorries using cameras. It is advisable to have the ability to move or lift masking elements or limit the recognition possibilities.

It is envisaged that the basic form of using such a robot will be its use in mechanized patrol. The platform will be transported on a trailer, and during the time of overcoming the threatened sections it will be controlled in the mode of teleoperation, from the steering and command vehicle. It is anticipated that it will enable the coordination of the activities of the group of 3 robots. Then, multifunctional control stations will be used. They should provide working conditions enabling the implementation of many hours of missions (patrols) without excessive operator fatigue In case of necessity to control the platform out of the scope of the steering and command vehicle and when supporting pedestrian engineering reconnaissance patrols (road or terrain), it is envisaged to use personal control stations with limited functionality. Effective implementation of the reconnaissance mission while securing the movement of troops requires from the platform:

- the high transport susceptibility (indispensable for not having to accompany the main forces and quickly reach the area of operation);
- the ability to prolong speeding over 10 km / h for a long time;
- quick transforming from transport to work position;
- effective detection of mines and IEDs located in the ground, in the recognized belt (dual detection system - basic and confirming);
- quick recognition of suspicious objects - it requires a camera with at least two degrees of freedom and a large working area of the manipulator that allows:
  - checking the interiors of standing cabins on the side of lorries;
  - checking the interiors standing on the side of passenger cars;
  - inspection of culverts (standing on the road crown), roadside ditches, and objects behind fences, walls etc.;
  - inspection of facilities located on shelters, trees, roofs, etc.
- very good visualization of the surroundings in the whole field of the manipulator's work and maneuvering the platform.

The following are critical for mission accomplishment:

- effective detection of threats by the detection system;
- high stability and stability of the detection system (ground penetrating radar);
- a very large manipulator area adapted to the anticipated, varied tasks (indicated minimization of the number of degrees of freedom to simplify the control system).

Conclusions

The battlefield of the future will be characterized by an increasing level of robotization. One should expect the introduction of entire groups of remote-controlled means, completing common tasks. For that to happen, though, there are still technical difficulties to be resolved. Those are mostly tied to mobility levels, detection systems, steering systems and manipulators. At the same time, new tactics should be developed alongside new technologies, in order to use them to their full potential.

Acknowledgements

This work was conducted within the framework of the project “Platforma średnia (klasa 800 kg)” - grant no. DOBR-BIO4/083/13431/2013. The authors are thankful for the Polish “National Centre for Research and Development”.

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