Implementation of collaborative robots in modern field medical stations

Nina Valchkova
Institute of Robotics
Bulgarian Academy of Sciences
Sofia, Bulgaria
email address: nvalchkova @abv.bg

***Abstract*— Field medical stations are an important element in the management of crisis situations such as natural disasters (earthquakes, floods, fires, etc.), as well as military and epidemic situations. The introduction of collaborative mobile robots in field medical stations is an innovative approach to improving medical services in emergency and crisis situations. The conceptual role of collaborative robots (cobots) is to assist medical personnel by performing repetitive, risky, or precise tasks in confined and dynamic environments. Field medical stations are designed to operate in harsh conditions and typically include a combination of autonomous or remotely controlled robots that perform various medical tasks. Based on the analysis of the structure and requirements of field medical stations and collaborative mobile robots, the article proposes a model for the implementation of a modern robotic medical field station.**

Keywords - Service Robot, mobile platform, Cobot, robotic medical field station.

INTRODUCTION

Modern field medical stations are high-tech solutions for providing emergency medical care at the scene of a crisis and play an important role in ensuring rapid and effective medical care for the injured in the following situations:

- Disasters and accidents, which have mass fractures, crush syndrome, blood loss, and medical personnel work in unstable conditions, limited logistics and multiple patients.
- Military context, where treatment of ballistic injuries and rapid surgical stabilization as part of damage control surgery is required.
- Epidemic situations, characterized by isolated surgical procedures for patients with high biological risk; UV/HEPA filtration for pathogen control.

Field medical stations are designed to perform various tasks [5], which can relieve the workload of medical personnel and increase patient safety. Essentially, they represent a significant advance in medical technology, offering new possibilities for treating and caring for the wounded and not only increasing the efficiency of medical services, but also increasing the safety of all participants in the treatment process.

The main advantages of robotic medical field stations [1] are:

❖ Increased precision: Collaborative robots (cobots) provide high precision in performing medical procedures, reducing the risk of errors.

❖ Personnel safety: By isolating the medical team from dangerous situations, cobots can prevent injuries and ensure safety.

❖ Speed of response: Task automation allows for faster response to emergencies, which is especially important in combat conditions.

❖ Accessibility: Collaborative robots can be located in different places in the infirmary, providing access to medical services in different situations.

I. MOBILE, AUTONOMOUS MEDICAL BASE

In real crisis and combat situations, where access to qualified medical care is difficult, mobile autonomous medical bases (Fig. 1) for emergency care offer fast and effective solutions. They are designed to provide primary care to the wounded on site and stabilize their condition before evacuation or further treatment.

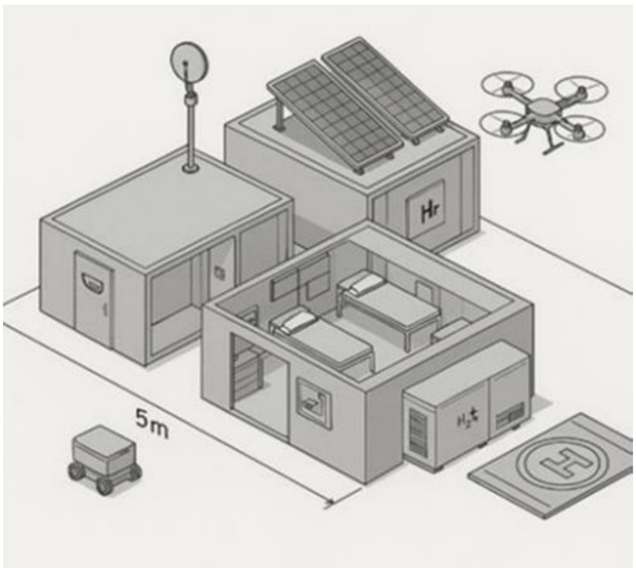

Fig. 1 Mobile, autonomous medical base.

The Mobile Autonomous Medical Base is a modular structure that can be deployed within minutes near a disaster site or battlefield. It is transported by military vehicles or drones and has the capacity to be automatically deployed.

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The base has robotic medical stations that are prepared to perform initial diagnostics and patient stabilization. In critical situations, they can perform automatic resuscitation or intubation, using telemedicine platforms. Doctors who are far from the disaster site or battlefield can control the robotic devices through secure communication links. This allows experts to perform complex operations remotely through:

❖ Integrated monitoring systems, where each bed in the Mobile Autonomous Medical Base is equipped with systems that monitor the vital signs of patients and send data in real time to medical teams.

❖ Autonomous emergency robots: The infirmary is equipped with robots that can provide emergency medical care. They are designed to perform basic life-saving procedures, such as:

- ✓ Automated hemostasis: Robots can quickly apply tourniquets or other systems to stop severe bleeding.
- ✓ Cardiopulmonary resuscitation (CPR): CPR robots are programmed to perform compressions at the correct rate and force when resuscitation is needed in cardiac arrest.

An example of such a robot is the LUCAS system (Fig. 2), which can continuously perform CPR without interruption while the patient is being transported to a hospital. This robot is designed to perform automated cardiac resuscitation (chest compressions) on patients who have suffered cardiac arrest. With specially programmed algorithms, it applies the correct pressure and rhythm, which increases the chances of successful resuscitation.

Фиг. 2 Системата LUCAS 3 – робот за CPR.

- ✓ Intubation and defibrillation: If necessary, robots can perform intubation to secure the airway, as well as defibrillation for arrhythmias.

❖ Diagnostic robots, which are equipped with ultrasound and X-ray machines, can perform rapid diagnosis of injuries such as fractures or internal bleeding. They can quickly scan the patient using X-ray, ultrasound or MRI systems and diagnose their condition. The data is transmitted in real time to remote doctors or medical staff.

❖ Telemedicine: Doctors located in safe areas or even in other countries can remotely control the robots in the mobile autonomous medical base and perform more complex procedures. They use high-resolution cameras and haptic feedback to operate remotely controlled surgical instruments.

❖ Autonomous evacuation drones: If the patient is stabilized, special autonomous drones can transport the injured from the infirmary to larger medical facilities. The drones are equipped with life support systems for monitoring patients during transport.

II. Structure Of Modern Field Medical Institutions

Medicine has specific requirements and structure [6] for modern field medical stations (Fig. 3), involving the construction of modular subunits.

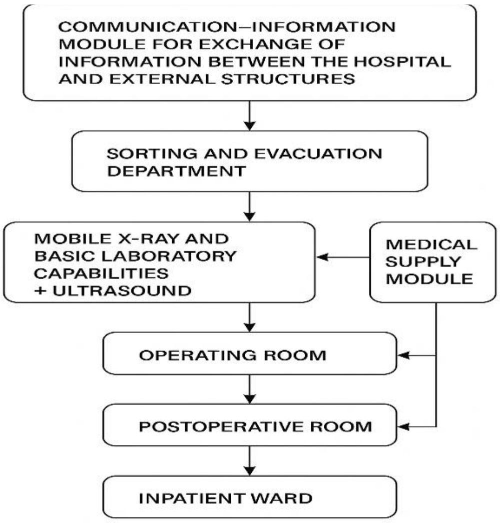

Fig. 3 Structure of modern field medical facilities.

By requirement, a field hospital must contain seven modules, with the main guarantee of its functioning being the communication and information module. Its structure is a key element of the healthcare and medical security management system. Its main goal is to ensure reliable, fast and secure exchange of information between hospitals, emergency centers, field medical posts, laboratories, state institutions and other units involved in the provision of medical care. This structure supports the coordinated actions of different teams and ensures effective management of resources and patient flow in real time.

The main functions of the communication and information module are:

Information exchange and integration of systems by ensuring automated data exchange between individual medical units - including patient information, test results, availability of medicines and equipment, as well as administrative data. It integrates electronic health systems (EHS), laboratory information modules, telemedicine platforms and emergency response systems, thus creating a single database for process management.

Coordination and communication between structures by ensuring constant communication between hospitals, emergency centers, field medical stations and government authorities via radio, mobile, satellite and optical connections. This allows for timely coordination of actions in crises, disasters or major incidents and optimal distribution of medical resources according to needs.

Management and decision-making support by providing management teams with analytical and visual data on the state of the health network, the occupancy of departments, the number of free beds, as well as available resources. This facilitates the decision-making process and supports strategic planning in real time in emergency circumstances.

Telemedicine and remote consulting by conducting remote medical consultations and diagnostics through video conferencing and sharing medical images and data. This function is especially important when serving remote areas or field conditions where access to specialists is limited.
Logistical and resource support by supporting the tracking and management of material and human resources - medical teams, ambulances, equipment, medications and consumables. Thanks to GPS and RFID technologies, transparency and control of the movement of resources in real time are ensured.
Information security and data protection by ensuring the security of medical information through encryption, access control and backup archiving. This protects patients' personal data and ensures the system's resilience in the event of accidents or cyberattacks.
In conclusion, it can be argued that the communication and information structure is fundamental for the effective functioning of the health system, especially in crisis and emergency situations. It ensures the continuity of medical services, improves the quality of care and supports rapid decision-making through reliable data exchange and technology integration. The construction and maintenance of a modern communication and information infrastructure is a prerequisite for sustainable, effective and coordinated healthcare.
Two other important modules are: triage and evacuation department, where victims are admitted and assistance is provided, and operating room.

The Sorting and Evacuation Department

(or triage and evacuation unit) is one of the most important structures in the system of field and hospital medical organization, especially in mass incidents, wartime situations or disasters. Its functions are related to the rapid reception, sorting, stabilization and referral of victims to the appropriate medical units. Here is how the functioning of the sorting and evacuation department looks like:

1. Reception and primary registration of victims
2. Medical sorting (triage). It divides patients into categories depending on the urgency:

• Group I – critically injured (requiring immediate assistance and stabilization)
• Group II – severely injured, but stable (needing medical assistance in the short term)

Fig. 4 Collaborative hominoid robot performing CPR, Cardiopulmonary Resuscitation – A life-saving procedure in the event of cardiac or respiratory arrest while another robot with tourniquets stops bleeding from wounds.

• Group III – slightly injured (can wait without risk)
• Group IV – no chance of survival (palliative care is provided)

This organization ensures effective use of medical resources and minimizes mortality.

3. Stabilization and primary medical care (Fig. 4).
4. Preparation and organization of evacuation.

Fig. 5 Example of evacuation. Once the patient is stabilized, an autonomous drone evacuates him to a larger medical facility for further treatment.

5. Keeping records and exchanging information.
7. Coordination with other medical structures.

The triage and evacuation department is a central link between primary medical care and subsequent hospital treatment.
It ensures organization, speed and accuracy in conditions of mass admissions of injured persons.
The effective functioning of this structure is of crucial importance for:

- ✓ Reducing mortality,
- ✓ Rational use of resources and
- ✓ Successful medical evacuation in crisis situations.

The first two groups of the triage and evacuation module, namely the critically and severely injured, enter the ***Operational Module*** (Fig. 6). It represents a critical functional area in the structure of each field medical station, as it provides conditions for carrying out emergency operational interventions in an environment often characterized by limited resources, high dynamics and unpredictability (disasters, accidents, military operations, epidemic situations).

Fig. 6 Operational module of a field medical station.

This module performs multiple interrelated functions that ensure continuity of medical care, stabilization of critically injured patients, and maintenance of high standards of surgical safety similar to those in inpatient hospital settings.
Evaluation of the effectiveness of the operating module is assessed by:

- time to life-saving intervention;
- autonomy (hours/days of continuous operation);
- biosecurity;
- logistical flexibility and deployment time (<60 minutes for modern systems);
- integration with other modules (triage, ICU, diagnostic modules).

The operating module is the core of the medical capability of the field station. Its effectiveness determines whether the mission can provide rapid and quality surgical care under extreme conditions. The combination of modern energy systems, intelligent surgical technologies, robotic assistance and well-optimized logistics turns this module into a fully functional mobile operating room, capable of operating autonomously and reliably even in the most severe scenarios..

III. Requirements For The Design Of A Field Medical Station

The field medical station (Fig. 7) requires specific equipment to provide effective medical care to the wounded.

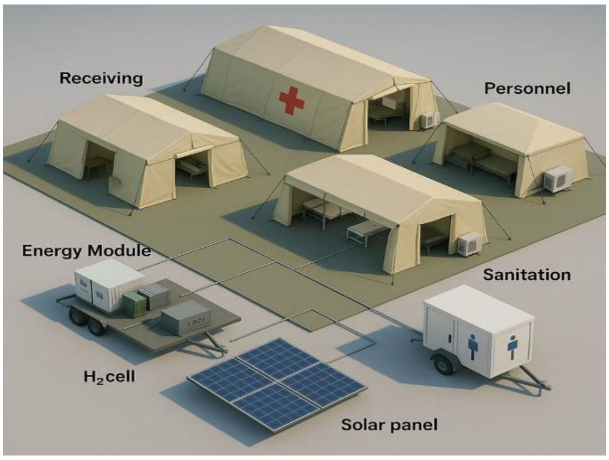

Fig. 7 Field medical station.

Here are the main categories of equipment needed:
1. Medical instruments: Surgical instruments (scalpels, tweezers, scissors, etc.); Diagnostic instruments (stethoscopes, thermometers, blood pressure monitors).
2. Beds and trolleys: Operating tables; Patient beds; Patient transport trolleys.
3. Medications: Painkillers; Antibiotics; Dressings and antiseptics.
4. Resuscitation equipment: Artificial respiration apparatus; Defibrillators.
5. Communication equipment: Radios; Telephones for communication with the main command post.
6. Disinfection and sanitation: Disinfection systems; Hazardous waste containers.
7. Supporting infrastructure: Electricity generators; Water supply and sanitation.
8. Personal protective equipment: Masks, gloves, protective clothing.

This equipment allows medical personnel to respond quickly and effectively to the needs of the wounded and provide the necessary care in conflict situations.

IV. COLLABORATIVE ROBOTS FOR FIELD MEDICAL STATION

Collaborative robots for field medical stations are collaborative robots that have the potential to improve efficiency, improve service quality, and reduce costs in various ways. The parameters of a service robot can vary depending on its intended function and design. However, here are some common parameters [2] that are often considered when developing a cobot.

- They come in a variety of sizes, ranging from small, desktop (stationary) robots to larger, human-sized robots.
- Work environment: the robot’s work area and workspace.
- In summary, the work area defines the physical boundaries of the robot’s operations, while the workspace refers to the volume of space within which the robot can reach and manipulate objects. Both concepts are important considerations in robot design, implementation, and safety planning.
- Mobility: These robots are designed to move autonomously or semi-autonomously both indoors and outdoors.
- Sensors: Service robots are equipped with a variety of sensors to perceive and interact with their surroundings. These sensors can include cameras, depth sensors, infrared sensors, touch sensors, and microphones. The specific sensors used depend on the robot’s tasks and the information it needs to collect.
- Manipulation & Gripping. This function enables precise operations to be supported by a multi-link manipulator or tool module for gripping, positioning and manipulating objects of various shapes and sizes. This is achieved by using force and tactile sensors to control pressure and prevent damage, making it suitable for surgical, logistical or service tasks in mobile medical stations.
- Power Supply: Powered by autonomous energy systems — Li-ion batteries, supercapacitors or hydrogen fuel cell, with critical operations requiring an uninterruptible power supply (UPS) and the ability to operate in conditions of limited electrical infrastructure. Optimized energy management is required for extended autonomous mode.
- Communication Interface to ensure support for wireless communication: Wi-Fi, LTE/5G, LoRa or tactical networks, as well as the ability to integrate with central medical systems and telemedicine platforms, low latency for real-time management, support for encrypted channels for secure communication.
- Processing & Control System is implemented through an embedded microcontroller or industrial computer to manage all functions and algorithms for local decision-making, navigation, stabilization or surgical precision through real-time processing of data from sensors (IMU, camera, force sensors). It is necessary to have the ability for remote monitoring and telesupport.
- Adaptability is implemented by automatically adapting to different loads, environments and operational situations, as well as adjusting operating parameters

according to the patient, task or conditions (temperature, vibration, lighting). This is achievable through a modular design for rapid reconfiguration in field conditions. Support for various tools or accessories is required.

❖ Safety features are guaranteed by mechanical and electronic protection mechanisms against overload, short circuit or movement errors, as well as emergency stop systems (E-STOP) and automatic diagnostics. It is important to be able to limit force and speed when interacting with personnel or patients. Certified medical safety protocols and electrical insulation must be used.

These are the main aspects and functions of collaborative robots [4], when implemented in a field hospital they are implemented through their functional subsystems, systematized in Table 1.

Table 1 Main functional subsystems of cobots

Subsystem / Component	***Description***
Collaborative Manipulator (Cobot)	Executes medical tasks, assists personnel, interacts safely with humans
Operator / Medical Staff	Controls and supervises robotic and medical processes
Power Supply System	Provides electrical power to all modules (battery, fuel cell, etc.)
Sensors	Collect environmental and operational data (vision, proximity, vital signs)
Communication Interface	Ensures data exchange between modules and remote medical teams
Processing and Control Unit	Performs computation, decision-making, control algorithms
Actuators	Enable movement, manipulation, positioning of the robot
Safety System	Ensures operational safety, emergency stops, collision avoidance

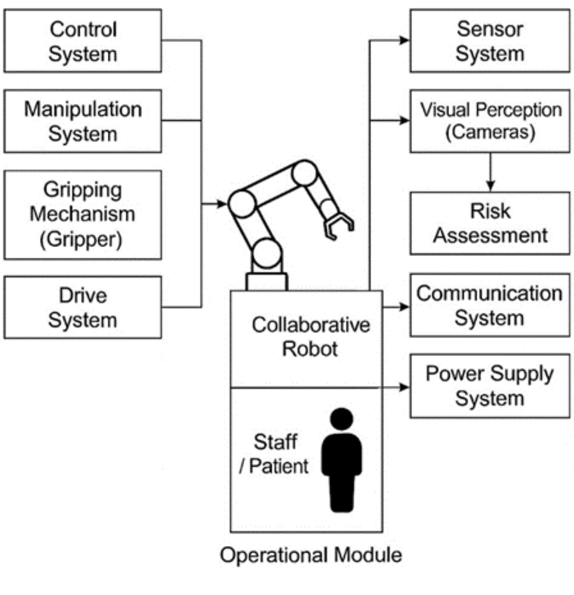

Fig 8 Functional subsystems of cobots

Robotization in the field medical station (Fig. 9) offers numerous advantages, including increased efficiency and reduced risks for medical personnel.

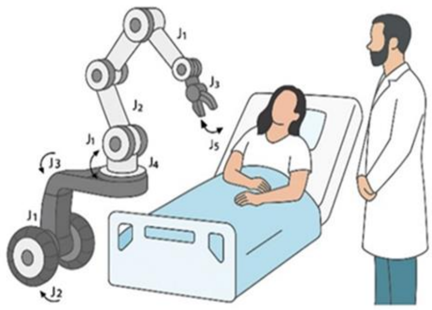

Fig. 9 Robotization of a field medical station.

Here, the conceptual role of collaborative robots (cobots) is that they are designed to assist medical staff by performing repetitive, risky or precise tasks in confined and dynamic environments. Unlike industrial robots, they are safe to work in close proximity to humans, with adaptive sensors, limited force and intelligent control. They are considered part of an intelligent mobile medical infrastructure operating in extreme conditions.

V. Implementation of Collaborative Robots in Modern Field Medical Stations

Through the use of robots and automated systems, various tasks can be performed, such as:

❖ Triage and monitoring: The robot can measure vital signs (temperature, pulse, SpO_2) and classify patients according to urgency.

❖ Operating room assistance: Supports surgical teams by positioning instruments, cameras or through precise manipulations (in sync with systems such as da Vinci).

❖ Disinfection and sterilization: Autonomously disinfects rooms and equipment using UV or aerosol systems.

❖ Logistics and delivery: Transports medications, supplies and samples between tents.

❖ Teleassistance: Connects remote specialists with field surgeons through audio-video connection and AR visualization.

❖ Psychological and communication support: In humanitarian missions – communication with patients, maintaining calm, language assistance.

However, it is important to pay attention to the ethical aspects and the interaction between the human and the collaborative robot [3], standards ISO 10218-1/2 and ISO/TS 15066 guarantee safe joint work.

Built-in force and proximity sensors prevent contact with people, which ensures safety. Built-in cybersecurity for the protection of medical data and communications is particularly important.

Fig. 10 presents a concept for a robotic field medical station, which has a built-in mobile collaborative robot, representing an anthropomorphic structure with degrees of redundancy, which performs mobile movement on a rail track. This allows the service area of the robot to increase significantly, so that it can reach the shelves with drugs and medications and deliver them to the doctor.

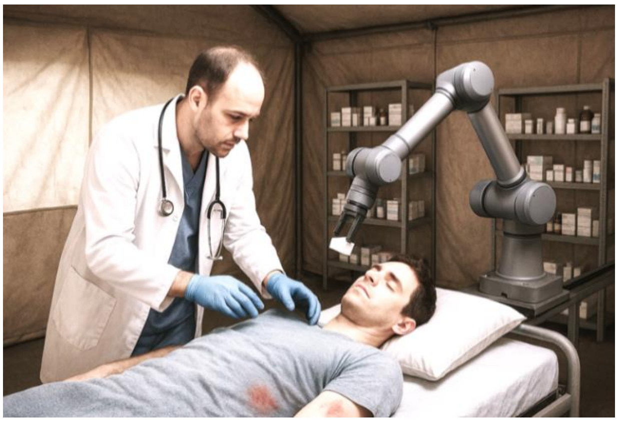

Fig. 10 Robotic field medical station TYPE 1.

The robotic field medical station type 2 (Fig. 11) has an auxiliary table to which the cobot delivers the medications and instruments requested by the doctor via voice command and removes them to the specified location. The use of an auxiliary table significantly increases the reliability of the system's operation.

Fig. 11 Robotic field medical station TYPE 2.

Future developments will be aimed at optimizing the mobility of the cobot.

CONCLUSION

The use of robotic technologies can increase the safety and efficiency of medical services, especially in conditions of natural disasters and combat operations.

Benefits of a field hospital are:

- ❖ Increased efficiency and accuracy with limited personnel.
- ❖ Reduced risk to medical teams in infectious or hazardous environments.
- ❖ Rapid deployment thanks to modular architecture.
- ❖ Energy independence through integration with H2 cells and photovoltaics.
- ❖ Interoperability with other mobile systems (drones, autonomous transport platforms).

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