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Research on The Spatial Heterogeneity of National Physical and Mental Health in China Based on Numerical Simulation

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Abstract: - Studying the spatial interactions between socio-economic and natural (SEN) factors and physical health (PF) can help improve national physical and mental health and develop health policies. In order to deeply analyze the relationship between social and economic environment, sports activities, and national physical and mental health, and improve the level of national physical and mental health, this study used mathematical numerical analysis methods using MATLAB and ArcGIS software to determine the determining factors of PF differences in China. The reported National Fitness Composite Index (NFCI) in China was extracted from the National Physical and Mental Health Fitness Monitoring Bulletin in 2015. The SEN factors were gathered from the China Statistical Yearbook in 2015. The OLS model and GWR model were then utilized to investigate the SEN factors of the NFCI. We found that the NFCI of each province had a strong relationship with the natural environment. The NFCI of the eastern coastal regions was higher but also similar to that of the central and western regions. It was also found that the impact of the natural environment on national physical and mental health fitness was greater than that of social and economic factors. Temperature and hours of sunshine were major environmental factors. Annual hours of sunshine (ANNsun, hours), health care expenditure (HEAexpe, Chinese yuan), annual temperature (ANNtem, °C), road distance (ROAdis, kilometers) and annual rainfall (ANNrai, millimeters)are socioeconomic and natural (SEN) determinants of factors and physical fitness (PF). We should increase physical exercise, change our concepts of health, develop a healthy lifestyle and improve our physical fitness in accordance with the national fitness strategy. The regression coefficients obtained by the GWR model show significant differences, indicating that the degree of influence of social, economic, and natural factors on national physical fitness varies significantly with geographical regions..

Keywords: Mathematical Numerical Analysis Methods, National Fitness Composite Index (NFCI), Ordinary Least Squares (OLS), Geographically Weighted Regression (GWR), Spatial Heterogeneity, China..

I. INTRODUCTION

An increasing number of studies have examined the relationship between socioeconomic and natural (SEN) and physical fitness (PF). Factors that influence or determine PF include personal, social, organizational, environmental and policy factors. In recent decades, with the rapid economic development of China, people's nutrition levels have improved [1,2], and the effects of socioeconomic factors on PF have begun to decrease; the effects of natural factors have played a leading role [3-7]. Many studies have found that the physical quality of adolescents is influenced by social, behavioral, environmental and psychological factors that will continue into adulthood [8-11].

People living in rural and remote areas generally have higher rates of mortality and chronic disease than people living in urban areas [12,13]. A growing body of literature has documented the relationship between socioeconomic position in individuals and residential areas and a wide range of health conditions, including cardiometabolic disease [14].

In today's digital age, big data has become one of the core resources in various industries. Massive amounts of data are constantly emerging, and how to efficiently process and analyze these data has become an important challenge faced by many enterprises and research institutions. As a powerful mathematical software tool, MATLAB provides us with an efficient and flexible way to process and analyze big data[15].

Updated policies to improve physical activity (PA) were promoted by the World Health Organization (WHO) in 2010. In recent years, an increasing number of policies have been proposed to promote PA[16]. The WHO has published policy guidelines and national policies to promote physical activity [17]. Bellew and Bull had proposed some policy criteria to promote physical activity [18,19]. These policies have helped to bring physical activity onto the public agenda and national policy agenda.

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II. Materials And Methods

A. Data Sources

China successfully completed four national physical and mental health fitness surveys in 2001, 2005, 2011 and 2015. For this paper, we selected 31 provinces and cities (autonomous regions) in China. Hong Kong, Taiwan and Macao were omitted owing to a lack of relevant data, as there has been no research on this subject in those areas. For this paper, we selected the National Fitness Composite Index (NFCI) of those 31 provinces (and autonomous regions) of China in 2015 as an indicator; the NFCI data were gathered from the "2015 National Constitution Monitoring Bulletin" issued by the State Sports General Administration. The SEN variables such as "natural growth rate (NATrat, %)", "per capita GDP (RMB yuan)", "health care expenditure (HEAexpe, Chinese yuan)", "road distance (ROAdis, kilometers)", "number of athletes (NUMath, people)", "number of coaches (NUMcoa, people)", "city population density (POPden, people/km2)", "annual temperature (ANNtem, °C)", "annual rainfall (ANNrai, millimeters)", and "annual hours of sunshine (ANNsun, hours)" were downloaded from the "2016 China Statistical Yearbook". A vector map file was downloaded from the National Geoinformation Public Service platform.

The NFCI is used to describe the general level of the national constitution, including body shape, physical function and physical quality. The NFCI is the average of the corresponding indicators of the first national constitution of China in 2000 (100) as the base.

B. Statistical analysis

1) Modeling methods: The main interest of this research was to uncover the impact of both the economic and the natural environment on China's NFCI. To deal with this subject, linear regression methods were utilized to regress the NFCI against the economic and natural environments.

2) OLS (Ordinary Least Squares): OLS is the best-known regression method. When the dependent variable {xij} and explanatory variable {yij} are given, the OLS regression model is as follows:

$$y_i = \beta_0 + \sum_{m}^{n} x_{ij}\beta_j + \varepsilon_i \qquad i = 1,2,...m,\ j = 1,2,...n \tag{1}$$

Where the regression coefficient β is assumed to take a constant value throughout the region and the least squares method is used to estimate βj.

3) GWR: GWR was proposed by Fotheringham, Charlton and Brunsdon as a regression analysis method allowing spatial changes in the model coefficient β. The GWR formula can be expressed as follows[20,21]:

$$y_i = \beta_0(u_i, v_i) + \sum_{m}^{n} \beta_j(u_i, v_i)x_{ij} + \varepsilon_i \qquad (i = 1,2,...m) \tag{2}$$

Where the subscript of the coefficient βj indicates the parameter associated with the observed value and is the n+1 element function of the spatial location (ui, vi) determined by testing the set of the points within the neighborhood clearly defined for each sampling point and ε indicates the random error at the first location.

III. Results

A. Results of OLS modeling

The OLS results can be used to diagnose multicollinearity and residual errors by means of the variance inflation factor (VIF) value (Table 1). If the VIF is greater than 7.5, then multicollinearity exists, with the explanatory variables removed from the regression model one by one. The VIF ranges from 1.328040 to 5.031937, all of which values are smaller than 7.5. The small sample revision of the Akaike information criterion (AICc) and R^2 are 256.288126 and 0.834748, respectively (Table 1). The coefficient of each explanatory variable simultaneously reflects its strength and the model of the relationship with the dependent variable; moreover, if the coefficient is negative, then it indicates a negative correlation. In the eleven explanatory variables, the coefficients are negative for both NUMath and NUMcoa, which shows that the two variables have a negative relationship with the comprehensive index of national PF. The probability of statistical significance ($p < 0.05$) exists for HEAexpt, ROAdis, ANNtem, ANNrai and ANNsun. The coefficient of ANNsun is far greater than that of other indexes, and from the overall point of view, currently, the impact of the natural environment and relevant factors is greater than that of socioeconomic factors on national PF.

Table1: OLS Results

Coefficients of OLS results

Variable	Coefficient	StdError	Probability	Robust t statistic	Robust_ Probability	VIF
Intercept	16.436172	7.867611	0.049054	1.583949	0.128148	--
HEAexpt	39.367117	13.975555	0.010332	3.167894	0.004637*	2.656168
TOTind	7.692595	15.445436	0.623624	0.701450	0.490724	2.778732
RADist	9.041877	15.832011	0.573984	0.768416	0.450796	2.283821
TOAdis	31.283170	13.514697	0.030833	2.453885	0.022947*	2.935864
NUMath	-17.142822	21.891903	0.442331	-1.217025	0.237096	5.031937
NUMcoa	-4.740502	13.987691	0.738046	-0.439262	0.664958	2.555869
POPden	8.587128	9.121707	0.357208	1.865980	0.076072	1.328040
NUMtax	4.971114	16.190053	0.761831	0.424992	0.675165	4.129043
ANNtem	36.345112	15.537794	0.029291	2.733642	0.012445*	3.792341
ANNrai	23.631041	16.080552	0.156508	2.208816	0.038435*	4.751774
ANNsun	43.711006	9.631321	0.000179	4.006662	0.000639*	1.723601
Diagnostics of OLS results						
Number of Observations	31		Jarque-Beta statistic		0.747818	
R^2	0.834748		Akaike's Information Criterion(AIC c)		256.28812633900	
Joint F statistic	9.643544		AdjR^2		0.748188	
Joint Wald statistic	67.894		Sigma2		150.074666	
Koenker(BP) statistic	21.5056					

B. Results of GWR

The eleven variables obtained via the OLS method were used for the GWR analysis with the dependent variable of the national PF comprehensive index. In ArcGIS 10.1, we used the GWR tool and selected a bandwidth of 5,702,819.22 meters. The residuals and local R^2 figures of the GWR were used for the formation of the NFCI (Figure 1), coefficient plot (Figure 2) and GWR estimation results (Table 2). Table 2 shows that R^2 was more than 0.81, indicating that the model had a good fit. In Table 2, C1~C11 represent the HEAexpt, TOTind, RADist, ROAdis, NUMath, NUMcoa, POPden, NUMtax, ANNtem, ANNrai, and ANNsun coefficients, respectively. The correlation coefficients of the social and natural environmental factors are successively from large to small as follows: ANNsun > HEAexpt > ANNtem > ROAdis > ANNrai > NUMath > RADist > POPden > TOTind > NUMtax > NUMcoa.

Table 2: GWR diagnostic value of the NFCI in 2015

Province	Cond	LocalR^2	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Heilongjiang	16.93	0.84	41.01	5.02	8.53	31.03	-16.62	-2.93	8.13	4.48	36.42	24.75	42.97
Inner Mongolia	16.76	0.83	39.69	6.02	8.26	31.03	-16.65	-4.08	8.24	4.88	36.12	24.30	43.35
Xinjiang	16.42	0.81	35.68	7.73	6.28	30.68	-16.55	-6.40	8.48	6.41	35.51	23.13	44.29
Jilin	16.93	0.84	41.32	5.33	9.08	31.09	-16.73	-3.08	8.14	4.30	36.46	24.68	42.82
Liaoning	16.89	0.84	41.16	5.68	9.24	31.12	-16.77	-3.39	8.17	4.32	36.40	24.56	42.84
Gansu	16.63	0.82	38.42	7.17	8.17	31.03	-16.77	-5.28	8.36	5.30	35.91	23.76	43.65
Hebei	16.82	0.84	40.49	6.17	9.10	31.13	-16.79	-3.95	8.23	4.53	36.25	24.34	43.04
Beijing	16.82	0.84	40.47	6.11	9.02	31.12	-16.78	-3.91	8.22	4.54	36.25	24.36	43.06
Shanxi	16.78	0.83	40.13	6.54	9.11	31.14	-16.83	-4.33	8.26	4.63	36.18	24.19	43.14
Tianjin	16.84	0.84	40.68	6.11	9.21	31.13	-16.81	-3.85	8.22	4.46	36.29	24.38	42.98
Shaanxi	16.75	0.83	39.81	6.92	9.19	31.15	-16.89	-4.70	8.30	4.73	36.12	24.03	43.21
Ningxia	16.70	0.83	39.25	6.93	8.68	31.10	-16.81	-4.86	8.32	4.97	36.03	23.96	43.41
Qinghai	16.57	0.82	37.69	7.67	7.98	31.00	-16.80	-5.83	8.42	5.56	35.81	23.49	43.82
Shandong	16.86	0.84	41.08	6.26	9.71	31.18	-16.89	-3.84	8.22	4.27	36.35	24.37	42.80
Tibet	16.48	0.81	36.47	8.58	7.71	30.95	-16.90	-6.79	8.52	6.02	35.69	23.00	44.07
Henan	16.82	0.84	40.65	6.71	9.76	31.20	-16.95	-4.30	8.26	4.39	36.26	24.19	42.92
Jiangsu	16.90	0.84	41.61	6.39	10.32	31.23	-17.00	-3.77	8.21	4.02	36.43	24.38	42.57
Anhui	16.88	0.84	41.39	6.61	10.35	31.24	-17.02	-4.00	8.23	4.09	36.38	24.30	42.63
Sichuan	16.69	0.83	39.13	7.69	9.32	31.17	-17.00	-5.44	8.37	4.94	36.02	23.70	43.36
Hubei	16.82	0.84	40.69	7.01	10.09	31.23	-17.03	-4.49	8.28	4.34	36.25	24.10	42.86
Chongqing	16.77	0.83	40.05	7.38	9.86	31.22	-17.04	-4.95	8.33	4.57	36.15	23.92	43.06
Shanghai	16.95	0.85	42.08	6.37	10.75	31.25	-17.06	-3.61	8.20	3.82	36.50	24.43	42.36
Zhejiang	16.94	0.85	42.09	6.59	10.98	31.27	-17.11	-3.77	8.21	3.79	36.49	24.37	42.33
Hunan	16.84	0.84	40.90	7.29	10.57	31.27	-17.13	-4.63	8.29	4.21	36.27	24.04	42.73
Jiangxi	16.90	0.84	41.55	7.00	10.90	31.28	-17.14	-4.23	8.26	3.96	36.38	24.20	42.50
Yunnan	16.72	0.83	39.29	8.26	10.05	31.24	-17.19	-5.78	8.41	4.81	36.05	23.55	43.23
Guizhou	16.78	0.83	40.13	7.70	10.27	31.26	-17.14	-5.15	8.35	4.50	36.16	23.83	42.98
Fujian	16.94	0.85	42.07	6.94	11.33	31.30	-17.20	-4.02	8.24	3.75	36.46	24.27	42.28
Guangxi	16.83	0.84	40.71	7.78	10.92	31.30	-17.25	-5.03	8.33	4.24	36.23	23.88	42.74
Guangdong	16.90	0.84	41.56	7.46	11.41	31.32	-17.27	-4.55	8.29	3.90	36.36	24.07	42.42
Hainan	16.90	0.84	41.27	8.05	11.78	31.35	-17.41	-5.03	8.34	3.95	36.30	23.87	42.45

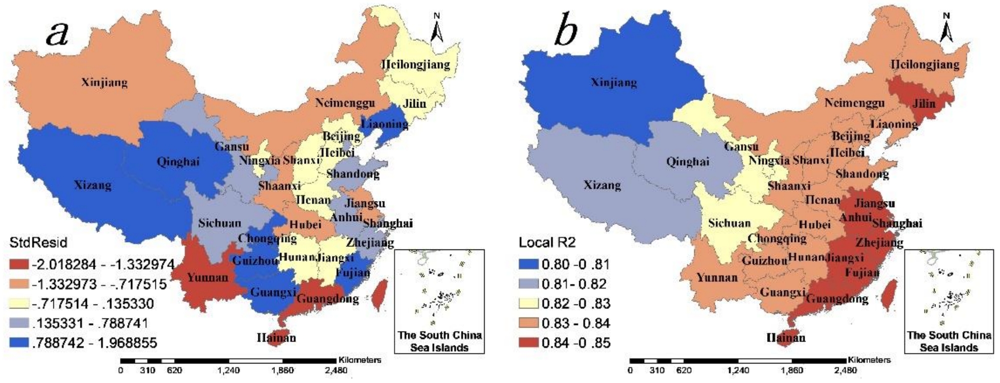

Figure 1: StdResid (a) and local R2 (b) of the GWR of the NFCI in 2015 (a: Using the GWR tool of ArcGIS 10.1 software to generate the residuals, b: Local R^2 results mapped over the spatial extent of our study area)

From Table 1, we can see that ANNsun, ANNtem and ANNrai, which represent the natural environment, have a greater influence on the NFCI than socioeconomic indicators. The positive correlation between the average temperatures is high, and the NFCI was higher in provinces such as Guangdong, Jiangxi, Zhejiang, Shanghai, and Hubei. However, the research found that the coefficients of NUMtax, TOTind and POPden were small.

The residuals of GWR (Figure 1a) indicate the areas subject to abnormal prediction, and higher deviation occurs between Guangdong, marked in dark red, and Liaoning, Fujian, Guizhou, Qinghai, Guangxi, Chongqing and Yunnan, marked in dark red, because the indexes of the NFCI are higher in Guangdong, Zhejiang and Liaoning but lower in Guizhou and Yunnan. Local R^2 results are mapped over the spatial extent of our study area (Figure 1b). R^2 is a measure of the degree of fit in the range of 0 to 1; the larger the value is, the better. Table 1 shows that R^2 is greater than 0.81.

In this paper, the coefficient of the eleven explanatory variables is divided into four categories: the red color represents that the coefficient is high, and the blue color represents that the coefficient is low (Figure 2).

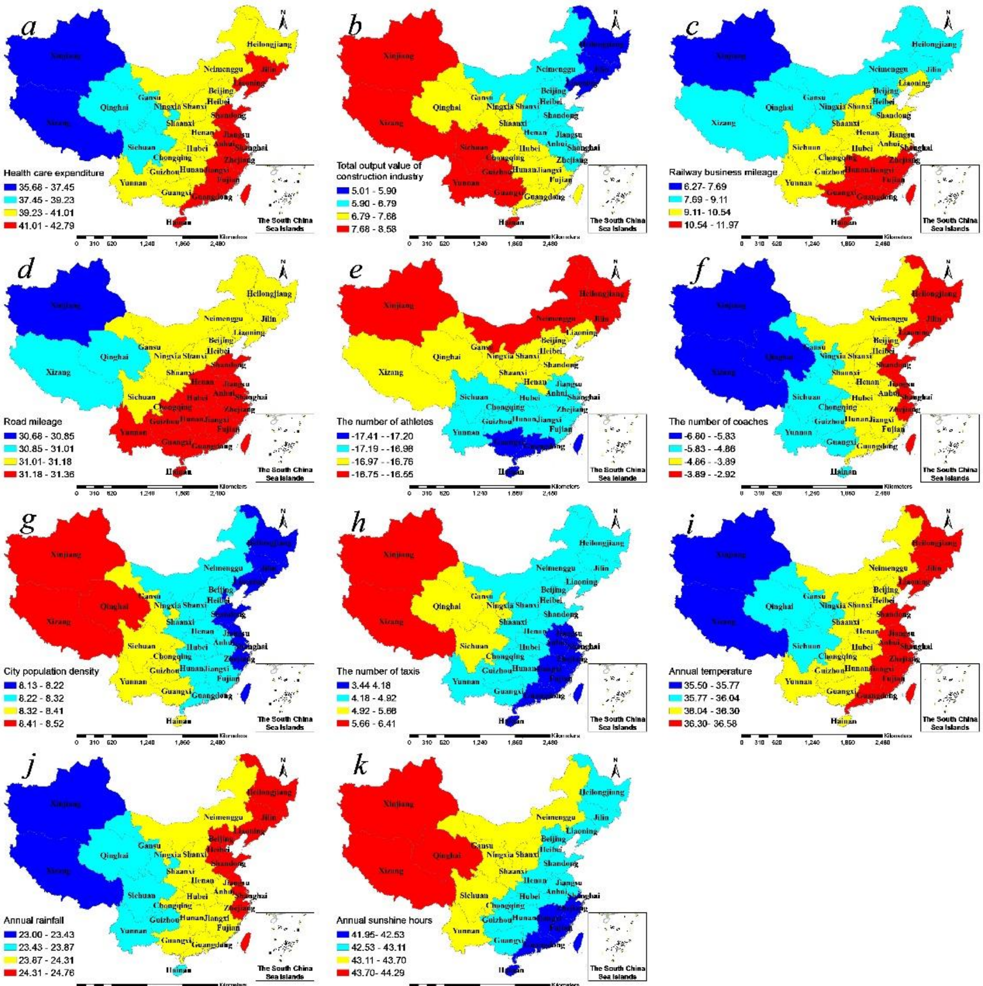

Figure 2: The spatial mapping of local regression coefficients (HEAexpe (a), TOTind (b),RADist (c), ROAdis (d), NUMath (e), NUMcoa (f), POPden (g), NUMtax(h), ANNtem (i), ANNrai (j), and ANNsun (k)) for each province based on GWR

C. Comparative analysis of GWR and OLS

Table 3 shows the independent variables and the GWR parameters estimated by means of the OLS method and simultaneously shows the GWR parameter estimation; moreover, the coefficients of the calculated parameters are kept within a certain data range. The diagnosis displayed in Table 3 is reduced against the sum of the squared residuals, and the corrective R2 increases while the AICc decreases. The adjusted goodness of fit reaches 84.9094%, which shows that the whole GWR model well reflects the combined impact of the NFCI as well as the neighborhood SEN factors on the local national PF.

Table 3: Global regression and prediction of NFCI

Predictive variable	Global parameter estimation	GWR estimation
HEAexpt,C1	39.367117	35.68～4279
TOTind,C2	7.692595 (Not significant)	5.02~8.58
RADist,C3	9.041877 (Not significant)	6.28～11.96
TOAdis,C4	31.283170	30.68~31.45
NUMath,C5	-17.142822 (Not significant)	-17.41～-16.55
NUMcoa,C6	-4.740502 (Not significant)	-6.79～-2.93
POPden,C7	8.587128 (Not significant)	8.13～8.52
NUMtax,C8	4.971114 (Not significant)	3.44~6.41
ANNtem,C9	36.345112	35.51～36.57
ANNrai,C10	23.631041 (Not significant)	23.00～24.75
ANNsun,C11	43.711006	41.95~44.29
Diagnosis		
R^2	0.834748	0.849094
Correction R^2	0.748188	0.759422
Number of effective parameters	11	11
AICc	289.260	289.158

D. Spatial autocorrelation analysis of the residuals

The most important part of GWR is the residual, and in the regression model, the relatively higher and lower expected values will be distributed at random. If the clustering of the relatively higher or lower expected values indicates that at least one key explanatory variable has been lost, we can understand whether those lost variables can be determined from the distribution patterns of the GWR model residuals. Spatial autocorrelation (Moran's I) can be used to evaluate the spatial independence of the residuals of the GWR model. Usually, the Moran's I index is between -1.0 and 1. If the Moran's I index value is positive, it shows a clustering trend, while if the Moran's I index value is negative, it indicates a discrete trend. If the Moran's I index is near 0, the spatial distribution is completely random. If spatial autocorrelation is found to exist in the residuals (Moran’s I$\neq$ 0), then the GWR model does not fit the dataset. When the ArcGIS 10.1 spatial autocorrelation tool is applied to the GWR regression residuals, the analysis results ensure the random spatial distribution of the regression residuals. The neighborhood search threshold is 1,178,669.9 meters, and the Moran’s I index, z score and p value are 0.001723, 0.475952 and 0.634109, respectively, and are free of clustering distribution, which indicates that the GWR model is correct.

IV. Discussion

The NFCI of China demonstrates not only spatial dependence but also significant spatial heterogeneity. It has been found that the influence of the natural environment (mainly including temperature and hours of sunshine) on human health is greater than that of social and economic factors. Table 1 shows that the coefficients of ANNsun, ANNtem and ANNrai are larger than those of other factors, which indicates that the natural climate conditions have a strong impact on human health. There is a positive correlation between ANNtem and human health. Provinces with high ANNtem, such as Guangdong, Jiangxi, Zhejiang, Shanghai and Hubei, have a higher NFCI. Regions with a high NFCI are concentrated in eastern coastal areas, where the residents have a more reasonable dietary structure and pay more attention to physical exercise in daily life due to the superior natural environment, pleasant climate and developed economy.

The impact of social and economic changes on PF varies with the developmental stage. Specifically, the socioeconomic impact on human health is different in different development periods. The impact of the economy on PF decreases when the economy develops to a certain level. The improvement of national PF indicates changes in people’s life attitudes in the region and can promote regional socioeconomic development.

China's economy has developed rapidly. With improvements in living standards, people are paying increasing attention to their physical and mental health. In terms of medical and health expenditure, greater changes have been made recently than in the twentieth century, and the expenditure on health care consumption has risen more than the total consumption expenditure. The 2015 health care expenditure of provinces in the eastern part of China are in the forefront, while four western region provinces (Tibet, Guizhou, Guangxi, Jiangxi) are also prominent.

V. Conclusions

The spatial heterogeneity of physical fitness was also analyzed. A GWR model was built for the NFCI 2014 and its influencing factors, and a geographical spatial correlation was found. The NFCI of the eastern coastal regions was higher but also similar to that of the central and western regions. It was also found that the impact of the natural environment on national physical and mental health fitness was greater than that of social and economic factors. Temperature and hours of sunshine were major environmental factors. We should increase physical exercise, change our concepts of health, develop a healthy lifestyle and improve our physical fitness in accordance with the national fitness strategy.

Traditional OLS only performs "average" or "global" analysis on parameters, and cannot reflect the non-stationary nature of parameters in different geographic spaces. The regression coefficients obtained by the GWR model show significant differences, indicating that the degree of influence of social, economic, and natural factors on national physical fitness varies significantly with geographical regions.

With the continuous growth of data and the popularization of data analysis, data modeling and prediction have become an indispensable part of the field of data science. In many fields, such as finance, business, healthcare, weather forecasting, etc., it is necessary to model and predict data to help people make decisions and plan for the future. Among them, MATLAB, as a widely used data analysis tool, is also widely used in data modeling and prediction.

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