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Visual Perception Location Dataset of Gubeikou Great Wall

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Abstract: The Great Wall is a crucial visual landscape resource with multiple meanings such as history, culture, and morphological aesthetics. Visual perception calculation and analysis is an important approach to exploring the value of the landscape resources of the Great Wall and presenting and explaining the multidimensional significance of the Great Wall. In this dataset, by designing the semantic feature point extraction and coding rules of the Great Wall landscape system, the landscape semantic feature points are generated based on the ontology resources of the Gubeikou Great Wall and ALOS 12.5m DEM data, and the viewshed raster is obtained by analyzing each feature point. Then, based on the landscape visual perception location information model, the landscape visual perception location dataset of the Gubeikou Great Wall was constructed using the NetCDF multidimensional data format. The dataset consists of three parts: (1) the subset of semantic feature points data selected manually, (2) the subset of semantic feature points selected by a program automatically, and (3) verification points. Data subsets (1) and (2) include the vector data of ontology features and semantic feature points of the Gubeikou Great Wall and the visual perception location data of the Gubeikou Great Wall landscape. The dataset is stored in .shp and .nc formats, and it consists of 64 data files with a total data size of 6.58 GB (compressed into 1 file, 63.8 MB).

Keywords: visual perception location; landscape semantic feature points; the Great Wall; NetCDF

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The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2024.04.03.V1 or https://cstr.escience.org.cn/CSTR:20146.11. 2024.04.03.V1.

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1 Introduction

Cultural heritage is an important carrier of history and culture and a witness to the development of human history. In recent years, the digitalization[1] and activation[2] of cultural heritage has increasingly become a focus of attention both domestically and internationally, while the ontological value of cultural heritage and the experience value it brings remain at the core. In July 2019, the 9th meeting of the Commission for Deepening Overall Reform of the CPC Central Committee deliberated and adopted the Construction Plan for the Great Wall, Grand Canal, and Long March National Cultural Park, marking the official launch of the construction of the national cultural park[3]. The Great Wall is a linear cultural heritage with a large volume, long time span, and strong ability in China, which plays an important role in promoting economic development, cultural exchange, as well as national integration in the Great Wall region[4]. The spatial combination and configuration of the main landscapes of the Great Wall, such as the wall, the enemy station, the beacon tower, the Guan fort, etc., has great aesthetic and cultural significance, while the ingenious integration with the environmental background further makes the Great Wall a valuable visual landscape resource. Vision is a fundamental condition for landscape perception[5]. To realize high-quality construction and development of the Great Wall National Cultural Park, it needs to comprehensively explore the visual perception location that can experience the significance of the Great Wall landscape. However, traditional field investigation methods are difficult to comprehensively search for visual landscape perception locations with rich semantic information, and existing research has not yet generated dataset products with landscape visual perception location information from a resource perspective.

The Gubeikou Great Wall is located in the southeast of Gubeikou Town, Miyun District, Beijing, and in the southern part of Luanping County, Chengde City. It includes four sections of Simatai, Jinshanling, Panlongshan, and Wohushan, and it has the characteristics of broad vision, dense enemy towers, unique landscapes, sophisticated craftsmanship, intact original appearance, etc., with high value in visual landscape resources. In this dataset, the landscape ontology of the Gubeikou Great Wall and its visual perception location information were investigated and integrated. The landscape ontology resource of the Gubeikou Great Wall was expressed digitally in the form of landscape semantic feature points, and its landscape semantic attribute information was expressed by coding; Meanwhile, the visual perception location information of the Gubeikou Great Wall was integrated and stored in the NetCDF multidimensional raster data format to establish the visual relationship between visual perception location and landscape semantics and to integrate target landscape, perceived location, and visual state information. The dataset provides data for heritage protection and integrated development of culture and tourism, and it supports the value mining of landscape resources based on visual perception.

2 Metadata of the Dataset

The metadata of the Landscape visual perception location dataset of Great Wall in Gubeikou[6] is summarized in Table 1. It includes the dataset's full name, short name, authors, geographical region, spatial resolution, data format, data size, data files, data publisher, data sharing policy, etc.

3 Methods

3.1 Data Sources

(1) The data on the Great Wall landscape resources were collected from the Ming Great

Table 1 Metadata summary of the Landscape visual perception location dataset of Great Wall in Gubeikou

Items	Description
Dataset full name	Landscape visual perception location dataset of Great Wall in Gubeikou
Dataset short name	Gubeikou_LVPLM
Authors	Li, Z. H. JTU-3036-2023, College of Geographical Sciences, Hebei Normal University, lizhhg@163.com Li, R. J. JZD-9102-2024, College of Geographical Sciences, Hebei Normal University, lrjgis@hebtu.edu.cn Sun, B. L. JYP-6636-2024, College of Geographical Sciences, Hebei Normal University, stayreal9523@163.com Li, J. H. JYP-6677-2024, College of Geographical Sciences, Hebei Normal University, ljh06524@163.com
Geographical region	Gubeikou Great Wall along the 5 km range grid
Spatial resolution	12.5 m
Data format	.shp, .nc
Data size	63.8 MB (compressed)
Data files	Gubeikou Great Wall ontology features and landscape semantic feature point vector data, landscape visual perception location multi-dimensional raster data
Foundations	Natural Science Foundation of Hebei Province(D2023205011); National Natural Science Foundation of China (41471127)
Computing environment	ArcGIS
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the 'ten per cent principal' should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[7]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

Wall heritage data provided by the National Cultural Relics Census and the Great Wall station volunteer geographic information platform[1]. The research area covers 26.49 km of the Great Wall, including 154 enemy stations, 13 beacon towers, 1 shop house, 2 water passes, and 1 Guan fort.

(2) The DEM data was derived from NASA's Earthdata website[2], and ALOS satellite data with a spatial resolution of 12.5 m was used.

(3) Environmental background and geographical elements were adopted from China's 1:100,0000 basic geographic dataset.

(4) The verification data were collected by the project team through a field survey.

3.2 Dataset Organization Framework

The Landscape Visual Perception Location Model (LVPLM)[8] was employed to organize the dataset, and each landscape semantic feature point was taken as a basic visual perception location calculation unit. The data result was stored in the NetCDF multidimensional data

[1] The Great Wall station volunteer geographic information platform. http://www.thegreatwall.com.cn/.

[2] NASA's Earthdata website. https://www.earthdata.nasa.gov/.

format. The organization model of the dataset is expressed in Equation (1).

$$LVPLM=f\,(X, Y, Points) \tag{1}$$

where, *X* and *Y* denote the location dimensions of the dataset, and the dimension values are the X and Y coordinates of the landscape visual perception location. *Points* represents the feature point dimension of the dataset, and the dimension value is the encoding of semantic feature points. The three dimensions of *X*, *Y*, and *Points* provide the spatial location and feature point coding information, and the data variables provide the visual perception information. Based on this, bidirectional queries of landscape semantic feature points and their visual perception state can be realized, thereby establishing the correlation between the landscape of the Gubeikou Great Wall and the visual perception location.

3.3 Data Procession

First, landscape ontology resource data was generated based on basic data interpretation, and the vector dataset of landscape semantic feature points of the Gubeikou Great Wall was constructed following feature point extraction and coding rules: including the wall line of the Gubeikou Great Wall and the point elements of the Great Wall itself (beacon tower, etc.), and the landscape semantic feature points in shapefile data format. Then, each landscape semantic feature point was calculated from the perspective, and the obtained visual grid was integrated and organized using the LVPLM, and the Great Wall landscape visual perception location dataset was constructed based on the NetCDF multidimensional raster data structure. Finally, the landscape visual perception information can be extracted from the dataset. The data research and development process is illustrated in Figure 1.

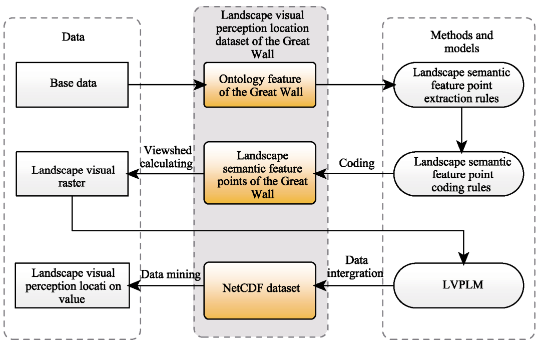

Figure 1 The flow chart of the dataset development

(1) The generation of ontology data of the Great Wall landscape resources

Based on the distribution vector of the Great Wall Station and the attribute information of the national cultural heritage survey data, and taking the ArcGIS Earth 3D terrain environment background as a reference, the author cooperated in interpreting, correcting, and generating high-precision landscape ontology resource data of the Great Wall at Gubeikou. It included the wall line data and the ontology feature point data of the Great Wall (such as enemy towers, beacon towers, etc.). Specifically, the wall line of the Great Wall was the center line of the wall, while the main landscape features of the enemy tower, beacon tower, and other features were the geometric center point of the features, and the height was set according to the height of the landscape features.

(2) Extraction and coding of semantic feature points of the Great Wall

Landscape semantic feature points are the foundation of the digital representation of visual landscape resources. According to the comprehensive idea of cartography, landscape ontology can be abstracted as landscape semantic feature points that can maximize the authenticity of landscape semantics[9–11]. Then, the extraction rules of semantic feature points were designed following the landscape resource classification and semantic feature point selection rules proposed by Guo[12].

According to the purpose of abstracting the morphological characteristics of the Great Wall as much as possible and fully expressing the landscape semantics, semantic feature points were extracted from the wall at an average interval of 30 m, and the points were taken from the places where terrain features changed significantly along the wall extension direction. The height of the feature points was taken from the average height of the Great Wall in the Gubeikou section at 6 m. Following the above principles, the feature points were divided into landscape feature points, terrain feature points, and average interval points using different extraction methods: (1) Landscape feature points, i.e., beacon towers, enemy stations, and other Great Wall ontology features, where the point data in the ontology features were directly used, all reserved because of the importance of its function and visual state in principle; (2) Terrain feature points were extracted at the point where the wall line of the Great Wall varied significantly in the plane or elevation direction, and encrypted points were taken in the extension direction. In the automatic extraction method of the program, the 3D Douglas-Peucker algorithm was used to screen out the terrain feature points on the wall line of the Great Wall[13], and a tolerance value of 15 m was set for calculation and extraction; (3) Average interval points, the average interval distance of 30 m was used to supplement the points on the wall line of the Great Wall. The extraction method is illustrated in Figure 2. According to the selection rules of semantic feature points, the landscape semantic feature points of each section of the Gubeikou Great Wall were extracted through artificial discriminant extraction and programmed automatic extraction respectively.

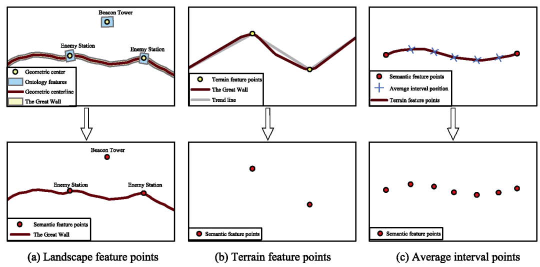

Figure 2 The schematic diagram of feature point extraction rules

After feature points were extracted, the hierarchical classification coding method was employed to encode all landscape semantic feature points in the system, and the basic coding structure was designed as 4-digit codes including section code, location sequence code, structural order code, and element type code.

(3) Landscape visual perception calculation

Based on DEM data, all landscape semantic feature points constituting the landscape system of the Great Wall of Gubeikou were calculated and analyzed in sequence in terms of the visual field. The whole research area and 10 km were calculated as visual field ranges respectively, and then visual field grids of different visual field ranges of each landscape semantic feature point were generated. It is a set of raster pixels that can cover the entire calculation area. The value of each raster pixel is 1 or 0, respectively representing the visible or invisible state of a certain landscape semantic feature point at that location. The spatial distribution information of visual perception location can be obtained based on the result of landscape visual perception calculation.

(4) Landscape visual perception location data integration based on LVPLM

According to the organization structure of the LVPLM model, the "raster to NetCDF" tool in the ArcGIS multidimensional toolbox was utilized to integrate all the visual raster layers generated by calculation into .nc multidimensional data, and the visual perception location dataset of Gubeikou Great Wall landscape was obtained.

4 Data Results and Validation

4.1 Data Composition

The dataset consists of three parts: (1) The subset of semantic feature points selected manually; (2) The subset of semantic feature points selected by program automatically; (3)

Verification points (archived in three folders called "Gubeikou_LVPLM_Manually" "Gubeikou_LVPLM_Automatically_10km", and "Gubeikou_LVPLM_Validation_Data"). Data subsets (1) and (2) include vector data of ontology features and semantic feature points of the Gubeikou Great Wall archived in the .shp format, and visual perception location data of the Gubeikou Great Wall landscape stored in the .nc format.

4.2 Data Products

(1) Semantic feature points of the Gubeikou Great Wall landscape

A total of 941 semantic feature points were extracted from the Gubeikou Great Wall through manual selection, and 944 semantic feature points were extracted through program selection. The overall spatial distribution and extraction results of feature points (manually selected) are shown in Figure 3 (for ease of expression, the feature points on the figure are extracted and displayed).

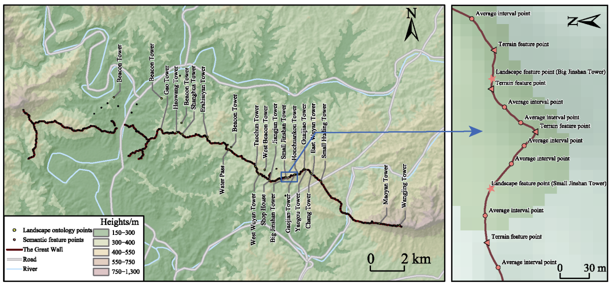

Figure 3 The extraction results of semantic feature points from the Gubeikou Great Wall landscape

Each feature point was recorded with a unique code carrying its landscape semantic information (Table 2). Under the range scale of the current dataset, each landscape feature was expressed by one feature point, so the structural order code (the fifth digit encoded) was all 1. If it is necessary to add feature points to the landscape feature in the future, it can be sequenced according to the structural order code.

Table 2 The coding of the landscape semantic feature points of the Gubeikou Great Wall (part)

Sample code	Section (code)	Location sequence	Structural sequence	Feature type (code)	Coding semantic parsing
100111	Simatai (1)	001	1	Wall (1)	Wall feature point of location No.1 in Simatai subsystem
101511	Simatai (1)	015	1	Wall (1)	Wall feature point of location No.15 in Simatai subsystem
110412	Simatai (1)	104	1	Enemy Station (2)	Enemy Station feature point of location No.104 in Simatai subsystem
211014	Jinshanling (2)	110	1	Shop House (4)	Shop House feature point of location No.110 in Jinshanling subsystem
220613	Jinshanling (2)	206	1	Beacon Tower (3)	Beacon Tower feature point of location No.206 in Jinshanling subsystem
220716	Jinshanling (2)	207	1	Guan Fort (6)	Guan Fort feature point of location No.207 in Jinshanling subsystem
301215	Panlongshan (3)	012	1	Water Pass (5)	Water Pass feature point of location No.12 in Panlongshan subsystem
317911	Panlongshan (3)	179	1	Wall (1)	Wall feature point of location No.179 in Panlongshan subsystem
400513	Wohushan (3)	005	1	Beacon Tower (3)	Beacon Tower feature point of location No.5 in Wohushan subsystem
403312	Wohushan (3)	033	1	Enemy Station (2)	Enemy Station feature point of location No.33 in Wohushan subsystem

(2) Overall statistical characteristics of visual perception location of the Gubeikou Great Wall landscape

The dataset integrated the overall visual perception location information of the landscape system. Through data aggregation, the visual perception metric value of each spatial location unit can be obtained, which reflects the number of overall visual feature points of the landscape system at the visual perception location. Based on this, the overall statistical feature analysis of landscape visual perception can be conducted. The more the number of semantic feature points of the visual landscape, the higher the value of the potential perceived location, and vice versa. The spatial distribution of the number of overall feature points in the visual perception location is illustrated in Figure 4.

(3) Visual location of the Gubeikou Great Wall landscape

Based on the visual perception location dataset of the Gubeikou Great Wall landscape, the following information can be extracted: (1) The visual perception location of specific semantic feature points, i.e., the visual distribution information of target feature points; (2) The visual semantic feature points of a specific location, i.e., the semantic feature points that can be seen at a specific observation point.

The representative landscape Maoyan Tower and Small Jinshan Tower were selected to identify the spatial distribution characteristics of their visual locations. As shown in Figure 4(e), the Maoyan Tower located in the Simatai section has a large and more concentrated landscape visual location range, which is mainly distributed in the southwest direction; However, the visual location of the Small Jinshan Tower in the Jinshanling section is scattered inside and outside the Great Wall, as demonstrated in Figure 4(d). Then, observation points were selected on the south and north sides of the Jinshanling section of the Great Wall, and the visual feature points of the area can be obtained based on the visual perception location information contained in the dataset, as shown in Figure 4(b) and Figure 4(c).

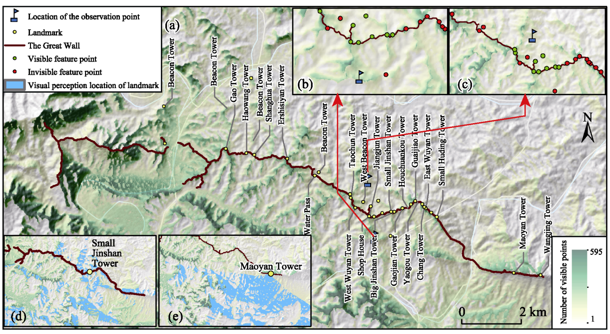

Figure 4 The spatial distribution of the overall feature points in the Gubeikou Great Wall

4.3 Data Validation

The project team went to Gubeikou Great Wall area from August 9 to 13, 2023 to verify the accuracy of the calculation results. Considering the characteristics of the Great Wall landscape, the spatial distribution of visual perception location, and the objective of accuracy verification, three types of verification areas were set up: the verification area on the Great Wall, the centralized verification area along the Great Wall, and the random verification area. In the accuracy verification, the consistency between the visual perception in real scenes and the visual perception calculation results was evaluated, and then the accuracy of the visual perception location dataset of the Great Wall landscape was evaluated.

(1) Selection of verification area and data collection of observation points

The verification area on the Great Wall was a verification area composed of observation points located on the Great Wall. The verification area was constructed by setting observation points in the Jinshanling section. The verification area along the Great Wall was selected in the south of the Simatai section, and a total of 11 regular squares of 500 m×500 m were set up. Observation points in the random verification area were randomly selected along the traffic lines and villages on both sides of the Great Wall at Gubeikou (Figure 5).

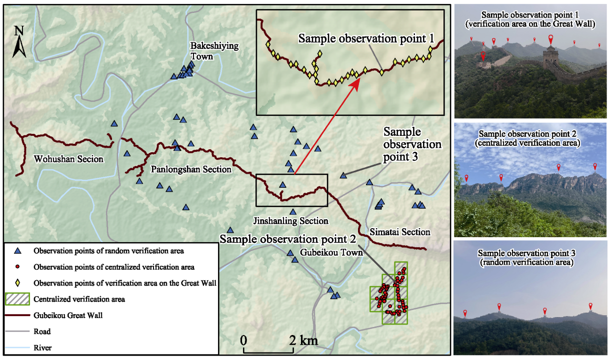

Figure 5 The distribution of verification areas and observation points in the Gubeikou Great Wall

Table 3 The field observation information at the Gubeikou Great Wall (part)

Time	Location	Reachable	Code	Latitude (N)	Longitude (E)	Factors affecting visibility	Semantic feature point code of visible features	Number of visible features
2023/8/9 12:40	On the wall	Y	J16	40°40′44.59″	117°15′4.10″	None	206112; 205512; 205012; 204712	4
2023/8/9 11:41	On the wall	Y	J23	40°40′39.20″	117°14′44.75″	Terrain	206712; 207212; 207912; 211014; 211112; 211512; 212112; 212313; 213212; 213612; 214012; 214312; 214812; 215212; 215712	15
2023/8/9 12:14	On the wall	Y	J19	40°40′40.36″	117°14′59.27″	Vegetation	201212; 202112; 202312; 202912; 203612; 204712; 205012; 205512	8
2023/8/11 15:49	Beyond the wall	Y	A742-B19	40°40′24.18″	117°16′51.20″	Vegetation; Weather	114212; 115112; 115712; 113612; 112812	5
2023/8/12 13:54	Beyond the wall	Y	A1059-1	40°42′3.59″	117°14′25.72″	Vegetation; Buildings; Terrain	None	0
2023/8/12 10:54	Beyond the wall	Y	A420-7	40°38′37.25″	117°17′23.94″	Vegetation; Buildings	100512; 102212; 103812	3
2023/8/11 11:19	Beyond the wall	Y	A735-1	40°40′15.72″	117°14′24.61″	Weather	210312	1
2023/8/10 17:11	Beyond the wall	N	A1237-B10	N/A	N/A	N/A	N/A	N/A

The project team members first went to the verification area to collect observation points. If the target point was not reachable due to objective factors such as terrain, land cover, or personnel safety, the point was recorded as inaccessible; If the target point was reachable, after the observation point was reached, the current coordinates were located through a handheld GPS instrument, and the visual situation of the single landscape of the Great Wall at the current point was recorded by taking photos (the photos contained the azimuth and other information), the 3D terrain view and the vector data of the single landscape in the verification area were loaded with OvitalMap software, and the semantic feature point code of all visible landscape in each photo was compared for identification. Finally, the above information, observation point code, factors affecting the visibility and other information were filled into the preset field observation information collection form for submission and summary (Table 3). After data collation, a total of 137 effective observation points were obtained in the verification work, including 27 observation points in the verification area onthe Great Wall, 60 observation points in the centralized verification area, and 50 observation points in the random verification area.

(2) Accuracy verification methods and results

The quantitative and content consistency of all observation points can be obtained by comparing the matching degree between the field observation data of each observation point and the feature point information of the visible single landscape (such as beacon tower, enemy station, etc.) at the corresponding location in the dataset in terms of the number of visible feature points and the corresponding relationship between the visible feature points[8]. Then, the dataset validation results were obtained by calculating the average quantitative and content fit according to different validation area types (Table 4). The average total quantity coincidence and content coincidence were 76.37% and 70.69%, respectively. Meanwhile, it was found that DEM accuracy, landscape preservation status, and construction and vegetation occlusion all affected the accuracy of the dataset. The verification results suggest that the dataset results are consistent with the field observation results, and the landscape visual perception location information of the dataset has high reliability.

Table 4 The verification results of the Gubeikou Great Wall LVPLM dataset

Type of verification area	Number of observation points	Number of fit averages	Content fit average
Verification area on the Great Wall	27	94.55%	76.32%
Centralized verification area	60	64.28%	62.29%
Random verification area	50	81.07%	77.73%
Overall	137	76.37%	70.69%

5 Discussion and Conclusion

In this dataset, the landscape resources of the Gubeikou Great Wall were digitally expressed in the form of vector geographic feature points, and the landscape semantic information of each feature point was recorded by coding, so as to obtain landscape ontology data of the Gubeikou Great Wall. Based on the raster data obtained from perspective analysis and the calculation of landscape semantic feature points, the location information of landscape visual perception was organized and stored in an integrated way based on the LVPLM model, and the correlation between visual perception location and landscape semantic feature points was established in the NetCDF multidimensional data format. In this approach, the bidirectional query from feature points to their visual location and from specific locations to corresponding visual feature points can be realized. Field verification analysis results indicate that the dataset's results have good reliability. Therefore, this dataset not only provides semantic feature point data that can characterize the landscape system characteristics of the Gubeikou Great Wall for researchers engaged in landscape planning and Great Wall research, but also provides multi-dimensional landscape visual perception location raster data with encoded semantic sequence information. With this dataset, further landscape visual perception information mining can be conducted to evaluate visual perception effects, select potential high-quality landscape perception locations, analyze different locations of the visual Great Wall landscape combination mode, and perform other application practices, thereby assisting in high-quality tourism spatial planning and the construction of the Great Wall National Cultural Park.

Author Contributions

Li, Z. H. successfully implemented the algorithm for automatic feature point extraction and data integration, and wrote the data paper. Li, R. J. formulated the overall development plan for the dataset and designed its organizational structure, while also being responsible for revising and approving the data paper. Sun, B. L. participated in producing and validation of the dataset. Li, J. H. contributed to designing and validating the data validation.

Conflicts of Interest

The authors declare no conflicts of interest.

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