A Framework for Multi-agent System to Support Emergency Medical Services: A Review

Omar Abdullatif Jassim[1] **Mohammed Jawad Abed**[2] **Zenah Hadi Saied**[3]
omar.abd@hiuc.edu.iq **mohamed.jawad@hiuc.edu.iq** **Zenah_hadi@mtu.edu.iq**

Abstract: The e-health system based on the agent system is considered one of the important and pioneering issues currently in the field of improving e-health care and the Internet of Things. Multi-agent systems have played a unique and crucial role in the interaction of mutual interdependencies, dynamic environments, uncertainty, and advanced control. There are many healthcare applications that depend on multi-agent systems. This review article presents a comprehensive review of the most current healthcare applications of multi-agent systems, by introducing multi-agent systems, their types and applications in the field of healthcare. In addition, the survey clarifies some of the literature that includes the use of smart multi-agent techniques in the field of health care and emergency cases.

Keywords: Healthcare, Multi-agent System, Emergency Medical Services.

1. Introduction

The growth of the healthcare industry is one of the most important and promising topics because of its crucial role in saving lives. Improving the current healthcare paradigm and ensuring a developed alternative for the future generation by proposing new techniques is always the main purpose of healthcare research. Bed management at the hospital is a critical issue that must be addressed, especially in cases of medical emergencies or accidents [1].

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[1] Assist. Lecturer, Medical Instrumentation Techniques Engineering Department, Al-Hikma University College, Baghdad, Iraq
[2] Assist. Lecturer, Medical Instrumentation Techniques Engineering Department, Al-Hikma University College, Baghdad, Iraq
[3] Senior Biologist., Department of Medical Laboratory Technologies, Institute of Medical Technology-Al-Mansour, Middle Technical University, Baghdad, Iraq

Efficient bed management will shorten the length of time that people have to wait in the emergency room, while also allowing doctors to keep tabs on the health status of several patients at once. Each department's data for resource planning must be provided to develop appropriate decision support systems [2].

The computer-based decision support system is highly suggested for this purpose because of the task's intricacy and the wide range of choice criteria [3].

A variety of studies using multi-agent system (MAS) modeling and supply chain management have shown that these strategies perform efficiently in crisis management by simulating and solving real-world situations. This approach offers solutions that are autonomous, reactive, and proactive. Healthcare models are being developed using these techniques. In addition, the MAS-based solution is adopted to improve the quality of elderly life and save healthcare costs [4].

Decision support systems, elderly care, self-treatment, and automatic access to patient records and treatment information have all been proposed as possible uses for automated systems in the medical field, taking into account patient confidentiality and other legal, ethical, and socioeconomic issues. The design and implementation of healthcare services are one of the multi-agent system's duties and barriers. It seems that using a multi-agent system to gather and analyze data from diverse and maybe heterogeneous sources in order to provide medical knowledge relevant to a specific user profile is a viable option for delivering automated medical knowledge [5].

This paper aims to introduce multi-agent systems, their types and applications in the field of health care. In addition, the survey clarifies some of the literature that includes the use of smart multi-agent techniques in the field of health care and emergency cases. The study contains a general introduction, then defines both agents and multi-agent systems, and includes their types and components. Then, the concept of a multi-agent system for the medical field is clarified using some studies within the same field. At the end, what was discussed was discussed along with the summary.

2. Agent Definition

The term "agent" refers to anybody or entity that senses its surroundings and acts with them [6]. "Intelligent agents," are defined as software entities that do some task on behalf of the user or another program with some degree of independence or autonomy, and utilize some knowledge or representation of the user's aims or desires [7]. The term "autonomous agent" refers to a computer system that can interact independently with its environment and accomplish objectives and tasks. An intelligent agent is software that has the following properties [8] as shown in (Figure 1):

- Flexible: It has multiple techniques and ways of achieving goals.
- Situated: It means that it does exist in an environment.
- Autonomous: It means that it is independent, and controlled externally.
- Proactive: It persistently pursues tasks and goals.
- Robust: It means that whenever it faces a problem or in case of any failure it has the ability to recover from a failure.
- Reactive: It means that it can respond to the potential changes in its environment.

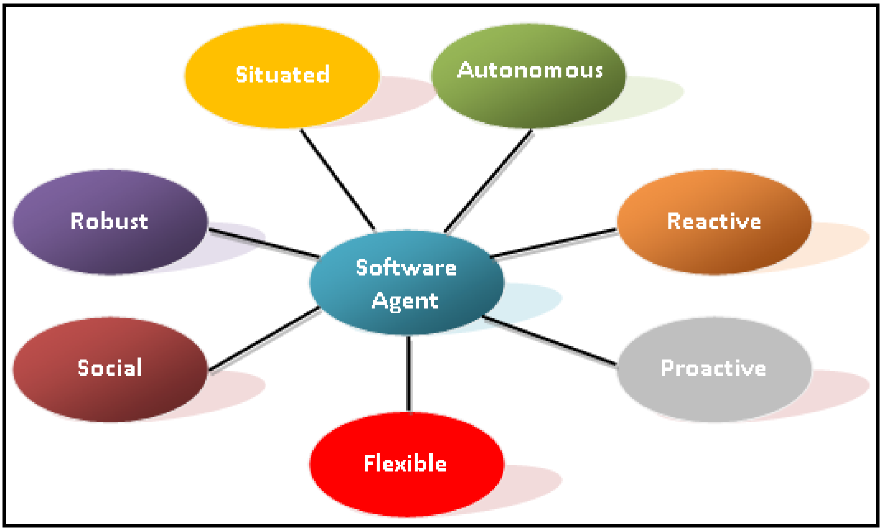

Figure 1: Characteristic of Intelligent Software Agent [9].

3. Multi-Agent Systems (MAS)

There are systems known as multi-agent systems that are composed of several interconnected components and work together to accomplish certain tasks in the system. These agents are completely autonomous creatures that can communicate with one another and make decisions about what and how to accomplish various sorts of activities to attain their own and other objectives in an environment [10].
Each party has its own unique aims, proprietary data and domain expertise, therefore the best way to model their interactions is by using multi-agent systems even if some parties tend to develop their systems [11].
On the other hand, creating a common system that encompasses all agents would be impossible. In general, organizations are against sharing their data and do not like to have their data handled by a representative of another organization. As a result, multi-agent systems can be considered as a network of agents that collaborate and exchange information [12].

It's also possible to segment MAS models into smaller, more manageable sub-problems, which may then be further broken down into individual problem-solving agents with their own interests and objectives. It's safe to say that multi-agent systems are a relatively recent sub-field of computer science that was inspired by ideas from artificial intelligence and distributed systems, respectively. Since the 1980s, the topic has attracted considerable interest and has seen rapid growths spurred by the notion that multi-agents are an acceptable paradigm for exploiting the potential of massively distributed artificial intelligence systems. According to [13], "Multi-agent systems appear to be a suitable model for understanding and developing a broad variety of what we may roughly term artificial social networks." Multi-agent systems are not restricted to a single domain and may be found in different applications.
Balaji and Srinivasan cover the MAS characteristics, especially the organizational types, and decision-making techniques, in addition to coordination and learning methods [10]. Dorri et al. discuss MAS problems and examine various MAS applications in networks, robotics, modeling complex systems, cities and built environments and smart grids [11]. Mostafa et al. extracted the pre-hospital emergency process and main components using a comparative review of existing pre-hospital emergency architectures. The results show the reliable utilization of multi agent system [14]. Mostafa examined and characterized the milestone accomplishments of the agent technology conception, modeling and enhancement platforms, identified the outstanding achievements of multi-agent systems and their modeling and development mechanism, defined relevant terms in the field and reveal, explain the technology of multi-agent systems, and investigated software agent and multi-agent systems topics. [15]. Abbas et al. presented a suggestion of providing MAS organizations containing prototypes and methodologies used for organizing agents in a static or dynamic fashion in MAS [16]. Chin et al. discuss various kinds of agent architectures and their attributes in order to utilize them to tackle actual challenges [17].

3.1 Structure of MAS

A MAS is defined as a system composed of the following requirements [18]:

- A set of relationships that connect objects together.
- An environment.
- A set of active agents.
- A set of passive objects that can be perceived, created, modified or destroyed by agents.
- The ability to perceive, generate, consume, change, and manipulate environmental rules is provided by a set of operations or abilities.

- Agents' activities and the world's response to those actions are represented by a set of rules that serve as operators. "Universal laws" is the name that will be given to these rules.

3.2 Advantages of MAS

There are many benefits of using a MAS more than serving one agent or a centralized approach:

a) In a MAS, computing resources and capabilities are distributed among a network of linked agents. The "single point of failure" issue associated with centralized systems is avoided by MAS since it is decentralized and hence does not suffer from resource restrictions, performance bottlenecks, or catastrophic failures.

b) In MAS, existing legacy systems may be interconnected and interoperated with one other. Such systems may be integrated into an agent society if they are wrapped in an agent.

c) It is more natural to depict job allocation, user preferences, team planning open environments, and so on using a MAS since it represents issues as autonomous interacting component-agents.

d) As previously mentioned, a MAS is capable of retrieving, filtering, and globally coordinating data from widely dispersed sources.

e) A MAS helps in instances when knowledge is dispersed in time and space.

f) A MAS boosts overall system performance, particularly in terms of compute efficiency, dependability, extensibility, resilience, maintenance ability, responsiveness, flexibility and reuse.

3.3 MAS Properties

MAS can have several properties that can be outlined as follows [19] (Figure 2):

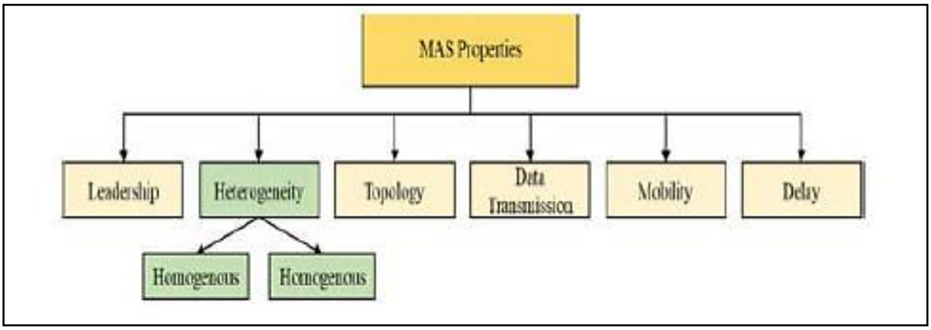

Figure 2: The MAS Properties [19].

3.3.1 Leadership

The MAS has a leader, i.e. an agent, who establishes a common aim and then assigns goals and objectives to other agents. There are two types of MAS: those with or without a leader (have a leader and follower agents). There are no leaders in a leaderless system, therefore each agent determines what to do based on its own aims, and the choice is affected if other agents work together to come to an agreement. An agent (leader) communicates with others (followers) to find the leader's location in a system known as a leader-follower. Others in the system choose the system's lead agent, and the system may have one or more of them. Agents that are being followed by a leader that moves around a lot may have additional processing requirements. When there is more than one leader agent, they may work together to take a decision by talking with each other.

3.3.2 Heterogeneity

A MAS can be classified to homogeneous or heterogeneous structure based on the system's design of autonomous agents:

- **Homogenous structure**: all MAS agents have the same basic internal structure. Each agent has a common set of objectives, sensory abilities, moods, reasoning methods, and behaviors according to the concept of "internal structure". According to their physical locations in relation to the environment, agents may be identified. It is possible for the agent to acquire sensory information from a number of different places around it. An overlap in obtaining sensory input may occur.

- **Heterogeneous Structure:** each of the agents in this system may have a wide range of skills, architectures, and performance levels. It is because of the dynamic nature of the environment and the location of a given agent that the actions chosen by each agent vary from those of other agents put in various parts, even though they can all perform the same function Models and simulations based on heterogeneous structures may better represent real-world issues. It is possible that the aims of one actor may conflict with the objectives of another.

3.3.3 Topology

There are static and dynamic topologies inside the topology. An agent's position and connection to other agents remain constant under a static topology. When one agent moves, leaves, or enters the system, or forms new connections with other agents, its position and relationships change in a dynamic topology.

3.3.4 Data transmission

Sensory data may be sent between agents in a time-triggered way so that the agent can often detect and gather information in a preset period of time. Agents are also capable of transmitting to other agents any newly acquired sensory data. When a given event happens, the agent just observes the environment. In the next step, the agent communicates this information to other members of MAS.

3.3.5 Mobility

An agent may be classified as either a stationary or mobile one. A mobile agent, on the other hand, leverages the resources of nearby agents, keeps an eye on them, and views the world from the perspective of other agents' locations and places in order to carry out operations.

3.3.6 Delay

Agents may encounter a variety of delays while carrying out their tasks. Agents may encounter delays in data exchange because of the means of connection, whether wired or wireless. There are two varieties of MAS: those that have a delay mechanism and those that don't. With no delays in transmission or calculation, the latter is a snap. Despite the fact that most Real-world contexts have a number of delays.

4. Agents and Multi-Agent Systems in Healthcare

Sensors are used by agents to get information about their environment. Recognizing and filtering away anticipated occurrences while paying attention to unexpected ones is a critical skill in perception. Effectors are used by intelligent agents to perform activities, either by delivering messages to other agents or by directly invoking application programming interfaces or system services, as needed. As stated by [20]. Some of the qualities of agents are autonomy, responsiveness, proactiveness, and sociality. Applications in which several independent software agents work together to solve complex issues are known as multi-agent systems (MASs) [21]. It is common for the information and data needed to address an issue to be spread out over several places, which presents a number of challenges when planning coordinated activities. The provision of healthcare typically involves the coordination of the efforts of several people (e.g., doctors, nurses, careers, social workers, managers, receptionists) with different skills and needs and located in different places, usually without the supervision of a single centralized coordinator. Many medical records cannot be electronically sent and must be accessible only at one specific location for reasons of data security. When it comes to medical information, there are a plethora of options, but the vast majority of them are based on textual data. Healthcare applications might find the agent technology is so handy in several situations [22]. Moreover, agents can naturally deal with intrinsically dispersed issues with diverse sources by collaborating and coordinating their actions and also acting proactively to execute tasks that may be useful for the user [23].

Fox et al. identified other benefits of agents in healthcare [24]:

a) Distributed agent systems have enough potential to improve the operation of healthcare organizations, where failures of communication and coordination are important sources of error.

b) Agent technology offers advanced platforms for building expert systems to assist individual clinicians in their work.

4.1 Multi-Agent System for The Medical Field

The medical multi-agent system is created for the purpose of information management and transfer. Data, knowledge, and even dispersed competence are hallmarks of the medical industry. The three elements (information, data and knowledge) might also be of numerous types: natural language descriptions, photographs, measurable signals and the outcomes of various tests and measurements (usual lists of numbers). Paper, images, slides, computer data, books (if we consider "traditional" knowledge"), and even private dialogues are all forms of archiving. You can only get them in a few places at once. Since judgments must be taken rapidly, this may be a serious issue. There are numerous experts in modern medical systems who specialize in a single area of medicine or surgery. Many different medical professionals must be consulted, and a variety of tests must be performed in the lab. Geographically and chronologically, medical expertise, tests, and treatments are dispersed. To achieve the overall goal of improving a patient's health, there must be a regular flow of information and trust among all parties involved. However, the content and structure of the essential information flow are not predetermined, and it is always developing and changing as a result of new information and responses. It is necessary to employ intelligent software programs in order to achieve these requirements and give the proper decision assistance [25].

Health system design for dispersed heterogeneous settings [26] has proven that multi-agent systems are the optimum technique of implementation for these contexts. It's important that these systems have distinct components that interact reactively, and some of these components should be created and withdrawn dynamically. An agent is a piece of software that serves a specific purpose in a system. In addition, an agent must be able to interact with other agents or human users. A group of similar systems that work together is known as a multi-agent system. The following benefits may be gained by adopting multi-agent technology in the system implementation, where the following advantages could be obtained [27]:

- **High flexibility**: An agent may be created for any situation, and it can serve as a bridge between several ontologies.
- **High performance**: Parallel running is possible. When a person's responsibilities and objectives are critical, they might be duplicated.
- **High modularity**: the number of connected sources can increase practically without limit. There is essentially no limit to the number of linked sources.

The use of multi-agent systems in the medical profession may help medical personnel make better decisions by giving more information about particular scenarios and lowering the number of procedures that must be completed by a human. There have been a number of medical multi-agent systems built to date across the globe. The following benefits may be obtained by using these systems:

- Patient monitoring and, in certain situations, prescription generation;
- Fast and automatic data extraction from medical databases; •
- Medical office scheduling efficiency;
- Scheduling of life-saving medications
- Patients' medical records, which are stored in a variety of databases, are accessible to doctors.
- Image processing for medical use.

5. Ambulance Abstract Agent (as an Emergency Medical Services):

The ambulance as an abstract agent comprised numerous agents (Figure 3), including the ambulance coordinator, teams of emergency medical responders, traffic agents, and locators. One ambulance coordinator, traffic agent, and tracking agent are assigned to each actual ambulance as follows [28]:

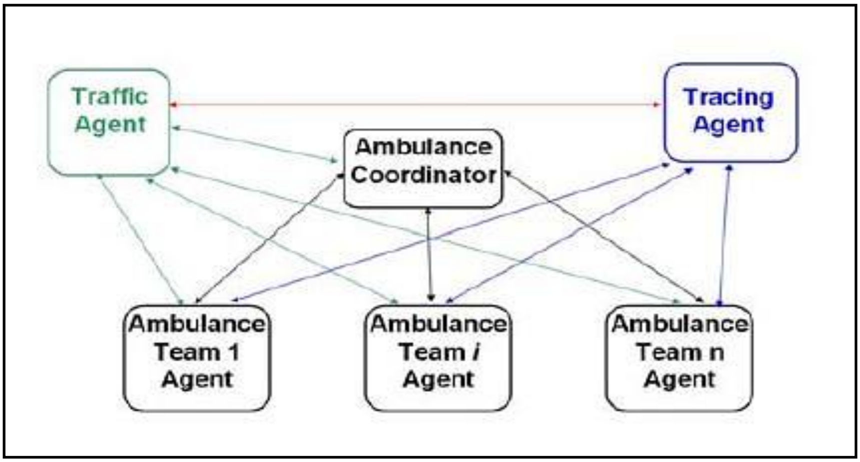

Figure 3: Ambulance multi-agent system [28].

5.1 Traffic Agent

There is a constant exchange of information with the national traffic center on traffic blockages, accidents and tempos. For Time-Critical Patient Treatment, Ambulance Coordination MAS rallies stopped streets and roads consequently, it is easy to pinpoint the locations where ambulances are unable to go. When the national traffic center detects a traffic incident, this agent immediately broadcasts the event's details to the whole ambulance squad. Similarly, it provides traffic information to the tracing agent, which needs to know if and why ambulance trajectories alter.

5.2 Tracing Agent

The mission of the tracing agent is to gather data about the ambulance's previous movements. This is especially true if an ambulance team's service is deemed to have been effective; in other words, if they arrived on time and in the correct location to treat the patient. A failure is recorded (1) if it does not occur (whether the driver followed the optimal path or not), (2) if there was an issue in the trajectory, (3) if it does not occur this data is saved in a trace file and may be accessed by the best agent to improve the dependability of the ambulance. When asked, this agent may also provide the ambulance crew with findings from earlier trips along the same path. Agents in the ambulance teams benefit from their previous experiences while making judgments.

5.3 Ambulance Coordinator Agent

This agent is in charge of selecting the ambulance crew that will transport the patient to the hospital from where they are currently located. An auction method is used to choose the ambulance.

5.4 Ambulance Team Agent

Bidder and Monitor are the primary functions of this agent, which represents a real-world automobile. As a bidder, you compete in an auction run by the ambulance coordinator for the right to pick up a patient. Monitors track the actual ambulance's route when a patient is allocated to an ambulance crew in order to identify probable deviations from the expected arrival time. Both the bidding and monitoring roles are dependent on the GPS and route planning capabilities. There are three components in each team agent: the GPS module, the Trajectory module and the decision module as seen in (Figure 4). It's possible to see the emergency vehicle's exact location on a map using GPS technology. The vehicle has an electronic gadget connected to it that continuously provides information to the ambulance agent regarding the location of the vehicle's position.

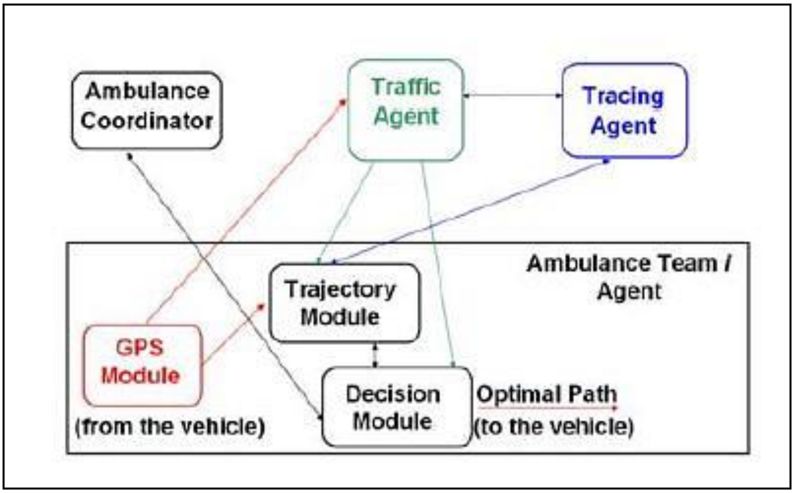

Figure 4: Component of the Ambulance Agent system that communicates with the other agents [27].

6. Conclusion

The e-health system based on the agent system is considered one of the important and pioneering issues currently in the field of improving e-health care and the Internet of Things. Among the factors that improve the applications of agent systems in healthcare is the agent's possession of key qualities such as independence, social communication, and the ability to adapt, because these qualities are necessary to make smart systems more effective and this leads to an increase in the performance of the systems generally. The study shows that the use of multi-agents, especially smart ones, to automate various stages within an integrated healthcare system, such as patient data monitoring and diagnosis, and medical decision support/alarming is a promising approach for e-health systems.
Medical systems should be patient-centered and include the views of the people who utilize them on a regular basis. Personal information about users' preferences may be stored in (or inferred from) the systems that they interact with and this data can be used to create services that are more relevant for those users. Agents operating on mobile devices also provide an intriguing prospect, since this is a technology that the majority of people, including the elderly and handicapped, can readily use. Reusing various components of these healthcare agent-based systems

is a good idea from an agent community perspective since it would allow researchers to avoid starting from scratch every time they work on a new healthcare agent-based system project (which is the present situation). There is the potential of creating a common framework for agent-based medical decision support systems. All systems' reusability might be improved by mandating the usage of widely accepted medical terminology and vocabulary.
For these reasons, despite the fact that agent technology shows great promise in the fight against healthcare issues, considerable work remains before agent-based systems are commonly utilized in medical settings.

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الإطار العام لنظام متعدد الوكلاء لدعم الخدمات الطبية الطارئة: مراجعة أدبية

عمر عبداللطيف جاسم[1] **محمد جواد عبد**[2] **زينة هادي سعيد**[3]

omar.abd@hiuc.edu.iq **mohamed.jawad@hiuc.edu.iq** **zenah_hadi@mtu.edu.iq**

المستخلص: يعتبر نظام الصحة الإلكترونية القائم على نظام الوكيل من القضايا المهمة والرائدة حالياً في مجال تحسين الرعاية الصحية الإلكترونية وإنترنت الأشياء. لقد لعبت الأنظمة متعددة العوامل دوراً فريداً وحاسماً في تفاعل الاتصال المتبادل والبيئات الديناميكية وعدم اليقين والتحكم المتقدم. هناك العديد من تطبيقات الرعاية الصحية التي تعتمد على أنظمة متعددة الوكلاء. تقدم المقالة دراسة أدبية تشمل مراجعة شاملة لأحدث تطبيقات الرعاية الصحية للأنظمة متعددة الوكلاء، من خلال إدخال أنظمة متعددة الوكلاء وأنواعها وتطبيقاتها في مجال الرعاية الصحية. بالإضافة إلى ذلك، توضح المراجعة بعض الأدبيات التي تتضمن استخدام التقنيات الذكية متعددة العوامل في مجال الرعاية الصحية والحالات الطارئة.

الكلمات المفتاحية: الرعاية الصحية، نظام الوكلاء المتعددين، الخدمات الطبية الطارئة.

[1] مدرس مساعد، قسم هندسة تقنيات الأجهزة الطبية - كلية الحكمة الجامعة - بغداد - العراق

[2] مدرس مساعد، قسم هندسة تقنيات الأجهزة الطبية - كلية الحكمة الجامعة - بغداد - العراق

[3] معاون رئيس بايوبوجيين ، قسم تقنيات المختبرات الطبية - المعهد الطبي التقني / المنصور - الجامعة التقنية الوسطى - بغداد - العراق