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Applying hierarchical grey relation clustering analysis to geographical information systems – A case study of the hospitals in Taipei City

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A R T I C L E I N F O

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Geographical information system
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A B S T R A C T

Deng proposed grey clustering analysis (GCA) in 1987. Later, Jin presented a new method in 1993, called grey relational clustering (GRC) method that combined grey relational analysis with clustering. However, the GRC method cannot use a tree diagram to make appropriate classification decisions without re-computation. This study thus attempts to combine GRC and hierarchical clustering analysis. Given the existence of an excess of medical resources in the Taipei area, this study attempts to understand the degree of concentration of medical resources in this area. Specifically, this study applies a geographical information system (GIS) to present the geographical distribution of hospitals in Taipei. Additionally, a new-type of cluster analysis, known as hierarchical grey relation clustering analysis, is used to analyze the distribution of hospitals and understand how they compete with one another. The analytical results demonstrate that hierarchical grey relation clustering analysis is a suitable method of analyzing geographical position. Tree diagrams can help policymakers make appropriate classification decisions without re-computation. The study results can inform hospitals of their competitors and help them to develop appropriate responses. Additionally, the analytical results can also provide a reference to government or hospital policymakers to help them position hospitals in areas, thus achieving a better distribution of medical resources in Taipei.

1. Introduction

According to the grey system theory proposed by Deng in 1982, the population system, which comprises population and environment, is a grey system, because the structure, function and interaction mechanism between the related factors that influence the system are extremely complex and relevant information is lacking. The grey systems theory is mainly utilized to study systems that model uncertainty, analyze system relations, establish models, and make forecasts and decisions (Tsai, Hsiao, & Liang, 2005). The grey clustering analysis (GCA) proposed by Deng in 1987. A cluster refers to a group of objects that are clustered according to some rule. Clusters thus by nature have a certain degree of homogeneity. However, Jin (1993) described various procedures, including factor relational analysis (Deng, 1989), fuzzy clustering, systematic clustering, grey clustering (Feng, 1992), etc., that are applied to multi-target objects. Because of the complex factors and confused nature of the information involved, a new method, known as the grey relational clustering (GRC) method, which combines grey relational analysis and clustering, is devised. Grey relation clustering distinguishes itself through simplicity, effectiveness and flexibility. However, the GRC method cannot use a tree diagram to make appropriate decisions to classify without re-computation. This study thus tries to combine the GRC and a hierarchical clustering analysis.

Computer science and technology recently have developed very rapidly, for example in the fields of geographical information system (GIS), remote sensing (RS), global positioning system (GPS), and so on (Shen et al., 2004). The speed of development of GIS has been especially fast. Different definitions of GIS exist in the foreign literature. Smith, Menon, Star, and Estes (1987) defined the GIS as a database system in which most data are spatially indexed, and on which a set of procedures are operated to answer queries regarding spatial entities in the database. Blakemore (1986) defined GIS as a computer packages which integrates the storage, manipulation, analysis, modeling and mapping of digital spatial information. Malpica, Alonso, and Sanz (2007) presented that GIS can be defined as a system of hardware and software used for the input, storage, retrieval, mapping, display and analysis of

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geographic data. Additionally, Antenucci, Brown, Croswell, Kevany, and Archer (1991) defined GIS as a computer system that stores and links non-graphic attributes or geographically-referenced data that possess graphic map features to permit various information processing and display operations, and map production, analysis, and modeling. The above demonstrates that different definitions of GIS existence finds that GIS encompasses a fundamental and universally applicable set of value-added tools for capturing, transforming, managing, analyzing, and presenting geographically referenced information (Tim, 1995). Cheng, Li, and Yu (2007) suggested that among the variety of GIS technology applications includes resource management, land surveying and business planning. Ford, Griffiths, and Watson (2005) indicated that GIS provides an effective means of analyzing the disparate data related to the cob buildings. Bhana (1999) also demonstrated that GIS enables the determination of the precise longitude and latitude at which a facility is positioned, and thus can determine the proper distribution of facilities and services. Savas Durduran (2010) presented that GIS has the ability to hold a vast amount of data that can be easily stored, shared analyzed and managed and also provides a platform for spatial data analyses. Consequently, spatial clustering has already been applied to GIS recently. The purpose of clustering is to divide objects into subclasses. Moreover, clustering applications are commonly applied to GIS; for example, Wu, Bruggen, Subbarao, and Pennings (2001) presented clustering analysis in geographic information systems on the interpolated disease incidence for different periods.

An average of the hospital bed number in 2009 in Taiwan counties, the area with the greatest excess of medical resources is Taipei City, with 15,788 beds (Department of Health, 2010). The above data demonstrate that Taiwan suffers from a problem of the uneven geographical distribution of medical resources. This study also finds that Taipei City has an excess of medical resources. Arnold (1991) stated that the increased number of hospitals exaggerates the competitiveness in a health care business. Goldstein, Ward, Leong, and Butler (2002) described that hospital location is strongly related to performance. According to the above statement, the hospital should not only pay careful attention to choosing operating location, but must also assess the local geographical distribution of medical resources level of competition. To understand the degree of concentration of medical resources in the Taipei City, this study applies GIS to present the geographical locations of hospitals in Taipei City. Additionally, the new type of cluster analytic call hierarchical grey relation clustering analysis is applied to analyze the distribution of hospitals and to understand how hospitals compete with one another.

The remainder of this paper is organized as follows. Section 2 then describes the calculation procedure of the GIS and the hierarchical relation grey clustering analysis. Next, to provide a clearer explanation of calculation procedure, Section 2 of this study selects 10 hospitals in Taipei for the analysis of hospital distribution to demonstrate the effectiveness of the proposed assessment procedure. Section 3 then describes the analysis results for the distribution of hospitals in Taipei City. Finally Section 4 presents conclusions.

2. Methods

This study thus attempts to combine GRC and hierarchical clustering analysis. The hierarchical grey relation clustering analysis calculation procedure is presented below:

Let x_{jk} denote the kth coordinate axis for the jth hospital, and let x_j represent the indices series of the jth hospital, which is written as:

$$x_j = (x_{j1}, x_{j2})$$

Step 1. Calculate the difference series

$$\Delta_{ij}(k) = |x_i(k) - x_j(k)| \tag{1}$$

where $i = 1,2,\ldots,m$, $j \in i$, $k = 1, 2$.

Step 2. Calculate the maximum and minimum of the difference series

$$\Delta_{\max} = \max_{\forall j \in i} \max_{\forall k} |x_i(k) - x_j(k)| \tag{2}$$

$$\Delta_{\min} = \min_{\forall j \in i} \min_{\forall k} |x_i(k) - x_j(k)| \tag{3}$$

where $i = 1,2,\ldots,m$, $j \in i$, $k = 1, 2$.

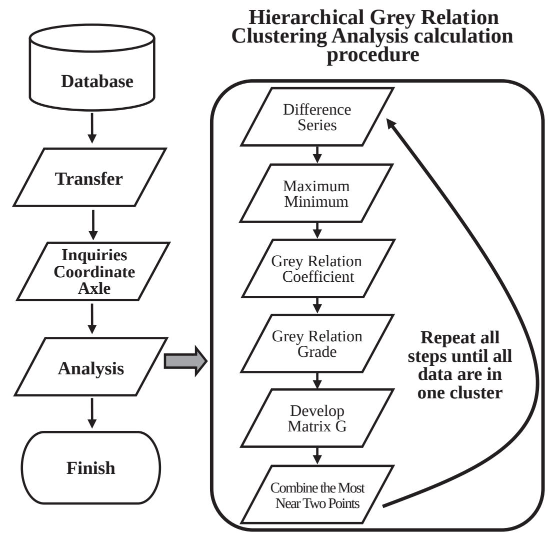

Fig. 1. The procedure of analysis.

Table 1
The coordinate axle data of Hospital.

ID	Hospital name	X axle (x_{j1})	Y axle (x_{j2})
1	Shin-Kong	121,520,417	25,096,045
2	Cathay	121,553,800	25,036,809
3	Mackay	121,522,597	25,058,372
4	Wan-Fang	121,557,646	24,999,680
5	Veterans	121,520,569	25,120,203
6	Yang-Ming	121,531,859	25,105,276
7	Chunghsing	121,509,434	25,050,916
8	Jen-Ai	121,545,103	25,037,545
9	He-Ping	121,507,082	25,035,793
10	Women and Children	121,519,331	25,028,799

Table 2
The result of the difference series (where the Shin-Kong hospital is regarded as the standard series).

Hospital	Difference series	
	$\Delta_{ij}(1)$	$\Delta_{ij}(2)$
Shin-Kong	0	0
Cathay	33,383	59,236
Mackay	2180	37,673
Wan-Fang	37,229	96,365
Veterans	152	24,158
Yang-Ming	11,442	9231
Chunghsing	10,983	45,129
Jen-Ai	24,686	58,500
He-Ping	13,335	60,252
Women and Children	1086	67,246

Table 3
Summary of the grey relation coefficient (taking the Shin-Kong hospital as the standard series).

Hospital	Grey relation coefficient	
	$\gamma(x_i(1), x_j(1))$	$\gamma(x_i(2), x_j(2))$
Shin-Kong	1.0000	1.0000
Cathay	0.2240	0.1399
Mackay	0.8155	0.2037
Wan-Fang	0.2056	0.0909
Veterans	0.9845	0.2851
Yang-Ming	0.4572	0.5107
Chunghsing	0.4673	0.1760
Jen-Ai	0.2808	0.1414
He-Ping	0.4195	0.1379
Women and Children	0.8987	0.1253

Step 3. Calculate the grey relation coefficient

$$\gamma(x_i(k), x_j(k)) = \frac{\Delta_{\min} + \varsigma\Delta_{\max}}{\Delta_{ij}(k) + \varsigma\Delta_{\max}} \quad \varsigma = 0.1 \; i = 1, 2, \ldots, m, \; j \in i, \; k = 1, 2 \tag{4}$$

where ζ value can be adjusted in accordance with need.

Step 4. Calculate the grey relation grade to develop matrix R

$$\Gamma_{ij} = \frac{1}{k}\sum_{k=1}^{k}\gamma(x_i(k), x_j(k)) \quad i = 1, 2, \ldots, \; m, \; j \in i, \; k = 1, 2 \tag{5}$$

$$R = (\Gamma_{ij}), \quad i, j = 1, 2, \ldots, m$$

Step 5. Develop matrix G

Matrix G which is presented below and is known as the grey similar matrix, lays the foundation for grey relational clustering,

$$G = [g_{ij}], \quad i, j = 1, 2, \ldots, m \tag{6}$$

where $g_{ij} = (\Gamma_{ij} + \Gamma_{ij})/2$.

Γ_{ij} and Γ_{ji} are grey grades with the form $\Gamma_{ij} = \gamma(x_i, x_j)$, $\Gamma_{ji} = \gamma(x_j, x_i)$

In where, parenthesis, the former is a reference series, the latter is one of compared series (Deng, 1989).

Step 6. Identify the two points (the hospital) of the most near

Identify the two hospitals of the most near, and the center value (based on the X and Y coordinate axes) is then calculated by combining the two nearest hospitals.

$$\max_{ij} g_{ij} \tag{7}$$

Step 7. Repeat steps 1–6 until all data are in one cluster

Table 4
Summary of the grey relation grade (matrix R).

	Shin-Kong	Cathay	Mackay	Wan-Fang	Veterans	Yang-Ming	Chunghsing	Jen-Ai	He-Ping	Women and Children
Shin-Kong	1.0000	0.1616	0.4402	0.1779	0.6602	0.5068	0.2600	0.1873	0.2553	0.5067
Cathay	0.1820	1.0000	0.1941	0.5016	0.1962	0.2293	0.2322	0.7028	0.5228	0.3713
Mackay	0.5096	0.2449	1.0000	0.2131	0.5095	0.3582	0.4133	0.2764	0.3122	0.4864
Wan-Fang	0.1483	0.4339	0.1226	1.0000	0.1681	0.1907	0.1224	0.2882	0.1663	0.2158
Veterans	0.6348	0.1458	0.4220	0.1681	1.0000	0.4488	0.2372	0.1715	0.2379	0.4858
Yang-Ming	0.4840	0.1920	0.2584	0.2105	0.4815	1.0000	0.1745	0.2465	0.1812	0.2643
Chunghsing	0.3217	0.2649	0.3865	0.1952	0.3340	0.2414	1.0000	0.2851	0.5701	0.3863
Jen-Ai	0.2111	0.7042	0.2222	0.3657	0.2283	0.2892	0.2520	1.0000	0.5049	0.3864
He-Ping	0.2787	0.5214	0.2500	0.2214	0.2984	0.2154	0.5304	0.5018	1.0000	0.4969
Women and Children	0.5120	0.3524	0.4136	0.2660	0.5117	0.2893	0.3252	0.3644	0.4774	1.0000

Table 5
Grey similar matrix G.

	Shin-Kong	Cathay	Mackay	Wan-Fang	Veterans	Yang-Ming	Chunghsing	Jen-Ai	He-Ping	Women and Children
Shin-Kong	1.0000									
Cathay	0.1718	1.0000								
Mackay	0.4749	0.2195	1.0000							
Wan-Fang	0.1631	0.4677	0.1679	1.0000						
Veterans	0.6475	0.1710	0.4658	0.1681	1.0000					
Yang-Ming	0.4954	0.2106	0.3083	0.2006	0.4652	1.0000				
Chunghsing	0.2908	0.2486	0.3999	0.1588	0.2856	0.2080	1.0000			
Jen-Ai	0.1992	**0.7035**	0.2493	0.3270	0.1999	0.2679	0.2685	1.0000		
He-Ping	0.2670	0.5221	0.2811	0.1938	0.2682	0.1983	0.5503	0.5034	1.0000	
Women and Children	0.5094	0.3619	0.4500	0.2409	0.4987	0.2768	0.3557	0.3754	0.4872	1.0000

Table 6
Summary of the combined processes.

Cluster	1	2	3	4	5
Grey similar value g_{ij}	0.7035	0.6475	0.6374	0.5123	0.4823
Combination	Cathay General hospital, Jen-Ai hospital	Shin-Kong, Veterans General hospital	Cluster 2, Yang-Ming hospital	Chunghsing hospital, He-Ping	Cluster 3, Mackay Memorial hospital
Cluster	6	7	8	9	
Grey similar value g_{ij}	0.3721	0.2846	0.1855	0.1060	
Combination	Cluster 5, Women and Children hospital	Cluster 1, Wan-Fang hospital	Cluster 6, cluster 4	Cluster 8, cluster 7	

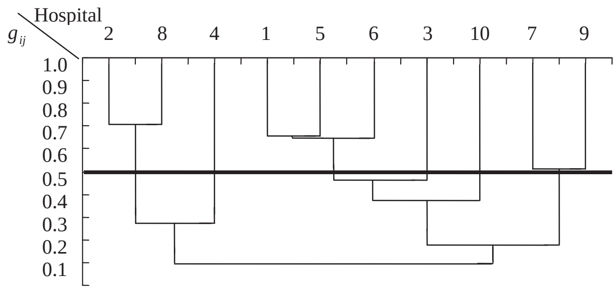

Fig. 2. Tree diagram of the 10 sample hospitals in Taipei.

3. Results

To explain calculation procedure more clearly, this study selects 10 hospitals in Taipei for the analysis of hospital distribution to demonstrate the effectiveness of the proposed assessment procedure. This study applies GIS to present the geographical locations of 10 hospitals in Taipei City. Additionally, hierarchical grey relation clustering analysis is applied to analyze the degree of concentration of geographical position. The calculation procedure is presented below (as show in Fig. 1):

Step 1. Transfer the data into the PAPAGO! SDK software (GIS)

Transfer the hospital address into the PAPAGO! SDK software (GIS).

Step 2. Calculate the *X*, *Y* coordinate axle data

The PAPAGO! SDK software can automatically make inquiries regarding the *X* and *Y* coordinate axle data according to hospital name or address. In order to explain more clearly, this study chose just 10 hospitals in Taipei City and analyzed their distribution (as listed in Table 1).

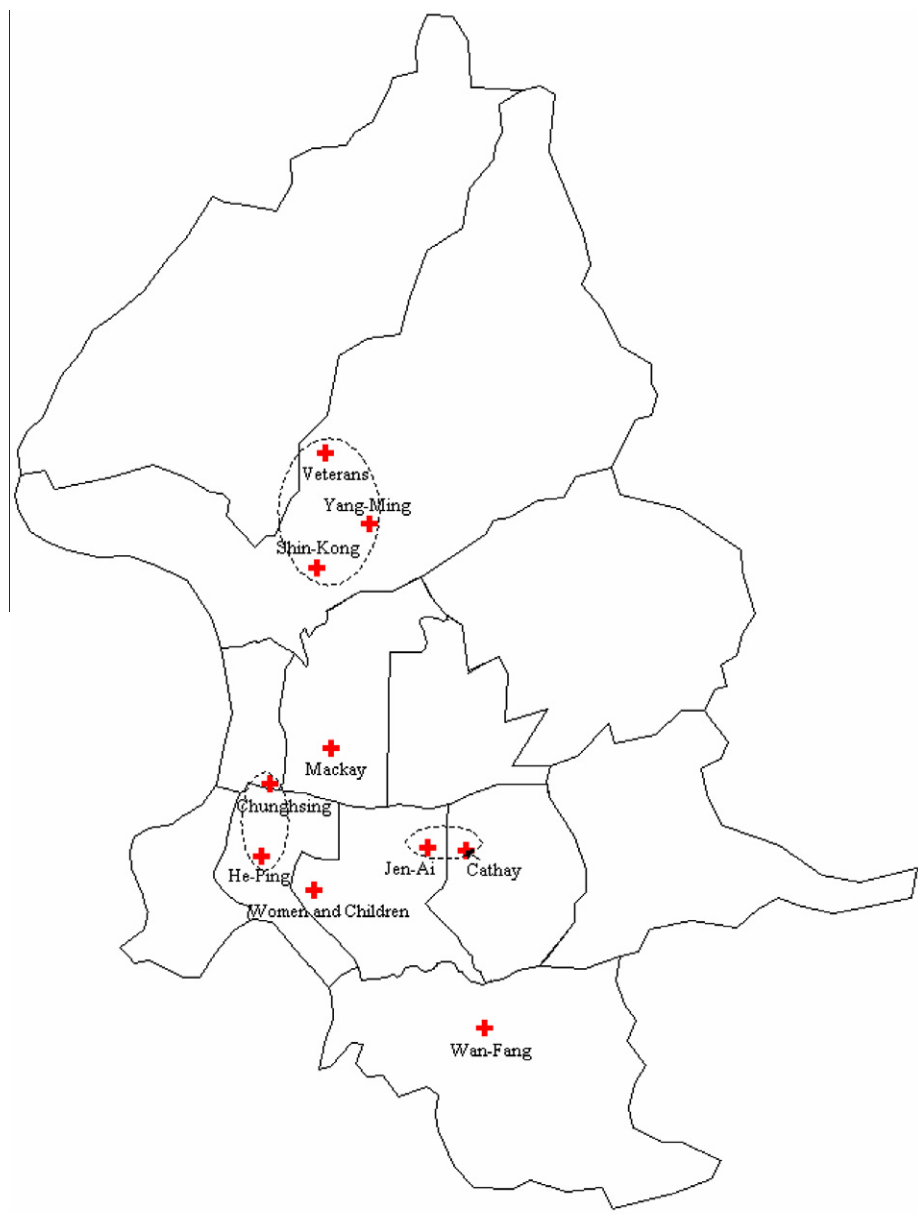

Fig. 3. The geographical position of the 10 sample hospitals in Taipei.

Step 3. Calculate the difference series

Shin-Kong hospital is taken as the standard series, the kth difference series of the first and second hospitals is $\Delta_{12}(k) = |x_1(k) - x_2(k)|$, $k = 1, 2$ using formula (1). When $k = 1$, the first difference series of the first and second hospitals is

$$\Delta_{12}(1) = |x_1(1) - x_2(1)| = |121{,}520{,}417 - 121{,}553{,}800| = 33{,}383$$
$$k = 2, \Delta_{12}(2) = |x_1(2) - x_2(2)| = |25{,}096{,}045 - 25{,}036{,}809| = 59{,}236$$

Treat the Shin-Kong hospital as the standard series, and the calculation results for the difference series as listed in Table 2.

Later, to analogize, take the Cathay, Mackay, Wan-Fang, Veterans, Yang-Ming, Chunghsing, Jen-Ai, He-Ping, Women and Children hospital as the standard series, and the difference series is calculated individually.

Step 4. Calculate the maximum and minimum of the difference series

Calculate the maximum and minimum using formula (2) and (3).

$$\Delta_{\max} = \max_{\forall j \in i} \max_{\forall k} |x_i(k) - x_j(k)| = 96{,}365$$
$$\Delta_{\min} = \min_{\forall j \in i} \min_{\forall k} |x_i(k) - x_j(k)| = 0$$

Later to analogize, take the Cathay, Mackay, Wan-Fang, Veterans, Yang-Ming, Chunghsing, Jen-Ai, He-Ping, and Women and Children hospital as the standard series, and calculate the maximum and minimum of the difference series individually.

Step 5. Calculate grey relation coefficient

Take the Shin-Kong hospital as the standard series, then the kth difference series of the first and second hospitals is $\gamma(x_1(k), x_2(k)) = \frac{\Delta_{\min} + \varsigma\Delta_{\max}}{\Delta_{12}(k) + \varsigma\Delta_{\max}}$, $k = 1, 2$ using formula (4). When $k = 1$, the first grey relation coefficient difference series of the first and second hospitals is,

$$\gamma(x_1(1), x_2(1)) = \frac{\Delta_{\min} + \varsigma\Delta_{\max}}{\Delta_{12}(1) + \varsigma\Delta_{\max}} = \frac{0.1 \times 96{,}365}{33{,}383 + 0.1 \times 96{,}365} = 0.2240$$

By analogy, when $k = 2$

$$\gamma(x_1(2), x_2(2)) = \frac{\Delta_{\min} + \varsigma\Delta_{\max}}{\Delta_{12}(2) + \varsigma\Delta_{\max}} = \frac{0.1 \times 96{,}365}{59{,}236 + 0.1 \times 96{,}365} = 0.1399$$

Taking Shin-Kong hospital as the standard series, the calculation result of the grey relation coefficient as listed in Table 3.

Subsequently by way of analogy, repeat steps 1–3. Take the Cathay, Mackay, Wan-Fang, Veterans, Yang-Ming, Chunghsing, Jen-Ai, He-Ping, and Women and Children hospital as the standard series, and calculate the grey relation coefficient individually.

Step 6. Calculate grey relation grade to obtain matrix R

The grey relation grade is $\Gamma_{12} = \frac{1}{k}\sum_{k=1}^{k}\gamma(x_1(k), x_2(k))$, $k = 1, 2$ using formula (5).

$$\Gamma_{12} = \frac{1}{k}\sum_{k=1}^{k}\gamma(x_1(k), x_2(k)) = \frac{1}{2}(0.2440 + 0.1399) = 0.1820$$

Later by way of analogy, calculate the grey relation grade individually (as listed in Table 4).

Step 7. Development matrix G

Table 5 lists the grey similar matrix G, where according to formula (6), for example $i = 1$, $j = 2$, then

$$g_{12} = (\Gamma_{12} + \Gamma_{21})/2 = (0.1820 + 0.1616)/2 = 0.1718$$

Step 8. Identify the two points (the hospital) of the most near

As shown the bold values in Table 5, Cathay and Jen-Ai hospital are identified as the two nearest points, $\max_{ij} g_{ij} = g_{28} = 0.7035$. The center value (based on the X and Y coordinate axes) is then calculated by combining Cathay and Jen-Ai hospital, and the results are presented X coordinate axle value = 121,549,451, Y coordinate axle value = 25,037,177.

Step 9. Repeat steps 1–6 until all data are in one cluster

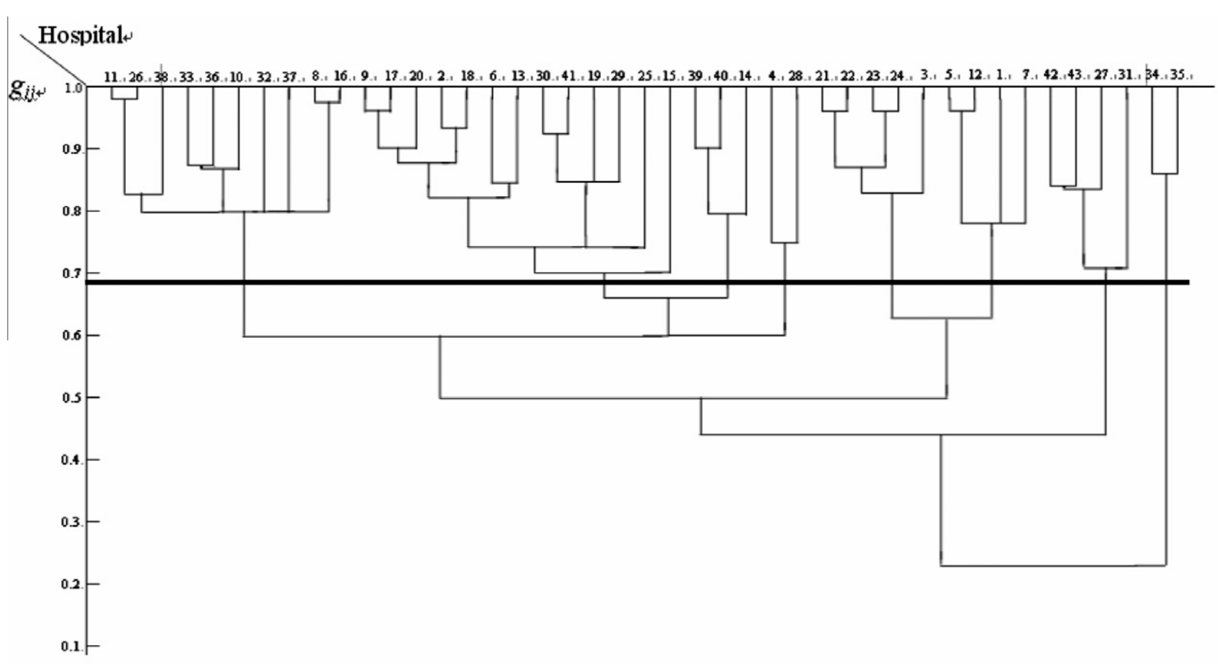

Fig. 4. Tree diagram of the hospitals in Taipei.

Table 6 summarizes the combined processes. Based on Table 6, a tree diagram can be produced, as shown in Fig. 2. Fig. 2 shows that decision makers wish to create five clusters, and thus determine the threshold $g_{ij} = 0.5$ in the form of a real line. That is, the 2 (Cathay) and 8 (Jen-Ai) hospitals are in the first cluster, the 4 (Wan-Fang) is in the second cluster, the 1 (Shin-Kong), 5 (Veterans), 6 (Yang-Ming) are in the third cluster, the 3 (Mackay) is in the fourth cluster, the 10 (Women and Children) is in the fifth cluster, and the 7 (Chunghsing), and 9 (He-Ping) are in the sixth cluster.

The results of analysis also show the distribution situation of the 10 sample hospitals in Taipei (as shown in Fig. 3).

The analytical result that the geographical position distribution of hospitals in Taipei City, Fig. 4 shows that decision makers wish to create eight clusters, and thus determine the threshold $g_{ij} = 0.71$ in line form. Table 7 lists the findings of this study regarding establish year, bed number, hospital property (private or public) and distribution district. As Table 7 and Fig. 3 show, the 5 (Veterans), 12 (Cheng Hsin), 1 (Shin-Kong) and 7 (Yang-Ming) hospitals concentrated in Shihlin districts comprise the first cluster, and the 9 (Jen-Ai), 17 (Country), 20 (Clinic), 2 (Cathay), 18 (Chung Shan), 6 (Chang Gung), 13 (Taiwan Adventist), 30 (Po Jen), 41 (Song Shan), 19 (Show Chwan), 29 (Pei Ling), 25 (Women and Children) and 15 (Zhongxiao) hospitals concentrated in the Daan, Songshan, Sinyi, Jhongshan and Nangang districts comprise the second cluster. Both these clusters are located in the southern area of Taipei, where agriculture developed relatively early and brought economic prosperity and a sharp increase in population, leading to medical resources being relatively plentiful compared to other areas. Furthermore, the 39 (Jen Kang), 40 (Taipei Medical University) and 14 (Songde) hospitals concentrated in Sinyi district comprise the third cluster, while the 21 (Fu Cyun), 22 (Tai An), 23 (Disease Control and Prevention), 24 (Cing Sheng) and 3 (Mackay) hospitals concentrated in Jhongshan district are in the fourth cluster. Additionally, the 4 (Wan-Fang) and 28 (Jin Mei) hospitals in Wunshan district comprise the fifth cluster, while the 11 (Women and Children) 26 (Postal), 38 (National Taiwan University), 33 (Yan Chai), 36 (Bei Hu), 10 (He-Ping), 32 (West Garden), 37 (Wan Hua), 8 (Chunghsing), and 16 (Taipei) hospitals concentrated in the Datong, Jhongjheng, Daan and Wanhua district form the sixth cluster. Because these areas are close to Taipei County, where medical resources are relatively scarce, policymakers have tended to set up hospitals in these areas, causing considerable centralization of medical resources. Furthermore, the 42 (Cathay Neihu), 43 (Tri-Service), 27 (Kang Ning) and 31 (Zih Sheng Tang) hospitals that are concentrated in the Neihu and Nangang districts comprise the seventh cluster, while the 34 (Gan Dau) and 35 (Yat Sen)

Table 7
Relevant information of 43 hospitals in Taipei.

Cluster	Hospital name	Establish year	Hospital property	Bed number	Distribution district
1	Veterans	1958	Public	2908	Shihlin
	Cheng Hsin	1967	Private	757	Shihlin
	Shin Kong	1986	Private	921	Shihlin
	Yang Ming	1950	Public	600	Shihlin
2	Cathay	1977	Private	772	Daan
	Jen Ai	1954	Public	757	Daan
	Country	1965	Private	136	Daan
	Chung Shan	1976	Private	217	Daan
	Show Chwan	1996	Public	74	Daan
	Clinic	1973	Private	227	Daan
	Chang Gung	1976	Private	3900	Songshan
	Taiwan Adventist	1955	Private	450	Songshan
	Pei Ling	1946	Private	85	Songshan
	Po Jen	1976	Private	348	Songshan
	Song Shan	1949	Public	500	Songshan
	Zhongxiao	1988	Public	350	Nangang
	Womens	1976	Private	49	Jhongshan
3	Songde	1969	Public	526	Sinyi
	Jen Kang	1977	Private	96	Sinyi
	Taipei Medical University	1976	Public	900	Sinyi
4	Mackay	1980	Private	1168	Jhongshan
	Fu Cyun	1977	Private	89	Jhongshan
	Tai An	2003	Private	101	Jhongshan
	Disease Control and Prevention	2000	Public	20	Jhongshan
	Cing Sheng	1975	Private	10	Jhongshan
5	Wan Fang	1997	Public	800	Wunshan
	Jin Mei	1979	Private	95	Wunshan
6	Chunghsing	1905	Public	563	Datong
	Taipei	1968	Public	709	Datong
	He Ping	1967	Public	567	Jhongjheng
	Women and Children	1974	Public	250	Daan
	Postal	1946	Public	46	Daan
	National Taiwan University	1946	Public	2564	Jhongjheng
	West Garden	1971	Private	247	Wanhua
	Yan Chai	1967	Private	87	Wanhua
	Bei Hu	1949	Public	47	Jhongjheng
	Wan Hua	1996	Private	98	Jhongjheng
7	Kang Ning	1970	Private	476	Neihu
	Cathay Neihu	1997	Private	170	Neihu
	Tri-Service	1990	Public	1721	Neihu
	Zih Sheng Tang	1971	Public	30	Nangang
8	Gan Dau	2000	Public	243	Beitou
	Yat Sen	1990	Private	288	Beitou

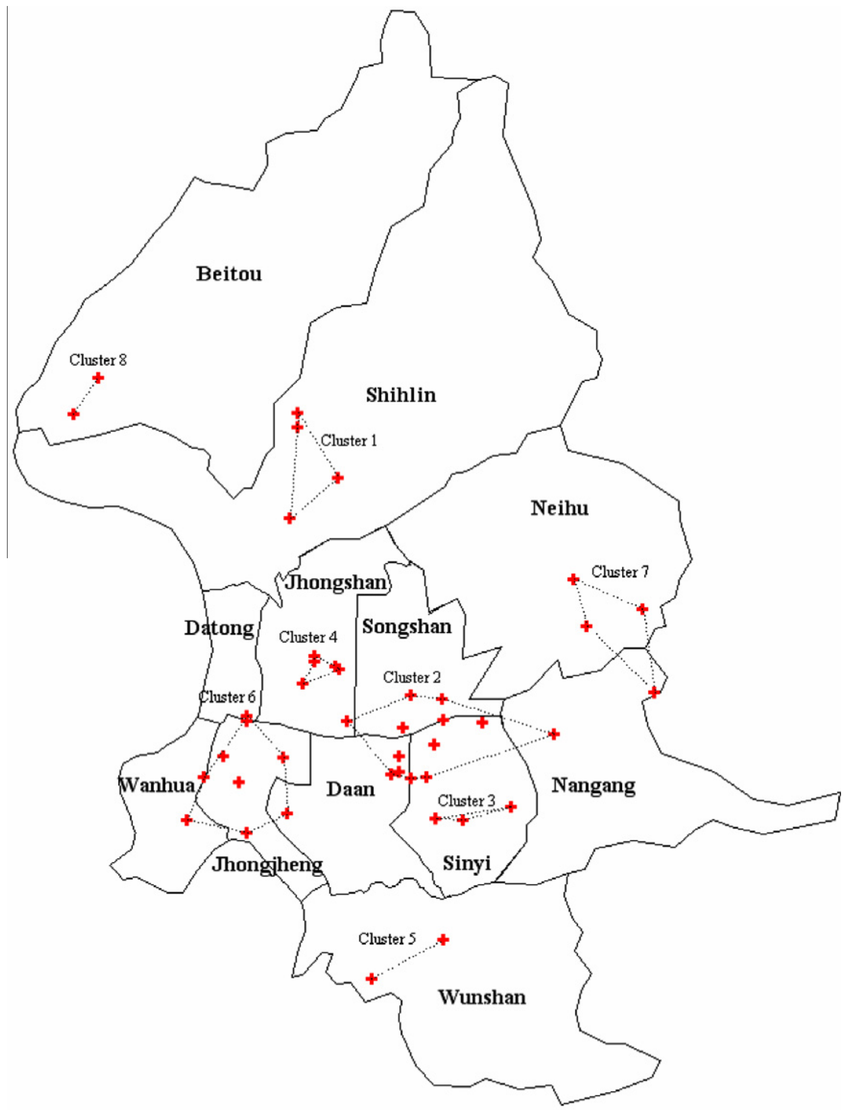

Fig. 5. Geographical position of hospitals in Taipei.

hospitals concentrated in Beitou district comprise the eighth cluster. Because transportation is difficult, these areas contain sparse populations, and relatively few hospitals are located there. Additionally, the analytical results also demonstrate the distribution of the hospitals in Taipei City (as shown in Fig. 5).

To summarize, the above analysis indicates an uneven geographical distribution of medical resources in Taipei City, with a concentration in the central city and a lack of resources in the suburbs. The distribution of medical resources is excessively centralized in Daan, Songshan, Sinyi, Jhongshan and Wanhua districts, creating excessive competition among hospitals. Meanwhile, the Wunshan and Beitou districts suffer a lack of medical resources. The lack of medical resources in certain districts causes considerable public inconvenience.

Table 7 demonstrates that many new hospitals have tended to locate in areas that already have abundant medical resources. For example, the district of Jhongshan, which already had ample medical services, saw the establishment of the Tai An hospital in 2003, the similarly well served district of Wanhua was selected as the location of the new Wanhua hospital in1996, and so on. This situation exists because medium and small hospitals have limited funding and reputation and face a survival challenge if they locate in remote areas with limited numbers of patients. Government hopes to achieve a more even distribution of medical resources. Therefore, governments are encouraging large and public hospitals such as Tri-Service, Wan-Fang, Gan Dau, etc. to set up in areas that lack medical resources.

4. Conclusions

The research results demonstrate that hierarchical grey relation clustering analysis can effectively analyze geographical position. This study presents the hierarchical grey relation clustering analysis, which does not need to determine the threshold, number of clusters or choice of initial cluster centers. Tree diagrams (as shown in Fig. 4) can help policymakers make appropriate classification decisions without re-computation.

The distribution of medical resources in Taipei City is too centralized. This phenomenon results in the border districts such as Wunshan and Beitou suffering from a lack of medical resources. In other words, the geographical distribution of medical resources in Taipei is uneven. Private medium and small hospitals tend to establish themselves in areas that already possess abundant medical resources, because remote areas that have fewer medical resources typically also have a lower population and thus less demand for medical resources. Unfortunately, excessive centralization of medical resources creates intense competition among hospitals and erodes profits. Therefore, policymakers must carefully consider how to reduce competition among hospitals and help hospitals to coexist. The results of this study can inform hospitals of their competition and help them develop appropriate responses to competitor. The government tends to support locating hospitals in remote areas to provide improved access to medical resources for the entire population. Governments thus encourage large hospitals and public hospitals to establish in areas lacking medical resources, for example between Beitou and Shihlin districts or between Daan and Songshan districts for a more even distribution of medical resources.

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