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RESEARCH STUDIES REGARDING MOBILE ROBOTS USED FOR EMERGENCY SITUATIONS

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Abstract: *This paperwork is intended for the study and research of robots desired for emergency situations. The first part, presents general notions about this range of robots, their classification and characteristics. The second part, is devoted to examples from the literature and in the third part, the authors propose a 3D model of an emergency situations robot.*
Key words: *Mobile robots, emergency used robots, bioinspired robotics, multimodal locomotion.*

1. INTRODUCTION

Mobile robotics has found its application in various fields of activity. A special category of mobile robots are mobile robots desired for emergency situations.

Emergency situations are diverse and involve different types of hazards and regarding this, involving human resources is far too dangerous for solving them.

Research efforts on using mobile robots in special missions have been mainly directed towards by replacing human personnel for the execution of high-risk missions in difficult-to-control environments [1].

The usage of mobile robots reduces the use of human resources, streamlines the mission process, more specifically the working time and the accuracy with which the mission is performed in these emergency situations.

The research directions developed for this type of robots are concerned with increasing work performance and decreasing mission times by:

- manufacturing modular robotic systems that can best adapt to mission needs,
- developing advanced locomotion systems that can adapt to irregular ground surfaces,
- making robot autonomy more efficient,
- modelling a control and command interface regarding for controlling the robot and acquire data from it.

This paper is further structured as follows: in the second part, categories of robots for emergency situations are presented and representative examples from the literature where their characteristics are presented. In the third part, the authors contribution in the field of mobile robots for emergency situations is presented and in the fourth part, the conclusions and bibliography of the paper are presented.

2. TYPES OF MOBILE ROBOTS USED IN EMERGENCIES SITUATIONS AND THEIR CHARACTERISTICS

Emergency robots are dedicated structures with an emergency-specific functionality. They are deployed for the purpose of acting critical situations. Due to the multitude of emergency situations, specialized robots have been developed for each of it. Thus, in Fig. 1, the spectrum of robots for emergency situations is shown.

The mechanical structure of these robots often has a special topology, as one of the major objectives is to enter in areas with rough terrain, bombed terrain, mined terrain, etc.

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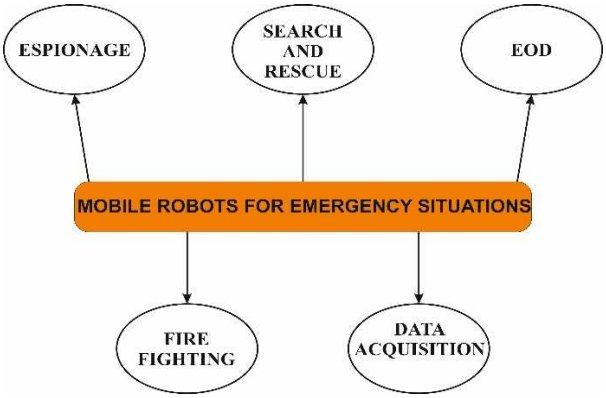


Fig. 1 Classification of robots according to the specific emergency situation

Mostly, mobility-enhanced locomotion systems with multimodal locomotion or biosystems-inspired robots are used.

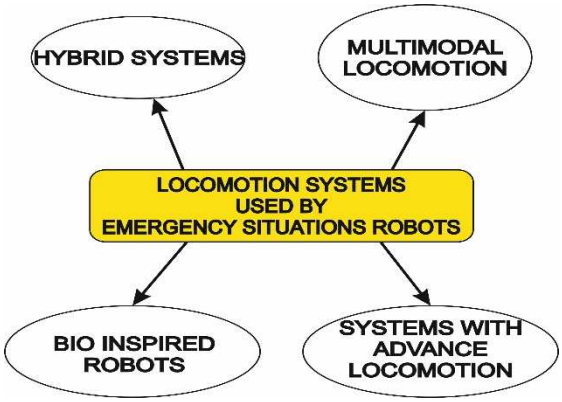


Fig. 2 Main locomotion systems used for emergency situations robots

The following are examples of the categories mentioned above in Fig. 2.

Robots for espionage

The first category of robots analyzed is, mobile robots intended for espionage, for the purpose of acquiring information from the working area.

These robots are designed to be difficult to detect, easy to camouflage and small in size. Their mechanical structure is equipped with devices that make it possible to acquire data from the environment in which they operate, such as audio/video data, information about temperature, humidity, pressure, etc.

The robot shown in Fig. 3 [2] is a flying robot, which looks like an insect. For developing process of this robot, had been used miniaturization techniques. Communication in between the modules and with the control center is achieved by using wireless technology.

Fig. 3 Spy robot [2]

This type of robot can operate in a network to collect information from the workspace, such as audio/video material.

A suggestive picture of the various tasks these robots can perform is shown in Fig. 4. These are:

a) surveillance (Fig. 4a),
b) agricultural tasks (Fig. 4b),
c) spying (Fig. 4c).

a) b) c)

Fig. 4 Aplications of the bug robot [2]
a) surveillance b) agriculture c) espionage

The next robot is also a micro flying vehicle, which it looks like a bird. It has a wing length of 7.4 cm and a total mass of 19 grams. The robot can reach a speed of 6.7 m/s, with a

wing movement frequency of 30 Hz. The main modules of this robot can be identified in Fig. 5 [3]:

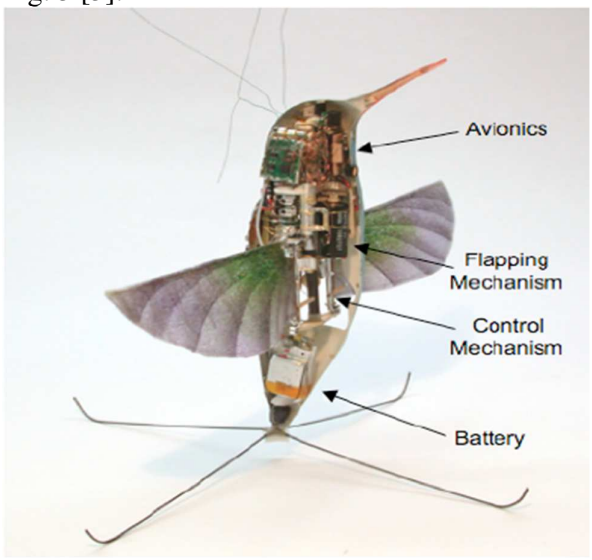


Fig. 5 Main modules of the bird robot [3]

The robot's wings allow it to remain at rest in flight, more precisely to float in the air. In Fig. 6 [3], the robot is shown floating in the air, with possible flight directions attached.

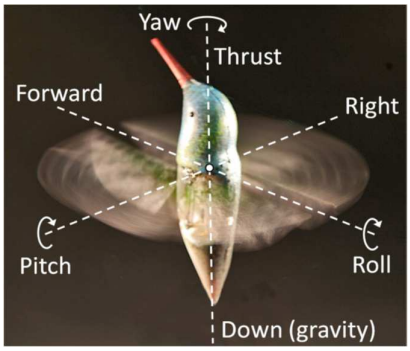


Fig. 6 Robot floating in the air [3]

The advantages of these micro robots are major, such as:

- small size,
- simple structure,
- they are difficult to detect,
- low power consumption.

Search and rescue robots

The robots presented below are specific to the field of search and rescue. These situations involve people whose lives are in danger. This is why mobile robotics has developed a specialised branch dedicated exclusively to these emergency situations.

Fig. 7 [4], shows a nature-inspired, snake-like modular mobile robot. These robots consist of several interconnected modules that give the robot high maneuverability during locomotion.

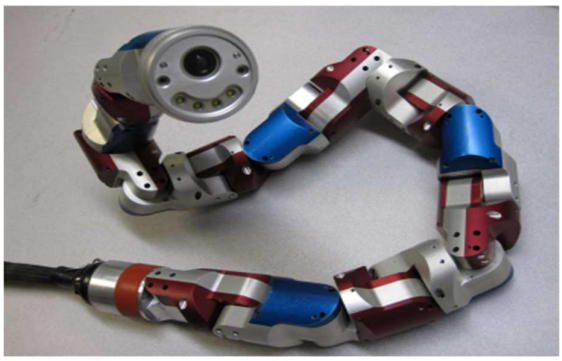


Fig. 7 Modular, snake-like robot [4]

This type of robots is used in search and rescue, especially for missions involving entering into a narrow, hard-to-reach spaces, such as caves, collapsed buildings, hard-to-reach confined spaces.

In Fig. 8 [5], such a scenario is shown, involving the rescue of a victim under the rubble of a cave.

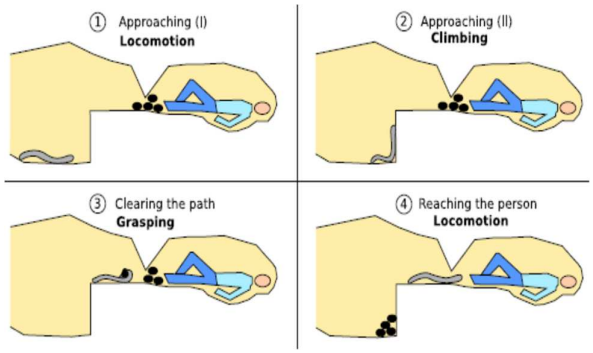


Fig. 8 Victim rescue scenario using a modular snake robot [5]

The robot moves by crawling, its high degree of maneuverability allowing it to clear

paths towards the victim and transmit information about the victim's current status to the command and control center.

The robot in Fig. 9 [6], is called HURCULES (Humanoid Rescue Robot for Calamity Response) [6]. It is made by a team of Korean researchers and was built with the purpose of searching, transporting and rescuing people in distress from the battlefront.

The locomotion system used is based on a complex structure of variable tracks, which can change their geometry so that the robot remains in balance during locomotion.

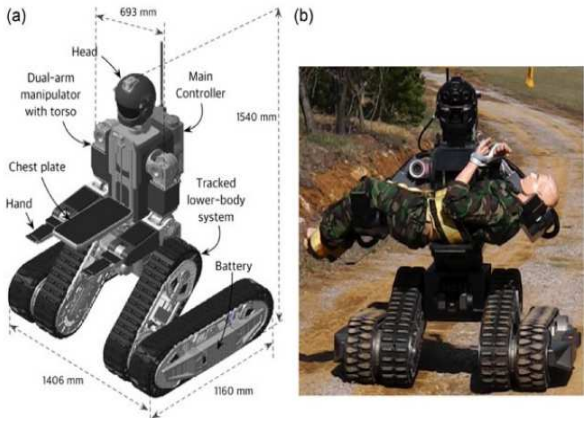


Fig. 9 HURCULES robot [6]

The upper part of the robot consists of two serial kinematic chains and a platform positioned in the chest area. This assembly of two serial arms and the platform in the chest area is intended to keep the injured person's body in a horizontal position without creating an imbalance in the robot's structure during locomotion.

The robot's drive system sets in motion several modules that make locomotion and transport of the injured person from the battlefront possible, these are:

- two locomotion modules with variable tracks (act as lower limbs);
- serial arms in the upper part of the structure (acting as upper limbs);
- a rotation joint that mimics the rotational movement of the human pelvis.

Thanks to its locomotion system, the HURCULES robot can change its body posture to climb a 0.25 m high obstacle.

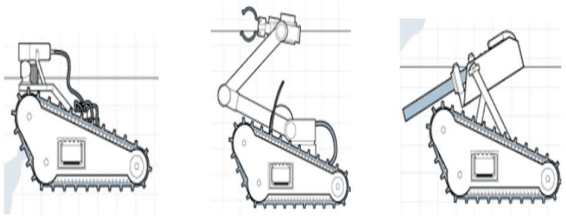
EOD robots (Explosive Ordnance Disposal)

Another emergency situation is the detection, handling and defusing of explosive material.

Robots specialising in these situations are known as EOD (Explosive Ordnance Disposal), robots and their role is to carry out surveillance or monitoring activities, handling and destroying explosive devices. The main reason for using EOD robots is to eliminate any risk to a person's life.

These robots are used to remotely recognize and defuse explosive devices.

Emergency situations involving the destruction of hazardous materials are of very high risk to humans and require highly maneuverable and accurate robots. These mobile robots are equipped with robotic arms and devices that can manipulate or destroy various objects. The main functions of these mobile robots are described in Fig. 10 [1].



a) b) c)

Fig. 10 Main functions of robots for the destruction and handling of hazardous materials [1]
a) surveillance b) handling c) destruction

Robot functionality, surveillance, manipulation and destruction are provided by the interchangeability of the devices.

One robot in this category is the MAARS robot (Fig. 11), its main tasks being reconnaissance and surveillance of the enemy on

the front line and destruction of dangerous materials that may endanger human life. Its presence in the mission, alongside the human, increases the security and protection of the mission.

Fig. 11 MAARS robot (Modular Advanced Armed Robotic System) [7]

The two robots in Fig. 12 [8] are used for the inspection of explosive material and are equipped with sensors, audio-video cameras, a complex locomotion system and a serial arm where different devices will be attached depending on the specifics of the current mission. These robots also have landmine detection capabilities for ground clearance.

Fig. 12 Robots for defusing and handling explosive materials [8]

Firefighting robots

A very common and deadly emergency is firefighting. This is why the focus has been on developing various robots that can enter fire zones to extinguish fires or obtain information about people in these risk areas.

Firefighting robots can be equipped with specific devices for this type of mission, such as:

- water/foam tank,
- audio-video camera,
- structure made of materials resistant to extreme temperatures.

The ANYmal robot (Fig. 13) [9] is a robot designed to detect victims and damage in a fire. It uses the four-legs topology for locomotion, and is resistant to extreme temperatures and water.

Fig. 13 ANYmal robot [9]

Fig. 14 [10] shows such a robot [10], equipped with specific fire-fighting equipment. The robot is remotely controlled and sent to the area where the fire is taking place.

Fig. 14 Robot for fire fighting [10]

These robots are made of special materials that are able to retain their properties under extreme conditions of temperature, humidity or pressure.

Acquiring data from the working environment is important, as the information gathered can be used to design strategies to combat and prevent possible emergencies.

Data acquisition robots

Robots created for data acquisition are the first to take part in an emergency situation, if data regarding for the danger level and/or data regarding for the mission area are uncertain or unknown.

These robots are designed to be fast to gather information from the mission area. Their structure is equipped with specific data acquisition devices and sensors such as:

- audio/video cameras,
- temperature sensors,
- humidity sensors,
- pressure sensors,

The acquired data is sent to the control center in order to design a future action plan.

The robot in Fig. 15 [11] is a robot used for various situations such as environmental data acquisition. It is a mobile robot with multimodal locomotion, being able to both swim and walk.

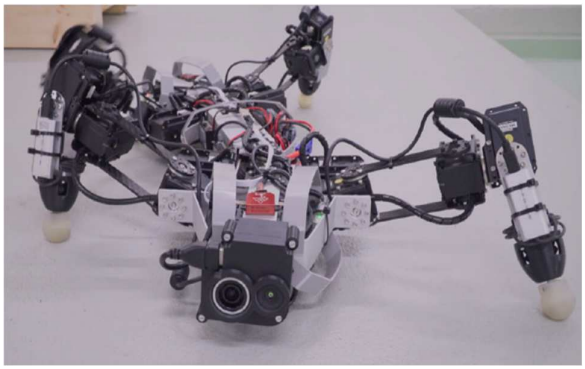


Fig. 15 Krock2 robot [11]

The robot is inspired by the living world and copies the locomotion pattern of the crocodile. At the same time, it falls within the realm of multimodal robotics by using two interchangeable modes of locomotion.

Another variant of a robot designed to acquire data from the work environment is the Packbot robot, (Fig. 16) [12]. It is designed to be able to move in areas with rough terrain in order to acquire information from the work environment.

The platform has a locomotion system with improved mobility, a tilting track system. The robot is equipped with an audio-video camera, ultrasonic and infrared sensors to respond to external factors.

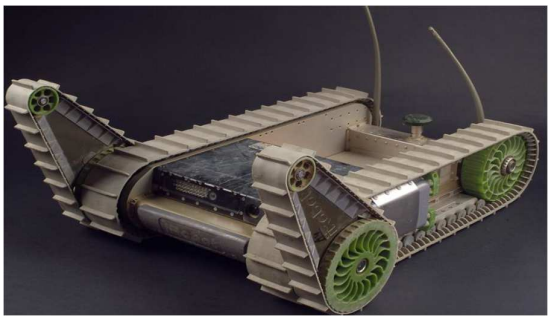


Fig. 16 Packbot robot [12]

A visible trend in the field of mobile emergency robots is the development and use of swarm robotics. This technology refers to the use of several identical robots working in unison and following instructions from the command center. This approach is inspired by nature. For example, one can look at ant colonies or bee colonies, which work exclusively as a team and share tasks provided by the colony superior.

Figure 17 shows the way in which an ant colony is managed to feed its individuals.

Fig. 17 Ant colony [13]

Based on this principle, several robots can be connected to each other based on wireless technologies, thus creating an ecosystem (Fig. 18).

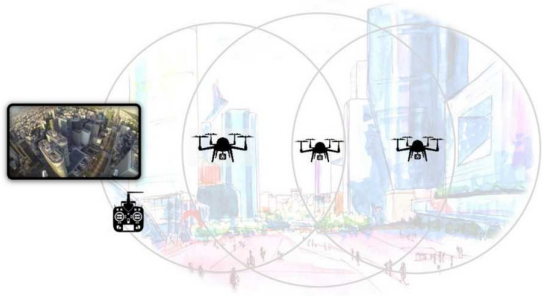


Fig. 18 Robotic ecosystem for ground surveillance for search and rescue [14]

This ecosystem is created for search and rescue purposes.

The applications of these robotic ecosystems are varied and can help make certain experiments more efficient:

- they can sample and analyse a hazardous soil sample, in detail,
- they can be sent and used in space for exploration,
- they can be used for search and rescue,
- remote analysis of situations too dangerous for human intervention,
- underwater surveillance using a robotic fish-bank ecosystem.

3. CONTRIBUTIONS TO THE DEVELOPMENT OF ROBOTS FOR EMERGENCY SITUATIONS

The authors' contributions in this area are presented below.

The proposed robot has a complex mobile structure on variable tracks, which consists of a pair of classical tracks and two pairs of tilting tracks. It has been developed for the purpose of acquiring information about the state of the environment or for verifying the existence of victims in disaster areas.

The tracked locomotion system gives the structure the ability to move in areas with uneven terrain, such as bumpy areas, potholes or sand.

Its structure will be equipped with mission-specific modules for emergency situations:

- audio-video cameras,
- light source,
- antenna for broadcasting and reception,
- a serial arm for handling objects.

This robot has 5 cameras included in the structure. The composite of all the images captured by the video devices gives a panoramic view of the workspace in which the robot is working.

The structure of the fully equipped mobile robot is shown in Fig. 19.

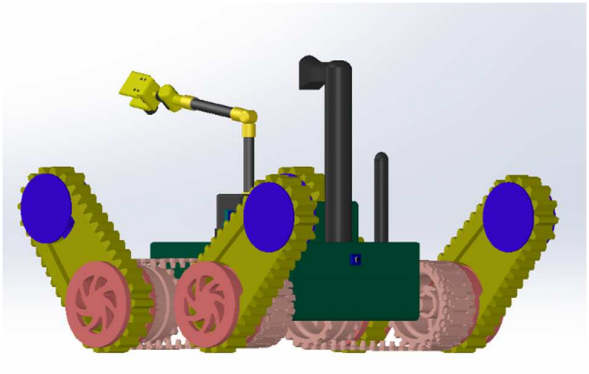


Fig. 19 The emergency situations robot

4. CONCLUSIONS

In general, each category of robot has its own specificity, based on the needs and specificity of the emergency situation for which it was created. However, all robots designed for emergency situations have common objectives:

- prevention of emergencies,
- mission resolution and hazard elimination,
- to acquire data in order to devise a plan to deal with the situation,
- reducing human mortality,
- to make the mission more efficient through high accuracy and reduced response time,
- search and rescue of injured persons.

The aim of this work was to search the literature in order to design a classification of mobile robots intended for emergency situations according to the particularity of each situation and to propose a robot model from this range. The structure of the proposed robot is based on

a tracked locomotion system with improved mobility.

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Studii și cercetări în domeniul roboților mobili pentru situații de urgență.

Rezumat: Lucrarea este destinată studiului și cercetării roboților destinați situațiilor de urgență. Prima parte a lucrării, prezintă noțiuni generale despre această gamă de roboți, clasificarea și carcateristicile acestora. A doua parte, este destinată exemplelor din literatura de specialitate, iar în a treia parte autorii propun un model 3D de robot pentru situații de urgență.

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