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Panoramic and Personalised Intelligent Healthcare Mode

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Abstract: Although the development of national conditions and the increase in health risk factors undoubtedly pose a huge challenge to China's medical health and labour security system, these simultaneously promote the elevation and transformation of national healthcare consciousness. Given that the current disease diagnosis and treatment models hardly satisfy the growing demand for medical and health care in China, based on the theory of healthcare and basic laws of human physiological activities, and combined with the characteristics of the information society, this paper presents a panoramic and personalised intelligent healthcare mode that is aimed at improving and promoting individual health. The basic definition and conceptual model are provided, and its basic characteristics and specific connotations are elaborated in detail. Subsequently, an intelligent coordination model of daily time allocation and a dynamic optimisation model for healthcare programmes are proposed. The implementation of this mode is explicitly illustrated with a practical application case. It is expected that this study will provide new ideas for further healthcare research and development.
Key words: panorama, personalisation, intelligent healthcare mode, implementation
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0 Introduction

With the acceleration of the aging process, aggravation of the double burden of chronic and acute infectious diseases, exacerbation of environmental pollution, and growing pace of life rhythm, the demand for medical services and healthcare is rapidly increasing. Large-scale general hospitals are frequently overcrowded, particularly during morbidity peak periods, which makes it difficult to seek medical services in China. Specifically, with the continuous increase in medical expenses not being curbed effectively, the disease-centred diagnosis and treatment mode that dominated the 20th century cannot address the new challenges of the 21st century[1].

According to the most recent statistics, by the end of 2019, among the population of 254 million aged 60 and above in China, over 180 million suffer from chronic diseases, up to 75% of whom have one or more chronic diseases①. Moreover, the Chinese average life expectancy has reached 77 years, which means that a large proportion of the elderly will live with chronic diseases for quite a long time, which is characterised by a relatively early onset of disease②. Moreover, China is currently faced with serious pressure owing to cardiovascular diseases. Research shows that 290 million Chinese people suffer from cardiovascular disease, the deaths of which rank above those of other diseases in urban and rural residents[2]. Since December 2019, the novel coronavirus disease (COVID-19)-related pneumonia[3], which was first reported in Wuhan, Hubei Province, has spread rapidly across the country and globally[4-5]. The Chinese government has exerted all-round efforts in epidemic prevention and control by adopting a series of unconventional measures, such as city lockdowns, hotel closures, and home quarantine, but these measures also bear a huge social and economic burden.

The disease-centred diagnosis and treatment mode cannot satisfy the growing demand for medical services and healthcare in China. Under the guidance of the Chinese government, the medical and health system of the entire country is undergoing a transformation from a disease-centred treatment mode to a prevention-centred healthcare mode[6-8]. In 2016, the Healthy China 2030 Plan was released, which placed extraordinary emphasis on the development of healthcare services for preventive disease treatment based on traditional Chinese medicine, and established the

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①http://www.stats.gov.cn/tjsj/zxfb/202001/t20200117_1723383.html
②http://www.gov.cn/xinwen/2019-07/31/content_5417631.htm

strategic policy of implementing a medical and health system that focuses on individual health[7]. In 2017, the Medium- and Long-Term Plan for the Prevention and Treatment of Chronic Diseases in China (2017—2025) was released, which noted that health promotion and healthcare should be the main measures taken to realise the transformation from a treatment-centred to a health-centred mode. In 2019, the Healthy China Action Plan (2019—2030) was released, which clearly illuminated the specific roads towards a health-centred or prevention-centred healthcare mode[9].

At present, we are living in an unprecedented era of big data, which is reshaping the processes and methods of management decision-making at the national, industrial, organisational, and personal levels[10]. Big data contributes new characteristics to management activities, including high frequency, real time, deep customisation, full-cycle immersive interaction, and multi-agent decision-making[11], which provide fresh ideas and diverse methods for analysing and solving problems in the healthcare field. For example, tracking and Internet data that are generated by mobile phones can be used to analyse the social networks, trajectories, and daily behaviours of users[12-13], so that the person's daily routine can be extracted individually, and subsequently, possible health risk factors can be identified indirectly. By combining voice, text, and other interactive data, anxiety, depression, loneliness, and other psychological states of the elderly can be intelligently recognised[14], so as to offer further real-time health abnormality warnings.

Full advantage can be taken of the available multi-source big data collected by the Internet of Things to assist in individual healthcare, carry out comprehensive risk assessments, provide early abnormality warnings, implement healthcare programmes, evaluate and offer feedback on the implementation effects, and realise preventive disease treatment and proactive healthcare responses in advance. In this manner, a complete closed-loop healthcare mode can be formed, which not only is beneficial for helping individuals to develop a healthy lifestyle and therefore to improve their health conditions, but also contributes to the strategic objective of Healthy China.

In view of the existing problems in the current healthcare mode, and combined with the changing characteristics of the information society, a panoramic and personalised intelligent healthcare mode based on the healthcare theory and scientific bases of human physiological activity is proposed. The main innovations of this study include the following:

(1) The basic definition and conceptual model of the panoramic and personalised intelligent healthcare mode are presented.

(2) The basic characteristics and specific connotations of this mode are expounded.

(3) The implementation method for realising this mode is provided.

The remainder of this paper is organised as follows. Section 1 presents a relevant literature review of work both in China and abroad. Section 2 provides the motivation and scientific bases of the study. Section 3 presents the panoramic and personalised intelligent healthcare mode in detail. Section 4 introduces the realisation process. Section 5 summarises the work and discusses possible future research directions.

1 Research Status Overview in China and Abroad

In the past decade, with the growing demand for an improved life and the rapid development of the information society, healthcare has gained increasing attention and a mode that focuses on individual health has been emerging. This section provides a review of the research status in China and globally according to three main aspects: healthcare mode, panoramic healthcare, and personalised healthcare.

1.1 Research Review in China

Four types of healthcare modes exist in China[15-16] (Table 1). Owing to the expansive territory areas, diverse social and economic conditions, and varying availability of access to medical and health services in China, people from various regions with distinct health conditions pursue different healthcare needs. However, overall, the current healthcare modes relate to medical institutions, are centred on disease treatment rather than early prevention, and focus on a small high-income group. Most of these modes have been established with the basic concept of offering health services to aristocrats, increasing the medical demand, and promoting

Table 1 Healthcare modes in China[15-16]

Mode name	Service provider	Profit	Main clients	Financing source
Insurance mode	Insurance company	Profit	Ordinary people	Personal payment
Hospital mode	Public hospitals at all levels	Non-profit	Ordinary people	Country compensation
Community mode	Community health service centre	Non-profit	Vulnerable groups, including women, children, and the elderly	Country compensation
Enterprise mode	Private healthcare company	Profit	High-end customers	Personal payment

medical consumption, but contribute few benefits for ordinary people who require even more health services[15].

Panoramic healthcare is a relatively new concept that has rarely been introduced in academic journals. Although panorama has been mentioned in social governance[17], teaching and training[18], management decision-making[10,19], and other fields, scholars have not provided a clear academic definition thereof. To summarise different descriptions of panorama in various fields, a preliminary understanding of the concept can also be obtained: panorama represents viewing and thinking over matters from diverse perspectives, multiple dimensions, and various factors. At present, the available multi-source big data and artificial intelligence technology offer new ideas and methods for individual-oriented healthcare, which enable "exogenous" panoramic information such as real time, physical space, and accessible resources to be acquired, and thus, can provide individuals with time-based and location-based health services.

In contrast, personalised healthcare was first introduced by Cai et al.[20] in 2009, but no universally accepted definition for it exists yet. Zhang et al.[21-22] stated that personalised healthcare programmes should consider multiple individual-related factors, including genetic characteristics, diet, lifestyle, economic status, and working conditions. In recent years, numerous scholars have conducted control experiments to study the application value, management effects, and intervention programmes of personalised healthcare in hypertension[23], stroke[24], and diabetes[25], with a series of personalised management measures such as diet, exercise, and psychological guidance implemented. The results demonstrated that personalised healthcare can effectively reduce disease risk, promote the cultivation of healthy behaviours, control and improve health conditions, and elevate the quality of life of patients.

1.2 Research Review Abroad

Since the middle of the previous century, the United States (US), Germany, Finland, and Japan have gradually formed different healthcare modes with distinctive characteristics, and in line with their national conditions and historical situations, as shown in Table 2[16,30-31]. Among these countries, the US put healthcare into practice the earliest, in the 1960s[26-27], when the American insurance industry made healthcare available for the first time. In 1990, the US government formulated a national healthcare plan named after Healthy People, and thereafter gradually formed a healthcare mode targeted towards all citizens[28-29].

In medicine, the panoramic concept was first introduced in medical radiology[32-33], in which panoramic X-ray imaging technology was used to identify oral health problems such as dental infection in the elderly in northern Europe. Panoramic medical imaging has been used extensively and it is easy to understand the implications of panoramic images from the perspective of medical radiology, which presents all-round, multi-dimensional silhouette, and broad viewing angles. However, the concept of panoramic healthcare is rarely mentioned in published academic journals, or it is considered that almost no scholars have mentioned it.

Foreign researchers have explored personalised healthcare from as early as the 1990s, which started with simple personalised diet intervention for diabetic patients. Telephone, video, computer networks, and other auxiliary tools have been used to help patients to set health goals, collect feedback information, and reply to consultation problems[34-35]. The purpose of personalised healthcare is to evaluate and reduce individual disease risk[36] and to achieve the maximum health benefits with a minimal cost[37]. Recently, with the development of communication technology and

Table 2 Healthcare modes abroad[16,30-31]

Country	Main contents	Main features	Financing source	Achievements/Challenges
US	Healthcare companies being commissioned by insurance companies to manage the health of applicants	Wide coverage, macro policy support	Personal payment + insurance company compensation	Improved national health, but upsurging medical costs
Germany	High-quality social medical insurance with personal preventive medical service	Limitless medical security, preventive medical service	Personal payment + country compensation	Great medical security system, but still high investment and low return
Finland	Changing living habits, impeding disease risk factors from the source	Close collaboration with community, regular healthcare project evaluation	Personal payment + country compensation	Improved utilisation efficiency of medical resources
Japan	National healthcare through health manuals, health diagnosis, national health insurance plan, etc.	Sound legal system guarantee, general health consciousness	Personal payment + country compensation	Life expectancy reaching 83, ranking first in the world

hardware equipment, an increasing number of scholars have paid more attention to the role and effect of big data[38], wearable devices[39], healthcare information systems[40], and other information technologies in the risk assessment and daily lifestyle management of patients with chronic diseases. These studies suggest that information technology can provide a convenient and feasible means of promoting personalised healthcare.

2 Motivation and Scientific Bases

2.1 Motivation

From the perspective of proactive healthcare that is centred on individual health, this study proposes the panoramic and personalised intelligent healthcare mode. In general, the motivation includes three main aspects:

(1) The deficiency of current healthcare modes makes proactive healthcare beyond hospitals, communities, and health companies particularly important. As mentioned previously, China has gradually formed four existing healthcare modes during the development of healthcare; however, these provide a disease-centred, passive management process, which makes it challenging to discard the conventional idea of diagnosis and treatment characterised by seeking medical treatment only when ill; thus, people opt for the hospital only when they feel sick or unwell. Furthermore, although many individuals and even enterprises arrange regular physical examinations every year, many people do not pay sufficient attention to the examination results, which is reflected in the manner that one often puts the results on the shelf after listening to the doctor's suggestions and regrets ignoring it before a certain disease occurs.

(2) Information technology can provide continuous and integrated healthcare services for individuals[41], thereby transforming the modern healthcare service mode. Using a big data-driven healthcare system, based on the real-time data collected by wearable devices, physical examination data, medical treatment data, and proactive user feedback data, the current health status of an individual can be comprehensively evaluated, and the risk of a certain disease can be predicted. If a certain health index exceeds the normal threshold, a timely alert message can be sent to the user to offer a reference for further measures. When a user needs to go to a hospital for medical treatment, the system can intelligently recommend the nearest hospital and appropriate doctors. In the process of rehabilitation after treatment, different healthcare suggestions can be received from the system, including thorough healthcare programmes or personal rehabilitation plans. Overall, the proactive individual health-centred healthcare mode combined with information technology is becoming increasingly useful and functional in helping people to manage their health in their daily lives, and this is likely to become a future trend in the healthcare field.

(3) The individual health-centred proactive healthcare mode can save on medical expenses to a certain extent, so as to aid public medical resources in achieving efficient and reasonable allocation. Research has found that[1,42] the most unhealthy 1% of the population and the 19% constituting chronic cases share 70% of medical expenses, and 80% of the medical expenditure is for the treatment of diseases that could have been prevented. Moreover, for diseases that require costly treatment expenses, such as heart disease, diabetes, and stroke, if preventive measures are taken in daily life in advance, even a small improvement in lifestyle can directly save on considerable medical costs[1]. The healthcare practice in the US has also revealed that any enterprise or individual can benefit from healthcare. If 1 RMB is invested in healthcare, the medical expenses will be reduced by 3 to 6 RMB, the practical benefits of which are even greater considering the return of investment resulting from the improvement in the production efficiency[28].

2.2 Scientific Bases

The proposed mode is based on the nature and scientific bases of healthcare and is also affected by the daily physiological activities of the human body.

2.2.1 *Essence of Healthcare*

The essence of healthcare is identifying and intervening in health risk factors based on scientific evidence, so as to maintain and promote health, reduce diseases, prolong the life span, and improve the quality of life, as illustrated in Fig. 1 and proposed by Chinese scholar Huang[1] in the embryonic stage of healthcare in China. Therefore, the concept of health risk factor identification and daily lifestyle intervention was already presented several years ago.

2.2.2 *Scientific Bases of Healthcare*

The book *Health Manager*[43] summarises two scientific bases of healthcare (as illustrated in Fig. 2). First, a dynamic balance exists between health and disease, as well as the occurrence, development process, and intervention strategies of diseases. A rather complex self-regulation and repair system exists in the human body, whereby targeted intervention prior to disease diagnosis may successfully block, delay, or even reverse the occurrence and development of the disease. Second, most risk factors of chronic diseases are changeable. Although chronic diseases caused by a lack of exercise, smoking, drinking, and other risk factors are difficult to cure, the risk factors themselves can be prevented and controlled. These two points indicate that the core concept underlying healthcare is taking pertinent prevention and intervention measures in people's daily lives.

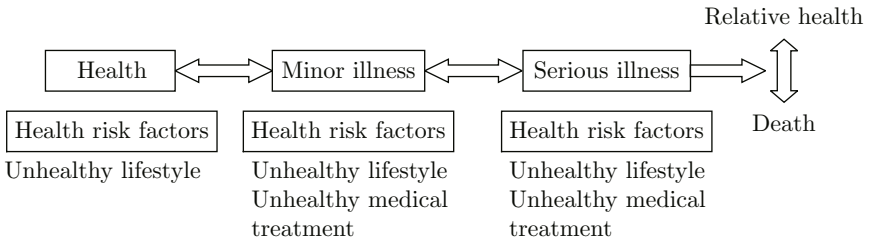

Fig. 1 Essence of healthcare[1]

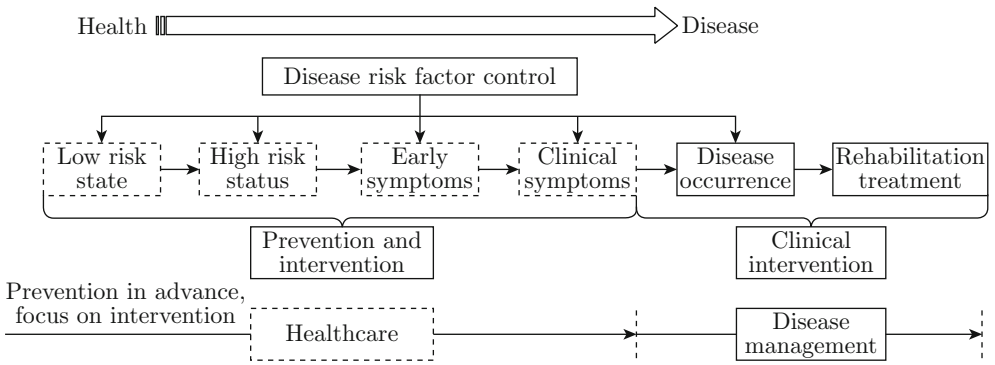

Fig. 2 Scientific bases of healthcare[43]

2.2.3 *Daily Physiological Activities of Human Body Regulated by Biological Clock*

The research conclusions of the 2017 Nobel Prize in Physiology or Medicine demonstrated that physiological function, emotional state, memory ability, and work efficiency of the human body exhibit distinct circadian rhythm fluctuations (Fig. 3). For example, a person generally has the soberest brain in the morning and the most active thinking in the afternoon, and the curative effect varies with medication time. However, unhealthy lifestyles such as staying up late and sedentary behaviour will cause circadian rhythm disorder, leading to diabetes, hyperlipidaemia, hypertension, and a series of diseases. Therefore, healthcare encouraging individuals to develop a healthy lifestyle is in line with the law of human physiological activities.

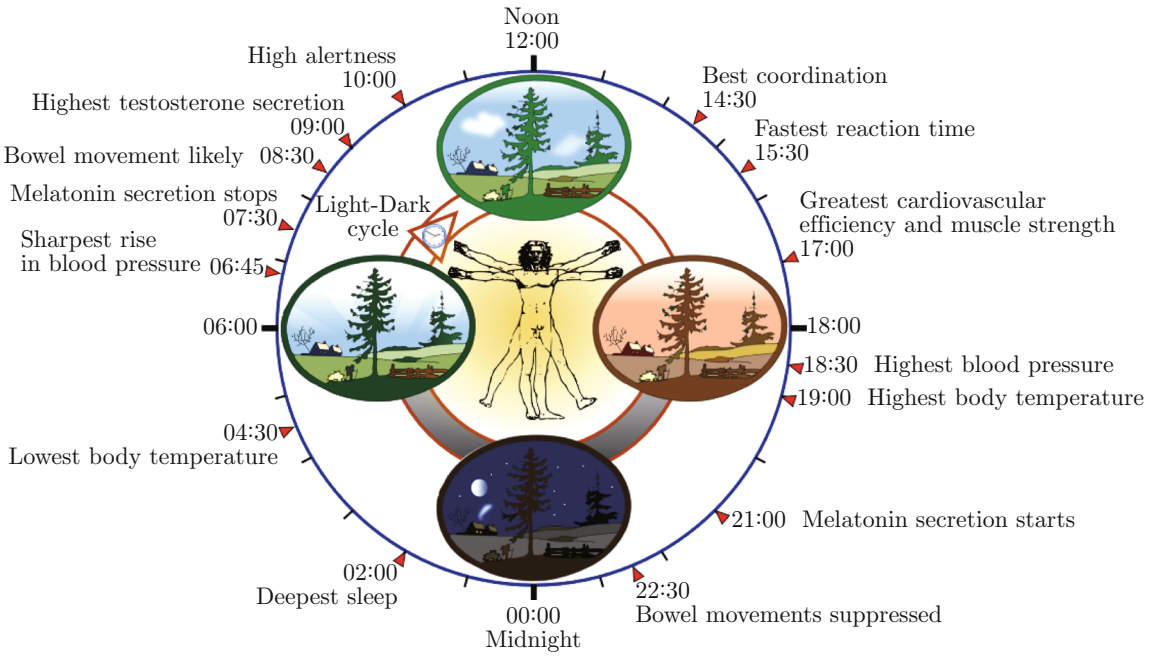

Fig. 3 Several features of human circadian (24 h) biological clock③

③https://en.wikipedia.org/wiki/Circadian_rhythm

3 Panoramic and Personalised Intelligent Healthcare Mode

3.1 Basic Definition

The panoramic and personalised intelligent healthcare mode is a comprehensive process that provides individuals with dynamic and proactive health services to realise the maximum health benefits with limited resources. It focuses on individual health, makes full use of information technology, combines panoramic elements such as time, space, and available resources with personalised characteristics that vary within each individual, and carries out individual physiological and psychological health comprehensive risk assessments, early abnormality warnings, healthcare programme implementation and evaluation, and feedback of the implementation effect.

The mode is suitable for ordinary individuals, focusing on the health of everyone. Its core idea is to take dynamic prevention and intervention measures in daily life, control disease risk factors, and promote the cultivation of healthy lifestyles. The basic premise is to offer healthcare programmes for individuals with the aid of information technology to improve individual health. The constraints consider time, space, available resources, and other panoramic elements, as well as age, gender, medical history, income, and other personalised characteristics. The ultimate goal is to help individuals to use limited resources to achieve their maximum health benefits effectively.

Focusing on individual health does not mean dispatching someone to intervene in individual health, but rather, applying information technology to provide individuals with appropriate healthcare programmes dynamically, so as to promote the management process of the daily lifestyle through proactive implementation. In this process, people can present personalised health demands according to their own health status. Furthermore, the healthcare programmes, which are proactively implemented by the individuals to achieve their own maximum health benefits, can satisfy the health demands of different people, just as people search on Amazon, eBay, and other e-commerce platforms to buy desirable commodities to achieve demand satisfaction.

It should be noted that this mode differs from the general process of medical treatment. The diagnosis and treatment of diseases belong to medically technical work (for example, prescribing, operating, and others), which must be conducted by a doctor who is licensed by the country[1]. However, the panoramic and personalised intelligent healthcare mode promotes the prevention and intervention process in daily life by means of information technology-based methods. It is not a medically technical method.

3.2 Conceptual Model

The panoramic and personalised intelligent healthcare mode (as illustrated in Fig. 4) starts with the health risk assessment, which identifies risk factors that are likely to affect the individual's physiological, behavioural, and psychological status. A comprehensive assessment report that reflects both the physical and mental health is obtained. Thereafter, combined with the environmental data collected by wearable devices, home sensors, video installations, and other Internet of Things devices, possible physical and mental abnormalities are monitored, analysed, and predicted in real time to remind the person to take corresponding management measures when anomalous situations occur

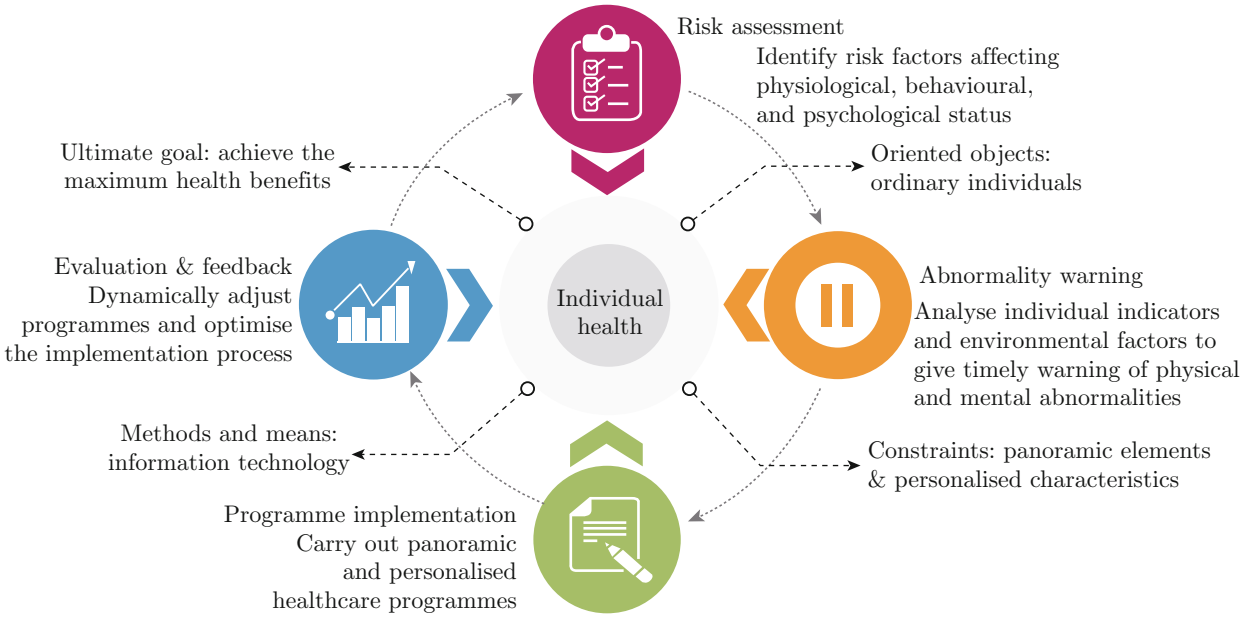

Fig. 4 Conceptual model of panoramic and personalised intelligent healthcare mode

and to accumulate data for further programme implementation simultaneously. Subsequently, using the dynamic feedback information analysed from the monitoring data, the background algorithm intelligently generates panoramic and personalised healthcare programmes to promote a healthy lifestyle based on times, places, and distinct individual characteristics. Finally, according to the evaluation and feedback information provided by the users, the healthcare programmes are adjusted and optimised dynamically to satisfy the health demand and iteratively narrow the gap between the algorithm-generated and user-intended programmes in reality, following which the next round of health risk assessment is conducted.

The four steps, namely health risk assessment, early abnormality warning, programme implementation and evaluation, and feedback, are mutually linked and progress step by step, forming a completely closed loop of healthcare. The previous loop accumulates data and collects information for the next one, which continuously iterates and improves itself based on previous experience and feedback, so that individuals can truly feel the health improvement in each risk assessment, thereby gradually forming positive feedback on health promotion, constantly developing a healthy lifestyle, and achieving the maximum health benefits.

3.3 Panoramic Connotations

Panorama consists of the exogenous preconditions considered during the healthcare loop, such as time, physical space, and available resources. The external environment in which an individual exists changes dynamically with time; therefore, various healthcare programmes should be available at different times and locations, even for the same individual.

Panoramic healthcare is based on the concept of the interconnection of all things, by thoroughly identifying the time state (such as morning, noon, night, four seasons of the year, and 24 solar terms), physical space state (such as longitude, latitude, altitude, residence, office, transportation, temperature, and humidity), available resource state (such as diet, exercise, entertainment, and sleep resources), and other panoramic elements (as illustrated in Fig. 5), so as to provide individuals with appropriate time-based and location-based healthcare programmes to achieve maximum health benefits.

The panorama accords with our basic understanding of daily life. From waking up to falling asleep, people inevitably interact with various ambient conditions, such as time, space, and available resources. Thus, healthcare programmes are also restricted by these panoramic constraints. For example, it is not suitable to recommend playing basketball at the stadium late at night or to recommend restaurants that are far away in Beijing for individuals living in Shanghai. Moreover, the human body is affected by the time and surroundings. In general, people feel tired at night and hot when the temperature increases. To achieve maximum health benefits, it is essential to consider these time and environmental factors that may influence health.

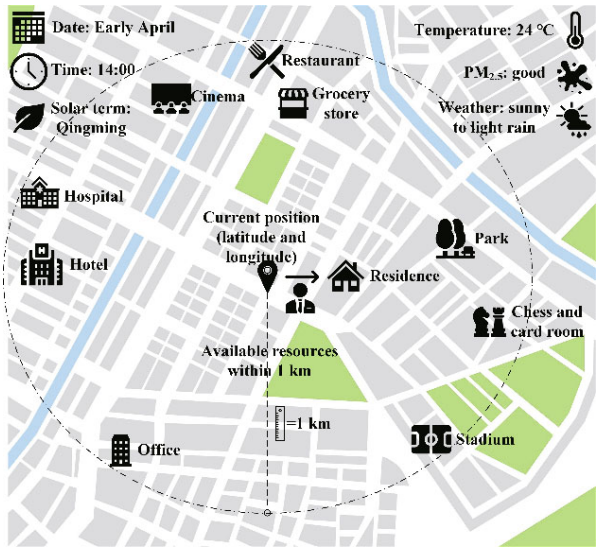

Fig. 5 Example of panoramic elements

Panoramic healthcare is featuring strongly in the information age. In the past, owing to underdeveloped information technology, people generally took preventive or intervening measures advised by doctors, based on their own life experience or learned and accumulated from books. However, owing to information asymmetry, it is difficult for doctors to understand patients' lifestyles completely, such as work and rest patterns, so the suggestions provided by a doctor may conflict with a patient's practical working hours, geographical location, income, and other individual-related factors, eventually leading to non-implementation. Moreover, it is impossible for the vast majority of ordinary people to seek doctors for advice every day. The accumulation of life experience or book knowledge may also be gradually forgotten because it is not recorded effectively. However, with the rapid developments in information technology, wearable devices can dynamically collect and record daily behavioural data in real time, which makes it possible to analyse individual routines for the further implementation of healthcare programmes. Furthermore, powerful information systems are online at all times, which facilitates information access at any time, thereby enhancing the supervision of the healthcare process.

3.4 Personalised Connotations

Personalisation refers to the endogenous preconditions considered during the healthcare loop, such as the body, mentality, disease, and economic space. Individuals differ in terms of their physical and mental status, medical and disease history, and income

and expenditure capability; therefore, varying healthcare programmes should be offered for distinct individuals, even at the same time and in the same place.

Personalised healthcare is based on the theory and methods of traditional Chinese and Western medicine, according to the physical and mental state (such as gender, age, height, weight, constitution type, special stage, and stress level), disease state (such as acute diseases, chronic diseases, genetic diseases, and allergens), economic space state (such as income level, expenditure preferences, occupational features, and interests and hobbies), and other personalised characteristics (as indicated in Fig. 6), so as to provide users with individual-based healthcare programmes to achieve maximum health benefits.

Physical and mental state

Sex:	Femal	Consitution type:	Damp heat
Age:	63	Special stage:	Senility
Height:	154 cm	Stress levels:	Low stress
Weight:	91 kg	...	...

Disease state

Acute diseases:	Gallstones (recovered 2 years ago)
Chronic diseases:	Hyperglycemia, hypertension, obesity, long-term insomnia
Genetic diseases:	None
Allergen:	Pollen
...	...

Economic space state

Income level:	4 000 RMB per month
Expenditure preferences:	Diet 50%, medicine 35%, entertainment 15%
Occupational features:	Retired employees
Interests and hobbies:	Square dancing, card playing
...	...

Fig. 6 Example of personalised characteristics

Personalised healthcare is certainly trending in this big data era and is also a typical feature distinguished from traditional popularised or general healthcare. In the past, personalised data could not be collected and recorded effectively owing to limited computing resources, underdeveloped network communication, and a lack of health consciousness. People generally gained fragmented and common health knowledge from advice of doctors, communication with others, newspapers, and magazines. For example, it is well known that physical exercise is beneficial to health, and patients with hyperlipidaemia should have a light diet. However, these health-related common sense facts either cannot match individual health characteristics to guide the healthcare process or cannot change dynamically to satisfy personalised healthcare demand in time.

However, at present, supported by hardware and software equipment with a high quality and competitive price, ubiquitous computer networks, and robust and efficient models and algorithms, it is much easier to collect and record personalised characteristic data related to individual health promptly, dynamically, and conveniently and to conduct real-time analysis and computation on this basis. Thus, under the constraints of the changing physical and mental state, disease state, and economic space state, a healthcare programme is proposed that is highly adaptable to individual health characteristics and iteratively optimises itself to promote the continuous improvement of health benefits. Naturally, people prefer personalised healthcare that is beneficial to their own health rather than general healthcare that is full of health common sense.

3.5 Intelligent Connotations

Intelligence means making full use of modern information technology (including but not limited to artificial intelligence, big data, network communications, and databases) in which the core is artificial intelligence to assist in healthcare. As discussed previously, the ever-changing panoramic elements, diverse personalised characteristics, and various complex factors affect individual health, so it is laborious or impossible to rely solely on human intelligence to accomplish the objective of panoramic and personalised healthcare. Therefore, it is sensible to draw power from machine intelligence in healthcare services.

By means of information technology, intelligent healthcare applies healthcare knowledge from traditional Chinese and Western medicine to the individual healthcare process to achieve maximum health benefits. If traditional healthcare is considered as a passive disease control process in which users take targeted intervention measures offline, intelligent healthcare can be deemed as a proactive disease prevention process whereby users pursue personalised health services online[44], just as each user has a personal doctor (as illustrated in Fig. 7).

In this proactive process, the healthcare knowledge (base) forms an essential part of intelligent

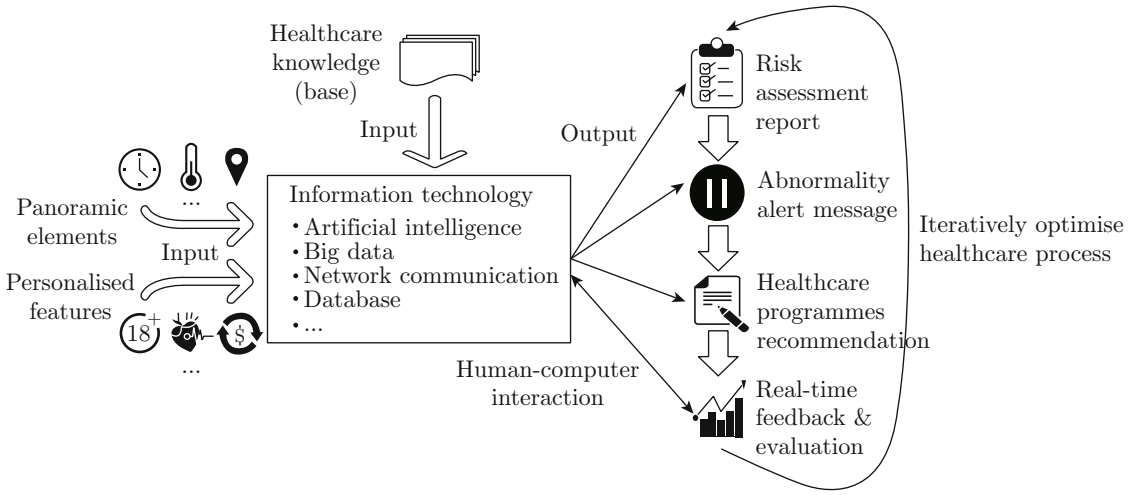

Fig. 7 Proactive intelligent healthcare

healthcare. The ultimate value of big data in the field of management is achieving more scientific and efficient decision-making, which requires the refinement of semi-structured and unstructured data to form a structured domain knowledge system so as to realise the value discovery process from data to knowledge to decision-making[11]. The knowledge (base) notes the application constraints, interrelations, and judgement criteria of the data. For example, the knowledge indicates what to eat or not, which constrains the edible conditions. Moreover, based on the interrelations, how much to eat appropriately and even the everyday diet composition can be deduced. Furthermore, knowledge defines the judgement standard of certain diseases, thereby directing people to collect relevant data for better healthcare. It can be stated that knowledge, as the theoretical basis, provides rules, conditions, and methods for data use, which plays a guiding role, but its ultimate purpose is to serve data. Data, as a practical result, not only can produce new knowledge, but can also verify or revise existing knowledge to a certain extent. Knowledge and data interact with one another to promote intelligent healthcare jointly. The relationship among these is depicted in Fig. 8.

Intelligent healthcare is the future of healthcare in the current information society, and it is also an effective means of applying artificial intelligence to assist human intelligence in realising panoramic and personalised healthcare. First, the information technology represented by artificial intelligence provides a solution for the timely processing and analysis of panoramic and personalised big data. It is predictable that daily healthcare characterised by lifestyle management and supported by artificial intelligence, along with big data, will become a new modality in the future medical field. This approach has been used extensively in five medical and health fields: influenza prediction, blood glucose management, health factor monitoring, medical and health services, emotional analysis, and big data[45]. Furthermore, the rapid development of artificial intelligence provides a strong guarantee for the realisation of panoramic and personalised healthcare. In the smart loop from risk assessment to evaluation and feedback, artificial intelligence can offer more comprehensive, dynamic, and timely information compared to human doctors, which can assist doctors in managing individual health to a certain degree when considering panoramic elements and personalised characteristics.

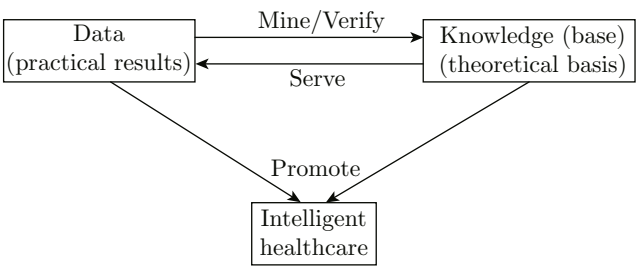

Fig. 8 Relationship among data, knowledge, and intelligent healthcare

4 Implementation of Panoramic and Personalised Intelligent Healthcare Mode

Intelligent healthcare systems as well as intelligent coordination and dynamic optimisation models play a significant role in implementing this mode. This section presents the implementation process and a case study of this mode.

4.1 Intelligent Healthcare System

An intelligent healthcare system (as depicted in Fig. 9) is essentially a decision support system. Decision support systems mainly apply computer

technology to establish systems and integrate system resources such as the model base, rule base, and knowledge base to provide useful information for decision-makers to improve the effectiveness of the management decision-making process[46-47]. The intelligent healthcare system uses data interaction with smart terminals, and the collection of surroundings data and personalised characteristic data in combination with the background knowledge base, rules base, algorithm and model base, and other content support. It provides users (decision makers) with useful health information, including risk assessment reports, abnormality warning messages, and healthcare programmes, which are proactively implemented by users to promote health benefits, and therefore, improve the effectiveness of healthcare processes. In this case, the users are the decision-making subjects. The management decision-making process involves users making subjective selections according to their own health demands and putting into practice the healthcare programmes recommended by the system. The ultimate objective of intelligent healthcare systems is to integrate relevant information to recommend appropriate time-based, location-based, and individual-based healthcare programmes for each user, so as to provide decision support for the implementation of programmes. Therefore, it is fundamentally a decision support system.

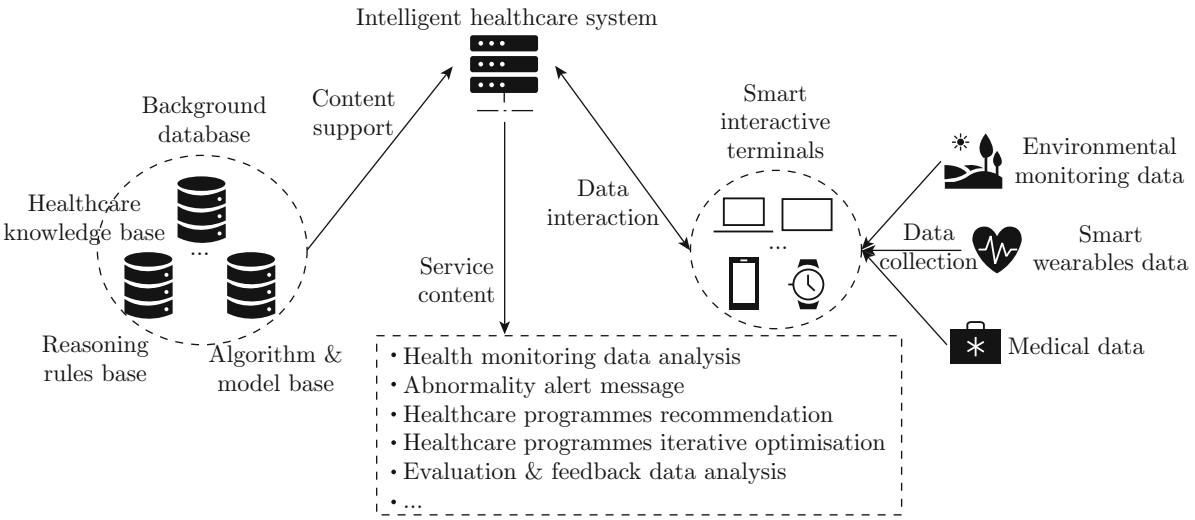

Fig. 9 Intelligent healthcare system

The implementation of a panoramic and personalised intelligent healthcare mode is inseparable from the intelligent healthcare system. Intelligent healthcare is a process that provides decision support for the implementation of healthcare programmes. As mentioned previously, intelligent healthcare applies healthcare knowledge in traditional Chinese and Western medicine to the individual healthcare process, during which the intelligent healthcare system uses environmental and personalised data collected by human-computer interaction to assess health risks, identify possible risk factors in physical and mental health, and thereby determine the current health status of each individual. An example is whether one has a low-, medium-, or high-risk status, and the possible risk factors of sedentary behaviour, lack of exercise, and depression. Based on the analysis of individual indicators and environmental factors, early abnormality warnings can be provided in time, which explains why an individual should adhere to healthcare programmes. For example, a person must exercise if they are being sedentary and adjust passive sentiments when experiencing depression. With the *what* and *why* as the content support, the user is still eager to know what to do next or how to improve the current health conditions, so specific healthcare programmes, such as exercise methods and durations, and effective measures to regulate psychological emotions, are recommended and implemented. Therefore, the ultimate aim of intelligent healthcare is to provide users with healthcare programmes as the decision support for programme implementation.

The decision support process of the panoramic and personalised programme implementation is closely linked to the decision support system. From the perspective of the development and evolution history of decision theory, the information considered in the decision model is gradually enriched. The early expected utility theory ignored individual differences and environmental factors, and the subsequent behavioural decision theory introduced the analysis of individual behavioural information. Later, in the research on

dynamic decision-making methods, scholars attached importance to the collection of environmental information, whereas the decision support system proposed further encompassed the interaction between the decision maker and external environment[10]. Decision support systems comprehensively consider individual differences and environmental factors; therefore, in an attempt to assist in the decision-making behaviour of decision-makers to a greater extent, the indicators of which the system itself considers, the information naturally coincides with that contained in panorama and personalisation. Moreover, the intelligent healthcare system is essentially a decision support system that plays a major role in data transmission, natural language processing, or intelligent recommendations of healthcare programmes. It is impossible to assign a human doctor to serve only one patient every day, and human intelligence has not yet been able to deal with complex reasoning in a timely manner. However, the powerful intelligent healthcare system is always online, thereby providing continuous and accessible online proactive healthcare services for different individuals. This not only enhances the supervision of the healthcare process, but also solves two problems in traditional healthcare to a certain degree, namely the lack of sustainability and participation[44].

As indicated in Fig. 9, the intelligent healthcare system, as an important component and key node of healthcare services, is supported by background databases and interacts with smart terminals to provide users with different healthcare services. In this case, the background databases mainly include the healthcare knowledge base, reasoning rules base, and algorithm and model base. The healthcare knowledge base stores basic theories and methods of traditional Chinese and Western medicine, which lays the theoretical foundation for the healthcare service. The reasoning rules base specifies if-then-else rules that can derive conclusions from the knowledge premise, which lays a logical foundation for complex reasoning based on multi-source available data. The algorithm and model base maintains machine learning methods used in knowledge reasoning, which provides a powerful guarantee for the practical application. The data collected by smart terminals, including environmental monitoring, physical examination, and medical treatment data, are processed and analysed by the intelligent healthcare system in the background. Finally, the data are oriented for serving users with personalised healthcare services, such as monitoring data analysis, abnormality alert messages, and healthcare programme recommendations. Therefore, the intelligent healthcare system is like a machine brain that never stops running or an artificial doctor who is always waiting and ready to serve, which can provide panoramic and personalised healthcare services for different individuals at any time.

4.2 Intelligent Coordination and Dynamic Optimisation Models

The key to implementing intelligent healthcare is to make full use of information technology, particularly artificial intelligence, to generate personalised daily lifestyle management programmes, so as to satisfy individual health demands effectively. Therefore, the intelligent generation of healthcare programmes is not only the basic concept of the panoramic and personalised intelligent healthcare mode, but it can also be considered as the key scientific issue to be solved when implementing this mode.

However, panoramic elements and personalised characteristics exhibit an endless variety. It is fairly complex to generate a healthcare programme intelligently that meets both panoramic and personalised constraints. Therefore, efforts have been made to research and develop an intelligent generation model for healthcare programmes. Specifically, based on the application scenes and programme types, this study proposes an intelligent coordination model and a dynamic optimisation model (as illustrated in Fig. 10) as the basis of the intelligent programme generation.

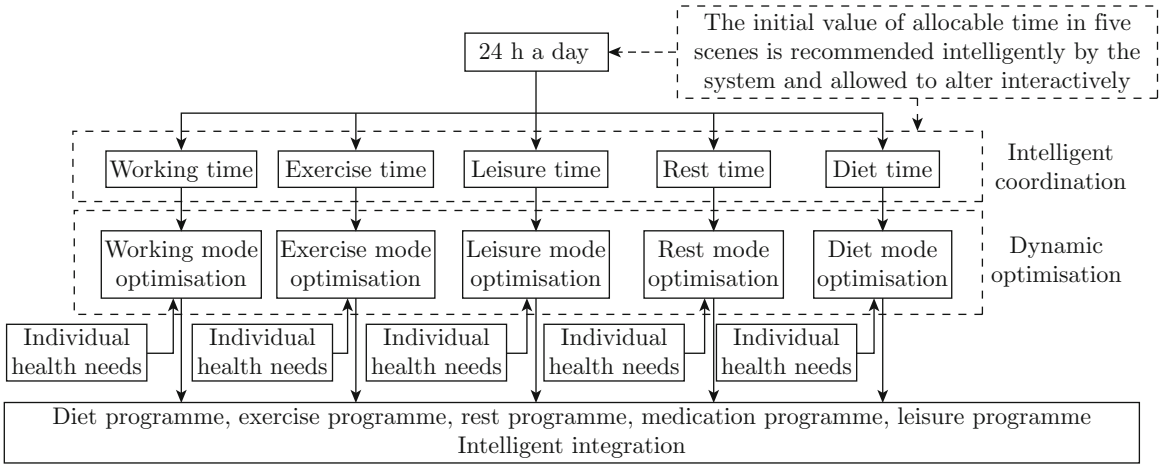

Fig. 10 Intelligent coordination and dynamic optimisation models

4.2.1 *Application Scenes of Healthcare Programmes*

Once the healthcare programme is to be implemented in daily life to satisfy the individual health needs, what are the basic scenes in daily life, or in which scenarios can the healthcare programme be applied? According to the everyday tracking of the human body for 24 hours per day and 365 days per year, the authors hold that the healthcare programme can be applied in the following five basic life scenes:

(1) Working (including learning) scene. This mainly refers to the time period of continuous working or learning for white-collar employees, students, and other groups.

(2) Exercise scene. This mainly refers to the time period of daily physical exercise.

(3) Rest scene. This mainly refers to the relatively constant time period of rest, such as sleep, every day.

(4) Diet scene. This mainly refers to the time period of three meals a day.

(5) Leisure scene. This mainly refers to the time period for recreational activities other than the above scenes, such as fishing, playing cards, singing, and watching movies.

4.2.2 *Types of Healthcare Programmes*

Once the healthcare programmes can be applied in the five scenes, which types of programmes can be recommended for individuals in these scenes, or which types of healthcare programmes exist? According to the healthcare items involved in basic life scenes, we hold that the healthcare programmes can be divided into five types: diet, exercise, rest, medication, and leisure programmes.

(1) Diet programme. This is mainly for the management of three meals a day.

(2) Exercise programme. This is mainly for the management of daily physical exercise.

(3) Rest programme. This is mainly for the management of rest.

(4) Medication programme. This is mainly to provide individuals with a reminder based on medical orders. It should be noted again that healthcare is not medically technical work, so it does not involve clinical procedures that should be conducted by professional doctors such as prescribing and operating. The medication programme does not refer to which medicine to take, but rather, prompting the relevant medication time, usage and dosage, adverse reactions, and other contents according to the doctor's advice.

(5) Leisure programme. This is mainly for the management of recreational activities in a leisure scene, in addition to the above programmes. It is helpful for sentiment relaxation and adjustment, social interaction promotion, etc.

4.2.3 *Intelligent Coordination Model of Daily Time Allocation*

Carrying out certain life matters during the correspondingly appropriate time is the best means of maintaining the body in a healthy condition. The intelligent coordination model of daily time allocation, based on an individual's daily allocable time and combined with the constraints of panoramic elements and personalised features, optimises the optimal time allocation mode of each scene for 24 h of the next day with the objective of maximising the individual health benefits, so as to provide time guidance for the further implementation of specific healthcare programmes. For example, in addition to the relatively fixed 10 working hours per day for office workers, the remaining 14 h should be coordinated reasonably to achieve maximal health benefits. For retired elderly people with comparatively flexible time every day, it needs to be determined for the time allocation mode in each life scene.

4.2.4 *Dynamic Optimisation Model of Healthcare Programmes*

The dynamic optimisation model of healthcare programmes further optimises certain configurations of the working, exercise, leisure, rest, and diet modes based on the daily optimal time allocation obtained by the intelligent coordination model to determine specific healthcare programmes within the available time range of each scene and to satisfy the health demands of different individuals. For example, it should be considered which types of programmes should be offered and how to determine the time slot combination in the fixed 10 h working period to achieve minimum mental fatigue. Within the sleep time for retired elderly people, concrete rest programmes or aid measures should be offered to reduce insomnia and to improve the sleep quality.

4.3 Implementation Process

A complete healthcare process begins with the user data input and programme selection the day before, and ends with the user evaluation and feedback the next day, as indicated in Fig. 11.

The day before, based on the personalised features and individual health needs that are input by the user, multiple healthcare programmes are intelligently generated through the intelligent coordination model and dynamic optimisation model, and ultimately determined by user self-selection. The next day, these selected programmes will be implemented successively by the user.

Prior to getting up the next day, combined with the data collected the day before, the system will present the health risk assessment report and inform the user of possible health risk factors. Before the implementation of each programme, if necessary, the user will receive an abnormality warning message according to real-time monitoring data such as wearable and environmental data. For example, if the weather forecast shows rain in a certain period, the user will receive a

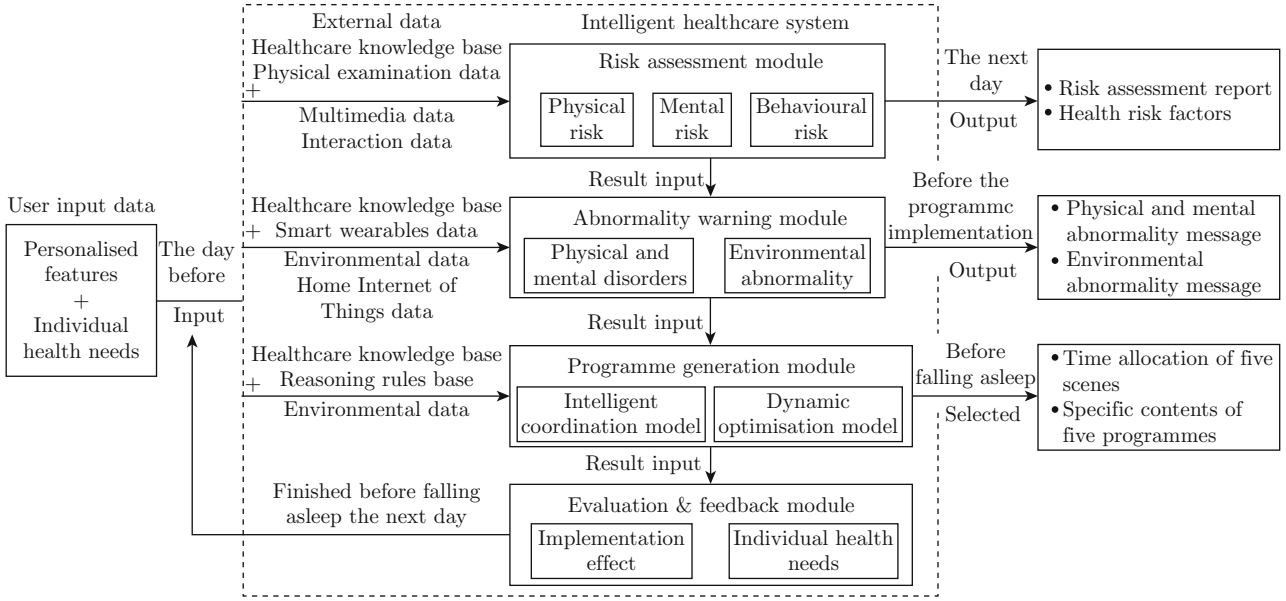

Fig. 11 Implementation process of panoramic and personalised intelligent healthcare mode

weather warning message before the programme implementation in that time. If the sleep time of the previous day is detected to be insufficient, the user will receive an insufficient sleep warning message when getting up. Based on an abnormality warning message, and further combined with a healthcare knowledge base, the system can trigger the addition of programme contents in the programme generation module. For example, if it is raining, the user will be reminded to take an umbrella. If insufficient sleep occurs, corresponding sleep aid measures will be added to the programme contents.

Before falling asleep the next day, the user can evaluate and provide feedback on the programme implementation effect on that day to the system and input their health needs for the following day, so as to continue in the next healthcare process.

4.4 Case Study

The following presents an application case of the panoramic and personalised intelligent healthcare mode. For simplicity, suppose that the individual activity scope in one day is set, as shown in Fig. 5; the personalised characteristics are set, as shown in Fig. 6; the background intelligent healthcare system is set, as shown in Fig. 9.

As illustrated in Fig. 6, this elderly female suffers from chronic diseases such as hyperglycaemia and hypertension, is seriously overweight (91 kg), and has long-term insomnia, which is mainly manifested as extreme excitement at night and difficulty falling asleep, thereby leading to her often taking sleeping pills and frequently browsing her mobile phone, or even getting up at midnight to watch TV. Owing to a variety of chronic diseases, she was classified into the group with a high risk of chronic diseases by the doctor. According to her physical examination report, the doctor provided several suggestions for daily lifestyle management, mainly including the following:

(1) Sleep. Go to bed early and get up early to ensure adequate sleep. A 30 min rest at noon is acceptable, but it should not be too long.

(2) Diet. Pay attention to the dietary balance; no greasy food and viscera, a light diet, less oil and salt.

(3) Medication. Take anti-hypertensive drugs and hypoglycaemic drugs on time every morning and try not to take sleeping pills.

(4) Exercise. Strengthen physical exercise and do not be sedentary.

(5) Psychology. Try to maintain a strong mentality and do not worry too much.

Her main health needs are to reduce insomnia and lose weight. According to the historical feedback information, it is usually easier to fall asleep after massage, square dancing, and tourism. Her main daily life items include getting up, measuring her blood glucose and blood pressure, taking medicine, breakfast, shopping for food, watching TV, lunch, noontime rest, entertaining outside, dinner, taking a walk, chatting with family, bathing, and sleeping. Based on the daily life trajectory, the routine items are classified into different life scenes, and it is supposed that the allocable time in the five scenes is first intelligently recommended by the system and then interactively confirmed by the user, as follows: 10 h for the rest scene, 2 h for the diet scene, 4 h for the exercise scene, 2 h for the working scene, and 6 h for the leisure scene. The possible intelligent healthcare services in each scene are presented in Table 3, where the time allocation mode optimised by the intelligent coordination model is indicated in the

Table 3 Essence of healthcare[1]

Life scenes	Time allocation	Risk assessment/Abnormality warning/Evaluation & feedback: examples	Programme implementation: examples
Rest scene	22∶00—07∶00	Risk assessment: high risk (disease number more than 3), risk factors include blood pressure, blood glucose. Abnormality warning: the sleep time last night less than 5 h.	Rest programme: go to bed at 22∶00 and get up at 07∶00. To fall asleep as soon as possible in the evening, please do not browse your mobile phone for 2 h before bedtime.
	13∶00—13∶30		Rest plan: a 30 min rest at noon is acceptable, which is conducive to heart rest.
Diet scene	07∶00—07∶30	Abnormality warning: blood glucose and blood pressure exceed standard values.	Diet programme: drink a glass of hot boiled water after getting up. Medication programme: take anti-hypertensive drugs and hypoglycaemic drugs in this period for the best curative effect.
	07∶30—08∶00		Diet programme: nutritious breakfast, no eggs, milk acceptable, have more grains.
	11∶30—12∶00		Diet programme: light lunch, no bean products, no lard, no viscera.
	18∶00—18∶30		Diet programme: less oil and salt for dinner, dietary balance, do not eat more than seven points.
Exercise scene	08∶30—09∶30	Abnormality warning: it is cool outside (15 °C) and during the special pandemic period.	Exercise programme: shop for food, with a spare dress and a mask when going out.
	16∶30—18∶00		Exercise programme: walk for the recommended route and targeted steps. Diet programme: drink hot boiled water, no strong tea or carbonated drinks (for gallstones).
	19∶30—20∶30		Exercise programme: square dancing.
Working scene (cooking)	10∶30—11∶30		Exercise programme: skipping rope during break. Diet programme: drink hot boiled water, no strong tea or carbonated drinks (for gallstones).
Leisure scene	09∶30—10∶30		Leisure programme: watch TV.
	13∶30—15∶30	Abnormality warning: it will be raining in this period.	Leisure programme: play cards in the chess and card room, take an umbrella and have a rest for 10 min when sedentary for 40 min. Diet programme: drink hot boiled water, no strong tea or carbonated drinks (for gallstones).
	15∶30—16∶30		Leisure programme: massage in massage parlor nearby.
	20∶30—22∶00	Evaluation & feedback: today's programme implementation effect, tomorrow's health needs. Historical feedback: easier to fall asleep after massage and dancing.	Leisure programme: watch TV. Have a rest for 10 min when sedentary for 40 min. Exercise programme: skipping rope during break. Diet programme: drink hot boiled water, no strong tea or carbonated drinks (for gallstones).

second column, the risk assessment/abnormality warning/evaluation and feedback, and their respective examples are indicated in the third column, and the programme types and examples optimised by the dynamic optimisation model are indicated in the fourth column.

It should be noted that the examples shown in Table 3 are combined with the individual's historical life experience and doctor's suggestions, but are not intelligently generated by the intelligent healthcare system according to the implementation process introduced in Subsection 4.3. Therefore, it can easily be observed that the examples of the programme implementation are highly pertinent to the doctor's suggestions, and although they are seemingly plausible, they are still not particularly concrete in providing, for instance, explicit dishes for three meals per day or more specific sleeping aid measures. These are research questions that should be considered in the dynamic optimisation model.

5 Conclusions and Prospects

The panoramic and personalised intelligent healthcare mode is centred on individual health, makes full use of information technology, and combines panoramic elements such as time, space, and resources with personalised characteristics in different individuals to provide comprehensive healthcare services for users, so as to achieve the maximum health benefits within limited resources. To put this mode into real practice, it is necessary to develop and deploy the intelligent healthcare system, as well as to focus on the research and development of an intelligent coordination model for daily time allocation and a dynamic optimisation model for healthcare programmes.

The proposed mode involves extensive research contents and covers a wide range of disciplinary knowledge, which is difficult to be perfectly implemented and can be considered as systematic healthcare engineering. However, the mode exhibits a strong possibility of becoming the future developmental trend in healthcare owing to its advanced concepts. In this paper, the basic definition, conceptual model, and specific connotations of the panoramic and personalised intelligent healthcare mode have been explained in detail, and this study is expected to provide new ideas for further research in the healthcare field.

References

[1] HUANG J. Healthcare in China: Theory and practice [M]//Blue paper on the development of preventive medicine. Beijing: Chinese Preventive Medicine Association, 2008: 27-41 (in Chinese).

[2] HU S, GAO R, LIU L, et al. Summary of the 2018 report on cardiovascular diseases in China [J]. *Chinese Circulation Journal*, 2019, **34**(3): 209-220 (in Chinese).

[3] ZHENG Y Y, MA Y T, ZHANG J Y, et al. COVID-19 and the cardiovascular system [J]. *Nature Reviews Cardiology*, 2020, **17**(5): 259-260.

[4] LI S, SHAN Y. Latest research advances on novel coronavirus pneumonia [J]. *Journal of Shandong University* (*Health Sciences*), 2020, **58**(3): 19-25 (in Chinese).

[5] LU R, ZHAO X, LI J, et al. Genomic characterisation and epidemiology of 2019 novel coronavirus: Implications for virus origins and receptor binding [J]. *The Lancet*, 2020, **395**(10224): 565-574.

[6] TANG J. Change the focus on treatment to focus on people's health [J]. *Social Security of Human Resources in China*, 2018(10): 52 (in Chinese).

[7] YAN C. Health management and health risk appraisal [J]. *Health Research*, 2018, **38**(1): 1-8 (in Chinese).

[8] WU X L. Actively promote the strategy of healthy aging [N]. *China Population Daily*, 2018-10-29(003) (in Chinese).

[9] Healthy China Action Promotion Committee. Health China Action (2019—2030): General requirements, major actions and main indicators [J]. *Chinese Circulation Journal*, 2019, **34**(9): 846-858 (in Chinese).

[10] CHEN G, ZENG D, WEI Q, et al. Transitions of decision: Making paradigms and enabled innovations in the context of big data [J]. *Management World*, 2020, **36**(2): 95-105 (in Chinese).

[11] XU Z, FENG Z, GUO X, et al. Big data driven management and decision frontier issues [J]. *Management World*, 2014(11): 158-163 (in Chinese).

[12] HARARI G M, LANE N D, WANG R, et al. Using smartphones to collect behavioral data in psychological science: Opportunities, practical considerations, and challenges [J]. *Perspectives on Psychological Science*, 2016, **11**(6): 838-854.

[13] MAST M S, GATICA-PEREZ D, FRAUENDORFER D, et al. Social sensing for psychology [J]. *Current Directions in Psychological Science*, 2015, **24**(2): 154-160.

[14] SHAHEEN S, EL-HAJJ W, HAJJ H, et al. Emotion recognition from text based on automatically generated rules [C]//*2014 IEEE International Conference on Data Mining Workshop*. Piscataway, NJ: IEEE, 2014: 383-392.

[15] LU J, WU J, WU J, et al. Construction of a health management system suitable for China's national conditions [J]. *Chinese General Practice*, 2009, **12**(3): 212-215 (in Chinese).

[16] ZHANG Y, WU X, CHU Y, et al. Development status of healthcare mode in China [J]. *Journal of Public Health and Preventive Medicine*, 2014, **25**(1): 78-80 (in Chinese).

[17] LAN Z. A panoramic and integral approach to rational public policy making and analysis [J]. *Chinese Public Administration*, 2017(2): 17-21 (in Chinese).

[18] ZHU H, YE T, YI Y, et al. Effect of "panoramic" case teaching in training of new graduate pediatric nurses [J]. *Journal of Nursing Science*, 2018, **33**(1): 75-76 (in Chinese).

[19] CHEN G, WU G, GU Y, et al. The challenges for big data driven research and applications in the context of managerial decision-making: Paradigm shift and research directions [J]. *Journal of Management Sciences in China*, 2018, **21**(7): 1-10 (in Chinese).

[20] CAI F, ZHANG H, ZHANG C. A management system based on personal health database [J]. *Beijing Biomedical Engineering*, 2009, **28**(5): 521-523 (in Chinese).

[21] ZHANG H, ZHANG N. Methods of personalized healthcare [J]. *Guiding Journal of Traditional Chinese Medicine and Pharmacy*, 2010, **16**(7): 85-86 (in Chinese).

[22] ZHANG H, YANG X, TANG Z, et al. Design of an individual health management system [J]. *Beijing Biomedical Engineering*, 2010, **29**(5): 528-530 (in Chinese).

[23] SHENG A. Drug therapy combined with individualized health management of community hypertension intervention randomized controlled study of combined traditional Chinese and Western medicine [J]. *Journal*

of Practical Traditional Chinese Internal Medicine, 2016, **30**(5): 77-80 (in Chinese).

[24] YUE F, LINGHU Y, HU D. Effect of individualized health management on risk factors of stroke in middle aged and elderly population [J]. *Contemporary Medicine*, 2017, **23**(34): 1-3 (in Chinese).

[25] LIU Q, ZHU H, LIU W, et al. The effect of individualized health management on community-residing diabetes patients [J]. *Journal of Nursing Science*, 2018, **33**(18): 86-89 (in Chinese).

[26] SNYDERMAN R, WILLIAMS R S. Prospective medicine: The next health care transformation [J]. *Academic Medicine*, 2003, **78**(11): 1079-1084.

[27] KONGSTVEDT P R. Essentials of managed health care [M]. 5th ed. Sudbury: Jones & Bartlett Publishers, 2007.

[28] WANG Y, WANG Y, HU A, et al. Development survey of health management in home and abroad [J]. *China Medical Herald*, 2013, **10**(1): 27-29 (in Chinese).

[29] LIU Y, WANG Z. The development model of health management in USA and its experiences for China [J]. *Asia-Pacific Economic Review*, 2016 (3): 75-81 (in Chinese).

[30] FU M, FENG Z, CHEN S. Enlightenment from experiences of health management in developed country [J]. *Chinese Health Service Management*, 2011, **28**(3): 233-236 (in Chinese).

[31] SHAO X. German health insurance and preventive medical service [J]. *China Health Industry*, 2006 (2): 80-81 (in Chinese).

[32] MEURMAN J H, PAJUKOSKI H, SNELLMAN S, et al. Oral infections in home-living elderly patients admitted to an acute geriatric ward [J]. *Journal of Dental Research*, 1997, **76**(6): 1271-1276.

[33] RUSHTON V E, HORNER K, WORTHINGTON H V. The quality of panoramic radiographs in a sample of general dental practices [J]. *British dental journal*, 1999, **186**(12): 630-633.

[34] GLASGOW R E, LA CHANCE P A, TOOBERT D J, et al. Long term effects and costs of brief behavioural dietary intervention for patients with diabetes delivered from the medical office [J]. *Patient Education and Counseling*, 1997, **32**(3): 175-184.

[35] MCKAY H G, FEIL E G, GLASGOW R E, et al. Feasibility and use of an Internet support service for diabetes self-management [J]. *Diabetes Educator*, 1998, **24**(2): 174-179.

[36] WILLIAMS R S, WILLARD H F, SNYDERMAN R. Personalized health planning [J]. *Science*, 2003, **300**(5619): 549.

[37] SIMMONS L A, DRAKE C D, GAUDET T W, et al. Personalized health planning in primary care settings [J]. *Federal Practitioner*, 2016, **33**(1): 27-34.

[38] CHAWLA N V, DAVIS D A. Bringing big data to personalized healthcare: A patient-centered framework [J]. *Journal of General Internal Medicine*, 2013, **28**: 660-665.

[39] CHIAUZZI E, RODARTE C, DASMAHAPATRA P. Patient-centered activity monitoring in the self-management of chronic health conditions [J]. *BMC Medicine*, 2015, **13**: 77.

[40] LEWY H, BARKAN R, SELA T. Personalized health systems: Past, present, and future of research development and implementation in real-life environment [J]. *Frontiers in Medicine*, 2019, **6**: 149.

[41] MA W, ZHANG J, YAN B. A study on the manageable and integrated healthcare service mode in the United States [J]. *China Health Human Resources*, 2012(1): 78-80 (in Chinese).

[42] HUANG J. National healthcare in the United States [J]. *China Healthcare Innovation*, 2007(3): 16 (in Chinese).

[43] WANG L, BAI S, CHEN J, et al. Health manager: Basic knowledge [M]. 2nd ed. Beijing: People's Medical Publishing House, 2019 (in Chinese).

[44] LI H, CHEN X, XIE W. Design and implementation of intelligent health management mode [J]. *Journal of Medical Informatics*, 2018, **39**(9): 7-11 (in Chinese).

[45] GAO Q, LÜ J. Intelligent medicine: Opportunities and challenges to public health in the era of artificial intelligence [J]. *E-Government*, 2017(11): 11-19 (in Chinese).

[46] CHEN X, WANG Z. Overview of theory and methods of decision support systems [J]. *Control and Decision*, 2006, **21**(9): 961-968 (in Chinese).

[47] ER M C. Decision support systems: A summary, problems, and future trends [J]. *Decision Support Systems*, 1988, **4**(3): 355-363.