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RESEARCH ON DEMONSTRATE TRANSPORTATION DEVELOPMENT WITH HEAT MAP

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ABSTRACT:

Heat map is an intuitive and accurate visualization tool for spatial data, which is wildly used in many fields. Based on analysis and setting the various layer weights and technical levels of traffic lines, we can use heat map to demonstrate the distribution state and development level of transportation in certain region, with using the comprehensively methods of inverse distance weight, histogram equalization, density compensation and repetitive parameter iteration. The heat map rule describes the rules of traffic line weighting, line-to-poly modification, dot density adjustment and liner fitting, et al, which can extract and demonstrate transportation development index accurately. Based on traffic layer of global geographic data in some Asian and African countries, heat map of transportation development index test has been done to verify the feasibility and reliability.

1. INTRODUCTION

The term “heat map” was originally proposed and created by software designer Cormac Kinney in 1991, use a 2D picture to describe and display real-time financial market information. The initial heat map are some rectangular colour blocks with colour coding, after years of evolution, the heat map on idioms is understood by most people as a smooth and fuzzy thermal map. In the big data application environment based on geographic information, a heat map is generally a thermal map that is visualized through a density function and used to represent the density of points in the geographic map, reflects the difference of observation and measurement in a large spatial range (Wei Yang et al., 2012).

With the great increase in the number of high-resolution satellites in orbit, the ability of geographic data acquisition, processing and database building has been continuously improved, global geographic information data is gradually improving and enriching. On the basis of existing achievements, it is particularly important for government decision-making and public services to realize statistical analysis based on geographic information data and carry out in-depth mining based on existing global geographic data (Jingnan Liu et al., 2014). The existing achievements of global geographic information resources mainly include digital orthophoto map, digital surface model, digital line graphic, place names data, land cover and other data. In terms of information extraction and data mining, domestic research of China mostly focused on traditional remote sensing images and mapping analysis methods such as image target recognition, regional statistics and cluster analysis, the exploration on how to combine the essential characteristics and spatial distribution contained in geographic information with the intuitive feelings of the public is slightly insufficient (Jinlei Li et al., 2019). For the digital line graphic data, its spatial features, element attributes and expression methods contain a lot of information closely related to human activities, which can be used as an effective data source to reflect the level of economic development and evaluate social development.

At present, the statistical index system of transportation industry lacks a "comprehensive index" that can characterize the operation status of transportation and reflect the development trend of transportation (Renhong Liang et al., 2019). Due to the lack of "comprehensive index" to evaluate the development level of the transportation, the government and transportation authorities can not accurately find the weak links and prominent problems of the industry, resulting in a certain blindness in the planning process, which not only wastes resources, but also fails to achieve the expected effect.

Based on the traffic network in the digital line graphic data, this paper attempts to establish the calculation rules of transportation thermal distribution ("comprehensive index"), reflects the development level of transportation in some countries in the world with heat map in an intuitive way.

2. HEAT MAP CONSTRUCTION ON TRAFFIC NETWORK

Traditional thermal calculation is based on points with spatial coordinates, through its attribute value, weight and influence range, the stack density and other information of each grid point in the drawing can be calculated, which can accurately and intuitively identify the spatial distribution of concerned

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information. Thermal calculation based on discrete points has been fully applied in geographic information data at all levels. However, in the thermal calculation of transportation development level based on traffic network, the following three problems need to be solved:

1. traffic lines are **linear** features and cannot be directly involved in scatter space calculation
2. The influence of traffic **grade** on thermal calculation should be much greater than its own spatial distribution density
3. The **search radius** and output **grid size** are closely related to the surface range and the reliability of the results

Some scholars have also conducted in-depth research and exploration on the buffering algorithm of linear features (Jiechen Wang et al., 2009), at the same time ESRI company also provides corresponding nuclear density analysis tools (ArcGIS desktop tools, 2021), which can be used as a good reference. This paper intends to establish the technical process of thermal calculation of transportation development based on the global traffic network, build the relevant rule system, and realize the automatic processing and visual display of transportation development level information.

The thermal calculation technical process of transportation development mainly includes three parts: traffic weighting, line to surface, optimization and coordination. It is shown in the figure below:

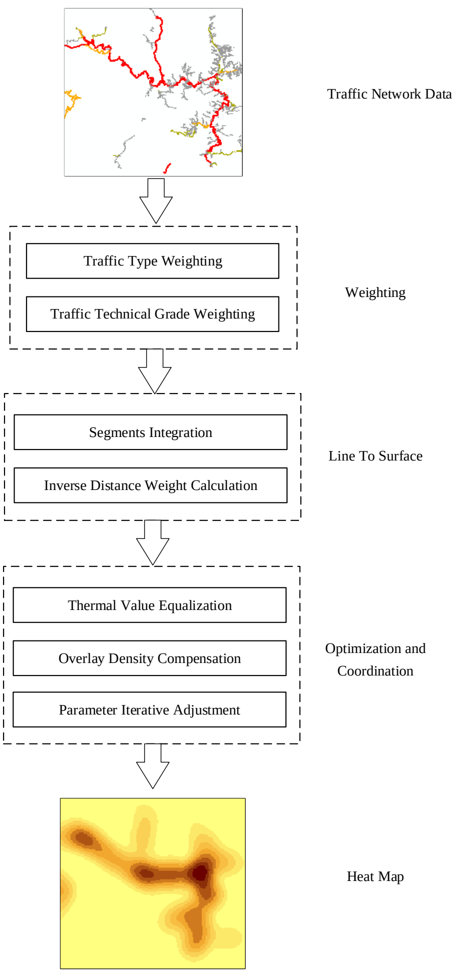

Figure 1. Thermal calculation process

Where the grey dotted line frame shows the corresponding processing rules in different process stages, mainly includes dozens of rule items such as weight assignment of route type (railway / highway / subway, etc.), weight assignment of traffic technical grade, automatic integration of segmented traffic lines, calculation of inverse distance weight from line to surface, coordination of distribution/stack density, comprehensive adjustment of the whole map, etc.

3. KEY ROLES OF CALCULATION

The key point of thermal calculation is to establish the corresponding relationship between the transportation development level in unit area and the grid thermal value. The traffic type, grade, density, fragmentation, buffer radius, output grid size and other factors are related to the calculation results of transportation development level. The correlation is a comprehensive influence and not a simple linear superposition correspondence. The reasonable formulation of thermal calculation rules can effectively avoid the excessive influence of a single factor on the judgment of transportation development, comprehensively consider the influence of various factors on thermal value, and improve the overall calculation efficiency and accuracy. The following focuses on the relevant rules of traffic weighting, line to surface and optimization coordination.

3.1 Traffic Weighting

The traffic network data in most global vector feature data is basically organized and stored in the hierarchy of "data layer - feature - attribute item". In order to comprehensively consider its influencing factors, it is necessary to establish a hierarchical weighting rules of data layer, element and attribute. By setting weights separately and training samples, we can get reasonable weight setting rules. Traffic weighting rules mainly include:

3.1.1 Traffic type weighting: For different types of traffic lines, such as railway, highway, subway and light rail, set the corresponding development degree influence weight. The initial weight seed value is set as railway, road, subway and tram = 5:3:4:4, and the weight of each layer is *WLayer*(for most traffic types are organized by data layers).

3.1.2 Traffic grade weighing: Then sub-classifying with different technical grade: railway can be divided into single-line railway and double-line railway; road can be divided into motorway, trunk, primary, secondary, tertiary, minor, very small path. Different grade of subway and tram usually play same role, so we can use weight with them. Finally, the seed weights of double-line-railway and single-line-railway are set to 8:5, seed weights of motorway, trunk, primary, secondary, tertiary, minor and very-small are set to 18:12:6:4:2:2:1. The weight of each traffic grade is *VGrade*.

3.2 Line to Surface

According to the relationship between the development level of the transportation and the position and score of the traffic line, the score is the largest at the position where the traffic line is located, and gradually decreases with the increase of the distance from the traffic line. The score is zero at the position where the distance from the line is equal to the specified search radius.

The transportation development index is inverse distance weighted interpolation of traffic line. Based on Silverman's

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quartic kernel function, we defined the kernel function for line features. The figure of line segment and the kernel surface fitted over it shows below:

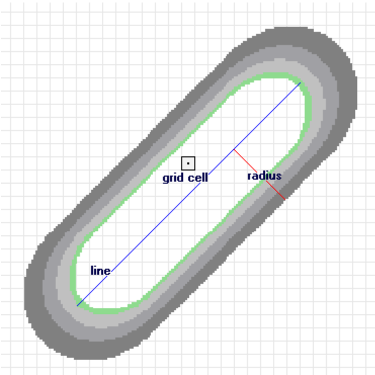

Figure 2. Line kernel function segmenting and fitting

The figure above shows the road line and the core surface covered above it. The space volume enclosed by the kernel surface (traffic score surface) and the lower plane is equal to the product of traffic line length and traffic score.

Considering the traffic line weights that have defined above, suppose that an output cell can meet n types of traffic lines and m grades of each type in searching distance R. The distance of cell and traffic line is $dist_{ij}$, the component value of cell is:

$$V_{point} = \sum_{i=1}^{n}\left\{WLayer_i \frac{1}{R^2}\sum_{j=1}^{m}\left[\frac{3}{\pi}VGrade_{ij}\left(1-\left(\frac{dist_{ij}}{R}\right)^2\right)^2\right]\right\} \quad (1)$$

Where V_{point} is output cell's component value
$WLayer_i$ is the weight of n-th traffic line type,
$VGrade_{ij}$ is the value of j-th technical grade in i-th traffic line type
R is searching radius
m is the number of grade in each traffic type
n is the number of type in traffic lines

Based on the fact that the global traffic data is multi-section lines, in order to reduce the impact of road fragmentation on the comprehensive value, it is necessary to do a job in the splicing and materialization of segmented traffic lines before line to surface, so as to ensure that the traffic lines of the same grade and same type form a complete line.

3.3 Coordination and Optimization

3.3.1 Histogram specification: The V_{point} should be transformed into H_{point} of heat map cell. The thermal value is an intuitive measure to reflect the development degree of the road, and its value should be adjusted appropriately on the basis of the road score. H_{point} is an estimate value without dimension, histogram equalization could be done in heat map to adjust its visual effect. The heat map's histogram specification should be firstly done, and then equalization will make the value percent more normally.

In order to better reflect the relationship between thermal value and transportation development, considering the stack passivation effect due to too much traffic factors and sharpening effect due to less traffic factors, the changes in its high value range and low value range are generally not paid more attention to. The following is an example of histogram specification:

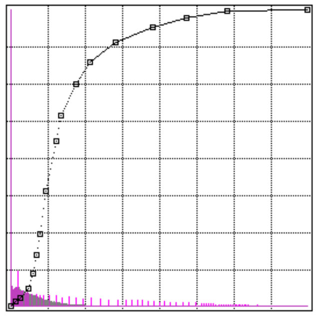

Figure 3. Heat map histogram specification

3.3.2 Stack density correction: To avoid the influence of a mess of traffic lines with very low grade such as track or footway, spatial density adjust based on road grade should be done. $M_{density}$ is the traffic line's density map, combined with distribution heat map M_{heat}, we can get the new distribution of heat map：

$$M_{heat\_new} = M_{heat} + K * M_{density} \quad (2)$$

Where K is adjusting factor (commonly set to -0.2 to -0.4)

3.3.3 Distance and size adjust: Searching distance and cell size is the important factor of result heat map, which should be repeat iterate to improve. Considering the range and complex in each country, the searching distance can be set to 15-70km, and cell size can be set to 100-900m.

4 RESULT AND DISCUSSIONS

4.1 Overall Results

Based on above rules and function, we developed a software to process traffic dataset to transportation development index map, and some country's traffic datasets are selected into process. Combined with the global traffic network data of OSM(OpenStreetMap), hundreds of adjustments have been made through the cycle of parameter setting, program iteration and visual interpretation. In Bhutan, Iran and Morocco, the traffic line dataset have been extracted and processed, and finally the whole country's transportation development index values are calculated and optimized, which is shown in below:

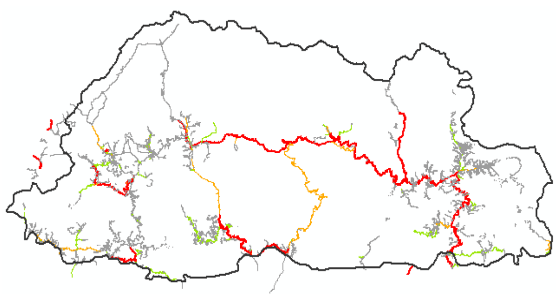

Figure 4. Traffic lines classification in Bhutan

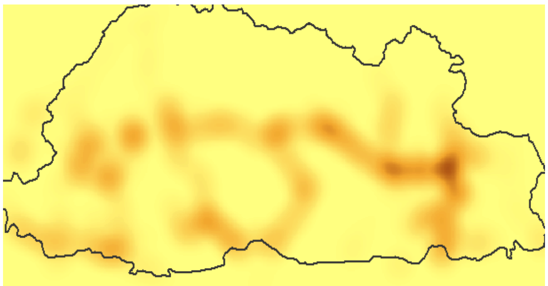

Figure 5. Transportation development index map in Bhutan

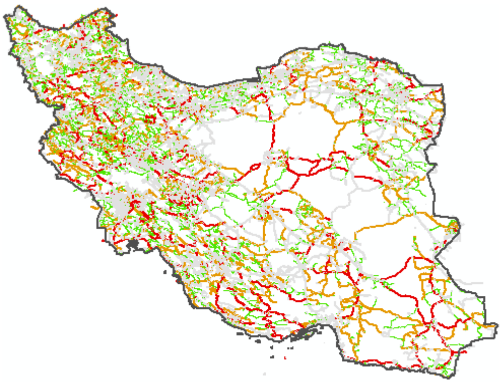

Figure 6. Traffic lines classification in Iran

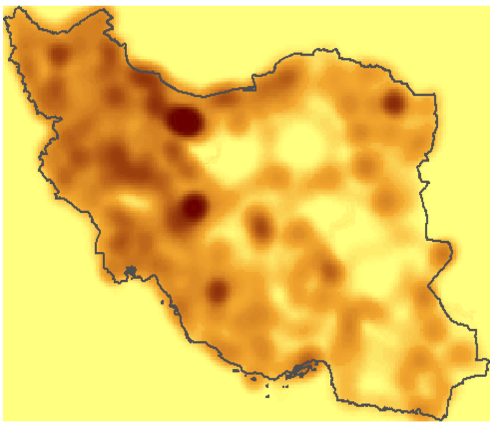

Figure 7. Transportation development index map in Iran

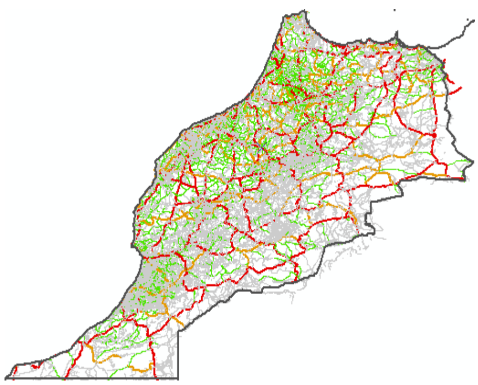

Figure 8. Traffic lines classification in Morocco

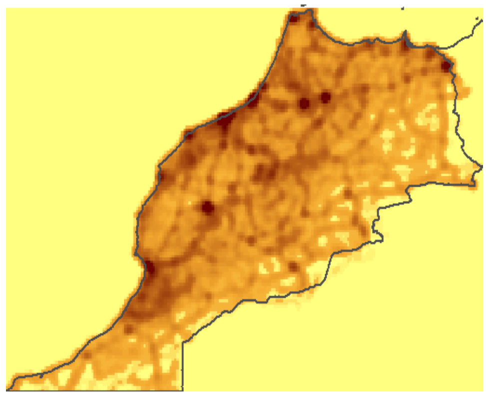

Figure 9. Transportation development index map in Morocco

Where The darker the colour in traffic line map, the higher the traffic grade
The redder the traffic lines, the higher the traffic grade of road and railway, etc
The darker the colour in heat map, the higher the transportation development index
The range of transportation development index values is set to 0 to 100

After repeated iterations, the search radius of Bhutan and Morocco was set to 18 kilometres, Iran's search radius is set at 60 kilometres due to its large land area. After many iterations, output cell size is set to 300m, the weight ratio of railway, road, subway and tram is set to 5:3:4:4, the weight ratio of railway technical grade weight of double-line-railway and single-line-railway are set to 7.3:6.1, road technical grade weights of motorway, trunk, primary, secondary, tertiary, minor and very-small are set to 11.3:5.5:2.8:1.7:0.8:0.8:0.3.

4.2 Detailed Discussion

4.2.1 **Stack density adjustment**: In a fix point on map, if multiple traffic lines with different traffic grades have multiple impacts on it, the thermal value formed at this point takes the cumulative value. As a result, the impact of multiple low-grade traffic lines may exceed that of a small number of high-grade traffic lines, even using high weight with high-grade policies, it cannot be adjusted correctly. The following figure is a typical excessive result:

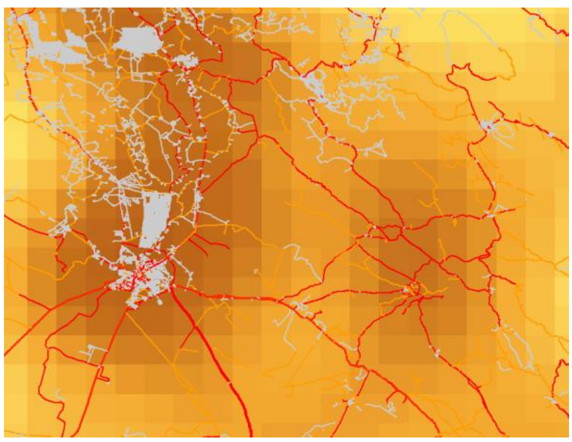

Figure 10. More lines lead to too high value

The red lines are primary road and light grey lines are low-grade traffic lines. The density of high-grade traffic lines of left part is basically the same as the right part one, but the thermal values are almost twice the value of right part one. When too many low-grade traffic lines' thermal values are accumulated at one point, significant reduction should be done to reduce unreasonable cumulative effect. Generally, the arctangent function is a very useful tool to deal with the above problems. It is assumed that the thermal value of low-grade traffic line's value is X_i, the multiple impacts value is Y, the following arctangent function can be used:

$$Y = \frac{2K}{\pi} * \arctan\left(\sum_{i=1}^{n} \frac{X_i}{\alpha}\right) \quad (3)$$

Where K is the max thermal value of multi impacts
$\alpha$is adjustment coefficient to prevent excessive growth(commonly set to 3 to 8)

Commonly K is set to 0.5-0.8 times of its upper level-grade multi impact thermal value, to minimize the incorrect high value caused by too many low-grade traffic lines.

4.2.2 **Output cell size influence:** Compared with road, railway subway and tram are the important form of transportation for cities, especially in big cities. It has the characteristics of short route (compared with cross city highway), large transportation volume and high construction technology level, which can obviously reflect the level of regional transportation development. If the evaluation is conducted within the urban area level, its influence performance is more accurate. However, its influence is obviously underestimated at the national or even transnational level. In order to avoid this situation, it is necessary to establish the fitting relationship between its weight and the output grid size. Obviously, the weight value needs to increase with the increase of the grid size, but there needs to be a limit, that is, it does not exceed twice the weight of the railway. The empirical formula is as follows:

$$W_{adjust} = A * \left(\frac{R_{cur}}{R_{max} - R_{min}}\right) W \quad (4)$$

Where A is the adjustment coefficient, commonly equals to 2
R_{cur} is current output cell size, R_{max} is max output cell size, R_{min} is minimum output cell size. All of the unit is meter
W_{adjust} is the adjusted weight of railway subway and tram, W is the initial weight of them

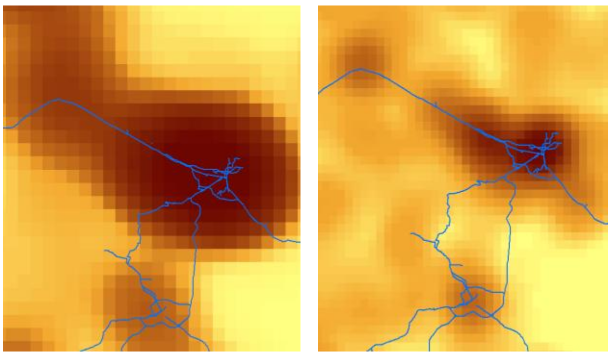

Figure 11. Different cell size of heat map in Tehran

The above images showed the different heat map value in Tehran of Iran with different output cell size. The left image's cell size is 9 kilometres and the right image is 5 kilometres, the blue lines is railway and other subway or tram. We can see that with the increase of output cell size, the impact of railway (or subway and tram) on transportation development will increase accordingly, which objectively reflects its influence on the macro scale.

5 CONCLUSTION

This article described the research on illustrate traffic transportation development by a new style of heat map, from traffic network data, we can weigh the main type and traffic grade of traffic lines and then transmit the value of traffic line to scattered cell value; normalize the multiple scores contained in the rules system and convert the basic data into dimensionless standard values. After repeated iteration and parameter optimization, and also stack density adjustment and output cell size selection, we can get a grid map that basically reflects the development degree of transportation in a specific region.

In the research process, the biggest problem is how to accurately and objectively reflect the actual level of road transportation development on various scales. On the macro scale (such as national or international level), it should accurately reflect the comparative value of different levels of cities, transportation hubs, key routes and other type of transportation regions; at the micro scale (such as city level or county level), it should be able to correctly express the influence difference of urban roads, subway and light rail on the degree of transportation development, so as to be used as the basis of spatial geographical analysis or support urban planning.

Transportation development degree is a comprehensive index. Although the traffic line is the most important factor, stations, docks, cargo distribution centres, aircraft routes and other traffic affiliations are also important. To improve the research on transportation development index from traffic network data, the above factors must be fully incorporated and focused on to deepening and expanding this content.

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