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LAND-ROBOT TECHNOLOGIES: THE INTEGRATION OF COGNITIVE SYSTEMS IN MILITARY AND DEFENSE

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Abstract: To face the challenges of military defense, modernizing army and their tactical tools is a continuous process. In near future various kinds of missions will be executed by military robots to achieve 100% impact and 0% life risks. Defense robot engineers and companies are interested to automate various strategies for higher efficiency and greater impact as the demand of land defense robots is growing steadily. In this study, land-robots used in military defense system are focused and various types of land-robots are presented focusing on the technical specifications, control strategies, battle engagement, and purpose of use. Recent integration of land-robot technologies in the world military forces, its necessities, and contributions of various international defense companies to the world economy are also presented in this study indicating supremacy in the military automation and economic stability. Limitations and challenges of recent development, robot ethics, and moral impacts are also discussed here with some vital points related to robot security and some suggestions to overcome recent challenges for the future development.

Keywords: *Land-robots; Military robots; Defense robots; Military defense engineering; Ground robots; UGV*

INTRODUCTION

To strengthen military defense system, significant development and increment of intelligent autonomous strategic capacity is necessary. Research on defense technology improvements is the priority in most of the first world countries to modernize the military defense. The characteristics of future warfare can be analyzed based on conflicts in various domains, such as: maritime, land, air, cyber, space, electromagnetic, and information. Cross-domain (X-domain) and multi-domain strategies are also needed to be focused with the improvement of modern intelligent and robot technologies. Unmanned Autonomous X-domain (multi-domain) Systems, shortly known as UAxS, are now in focus of research and development to make the military forces more strong, powerful, and intelligent. Figure 1 presents Multi-domain and X-domain warfare model.

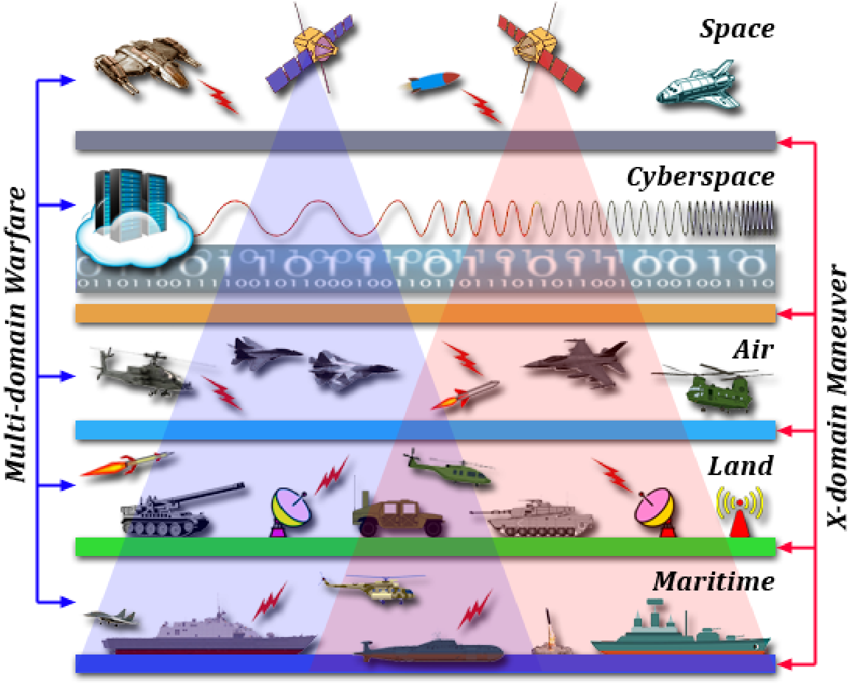

Figure 1: *Multi-domain & X-domain warfare model*

Modern defense mechanism can be studied in four interrelated areas: advance warship, good communication, artificial intelligence, and autonomous weapons. This basically implies the implementation of robot technologies in the military defense system. A well-equipped mechanized force is very important asset to a commander in a battlefield. In a warfare, commander must focus on firepower, mobility, man-machine cooperation, decision making, support armor, and command infantry. In future, robots and automated systems will help on these points by providing supports and reducing burdens, as the systems will be more intelligent, reliable, and cooperative. In the recent military activities, robot and autonomous technologies are used for reconnaissance, equipment supply, surveillance, minesweeping, disaster recovery, injured soldier retrieval, etc. (*Dufourda, & Dalgalarrondo, 2006; Akhtaruzzaman, et al., 2020*).

To ensure reliable use and get the highest impact of the technology, robots must be well designed with semi-automated, automated, and man-machine interaction engineering. Unmanned ground vehicles (UGV) are promising and have great potentials for defense applications where a faster and reliable communication links (link-budget) and Rapid Access to Information (RAtI) are highly required (*Akhtaruzzaman, et al., 2020*). Robots are valued to be worth less than a human life. Robots are faster in sensing, detecting, measuring, and analyzing. Robots does not have any passion or emotion, does not go under fatigue or tired like human, rather remain functioning under extreme and critical conditions. In near future robots will be the core technology for combat planning and engagement (*Abiodun, & Taofeek, 2020*). They will be able to communicate with the environment through smart sensor technologies, understand it through modeling, understand human actions, define threats, follow commands, access to information with grater processing capabilities, interact with other robots through information exchange and sharing, adapt autonomously with hostile environment through advanced control technology, and apply intelligence for self-learning through strong computing capability with auto generated programs (*Akhtaruzzaman, & Shafie, 2010a, 2010b; Karabegović, & Karabegović, 2019*).

UGV systems will be the key technology for military operations in near future as they will ensure almost zero human risks by repositioning no human force directly to the battle. The UGV systems will also be able to open various facilities like load carrying, automatic surveillance, border patrol, risk reducer, obstacle clearance, force multiplier, remote manipulation, signal relay, etc. (*Sathiyanarayanan et al., 2014*). Land defense robots must be adaptable in various rough terrains, ill-environment, and unstructured areas while playing the assigned roles and maintain the command hierarchy. As an extent of military troops, land-robots must not impose any extra workload to the team. Thus, an efficient artificial intelligent (AI) engineering must be imposed for reliable man-machine cooperation between the UGV or land-robots and action troops.

Today's intelligent robots or autonomous weapons are still at the level of Artificial Narrow Intelligence (ANI) (*Horowitz, 2019*) or somehow in between the ANI and Artificial General Intelligence (AGI). Which reflects that they are not yet ready to be fully autonomous and taking reliable decisions in hostile situations like disaster or warfare. Human has intelligence to apply perceptual experiences in a great extent, able to adapt with environment, and can take appropriate decisions in critical situation. If these capacities can be implanted in a robot's brain, the system can be said as AGI system. Though, robots can stand against dull, dirty, and dangerous jobs compared to human, they include some limited functionalities like waypoint or goal-oriented navigation, obstacle detection, obstacle avoidance, threat detection, human detection and identification, localization, map building, information extraction through image and sound processing, and a kind of cooperation with other robots. Thus, a military ground robot would be most efficient if a good collaboration can be ensured between robots and human where a robot will work autonomously under human supervision.

This study presents a review on military land-robot systems, recent technological advancements, applications, and moral impacts. Present situation of some developed and underdeveloped countries, industrial impacts to the world economy through advancing and treading the military arms, automated weapons, and intelligent technologies are reflected in the review study. The paper also delineates the robot ethics in engaging warfare and impacts of the technology in the moral states. The study mainly tries to identify the recent applications and implementations of the ground robot technology through determining the recent gaps, limitations, and ethical impacts of the technological advancements.

ADOPTION OF LAND-ROBOTS IN THE WORLD FORCES AND ECONOMIC ROLE OF MILITARY INDUSTRIES

The typical scenario of linear threat in a battlefield is already replaced with 360-degrees threats (*Baker, 2017*) and it is going to be more dynamic soon with the blessing of modern intelligent technologies (*Talukder, 2016*). To adapt with this situation, a modern army soldier is not only acting in a battlefield as a traditional soldier but also plays important roles as a technocrat, cyber-warrior, and so on. Extremely large military forces, enormous power, automated weapons, unmanned vehicles, intelligent robot technologies, and economic supremacy have made USA the most powerful and uncontested in the globe. They are working continuously to shape the future opportunities and upgrade the power in facing the future challenges through integration of automated robots and intelligent systems. Current military operations in various regions (Pakistan, Yemen, Afghanistan, Iraq, and other) show the application of automated combat strategies (mostly one-sided) of the US soldiers (*Gartzke, 2019*).

One of the strategic competitors to USA is China. In terms of economic growth and modernization of military force, China is treated as the next superpower in the world (*Talukder, 2016*). China has extended its activity in Africa, North America, Asia, and some other parts of the world. Chinese maritime boundary, exclusive air defense strategy, intelligent ground robot soldiers, and UGVs raised tension to many of the recent superpowers. Troops of military robots specially the land-robots are likely to be adopted soon along with the human soldiers in the battel field (*Tang, 2020*).

Russia is not in the sideline of the international conflicts, rather they are renovating and upgrading their defense strengths by introducing new mechanized tanks, aircrafts, missiles, autonomous systems, intelligent robots, and nuclear technologies. During Ukraine crisis and military intervention in Syria reflect the advancement and tactical strength of their military force (*Talukder, 2016*). Russia has demonstrated their own armed ground robot technologies successfully and systematically focusing on AI based advanced military robots and autonomous technologies (*Kozyulin, 2019; Zysk, 2020*).

Iran and North Korea are continuously denying the supremacy of USA and developing their military technologies and demonstrated successful implementation of various types of ground robot soldiers sometimes known as autonomous killer robots. Another nuclear hotspot in South Asia is always rising because of the bitter relation between India and Pakistan. Some countries like Israel, Afghanistan, Iraq, Palestine, Syria, Somalia, and Bosnia are considered as constant warzone in the recent world. Nigerian Military had several loses of its men in the war against Boko Haram terror, that raises the demand of military robots and automated weapon system (*Abiodun, & Taofeek, 2020*). In the rest, most of the countries are relatively in peace. They possess various sizes of military forces and continuously trying to cope with technological advancement on intelligent robots, especially UGV robots, autonomous technologies, and weapons to compete the modern challenges and dynamic threats.

Military industries play important role to contribute to the countries' economy. France is considered to have the strongest and efficient military forces in Europe. According to a statistical study (*Fregan, & Rajnai, 2019*), the total sales of armaments from twenty defense-related companies in several countries are about $263,570.00 million USD. Among these companies, eleven companies are USA based ($172,720.00 million USD), three are UK based ($45,650.00 million USD), three are in Russia ($20,930.00 million USD), two are in France ($13,730.00 million USD), and one is in Italy ($10,540.00 million USD).

Figure 2(a) presents the graphs of armament sales by various countries and Industries as depicted by *Fregan, and Rajnai (2019)*. Comparing to the statistics, percentage of arms sales in the years 2015, 2016, and 2018 demonstrated the similar characteristics as illustrated in several studies conducted by *Fleurant et al.* (*2016, 2017, & 2019*). The statistics are demonstrated in Figure 2(b). Though the trend shows that USA reflects comparatively a little less percent (%) in sales comparing to the statistics in 2014, still the country is superior to the other countries having differences as about 6 to about 50 times higher. It is important to note that, the statistics reflect the top 100 arms industries in the world according to the countries in which they have their headquarters. The top 100 do not indicate the total industry of a mentioned country.

Figure 2(c) presents exports and imports of military arms and equipment in five various regions for the duration of ten years, 2007 to 2017 (*Macias & Rattner, 2020*). The highest exports were made by USA about 80.2% while the imports percentage was about 12.2%. Conversely, Asia reflects the opposite scenario with a very low exports (3.5%) and a very high imports (56.1%) of military equipment. Another recent study-report on global share of major arms exports from 2015 to 2019, conducted by *Wezeman et al.* (*2020*), has presented the same characteristics, as shown in Figure 2(d). All the statistical graphs reflect that the production and sales of arms in USA are much higher and beyond reach of other countries where Asia is entirely out of the count.

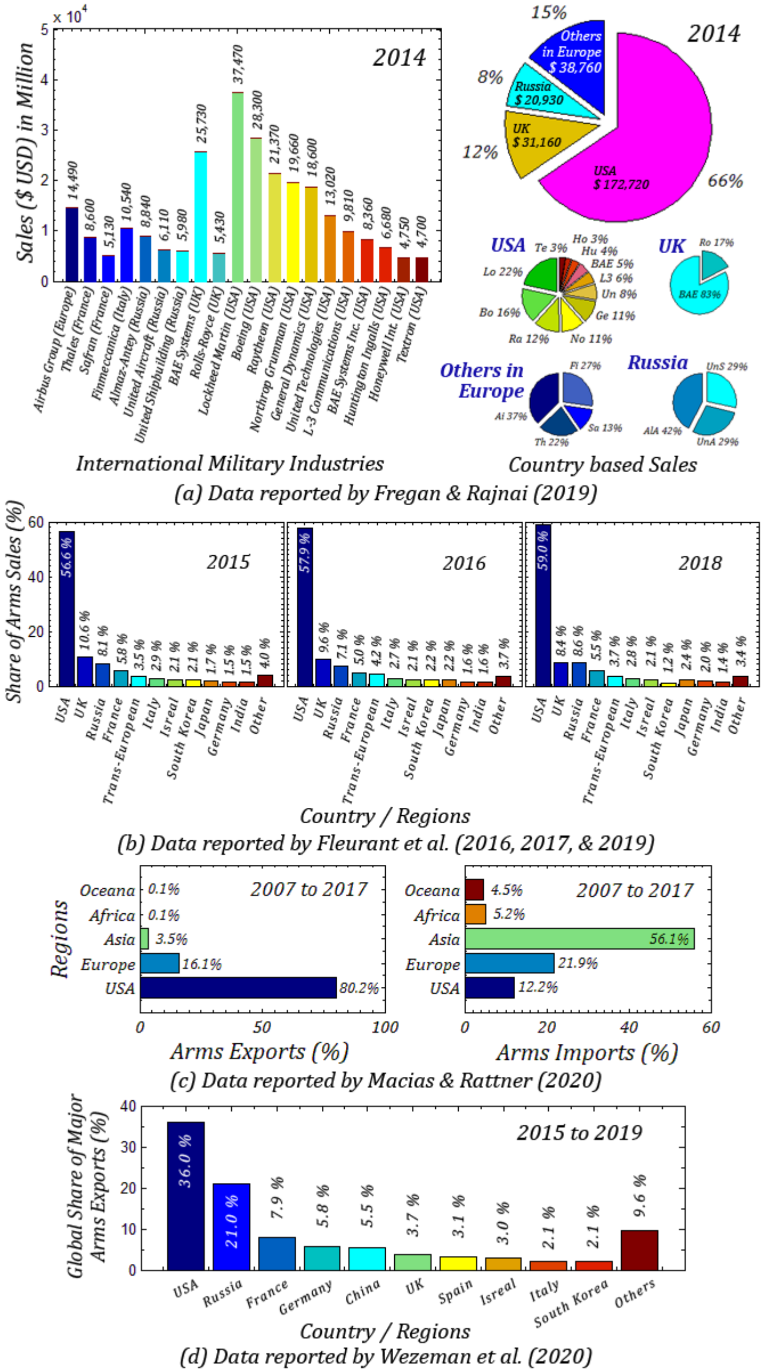

Figure 2: *Military armament sales in various years from various countries and international companies (Fleurant et al., 2016, 2017, & 2019; Fregan, & Rajnai, 2019; Macias & Rattner, 2020; Wezeman et al., 2020)*

TYPES OF LAND-ROBOTS FOR MILITARY USE

Technological advancement has presented new, more complex, dynamic, and intelligent systems that changes the face of war tactic. Usages of drones, UAV, UGV, Unmanned Underwater Vehicle (UUV), Automated Weapon System (AWS) are changing the strategies of force engagement in the warfare. Modern armed forces do not rely on human scouts anymore, rather use small robots which are capable of being invisible to the enemy. UGV robots operates mainly on the ground and perform some specific jobs autonomously or controlled while following command hierarchy. Several research activities are carrying on all over the world to develop various kinds of robots like climbing (wall or tree) robots, robot navigations, bipedal robot locomotion, quadruped robots, snake robots, and so on (*Hossain et al., 2013; Akhtaruzzaman et al., 2009, 2011, 2017*).

Minesweeping Autonomous Vehicle

For mine (both land and sea mines) reconnaissance and area clearance, minesweeping military robots can play important role by ensuring zero live damage. About $(4.45 \times 2.01 \times 1.49)\, m^3$ and $6.8\, ton$ weighted hi-tech URAN-6 robot soldier was deployed by Russia in 2016 for clearing mines in the historic World Heritage site (*Dilipraj, 2016*). During the mission, the robot defused about $3{,}000$ explosives including mines.

A low-cost Robot Aided Mine Sweeper (RAMS) was designed in University of Moratuwa, Sri Lanka with the collaboration of University of Genova, Italy (*Hemapala, & Razzoli, 2012*). The system was inspired by potato digger system and developed based on a tractor unit, and standard agricultural equipment after slight modification. The $\approx 250\, kg$ weight system (about $2.68 \times 0.96 \times 1.25\, m^3$) can be controlled remotely within $300\, m$ of range and can run about $0.72\, km/h$.

For the mine clearing tasks, German army applied UGVs in Afghanistan. The robot was developed under a project "Route Clearing System". There are four robot vehicles under the full system, 1) Command and operating unit, 2) Detection unit, 3) Demining unit, and 4) Transportation unit (*Smolarek, 2019*). The armored transporter (TPz Fuchs KAI) is the main unit for a crew operator to command and direct other UGVs to perform tasks. The commanding UGV unit has a powerful manipulator for demining and can play independent role for reconnaissance. The detection UGV unit (remote-controlled Wiesel/Weasel tracked vehicle, average weight is about $10\, ton$ and size about $3.55 \times 1.82 \times 1.82\, m^3$) is equipped with ground-penetrating radar and metal detector to detect mines, improvised explosives, and unexploded ordnances. The transportation unit has special manipulator where various kinds of sensors and end-effectors can be attached for surveillance and checking hotspots. The demining unit (Mini Mine Wolf, MW-240) can be mounted with various demining equipment like robotic manipulator, tiller unit, flail unit, etc.

Figure 3 shows some minesweeping UGVs used for military activities. Table 1 presents some important specifications of the above-mentioned UGV robots.

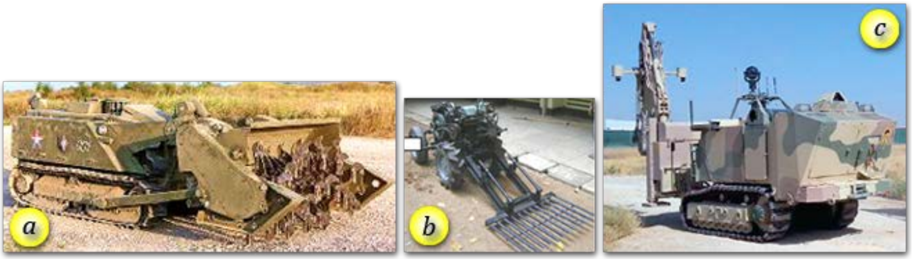

Figure 3: *Some autonomous vehicles (UGVs) used for field minesweeping, (a) URAN-6, (b) RAMS, and (c) Rout Clearing System (detection unit) (Hemapala, & Razzoli, 2012; Dilipraj, 2016; Smolarek, 2019)*

Table 1: *Some notable military minesweeping robots (Hemapala, & Razzoli, 2012; Dilipraj, 2016; Smolarek, 2019)*

Robots	Purpose	Speed $(km.h^{-1})$	Size (l, w, h) m	Weight (kg)	Control
URAN-6 (Russia)	Mine clearance	≈ 5.00	$4.45, 2.01, 1.49$	6.2×10^3	Remotely controlled ($1\ km$)
RAMS (Sri Lanka)	Mine clearance	≈ 0.72	$2.68, 0.96, 1.25$	2.5×10^2	Remotely controlled ($0.3\ km$)
Route Clearing System (RCS) (German)	Mine detection and clearance	≈ 70.0	$3.55, 1.82, 1.82$	9.072×10^3	Remotely controlled

Surveillance and Reconnaissance Robots

This type of robots monitors opponent forces or a particular area and transmit videos, pictures, audios, etc. through Global Positioning System (GPS) and Satellite communications. Among various reconnaissance systems, PD-100 (presented in Figure 4(a)) is a small sized personal reconnaissance system that can be ready to engage within a minute. The system is relatively fast, quiet, difficult to catch, has small size flying unit, micro camera, can be controlled (command based or automated) within one kilometer of range, presents itself as a well-equipped spying tool for military use (*Abiodun, & Taofeek, 2020*).

Researchers are working on designing modular snake robot to achieve better mobility on sand hills, trees, land and water, and uneven structures. Such kind of robots basically free modulated hyper-redundant robot, able to move through tight and narrow pathways, can be used for surveillance, reconnaissance, spying, and monitoring purpose. Carnegie Mellon University, USA has presented a seriallinkage modular Unified Snake robot for surveillance (*Wright et al., 2012*). The robot snake runs on $36V$ $1.5A$ Li-ion battery with $36V$ Brushed DC Motor ($1.3\ Nm$ torque), Analog NTSC video module, 3-axis accelerometer & gyroscope, joint angle sensor, temperature sensor, voltage, and current sensors, and RS-485 Serial link for data transfer. Weight of one module is $0.16\ kg$ ($2.9\ kg$ for 16 modules full robot) and dimensions are $0.051\ m$ in diameter with $0.94\ m$ in length. The robot can move through narrow tunnel, on rough terrain, and can climb tree as shown in Figure 4(b).

A small but smart reconnaissance robot, RABE (Figure 4(c)), is developed by Endeavour Robotics Company, USA and sold to German army in 2018 (*Smolarek, 2019*). The robot UGV is equipped with 4 cameras for $360°$ views from a distance of $0.3\ km$ even in low-light conditions, called as the "Eye of troops". The small sized ($38.1 \times 22.9 \times 10.2\ cm^3$) robot is weighted as $2.5\ kg$ and has demonstrated unbroken (full functional) capability for dropped from $5.0\ m$ height or thrown into a building from a hole or a window. The robot runs on Li-ion battery and can be used continuously for about 6 hours. Table 2 presents some important parameters of the mentioned autonomous robots used for military surveillance and reconnaissance.

Figure 4: *Some examples of autonomous robots for military surveillance and reconnaissance, (a) PD-100, (b) Modular snake robot, and (c) RABE (Wright et al., 2012; Smolarek, 2019; Abiodun, & Taofeek, 2020)*

Table 2: *Notable surveillance and reconnaissance robots for military use (Wright et al., 2012; Smolarek, 2019; Abiodun, & Taofeek, 2020)*

Robots	Purpose	Speed ($km.h^{-1}$)	Size (l, w, h) m	Weight (kg)	Control
PD-100 (Norway)	Surveillance & Reconnaissance	≈ 21.0	$0.10, 0.025$	0.16	Remotely controlled ($1.6\ km$)
Unified Snake Robot (USA)	Surveillance & Reconnaissance	Relatively slow	0.051 (dia.) 0.94 (length)	2.9	Remotely controlled
RABE (USA/Germany)	Surveillance & Reconnaissance	≈ 05.5	0.38, 0.23, 0.10	2.5	Remotely controlled ($0.3\ km$)

Load Carrying and Transportation Robots

This kind of robot can replace soldier in transporting artillery, bomb, military supplies, heavy equipment, other materials, or even soldiers if necessary. Autonomous Platform Demonstrator (APD) is a military UGV robot used by US army for autonomous navigation and transportation. Hybrid-electric drive, advanced suspension, six drive wheels, and lightweight chassis have made the UGV super cool for military use (*Army Guide, 2020a*). The vehicle (weight about $9.0\ ton$) can run at speed up to $80 - 50\ km$ per hour (*RDECOM, 2010*). Figure 5(a) presents some UGVs for military logistic support.

To transport logistical units, Big Dog robot (Figure 5(b)) was developed for US army by Boston Dynamics. The hydraulic powered four-legged robot is able to move (walk) on any kind of rough terrain (Rocky, Icy, muddy, sloppy ($\approx 35°$), or even slippery terrains) where a conventional vehicle cannot travel on. The robot is able to carry 150 kg of additional load, follow command from a distance, and can travel $4\ to\ 6.4\ km.h^{-1}$ (*Dilipraj, 2016*).

Another Big Dog like four-legged robotic mule LS3 (Cujo or Alpha Dog) was presented in 2012 by the same company, shown in Figure 5(c). The robot can carry $180\ kg$ of load for $32\ km$ without refueling. One of the main drawbacks of these types of robots is the loud noise (*Sapaty, 2015; Hua, 2020*). The $362.9\ kg$ weight robot ($2.00 \times 0.90 \times 1.90\ m^3$) is autonomous, remotely controlled, and able to reach about $11.1\ km/h$ as maximum speed.

RS2-H1 Small Multipurpose Equipment Transport (SMET) is another UGV robot (pack-bot) used in US military forces for load carrying and logistic support, as shown in Figure 5(d). The Howe and Howe technology's SMET robot has demonstrated about $97\ km$ march (average speed $2.0\ km.h^{-1}$) through rough and tough terrains (jungle) while carrying about $454\ kg$ of load, clearly reflecting a great usability and support for army. The system is a mid-sized electric drive energy efficient hybrid autonomous vehicle capable of producing high torque while moving. Report says that the company is going to manufacture thousands of units of the UGV in the recent year for US army (*Layton, 2018; DefPost, 2020*). SMET could be configured for reconnaissance or autonomous weapon system (*CRS Report, 2018*). Table 3 presents basic specifications of the described robots.

Figure 5: *Example UGVs for military logistic support, (a) APD, (b) Big Dog, (c) LS3 Cujo, and (d) RS2-H1 SMET (Army Guide, 2020a; DefPost, 2020; Hua, 2020)*

Table 3: *Technical specifications of some notable robots for Logistic Support (Dilipraj, 2016; Layton, 2018; DefPost, 2020; RDECOM, 2010; Army Guide, 2020a)*

Robots	Purpose	Speed $(km.h^{-1})$	Size $(\boldsymbol{l}, \boldsymbol{w}, \boldsymbol{h})\ \boldsymbol{m}$	Weight $(\boldsymbol{kg})$	Control
APD (USA)	Navigation and Transportation	$80\ to\ 50$	$4.62, 2.49, 2.21$	8.2×10^3	Automatic & Remotely controlled
BIG DOG (USA)	Logistics Support	≈ 06.4	$1.10, 0.30, 1.00$	108	Automated & Remotely controlled
LS3 (Cujo) (USA)	Logistics Support	≈ 11.1	$2.00, 0.90, 1.90$	3.63×10^2	Automated & Remotely controlled
RS2-H1 SMET (USA)	Load carrying and logistic support	≈ 02.0	mid-sized electric drive UGV	Unknown	Automated & Remotely controlled

Search and Rescue Robots

A robot army can participate in search and rescue mission in desert, wild area, forest, flooded area, wreckages, tsunami, chernobyl, or even under water. Robots can move freely in biological, radiological, or chemical environment and search, track, and rescue which is totally impossible for a human rescuer. In a rescue mission, majority of casualties occurred because of the delay in providing necessary aid to the victims. Rescue robots can be used to minimize the delay time to save maximum number of lives.

Extremely light weight (Mini-VIPeR $3.5\ kg$ and Maxi-VIPeR $11.4\ kg$) and easily portable UGV called Versatile-Intelligent-Portable-Robot (VIPeR) was introduced in Israel (*Dilipraj, 2016*). The advanced sensory systems have made the robot intelligent enough for automated surveying before engaging any actions. The robot is claimed to be highly suitable for field analysis and supporting land warriors. The advantages of the robot are, it can be mounted with Galileo Wheel, attached with small arms, and used for surveillance and reconnaissance (*Army Guide, 2020b*).

One of the most advanced bipedal (humanoid) robot is Atlas from Defense Advanced Research Projects Agency (DARPA) and Boston Dynamics. Custom made motors, valves, and most compact mobile hydraulic system enable the bipedal robot to produce high power to each joint of the 28-DoF (Degree of Freedom) system. Advance balance control mechanism enables the anthropoid to become more agile almost like a human. The $1.5\ m$ tall Bipedal Intelligent Machine (BIM) weighted about $80\ kg$ and runs at the speed of $5.4\ km.h^{-1}$. The robot can move on any kind of rough terrain, can crawl, jump, hop, forward flip, backflip, jump-turn, jump-roll, climbing stairs, traverse a door, and so on. The robot is designed as a rescue robot but the future of this type of robot will be more dramatic and ominous (*Banerjee et al., 2015; Antal, 2016*).

In the early 21st century, Wolverine V2, the post disaster rescue robot was deployed by Mine Health and Safety Administration (MHSA), USA (*Reddy, 2015*), shown in Figure 6(c). The remotely controlled robot was basically designed for military use as a rescue (specially mine rescue) and bomb squad robot which is equipped with three cameras, and gas sensor with continuous sampling capability. The robot is controlled through a fiber-optic cable from about $1.5\ km$ away and able to feed live video data to the control unit. The $1.27 \times 0.76\ m^2$ robot was weighted as $550\ kg$. The main drawback of the robot was its heavy weight and long cable attachment.

Figure 6 shows the above-mentioned rescue robots for military uses. Some important specifications are presented in Table 4.

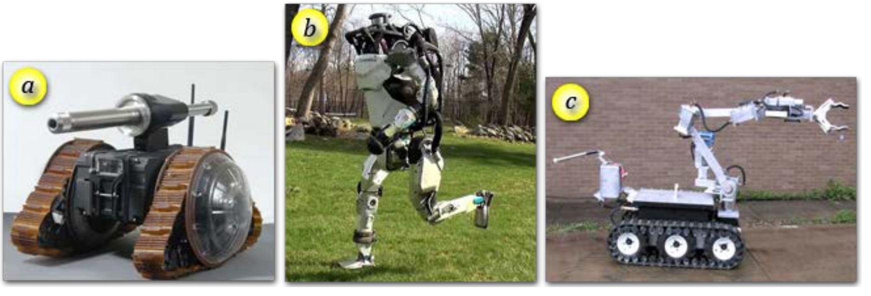

Figure 6: *Some military robots used in search and rescue missions, (a) Maxi-VIPeR, (b) Atlas, and (c) Wolverine V2 (Banerjee et al., 2015; Reddy, 2015; Antal, 2016; Dilipraj, 2016)*

Table 4: *Basic specifications of some remarkable Search and Rescue Robots used in Military (Banerjee et al., 2015; Reddy, 2015; Antal, 2016; Dilipraj, 2016)*

Robots	Purpose	Speed $(km.h^{-1})$	Size $(l, w, h)\ m$	Weight (kg)	Control
Maxi-VIPeR (Israel)	Automated surveying	Unknown	$0.46, 0.46, 0.23$	≈ 11.4	Remotely controlled with a helmet-mounted display
Atlas (USA)	Search and rescue	≈ 5.4 (Running)	$1.5\ m$ tall	≈ 80.0	Automated and remotely controlled
Wolverine V2 (USA)	Mine rescue and Bomb squad	Unknown	$1.27, 0.76$	≈ 550.0	Through fiber-optic cable ($1.5\ km$)

Bomb Disposal and Chemical Detection Robots

To identify and disarm explosive devices and dangerous objects, Explosive Ordnance Disposal (EOD) robots are used. Some well-known potential EOD robots are TALON, iRobot 510 PackBot, tEODor, and Dragon Runner.

Electric powered remotely controlled root DAKSH (DRDO DAKSH, India) is designed for recovering Improvised Explosive Devices (IEDs), localizing dangerous objects, bombs, suspicious packages, and destruct or defuse these dangerous objects (*Dilipraj, 2016*). The rubber wheel (6-wheels) based robot can be operated within half of a kilometer away and the system is equipped with camera, control equipment, reconnaissance system, robotic arm, X-ray device, water-jet, and large-caliber shotgun. The robot can blast closed door, climbs stairs, over steep hills, maneuver in tight spaces, and more. DAKSH can run for 3 hours and handle $20kg$ from $2.5\ m$ and $9\ kg$ from $4\ m$ extension of arm.

The telerob Explosive Ordnance Disposal and observation robot, shortly known as tEODor, is successfully used by German soldiers in Afghanistan (*Smolarek, 2019*). The robot weights $360\ kg$, runs at $3\ km.h^{-1}$, and can be operated remotely from the range of $0.2\ km$. The robot was designed for EOD, identification, and removal of IEDs. The robot can work continuously for four hours (20 hours for only camera functioning mode) and can handle $20\ kg$ to $100\ kg$ for the operating distance at $1.81\ m$ to $0.4\ m$.

In late 2015, the PackBot 510 (shown in Figure 7(c)) was deployed by US army in the Camp Stanley, Republic of Korea for chemical detection. The robot was specially designed with Chemical Biological Radiological Nuclear and Explosives (CBRNE) detection capabilities. The robot also can be used as a bomb disposal, monitoring, surveillance, and reconnaissance system (*Antal, 2016*).

Example of some bomb disposal military UGVs are presented in Figure 7. Some important parameters are presented in Table 5.

Figure 7: *Example of some military robots used for Bomb disposal and Chemical detection, (a) DAKSH, (b) tEODor, and (c) PackBot 510 (Antal, 2016; Dilipraj, 2016; Smolarek, 2019)*

Table 5: *Some important specifications of the above-mentioned EOD robots for military use (Antal, 2016; Dilipraj, 2016; Smolarek, 2019)*

Robots	Purpose	Speed ($km.h^{-1}$)	Size (l, w, h) m	Weight (kg)	Control
DAKSH (India)	Recover IEDs and Bomb disposal	Faster (Unknown)	Unknown	Lighter (Unknown)	Remotely operated (0.5 km)
tEOD (Germany)	Observation and EOD	≈ 3.0	$1.37, 0.69, 1.13$	≈ 360.0	Remotely operated (0.2 km)
PackBot (USA)	Bomb disposal, monitoring and surveillance	≈ 9.3	$0.69, 0.52, 0.18$	≈ 14.3	Remotely operated (1.0 km)

Firefighting Robots

Military firefighting robot is a kind of unmanned autonomous vehicle equipped with a hydrant or other equipment to extinguish fire. This kind of robot can save lives by minimizing the risks of a human firefighter (*AlHaza et al., 2015*). The common and useful sensors used by a firefighting robot are visual camera, gas sensor, Infrared (IR) camera, flame detection sensors, temperature sensor, extinguishers, multi-directional nozzle, etc. A fire-fighting robot must be capable of working in high temperature ($700°$ or more) environment (*AlHaza et al., 2015*). Recently some gigantic automated controlled firefighter robots are in under research and development.

The Shipboard Autonomous Firefighting Robot (SAFFiR) was the first firefighting humanoid (bipedal) robot deployed by US Navy (*Nuţă et al., 2015*). The humanoid can detect and extinguish fire autonomously. It is also able to work cooperatively with human firefighters and has the heat tolerance level up to $500°C$. Advance navigation and balance control technology have made the robot capable to navigate on board and search for survivors while by maintaining its upright position during pitching and rolling sea condition. The 33 DoF waterproof bipedal fire-fighting robot is $1.78\ meter$ in height and equipped with camera, gas sensor, temperature sensor, IR, Ultra Violate (UV) sensor, heavy duty gripper, and more. The robot can be engaged to any fire-fighting situation and able to support for about 30 minutes continuously (*Kim, & Lattimer, 2015; Nuţă et al., 2015; Liu, 2016*).

A remotely controlled (wireless $260\ m$) double tracked fire-fighting robot from A2Z Smart Technologies Corp., Israel, is named as Fire Fighting and Rescue (FFR-1) robot (*Tan et al., 2013*). The fire-fighter robot can be deployed to handle hazardous situations like high temperature, chemical fumes, and risky buildings. The $940\ kg$ weighted (length $1.62\ m$, width $1.14\ m$, and height $1.38\ m$) robot runs on $24\ V$ battery powered two electric motors and able to reach at the speed of about 3 to $4\ km.h^{-1}$. The robot can carry $3\ inch$ fire hose, able to climb $30°$ inclined terrain, and can handle water flow up to $4.2 \times 10^3\ liters.\min^{-1}$ at $15\ bars$. The robot has its internal cooling system (double-walled) to control internal temperature because of high external heat. A multi-functional surveillance camera, one front-road camera, and one spot-light unit have made the robot user friendly during operation.

Robotic firefighting must ensure certain tasks like locating, detecting, and analyzing fires; assisting search and rescue operations; monitoring hazardous variables; and most importantly the fire control and suppression. To support these jobs, a small tank-sized autonomous vehicle, Thermite robot, is designed for US army (*Nuță et al., 2015*). The remotely operated (form a distance of $0.4\ km$) robot can pump $2.3 \times 10^3\ liters$ of water per minutes. Small size ($l = 0.188\ m; w = 0.088\ m; h = 0.139\ m$) and light weight of the robot increase its ability to pass through a door, surf indoor environment, and easy to carry (two robots) by specially designed Bulldog Fire-fighting Truck (*Nuță et al., 2015*). Its internal cooling system uses some of the pumped water, as a coolant, through its body. The robot has a high-resolution camera and can be used as a multipurpose system like surveillance robot, bulldozer, bomb disposal and improvised explosives neutralizer through robotic arm.

Some other fire-fighting robots are Colossus from Shark Robotics, France; TC800-FF from Tecdron, France; Parosha Cheatah GOSAFER from Netherland, Multiscope Rescue from Milrem Robotics, Estonia, UK; URAN-14 from Russia, Turbine Aided Firefighting Machine (TAF 20) from Emi Controls, Bolzano, Italy; and so on.

Figure 8 shows some notable fire-fighting robots. Basic technical parameters of the described UGVs are provided in Table 6.

Figure 8: *Fire-fighting UGVs, (a) SAFFiR, (b) FFR-1, (c) Thermite, and (d) TAF-20 (Tan et al., 2013; AlHaza et al., 2015; Kim, & Lattimer, 2015; Nuță et al., 2015; Liu, 2016; AirCore TAF35, 2020)*

Table 6: *Some fire-fighting robots for military support (Tan et al., 2013; AlHaza et al., 2015; Kim, & Lattimer, 2015; Nuță et al., 2015; Liu, 2016; AirCore TAF35, 2020)*

Robots	Purpose	Speed ($km.h^{-1}$)	Size $(l, w, h)\ m$	Weight (kg)	Control
SAFFiR (USA)	Fire-fighting humanoid	Slow	1.78 (height)	≈ 63.50	Autonomous with supervision
FFR-1 (Israel)	Fire-fighting UGV	≈ 4.00	$1.62, 1.14, 1.38$	≈ 940	Remotely controlled
Thermite RS1 (USA)	Combat fires	≈ 9.66	$0.19, 0.09, 0.14$	$\approx 7.26 \times 10^2$	Remotely operated ($\approx 0.4\ km$)
TAF-20 (Italy)	Fire-fighting UGV	≈ 9.00	$2.91, 1.62, 2.15$	$\approx 3.9 \times 10^3$	Remotely controlled ($0.3\ km$)

Armed Military Robots

Some military robots are equipped with heavy artillery, bomb, weapons, and guns; directly engaged in a warfare and attacks the target enemy while ensuring zero threats to the troops. Combat support military robots can be applied for anti-submarine operation, fire support, laying mines, battle damage management, electronic warfare, strike mission, etc. Russia has developed and implemented several combat robots, like Platform-M, WOLF-2, and Shooter. The WOLF-2 (MPK-002-BG-57 VOLK-2) was deployed as strategic missile forces to protect Topol-M and Yasr missiles. The robot is equipped with Kalashnikov, large-caliber Utes, and Kord machine guns, high-tech camera, a laser range finder, gyrostabilizer, and protected by special armor. It can run $35.41\ km.h^{-1}$ at the same time able to shoot with precision in any weather condition and can be controlled remotely within $3\ km$ in range (*Dilipraj, 2016*).

For automated mission support, Tracked Hybrid Modular Infantry System (THeMIS) UGV was unveiled by MilRem Robotics supported by Estonian Ministry of Defence. The $2.1\ m$ length ($850\ kg$ weight) robot can run at $50\ km.h^{-1}$ speed and can carry $750\ kg$ of payload (*Army Technology, 2020*). The main purpose of the robot is to support military missions in dangerous and hazardous area where it is hard-to-reach by the human military force. The UGV is able to provide multipurpose supports, such as surveillance, reconnaissance, logistic support, target acquisition, rescue, firefighting, communication relay, emergency evacuation, troops transportation, and so on. The on-board video tracking mechanism (through day-night imaging system) and Laser range finder ensure the UGV to engage on stationary as well as moving targets. On demand, the UGV can be equipped with heavy machine-guns, grenade launcher, and air-bursting munition system.

The Ripsaw M5 Robotic Combat Vehicle (Ripsaw M5 RCV) is an extreme and most grievous mid-size off-road super-tank designed for US army operations.

The remote controlled UGV is equipped with $360°$ visual camera, thermal imaging system, gimballed surveillance system, real-time situation/environmental awareness system, terrain engagement mechanism, and a medium-caliber cannon ($30\ mm$ next-generation Chain Gun cannon or Mk44 Bushmaster II cannon). Other sophisticated and hi-tec mechanisms like SkyRaider drone, mine clearing mechanism, defeat rollers, and CROWS Javelin missile have made the RCV more deadly and dangerous to the target. The RCV weighted as $\approx 3.9 \times 10^3\ kg$, has $600\ hp$ Duramax diesel engine, and can run at a top speed of about $96.6\ km.h^{-1}$ (*Mizokami, 2019*).

Figure 9 shows some remarkable armed UGVs used in Military combat. Some important technical specifications are presented in Table 7.

Figure 9: *Armed UGVs, (a)* WOLF-2*, (b)* THeMIS*, and (c)* Ripsaw M5 RCV *(Dilipraj, 2016; Mizokami, 2019; Army Technology, 2020)*

Table 7: *Some notable military UGV armed robots with some technical specifications (Dilipraj, 2016; Mizokami, 2019; Army Technology, 2020)*

Robots	**Purpose**	**Speed ($km.h^{-1}$)**	**Size (l, w, h) m**	**Weight (kg)**	**Control**
WOLF-2 (Russia)	Guard and protection	≈ 35.41	Small size tank	0.9×10^3	Remotely controlled ($3\ km$)
THeMIS (UK)	Mission support (multipurpose)	≈ 50.00	$2.10, 2.10, 0.98$	850	Automated & Remotely controlled
Ripsaw M5 RCV (USA)	Combat Vehicle	≈ 96.6	Mid-sized Tank	3.9×10^3	Automated & Remotely controlled

Automated Weapon System (AWS)

Autonomous weapon technology is considered as the third revolution in warfare after gunpowder and nuclear arms. This technology can be seen in all military domains, marine, land, air, and space. The recent well-known baneful AWS systems are Aegis Combat System (ACS), Phalanx CIWS, X-47B UCAS, Patriot, MANTIS, IAI Harop (IAI Harpy) air defense systems, and so on (*Abaimov, & Martellini, 2020*).

An old but powerful automated weapon system, Goalkeeper, was developed by Netherlands in 1979. The system was able to track enemy missiles, aircraft, surface vehicles, or any high-speed threats and destroy with the capability of 4200 shots per minute (*Abiodun, & Taofeek, 2020*). Its dual locator system (two radar sub-systems) can identify the locations and attacks the highest priority threats instantaneously through its GAU-8/A 30 mm Gatling gun, the high precision seven-barrel cannon. The active system automatically embarks on the complete air defense activity such as observation, sensing, targeting, destroy, and selection of the next high precedence target. The system can handle 18 targets at a time. The land-based automatic system is known as Centurion C-RAM (Counter-Rocket, Artillery, and Mortar weapon) system.

Advanced Test High Energy Asset (ATHENA) is a Military Anti-UAV lethal weapon system which is the upgraded version of Area Defense Anti-Munitions (ADAM) system (*Yaacoub et al., 2020*). It has 30-KW Accelerated Laser Demonstration Initiative (ALADIN) laser which is a collective single beam power of three 10-KW fiber lasers. The system is developed by Aerospace and defense company named Lockheed Martin Corporation in USA to defeat low-value threats like UAVs, improvised rockets, baleful vehicles, UGVs, and small boats. ATHENA is a ground-based transportable laser weapon system for military use. Operation range of the system is several kilometers where the laser travels at light speed and produce intense light and heat on a small spot that bedazzles, damages irreparably, or destroys the target (*Kaushal & Kaddoum, 2017*).

To protect the forward-operating bases of the German Army in Afghanistan, NBS MANTIS (NBS C-RAM) was developed by Rheinmetall AG in Germany (2007-2011). The weapon is a very short-range $35\,mm$ fully automated air defense system based on the Skyshield gun of the designer company (*ICRC, 2014*). The AWS is also used to protect military installations from artillery, rocket, and mortar attacks. The full system consists of three units, shooting unit, sensor unit, and a central command ground-control unit. The shooting unit consists of six $35\,mm$ automatic guns; the sensor unit has two sub-units equipped with radar, effectors, and electro-optical sensors. The lethal fully automated system is active all the time (24 hours – 7 days) and responses within 4.5 seconds to detect and shoot the target (*ICRC, 2014; Amoroso et al., 2018*).

Autonomous weapons may not be considered as robots and they are not even UGVs. But the systems are intelligent enough to detect, track, shoot, and destroy any threat autonomously, thus reflecting one step ahead of Artificial Narrow Intelligence (ANI). Examples of some autonomous weapon systems are shown in Figure 10. Key specifications of some remarkable autonomous weapon systems used in military are presented in Table 8.

Figure 10: Automated weapon systems for military use, (a) Goalkeeper*, (b)* ATHENA*, and (c)* NBS MANTIS *(ICRC, 2014; Kaushal & Kaddoum, 2017; Amoroso et al., 2018; Abiodun, & Taofeek, 2020; Yaacoub et al., 2020)*

Table 8: Some key specifications of noteworthy autonomous weapon system used for military combat (ICRC, 2014; Kaushal & Kaddoum, 2017; Amoroso et al., 2018; Abiodun, & Taofeek, 2020; Yaacoub et al., 2020)

Autonomous weapons	Purpose	GUN Type	Response time	Firing range	Setup
Goalkeeper/ Phalanx/C-RAM (Netherlands)	Track high-speed threats and destroy	GAU-8/A 30 mm Gatling gun	5.5 seconds & 4200 shots/min.	Effective range $1.5\ to\ 2.0\ km$	Defense system for battel ship and Land-based transportable weapon system
ATHENA (USA)	Defeat improvised vehicles	30-KW ALADIN laser	Laser travels at light speed	Several kilometers ($> 1.6\ km$)	Ground-based transportable laser weapon system
NBS MANTIS (Germany)	Air defense system, active for 24/7	Short-range $35mm$ fully automated	4.5 seconds to detect and shoot & 1000 rounds/min.	Missiles detection $3km$ and engage firing	Ground-based (fixed) shooting unit, sensor unit, and command unit

LIMITATIONS AND CHALLENGES OF RECENT DEVELOPMENT

Though a great advancement on military ground robot technologies is observed nowadays, none of the systems are fully autonomous or independent task solver. It is very important for a military robot to take minimum control commands and behave more likely to be loyal independent system. Most of the recent systems are comparatively complex in control which engage soldiers to operate the system. Minimum manpower and minimum engagement are very much required in a battlefield. Moreover, cooperative robots (robot-robot cooperation and human-robot interaction) are in a great demand to run a robot troops with basic control commands to ensure zero damage to human lives. Collaborative Robotic

Cyber-Physical System (CRCPS) is one of the most interesting concepts which could be adopted in designing military collaborative robots.

Robots are mainly mechatronics (sometimes bio-mechatronics) systems which requires electric power to run, mostly battery powered. Other than the battery cells, power generators are loud and noisy, thus breaks the theme of the silence operations. Notably, most of the actuators of land-robots are noisy while moving or in action. Furthermore, providing services for long time requires more power backup and quick recharging capabilities, which are still not so easy and most of the cases are impossible in a battlefield.

Robots could be threatened by other robots or robot-worms. The term 'robot-worm' is new which indicates some tiny or little sized flexible or as usual robotic systems which can block some sensitive parts or sensors of a robot physically undetected and produces fake signals to confuse the robotic system in making its decisions. As the shield of this threat, anti-worm technology needs to be thought and designed. Another issue that blocks communication channel is signal jammer. Sometimes signal jammer may cut off the communication from the base control, thus autonomous intelligent robots are required.

Recently, there are several issues raised against service robots that caused harms to workers, infants, and general people (*Shyvakov, 2017; Bhardwaj, Avasthi, & Goundar, 2019*). These enlighten some big questions about the uses of autonomous military lethal robots. Results could be more devastating if a robot is hacked or tempered. Robot safety and security are the vital concern prior to provide any type of service. Robot security is complicated than a computer security as robot has some unique capabilities such as object manipulation, interaction to the environment, cognition through cameras and auditory sensors, complex and freedom motions, access to the internet, uses of cellular or satellite network, etc. A robotic system is equipped with sensors, actuators, drivers, controllers, thus vulnerable to several problems such as intrusion or hardware failure. Nowadays, robots run on a complete operating system which raise the issue of virus attack, DoS/DDoS attack, or hacking, same as computer operating system (*Breiling, Dieber, & Schartner, 2017*). Third-party control systems of robots' modules may open intrusion windows leads to unauthorized access to the system. Internal and external cyber-attack also need to be considered in designing an intelligent and knowledge based CRCPS (*Khalid et al., 2018*). The following issues could be pointed out because of which a robot can be in vulnerable attack.

- Opensource framework and libraries
- Insecure network and communication
- Missing authentication
- Weak configuration
- Weak cryptography

- Weak filtering of command
- Weak authentication procedure
- Command injection
- Memory or data corruption
- Flaws in mechatronics system design
- Physical damage
- Insecure or compromised control center
- Weak anti-virus or anti-worm technology
- Uses of untrusted third-party control modules
- Unstructured and weak security framework

The major limitations of recent technological developments can be identified as follows.

- Strong rules and regulations are absent in terms of development, applications, and uses or control of the modern intelligent technologies.
- Constructive and combined support for research and development of the technology are still not satisfactory, mostly absent.
- Security framework is not strong enough and even not well defined.
- Reliable, efficient, and continuous power support are imperative for an intelligent UGV robot which are still not in acceptable and desired level.
- The actuating mechanisms of available systems are still not in its reliable state in terms of size, power consumptions, noise, durability, and generated torque or force.
- Reliable, high-capacity, and compound sensory mechanisms are required for an intelligent system which are rarely found in the recent development.
- Secured, reliable, long-range, and fast communication are still under research and development.
- Higher memory and swift processing capacity will provide power to an intelligent autonomous robot for huge storage, faster data retrieval, quick analysis of environment, and accurate decision making. This capacity is still not reflected in the recent systems.
- The recent developments are limited to some specific terrains or environment. An expert system for universal terrain is still absent.

- To investigate and determine the possible causes and explanations of failure or any vulnerability of robotic system is time consuming and most of the cases very difficult.
- Autonomous in a sense of independent decision making and controlled action with environmental constraints are not observed in any of the recent systems.
- Mission sensitive materials in a sense of smart materials which actualize its environment and response accordingly are rarely used in designing the skeleton of the intelligent UGV robots.
- Anti-worm strategies have not yet been incorporated, not even thought to be integrated in designing a well-equipped intelligent ground robot for military use.
- UAxS are still absent in the military application.

Table 9 presents some characteristics of the above-mentioned military robots and autonomous weapons in terms of research stage, usability, combat support, service, easy transform capability, field application, and expected outcomes.

Table 9: *Characteristics and recent status of some military land-robots*

Types	Robots	Initial stage	Usable	Lethal	Service robot	Can modify	Applied	Expected results
Minesweeping	URAN-6	×	√	×	√	×	√	√
	RAMS	√	×	×	√	×	×	×
	RCS	×	√	×	√	√	√	√
Surveillance	PD-100	×	√	×	√	×	√	√
	Snake	√	√	×	√	×	×	×
	RABE	×	√	⊙	√	√	√	√
Logistic support	APD	×	√	⊙	√	√	√	√
	BIG DOG	√	√	⊙	√	√	×	×
	LS3 (Cujo)	√	√	⊙	√	√	×	×
	RS2-H1 SMET	×	√	⊙	√	√	√	√

√ → *Yes*; × → *No*; ⊙ → *Sometimes*;

Table 9: *(Continued.)*

Types	Robots	Initial stage	Usable	Lethal	Service robot	Can modify	Applied	Expected results
Search & rescue	VIPeR	×	√	⊙	√	√	√	√
	Atlas	√	×	×	√	√	×	×
	Wolverine V2	√	√	⊙	√	√	√	×
EOD robots	DAKSH	×	√	⊙	√	√	√	√
	tEOD	×	√	⊙	√	√	√	√
	PackBot	×	√	⊙	√	√	√	√
Firefighting	SAFFiR	√	×	×	√	×	×	×
	FFR-1	×	√	×	√	√	√	√
	Thermite RS1	×	√	×	√	√	√	√
	TAF-20	×	√	×	√	√	√	√
Armed robots	WOLF-2	×	√	√	√	√	√	√
	THeMIS	×	√	√	√	√	√	√
	Ripsaw M5 RCV	×	√	√	√	√	√	√
Autonomous weapons	Goalkeeper	×	√	√	×	×	√	√
	ATHENA	×	√	√	×	×	√	√
	NBS MANTIS	×	√	√	×	×	√	√

√ → *Yes*; × → *No*; ⊙ → *Sometimes*;

ROBOT ETHICS AND MORAL IMPACTS

Technological advancements have brought us in the age of AI where machine artifacts are displaying their smartness and mightiness in most of the cases. It is not the responsibility of scientists to eliminate or reduce human inhumanity through technological integration. It is impossible. Thus, if it flushes up during a warfare, it raises a big question to the humanity. Military training is to build a soldier more like a robot, which will never be achieved. On the other hand, the more a machine advances towards Artificial Super Intelligence (ASI), the more it tries to achieve humanity, and that will always be nothing but a dream.

There may always be counterarguments to the use of robotic armies. It is very difficult, sometimes contradictory, to blame if something goes wrong with a robot. Usages of autonomous robots may lower the tolerance level of entering a warfare. The meaning of unilateral engagement to a warfare could reflect some different meaning far beyond just a warfare. Misleading or disobeying an order could raise threats to the commander and the troops. Distinguishing valid and invalid targets is also under the consideration of robot ethics. As the modern weapons are autonomous, moral programming is imperative (*Umbrello, Torres, & De Bellis, 2020*).

Justifying political issues may mislead an intelligent robot. Winning support of the public and civilian will be impossible if a robot is allowed and permitted to destroy or kill. Technology transfer could raise another big question if the system comes on the hand of terrorist groups. Moreover, advance AI robots may enforce to realize human as threat to robots' existence, the reflection could be a nightmare to humanity.

Literally, laws can be considered as the moral actors in deciding life and death without human intervention. Robots must be bounded by the defined and specific state laws and moral rules same as for human. A robot must not be allowed in a battlefield if it does not pass some predefined tests. Asimov's three laws of robotics are perfect. If any intelligent machine does not obey these three rules, must not be defined as robots, rather be defined as Monster Robot (Monster-bot or Mobot), the ultimate threat to humanity. A combat robot must possess some specific sensors or equipment to collect combatant data for further analysis and comparisons. This implies the uses of Black Box equipped with a robot system as the Command and Action Recorder (CAR). Sooner or later robots will be more active in battlefields. Whatever the nature of a military robot is (manual, semi-automated, or automated), they must be supervised and human controlled. Otherwise, there will be no halter and "Robotanity" (opposite of Humanity to the robots ASI) will walk one step ahead than the benevolence and humankind will be under threat.

RECOMMENDATIONS

Following recommendations can be made for the future development and improvement of the intelligent land-robot technology.

- First, it is obvious to define state laws and moral ethics to control the development, applications, distributions, and access to the technology and system. If the technological development is not monitored, if the control goes to wrong hand, or distributed to some unauthorized community, the impact will be devastating, and human existence will be under unbearable and undeniable threat.

- States, institutions, and industries should come forward and work together to provide legitimate support, research support, and economic security to conduct any development process smooth and uninterrupted. Technological research facilities should be created in state level as well as institutional and industrial level.
- A well-structured security framework should be engineered for the future design and development of the autonomous weapons and robot technologies.
- Stable, efficient, and longtime power support are very much required to get continuous support from a UGV robot. Thus, requires a high-class research and development activities on the power support system. Some efficient techniques are needed to be discovered for efficient and faster (or ultra-fast) charging of the power storage devices.
- Efficient electro-mechanical actuators are required with zero noise level to ensure any defense operation undetected by the opponent. This will involve a high-quality research on electro-mechanical engineering.
- Efficient sensor technologies will provide wide opportunity to the intelligent robots to sense, recognize, understand, and adapt in any kind of environment. This points to the world class research on sensor technology.
- Reliable, long range, faster, and continuous communication is one of the important requirements for military land-robot and autonomous technologies. Efficient devices for communication are required to ensure a secured and reliable transfer of data. This basically opens another wide field of research and development opportunity.
- High quality faster processing capability is another requirement for a military land-robot. Efficient image and data processing capability will increase the efficiency of the intelligent autonomous system.
- Moving on all kinds of terrains (uneven, bumpy, slippery, rocky, icy, and so on) and obstacle avoidance are one of the challenges in the field of defense land-robotic research. Efficient multi DoF, multi legged, multi wheeled, or transformable mechanism with modern and advanced control engineering application could solve the problem.
- Any kind of failure of a robotic platform must be analyzed and investigated which is found absent in most of the development programs. To adapt this facility, a kind of Black Box system can be implemented for command and action recording.

- Military robots must be designed with autonomous capability for navigation, decision making, and action to its environment. For any communication cut off or signal jamming, the robot must take its own decision to survive and return to the base.
- Military robot skeleton and body frame must be designed with optimum structural concept (armored, light, heavy, flexible, transformable, transparent, invisibility, or color shifting). Thus, smart materials are required which opens another potential field of research and development.
- Robots must be design with anti-worm defense mechanism. A defense robot may carry several tiny robots (robot-worms or swarm-robots) which could be applied to attack opponents and create illusions.
- Intelligent autonomous robots could be developed and tested with the focus of universal support for x-domain (cross domain) applications. This mainly accumulates several engineering approaches like maritime engineering, aerospace engineering, cyberspace engineering, communication engineering, and robotics.

CONCLUSION

Eventually, military robot forces will be applied more effectively in near future to carryout investigations, surveillance, reconnaissance, petrol operation, gather information, spy location, breach enemy security, and provide supports in a battlefield. It is obvious that the next modern warfare will be based on autonomous weapon and intelligent defense systems. Some statistics say that the US army are renovating and applying the UGV robots and autonomous weapon systems which are about 60% of the total army (*Sapaty, 2015*). By the year 2025, US army will be well equipped with more UGVs, and robots than human soldiers (*Antal, 2018*). China is entering into the Golden Age of AI development and going to be the next leader as they receive a huge support from the highest level of Chinese policies and leadership. Russia have seen the future as, whoever become the leader in the field of AI will be the ruler of the future world. Future warfare will engage soldiers in operation and control of intelligent machines rather than direct shooting to each other. Bipedal Intelligent Machine (BIM) will be the next level of AGI and will continue to reach beyond the ASI soldiers in a future battlefield. The concept of Cloud Robotics and Internet of Things (IoT) based Cloud Computing will make the Intelligent Machine (IM) more powerful (*Ahmed et al., 2020*) in terms of data processing, information storage, information sharing, information analysis, RAtI, decision making, automated combat planning, and even thinking. All of these will be the blessings of technological advancement like super-computer, faster processor, super-fast communication, and huge data storage capability. In a word, cloud will hold the brain of a future

IM and the machine on the ground will be responsible to provide feedback and execute commands. Whatever the situation will be in the future, it is mandatory to establish a good and reliable man-machine cooperation mechanism for the automated machines by setting the rules and obeying the ethics of war, otherwise humanity will be in irrecoverable danger.

This study basically tried to present a variety of land-robot technologies used in various military activities. Challenges in recent technologies, robot security issues, robot ethics, and moral impacts are also discussed in this study. Future study could focus on a particular type of land-robot to analyze recent development challenges, gaps, impacts, and future potentials. Robot security and robot ethics are other two domains which could be focused extensively to design a structured framework in using such intelligent robot technologies in military combat and warfare. Of course, human will be benefited by the integrated intelligent technology only if the misuse of the technology can be controlled through strong command and control with fine morality and ethics.

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