Economics and Organization of Logistics
5 (4), 2020, 43–57

DOI: 10.22630/EIOL.2020.5.4.28

Konrad Michalski[1]***, Marek Nowakowski***[2, 3]
[1] Warsaw University of Life Sciences – SGGW
[2] State Higher Vocational School in Suwałki – PWSZ
[3] STEKOP S.A.

The use of unmanned vehicles for military logistic purposes

Wykorzystanie pojazdów bezzałogowych do celów logistyki wojskowej

Abstract. Nowadays the innovations and inventions allow the development of new technologies that can be implemented in various fields, including logistics. Technologically advanced robots and unmanned vehicles can not only support activities, but also in many cases they replace human being activities, such as controlling, identifying and managing goods, warehouse and critical infrastructure, or transport routes. Smart devices can eliminate human presence in the most advanced activities like firefighting or contamination of storage or transhipment. The aim of the study overview is to diagnose the current state and trends in the development of military technologies of unmanned vehicles. For this purpose some of the solutions in the field of unmanned ground vehicles and possibilities of their use considering military missions requirements were presented. The status of global projects implementation was reviewed. Polish solutions and technologies related to autonomous vehicles were discussed. A comparative analysis related to the global and domestic solutions was used. Recommendations, directions of development and possibilities of advanced technologies in terms of safety logistics, transport or fighting the effects of natural disasters were defined.

Key words: innovations in logistics, UAV, UGV, military logistics

Synopsis. Współczesne innowacje i wynalazki pozwalają na rozwój nowych technologii, które można wdrażać w różnych dziedzinach, w tym w logistyce. Zaawansowane technologicznie roboty i bezzałogowe pojazdy mogą nie tylko wspomagać działania logistyczne człowieka, ale także w wielu przypadkach zastępować go, czego przykładem jest kontrola, identyfikacja i zarządzanie towarami, infrastrukturą magazynową i krytyczną, a także szlakami transportowymi. Inteligentne urządzenia mogą wyeliminować obecność ludzi podczas najbardziej zaawansowanych czynności, takich jak gaszenie pożarów, czy skażenie składowania lub przeładunku. Celem przeglądowego opracowania jest diagnoza obecnego stanu oraz trendów rozwoju wojskowych technologii pojazdów bezzałogowych. W tym celu dokonano przeglądu rozwiązań w zakresie bezzałogowych pojazdów lądowych oraz możliwości ich zastosowania z uwzględnieniem wymagań misji wojskowych. Dokonano przeglądu stanu globalnej realizacji projektów. Omówiono polskie rozwiązania i technologie związane z pojazdami autonomicznymi. Zastosowano analizę porównawczą w odniesieniu do rozwiązań globalnych oraz krajowych. Określono rekomendacje, kierunki rozwoju i możliwości zaawansowanych technologii w zakresie logistyki bezpieczeństwa, transportu, czy walki ze skutkami klęsk żywiołowych.

Słowa kluczowe: innowacje w logistyce, UAV, UGV, logistyka wojskowa

Introduction

New challenges of logistic as well as many tasks related to ensuring an appropriate level of security in transportation require implementation of modern solutions and concepts like unmanned aerial vehicles (UAV) or unmanned ground vehicles (UGV) [Galaret et al. 2020]. Nowadays, UGVs are gaining more and more interest in terms of military applications. It should be underlined that unmanned vehicles can greatly facilitate key industrial operations like optimization of flows and improving warehouse management according to just-in-sequence production and just-in-time logistics. The nearest future should bring more intensive developed regarding automation process. Significant trend can be seen in unmanned ground vehicle market size looking at the last years and the forecast for the nearest future (Figure 1).

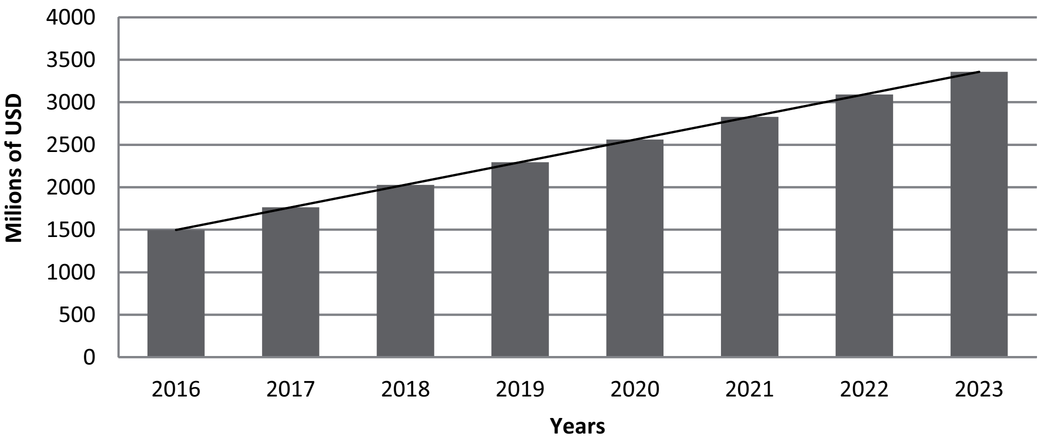


Figure 1. UGV market size in 2016–2023

Rysunek 1. Wielkość rynku UGV w latach 2016–2023

Source: [OpenPR 2020].

Published UGV protypes are intended as logistics carriers, remote weapons platforms, soldier companions, or surrogates for reconnaissance, surveillance, and target acquisition [National Research Council, 2003]. In USA authorities proposed unmanned vehicle called "mule robotic" which can perform variety of sustainment [Parker 2019]:

- carrying dismounted soldier loads
- operating in terrain requiring dismounted operations
- performing non-standard Casualty Evacuation and other services, such as battery recharging

– delivering classes of supply from battalion through company to the soldier to include resupply of ammunition
– performing combat tasks such as reconnaissance of high-risk areas.

Autonomous ground platforms without a human operator onboard covers a broad range of autonomy using technologies including navigation, mission sensing (object recognition), communications and piloting, machine intelligence for planning, learning and data analysis, mobile manipulation, energy storage and management, human-machine interface (HMI) [Ivanowa et al. 2016].

International applications of autonomous vehicles for land logistic

The unmanned vehicle can move freely in almost any environment under risk of explosion, fire, flooding, as well as operating in contaminated area. Unmanned platforms are suitable to carry out military activities also in urbanized areas. Their loss would not cause socio-political repercussions as death or serious injuries. Additionally we can noticed the manpower reduction in armed forces all over the world, so unmanned platforms and robotization can be a solution due to growing operational requirements.

In Europe and in the Western armies UGV`s are considered mainly as support for soldiers. Autonomous platforms should be capable to transport goods, ammunition, rucksacks, and to carry out missions when returning back from the fighting area. In the Middle East and Asia armies have a different approach, focusing on weaponised platforms, which allow to take part in warfare without risking soldier's life.

UGV implementation in UK

UK Ministry of Defence, Under Project Theseus, have purchased five unmanned ground vehicles type Horiba Mira. Three of technology demonstrators are wheeled Viking UGVs (Figure 2a) and two tracked Titan platforms [Advance 2020]. Project was launched for the development and operational field experimentation of autonomous logistic resupply systems.

Horiba Mira Viking is the UGV that has go an operational range of 200 km powered by diesel engine. It is equipped with hybrid drive allowing to move in the distance of 20 km using an electric drive for silent operation. Described demonstrator prototype is able to carry up to 800 kg of goods [Horiba Mira]. VIKING's 6-wheel independent suspension supporting troops using advanced AI-based autonomy with GPS-denied navigation. Vehicle is designed to travel at challenging terrain and tarmac as well as on the road up to 50 km/h. Despite of efficiently resupplying soldiers, Viking has got surveillance feature like providing a remote weapon station platform [Leigh 2020].

Armed Forces have also ordered Rheinmetall Mission Master vehicles (Figure 2b) under United Kingdom's Robotic Platoon Vehicle programme. It is the cargo version of unmanned vehicle which supposed to increase the combat capabilities of on the front line soldiers [Rheinmetall Mission…].

The ordered Cargo system will reduce the combat load, tactical kit, or medical equipment and boost soldier mobility and efficiency. It has got shoulder with payload

a) b)

Figure 2. View of Horiba Mira (a) and Rheinmetall's Mission Master (b)
Rysunek 2. Widok Horiba Mira (a) oraz Rheinmetall's Mission Master (b)
Source: own work based on [Eder Magazine 2018].

of up to half a ton of goods. Mission Master can operate in fully controlled, autonomous or semiautonomous mode due to implemented artificial intelligence allowing to execute a multitude of dull, dirty, and dangerous tasks.

Mission Master has got Lithium battery pack that allows to operate continuously for 8 hours at 30 km/h, carrying the full 600 kg maximum payload. Its sensors like Lidars, a front and a rear cameras and a 360° optronic system together with on-board computer , ensuring effectively operation in GPS denied urban areas and others [MilitaryLeak 2020]. Configuration includes bidirectional audio communication system and microphones.

UGV project supported in Europe

Estonian company Milrem Robotics is well-known for the development of the THeMIS (Tracked Hybrid Modular Infantry System) modular ground unmanned system, already validate in combat conditions. Based on this platform a new solution will be created under program called iMUGS (integrated Modular Unmanned Ground System). The main aim of this project is to develop modular and scalable solution allowing to create a whole family of manned and unmanned systems that would become the European standard for land unmanned vehicles [Sprenger 2020].

Milrem Robotics, as the leader of a consortium composed of several European defence, communication, cybersecurity and high technology companies expect the need of thousands of UGVs during the next 10–15 years growing the value of the market into billions of Euro [Cozzens 2020].

As it was mentioned above the modular construction makes the THeMIS effective autonomous ground vehicle for fulfilling missions in extreme environments. UGV has completed the first stage of implementation and combat trials supporting soldiers in Mali as part of the anti-terrorist Operation Barkhane [Milem Robotics]. The platform is designed to support troops by carrying everything what a soldier would normally carry (Figure 3).

It is a remote-controlled platform with a payload of 750 kg, powered by a hybrid system consisting of diesel and electric engines. UGV is equipped with many types of tie downs and restraints to prevent load movement. All the drive and control system are located in the side modules, inside the gap between upper and down part of tracks.

THeMIS allows to travel up to 10 hours, including about 90 minutes in silent mode when it uses only electric drive. The maximum speed is about 35 km/h and the range depends on the environment conditions. The vehicle is controlled by the operator via radio using sensors and the weapon system. It is also possible to transmit the collected data (an image form) to the appropriate command systems [Eder Magazine 2020].

a) b)

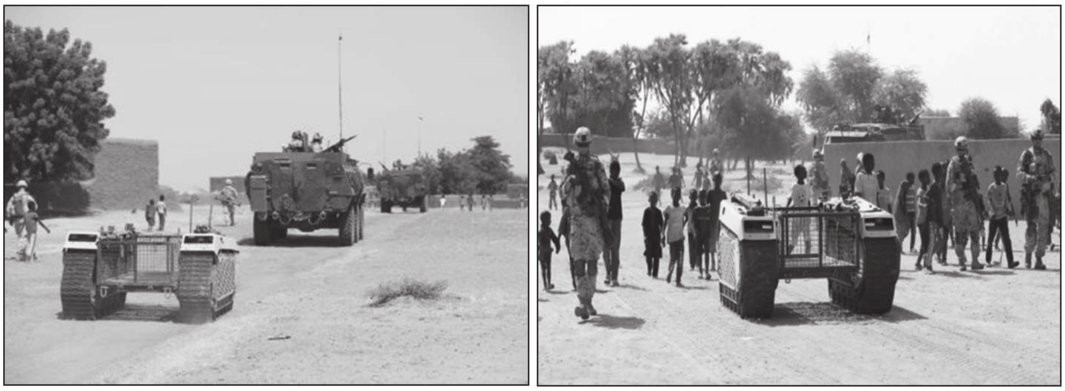


Figure 3. Themis UGV during misison in Mali: convoy (a) and anti-terrorist operation support (b)
Rysunek 3. Themis UGV podczas misji w Mali: konwój (a) i wsparcie operacji antyterrorystycznej (b)
Source: own work based on [Eder Magazine 2020].

Review of autonomous platforms under operation in the USA Army

US Army has developed a document called "Robotic and Autonomous Systems", referred to as the strategy for the development of vehicles in the future. Report includes a vision describing the cooperation of manned and unmanned controlled systems, as well as semi-autonomous and fully autonomous systems on the future battlefield. It also includes guidelines for robots, assisting troops which are considered as an urgent need [Walsh and Strano 2018].

The concept of a supporting soldiers robot, that was announced by SMET (Squad Multipurpose Equipment Transport) program, dominates the US Army (Figure 4). SMET focuses on creation of robots designed to relieve troops in the transport of weapons, ammunition, food and other necessary equipment, or to carry out reconnaissance and tasks related to the detection and removal of dangerous goods along the way. It means the proposed structures can also be armed.

The tactical and technical requirements assume that the vehicle can carry loads about 450 kg, which is related to four American military backpacks, six boxes of food rations and four water canisters. The range at maximum load should cover a distance of up to 100 km, and operate at lasts 72 hours [Cox 2020]. UGV should generate 3 kW of power (station-

Figure 4. The Army's Small Multipurpose Equipment Transport (SMET)
Rysunek 4. Wojskowy mały transport wielozadaniowy (SMET)
Source: [The General Dynamics…].

ary) and 1 kW (drive) keeping equipment and charging batteries during movement. The vehicle can be optionally armored, and potentially perform the function of electronic reconnaissance and neutralization of improvised explosives.

Technology applications in other destinations

Praesidium Global announced in 2017 that it was awarded to supply its UGV for validation by the Australian Army. The company offered Mission Adaptable Platform System (MAPS). It is semi-autonomous platform which can be equipped with additional on-board devices like charging generator, additional batteries, acoustic detectors and even low-recoil 30 mm cannon.

a) b)

Figure 5. UGV platform in Australian Army (a) and the Russian Marker roboti (b)
Rysunek 5. UGV platforma w armii australijskiej (a) i rosyjski robot Marker (b)
Source: [Drwiega 2020].

Proposed UGV version is suitable for tactical and non-tactical operations. According to an implement algorithm is designed to be controlled by operator, follow a soldier, or run between two defined points autonomously [Beurich 2019]. The Australian Army used the MAPS during the summer exercise Talisman Sabre 2019 (Figure 5a) held in Shoalwater Bay Training Area, Queensland. The six-wheeled UGV has got payload over 500 kg of equipment to carry out missions [Wong 2019].

The Russian Foundation for Advanced Research Fund (National Center for the Development of Technologies) and Basic Elements of Robotics have shown new version of the modular unmanned ground vehicle called Marker (Figure 5b). The Marker is under validation by Special Operations Forces. The vehicle is very similar to a regular tank but design could be changed soon. According to published article by National Center the prototype managed mission in wild territory with a snow for 30 km in Chelyabinsk region [Papadopoulos 2020].

There are many more examples of developed unmanned ground vehicles playing an important role in support and assisting in logistics operations by army forces. UGVs are able to operate in very wide variety of situations require solving a number of difficult technical challenges.

Overview of domestic programmes in Autonomous Vehicles

In Poland, there are currently several centres dealing with robots dedicated to perform various tasks regarding land missions like Industrial Research Institute for Automation and Measurements (PIAP), the Military University of Technology and University of Technology allocated in Bialystok as well as Kielce.

The most recognized center under Łukasiewicz Research Network – PIAP is a manufacturer of Polish mobile robots, including for example C-IED applications and diagnosis [Łukasiewicz – Przemysłowy Instytut…]. In addition to the institute, the scientific and industrial consortium, consisting of ZM "Tarnów" S.A., Military University of Technology and STEKOP S.A., conducts research on the Perun platform called Autonomous wheeled vehicle with a weapon module for reconnaissance and combat tasks under support by National Centre of Research and Development of the Republic of Poland as part of the scientific research program for the defense and security [Nowakowski and Wacławik 2020]. It should be underlined that STEKOP has developed several variants of unmanned ground vehicles under TARVOS project powered by an electric motor and the internal combustion engine (Figure 6).

The first variant of TARVOS was based on a chassis from mass-produced quad. Company used a complete frame form the factory-manufacured vehicle along with the suspension and steering. The internal combustion engine and gearbox were replaced by an electric drive unit connected to the original drive shafts to carry out the project. Due to described modifications precise control of the platform was obtained with its diagnostics of the all driving conditions. Additionally, a new body was installed along with the necessary equipment including battery packs, a generator set, etc. The developed self-supporting body structure also allows to install all electronic devices controlling the vehicle, sensors, radio transmitters, cameras and an optoelectronic surveillance head [NCBR].

As part of the ongoing work, a conversion system was developed that allows to carry out a complete automation process of any special-purpose land vehicle, enabling remote control and data acquisition, both about the environment and the vehicle itself. The system consists of three elements: CVCP – Central Vehicle Control System, set of dedicated effectors and radio link. The proposed system will significantly expand the functionality

a) b)

Figure 6. Electric TARVOS CARGO (a) and TARVOS CARGO S90 equipped with combustion engine (b)
Rysunek 6. Elektryczny TARVOS CARGO (a) i TARVOS CARGO S90 wyposażony w silnik spalinowy (b)
Source: own work based on [Nowakowski and Wacławik 2020].

of the unmanned ground vehicle in line with the expectations of the modern IT-based battlefield.

Launched functionality allow to operate in remote, semi-autonomous and autonomous mode to transport goods, weapons, and related goods Additional value is simplification of maintenance. System is designed to be maintained easily as well as long-term usage can be managed sufficiently after basic training.

Technologies supporting autonomy of vehicles

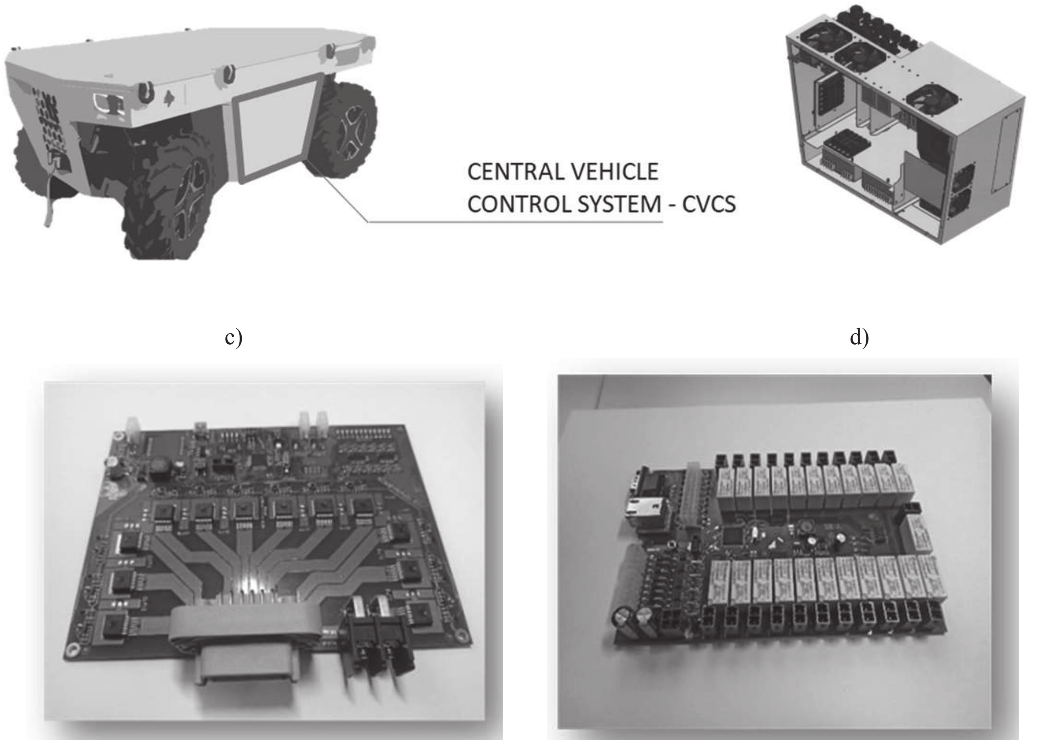
The core element of the conversion technology is developed electronic control unit called CVCS (Figure 7). It is an operating unit containing the necessary IT infrastructure (IT) allowing for remote control of the whole vehicle as well as semi-autonomous and autonomous mode.

Operation of the system requires installation of additional effectors as mechatronic solutions that allows adaptation with the mechanisms like brake systems, electromechanical steering wheel and automatic gearbox operation system, etc.

Despite of components managing the chassis, an important role is played by sensors that enable the implementation of safety and autonomous functions. The platform should have an ability to detect surroundings for autonomous mobility. It should be stressed that environment is very dynamic so data fusion from navigation system, like global positioning system (GPS) and other devices is required. The vehicle must be able to use collected data from installed sensors to plan and follow a defined path avoiding obstacles.

The most important issue is to develop an effective system to recognize the vehicle's surroundings – including detecting and locating obstacles that may be dangerous during vehicle movement or insurmountable. Data fusion of vision systems with laser rangefinders may allow to create an effective system of environmental recognition. UGV

a) b)



c) d)

Figure 7. Location of CVCS (a) , central unit (b) and examples of designed internal modules (c, d)
Rysunek 7. Lokalizacja CVCS (a), jednostki centralnej (b) i przykłady zaprojektowanych modułów wewnętrznych (c, d)

Source: own work based on own materials of STEKOP company.

obstacle determination is based on the following devices: MRS1000 multi-layer scanner (LIDAR), Velodyne VLP laser scanner and cameras installed on each side of the vehicle (Table 1) [SICK Sensor Intelligence]. This enables the creation of a spatial model of the terrain and the determination of the location of terrain obstacles. Additionally the system allows to observe the environment through the installed Mobile Surveillance Solution Hikvision iDS.

Creation of spatial model of the area around the vehicle combined with a digital map of the terrain allows the vehicle to move autonomously. During parameter selection of the system, subsystems for determining the position and navigation should be considered. The issues of visualization of the environment must be related to the process of GPS tracking and automatic operation in case there is lack of signal transmission from satellite using build in gyroscopes and accelerometers contained inside an inertial measurement unit (IMU). Position accuracy can be improved when the INS is aided by Global Navigation Satellite System (GNSS) [InterialLabs].

Table 1. List of devices supporting navigation and anti-collision
Tabela 1. Lista urządzeń wspomagających nawigację oraz antykolizyjnych

Aided Inertial Navigation Systems (INS)	
Velodyne VLP	
SICK MRS1000	
Mobile Surveillance Solution Hikvision iDS	
IP cameras BCS	

Source: own work based on [Mapix technologies].

Tasks performed by autonomous vehicles

The four-wheeled autonomous vehicle is adapted for operation in urban and rural areas. TARVOS can be controlled on 3 levels: stationary, mobile and emergency (Figure 8). At the operator's position, the mission of the platform can be supervised by the operator by analysing the data transmitted from the installed vision systems and sensors on the unmanned vehicle.

Additionally (Figure 9), the vehicle can operate in the "follow me" mode by following the marked object. It can be a vehicle or a guide soldier.

The follow me system improves UGV functionality, because the platform is autonomously following the operator, recording his path and keeping safe distance, without

a) b) c)

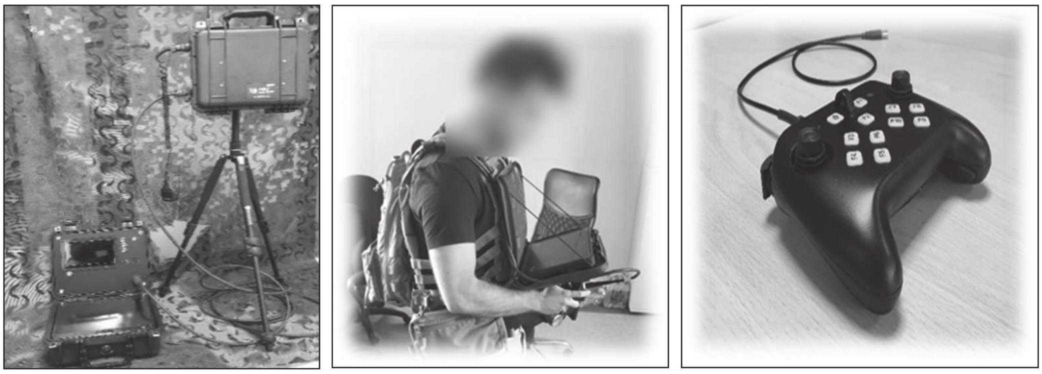


Figure 8. View of the control system: stationary (a), mobile (b), emergency (c)

Rysunek 8. Widok układu sterowania: stacjonarny (a), mobilny (b), awaryjny (c)

Source: own work based on own materials of STEKOP company.

a) b)

Figure 9. Follow me mode soldier (a), vehicle (b)

Rysunek 9. Żołnierz w trybie Follow me (a), pojazd (b)

Source: own work based on own materials of STEKOP company.

necessary actions from the operator side. The proposed system is based on printed pattern and cameras detecting its shape based on implemented algorithm. Based on measurements, system estimates relative operator's position and provide control signals for platform driving system.

Technology development plans

Unmanned Ground Vehicles received a lot of interest in recent years as a part of modern armed forces with an increasing number of dual use and civil applications. Current propulsion systems are based on different types of internal combustion engines related to fossil fuels. Due to the global energy policy alternative systems like fuel cells are considered for further development [Baldic et al. 2010]. More simple and faster to implement solutions is based on hybrid electric power train. Torsional moment electric motor allows to run in silent mode without using internal combustion engine. The combustion engine can recharge batteries and runs at a constant and efficient rate. Both option are under discussion for further development of TARVOS platform.

Taking into consideration safety issues and autonomous mode efficiency in all environmental conditions the perception system must be improved using more sensors like radars to detect, classify, and locate a variety of natural and manmade features.

An important research is the development of tools and specialist equipment allowing the implementation of various technological functions based on the fusion of data from advanced sensors. The accomplishment of this task requires the multi-level approach related to optoelectronics, computer science and radar technology.

Conclusions

Many autonomous unmanned vehicle technology is being used in more and more sophisticated areas, also civilian applications. An example is the use of drones for a long time to guard the warehouses of valuable cargo [Kuk 2015] or for logistics in the forest district [Michalski and Gębicki 2018]. These applications contribute to the increase of the broadly understood effectiveness of logistic activities, including bigger human safety.

Regarding UGVs, this technology is used widely in the teleoperation mode but one of the main directions of the armed forces is reducing human being involvement and risk, even in the most developed countries. High operational efficiency can be achieved by launching autonomous platforms in various defence applications to carry out transportation and rescue missions, combat support. In case of land platforms there are some challenges related to the requirements of the carrier as well as communication and control system. All authorities are working closely to define unification and standardization for unmanned vehicles.

There are various of common applications of unmanned vehicles for civilian and military purpose especially in rescue sector. Platforms support evacuation of the injured and managing transport rescuers. Such tasks require installation of additional sensors scanning the area by UGVs to search for the missing in debris or landslides. Many of introduced platforms can be also easily equipped with external fire extinguishing systems to assist in operations without human being presence like reconnaissance in the following places: industrial buildings, hazardous materials warehouses, underground parking lots, etc.

References

Advance, 2020: Dstl acquires autonomous ground vehicles from HORIBA MIRA and QinetiQ, [electronic source] https://www.adsadvance.co.uk/dstl-acquires-autonomous-ground-vehicles-from-horiba-mira-and-qinetiq.html [access: 15.11.2020].

Baldic J., Osenar P., Lauder N., Launie P., 2010: Fuel cell systems for long duration electric UAVs and UGVs, [in:] Defense Transformation and Net-Centric Systems, J. Suresh (ed.), SPIE Proceedings 7707. DOI: 10.1117/12.851779

Beurich S., 2019: Mechanical mule trialled during Talisman Sabre 2019, Australian Government, Department of Defense, [electronic source] https://news.defence.gov.au/national/mechanical-mule-trialled-during-talisman-sabre-2019 [access: 15.11.2020].

Cox M., 2020: Army Close to Awarding New Contract for Robotic Mule to Carry Gear for Grunts, Military.com, [electronic source] https://www.military.com/daily-news/2020/06/10/army-close-awarding-new-contract-robotic-mule-carry-gear-grunts.html [access: 15.11.2020].

Cozzens T., 2020: GMV to help develop unmanned ground vehicle for European defense, GPSWOrld, [electronic source] https://www.gpsworld.com/gmv-to-help-develop-unmanned-ground-vehicle-for-european-defense/ [access: 15.11.2020].

Drwiega A., 2020: Unmanned Ground Vehicles: Transitioning Capability, [electronic source] https://asianmilitaryreview.com/2020/03/unmanned-ground-vehicles-transitioning-capability/ [access: 15.11.2020].

Eder Magazine, 2018: Mission Master multiplies its versions, [electronic source] https://www.edr-magazine.eu/master-mission-multiplies-its-versions [access: 15.11.2020].

Eder Magazine, 2020: Milrem Robotics' THeMIS UGV completes first deployment in Mali proving its effectiveness and reliability, [electronic source] https://www.edrmagazine.eu/milrem-robotics-themis-ugv-completes-first-deployment-in-mali-proving-its-effectiveness-and-reliability [access: 15.11.2020].

Galar D., Kumar U., Senevirante D., 2020: Robots, Drones, UAVs and UGVs for Operation and Maintenance, CRC Press, Taylor & Francis Group.

Horiba Mira, [electronic source] https://www.horiba-mira.com/unmanned-ground-vehicles/media-centre/case_study/viking-multirole-ugv-platform/ [access: 15.11.2020].

InterialLabs, [electronic source] https://inertiallabs.com/ [access: 20.11.2020].

Ivanova K., Gallasch G.E., Jordans J., 2016: Automated and Autonomous Systems for Combat Service Support: Scoping Study and Technology Prioritization, Australian Government, Department of Defense, [electronic source] https://www.dst.defence.gov.au/sites/default/files/publications/documents/DST-Group-TN-1573.pdf

Kuk M., 2015: Drony PKP CARGO pilnują pociągów, wartość kradzieży ładunków spada – komunikat prasowy [PKP CARGO drones guard trains, the value of cargo theft decreases – press release], PKP Cargo, [electronic source] https://www.pkpcargo.com/pl/aktualnosci/drony-pkp-cargo-pilnuja-pociagow-wartosc-kradziezy-ladunkow-spada/ [access: 15.11.2020] [in Polish].

Leigh N., 2020: UK Purchase Titan and Viking Unmanned Ground Vehicles, Overt Defense, [electronic source] https://www.overtdefense.com/2020/03/23/uk-dstl-purchase-titan-and-viking-unmanned-ground-vehicles/ [access: 15.11.2020].

Łukasiewicz – Przemysłowy Instytut Automatyki i Pomiarów – PIAP, [electronic source] https://piap.pl/ [access: 15.11.2020] [in Polish].

Mapix technologies, [electronic source] https://www.mapix.com/lidar-scanner-sensors/ [access: 20.11.2020].

Michalski K., Gębicki M.: 2018, The use of civil drones in forest district logistics, Transport Economics and Logistics 78, 133–146. DOI: 10.26881/etil.2018.78.11

Milem Robotics, [electronic source] https://milremrobotics.com/product/themis-transport/ [access: 15.11.2020].

MilitaryLeak, 2020: UK Orders Rheinmetall's Mission Master Unmanned Ground Vehicle, [electronic source] https://militaryleak.com/2020/04/19/uk-orders-rheinmetalls-mission-master-unmanned-ground-vehicle/ [access: 15.11.2020].

National Research Council, 2003: Technology Development for Army Unmanned Ground Vehicles, National Academies Press, Washington, DC.

NCBR, Projekt „Autonomiczny pojazd kołowy z modułem uzbrojenia do zadań rozpoznawczych i bojowych", [The project „Autonomous wheeled vehicle with reconnaissance weapons module and combat"], STEKOP, [electronic source] https://stekopsystems.pl/ncbr/ [access: 15.11.2020] [in Polish].

Nowakowski M., Wacławik K., 2020: Simulation of the possibility of using a broadband radio system based on a mesh network to control an unmanned ground vehicle, [in:] Komputerowe wspomaganie projektowania, wytwarzania i eksploatacji [Computer aided design, manufacturing and operation], R. Trębiński (ed.), WAT, Warszawa, 177–193.

OpenPR, 2020: Unmanned Ground Vehicle Market Size, Share, Trends, Growth, Forecast, Value, Forecast, Industry Statistics – Valuates Reports, [electronic source] https://www.openpr.com/news/2114271/unmanned-ground-vehicle-market-size-share-trends-growth [access: 17.08.2020].

Papadopoulos L., 2020: Russia's Unmanned Ground Vehicle Treks up 18-mile Path, Interesting Engineering, [electronic source] https://interestingengineering.com/russias https://interestingengineering.com/russias-unmanned-ground-vehicle-treks-up-18-mile-path [access: 15.11.2020].

Parker Ph.M., 2019: The 2020–2025 World Outlook for Unmanned Ground Vehicles (UGV), ICON Group International, Inc, Dublin.

Rheinmetall Mission Master, Rheinmetall Canada, [electronic source] https://www.rheinmetall-defence.com/en/rheinmetall_defence/systems_and_products/unbemannte_fahrzeuge/mission_master/index.php [access: 15.11.2020].

SICK Sensor Intelligence, [electronic source] https://www.sick.com/pl/pl/ [access: 20.11.2020] [in Polish].

Sprenger S., 2020: European Union awards grant to forge unmanned ground vehicle standard, DefenseNews, [electronic source] https://www.defensenews.com/global/europe/2020/12/16/european-union-awards-grant-to-forge-unmanned-ground-vehicle-standard/ [access: 15.11.2020].

The General Dynamics Small Multipurpose Equipment Transport SMET, European Security & Defense, [electronic source] https://euro-sd.com/2020/02/articles/16269/enhanced-urban-assault-technology/attachment/the-general-dynamics-small-multipurpose-equipment-transport-smet/ [access: 15.11.2020].

Walsh S.W., Strano M.S. (eds.), 2018: Robotic Systems and Autonomous Platforms. Advances in Materials and Manufacturing, Woodhead Publishin, Cambridge, USA, Kidlington UK. DOI: 10.1016/C2016-0-01129-4

Wong K., 2019: Australian Army trials logistics UGV during 'Talisman Sabre' 2019, Janes, [electronic source] https://www.janes.com/defence-news/news-detail/australian-army-trials-logistics-ugv-during-talisman-sabre-2019 [access: 15.11.2020].

Correspondence addresses:

Konrad Michalski, PhD
(https://orcid.org/0000-0001-6997-352X)
Warsaw University of Life Sciences in Warsaw – SGGW
Management Institute
166 Nowoursynowska St., 02-787 Warsaw, Poland
e-mail: konrad_michalski@sggw.edu.pl

Marek Nowakowski, PhD Eng.
(https://orcid.org/0000-0003-3864-076X)
State Higher Vocational School in Suwałki – PWSZ
Politechnic Department
10 Teofila Noniewicza St., 16-400 Suwałki, Poland
e-mail: marek.nowakowski@pwsz.suwalki.pl;
STEKOP S.A.
Director of Technical Department
9 Mołdawska St., 02-127 Warsaw, Poland