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ASPECTS ON THE DESIGN OF A TRACKED MINI ROBOT DESTINED FOR SPECIAL APPLICATIONS IN THEATRES OF OPERATIONS

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Abstract: *The authors of this paper wish to highlight elements regarding the organology, functioning and simulation, in a real workspace, of a tracked mini-robot with electric actioning obtained from solar energy capture with a load of explosives attached a technological product which is subject to a patent granted to our institution. The issues outlined in this paper are aspects related to the original invention in comparison with other mini-robot structures, the inventors presenting succinctly the technological product description and its applicability both in the military and applicative area as well as in the educational one. Additionally, the advantages of using the technological product are shown in a real workspace, the constructive and functional solution before, finally, presenting, based on the modeling of the mechanical structure of the tilting module attached to the mini-robot, an application on the simulation and programming of the mini-robot under study.*
Keywords: *tracked mini-robot, advanced military technologies, human-artificial "partnership", modular structure, special applications.*

1. INTRODUCTION

Circumscribing the knowledge triangle (science, research and innovation) the technological products – fruits of research contracts – transpose the results of scientific research in the plan of teaching and support learning through practice, providing a meaningful reading grid of the educational paradigm specific to the 21st century. This is the framework where research contract named "*Research on the Optimization of Military Logistics System Capabilities through the Implementation of Solutions Specific to Robotized Technologies*" (abbreviated *ROBMILCAP*), within which the technological product – Tracked mini robot destined for special applications in theatres of operations – was developed, a product included in the technical field advanced military technologies [1]. Connecting the military environment to the imperatives of the moment is visible also in the light of energy initiatives undertaken by the military, circumscribed to the concepts of responsible intelligence and applied humanism and aimed at ensuring the balance between the planetary operational challenges, protecting the human factor and the concern for the health of the planet. An important role in this direction is held by the technological solutions used in operations theatres – the vanguard of the human element in high-risk areas – able to develop friendly behavior towards the environment by limiting fossil fuel consumption and by reducing pollution.

2. THE CONSTRUCTIVE AND FUNCTIONAL SOLUTION OF THE TRACKED MINI-ROBOT

The robots, partners of the military operating in the theatres of operations of the present, such as the Daksh and MARCbot robots, pay less attention to operations with electricity from clean energy sources. The functional product proposed by the present research conducted within the aforementioned research contract eliminates this drawback by exploiting solar energy (environmentally sound, virtually inexhaustible medium and long term) able to represent a real gain for energy security, for the economy, for the environment. Also, the designed mini-robot mechanical structure comprises a compartment for storing explosives, disposed on the base platform, which facilitates reclamation/demining operations, destroying unexploded ordnance (UXO) and improvised explosive devices (IED), performed by the human operator outside the risk area (the control panel of the mini-robot) and which can command the prehension device, attached to the modular robotic arm, to take the amount of explosives needed for the engineering applications mentioned above. In this way, it is not necessary for the mini-robot to return for explosive supply whenever the situation requires it.

The study of technological products specific to the engineering field in conjunction with the research conducted in the aforementioned research contract, led to the conclusion that the EOD prototype heavy weight is not important, but that the focus should be instead on its maneuverability and the accuracy with which it works in defusing, demining/reclamation operations. Therefore the light weight of the technological product (35 kg), recommends it to be used on the front line because it is easily transportable, it can operate in spaces that are tight or out of the human operator's sight, and by replacing the classic disrupter with the compartment destined for explosive storage, it has the ability to protect itself in due time from shrapnel, explosive blasts or materials resulting from reclamation/mine clearance.

This technological product refers to a tracked mini-robot with autonomous displacement and electric actioning obtained by means of the solar cells encapsulated in panels and attached to the mechanical structure of the mini-robot and with a compartment destined for the storage of the explosive necessary for the demining/reclamation disposed on the base platform, possessing four degrees of mobility (without the opening or closing of the fingers corresponding to the prehension device), a simple, compact mechanical structure and formed of modular components, the joining of the constituent modules (the base of the mini-robot and the modular robotic arm, respectively) being performed at the level of the rotation joints by means of flanges and retaining screws, using in its structure materials resistant to hazardous environments. The technological product has applicability both in the military – applicative area (by improving the detection, reclamation/demining capacity of UXOs and IEDs in view of protecting the human factor operating in theatres of operations, the mechatronics components operating in conflict areas, as well as the environment), but also in the educational area (by the formation within bachelor and master degree studies of highly educated and specialized human resources able to deal with the diversity of current missions and challenges).

The designed tracked mini-robot, shown in figure 1, offers the following advantages:

- harnessing of the present technological product in the industrial plan can help reduce the negative impact of the energy sector on the environment;
- the solar mini-robot operation – an economic and ecological solution – contributes to the creation/strengthening of a culture of energy accountability among military, respectively civilian personnel;

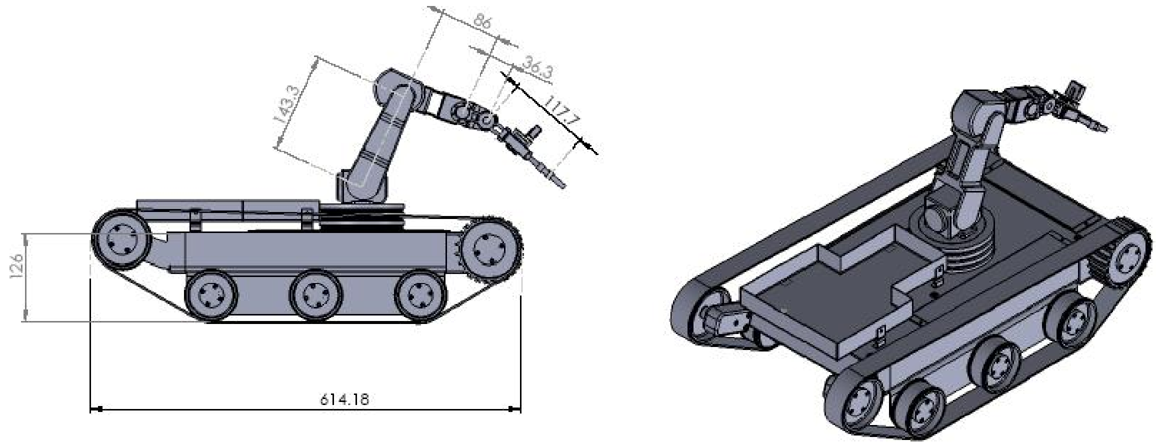


Figure 1: The tracked mini-robot with electric actioning obtained from solar energy capture

- protecting the human factor and organological components, corresponding to mini-robot mechanical structures exposed to high risk engineering applications;
- the modular robotic arm performing a stroke of up to 355^0 and which is incorporated in the mechanical structure of the mini-robot helps in case of overturning – the mini-robot can be recovered simply by pushing the arm in the ground;
- actional flexibility by enabling semi-circular folding (180^0) of the modular robotic arm attached to the mini-robot and by replacing the classic disrupter with the explosive storage compartment;
- compact architecture, minimum power consumption, small size, possibility of operation on rough terrain and tight or hidden spaces, high efficiency and relatively low costs of construction;
- easy to use in automatic modes, programming of movements being performed through learning or manually;
- real-time operation, meaning observation of the target area by equipping the technological product with video, audio equipment and radio control system.

The mini-robot under study, whose structural kinematic scheme is shown in figure 2, consists of two main modules (the rotation module and the modular robotic arm), each having at least one degree of mobility, to which is added the *MB* base module of the mini-robot (fig. 3a).

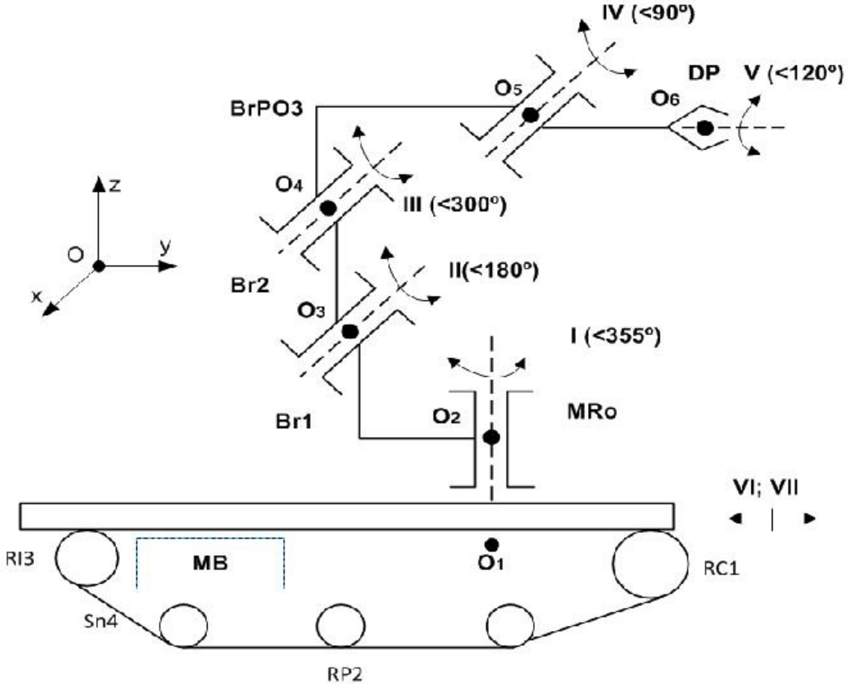


Figure 2: The structural kinematic scheme of the mini-robot

The *Mro* rotation module consists of the following elements: the *CRo* rotation joint having a cylindrical surface and a *PRo* rotation plate, the fixing and positioning of the *CRo* rotation joint onto the mini-robot being performed by means of a flat annular piece and retaining screws, while the positioning and fastening of the *MRo* rotation module onto the *MB* base module of the mini-robot being accomplished with the help of a flange with retaining screws. The rotation movement around the *z* axis of the *CRo* rotation joint, driven by the *M3* electric motor is obtained on the *PRo* rotation plate, friction between the two elements being removed through the low roughness of the contact surfaces, solution obtained by means of high accuracy mechanical processing. The radial displacement of the shaft is stopped by a shoulder provided in its design and implementation.

The modular robotic arm has a serial open chain construction and consists of the following elements: the *Br1* arm, the *Br2* arm, the orientation and positioning *BrPO3* arm, the *DP* prehension device with sliding gripping fingers having a pivotal articulation of the wrist, enabling it to grasp any object with dimensions up to 4.30 [cm]. In this way, the modular robotic arm attached to the structure of the designed mini-robot has four degrees of freedom (three rotational movements along the *x* axis together with the pivoting movement of the *DP* prehension device along the *z* axis), to which is added the vertical rotation, as well, along the *z* axis, corresponding to the base of the mini-robot.

Degree of mobility I (fig. 1, fig. 2) – the rotations of the *CRo* joint and of the modular robotic arm – are achieved through an *M3* electric stepper motor. The motor is positioned horizontally in the body of the *MRo* rotation module, transmitting the rotation movement to the *CRo* joint by means of a cylindrical gear using a mechanical coupling, respectively. The motor transmits to the *CRo* joint a rotation along the *z* vertical axis with values of up to 355^0, the rotation speed being variable, programmable and controllable through specific computer programs.

Degrees of mobility II, III and IV (fig. 2, fig. 3) – rotation of the *Br1*, *Br2* arms and the orientation and positioning *BrPO3* arm along the *x* axis – is obtained using the *M4, M5* and *M6* electric stepper motors. The motors transmit rotation movements of up to 180^0 to the *Br1* arm, of up to 300^0 to the *Br2* arm, and the orientation and positioning *BrPO*3arm is able to rotate at angles up to 90^0, depending on the positioning and orientation of the target object.

Degree of mobility V (fig. 2, fig. 3, fig. 4) – the pivoting of the fingers in the structure of the *DP* prehension device – is obtained with the help of the *M7* electric stepper motor, thus achieving the gripping-fastening movement along the *z* axis. The fingers needed for the gripping-fastening operations are designed so as to be able to manipulate objects of different geometries, with sizes of no more than 4.30 [cm]. The maximum opening of the fingers corresponding to the *DP* prehension device ranges up to the value of 120^0.

Degrees of mobility VI and VII (fig. 3, fig. 4) – the displacement and direction of the designed mini-robot – are ensured by the *M1* and *M2* electric stepper motors. The motors are mounted parallel with respect to one another, and the rotation movement is transmitted, through some mechanical couplings, to a double acting cylinder gear towards the *RC1* leading wheel pair, which will, in their turn, generate the rotation of the *RP2* carrier wheel pairs, the *RI3* tensioning wheels, and to the *Sn4* track pairs, respectively.

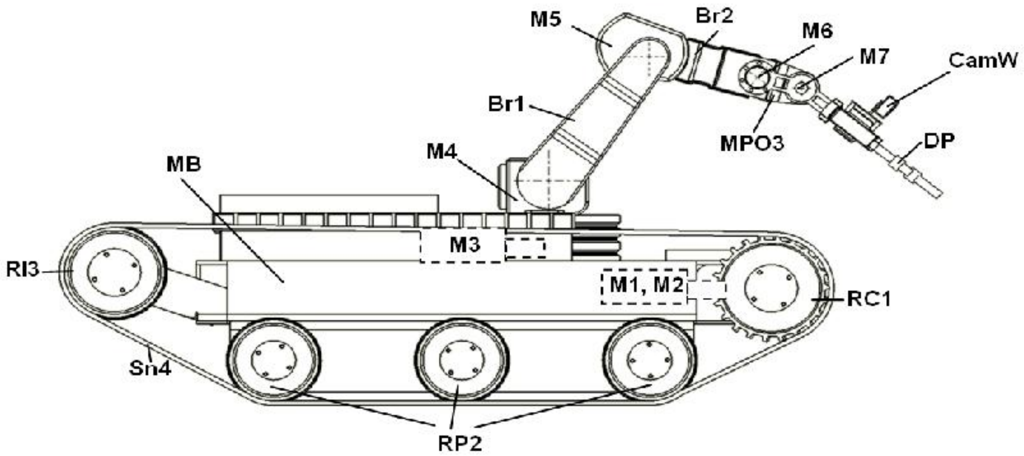


Figure 3: The general structure of the mini-robot (side view)

By breaking an engine, the driving wheel corresponding to the braked engine will stop, remaining with only one driving wheel in engagement; this way achieving the left and right turn movements as well the horizontal rotation of the mini-robot. The *Sn4* track pair enables the mini-robot to overcome obstacles with a propensity up to 45^0, and the travel distance of the technological product is unlimited, the maximum movement speed being of 0.5 [m/s], depending on the nature of the displacement terrain.

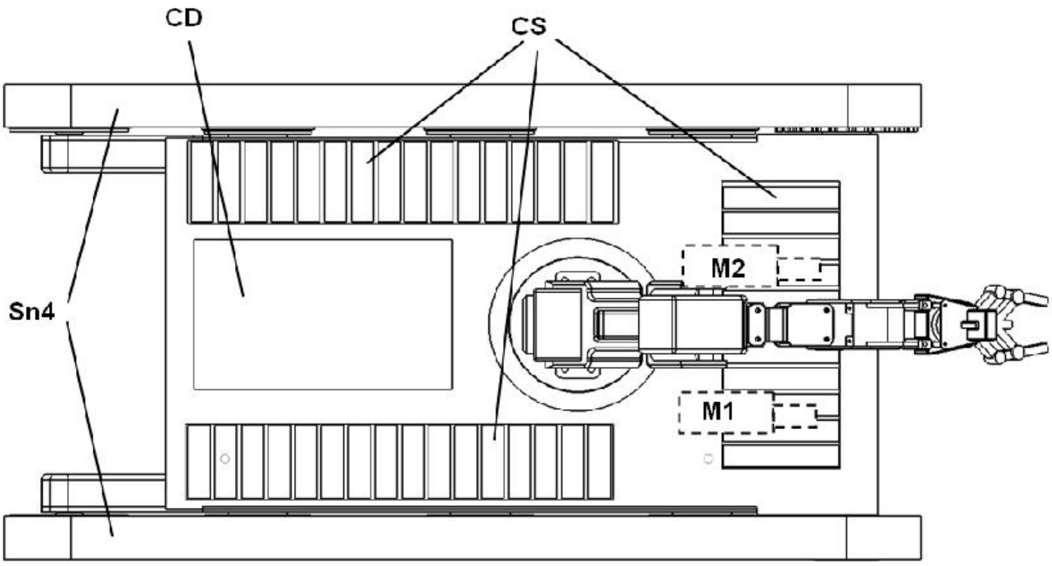


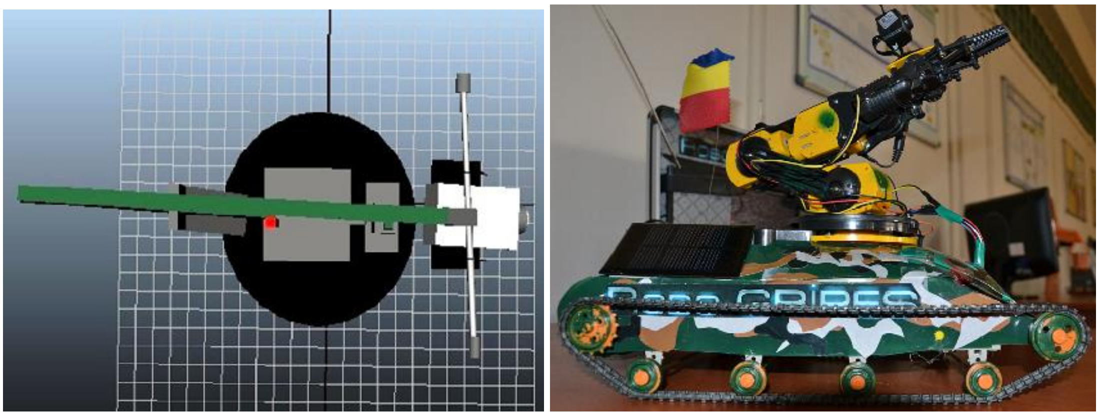
Figure 4: The general structure of the mini-robot (top view)

The actuators in the structure of the mini-robot are fueled by means of the solar cells embedded in two *CS* panels (fig. 4) when the mini-robot operates during daytime, and by means of batteries, charged by the third *CS* solar cells incorporated panel, whenever the mini-robot is operated nighttime. The three *CS* panels with solar cells encapsulated are arranged on the side surface of the *MB* basic module attached to the mini-robot, which are protected with metal frames fixed by stud bolts with retaining screws. The arrangement of the *CS* solar cells panels on the surface of the mini-robot enables the capture of solar energy throughout the day, which leads to an unlimited energy operation of the technological product design.
The mechanical structure of the mini-robot was also provided with a *CD* storage compartment for explosives, attached to the *MB* base module of the mini-robot by spot welding, as well as a *CamW* web camera (fig. 3) providing real time information to the human operator behind the control panel.

All the degrees of mobility of the mini-robot can operate simultaneously and/or independently, the movement control of each degree of mobility being provided through the incremental angle transducers mounted on the axles of each electric motor in the structure of the designed technological product. The total mass of the mini-robot is 35 [kg], and the maximum load that it can carry is 1.5 [kg]. The operating system is composed of 20 orders, and the operating modes are automatic or programming movements through learning or manually.

3. THE MINI-ROBOT'S SIMULATION AND PROGRAMMING

In order to validate the research, the authors of this paper conducted, within the *Mechanical Engineering II* laboratory from our institution, a simulation of the experimental tracked mini-robot prototype and a programming in virtual workspace using the *Arduino* software and the *Maya* program [2]. For starters, a modeling of the tilting module attached to the mechanical structure of the mini-robot was performed (fig. 5) in order to highlight the workspace and to be able to perform a simulation there of with the aid of the *Macromedia Flash 8*.



a) b)

Figure 5: The modeling of the tilting module attached to the experimental prototype: a) top view; b) the "*Robo Gripes"* prototype mini-robot

The simulation consisted of having the mini-robot research a mined area, discovering projectile by means of its mechanical structure, and capturing and broadcasting information to the human operator via the attached video camera.

4. CONCLUSION

With the evolution of military conflicts, evolution of technique and equipment in the military environment has become obvious, as well. Given that a wide range of requirements must be atckled, including the performance of high-risk missions, soldiers need, in addition to specialized knowledge and skills, equipment and technology. During the actions that require EOD intervention, danger is around the corner, and soldiers need equipment to ensure their protection. Mini-robots, built for various actions (observation, detection, information gathering and rehabilitation, reclamation/demining capacity of UXOs and IEDs in view of protecting the human factor operating in theatres of operations), are of vital importance, providing operators, in addition to safety in action, the ability to operate with high precision, without endangering human lives.

REFERENCES

[1] Petrişor S.M., Bârsan Gh., Ioan D.A.A., Tracked mini-robot destined for special applications in theatres of operations, Invention Patent No. RO 128494, Official Bulletin of Industrial Property, Patent section, No. 8, State Office for Inventions and Trademarks (OSIM), p. 72, ISSN 2065-2100, Bucharest, 2016.
[2] Petrişor S.M., Bârsan Gh., Aspects on the design, implementation and simulation of a tracked mini robot destined for special applications in theatres of operations, Journal Proc. of SPIE (Society of Photo-Optical Instrumentation Engineers), SPIE Digital Library, vol. 9067, pp. 1 ÷ 5, EI Compendex, ISI Thomson Reuters, 2013.
[3] Altman J., Arms Control for Armed Uninhibated Vehicles: An Ethical Issues, in "EIT", no. 15, 2013.

[4] Hellström T., On the Moral Responsibility of Military Robots, in “Ethics and Information Technology”, vol. 15, issue 2, pp. 99-107, June 2013.
[5] Quintana E., The Ethics and Legal Implications of Military Unmanned Vehicles - occasional paper, London, UK RUSI, 2008.
[6] Lin P., Abney K., Bekey G., Autonomous Military Robotics: Risk, Ethics and Design – Technical Report for the U.S.Department of the Navy, Office of Naval Research, 2008.
[7] Vică C., Visează androizii garduri electrice?, in “Dilema Veche”, no. 536, 22-28 May, 2014.
[8]. Wallch W., Allen C., Moral Machines Teaching Robots Right from Wrong, Oxford University Press, 2008.