Team Control Data
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Problem Chosen
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Summary

In Task1, an GM（1,1）model are established to predict the aging trend of China. And we build a multiple linear regression model for the medical needs of the residents and try to find out the factors affecting the medical needs of the residents. Using GM（1,1）model to predict the data of all the affecting factors, the trend of the medical needs can be predicted according to the multiple linear regression model with the predicted data of affecting factors. The aging trend of China and the medical needs have a fast increase in the future 10 years.

In Task2, we take Macao, which is at the same level as the province, as an example and select the data of specialist outpatients from 2007 to 2018 to represent the data of patients with various common diseases. This paper makes use of the GM (1, 1) Model to predict the different types of diseases and analyze its future growth trend. According the predicted data, internal medicine diseases and physiotherapy diseases are the most common and we put forward reasonable suggestions for the internal structure of public hospitals.

In Task3, we build a queuing theory model to solve the problem of excessive queue time to improve the efficiency of patients in queue examination. The arrival rate of patients in the queuing theory model is determined according to the scale of visits from task 2. We limit the average waiting time in the queuing to decide different checkpoints assigned to departments of different types of diseases so that the hospital can improve the efficiency of examination. For example, when there are 5 checkpoints in the internal medicine department, the average queue time of each person is about 2 minutes.

In Task 4, there is complex competition and cooperation between private hospitals and private hospitals, and the needs of patients they concern are different. Task four requires us make the optimal cooperation and competition strategy between multiple hospitals under this background. In order to solve this problem, this paper first makes the SWOT analysis of public hospitals and private hospitals and puts forward competitive and cooperative strategies from the aspects of talent, technology, resources and so on.

In Task5, based on the study of the trend of medical needs in China, this paper puts forward the following suggestions according to the differences of urban and rural areas and differences of public hospitals and private hospital. Improving the medical needs system for the elderly and adjusting medical resources for the future common diseases like Internal medicine and physical therapy diseases are also necessary.

Key word: **GM（1,1）Model; Multiple Linear Regression Model; Queuing theory Model; SWOT**

Content

1. Introduction

1.1 Background

With the rapid development of China's economy and society, and the aging trend, the demand for hospital health service continues to increase. At the same time, along with the rapid industrialization and urbanization process, ecological and food safety are subject to different levels of challenges. These overall developments have also brought a series of new challenges to medical and health work.

The rapid growth and diversified developments of medical needs have led to an increase in the data of private hospitals. At present, private hospitals and public hospitals have formed different levels of competition and cooperation. For public hospitals, how to satisfy the growing demand for universal medical care for residents so as to improve comprehensively the residents' demand for hospitals is the main direction of efforts. For private hospitals, how to effectively meet the peak demand in public hospitals and the demand for special diseases is the main direction of their efforts.

1.2 Task

Task1: With the relevant statistical analysis data of the National Bureau of Statistics like residents' income, age structure of the population and the economic development level, we will make reasonable predictions of the aging trend of China and the medical needs of the residents.

Task2:Taking a certain province as an example，we plan to analyze the most common disease in the future in the province, and provide suggestions for the overall development of major public hospitals in the province.

Task3: Under the assumption that different types of patients may need to do different inspections in the hospital, different inspection items may be distributed in different locations and there may be a large gap in the data of people in the queue. We will propose a common queuing theory and its related optimal queuing method for this kind of queuing problem.

Task4: Combining the complex cooperation and competition between private hospitals and public hospitals, we plan to propose the optimal cooperation and competition strategies among multiple hospitals.

Task5: Combining previous questions, we will write a proposal for the relevant medical management department, and provide a reference for its preparation of the "14th Five-Year Plan".

2. Problem analysis

2.1 Analysis of task one

Task1 requires us to build a model to make reasonable predictions of the aging trend of China and the medical needs of the residents with the relevant statistical analysis data of the National Bureau of Statistics like residents' income, age structure of the population and the economic development level. In order to make predictions of the aging trend of China, we established an GM（1,1）model. It considers previous data to predict future data of the aging trend of China. Furthermore, we build a multiple linear regression model for the medical needs of the residents and try to find out the factors affecting the medical needs of the residents. Using GM（1,1）model to predict the data of all the affecting factors, the trend of he medical needs can be predicted according to the multiple linear regression model with the predicted data of affecting factors.

2.2 Analysis of task two

Task2 requires us to analyze the most common disease in the future in the province, and provide suggestions for the overall development of major public hospitals in the province by taking a certain province as an example. This paper takes Macao, which is at the same level as the province, as an example to explore the most common diseases in the future. Based on the completeness of the model and the availability of the data, this paper selects the data of specialist outpatients published by the Macao Bureau of Statistics from 2007 to 2018. The data of outpatients in each specialty represents the data of patients with various common diseases. Therefore, this paper makes use of the GM (1, 1) Model to predict the different types of diseases and analyze its future growth trend. According to the prediction of different types of diseases, we can judge the most common diseases and puts forward reasonable suggestions for the internal structure of public hospitals.

2.3 Analysis of task three

Task3 requires us to find out a related optimal queuing method for the queuing problem. In order to improve the efficiency of patients in queue examination, this paper solves the problem of excessive queue time by queuing theory model. On the basis of the data of the data of outpatients in Macao according to task 2, the scale of visits to different common diseases was analyzed, and the arrival rate of patients in the queuing theory model was determined according to the scale of visits. In order to solve the problem of too long queue time, this paper limits the average waiting time in the queuing process. Different checkpoints are assigned to departments of different types of diseases to meet the inspection needs of different types of patients so that the hospital can improve the efficiency of examination.

2.4 Analysis of task four

In the background of the problem, there is complex competition and cooperation between private hospitals and private hospitals, and the needs of patients they concern are different. So task four requires us make the optimal cooperation and competition strategy between multiple hospitals under this background. In order to solve this problem, this paper first makes the SWOT analysis of public hospitals and private hospitals， and then puts forward competitive and cooperative strategies from the aspects of talent, technology, resources and so on.

2.5 Analysis of task five

Task5 requires us to write a proposal for the relevant medical management department, and provide a reference for its preparation of the “14th Five-Year Plan”. Based on the study of the development trend of medical needs in China, this paper puts forward the following suggestions for Medical and Health Care in China: First, to establish a basic medical and health system covering urban and rural residents, so as to alleviate the problem of difficult and expensive medical treatment. Second, in view of the difference of medical needs between urban and rural areas, we should reasonably plan the allocation of medical resources and narrow the gap between urban and rural areas. Third, facing the trend of aging development, promoting the integration and development of medical industry and pension industry can improve the medical security system for the elderly. Finally, it is necessary to coordinate the medical resources of public hospitals and private medical institutions and establish an effective medical operation system to improve the efficiency of medical and health services. In the future trend of national health development, internal medicine, physical therapy diseases, and surgical diseases are large in scale. Therefore, medical resources should be rationally adjusted, and medical personnel should be trained to make more resources for the future common diseases.

3. Assumptions

1. Assume a hospital checkpoint only checks one patient at a time.
2. Assume that the inspection time for each inspection is independent.
3. Assume that the time the patient arrives at the hospital is independent.
4. Assume that the assignment of the patient's inspection of the queuing process factors is close to the real situation.

4. Model

4.1 Task one

Task1 requires us to build a model to make reasonable predictions of the aging trend of China and the medical needs of the residents with the relevant statistical analysis data of the National Bureau of Statistics like residents' income, age structure of the population and the economic development level. In order to make predictions of the aging trend of China, we established an GM（1,1）model. It considers previous data to predict future data of the aging trend of China. Furthermore, we build a multiple linear regression model for the medical needs of the residents and try to find out the factors affecting the medical needs of the residents. Using GM（1,1）model to predict the data of all the affecting factors, the trend of he medical needs can be predicted according to the multiple linear regression model with the predicted data of affecting factors.

4.1.1 Aging Trend Prediction based on GM (1,1) Model

In order to predict the development trend of aging in China in Task 1, this paper makes use of the grey time series prediction of GM (1, 1) model to predict the development trend of aging in China. Combined with the task requirements and related data, this paper uses the proportion of the elderly population over 65 years of age in each year to construct a grey prediction model to predict the development trend of aging in the future. The mathematical model of the problem is explained below:

Make $X^{(0)}$ as GM (1, 1) modeling sequence: $X^{(0)}=(x^{(0)}(1),x^{(0)}(2),...,x^{(0)}(n))$, so $X^{(1)}$ is the 1-AGO sequence of $X^{(0)}$: $X^{(1)}=(x^{(1)}(1),x^{(1)}(2),...,x^{(1)}(n))$.

So we can get:

$$x^{(1)}(k)=\sum_{i=1}^{k}x^{(0)}(i), \quad k=1,2,...,n$$

The following whitening form of differential equation of $X^{(1)}$ can be established, that is, GM (1, 1) model:

$$\frac{dx^{(1)}}{dt}+ax^{(1)}=b$$

So there is a whitening form of differential equation: $\frac{dx^{(1)}}{dt}+ax^{(1)}=b$, The solution of this equation is also called time response function:

$$\hat{x}^{(1)}(t)=(x^{(1)}(0)-\frac{b}{a})e^{-at}+\frac{b}{a}$$

There is the time response sequence of GM (1,1) Grey Differential Equation:

$$\hat{x}^{(1)}(k+1)=[x^{(1)}(0)-\frac{b}{a}]e^{-ak}+\frac{b}{a}, \quad k=1,2,...,n$$

Its restore value is: $\hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k)$

In the process of establishing GM (1, 1) model, residual test, correlation degree test and post-verification test are needed, and the specific process is as follows:

(1) Residual Test

Residual test, that is, the residual value of the model value and the actual value are tested point by point. First, the $\hat{x}^{(1)}(i+1)$ is calculated according to the model, and the $\hat{x}^{(1)}(i+1)$ is reduced to $\hat{x}^{(0)}(i)$. Finally, the original sequence $x^{(0)}(i)$ and the absolute residual sequence of $\hat{x}^{(0)}(i)$ are calculated.

$$\Delta^{(0)}=\{\Delta^{(0)}(i), i=1,2,...,n\}, \quad \Delta^{(0)}(i)=\left|x^{(0)}(i)-\hat{x}^{(0)}(i)\right|$$

And relative residual sequences also can be gotten:

$$\phi=\{\phi_i, i=1,2,...,n\}, \quad \phi_i=\left[\frac{\Delta^{(0)}(i)}{x^{(0)}(i)}\right]$$

Then calculate the average relative residual:

$$\bar{\phi}=\frac{1}{n}\sum_{i=1}^{n}\phi_i$$

Given α, when $\bar{\phi}<\alpha$ and $\phi_n<\alpha$, the model is called residual qualified model.

(2) Correlation Degree Test

Correlation degree test, that is, by investigating the similarity between the model value curve and the modeling sequence curve. According to the calculation method of correlation degree described above, the correlation coefficient between $\hat{x}^{(0)}(i)$ and the original sequence $x^{(0)}(i)$ is calculated, and then the correlation degree is calculated. According to experience, it is satisfactory that the correlation degree is greater than 0.5.

(3) Post-inspection Difference Test

Posterior error test is to test the statistical characteristics of residual distribution. First, the average value of the original sequence is calculated:

$$\bar{x}^{(0)}=\frac{1}{n}\sum_{i=1}^{n}x^{(0)}(i)$$

The second step is to calculate the mean square error of the original sequence $X^{(0)}$:

$$S_1 = \left(\frac{\sum_{i=1}^{n}[x^{(0)}(i) - \bar{x}^{(0)}]^2}{n-1}\right)^{1/2}$$

Step three, calculate the mean value of the residual:

$$\bar{\Delta} = \frac{1}{n}\sum_{i=1}^{n} x^{(0)}(i)$$

Step four, calculate the mean square error of the residual:

$$S_2 = \left(\frac{\sum_{i=0}^{n}[\Delta^{(0)}(k) - \bar{\Delta}]^2}{n-1}\right)^{1/2}$$

Step five, calculate the variance ratio C:

$$C = \frac{S_1}{S_2}$$

Finally, the probability of small residual is calculated:

$$P = P\{\left|\Delta^{(0)}(i) - \bar{\Delta}\right| < 0.6745 S_1\}$$

Make $S_0 = 0.6745 S_1$, $e_i = \left|\Delta^{(0)}(i) - \bar{\Delta}\right|$, that is $P = P\{e_i < S_0\}$.

If $C < C_0$ for a given $C_0 > 0$, the model is called a mean-variance-ratio-qualified model; for a given $P_0 > 0$, when $P > P_0$, the model is a small-residual-probability -qualified model, and the posterior difference test discrimination reference table is as follows:

Table1 The posterior difference test discrimination reference

P	C	Model accuracy
>0.95	<0.35	Excellent
>0.80	<0.5	Eligibility
>0.70	<0.65	Barely Qualified
<0.70	>0.65	Not Qualified

If the relative residual, correlation degree and posterior error test are within the allowable range, the model can be used to predict, otherwise the residual error should be corrected.

4.1.2 Medical needs Trend Prediction based on Multiple linear Regression Model

This build a Multiple linear regression model for the medical needs of the residents and try to find out the factors affecting the medical needs of the residents.

In the classical health demand model, the growth of medical and health expenses comes from the demand caused by medical and health demand. The per capita health expenditure is an important index to measure the overall medical needs in our country. The per capita health expenditure is used as a comprehensive measure in the form of currency, which comprehensively reflects the funds consumed by a country or region in a certain period of time. The change of this index is affected by many factors. The research results in related fields generally believe that the level of economic development, population structure, living standards of residents, social security system and so on have a significant impact on medical needs.[1][2][3][4][5]

With the improvement of economic level and the gradual promotion of the strategy of "healthy China", the national health level of our country has steadily improved on the whole. But there is also an imbalance between regions and between urban and rural areas, among which the gap between urban and rural areas is the most obvious.

According to the 2015 Statistical Communique on the Development of Health undertakings in China, the per capita health expenditure in China in 2015 is 2952 yuan, including 3558.3 yuan in cities and 1412.2 yuan in rural areas. The per capita health cost in rural areas is less than 40% of that in cities, and the inequality between the two is reflected in four aspects: health level, utilization of medical services, health financing and accessibility of health services.

When exploring the causes of the great difference in medical needs, it is necessary to realize the difference of the economic development level of the urban and rural dual structure. Because of the influence of the phenomenon, the disposable income of the urban residents, the medical resources and the welfare of the medical security system are superior to the rural residents. And some of the hidden factors, such as the difference of the consumption concept, have an effect on the difference of medical needs in the urban and rural areas.

In this background, this paper further discusses the causes of the inequity and makes the prediction of the future development of the medical needs of the people in the urban and rural areas, which is of great significance to the research of the medical needs of our people. This paper establishes the following index system to predict the development of medical needs:

Table2 Index system

Type	Significance of Index	Representation of Symbol
Urban	**Urban per capita health expenses (Yuan)**	Y_1
	Consumption level of Urban residents (Yuan)	X_{u1}
	Urbanization rate	X_{u2}
	Total average wage of employed persons (yuan)	X_{u3}
	Proportion of population over 65 years of age (%)	X_{u4}
	Gross domestic product (GDP) (100 million yuan)	X_{u5}
	Data of people enrolled at the end of the basic medical insurance	X_{u6}
Country	**Per capita health expenditure in rural areas (yuan)**	Y_2
	Data of people enrolled at the end of the basic medical insurance	X_{c1}
	Per capita cash disposable income of rural residents (yuan)	X_{c2}
	Minimum living security for rural residents (10,000)	X_{c3}
	Proportion of population over 65 years of age (%)	X_{c4}
	Gross domestic product (GDP) (100 million yuan)	X_{c5}

Based on the above analysis, we will carry out multiple linear regression model according to urban and rural areas.

The multiple linear regression model of the city is established as follows:

$$Y_1 = \beta_0 + \beta_1 X_{u1} + \beta_2 X_{u2} +_1 \beta_3 X_{u3} + \beta_4 X_{u4} + \beta_5 X_{u5} + \beta_6 X_{u6} + \mu_1$$

The multiple linear regression model in rural areas is established as follows:

$$Y_2 = \beta_0 + \beta_1 X_{c1} + \beta_2 X_{c2} +_1 \beta_3 X_{c3} + \beta_4 X_{c4} + \beta_5 X_{c5} + \mu_2$$

Using GM（1,1）model to predict the data of all the affecting factors, the trend of he medical needs can be predicted according to the multiple linear regression model with the predicted data of affecting factors.

4.1.3 Prediction results of Aging trend based on GM (1, 1) Model

In this paper, the proportion of population over 65 years old in the National Bureau of Statistics from 2004 to 2018 is selected to represent the degree of aging.[6] With the help of grey prediction GM (1, 1) model, the proportion of the population over 65 years old in the next ten years is predicted, and the aging trend in China in the next decade is analyzed. The forecast results are as follows:

Table3 Aging trend in China

Year	2019	2020	2021	2022	2023
Aging degree(%)	12.06%	12.47%	12.90%	13.34%	13.80%

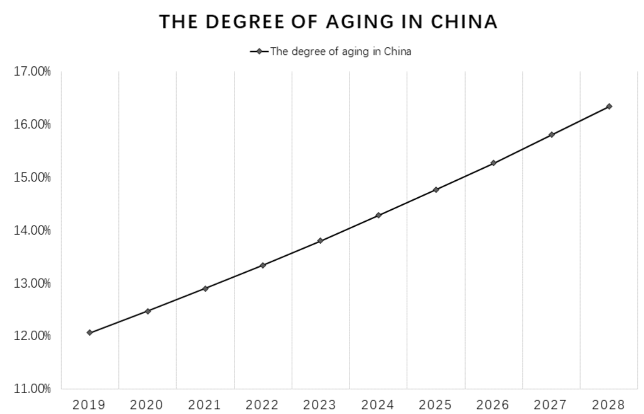
Year	2024	2025	2026	2027	2028
Aging degree(%)	14.28%	14.77%	15.27%	15.80%	16.34%

The residual test: $\alpha = 0.0112 < 0.05$

Correlation test $\varphi = 60.58 > 50\%$

Post-inspection Difference Test: $p = 1 > 0.95; c = 0.089 < 0.35$

According to the above data, the 10-year predicted value of the proportion of population over 65 years old has been tested, and the accuracy is very high. So it can be considered that the prediction results are accurate and credible. Based on this, we can reasonably infer that the aging degree of China will deepen in the future. On the basis of the data obtained from the model solution, the following development trend map of aging in China from 2019 to 2028 can be obtained.



Picture1 The degree of aging in China

From the above figure, we can see that the aging degree of China will be deepened in the future, which will rise to 16.34% in ten years. The occurrence of this phenomenon is a necessary stage of China economic development, which is mainly caused by the following two aspects: the first one is that economic development leads to the improvement of living standards and medical and health conditions. So the life expectancy of the population is extended. The other is that policy, fertility willingness and other factors caused the decline of fertility level. With the influence of these two reasons, the aging degree of China is deepening, which brings some challenges to the development of medical and health care in China.

4.1.4 Prediction results of Medical needs based on multiple Linear regression

In this paper, the relevant data indicators from 2004 to 2014 in the National Bureau of Statistics are selected to establish the multiple linear regression model and make the analysis of urban and rural areas. On the basis of the classical health demand theory, the urban per capita health cost and the rural per capita health cost are used to express the medical needs of the two main bodies in urban and rural areas, respectively. the higher the urban per capita health cost and the rural per capita health cost, the higher the medical needs in China is also increasing year by year. Based on the task-one model and the index system of influencing factors, this paper combines the relevant data and uses SPSS software to solve the medical needs forecasting models of urban and rural subjects respectively.

The prediction model of the urban town is as follows:

$$\ln Y_1 = -9.025 + 2.179 \ln X_{u1} + 5.4 \ln X_{u2} - 3.217 \ln X_{u3} + 2.954 \ln X_{u4} - 0.498 \ln X_{u5} + 0.768 \ln X_{u6} + \mu_1$$

The test table for each influencing factor is as follows:

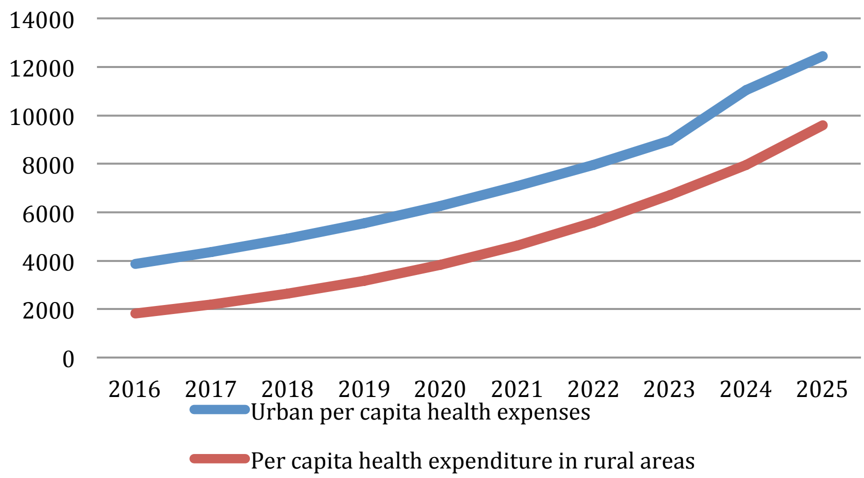
Table4 Test table for each influencing factor

Model	B	standard erro	t	P
Constant	-9.025	8.698	-1.038	0.358
Consumption level of Urban residents	2.179	0.643	3.389	0.028
Urbanization rate	5.4	5.311	1.017	0.367
Total average wage of employed	-3.217	1.225	-2.626	0.058
Proportion of population over 65 years of age	2.954	1.079	2.739	0.052
GDP	-0.498	0.199	-2.501	0.067
Data of people enrolled at the end of the basic medical insurance	0.768	0.134	5.745	0.005

According to $F \geq 348.563$, the model has passed 99% significance test, and it can be considered that the model has very high reliability. In this model, the factors that have positive effect on the improvement of resident medical expenses are consumption level, urbanization rate, proportion of elderly population and the data of medical insurance participants. Therefore, we can see that the improvement of living standards, urbanization, aging and the construction of medical insurance system have led to medical needs. On the one hand, the improvement of living standards, the process of urbanization has increased the cost of medical services and thus stimulated medical needs. Aging and the construction of medical insurance system release the demand of residents for medical services. However, the average wage level and gross domestic product (GDP) of employed people have a negative effect on the increase of resident medical expenses. The cause behind this phenomenon can be attributed to the continuous improvement of the medical insurance system in our country. With the improvement of the system, the personal medical risk can be transferred and the cost is relatively reduced. The forecast model for the countryside is as follows:

$$\ln Y_2 = -7.106 + 0.208\ln X_{c1} + 1.45\ln X_{c2} - 0.229\ln X_{c3} - 0.575\ln X_{c4} + 0.157\ln X_{c5} + \mu_1$$

Among them, $F \geq 254.951$, the model has passed 99% significance test, and it can be considered that the model has very high reliability. From the forecast model of rural medical needs, we can see that the income level and the construction of medical insurance social security system play an important role in stimulating medical needs, which is similar to the development of medical needs of urban residents. However, the deepening of aging can’t release the medical needs of this group. Combined with the level of rural economic development and the concept of consumption of rural residents, it is not difficult to infer that the elderly in rural areas dare not see a doctor because of fear of disease leading to family poverty, which challenges of our country's medical needs.



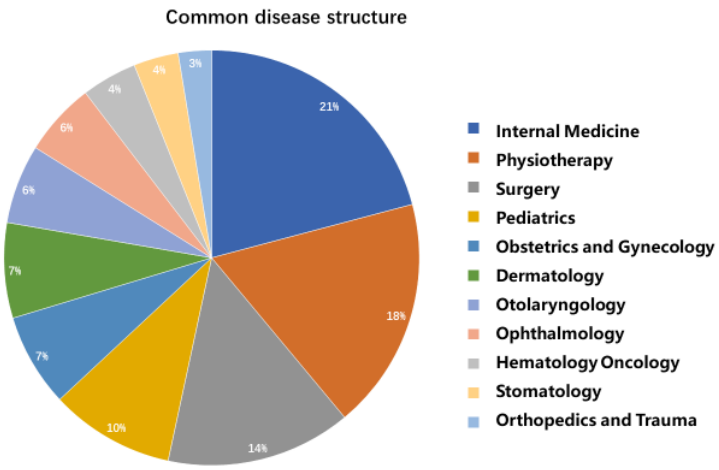
Picture2 The trend of the medical needs from 2016 to 2025

We using the GM (1,1) model to predict the value of each factor in ten years, and combined with Multiple Linear Regression Model to solve the trend of medical needs of urban and rural residents in ten years. It is not difficult to see from the figure that rural and urban areas still have a certain gap in the development process. However, with the increasing urbanization rate, the number of rural residents is decreasing. Therefore, even if this gap exists, it will also have an overall medical needs for China. The impact of development is small. In addition, the slope of the medical needs development curve has an increasing trend after 2025. Combined with the development trend of aging in China and the development of medical pension industry, it can be reasonably speculated that the phenomenon of accelerated growth of medical needs is closely related to aging.

4.2 Task two

Task2 requires us to analyze the most common disease in the future in the province, and provide suggestions for the overall development of major public hospitals in the province by taking a certain province as an example.

In order to solve this problem, this paper takes Macao, China, which is at the same level as the province, as an example to explore the most common diseases in the future.[7] Based on the completeness of the model and the availability of the data, this paper selects the data of specialist outpatients published by the Macao Bureau of Statistics from 2007 to 2018. The data of outpatients in each specialty represents the data of patients with various common diseases in this area. Therefore, this paper uses the grey prediction model GM (1, 1) to predict the different types of diseases in 11, analyzes its future growth trend, in order to judge the most common diseases, and puts forward reasonable suggestions for the internal structure of public hospitals. The following figure shows that by 2018, the proportion of patients in each department is relatively large. As can be seen from the figure, the current data of visits in internal medicine is relatively large.



Picture3 Common disease structure

4.2.1 Disease Prediction Model based on GM (1, 1) Model

Based on the data of specialist outpatients from 2007 to 2018 and combined with grey prediction model, this paper forecasts the data of outpatients in 11 different departments, so as to predict the development trend of different types of diseases in the past ten years. The following is an explanation of the grey prediction mathematical model:

Make $X^{(0)}$ as GM (1, 1) modeling sequence: $X^{(0)}=(x^{(0)}(1),x^{(0)}(2),...,x^{(0)}(n))$, so $X^{(1)}$ is the 1-AGO sequence of $X^{(0)}$: $X^{(1)}=(x^{(1)}(1),x^{(1)}(2),...,x^{(1)}(n))$.

So we can get:

$$x^{(1)}(k)=\sum_{i=1}^{k}x^{(0)}(i), \quad k=1,2,...,n$$

The following whitening form of differential equation of $X^{(1)}$ can be established, that is, GM (1, 1) model:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b$$

So there is a whitening form of differential equation: $\frac{dx^{(1)}}{dt} + ax^{(1)} = b$, The solution of this equation is also called time response function:

$$\hat{x}^{(1)}(t) = (x^{(1)}(0) - \frac{b}{a})e^{-at} + \frac{b}{a}$$

There is the time response sequence of GM (1,1) Grey Differential Equation:

$$\hat{x}^{(1)}(k+1) = [x^{(1)}(0) - \frac{b}{a}]e^{-ak} + \frac{b}{a}, \quad k = 1,2,\ldots,n$$

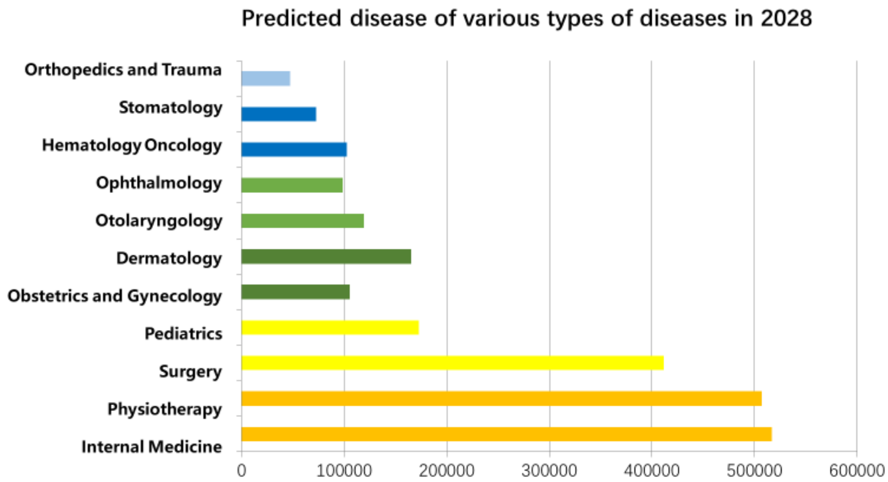
Its restore value is: $\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k)$

4.2.2 Disease Prediction Results based on GM (1, 1) Model

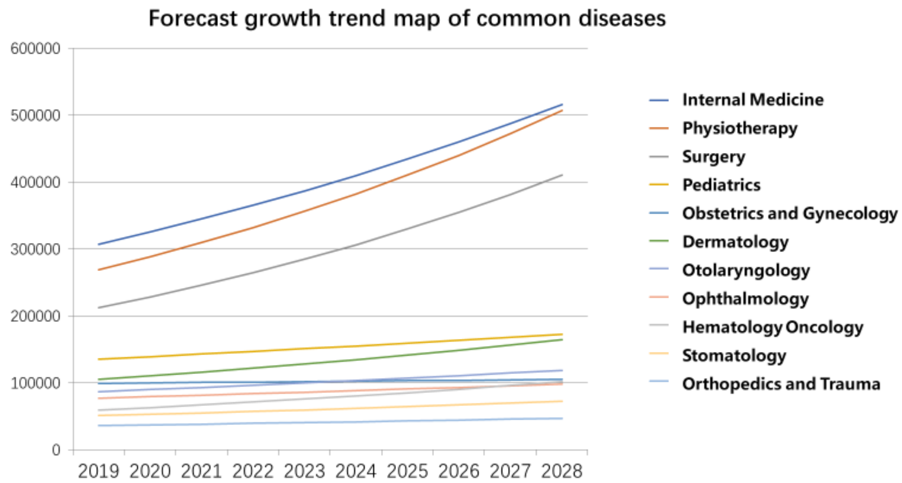
Combined with the data of specialist outpatients and grey prediction models from 2007 to 2018, the development trend of 11 different types of diseases, such as internal medicine diseases, physiotherapy diseases, surgical diseases, pediatrics diseases, obstetrics and gynecology diseases, dermatology diseases, otorhinolaryngology diseases, ophthalmic diseases, hematological oncology diseases, stomatology diseases, orthopaedical diseases and trauma diseases, were obtained in the next 10 years. Then the most common diseases in the future are judged, and reasonable suggestions are put forward for the internal structure of public hospitals.

Picture4 11 types of common disease

The prediction of 11 diseases is carried out by MATLAB, and the outpatient data of 11 common diseases from 2019 to 2028 were obtained. among the grey prediction tests, the prediction accuracy of internal medicine diseases, physiotherapy diseases, surgical diseases, pediatrics diseases, dermatological diseases, otorhinolaryngological diseases, ophthalmic diseases, hematological oncology diseases, stemmatological diseases, orthopedic diseases and trauma diseases was relatively high. However, the accuracy of the test and prediction of obstetrics and gynecology diseases is relatively low, but the overall accuracy test of grey prediction is in accordance with the accuracy test of grey prediction. The forecast values of all kinds of common diseases in 2028 are as follows:



Picture5 Prediction of various types of diseases in 2028



Picture6 Forecast growth trend map of common deseases

Whether from the development trend of various types of diseases or the data of diseases in ten years later, it is not difficult to see that internal medicine, physiotherapy and surgical diseases have the fastest development rate and the largest data of patients. This phenomenon is closely related to the specific symptoms and social development of various departments. From the point of view of diseases in various departments, medical diseases mainly include cold, pneumonia, emphysema, tuberculosis, bronchiectasis, asthma, lung cancer, cor pulmonale, respiratory failure, chronic bronchitis, etc. Physiotherapy diseases include inflammation, tissue injury, functional disorders and so on. Surgical diseases are mainly trauma, infection, tumor, deformity and dysfunction. Compared with pediatrics, obstetrics and gynecology and other departments, these three diseases affect a wide range of people, have a strong recurrence, the possibility of disease is higher, so the data of patients is the largest.

On the other hand, social development also has an impact on the development trend of various types of diseases. First of all, from the point of view of the potential causes of diseases, the decline of atmospheric quality and serious pollution caused by economic development in China have a serious impact on human health, especially the respiratory tract diseases caused by air pollution are the most significant. Secondly, from the point of view of patient group, the change of population structure, especially the deepening of aging degree, the data of common chronic diseases (such as chronic bronchitis, etc.) in the elderly increases year by year, which further promotes the rapid development of physiotherapy department, which is dominated by the course of rehabilitation of chronic diseases.

Based on the above discussion, combined with the future development trend of diseases in various departments, this paper holds that in the construction of medical institutions in the future, we should pay attention to the characteristics of various types of diseases and the changes of medical needs caused by the changes of social environment, such as population structure, reasonably plan medical resources and personnel training, and tilt more resources to medical diseases, physiotherapy and surgical diseases, so as to cope with the future trend of the rapid development of internal medicine and physiotherapy.

4.3 Task three

Under the assumption that different types of patients may need to do different inspections in the hospital, different inspection items may be distributed in different locations and there may be a large gap in the data of people in the queue. We will propose a common queuing theory and its related optimal queuing method for this kind of queuing problem. In order to improve the efficiency of patients in queue examination, this paper solves the problem of excessive queue time in some hospitals by means of queuing theory model. On the basis of the data of the data of outpatients in Macao according to the department of task 2, the scale of visits to different common diseases was analyzed, and the arrival rate of patients in the queuing theory model was determined according to the scale of visits. In order to solve the problem of excessive queuing time, this paper takes the average waiting time in the queuing process as the constraint, and then analyzes the inspection sites that need to be equipped in different types of diseases to improve the inspection efficiency.

4.3.1 Optimal Queuing Model of Medical Inspection based on Queuing Theory

In the model building process, it is assumed that the patients only reach the hospital, the successive arrival time interval is subject to the Poisson distribution of the parameters, the data of out-patient clinics of the macao departments found according to the second problem is analyzed, the treatment scale of the different diseases is analyzed, The arrival rate of different types of patients in the queuing theory model was determined according to the scale of the visit. It is clear that the size of the examination of the internal medical condition is relatively large, so the patientundefineds arrival rate is relatively high. However, the size of the patients with otolaryngology is small, so the arrival rate of the patients is relatively small. Different examinations are required for different types of patients, which are distributed in different sections, for example, in the case of internal medical conditions, to the internal medicine for examination, but the medical condition is likely to be too long due to the large size of the patient. In this paper, by limiting the average waiting time to reduce the patientundefineds waiting time, it is determined that the total data of required s_i inspection sites required for different departments within the limited average waiting time, and the time required for the check of each check point are independent of each other. According to the experience, it is assumed that the average time of each examination for 11 different types of diseases is 15 minutes, and when the patient reaches the hospital, the different treatment scales of different diseases are used as the probability of the different types of diseases of the patient, and therefore, the examination is carried out in different departments. A total of the departments in the department need to check the location, and if the check-in is in the idle period of the inspection, arrange the check immediately, otherwise, they are arranged in a queue for waiting and the waiting time is infinite.

$$\lambda_i = \frac{\lambda_0}{P_0} P_i \quad (i = 1,2,...,10)$$

$$\rho_s = \frac{\rho}{s} = \frac{\lambda_i}{s\mu} \quad (i = 1,2,...,10)$$

λ_i is the arrival rate of patients with different types of diseases, that is, how many patients arrive per minute; λ_0 is the arrival rate of medical diseases set, μ is the examination efficiency of doctors in different types of departments, that is, how many patients can be examined at the checkpoint per minute; ρ is the inspection intensity of the checkpoint.

$$\rho_0 = \left[\sum_{n=0}^{s-1} \frac{\rho^n}{n!} + \frac{\rho^s}{s!(1-\rho_s)} \right]^{-1}$$

$$p_n = \begin{cases} \frac{\rho^n}{n!} p_0, n = 1,2,...,s \\ \frac{\rho^n}{s! s^{n-s}} p_0, n \geq s \end{cases}$$

Make $p_n = P\{N = n\} (n = 0,1,2...)$ the probability distribution of the data of patients waiting in line after the system reaches a steady state. When the data of patients with a particular disease is greater than the checkpoint in the department, the latter patient must wait for the examination, so the probability that the patient will have to wait when he or she arrives in the system is given as follows:

$$c(s,\rho) = \sum_{n=s}^{\infty} p_n = \frac{\rho^s}{s!(1-\rho_s)} p_0$$

The optimization of queuing system means that the objective function is optimized by given a system. The data of doctors in different departments can limit the waiting time of patients to a certain time. However, with the increase of checkpoint, the labor cost and equipment cost will be relatively high. Therefore, different datas of checkpoint are set up for the examination of different types of diseases within a reasonable range, so that the efficiency of inspection can be improved.

$$L_q(s)=\sum_{n=s+1}^{\infty}(n-s)p_n=\frac{p_0\rho^s\rho_s}{s!(1-\rho_s)^2}$$

$$L_s(s)=L_q+\rho$$

$$T_{\min}(s)=\frac{L_s}{s}T_i$$

$$T_i=\frac{1}{\lambda_i}(i=1,2,...,10)$$

It is easy to know that $T_{\min}(s)$ varies with s, so $T_{\min}(s)=T$, using marginal analysis:

$$T_{\min}\Rightarrow\begin{cases}T\left(s^*\right)\leq T(s^*-1)\\ T\left(s^*\right)\leq T(s^*+1)\end{cases}$$

combine $T_{\min}(s)=\frac{L_s}{s}(T_{service}+T_{Drive})$, take $s=1,s=2,s=3,.....$ in turn, when $s=s^*$ satisfies the above constraints, $s=s^*$ is what the model desired.

For the departments with multiple checkpoints, the queue leader L_q can be obtained from the steady distribution. The total data of patients in the department L_s is the patient platoon leader L_q plus the service intensity ρ at the checkpoint. T is the examination time of the patient. Therefore, according to the experience, the setting time range is 15 minutes.

4.3.2 Optimal Queuing Results of Medical Inspection based on Queuing Theory

Based on the queuing theory model and the data of outpatients in Macao departments, this paper establishes the queuing model of each department of the hospital, assuming that the average time of each examination of 11 different types of diseases is 15 minutes. In the queuing model of the internal medicine department, the internal medicine patient reaches one in 5 minutes, that is, the arrival rate λ_0 is 0.2. thus, the queuing model of the internal medicine department is established, and the MATLAB is used to establish the queuing model of the internal medicine department. The software is compiled and solved, and the results are as follows:

$$\lambda_0=0.2$$
$$\mu=0.067$$

Therefore, the service intensity of internal medicine is:

$$\rho_0=\frac{\lambda_0}{\mu}=2.98$$

On this basis, the design scheme of the optimal checkpoint in all types of diseases is obtained, such as Table 5:

Table5 the design scheme of the optimal checkpoint in all diseases

Diseases	s	Lq	Wq<5
Internal Medicine	5	0.34	1.72
Physiotherapy	4	0.6	3.52
Surgical	4	0.17	1.27
Pediatrics	3	0.19	1.98
Obstetrics and Gynecology	2	0.33	4.91
Dermatology	2	0.33	4.91
Otorhinolaryngology	2	0.19	3.32
Ophthalmic	2	0.19	3.32
Hematological oncology	2	0.05	1.31
Stomatology	2	0.02	0.71
Orthopedics and Trauma	2	0.02	0.71

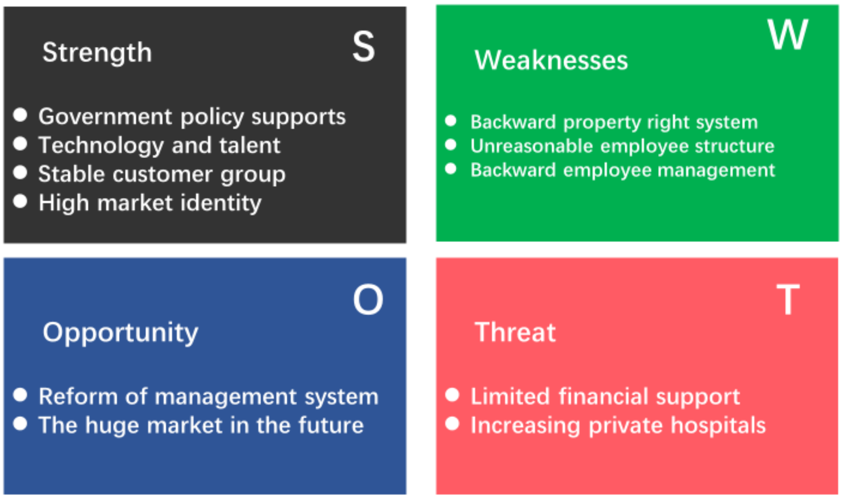
We using the GM (1,1) model to predict the value of each factor in ten years, and combined with multiple regression to solve the development trend of urban and rural residents' medical needs in ten years. It is not difficult to see from the figure that rural and urban areas still have a certain gap in the development process. However, with the increasing urbanization rate, the number of rural residents is decreasing. Therefore, even if this gap exists, it will also have an overall medical need for China. The impact of development is small. In addition, the slope of the medical need development curve has an increasing trend after 2025. Combined with the development trend of aging in China and the development of medical pension industry, it can be reasonably speculated that the phenomenon of accelerated growth of medical needs is closely related to aging.

4.4 Task Four

Task 4 requires us make the optimal cooperation and competition strategy between multiple hospitals under this background that there is complex competition and cooperation between multiple hospitals. In order to solve this problem, this paper first makes the SWOT analysis of the hospitals with the help of actual operation of various types of hospitals and related research literature, and then puts forward competitive and cooperative strategies from the aspects of talent, technology, resources.

In the process of public hospital management, its government background and long development history provide it with the support of policy resources and the advantages of talent and technology. However, the national background of public hospitals makes the problems of unclear property rights, unknown responsibilities and unscientific management. There is a lack of medical staff and the redundancy of administrative logistics employee in the staffing establishment, which all restrict the further development of the hospital. And with the in-depth development of medical system reform, the backward property right system and personnel system of public hospitals have been improved and developed. Also, the national strategy of "Healthy China" has promoted the diversification of national medical needs and the improvement of quality. However, the limited government funds and the increasing number of private hospitals have led to the reduction of the technological advantage of talents in public hospitals, and the market space has been squeezed.

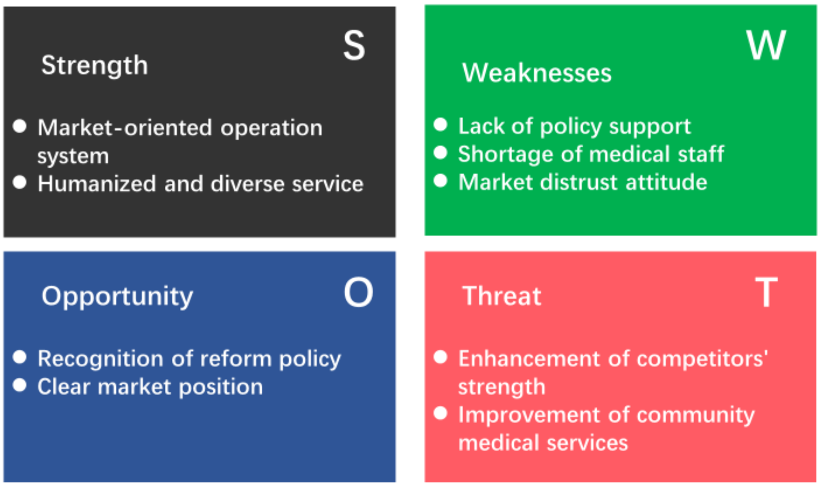
Based on the above analysis, we can get the SWTO analysis chart, as shown below:



Picture7 The SWTO analysis chart of public hospital

Private hospital isn't a medical and health institution sponsored by the government. Its market-oriented operation mechanism improves the efficiency of talent management system and management system. In terms of disadvantage, they lack policy support in the process of operation, so they are facing great economic pressure. Because of the unreasonable charge in some hospitals, the market has a distrustful attitude towards this type of hospital.

From the point of view of development opportunities, with the development of the new medical reform system, the private hospitals' advanced and diversified service characteristics are clearer. However, the reform of the health care system has also enhanced the operational efficiency and strength of the competitors of public hospitals, and the market share of private hospitals is threatened. In addition, the improvement of community medical and health services also hinders the development of private hospitals.



Picture8 The SWTO analysis chart of private hospital

Based on the SWOT analysis of public hospitals and private hospitals, this paper believes that both have advantages and disadvantages in the development process. In order to better play their respective functions, the two must develop a competitive cooperation strategy in terms of management systems, talents, technology, and medical resources. The following explains the details of the competition cooperation strategy:

(1) Establish a two-way referral system

Because some diseases are contagious and seasonal, the number of patients in public hospitals will increase rapidly during a certain period of time. This phenomenon puts pressure on the operation and management of public hospitals. By establishing a referral system, some patients can be transferred to other private hospitals during peak hours. On the one hand, this measure alleviates the pressure on managing hospitals, and on the other hand, it fully utilized the idle medical resources of private hospitals.

(2) Conducting talent exchange and training

Compared with private hospitals, public hospitals have medical staff with rich experience whose professional skills are strong. Public hospitals can hold regular lectures, seminars and other activities to promote the exchange of talents between different types of hospitals, it also can enhance the professional skills of private hospitals, raise medical quality and solve the lack of talent. On the other hand, public hospitals can introduce management teams of private hospitals to help manage hospitals to improve operational management efficiency.

(3) Promote the sharing of medical resources and technology

Public hospitals and private hospitals can deepen cooperation, promote the sharing of medical resources and technology. They also can rationally plan and allocate medical resources of cooperative hospitals, which can promote the rational use of idle resources. For example, public hospitals can provide large-scale medical equipment inspections such as nuclear magnetic resonance for private hospitals, achieving public and private hospital resource sharing.

4.5 Suggestions for Plan of Medical and Health Care

Based on the study of the development trend of medical needs in China, this paper puts forward the following suggestions for the 14th five-year Plan of Medical and Health Care in China: First, to establish a basic medical and health system covering urban and rural residents, so as to alleviate the problem of difficult and expensive medical treatment. Second, in view of the difference of medical needs between urban and rural areas, we should reasonably plan the allocation of medical resources and narrow the gap between urban and rural areas. Third, face the trend of aging development, promote the integration and development of medical industry and pension industry, and improve the medical security system for the elderly. Finally, it is necessary to coordinate the medical resources of public hospitals and private medical institutions, establish an effective medical operation system, and improve the efficiency of medical and health services. In the future trend of national health development, internal medicine, physical therapy diseases, and surgical diseases are large in scale. Therefore, medical resources should be rationally adjusted, and medical personnel should be trained to make more resources for the future common diseases

(1) Promote the full coverage of the basic medical system

Establishing a basic medical and health system covering urban and rural residents are necessary. On the basis of completing the basic medical system covering urban and rural residents, we will further implement the public welfare of medical needs to realize everyone access to basic medical and health services. In order to alleviate the problem of expensive medicine, the standard of basic medical subsidy should be raised. And more essential drugs should be included in the medical insurance drug reimbursement catalogue.

(2) Reasonable planning of medical resources allocation and narrowing of the gap between urban and rural areas

In order to solve the problem of large differences in medical expenses burden between urban area and rural area, we should reasonably plan the allocation of medical resources and narrow the gap between urban and rural areas. In the aspect of rural areas, we should attach importance to the development of township health centers and village hospitals. The ability of primary medical services should be improved to release the medical needs of rural residents. In the aspect of city, the layout of community hospital should be planned reasonably and the role of community health service organization should be brought into play.

(3) Promote the health care system of the old people

In view of the increasing proportion of the old people, we should promote the further development of the health care system of the old people. It is necessary to promote the integration of the old-age industry and the medical industry to combine the medical resources with the old-age resources and alleviate the old-age medical problem.

(4) Reasonably planning the medical resources and building a high-efficiency medical operation system

There is a competitive and cooperative relationship between public hospitals and private medical institutions in the construction of an efficient medical operation system. The government should play an important role in these medical resources. While making public hospitals play the role of improving the medical level and meeting the basic medical needs, private medical institutions should play the role of alleviating the peak medical needs and meeting the areas not covered by public hospitals.

(5) Reasonable Planning and allocation of Medical Resources and training of medical talents

In the future development of national health in our country, the proportion of demand between internal medicine and physiotherapy is the largest and the fastest. In the face of the diversified medical needs of the people, medical resources should be rationally adjusted and medical personnel should be trained to meet future medical needs.

5.Strengths and Weakness

The development of a country's aging has complex causes, and the introduction of gray prediction models reflects the rigor and comprehensiveness of the modeling process. Combining China's special national conditions, we will consider the development of China's medical needs from the perspectives of urban and rural areas. While considering the comprehensive problem, we use multi-regression model to explore the specific mechanisms affecting China's medical needs. Therefore, the policy opinions we proposed are more realistic.

Due to the availability of data and the intuitiveness of the results, this paper uses the number of visits in various departments of Macao hospitals as research data. It also uses the gray prediction model to study the future development trend of various departments. This prediction results are accurate and reliable. However, due to the lack of data on the number of patients with various types of diseases, this article cannot further explore the development trend of specific diseases.

Using the queuing theory model we get the optimal number of services in each department, that is, the number of doctors on duty. This result has practical significance for hospitals to coordinate medical personnel to meet patient needs. However, the lack of relevant data such as the daily change in the number of hospital visits leads to poor accuracy of the model solution. Therefore, we are unable to carry out further planning and coordination of the doctors' duty time in each department.

We use the SWOT theoretical model and analyze the public and private hospitals in combination with the actual situation. And on this basis, the competition cooperation strategy is proposed, so we consider the issue to be more comprehensive. Similarly, due to the lack of data, the game model for establishing a competitive cooperation model is not feasible. Therefore, we only conduct qualitative analysis, which is highly subjective.

This paper puts forward the opinions of the 14th Five-Year Plan of China's medical management departments from the perspective of urban-rural differences and resource pooling of public private hospitals. The rational model established in the previous article provides reliable evidence for the submission of opinions.

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Appendix

Task 1

Aging trend

year	2004	2005	2006	2007	2008	2009	2010	2011
	7.6	7.7	7.9	8.1	8.3	8.5	8.9	9.1
year	2012	2013	2014	2015	2016	2017	2018	
	9.4	9.7	10.1	10.46544	10.8	11.4	11.9	
year	2019	2020	2021	2022	2023			
	12.06%	12.47%	12.90%	13.34%	13.80%			
year	2024	2025	2026	2027	2028			
	14.28%	14.77%	15.27%	15.80%	16.34%			

Linear regression analysis results

constant	-7.106	0.941	-7.555	0.001
Data of people enrolled at the end of the basic medical insurance	0.208	0.17	1.223	0.276
Per capita disposable income of rural residents	1.45	0.679	2.134	0.086
Minimum living security for rural residents	-0.229	0.065	-3.521	0.017
Proportion of population over 65 years of age	-0.575	2.345	-0.245	0.816
Gross domestic product (GDP)	0.157	0.238	0.66	0.538

Mmedical needs of urban area

	y1	x1	x2	x3	x4	x5	x6
2004	1261.93	8880	41.76	15920	7.6	143657.8	12403.6
2005	1126.36	9832	42.99	18200	7.7	187318.9	13782.9
2006	1248.3	10739	44.34	20856	7.9	211147.7	15731.8
2007	1516.29	12480	45.89	24721	8.1	241195.8	22311.1024
2008	1861.76	14061	46.99	28898	8.3	264472.8	31821.627
2009	2176.63	15127	48.34	32244	8.5	289329.9	40146.9728
2010	2315.48	17103.53974	49.95	36539	8.9	413030.3	43262.9442
2011	2697.48	19911.74913	51.27	41799	9.1	452429.9	47343.2277
2012	2999.28	21861.23557	52.57	46769	9.4	487976.2	53641.2673
2013	3234.12	23608.95619	53.73	51483	9.7	525835.4	57072.5729
2014	3558.31045	25424.23112	54.77	56360	10.1	564194.4	59746.9241

	y1	x1	x2	x3	x4	x5	x6
2015	3866.253703	29141	56.7787	65600	10.0095	680000	76670

2016	4360.16135	32399	58.3345	73980	10.3168	769700	87610
2017	4916.715885	36022	59.933	83430	10.6336	871400	100100
2018	5542.190694	40050	61.5752	94100	10.9601	986500	114380
2019	6250.280516	44528	63.2625	106120	11.2966	1116700	130700
2020	7076.996126	49608	64.996	119690	11.6435	1264200	149340
2021	7945.753389	55044	66.777	134980	12.001	1431200	170650
2022	8956.904881	61199	68.6068	152240	12.3694	1620200	194990
2023	11044.11421	68042	70.4867	171690	13.1407	1834100	222800
2024	12450.97587	75650	72.4181	193640	13.5442	2076300	254590
	u	0.0213	0.0044	0.0297	0.0054	0.0658	0.1645
	a	65.88%	63.17%	59.33%	62.69%	59.17%	54.45%
	c	1	1	1	1	1	1.00%
	p	0.0814549	0.059315	0.07574	0.0676444	0.181799	0.262291

Mmedical needs of Rural area

	y1	x1	x2	x3	x4	x5
2004	301.61	12403.6	2936.4	488	7.6	143657.8
2005	315.83	13782.9	3254.92963	825	7.7	187318.9
2006	361.89	15731.8	3587.04	1593.1	7.9	211147.7
2007	358.11	22311.1024	4140.4	3566.3	8.1	241195.8
2008	455.19	31821.627	4760.62	4305.5	8.3	264472.8
2009	561.99	40146.9728	5153.17	4760	8.5	289329.9
2010	666.3	43262.9442	5919.01	5214	8.9	413030.3
2011	879.44	47343.2277	6977.29	5305.7	9.1	452429.9
2012	1064.83	53641.2673	7916.58049	5344.5	9.4	487976.2
2013	1274.44	57072.5729	8747.1344	5388.02	9.7	525835.4
2014	1412.21336	59746.9241	9698.19557	5207.2404	10.1	564194.4

	y1	x1	x2	x3	x4	x5
2015	1814.776511	76670	11146	6954	10.0095	680000
2016	2187.857203	87610	12612	7656	10.3168	769700
2017	2637.95249	100100	14272	8429	10.6336	871400
2018	3180.468419	114380	16150	9281	10.9601	986500
2019	3834.88801	130700	18276	10218	11.2966	1116700
2020	4623.638659	149340	20681	11250	11.6435	1264200
2021	5574.578606	170650	23402	12386	12.001	1431200
2022	6721.339098	194990	26482	13637	12.3694	1620200
2023	7963.976715	222800	29967	15015	13.1407	1834100
2024	9602.363484	254590	33911	16531	13.5442	2076300
	u	0.1645	0.0162	0.4096	0.0054	0.0658
	a	54.45%	62.58%	60.85%	62.69%	59.17%
	c	1	1	0.909091	1	1
	p	0.262291	0.0529489	0.49265	0.0676444	0.181799

Task 2

year	1	2	3	4	5	6
2009	175379	124811	104549	94515	91107	62949
2010	178068	146499	114415	103199	89196	69245
2011	192376	157825	123302	113458	96560	72815
2012	223579	160257	123569	115032	100132	75003
2013	212108	180832	129762	112698	96509	77771
2014	216212	183397	141524	114935	102566	82173
2015	234100	216054	157057	124870	97917	85066
2016	279804	216312	174511	127937	95070	88769
2017	276412	233848	188546	126143	94530	97699
2018	284870	247041	197020	132331	99118	101268
r	64.54%	64.37%	55.72%	51.08%	62.20%	55.85%
p	1	1	1	1	0.545455	1
c	0.261661	0.132302	0.134198	0.251827	0.879798	0.112064
a	0.0372	0.0288	0.0291	0.0237	0.0292	0.0159
2019	307666.9538	269330.1614	212587.2833	135775.1168	99630.5203	105587.6546
2020	325911.5867	288947.8979	228763.6055	139483.2234	100256.8144	110943.3241
2021	345238.1253	309994.5704	246170.8263	143292.6009	100887.0454	116570.6466
2022	365710.7265	332574.2613	264902.608	147206.0148	101521.2382	122483.4008
2023	387397.3518	356798.634	285059.74	151226.3067	102159.4176	128696.0648
2024	410369.9928	382787.4855	306750.6809	155356.3953	102801.6088	135223.8506
2025	434704.91	410669.3386	330092.1421	159599.2794	103447.8368	142082.742
2026	460482.8865	440582.0777	355209.7162	163958.0393	104098.1272	149289.5334
2027	487789.4955	472673.6305	382238.5521	168435.8399	104752.5054	156861.8714
2028	516715.3849	507102.6995	411324.0828	173035.932	105410.9971	164818.2972
	7	8	9	10	11	
2009	57696	59604	34732	36005	26222	
2010	60312	61709	35497	35531	26459	
2011	65476	63858	37151	37084	29689	
2012	70516	64360	38384	36108	29955	
2013	73192	64734	41391	42825	30167	
2014	74715	66947	45116	44033	31347	
2015	76083	68563	44560	47042	32540	
2016	78623	69616	50086	45305	33569	
2017	78896	73665	52068	47987	33574	
2018	84289	78042	58915	47715	35281	
r	67.02%	64.51%	65.89%	60.69%	68.39%	
p	1	1	1	0.909091	1	
c	0.216995	0.223838	0.165342	0.347309	0.216399	
a	0.0205	0.0151	0.0242	0.0362	0.0165	
2019	87155.98539	77535.55009	59854.88525	51496.84655	36338.82198	

2020	90233.13024	79643.31703	63537.01993	53508.40286	37439.09718	
2021	93418.91732	81808.38261	67445.67106	55598.53406	38572.68676	
2022	96717.18237	84032.30446	71594.7734	57770.30941	39740.59943	
2023	100131.8966	86316.68257	75999.11896	60026.91808	40943.87442	
2024	103667.1713	88663.1604	80674.40972	62371.67381	42183.58245	
2025	107327.263	91073.42612	85637.3136	64808.01977	43460.82665	
2026	111116.5786	93549.21375	90905.52389	67339.53364	44776.74353	
2027	115039.6804	96092.3045	96497.82234	69969.93284	46132.50405	
2028	119101.292	98704.52795	102434.1461	72703.08	47529.3146	

Code

Q1：

```
function [px0,rel_err,r,e0]=gm11_A1(x0,number)
%[px0,ab,rel]=gm11(x0,number)

x0=[7.6,7.7,7.9,8.1,8.3,8.5,8.9,9.1,9.4,9.7,10.1,10.465,10.8,11.4,11.9];

if nargin==1
number=max(size(x0));
end

n=max(size(x0));
x1=zeros(size(x0));
for k=1:n
for i=1:k
x1(k)=x1(k)+x0(i);
end
end
z=zeros(size(x0));
for k=2:n
z(k)=0.5*(x1(k)+x1(k-1));
end
y=x0';
y(1)=[];
B(:,1)=-z';
B(:,2)=1;
B(1,:)=[];
ab=inv(B'*B)*B'*y;
a=ab(1);
b=ab(2);
px0(1)=x0(1);
X1(1)=x0(1);
n = n + 9;
for k=1:n
X1(k+1)=(x0(1)-b/a)*exp(-(a)*k)+b/a;
end
px0(1)=x0(1);
for k=1:n
```

```
px0(k+1)=X1(k+1)-X1(k);
end
disp('1');
disp(px0(2:n+1));
n = n - 9;
for k=1:n
e0(k)=px0(k)-x0(k);
end
epsilon=e0./x0;
epsilon=abs(epsilon);
rel_err=sum(epsilon)/(n-1);
disp(rel_err);
p=0.5;
max_err=max(abs(e0));
r=0;
for k=1:n
r=r+p*max_err/(abs(e0(k))+p*max_err);
end
r=r/n;
str = sprintf( ' %g%% ',r*100);
disp(str);

aver_e0=sum(e0)/n;
aver_x0=sum(x0)/n;
s1=sqrt(sum((x0-aver_x0).^2)/n);
s2=sqrt(sum((e0-aver_e0).^2)/n);
c=s2/s1;
s0=0.6745*s1;
m=0;
for k=1:n
if abs(e0(k)-aver_e0)<s0
m=m+1;
end
end
P=m/n;
str = sprintf( ' p=%g c=%g ',P,c);
disp(str);
if P>0.95&c<0.35
disp('good');
else if P>0.8&c<0.5
disp('agree');
else if P>0.7&c<0.65
disp('pass');
else disp('don’t pass');
end
end
end
fprintf('\n');
end
```

Q2：

```
function [px0,rel_err,r,e0]=gm11_A2(x0,number)
%[px0,ab,rel]=gm11(x0,number)
x11=[180229,175379,178068,192376,223579,212108,216212,234100,279804,276412,2
84870];%
x22=[106040,124811,146499,157825,160257,180832,183397,216054,216312,233848,2
47041];%
x33=[107308,104549,114415,123302,123569,129762,141524,157057,174511,188546,1
97020];%
x44=[94515,103199,113458,115032,112698,114935,124870,127937,126143,132331];%
x55=[94366,91107,89196,96560,100132,96509,102566,97917,95070,94530,99118];%
x66=[63088,62949,69245,72815,75003,77771,82173,85066,88769,97699,101268];%
x77=[57696,60312,65476,70516,73192,74715,76083,78623,78896,84289];%
x88=[60141,59604,61709,63858,64360,64734,66947,68563,69616,73665,78042];%
x99=[31455,34732,35497,37151,38384,41391,45116,44560,50086,52068,58915];%
x100=[38459,36005,35531,37084,36108,42825,44033,47042,45305,47987,47715];%
x111=[26222,26459,29689,29955,30167,31347,32540,33569,33574,35281];%
for T = 1:11

x11=[180229,175379,178068,192376,223579,212108,216212,234100,279804,276412,2
84870];
x22=[106040,124811,146499,157825,160257,180832,183397,216054,216312,233848,2
47041];
x33=[107308,104549,114415,123302,123569,129762,141524,157057,174511,188546,1
97020];
x44=[94515,103199,113458,115032,112698,114935,124870,127937,126143,132331];
x55=[94366,91107,89196,96560,100132,96509,102566,97917,95070,94530,99118];
x66=[63088,62949,69245,72815,75003,77771,82173,85066,88769,97699,101268];
x77=[57696,60312,65476,70516,73192,74715,76083,78623,78896,84289];
x88=[60141,59604,61709,63858,64360,64734,66947,68563,69616,73665,78042];%
x99=[31455,34732,35497,37151,38384,41391,45116,44560,50086,52068,58915];%
x100=[38459,36005,35531,37084,36108,42825,44033,47042,45305,47987,47715];%
x111=[26222,26459,29689,29955,30167,31347,32540,33569,33574,35281];%
if T == 1
    x0=zeros(size(x11));
    fprintf('1\n');
    x0 = x11;
end
if T == 2
    x0=zeros(size(x22));
    fprintf('2\n');
    x0 = x22;
end
if T==3
    x0=zeros(size(x33));
    fprintf('3\n');
    x0 = x33;
end
```

```
if T==4
    x0=zeros(size(x44));
    fprintf('4\n');
    x0 = x44;
end
if T==5
    x0=zeros(size(x55));
    fprintf('5\n');
    x0 = x55;
end
if T==6
    x0=zeros(size(x66));
    fprintf('6\n');
    x0 = x66;
end
if T==7
    x0=zeros(size(x77));
    fprintf('7\n');
    x0 = x77;
end
if T==8
    x0=zeros(size(x88));
    fprintf('8\n');
    x0 = x88;
end
if T==9
    x0=zeros(size(x99));
    fprintf('9\n');
    x0 = x99;
end
if T==10
    x0=zeros(size(x100));
    fprintf('10\n');
    x0 = x100;
end
if T==11
    x0=zeros(size(x111));
    fprintf('11\n');
    x0 = x111;
end

if nargin==1
number=max(size(x0));
end

n=max(size(x0));
x1=zeros(size(x0));
for k=1:n
for i=1:k
```

```
x1(k)=x1(k)+x0(i);
end
end
z=zeros(size(x0));
for k=2:n
z(k)=0.5*(x1(k)+x1(k-1));
end
y=x0';
y(1)=[];
B(:,1)=-z';
B(:,2)=1;
B(1,:)=[];
ab=inv(B'*B)*B'*y;
a=ab(1);
b=ab(2);
px0(1)=x0(1);
X1(1)=x0(1);
n = n + 9;
for k=1:n
X1(k+1)=(x0(1)-b/a)*exp(-(a)*k)+b/a;
end
px0(1)=x0(1);
for k=1:n
px0(k+1)=X1(k+1)-X1(k);
end

disp(px0(2:n+1));
n = n - 9;
for k=1:n
e0(k)=px0(k)-x0(k);
end
epsilon=e0./x0;
epsilon=abs(epsilon);
rel_err=sum(epsilon)/(n-1);
disp(rel_err);

p=0.5;
max_err=max(abs(e0));
r=0;
for k=1:n
r=r+p*max_err/(abs(e0(k))+p*max_err);
end
r=r/n;
str = sprintf( ' %g%% ',r*100);
disp(str);

aver_e0=sum(e0)/n;
aver_x0=sum(x0)/n;
s1=sqrt(sum((x0-aver_x0).^2)/n);
```

```
s2=sqrt(sum((e0-aver_e0).^2)/n);
c=s2/s1;
s0=0.6745*s1;
m=0;
for k=1:n
if abs(e0(k)-aver_e0)<s0
m=m+1;
end
end
P=m/n;
str = sprintf( ' p=%g c=%g ',P,c);
disp(str);
if P>0.95&c<0.35
disp('good');
else if P>0.8&c<0.5
disp('agree');
else if P>0.7&c<0.65
disp('pass');
else disp('don’t pass');
end
end
end
fprintf('\n');
clear all;
end
clear all;
end
```

Q3：

```
#include<stdio.h>
#include<math.h>
int main()
{
	float arr_lambda[11];
	int i;
	arr_lambda[0] = 0.2; //内科到达率
	float hospital[11] = {0.21,0.18,0.14,0.1,0.07,0.07,0.06,0.06,0.04,0.03,0.03};
	for(i = 1;i<=10;i++){
		arr_lambda[i] = (arr_lambda[0] / 0.21) * hospital[i];
		printf("%f\n",arr_lambda[i]);
	}
}
```

```
function[num,Lq , L , W , Wq] = A_3(s , mu , lambda)
clc;
ii =9;
ss=[1,2,3,4,5,6,7,8];
arr_lambda =
[0.2,0.171429,0.13333,0.095238,0.066667,0.066667,0.057143,0.057143,0.038095,0.028
```

```
571,0.028571];
for iii = 1:11
	lambda = arr_lambda(iii);
	fprintf(' %f',iii);
for i = 1:8
	s = ss(i);
  mu=0.067;

ro=lambda/mu;
ros=ro/s;
sum1=0;

for j=0:(s-1)
	sum1=sum1+ro.^j/factorial(j);
end

sum2=ro.^s/factorial(s)/(1-ros);

p0=1/(sum1+sum2);
p=ro.^s.*p0/factorial(s)/(1-ros);
Lq=p.*ros/(1-ros);
L=Lq+ro;
W=L/lambda;
Wq=Lq/lambda;
if   (Wq>0) &&(Wq<5)

	if (s<ii)
		fprintf(' %d\n',s)
		fprintf(' %5.2f \n',L)
		fprintf(' %5.2f \n',Lq)
		fprintf(' \n',W)
		fprintf(' \n',Wq)
	end
	ii = s;
else
	fprintf(';')
end
fprintf('\n')
end
end
```

Q city

```
function [px0,rel_err,r,e0]=gm11_A2(x0,number)
%[px0,ab,rel]=gm11(x0,number)
clc

x11=[8880
```

```
9832
10739
12480
14061
15127
17103.53974
19911.74913
21861.23557
23608.95619
25424.23112
];
x22=[41.76
42.99
44.34
45.89
46.99
48.34
49.95
51.27
52.57
53.73
54.77
];
x33=[15920
18200
20856
24721
28898
32244
36539
41799
46769
51483
56360
];
x44=[7.6
7.7
7.9
8.1
8.3
8.5
8.9
9.1
9.4
9.7
10.1
];
x55=[12403.6
13782.9
```

```
15731.8
22311.1024
31821.627
40146.9728
43262.9442
47343.2277
53641.2673
57072.5729
59746.9241
];

for T = 1:5
    x11=[8880
9832
10739
12480
14061
15127
17103.53974
19911.74913
21861.23557
23608.95619
25424.23112
];
x22=[41.76
42.99
44.34
45.89
46.99
48.34
49.95
51.27
52.57
53.73
54.77
];
x33=[15920
18200
20856
24721
28898
32244
36539
41799
46769
51483
56360
];
x44=[7.6
```

```
7.7
7.9
8.1
8.3
8.5
8.9
9.1
9.4
9.7
10.1
];
x55=[12403.6
13782.9
15731.8
22311.1024
31821.627
40146.9728
43262.9442
47343.2277
53641.2673
57072.5729
59746.9241
];
if T == 1
    x0=zeros(size(x11'));
    fprintf('1\n');
    x0 = x11';
end
if T == 2
    x0=zeros(size(x22'));
    fprintf('2\n');
    x0 = x22';
end
if T==3
    x0=zeros(size(x33'));
    fprintf('3\n');
    x0 = x33';
end
if T==4
    x0=zeros(size(x44'));
    fprintf('4\n');
    x0 = x44';
end
if T==5
    x0=zeros(size(x55'));
    fprintf('5\n');
    x0 = x55';
end
```

```
if nargin==1
number=max(size(x0));
end

n=max(size(x0));
x1=zeros(size(x0));
for k=1:n
for i=1:k
x1(k)=x1(k)+x0(i); %
end
end
z=zeros(size(x0));
for k=2:n
z(k)=0.5*(x1(k)+x1(k-1)); %
end
y=x0';
y(1)=[];
B(:,1)=-z';
B(:,2)=1;
B(1,:)=[];
ab=inv(B'*B)*B'*y; %
a=ab(1);
b=ab(2);
px0(1)=x0(1);

X1(1)=x0(1);
n = n + 9;
for k=1:n
X1(k+1)=(x0(1)-b/a)*exp(-(a)*k)+b/a;
end

px0(1)=x0(1);
for k=1:n
px0(k+1)=X1(k+1)-X1(k);
end
disp('');
disp(px0(2:n+1));

n = n - 9;
for k=1:n
e0(k)=px0(k)-x0(k);
end
epsilon=e0./x0;
epsilon=abs(epsilon);
rel_err=sum(epsilon)/(n-1);
disp(rel_err);
```

```
p=0.5;
max_err=max(abs(e0));
r=0;
for k=1:n
r=r+p*max_err/(abs(e0(k))+p*max_err);
end
r=r/n;
str = sprintf( ' %g%% ',r*100);
disp(str);


aver_e0=sum(e0)/n;
aver_x0=sum(x0)/n;
s1=sqrt(sum((x0-aver_x0).^2)/n);
s2=sqrt(sum((e0-aver_e0).^2)/n);
c=s2/s1;
s0=0.6745*s1;
m=0;
for k=1:n
if abs(e0(k)-aver_e0)<s0
m=m+1;
end
end
P=m/n;
str = sprintf( ' p=%g    c=%g ',P,c);
disp(str);
if P>0.95&c<0.35
disp('good');
else if P>0.8&c<0.5
disp('agree');
else if P>0.7&c<0.65
disp('pass');
else disp('don't pass');
end
end
end
fprintf('\n');
clear all;
end
clear all;
end
```

Qcountryside

```
function [px0,rel_err,r,e0]=gm11_Acontryside(x0,number)
%[px0,ab,rel]=gm11(x0,number)

x11=[12403.6
```

```
13782.9
15731.8
22311.1024
31821.627
40146.9728
43262.9442
47343.2277
53641.2673
57072.5729
59746.9241
];
x22=[2936.4
3254.92963
3587.04
4140.4
4760.62
5153.17
5919.01
6977.29
7916.58049
8747.1344
9698.19557
];
x33=[488
825
1593.1
3566.3
4305.5
4760
5214
5305.7
5344.5
5388.02
5207.2404
];
x44=[7.6
7.7
7.9
8.1
8.3
8.5
8.9
9.1
9.4
9.7
10.1
];
x55=[143657.8
187318.9
```

```
211147.7
241195.8
264472.8
289329.9
413030.3
452429.9
487976.2
525835.4
564194.4
];

for T = 1:5
    x11=[12403.6
13782.9
15731.8
22311.1024
31821.627
40146.9728
43262.9442
47343.2277
53641.2673
57072.5729
59746.9241
];
x22=[2936.4
3254.92963
3587.04
4140.4
4760.62
5153.17
5919.01
6977.29
7916.58049
8747.1344
9698.19557
];
x33=[488
825
1593.1
3566.3
4305.5
4760
5214
5305.7
5344.5
5388.02
5207.2404
];
x44=[7.6
```

```
7.7
7.9
8.1
8.3
8.5
8.9
9.1
9.4
9.7
10.1
];
x55=[143657.8
187318.9
211147.7
241195.8
264472.8
289329.9
413030.3
452429.9
487976.2
525835.4
564194.4
];
if T == 1
    x0=zeros(size(x11'));
    fprintf('1\n');
    x0 = x11';
end
if T == 2
    x0=zeros(size(x22'));
    fprintf('2\n');
    x0 = x22';
end
if T==3
    x0=zeros(size(x33'));
    fprintf('3\n');
    x0 = x33';
end
if T==4
    x0=zeros(size(x44'));
    fprintf('4\n');
    x0 = x44';
end
if T==5
    x0=zeros(size(x55'));
    fprintf('5\n');
    x0 = x55';
end
```

```
if nargin==1
number=max(size(x0));
end

n=max(size(x0));
x1=zeros(size(x0));
for k=1:n
for i=1:k
x1(k)=x1(k)+x0(i);
end
end
z=zeros(size(x0));
for k=2:n
z(k)=0.5*(x1(k)+x1(k-1));
end
y=x0';
y(1)=[];
B(:,1)=-z';
B(:,2)=1;
B(1,:)=[];
ab=inv(B'*B)*B'*y;
a=ab(1);
b=ab(2);
px0(1)=x0(1);

X1(1)=x0(1);
n = n + 9;
for k=1:n
X1(k+1)=(x0(1)-b/a)*exp(-(a)*k)+b/a;
end

px0(1)=x0(1);
for k=1:n
px0(k+1)=X1(k+1)-X1(k);
end

disp(px0(2:n+1));

n = n - 9;
for k=1:n
e0(k)=px0(k)-x0(k);
end
epsilon=e0./x0;
epsilon=abs(epsilon);
rel_err=sum(epsilon)/(n-1);
disp(rel_err);
```

```
p=0.5;
max_err=max(abs(e0));
r=0;
for k=1:n
r=r+p*max_err/(abs(e0(k))+p*max_err);
end
r=r/n;
str = sprintf( ' %g%% ',r*100);
disp(str);


aver_e0=sum(e0)/n;
aver_x0=sum(x0)/n;
s1=sqrt(sum((x0-aver_x0).^2)/n);
s2=sqrt(sum((e0-aver_e0).^2)/n);
c=s2/s1;
s0=0.6745*s1;
m=0;
for k=1:n
if abs(e0(k)-aver_e0)<s0
m=m+1;
end
end
P=m/n;
str = sprintf( ' p=%g c=%g ',P,c);
disp(str);
if P>0.95&c<0.35
disp('good');
else if P>0.8&c<0.5
disp('agree');
else if P>0.7&c<0.65
disp('pass');
else disp('don't pass');
end
end
end
fprintf('\n');
clear all;
end
clear all;
end
```