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## Metaheuristic Algorithms for Healthcare: Open Issues and Challenges<sup>☆</sup>

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### ABSTRACT

Inspired by the observation that a healthcare system usually involves various intelligent technologies from different disciplines, especially metaheuristics and data mining, this paper provides a brief survey of metaheuristics for healthcare system and a roadmap for researchers working on metaheuristics and healthcare to develop a more efficient and effective healthcare system. This paper begins with a discussion of changes for healthcare, followed by a brief review of the features of “up-to-date technologies for healthcare.” Then, a learnable big data analytics framework for healthcare system is presented which provides a high performance solution to the forthcoming challenges of big data. Finally, changes, potentials, open issues, and future trends of metaheuristics for healthcare are addressed.

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## 1. Introduction

As observed by the world health organization, people aged over 60 years of the world population will be increasing from 841 million today to 2 billion in 2050 [12]. With the advance of medical treatment available for all, it is expected that the longevity will become a norm of humans. How to provide a convenient environment to elderly or ill people and children has therefore attracted the attention of researchers from different disciplines [9,25,31,45–47,53,76]. That is why healthcare system has become an active research area today. With the advance of information technology and smart home applications [25,28,51,71], the focus of healthcare system has undergone several changes over time, such as personal digital assistant (PDA), data mining, internet of things, and cloud computing. From the viewpoint of data analytics, PDA is used in a smart home healthcare system [51] (e.g., as the gateway of the smart home healthcare system) for integrating different types of data captured by sensors and for analyzing the data thus obtained to find out information that is useful in supporting a decision-making system at the initial stage. Nowadays, personal systems and smart handheld devices are also used for integrating and analyzing data of healthcare system. According to the observation of [53], in the early stage, i.e., 1990s, the focus of healthcare is on the collection and monitoring of physiology information and on the support of decision-making. Starting from 2000, due to innovative technologies and products, video for monitoring and analyzing human behavior, teleconsultation, nursing, wearable biosensors, smart home, and even sleep analysis have become the promising research topics. For example, we can buy an Apple Watch to monitor our physical condition, to adjust our exercise and sleep habits.

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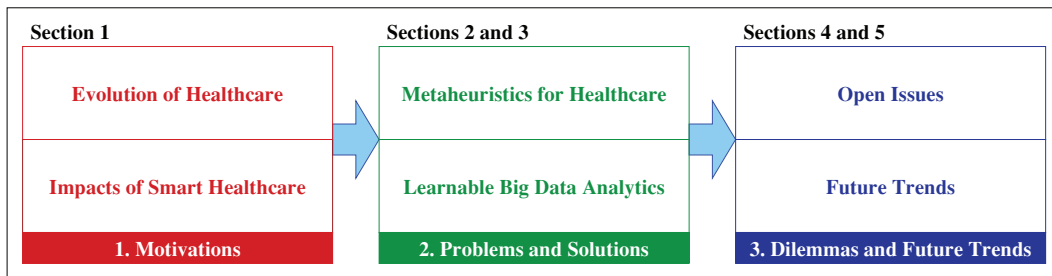


Fig. 1. Roadmap of this paper.

It is estimated that healthcare system will cost American people about 1.3 trillion dollars in 2015 and will be increased to 4.5 and 5 trillion dollars in 2019 and 2022, respectively [1,6] and that the healthcare system in China costs about 350 billion dollars today and will be reaching 1 trillion dollars in 2020 [67]. The similar situations can also be found in other developed countries (e.g., United Kingdom, France, and Japan) in which the public health spends more than 5% of the economy [4]. This indicates that the gradually increasing cost of healthcare system will strongly impact the budget of a government and the daily life of her people.

Data mining and metaheuristics can provide a useful solution in the construction of a smart and intelligent healthcare system, especially for data analytics. The main reason is that more detailed data can be collected by new hardware (e.g., innovative sensors), but assessing the situation from the collected data requires a powerful forecasting and recognition tool. Since metaheuristics can be used for solving data mining problems (i.e., can be a data mining algorithm by themselves) or enhancing the performance of data mining algorithms for healthcare, they can typically be used to help us analyze unknown and known data. As a result, they will be an indispensable part of modern researches on healthcare system. The main contributions of this paper can be summarized as follows:

1. This paper first gives a systematic discussion of studies on metaheuristics for healthcare system as well as provides some open issues and future research trends for the researchers interested in this area.
2. A learnable data analytics framework is presented to provide a possible solution to the integration of various types of input data from different appliances, sensors, and devices as well as to provide an incremental solution to the big data problem a healthcare system will encounter.

The roadmap (as shown in Figure 1) and the remainder of this paper are organized as follows:

1. A brief discussion on the research issues and relevant technologies of metaheuristics for healthcare system are given in Section 2, to lead the audience to the problems and solutions of this research domain, e.g., the classification algorithms for recognizing whether the posture of elderly people indicates a fall or not.
2. A unified framework, called learnable big data analytics framework (LBDAF), is presented in Section 3 to deal with the big data problem of a healthcare system. Also presented in this section is a parallel incremental data mining algorithm (PIDMA) (as a part of LBDAF) for the big data mining problem.
3. The relevant technologies for using metaheuristics for healthcare system are discussed in Section 4. The discussions of smart devices, wireless sensor networks, and internet of things are focused on how to extract the data from people and environment; the discussions of big data mining are focused on the data analytics system; and the discussions of cloud computing system are focused on the forthcoming system environment.
4. The possible research trends of metaheuristics for healthcare system are discussed in Section 5, to depict the important research trends of this research domain.

## 2. The Metaheuristic Algorithm for Healthcare

The healthcare system will undoubtedly strongly impact the economy of a country and the daily life of her people; however, an interesting finding described in [61] is that there lacks a consensus terminology and taxonomy of devices at the national and international level now. Fortunately, some studies [9,53] attempted to provide systematic survey to help us better understand what a healthcare system is and how to realize this kind of system. In [53], Koch provides an overview to explain the focus of contemporary healthcare systems on different durations. An interesting finding by Koch is that the top 3 terms searched on the Medline database during 1990–2003 are home monitoring, home telemedicine, and information systems and home care. In [9], Alemdar and Ersoy pointed out that the body area networks, personal area networks, gateway to the wide area networks, wide area networks, and end-user healthcare monitoring applications are the main considerations of a pervasive healthcare monitoring system. These discussions explain that how to gather data from sensors, how to integrate and analyze the gathered data, and how to display the information of a healthcare system will become essential research topics for healthcare. A distinguishing feature of healthcare is that most of the studies would like

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