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The Tendency of Development and Application of Service Robots for Defense, Rescue and Security

Isak Karabegović[1] - Milena Dukanović[2]

[1]Department of Technical faculty, University of Bihać, Bosnia and Herzegovina
[2]Department of Electrical Engineering, University of Montenegro, Montenegro

Abstract**—***The development of sensor, information and communication technology, or new technology, has contributed to the development of robot technology. A new generation of service robots has been developed, and the highest number of their practical applications is for defense and security. Progress and development of information technology, sensor technology and servo-drive is responsible for the development of over 600 different types or prototype service robots. Service robots are designed for professional jobs and service jobs that are used in everyday life. The rapid development of computer management enabled the rapid development of various service robots that can move independently, autonomously exchange information with their surroundings and act completely autonomously (UV Unmanned Vehicles - vehicles that operate autonomously without human management). They can be used in all operating conditions on land, air and water, which is most important for the development of service robots for defense and security. Different applications of service robots for defense and security have been developed, and some are described in the paper, as well as the tendency of their application in the recent years. A large number of service robots for defense and security were developed, which are used for obtaining information about the vulnerability of human populations during earthquakes, fires or military activities. After obtaining information, we can make proper decisions that will serve the purpose of rescue and assistance to the ones in danger. The tendency of application of service robots for security and defense is constantly rising in the past few years. It is estimated that the development of sophisticated service robots for defense, rescue and security will continue in the future, and the number of applications will increase.*

Keywords— Robot, Service Robot, Application of Service Robots, Defense, Rescue, Security.

I. INTRODUCTION

Robotic technology has a noble objective – for example, to replace the man in performing tedious, monotonous or dangerous and health-endangering jobs. During the 20thcentury, advances in new technologies, sensors technology, computers and servo-drive enabled the development of hundreds of different types of service robots for non-production applications. Robotic technology is the technical branch, which already has its own rich tradition. Robots, just like people, have passed generation cycles. The development of supporting technologies, such as information and communication and sensor technology, enables each new generation of robots to receive more advanced features than the previous one, which is primarily related to the achieved degree of intelligence, supporting computing power, improved dynamic characteristics, as well as advanced algorithms [1,2,4,13,20]. Service robots for defense, rescue and security are manufactured in different shapes and sizes, from unmanned combat vehicles to groups of insectoid devices that will cooperate in certain task in the near future. The largest operation in their development process is conducted, of course, in the USA, where community sponsors projects involving many different new technologies. In many cases, inspiration for these projects comes directly from nature, because they copy the way the various living organisms perceive and feel their surroundings, determine the course of action, cooperate with other individuals, move and perform some of their tasks. Different remotely control devices are already in use today, mostly in dangerous jobs such as mine clearance and destruction of planted terrorist bombs. Remot-controlled service robots have been introduced in many defense units. They present a transitional step to gather experience for the transition to a new generation of remotely controlled service robots. During operation, remote operator will only occasionally operate service robot, while most of the time the service robot will be autonomous. The ultimate goal of development is for one operator to manage multiple remote-controlled service robots. Such service robots will be reprogrammable, will retain stable behavior even in complex, uncertain and changing conditions, will be able to learn, and will be

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safely and reliably used in close proximity to people. For certain operations, they will be so small, so that they can be stored in the military jacket pocket. It is necessary to develop service robots that will operate in risky areas, in order to avoid presence of man. Risky areas include war zones, detection and destruction of landmines, firefighting, inspection of nuclear reactors and steam generators, inspection and analysis of waste water, inspection of pipelines, inspection of power transmission lines [3,4,12,16,19].

II. DISSEMINATION OF SERVICE ROBOTS FOR DEFENSE, RESCUE AND SAFETY IN THE WORLD

According to the classification created and adopted by the UNECE- United National Economic Commission for Europe and IFR- International Federation of Robotic, service robots are divided in two groups: professional service robots and personal/home service robots. The development of new technology such as digital technology, information communication technology, sensor technology, new materials and others, had an enormous impact on the development of robot technology. So far, more than 600 different types of service robots have been developed and applied in different fields [4,14,17]. The need for the development of service robots initiated the development of companies that conduct research and production of service robots. In 2016, IFR – International Federation of Robotic, identified about 620 companies for the production of service robots in the world. The percentage of representation of such companies per continent is shown in Figure 1 [5].

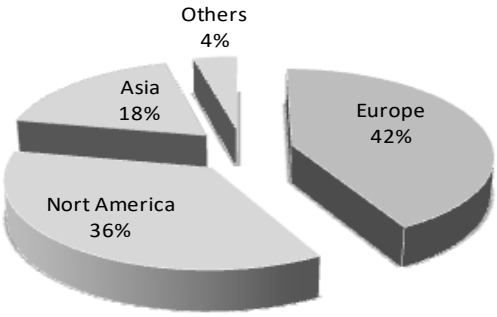

Fig. 1: Percentage of service robot production companies per continent

Based on Figure 1 we can conclude that that IFR-International Federation of Robotic identified the largest number of service robot production companies in Europe, about 258 companies, which presents 42 % of total number of identified companies. The second place is held by North America with about 226 companies, which is about 36 % of the total number of identified companies. The third place is occupied by Asia with 112 identified companies, which presents 18 % of total number of service robot production companies. Other continents have about 4 % of service robot production companies. The tendency of production of service robots in the world per individual countries is shown in Figure 2 [5-15].

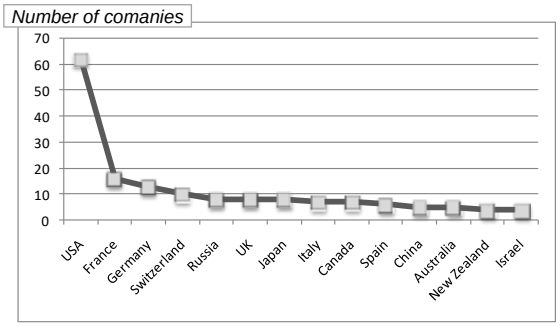

Fig.2: The number of companies for service robot production per countries in the world

Based on Figure 2, we can assert that the united States are in first place by the number of companies for the robot production where the International Federation of Robotics (IFR) has identified around 62 companies. The second place is held by France with 16 companies, followed by Germany with 13 companies and Switzerland with 10 companies for robot production. All other identified countries shown in the Figure 2 have less than 10 companies for robot production. Economic Commission at the United Nations for Europe (UNECE), the Organization for Economic Co-operation and Development (OECD) and the International Federation of Robotics (IFR) adopted the introductory system for the classification of service military robots by categories and types of interaction, so that service robots in defense have the following classification: demining robots, unmanned aerial vehicle, unmanned off-road vehicles and other robots for defense, whereas service robots for security and rescue are separately classified. In order to create a quality tendency of application of service robots in the world, as well as service robots for security and defense, the statistical data is taken from the International Federation of Robotics (IFR), the Economic Commission at the United Nations for Europe (UNECE) and the Organization for Economic Co-operation and development (OECD) [1,2,5-11]. The tendency is shown in Figure 3. Analysis of the chart of the application of service robots for professional services leads to the conclusion that the tendency of application of service robots for professional services during the period 2005-2015 is constantly growing. In 2005, about 5.000 service robot units were applied, with the tendency increasing each year. It is notable that in 2011 about 16.500 robot units were applied, which indicates the linear tendency of increase of the use of service robots for professional

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services. In the period 2011 – 2015, there was a sudden increase in the application of service robots for professional services, as per exponential function, so that about 41.000 service robots for professional service were used in 2015.

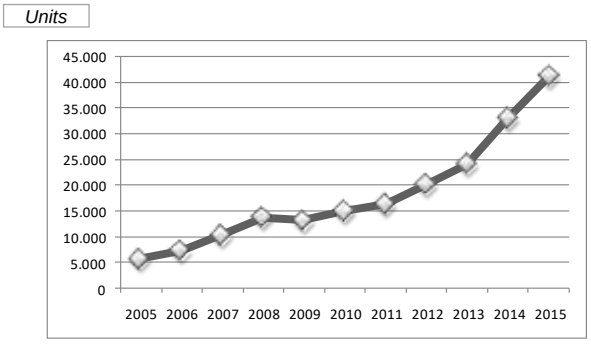

Fig.3: Total annual production of service robots for professional services for the period 2005-2015 [4-11]

This tendency of application of service robots is enabled by the development of new technologies, especially information and sensor technologies that are promoting robotic technology. It is expected that this tendency of the application of service robots for professional services in the world will continue. Service robots for professional services are used in medicine, defense, rescue, security, agriculture, cleaning, construction, underwater systems, household, inspection and maintenance, public relations, space research, or in other words in all segments of society where there is a need to replace the man to perform certain tasks [4,13,18,21-25]. To date, the largest number of service robot units is applied in defense, rescue and security, and therefore the tendency of application of service robots in this area is shown in Figure 4.

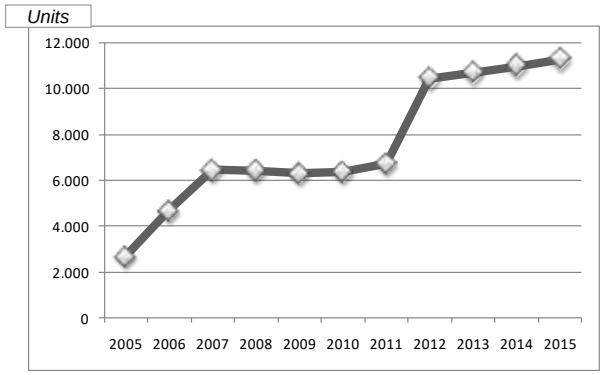

Fig.4: Annual application of service robots for defense, rescue and safety for the period 2005 – 2015

The tendency of annual application of service robots for defense, rescue and security, shown in Figure 4, is linearly increasing, starting with the application of 2.700 robot units in 2005 to the application of 6.400 robot units in 2007. In the period 2007 – 2011 there was little deviation in terms of application of service robots for defense, rescue and security on annual basis, so that the application was approximately 6.500 robot units. In 2012 there was a sudden increase in the application of these robots with 10.000 robot units. The application of robots continued to grow and in 2015, 11.300 robot units were used. It is estimated that this increasing tendency will continue in the future [5]. We can conduct a comparative analysis of the application of service robots for defense, rescue and security with other service robots for professional services in 2015, as shown in Figure 5.

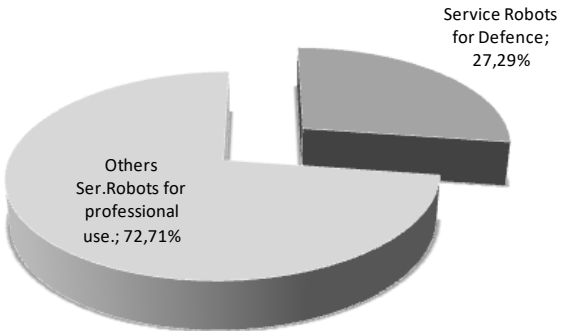

Fig. 5: Percentage of application of service robots for defense, rescue and security in 2015 worldwide

Based on statistical data published in [5], we come to the conclusion that in 2016 total 41.000 service robot units for professional services were applied in the world, of which 11.200 robot units are for defense, rescue and security, which presents 27,29 % of total robots used. All other applications of service robots constitute 72.71 % of robot units. To date, the highest detected application of service robots is for defense, rescue and security. The highest relevant useful factors are: high quality of work and productivity, reduction of manual labor, increased safety and avoiding risk, increase of operational usability, temporary flexibility, new, previously available contents and conditions etc. Table 1 shows the evaluation of the relevance of the factors for service robots that are applied in defense, rescue and security [1,2,4].

Table.1: Assessment of relevance factors for the types of service robots in defense, rescue and security

Defense, Rescue and Security	**Hogh quality work productivity**	**Reduction of manual work**	**Increasing safety avoidance risik**
Demining robot	0	• •	•
Unmanned spacecraft	0	0	• •
Unmanned vehicles	0	•	• •

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Rob.for fire and mines	0	• •	•
Security robot	0	0	• •

Table shows the assessment of the relevance of factors for each type of service robot, with the degree of relevance marked from 0 (not relevant) to the two points (high relevance). We can conclude that the best useful factor of the increase of security and risk avoidance is with service robots for defense, rescue and security.

III. APPLICATION OF SERVICE ROBOTS FOR DEFENSE, RESCUE AND SECURITY IN THE WORLD

The complexity, ambiguity and unpredictability of the environment of mobile service robots and certain details of their tasks are far greater than that of stationary robots. Therefore, it is generally impossible to create a detailed plan and program of action of mobile service robots in advance. In order for such service robot to completely independently successfully operate in unstructured natural environment, it must have a complex set of senses (sensors) by means of which will be able to follow actions in the environment. In addition, they have to have power to process and understand information gathered with sensors, followed by artificial intelligence with which to make decisions about their further activities, as well as highly movable and navigated authorities by which they will implement decisions into action. All these very complex systems should ideally be placed inside ofa very small service robot, and use very limited resources of energy during operation. In addition to the above, practical applicability of autonomous robot requires high safety, robustness and resistance to the most diverse failures and unexpected occurrences in the environment. Creating such a service robot is a large initiative whose realization is still a major challenge. The development of new technologies which include digital technology, information and communication technology, sensor technology, and technology of new materials contributed to the development and improvement of service robots for defense, rescue and security. Many applications were developed for demining, unmanned aircrafts, unmanned field vehicle robots, firefighting robots, and robots for security. Unmanned vehicles have proved to be indispensable in carrying out many tasks that would be dangerous for people (mine removal, handling radioactive materials, reconnaissance from the air) or tasks that are located in inaccessible environment for a man (underwater, space). According to the medium through which or by whom service robots move, and according to the basic features of their task, service robots are divided into many classes. Many constructions of unmanned aerial vehicles and service robots for rescuehave been developed. Many companies in the world are working to develop new applications of unmanned aerial vehicles, and service robots for extinguishing fire and rescue. Likewise, there are many solutions for application of service robots for the removal of mines in areas which are a consequence of the war [4,21-28]. Lightweight mobile robots were developed and designed, among other things, for the destruction of explosive devices, for handling hazardous materials, for search and control, to rescue hostages, for handling explosives, and for SWAT (Special Weapons and Tactics Team) teams and military units. They use a mechanical arm that has a full range of audio and video sensors with 8 modulators of user information. Robot weighs less than 24 kg with full equipment, can be carried by hand, can be quickly loaded into a truck and transported to the desired location. In addition, robust robotic systems for demining in war zones were also developed. A series of service robots for surveillance and reconnaissance by day and night were also developed for defense purposes. These service robots are used for observation of the terrain by day and night for safety reasons. Combat versions of these robots have also been developed, which can be armed with long-range missiles, automatic cannon and machine gun. The list of weapons makes it one of the most dangerous robotic platforms. They are still in development, and completed samples should have remarkable AI programs for autonomous action on the ground. These robots are already used by certain armies in the world. In addition, some of these robots are used in police actions, as they are equipped with cameras and night vision devices, as well as other equipment needed by police forces necessary for operations dealing with people safety. Besides mentioned applications of service robots for defense, rescue and safety, many other constructions have been developed, that serve various purposes, including fight service robots, reconnaissance, supply, operation in dangerous areas, construction of service robots for assistance to soldiers in cases of injuries in military operations.

IV. CONCLUSION

Lots of experience collected while using a variety of remotely controlled devices and drones have led researchers to work in the direction of full autonomy. Unmanned platforms should soon take unconditional, dangerous and tedious jobs. Service robots for defense, rescue and security are made in different shapes and sizes, from unmanned combat vehicles to the group of insectoid devices that will cooperate in certain operations in the near future. Most of the companies that produce service robots for defense, rescue and security are based in the

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USA, where defense community sponsors projects involving many different new technologies. In many cases, the inspiration for these projects comes directly from nature, because they copy the way the various living organisms perceive and feel their surroundings, determine the course of action, cooperate with other individuals, move and perform some of their tasks. Different remote-controlled devices are already in use today, mostly in dangerous jobs such as mine clearance and destruction of planted terrorist bombs. The US military is already using remote-controlled service robots. They present a transitional step to gather experience for the transition to a new generation of remotely controlled service robots. During operation, remote operator will only occasionally operate service robot, while most of the time the service robot will be autonomous. The ultimate goal of the development is for one operator to manage multiple remote-controlled service robots. Such service robots will be reprogrammable, they willretain stable behavior even in complex, uncertain and changeable conditions, they will be able to learn, and could safely and reliably be used in close proximity to people. For certain jobs, they would be so small, so that they can be stored in the military jacket pocket. The objective of the development of these robots is the removal of crew (man) off the weapon system, which reduces the need for armored protection, and reduced the size and perception of the system. This ultimately means greater flexibility and survivability, greater strategic and operational mobility and ease of logistical support. The most likely direction of development is the combination of unmanned and manned platforms, whereas unmanned service robots would be used in most dangerous operations. These two types of platforms should be similar to each other, so that the enemy would not be able to easily identify service robots. Forms of service robots depend on the type of the task for which the service robot was developed. Service robots that must overcome difficult terrains use caterpillar tracks. Some constructions of service robots are the size of a truck, and look quite similar to tractors or bulldozers, as shown in the figures in the paper. Other, smaller service robots have a very low profile to allow the greater mobility. Autonomous service robots use a computer program that allows service robot to process information and make some decisions independently. Instead of autonomous service robots, most military robots are still controlled by humans.

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Isak Karabegović Qualification: Doctor of Technical Sciences Professional and academic career: Full professor at University of Bihać.

Competitive research or professional awards received: Author and coauthor of more the 26 books, 80 scientific papers published in international journals, 300 papers published proceedings in international conferences. Editor and coeditor of significant number of conference proceedings. Member in editorial board of 21 international journals. Sketch biography (200 words): Prof. Isak Karabegović is a Full professor at University of Bihać, Technical Faculty in Department of Mechanical engineering. He received doctoral degree from Faculty of Mechanical Engineering, University of Sarajevo in 1989, his Master of Science degree from Faculty of Mechanical engineering and naval architecture Zagreb, University of Zagreb in 1982, and bachelor degree of mechanical engineering from Faculty of Mechanical engineering Sarajevo, University of Sarajevo in 1978. His career as professor started on Technical College and later become Full professor at University of Bihać. In this period of time he was Dean of Technical faculty in several occasions and also rector of University of Bihać in several occasions. His research interest includes domains of Mechanics and Robotics. He also works as reviewer, editorial and technical board member in many reputed national, international journal and conferences. He publishes more then 400 papers of different type in international journals, conference proceedings and book chapters.

Full name : Isak Karabegović
Date of birth : 19.10.1955
Nationality : Bosnian
Department : University of Bihać, Technical faculty
Area of teaching : Mechanics, Robotics
Email : isak1910@hotmail.com
Tel : ++38737226273
Bosnia and Herzegovina