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Multi-agent Intelligent System Design for Telemedicine Applications to Develop Health Care Systems of Developing Countries

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Abstract

Various factors controlling health care in any country, but still there is a weakness in the infrastructure of health care systems in some developing countries, including many Arab countries, due to the shortage of medical specialists personnel, global economic crisis, and wars and disasters that struck many countries. A crying need for a tele-medical care becomes a necessity, and in order to overcoming this weakness we have proposed a multi-agent intelligent Telemedicine system in this research, this prototype consists of two main units one for the specialized doctor and one for the patient, both of them are communicating online through some Telemedicine applications and exchange information via different types of cloud databases. The proposed system can help solve the shortage of specialists urgently and at lower costs. Furthermore, it can save the efforts of the patients' expensive travel for treatment abroad. Moreover, it can avoid infections from social closeness in times of disasters and pandemics.

Nowadays Telemedicine systems have gradually become a popular medical model which have always attracted much attention due to the continuous development of the multi-agents' structure and capabilities of the artificial intelligence systems. So we will focus in the prototype design of our system on the algorithms, techniques and devices that support the multi-agents' structure and AI technologies. The Multi-agent approach happens to be a suitable structure for the development of Telemedicine systems. Worth mentioning it can solve problems that are difficult or impossible for an individual agent or a monolithic system, and the AI capabilities will minimize human errors and improve health care outcomes.

We will start by a state-of-the-art literature survey as conducted on the E-health system architecture, AI capabilities, and multi-agent platform, and then we will illustrate prototype design of the suggested Multi-agent intelligent system for Telemedicine which will contribute in the development of the health care systems in the developing countries.

Keywords: Artificial Intelligence; Healthcare System; Medical System; Multi-Agent; Telehealth; Telemedicine

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1. Introduction

One of the most rapidly evolving government sectors in any country is the healthcare industry. Today, the healthcare system in the developing nations is facing the various challenges presented by economic crisis, wars and disasters.
Over the past 10 years, debates on global health have paid increasing attention to the importance of health care systems. It has become especially important to emphasize health care systems in low- and middle-income countries because of the substantial external funding provided for disease-specific programs, especially for drugs and medical supplies, and the relative underfunding of the broader health care infrastructures in these countries. Recent analyses have drawn attention to the weaknesses of health care systems in low- and middle-income countries especially the developing countries. The strengthening of health care systems in these countries must be seen as a long-term developmental process [1].

A multi-agent system (MAS or "self-organized system") is a computerized system composed of multiple interacting intelligent agents [2]. It can solve problems that are difficult or impossible for an individual agent or a monolithic system to solve. Nowadays, agents have an important and basic role in many practical programs of E-health among which the disease diagnosis system. The best ideas for creating the practical programs of E-health and supporting next generation are practical programs and services of E-health multi-agent systems. Intelligence may include methodic, functional, procedural approaches, algorithmic search or reinforcement learning [3].
Technology permeates so much of healthcare today that it's impossible to separate Telemedicine from medical care in general. While not every instance of Telemedicine involves AI, the use of AI within the field of healthcare has expanded dramatically in recent years. According to a study by MIT, 75% of healthcare institutions that implemented AI acknowledged an augmented ability to treat illnesses [4].

In this research we will focus on the ability of AI in developing the healthcare systems in the developing countries through the multi-agent E-health systems that uses different applications of Telemedicine. In the following sections we will introduce the structure of multi-agent system, the AI E-health systems, and then we will propose a multi-agent intelligent system for Telemedicine applications which help in the development of health care systems in the developing countries. The suggested prototype system can serve all patients in any country remotely through Telemedicine applications that connecting a community national hospitals and medical main centers in the country with a specialized hospitals in the regional area and international, and to focus on applying AI algorithms, techniques, and devices in this system in order to establish a new intelligent Telehealth system for developing countries, this system will fill the shortage and weakness of the medical care system in these countries.

The aim of this research is to develop a multi-agent system for telehealth care, which has the following main objectives:
First: It guarantees Tele-diagnosis and other important Telemedicine applications as medical treatments in qualified and high-quality medical centers with lower costs and without travelling difficulties and costs.
Second: It guarantees that provides the requirements of prevention and protection from infection and ensures social distancing in times of disasters and pandemics.

Third: It provides various artificial intelligence capabilities of algorithms, techniques and devices; at the end all these procedures and developments will be increasing the quality of health care system in the country.

E-health and Developing Countries

Telemedicine refers to the use of advanced technology to deliver healthcare services remotely (E-health). The terms E-health (Telehealth) and Telemedicine are often used interchangeably, but Telehealth has evolved to encapsulate a broader array of digital healthcare activities and services. Telemedicine refers specifically to the practice of medicine via remote means; Telehealth is a blanket term that covers all components and activities of healthcare and the healthcare system that are conducted through telecommunications technology.

Telehealth can also be combined with medical insurance system in order to develop health care system in some countries, Telehealth Medical Insurance System (TMIS) that facilitates communication between the patients and medical providers remotely through insurance companies guarantee protection rules of dealing with pandemics, preserve patients from infection by some viruses or other infectious diseases, and it guarantees medical treatments in a qualified high-quality medical provider with lower prices and without travelling difficulties and costs. [5]

Several technologies are being deployed for Telehealth including mHealth (or mobile health), video and audio technologies, digital photography, remote patient monitoring (RPM), and store and forward technologies, in addition the communications technologies will provide health care from a distance, these technologies may include computers, cameras, Internet, videoconferencing, and satellite and wireless communications. Table 1 illustrates the E-health main advantages and Telemedicine popular examples [6]:

Table 1. E-health main advantages and Telemedicine popular examples

E-health Advantages and Benefits	E-health / Telemedicine Examples
Enhancing quality and extending domain of health care.	Virtual visit with a health care provider for Tele-diagnosis.
Empowerment of consumers and patients	Remote patient monitoring.
More support for people who are managing their health conditions	Surgeon using robotic technology or do surgery from a different location.
Online education of physicians.	Sending your provider a message through your electronic health record (EHR).
Getting care after office hours, and getting care at home from a specialist who is not close by.	Watching an online video sent by your provider about how to use an inhaler.
Lower cost, since virtual visits may be cheaper than in-person visits	Getting an email, phone, or text reminder that it's time for a cancer screening.

Recently, in the developing countries, including Arab countries, Telemedicine has been gaining popularity in recent years which includes: Remote Consultations, Remote Monitoring, Telepharmacy, Mental Health and Medical Education. But some analyses found a lack of innovation in the field of digital health in the Arab countries and many gaps in research were found in Arab countries, Digital health research was clustered around themes of big data and artificial intelligence; a lack of progress was seen in telemedicine and digital health.

Role of AI and Multi-agent in E-health

Artificial Intelligence and Telemedicine go hand in hand today. The application of this technology to the healthcare system has various benefits like cost reduction, fast processing of patient records, and much more. There are three main types of telemedicine where artificial intelligence is widely used. Patient monitoring, healthcare information technology, and Tele-diagnosis are among them. So, let's look at each of them in detail [7].

The main AI use cases in Telehealth include information analysis and collaboration, remote patient monitoring, and intelligent diagnostics and assistance. The power of AI can be leveraged to augment physicians in their abilities to diagnose and treat patients, mitigate their own burnout and enhance the entire spectrum of the patient journey. The distributed artificial intelligence is used in creating software based on intelligent agents in E-health special parts. The controversial issues here are: Communicative protocols among electronic groups including, negotiation template, virtual chat rooms, role definition, agents' responsibilities, and reorganizing the system in a dynamic way when new members sign in as agents or creating a new multi-tasking system with a new objectives [8].

The AI system used is called "deep learning technology," which is a computer-aided diagnosis. With the implementation of this technology based on ICTs and AI, benefits can be achieved such as reduction of diagnostic costs, improvement in the quality of medical care and diagnosis, reduction of the average time for diagnosis, and extension of remote diagnostic screening services to locations with few specialized professionals and equipment, as has been shown in other countries [4]. A well-known existing area for Tele-diagnosis is Tele-dermatology, which lends itself well to automation through AI. Similar promise is offered in other areas of automated diagnosis such as breast cancer or cervical cancer screening. AI systems for Tele-monitoring depend on and also expand the scope of other health system ICT components [9].

The agent technology has had a significant growth in all fields, especially in the field of E-health. Multi-agent systems are following a growing field of distributed artificial intelligence. Coordination subject in multi-agent systems is the fundamental issue, without which the benefits such as interaction and social behavior of agents fade. Multi-agent systems in creating and developing vital systems, non-coherent, dynamic, complex, distributed, and communication between remote users are useful to create E-health applications [10].

Recently, the agents played essential roles in the practical programs of E-health, which includes the diagnosing system, facilitating and accelerating the treatment process and avoiding disorganized data system. The best way to create E-health practical programs and to support the future generation is multi-tasking systems. Multi-tasking systems are helpful in creating and developing vital, heterogeneous, dynamic, complicated and distributed systems among agents to make E-health programs practical and possible [2].

Table 2. Capabilities of AI and reasons for using multi-agent for Telemedicine

Artificial Intelligence Capabilities for Telemedicine	Multi-agents Features and Reasons of using for Telemedicine
AI can provide prompts that make it easier to take a patient's history during a telemedicine visit, dynamically adjusting questions based on responses	Intelligence and Autonomy
AI algorithms can also help with diagnostics, especially for conditions such as melanoma	Reliability and Reduce human error due to fatigue, stress, inexperience
AI-based tools can offer personalized reminders for medication and recommend routine condition checks based on personal monitoring data.	Necessity and Reactive
AI integrates more health data into these systems, helping detect patterns pointing to potential issues. (track daily blood pressure and glucose levels).	Parallelism, Concurrency, and Communication
Many of the computer technologies and digital tools used by clinicians and patients have built-in AI	Extensibility, Adaptability and Cooperation
AI-driven tools monitor patients, both inside medical facilities and outside hospital walls	Saving time and costs
AI helps clinicians triage patients, diagnose their conditions and plan optimal treatments.	Easiest Programmable and performing automatic functions.

Table 2 stated the capabilities of Artificial Intelligence to Telemedicine and reasons for using multi-agent systems, all of these combined makes any intelligent Telemedicine system more strong and effectiveness in developing health care systems in the country [11, 12, and 13].

The prospects for smart healthcare are vast. For individual users, smart healthcare can facilitate better health self-management. and the content of medical services will be more personalized. For medical institutions, smart healthcare can reduce costs, relieve personnel pressure, achieve unified management of materials and information, and improve the patient's medical experience [14].

A Proposed Model for Multi-agent Telemedicine System

Due to the low levels of health care systems in some developing countries, including many Arab countries, for various reasons, including the global economic crisis, wars and disasters that struck many of these countries, which led to a weakness in the infrastructure of health care and a shortage of medical personnel. And in order to overcoming this weakness and shortage urgently and at lower costs and saving effort on patients instead of their traveling and to avoid infection from social closeness in times of disasters and pandemics, we have proposed in this paper a prototype design of a Telemedicine system that provides advanced capabilities, including multi-agents structure and using various artificial intelligence techniques of algorithms, techniques and devices, so by applying machine learning methods to large datasets of disease populations, AI is on its way globally to making a significant impact on the way doctors could diagnose a potential disease. This system can develop the healthcare systems in these countries to a reasonable and economical extent.

Multi-agent systems are considered as the best and most appropriate technology that can be applied to fulfill the need required in healthcare system. In multi-agent system, the agents are representing and acting on behalf of users and owners with very difficult goals and motivations. The agents cooperate, coordinate and negotiate with each other in the same way that we cooperate, coordinate and negotiate with other people in

day-to-day life and consequently can be used as the best technology to solve the problem arrived in medical healthcare system [15].
Creating multi agent Telemedicine systems can guarantee better online services to patients. This section provides a proposed multi agent Telemedicine system which can be used in the developing countries to provide patients with high quality online medical services and to compensate the shortfall in the medical care system of these countries. In Figure 1, the use case diagram of this system is displayed.
In this system, patients have direct communication with admission section, Telemedicine application, nurse (or medical assistant) agent and doctor agent. Doctors and nurses can update medical and nursing knowledge base of hospital. Agents relevant to the database can be updated. Agent can make sensitive decisions away from the tiredness and mistake, according to their features, and inform the doctor and the nurse.

- **System Prototype Structure**

Fig.1 shows the proposed Multi-agent Telemedicine system prototype, in which there are two main units one for the specialized doctor and one for the patient,

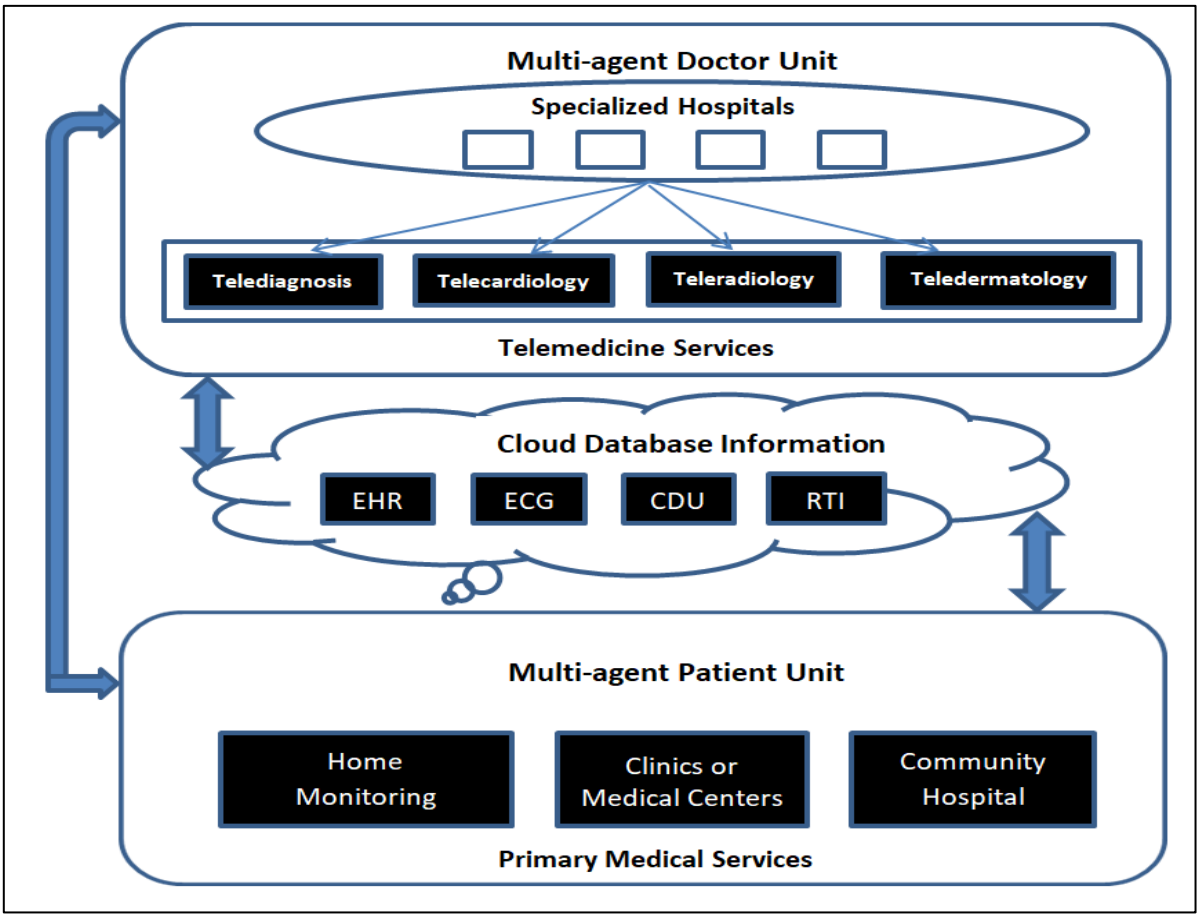

Fig. 1. Proposed Multi-agent Telemedicine System Prototype

Both of the doctor and patient are communicating online through some Telemedicine applications and exchange information via the following types of cloud databases:
EHR: Electronic Health Record.
ECG: Electro Cardio Gram.
EDU: Clinical Decision Unit.
RTI: Radiograph and Tomography Images.

The specialist communicates with patient from the specialized hospital through different popular Telemedicine application (Telediagnosis, Telecardiology, Teleradiology, and Teledermatology). The patient contacts the specialist either from the community hospital (or clinic) for telediagnosis via Telemedicine workstation with the help of the General practitioner (GP) in that hospital, or from the patient's computer at home for urgent medical consultations.

- **System Use Case Diagram**

Fig.2 shows the use case diagram of the proposed multi-agent Telemedicine system, in which the specialist Doctor, and Nurse/Medical Provider are exchanged messages about the patient, each actor has a page in the Telemedicine application with some specified functions. Doctor and Nurse also communicate with other different agents of GP doctor and medical providers in the doctor agent or medical provider agent. The patient, doctor, nurse, and other medical provider communicate each to other from his page in the Telemedicine application.

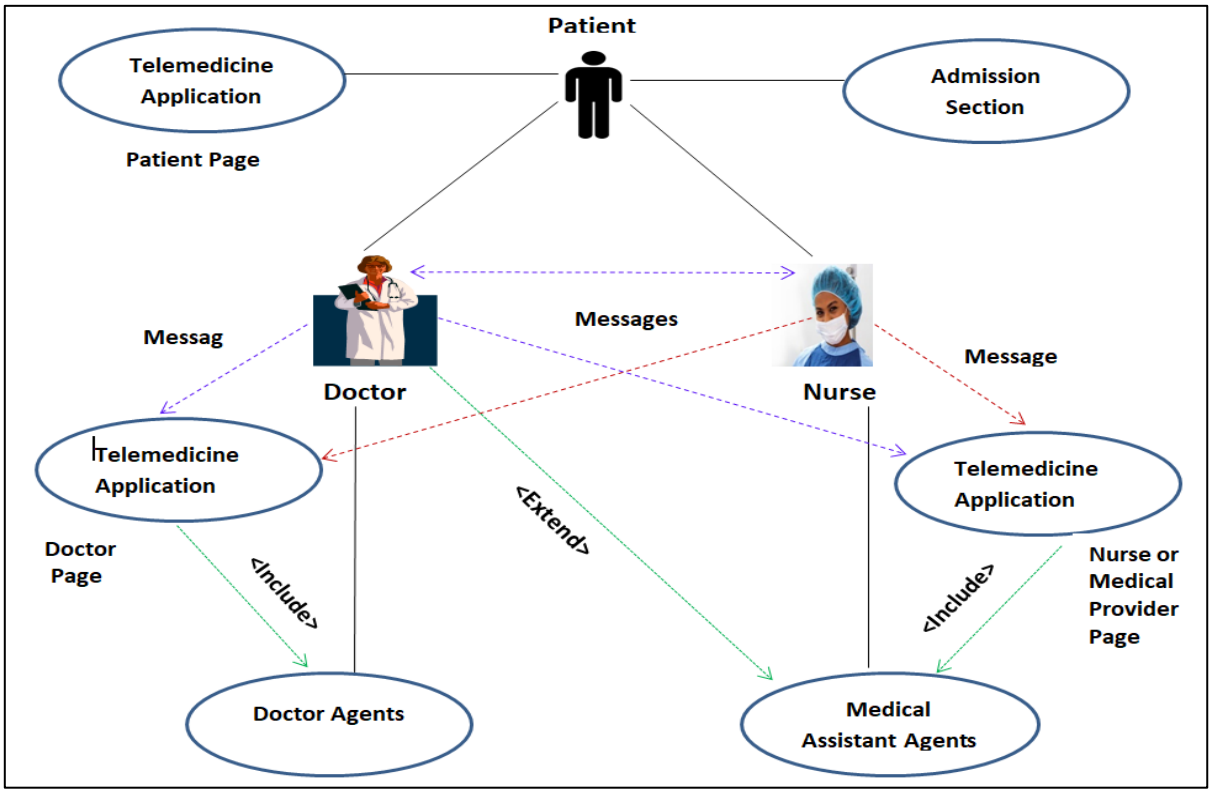

Fig. 2. Use Case Diagram of the Proposed Multi-agent Telemedicine System

2. Conclusion

In order to overcome the weakness in the infrastructure of health care systems in the developing countries ، the shortage of medical personnel urgently and at lower costs ،saving effort on patients' traveling and to avoid infection from social closeness in times of pandemics, we have proposed in this research a prototype design of a Telemedicine system that provides advanced capabilities, including multi-agents structure and using various capabilities of artificial intelligence.

Agent technology and AI has underwent tremendous expansion in recent years in various disciplines, particularly in the domain of E-health. The multi-agent system approach and the artificial intelligence possibilities provide a powerful platform for modeling and solving real world problems such as healthcare.

With the continuous development of multi-agent system and AI technology, gradually Telemedicine implementation and its uses have become more popular and advanced medical model which has always attracted much attention and can be used in the development of the health care in several countries. Multi-agent systems in healthcare data are the best combination possible to utilize the advantages that are available in the capabilities of AI.

The suggested AI-enabled Telehealth offers contributions in the form of quality improvement and enhancement of health care system in all countries and improve procedures to be specialized to solve specific problems in the implementation of Telemedicine. The flexibility of both AI and Telemedicine will give the endless possibilities for development of E-health systems.

The anticipated outcomes if this system completed implemented according to the proposed prototype are: for individuals, Telehealth care can facilitate better health self-management. Timely and appropriate medical services can be accessed when needed, and the content of medical services will be more personalized. For medical institutions, Telehealth care can reduce costs, relieve personnel pressure, achieve unified management of materials and information, and improve the patient's medical experience. . However, there are still some problems in the development process. The solution to these problems depends not only on technological progress and patients' information security, but also on the joint efforts of patients, doctors, health institutions, and technology companies.

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