Research on the System Restoration of Military Settlements in Jin Dynasty from the Perspective of Digital Intelligence Empowerment

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ABSTRACT

Under the background of the transformation of digital humanities research, the research on historical military settlements needs to break through the limitations of traditional literature textual research and qualitative analysis, and the research on historical military settlements, which traditionally relies on literature textual research and empirical judgment, faces a breakthrough in methodology. In recent years, although intelligent technology has made phased achievements in archaeology and heritage protection of historical buildings, and has gradually become an important supporting tool for heritage research and inheritance, there are still few researches on the early Great Wall in China, especially the military settlements in Jin Dynasty. Taking the Northeast Road of the Great Wall in Jin Dynasty as an example, the existing research mostly focuses on the individual form or local layout of military facilities, and lacks the overall restoration of the hierarchical relationship and spatial logic of the whole settlement system. This paper attempts to reconstruct the system structure of the Great Wall military settlement in Jin Dynasty with the help of digital modeling and spatial analysis, and further explore the spatial interaction characteristics between its internal composition and its surrounding environment. Through multi-dimensional technical interpretation, it not only presents the wisdom crystallization of the construction concept of the Jin Dynasty border defense system, but also expands the understanding depth of the Great Wall heritage. This intelligent research path has built a dialogue bridge between the protection of historical and cultural heritage and contemporary scientific and technological tools, which not only enriches the traditional research paradigm, but also opens up new theoretical space and practical ideas for the sustainable inheritance of heritage.

Keywords: Digital Intelligence Empowerment; Military Settlements; the Early Great Wall; System Restoration; Digital Transformation

1 Introduction

With the deepening of globalization and the increasing penetration of digital technology, the research on historical military settlements is facing unprecedented demand for updating methods. Traditional research methods mainly rely on literature sorting and empirical judgment, which is often limited by the bottleneck of single information dimension, lack of correlation between elements and inability to realize dynamic simulation when dealing with spatial systems with complex structures, and it is difficult to effectively reveal the multi-dimensional interaction mechanism within settlements. The rise of a new generation of digital tools, especially the ability expansion in modeling and simulation, provides an innovative path for related research. Driven by the algorithm, the dynamic evolution process of historical space can be quantified and visualized, so that the heritage objects such as the early military settlements along the Great Wall, which have both functional diversity and temporal and spatial mobility, can break through the previous static perspective and realize the comprehensive reconstruction at the three-dimensional and system levels.

Re-examining the defensive remains of the Great Wall from the perspective of settlement system will not only help to deeply understand the construction wisdom and spatial organization strategy of various ethnic groups in military engineering, but also further reveal the interactive relationship between human activities and natural geographical conditions, enrich the cultural connotation of related heritage, and provide theoretical support for the protection strategy of the Great Wall settlements under the background of multi-ethnic. As one of the typical linear cultural heritages, the Great Wall in Jin Dynasty carries important historical information, but there are still obvious gaps in related research, and the overall systematic understanding of it is not perfect, and a systematic protection mechanism has not yet been formed. Due to the scattered historical records of military settlements in the Jin Dynasty, it is often difficult to accurately restore their social structure and spatial layout characteristics by relying on traditional textual research methods, and it is urgent to make a multi-dimensional analysis by means of quantitative research methods.

This study relies on theoretical and technical progress of the current digital research of cultural heritage, with the academic support of settlement archaeology theory, and introduces quantitative methods to analyze on the basis of qualitative judgment. Taking the military settlement system in the northeast section of the Great Wall as the research sample, combining with geographic information system (ArcGIS) and statistical analysis software (SPSS), integrating the field archaeological achievements and historical spatial data, this paper systematically analyzes the hierarchical system and spatial structure evolution logic of its settlement organization. This kind of integrated research paradigm can not only deepen the understanding of the construction concept of frontier defense system in Jin Dynasty, but also provide a solid theoretical basis for the subsequent scientific protection, value exploration and inheritance strategy formulation.

2 Research Methodology and Data Acquisition

2.1 Research Methodology

This study explores the application of digitization in the restoration of early military settlement systems. Based on various conventional research methods such as basic literature research, image research, and mathematical statistical analysis, spatial data analysis is used as the technical core. With the support of ArcGIS geographic information platform, a spatial database of military settlements on the Northeast Road of the Great Wall in Jin Dynasty is established. Weighted Voronoi diagram spatial modeling technology is used to analyze the spatial radiation range of settlements at all levels, and clustering algorithms are used to quantify the hierarchical membership relationships between settlements. On this basis, the innovative fusion of settlement archaeological site grading theory, combined with Tyson polygon spatial segmentation method and site resource domain analysis model, introduces K-means machine learning algorithm for military unit division, forms a multidimensional and quantitative settlement grading system classification standard, and ultimately realizes the systematic restoration of the military defense system of the Northeast Road of the Great Wall in Jin Dynasty.

2.2 Data Acquisition

In the study of early heritage, data acquisition is very important. Digital technology provides accurate data support for protection work, improves work efficiency and reduces errors and risks of manual operation. The spatial data construction of this study adopts multi-source heterogeneous data acquisition system: the basic geographic information data comes from the authoritative database of China National Basic Geographic Information Center; The 30-meter resolution digital elevation model (DEM) data is quoted from the international scientific data mirroring platform of the Global Academy of Sciences. The research team systematically collected the GPS location site data of cultural protection institutions in Inner Mongolia, Heilongjiang and Jilin provinces, combined with the spatial registration and data verification of Google Earth satellite images, and formed a standardized spatial data set through multi-source data fusion. After double verification by field investigation and literature research, a special spatial database containing 124 military settlements on the northeast road of the Great Wall was finally constructed.

Using laser scanning and photogrammetry technology to collect data during the team visit can obtain a large number of cloud data of the Great Wall site in Jin dynasty quickly and accurately, greatly improve the efficiency and accuracy of data acquisition of the early Great Wall site, help to establish a related information database, form a complete set of digital files integrating management, research and application, and realize long-term preservation and dynamic update of data.

3 Application of Digitalization in the Research of Military Settlement System Restoration

Analyzing the composition of the military settlement system of the Great Wall is an important prerequisite for deepening the system research. The system takes hierarchical military settlements as the core element, forms multiple system units under the framework of specific management system, and builds a complete system architecture through synergy. The integrated application of digital technology constructs a circular research system of "data-driven-model analysis-context verification", and restores the military settlement system of Northeast Road of the Great Wall from two dimensions of hierarchy division and system unit through quantitative means, providing a verifiable digital research path for military settlement research.

3.1 Classification Framework of Military Settlements

3.1.1 Classification Scheme

Drawing upon settlement archaeology methodologies, this study employs systematic clustering via SPSS software to categorize the military settlements on Northeastern Road into four tiers: Zhaotaosi (supreme command posts), Meng'an (chiliarch garrisons), Mouke (centurion outposts), and Punian (subsidiary stations).

Accounting for the unique defensive characteristics of Great Wall military settlements, this study establishes a hierarchical classification system based on archaeological data from the Northeastern Road sites. Three key indicators—settlement perimeter, defensive infrastructure (barbicans, watchtowers, fortified gates, moats, double walls, inner citadels, and intra-fort observation platforms), and residential facilities (dwellings, wells, granaries)—were selected to construct the evaluation framework (Table 1). A binary coding system (presence=1, absence=0) quantified the defensive and residential features, with cumulative scores calculated for each category. To address dimensional disparities among variables, perimeter measurements and feature scores were normalized to the [0,1] range through normalization, forming the analytical basis for settlement tier classification.

Table 1 Classification indicator system of military settlements on the Northeast Road of the Great Wall in Jin Dynasty

Primary indicators	Secondary indicators	Data recording criteria
Settlement perimeter	-	Perimeter measurements
Defensive infrastructure	Barbicans	presence=1, absence=0
	Watchtowers	presence=1, absence=0
	Fortified gates	presence=1, absence=0
	Moats	presence=1, absence=0
	Double walls	presence=1, absence=0
	Inner citadels	presence=1, absence=0
	Intra-fort observation platforms	presence=1, absence=0
Residential facilities	Dwellings	presence=1, absence=0
	Water Well	presence=1, absence=0
	Granaries	presence=1, absence=0

In order to improve the clustering accuracy and reflect the defense characteristics of military settlements, a differentiated weight clustering scheme is constructed. Combining the results of multi-scheme clustering and referring to the research results of archaeology and history, the settlement levels are finally determined (Figure 1). The weight scheme includes: the first scheme adopts the equal weight distribution method; In Scheme 2, the perimeter weight is 50%, the defense facilities are 25%, and the residential facilities are 25%; In Scheme 2: The weight of defense facilities is 50%, the perimeter is 25%, and the residential facilities are 25%; The perimeter and defense facilities of the scheme account for 50% and 50% respectively.

3.1.2 Classification Results

According to the military settlement classification scheme of Northeast Road, the processed basic data are imported into SPSS software for systematic cluster analysis. The final division result is: five Zhaotaosi (supreme command posts), eight Meng'an (chiliarch garrisons), twenty-one (Mouke centurion outposts), ninety (Punian subsidiary stations). Spatial distribution of these hierarchical settlements is illustrated in Figure 2.

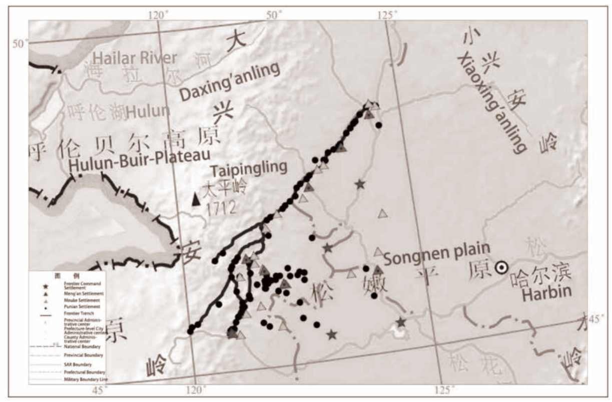

Figure 2 Distribution map of different levels of military settlements on the Northeast Road of the Great Wall in Jin Dynasty

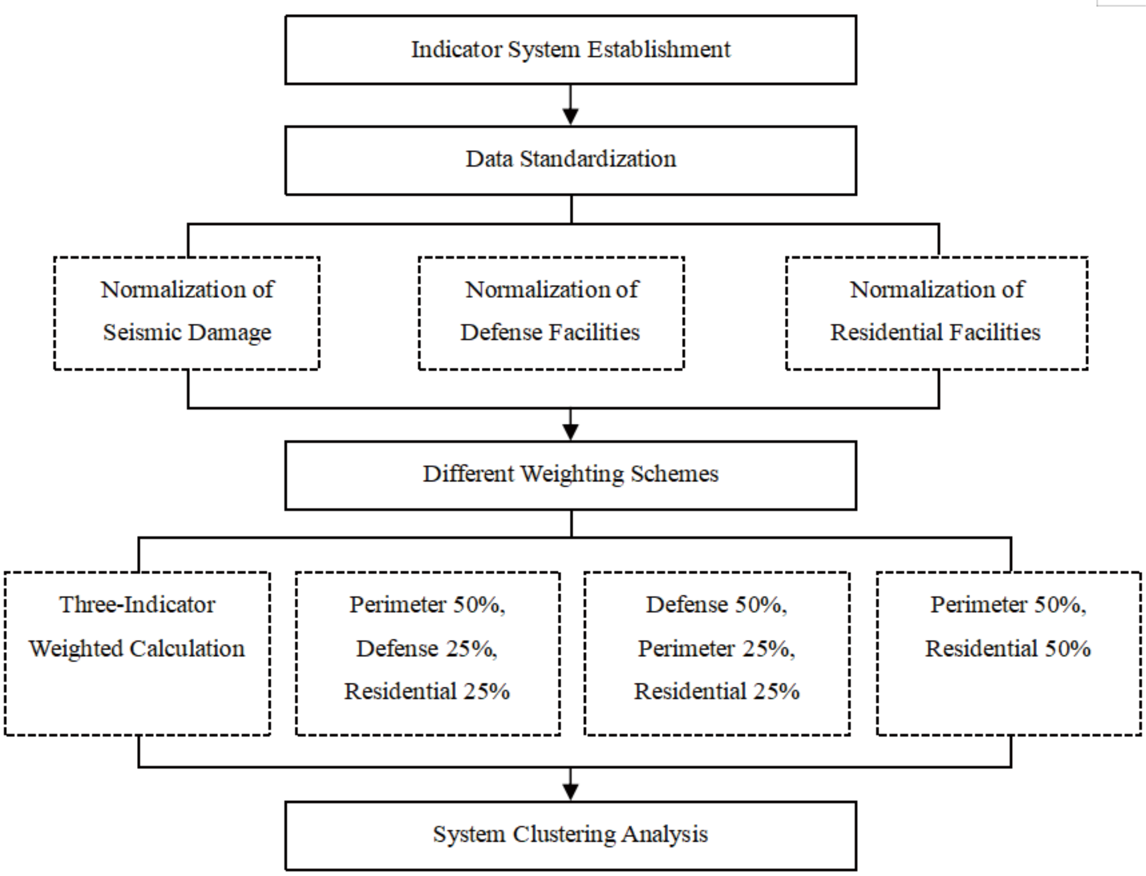

Figure 1 Flow chart of classification of military settlements on the Northeast Road of the Great Wall in Jin Dynasty

3.2 Restoration of the Military Settlement System Units

The empowerment of digital intelligence introduces a new research paradigm for the structural restoration of the Military Settlement System on the Northeast Road of the Great Wall in Jin Dynasty. By leveraging GIS spatial analysis techniques and big data correlation algorithms, it becomes possible to accurately simulate the control range and defensive boundaries of the Meng'an settlement group units, and through settlement-level topological network modeling, dynamically analyze the subordinate relationship chains among the Mouke, Punian, and Meng'an settlements, thereby achieving a digital reconstruction of the military administrative hierarchy.

In this system, settlements do not exist in isolation. At the military administrative level, lower-level Mouke and Punian settlements are subordinate to a specific Meng'an settlement, forming a single Meng'an settlement group unit; eight such group units together constitute the entire Military Settlement System on the Northeast Road. From the perspective of defensive coordination, each of the eight Meng'an settlement groups is responsible for safeguarding a particular area within the Northeast Road region, and when the defensive areas of two or more groups are in very close proximity, collaborative defensive interactions occur more frequently than between groups that are farther apart, leading to the emergence of distinct defensive unit sectors. This section examines, on one hand, the delineation of defensive unit sectors within the Northeast Road Military Settlement System from the standpoint of settlement control ranges, and on the other hand, the grouping of Meng'an settlement units based on hierarchical subordination. Through these two levels of unit delineation, the structure of the Northeast Road Military Settlement System is comprehensively restored.

3.2.1 Partitioning of Defensive Unit Sectors within the Military Settlement System on the Northeast Road

3.2.1.1 Methods for Defensive Sector Partitioning

(1) Thiessen Polygons

Thiessen polygons were first proposed by the Dutch scholar A. H. Thiessen. The process for constructing these polygons is as follows: first, Delaunay triangles are formed using adjacent discrete points as vertices; second, the perpendicular bisectors of each edge of these triangles are drawn; and finally, by connecting the intersections of these bisectors, the vorono polygons corresponding to the discrete points are obtained (as shown in Figure 3). This method has been extensively and successfully applied in disciplines such as physical geography, urban planning, and settlement archaeology.

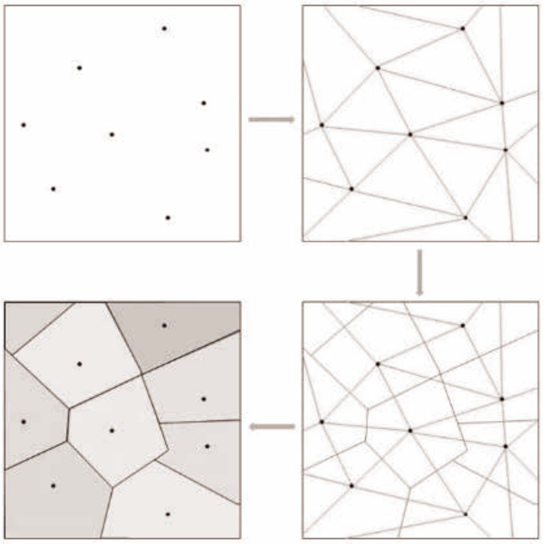

Figure 3 Schematic diagram of Thiessen polygons establishment

In settlement archaeology, the underlying principle of using Thiessen polygons is to assume that two contemporaneous neighboring settlements exert an equal probability of developing and controlling their surrounding environment. Consequently, a perpendicular line is drawn at the midpoint of the line connecting the two settlements to serve as the boundary for their respective environmental development and control.When such bisectors are applied across multiple settlements, the Thiessen polygon formed around each settlement can be regarded as its theoretical control range—a method that harmonizes with the resource-driven traditional settlement development model and effectively addresses the challenge of delineating the control areas of conventional settlements.

(2) Site Resource Domain

Site Resource Domain analysis emerged in the

1970s as an innovative method developed within the Western archaeological community. Initially applied by Vita-Finzi and Higgs in field studies in Palestine, it has since become a crucial component of environmental archaeology and one of the primary approaches for analyzing the relationship between archaeological sites and their surrounding environments. The infusion of digital intelligence provides new technological impetus for the integrated application of Thiessen polygons and site resource domain methods, dynamically balancing the coupling between the geometric partitioning inherent in Thiessen polygons and the environmental elements of site resource domains. This combined approach offers a comprehensive analytical framework for examining how settlements utilize their surrounding environments, thereby advancing research on the Great Wall in Jin Dynasty Military Settlement System. From a military hierarchy perspective, within the Northeast Road military defense system of the Jin Dynasty, the Meng'an settlement functions as a primary grassroots military center, with lower-level Mouke and Punian settlements subordinate to it within its controlled territory. In terms of military defense, the defensive group led by the Meng'an settlement not only secures the resources of its controlled area but also, through inter-group collaborative defense, forms a defensive sector whose resource control is vital for ensuring territorial dominance in the Northeast Road region. Owing to the scarcity of fundamental historical records, the subordinate relationships and defensive ranges among settlements within this system remain uncertain. Therefore, drawing on settlement archaeological research into prehistoric settlements with limited written documentation, this study employs the methods of Thiessen polygons and site resource domain partitioning to determine the defensive range in the Northeast Road area, with the aim of quantitatively resolving the delineation of control areas within military settlements.

From the perspective of military system, Meng'an settlement is the first-level command node in the northeast road defense system, and the Mouke and Punian settlements in its control area form a hierarchical subordinate network; From the perspective of strategic deployment, the defense group with Meng'an as the core builds a multi-level territorial control system through the coordination of resource management and defense zones. In view of the serious lack of military archives in Northeast Road in Jin Dynasty, this study creatively transplanted the analysis method of settlement archaeology to prehistoric society, and built a quantitative division model of military settlement control field through the double verification mechanism of "Thiessen polygons space division+site resource domain efficiency evaluation". This method breaks through the limitations of traditional literature research and realizes the interpretation of three key issues at the level of spatial topology: first, define theoretical control boundary of Meng'an settlement defense zone; Second, quantify the coverage of joint defense coordination; Thirdly, restore the strategic subordinate relationship of low-level settlements, so as to systematically solve the academic problem of dividing the control field of military settlements.

3.2.1.2 Results of Defensive Sector Partitioning

Based on ArcGIS 10.8 geographic information platform, integrating the vector data of the military settlement in the northeast road of the Great Wall with the 30M digital elevation model (DEM) of the research area, and using the tool of "Creating Thiessen Polygons" in the spatial analysis module, the initial Thiessen Polygon was generated centering on eight Meng'an settlement sites. By superimposing the complete spatial distribution layers of the settlement, the visual expression of theoretical control range of Meng'an settlement is completed.

The site resource domains of military settlements are defined based on the range accessible by military reinforcements. When a Mouke or Punian settlement is subjected to significant enemy incursion, its central command settlement—the Meng'an settlement—must be capable of receiving intelligence promptly and dispatching sufficient reinforcements within 24 hours. If reinforcements arrive within a set timeframe, the besieged settlement can hold its ground; otherwise, it risks falling to the enemy. Assuming a maximum reinforcement response time of one day, and considering the average daily march of ancient cavalry at 70 kilometers, a site resource domain was delineated using a 70-kilometer radius centered on each Meng'an settlement on the ArcGIS platform. By overlaying this with the geographic spatial data of the settlements, a site resource domain map for the Meng'an settlements was generated. The overlay of the Thiessen polygon and site resource domain layers resulted in a theoretical analysis map of the Thiessen polygons and resource domains for the Meng'an settlements along the Northeast Road of the Great Wall in Jin Dynasty (Figure 4).

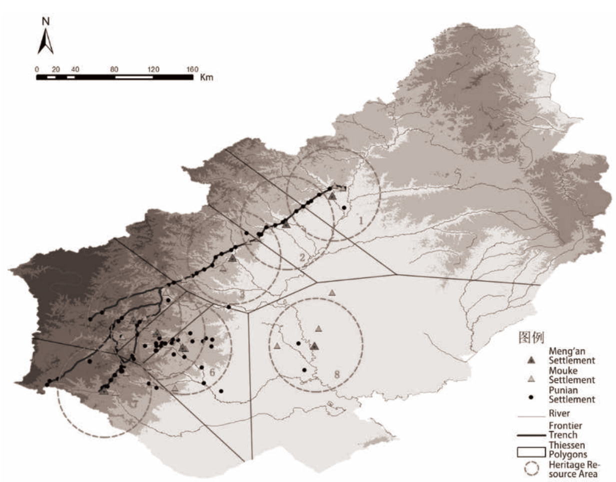

Figure 4 Analysis diagram of Thiessen polygon and site catchment analysis of Meng'an settlement on the Northeast Road of the Great Wall in Jin Dynasty

The results of spatial superposition show that the overlapping rate of resource domains of Chahayang ancient city (resource domain No.1), Alenhe ancient city (No.2) and Shajiajie ancient city (No.3) is 68.3%, and its Thiessen polygon presents continuous distribution characteristics, so it is designated as joint defense zone A; The overlapping areas of the ancient cities of Halagentai (No.4), Shaligen (No.5), Princess Mausoleum (No.6) and Tuilemaodudong (No.7) cover 53.6% of the Thiessen polygon area, forming a compound defense zone B; The resource domain of Lamacang Ancient City (No.8) is completely contained in its own Thiessen polygon, and it is established as an independent defense zone C. Through topology check and buffer analysis, the modified Thiessenpolygon map of the northeast road of the Great Wall is obtained after the initial Thiessen polygon boundary is modified (Figure 5), and the partition map of the military settlement system of the northeast road of the Great Wall is obtained (Figure 6).

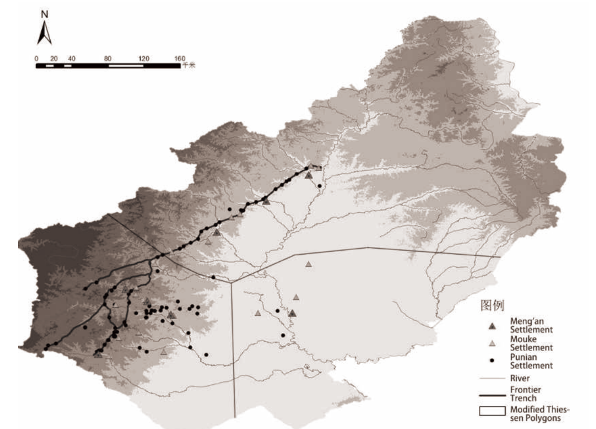

Figure 5 Modified Thiessen polygon of the Northeast Road of the Great Wall in Jin Dynasty

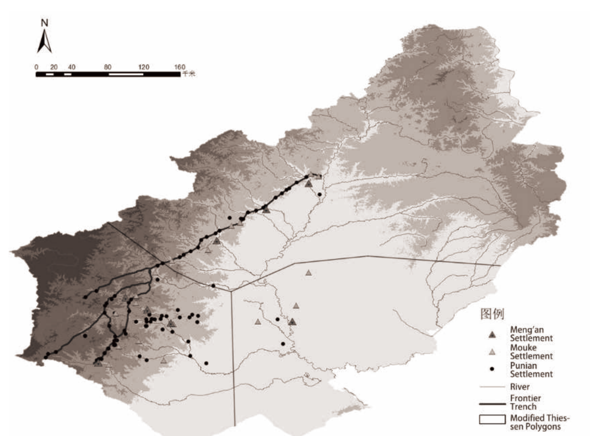

Figure 6 Division of defense zone of military settlement system on the Northeast Road of the Great Wall in Jin Dynasty

The spatial analysis of the defense zone division map shows that the defense zone I presents a typical linear defense pattern, and its military settlements are continuously distributed in the east-west direction along the northern line of Lingnan boundary trench. The defense system starts from the Houyiwoqi ancient city in the east and reaches Castle No.24 in the west. The boundary trench section under its jurisdiction starts from the junction of Nierji Reservoir in the north and reaches the strategic point on the east bank of Handahan River in the south, forming a complete linear defense chain. The settlement points in the defense zone are strictly arranged along the main line of the trench, which reflects the high coordination between military deployment and geographical barrier.

Defense Zone II has built a compound defense network, and its military settlements extend in a network along the secondary boundary trench and Huolin River system. The spatial framework is supported by Bayanwulan East Ancient City in the north, reaches the frontier post of Huolin Ancient City in the south, starts from the traffic node of Mongolian Tuncheng site in the east, and reaches the western gateway of Harinura Ancient City in the west, forming a core defense zone covering the main section of the northeast road boundary trench (except the defense zone I). In this area, a number of defense clusters are connected in series through the water corridor, which realizes the rapid response and resource allocation within the defense zone.

Defense Zone III shows a unique scattered defense form, and military settlements are distributed radially along the main stream of Nenjiang River and its main tributaries. Based on the trend of water system, the settlement points form a natural defense corridor, starting from the alluvial plain in the middle reaches of Nenjiang River in the north and reaching the confluence of tributaries in the south, and constructing a defense system in depth through the strategic deployment of river bank highlands and ferry nodes. The spatial layout of the defense zone fully reflects the adaptive relationship between military defense and hydrological environment.

3.2.2 Division of Group Units within the Military Settlement System on the Northeast Road of the Great Wall in Jin Dynasty

3.2.2.1 Methods for Group Unit Division

(1) K-means Clustering Algorithm

The K-means clustering algorithm was independently proposed by Steinhaus (1955), Lloyd (1957), Ball & Hall (1965), and McQueen (1967) across diverse disciplinary fields. Since its introduction, it has been widely applied in numerous disciplines due to its superior effectiveness and simplicity compared to other clustering methods.

As an unsupervised clustering algorithm, K-means employs Euclidean distance to measure similarity between data objects, where greater distances correspond to lower similarity. The core procedure involves partitioning data objects into K predefined groups, assigning initial cluster centers, calculating Euclidean distances between data objects and these centers, and iteratively reassigning objects to the nearest cluster while updating cluster centers based on mean distances. This iterative process minimizes the Sum of Squared Error (SSE) until termination criteria are met: (1) no reallocation of data objects, (2) stable cluster centers, or (3) unchanged SSE values.

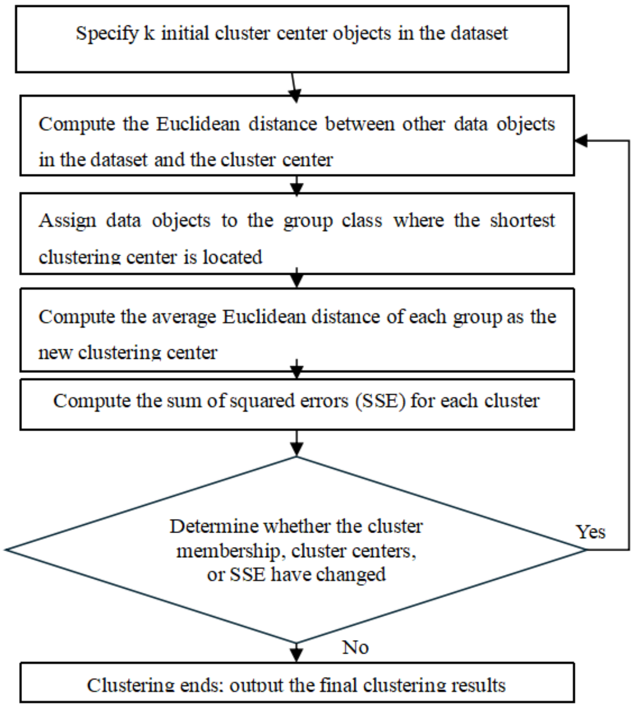

Figure 7 Flow chart of optimized K-means clustering algorithm

Although K-means clustering algorithm has the characteristics of simple implementation and high efficiency, there are still some technical limitations in practical application. The first thing to note is that the algorithm needs to set the cluster number k value in advance in the initialization stage; Secondly, the initial clustering center has the characteristics of random generation, which may select any data point or non-data set entity in the data set; Furthermore, outliers in data sets will interfere with the final clustering quality. Based on these characteristics, academic circles continue to carry out research on algorithm improvement to enhance its disciplinary applicability.

(2) Optimized K-means Clustering Algorithm

In the field of settlement archaeology, this algorithm is used to solve the difficult problem of dividing settlement groups with strong spatial heterogeneity and huge number of sites, which lays the foundation for analyzing the organizational structure between settlements. However, the existing clustering process lacks consideration of key parameters such as settlement scale difference, functional distinction and the control effect of high-level settlements on secondary settlements. On the basis of inheriting the previous research results of settlement group division, this study combines the special needs of settlement group division in the military defense system of the northeast road of the Great Wall, and improves the K-means algorithm to obtain the clustering results that are more in line with the characteristics of the research object.

The improvement of this algorithm mainly focuses on two dimensions: the determination mechanism of cluster center and the Euclidean distance calculation model. In the establishment of cluster center, the military settlement hierarchy of the Great Wall is strictly followed, and Meng'an or Mouke settlement is selected as the initial cluster center. In order to ensure the directional migration of low-level settlements to high-level centers in the process of clustering, a weight assignment system based on military rank is specially constructed to quantify the importance of settlements. On the level of distance calculation, considering the actual geographical elements of military forces dispatching, a weighted Euclidean distance model is constructed, which includes the superposition of multiple factors such as altitude, terrain slope, landform fluctuation, water system distribution and trench trend. The optimized K-means clustering algorithm flow is shown in Figure 8.

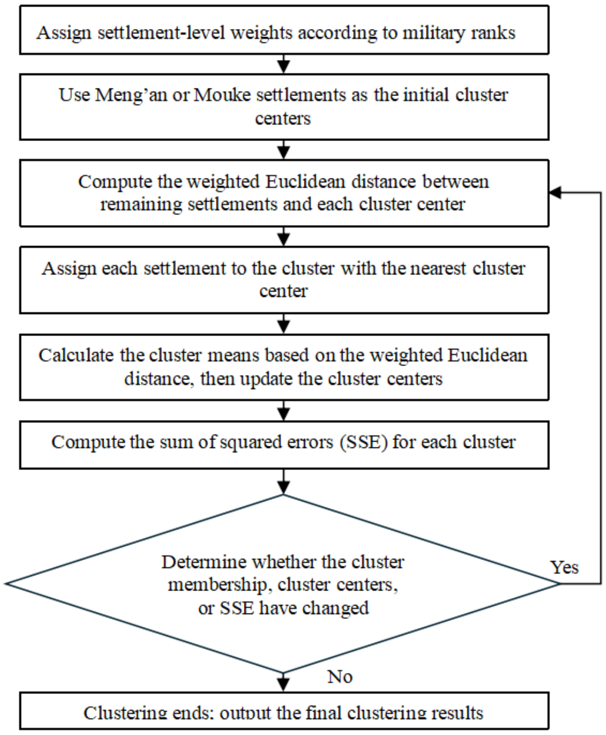

Figure 8 Flow chart of optimized K-means clustering algorithm

Based on the optimization algorithm, the division of the defense zone of the northeast road of the Great Wall is analyzed in two stages: in the first stage, the division of Meng'an settlement group is implemented, and the first-level military defense unit with Meng'an settlement as the core is emphatically analyzed; In the second stage, the subordinate relationship of Punian settlement is judged, focusing on the ownership of secondary settlements in each Meng' an group. Through the preliminary analysis of the distribution map of the defense zone, it is found that Punian settlements are densely distributed around some Meng'an settlements, while the spatial distribution density of Mouke settlements is significantly lower than Punian settlements. This reveals that there are two hierarchical structure modes in the military settlement system of Northeast Road: the traditional three-level system

(Meng'an-Mouke-Punian) and the two-level direct control (Meng'an-Punian). In order to clarify the hierarchical organization structure, it is necessary to further analyze the attribution characteristics of Puyan settlement after the division of Meng'an group.

3.2.2.2 Results of Group Unit Division

In order to realize the demarcation of the defense zone group of the northeast road military settlement system of the Great Wall, before the demarcation step, the basic database of group division is designed, and the database structure is shown in Table 2.

(1)Division of Meng’an Settlement Groups

The implementation process of applying the improved algorithm to group division of Meng'an settlement in the third defense zone includes: ① integrating the spatial data layers of topography, water system and moat, calculating the weighted Euclidean distance matrix, and constructing the basic database for group division of defense zones; ② Extracting core parameters such as settlement ID, name, coordinates, grade weight and weighted distance from the database; ③ Determine the K value according to the actual number of Meng'an settlements in each defense zone; ④ Run the improved algorithm to complete the clustering calculation and result output; ⑤ Create the Meng'an group division map by means of spatial visualization (Figure 9).

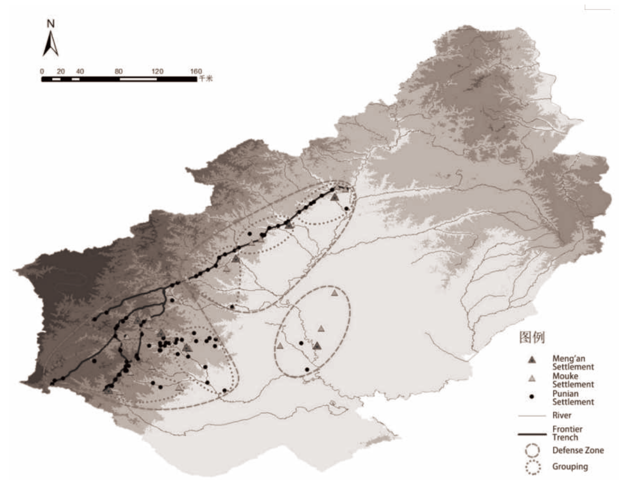

Figure 9 Division of Meng'an settlement groups in the defense zone of military settlement system on the Northeast Road of the Great Wall in Jin Dynasty

(2) Subgroup Division within Clusters

Building upon the optimized K-means clustering algorithm, the internal subgroup composition of Meng’an settlement clusters in the military settlement system along the Northeast Road of the Great Wall in Jin Dynasty was further delineated through a four-step digital workflow. The process began with extracting essential spatial and hierarchical data—including settlement IDs, names,

Table 2 Basic database for group division of military settlement system in Northeast Road of the Great Wall in Jin Dynasty

Attribute Name	Attribute Description	Data Type	Width	Decimal Places	Nullable	Primary Key (PK)
ID	Serial Number	Integer	9	-	No	Yes
Name	Settlement Name	Txt	50	-	No	No
Cor_x	Horizontal Coordinate of Settlement	Float	18	5	No	No
Cor_y	Vertical Coordinate of Settlement	Float	18	5	No	No
Z	Grade Weight Value	Integer	9	-	No	No
Distance	European Distance between Settlements	Float	18	-	No	No
Quan-distance	Weighted Distance between Settlements	Float	18	-	No	No
Class	Clustering Results	Integer	9	-	No	No

coordinates, weight values, and weighted Euclidean distances—from the foundational database. Subsequently, the cluster number K was algorithmically determined based on the quantity of Mouke settlements within each Meng’an group. The optimized K-means algorithm, enhanced by terrain and military hierarchy parameters, was then applied to perform intelligent clustering analysis, generating structured outputs that revealed subgroup affiliations. Finally, with the help of ArcGIS geographic information system, the spatial visual expression of the results is completed, and the group division map of the military settlement system in the northeast road of the Great Wall is obtained (Figure 10- Figure 12).

Figure 10 Division of groups in defense zone I of military settlement system in Northeast Road of the Great Wall in Jin Dynasty

Figure 11 Division of groups in defense zone II of military settlement system in Northeast Road of the Great Wall in Jin Dynasty

The results of visual analysis show that there are not only two hierarchical structures in the basic theoretical model —— "Meng'an-Mouke-Punian" and "Meng'an-Punian" in the four Meng'an units in the defense zone II, but also a third new hierarchical relationship, "Meng'an-Mouke", which is characterized by no lower Punian in the Mouke settlement.

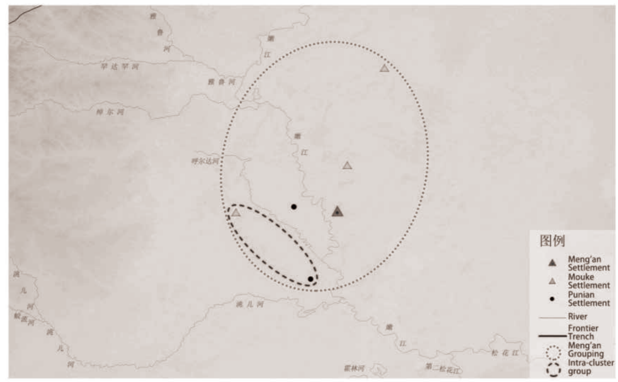

Figure 12 Division of groups in defense zone III of military settlement system in Northeast Road of the Great Wall in Jin Dynasty

Through the statistical analysis of data, it is found that the quantitative relationship between Meng'an and Mouke settlements presents regular characteristics: a single Meng'an settlement usually governs 2-3 Mouke settlements, and the overall quantitative ratio between them is stable at around 1:2.5. However, the hierarchical ratio between the Mouke and Punian settlements presents significant heterogeneity. The number range of Punian settlements under a single Mouke settlement is 0-9, and the overall average number ratio reaches 1:5. This level configuration difference shows that the establishment scale between Meng'an and Mouke levels has strong stability, while the organization mode of Mouke-Punian level shows obvious elastic characteristics.

The research reveals the internal hierarchy diversity of Meng'an Group in the northeast road defense area of the Great Wall, which has dual historical system connotations: firstly, it proves that the military settlement system in the middle and late Jin Dynasty has broken through the initial organizational norms, and the number of Meng'an Mouke units has been reduced in a cliff-like manner compared with the early days of the founding of the People's Republic of China; Secondly, it highlights the remarkable characteristics of the military management system in maintaining organizational flexibility in actual operation, and the formation scale of its grass-roots military units can be dynamically adjusted according to strategic needs.

5 Conclusions and Prospects

5.1 Conclusions

This study focuses on the application of digital intelligence in the systematic restoration of military settlements during Jin dynasty, demonstrating its superior efficiency, authenticity, and scalability compared to traditional methodologies. By examining the military settlements along the Northeast Road of Jin dynasty through a digital perspectives, the research integrates multi-source data to reconstruct the hierarchical structure and defensive zoning of these settlements. First, the military administrative system of the Great Wall in Jin Dynasty was analyzed, identifying a four-tier hierarchy: Zhaotaosi (supreme command posts), Meng'an (chiliarch garrisons), Mouke (centurion outposts), and Punian (subsidiary stations). This framework established a theoretical basis for classifying settlement hierarchies in the Northeast Road region. Second, hierarchical scaling principles were introduced, synthesizing prior methodologies to develop weighted classification schemes using systematic clustering. Finally, settlement data from the Northeast Road were processed through SPSS statistical software for clustering calculations. The results were refined by cross-referencing archaeological evidence and visualized to map the hierarchical distribution of settlements. At the systemic level, the integration of site resource domain analysis and Thiessen polygon methodology enabled the division of the Northeast Road into three defense zones. An optimized K-means clustering algorithm was further applied to delineate settlement clusters within these zones, revealing three distinct hierarchical configurations: (1) Meng'an-Mouke-Punian, (2) Meng'an-Mouke, and (3) Meng'an-Punian. These findings not only elucidate the complexity and dynamism of the Jin military settlement system but also bridge archaeology, historical geography, and digital humanities, underscoring the transformative role of digital technologies in reconstructing historical landscapes. The study advances a novel paradigm for systemic restoration and heritage interpretation of early Great Wall military settlements, offering methodological innovations that transcend conventional qualitative approaches.

5.2 Research Prospects

In this paper, the military settlements in the northeast area of the Great Wall are selected as the analysis object, but there are still three military regions in the Great Wall. In the basic data sorting work before the author carried out this study, it was found that the distribution of the four military settlements in the Great Wall showed different spatial distribution characteristics, which was related to the different social attributes in different areas of the Jin Dynasty. Consequently, some conclusions obtained in this paper may not be applicable to the other three roads, and it is difficult to directly extend the restoration conclusions based on the Northeast Road to the global defense system of the Great Wall. In the future, if we build a geographic information database of cross-regional military settlements with the support of digital intelligence technology, we will compare and analyze the logic of defense zone division and the characteristics of hierarchical network in different sections, reveal the regional differentiation law of military system in Jin Dynasty, and thus enhance the integrity and universality of defense system cognition.

On going archaeological excavations, including newly discovered settlement remnants, weapon caches, and fragmented documents, will provide high-precision data for digital restoration. Emerging technologies such as LiDAR (Light Detection and Ranging) could reveal subtle topographic features of buried sites, while hyperspectral imaging might clarify construction sequences of rammed-earth fortifications. Although digital and intelligent methodologies have opened new dimensions for historical military settlement research, their full potential remains untapped. Future studies should adopt interdisciplinary collaboration, technological iteration, and cultural heritage activation as driving forces. By shifting focus from localized restoration to global reconstruction and from academic exploration to societal engagement, research on the Great Wall in Jin Dynasty defense system can achieve both scholarly rigor and public relevance, ultimately revitalizing this cultural legacy for contemporary appreciation.

References:

[1]Wang Guowei. Guantang Jilin[M]. Beijing: Zhonghua Book Company, 1959.

[2]Jia Zhoujie. Preliminary Discussion of the Great Wall in Jin Dynasty[J]. Journal of Inner Mongolia University (Philosophy and Social Sciences), 1979(Z2): 170-178.

[3]Sun Wenzheng, Wang Yongcheng. Research Collections on the Great Wall in Jin Dynasty[M]. Jilin: Jilin Literature and History Press, 2009.

[4]Dong Yaohui. Collected Essays on Great Wall Studies[M]. Beijing: Science Press, 2004.

[5]Feng Yongqian. Archaeological Discoveries and Research on the Great Wall in Jin Dynasty[A]. Editorial Department of China Great Wall Museum. China Great Wall Museum, No.4, 2006 (Special Issue of China Qiqihar the Great Wall in Jin Dynasty Symposium) [C]. The Great Wall Society of China, 2006:28.

[6]Feng Yongqian. Analysis of the Construction Period of the Great Wall in Jin Dynasty[J]. Northeast History and Geography, 2008(03): 46–56.

[7]Feng Yongqian. Structural Forms, Characteristics, and Nomenclature of the Great Wall in Jin Dynasty[J]. Northeast History and Geography, 2009(05): 22–29.

[8]Sun Wenzheng, Xin Jian. Overview of Terminology for the Great Wall Fortresses in Jin Dynasty[J]. Studies on the History of Liao, Jin, Qidan and Nvzhen Dynasties, 2004(34).

[9]Xie Dan. Research on the Military Defense System and Spatial Planning Layout of the Great Wall in Jin Dynasty [D]. Tianjin University, 2012.

[10]Chang Hai. Studies on the Great Wall in Jin Dynasty[D].Inner Mongolia University, 2012.

[11]Dindar. Typological Study of the Great Wall Frontier Fortresses in Jin Dynasty[D]. Inner Mongolia Normal University, 2013.

[12]Jin Zhu. On Great Wall Fortress on the Northeast Road in Jin Dynasty n Heilongjiang Province[J]. Heihe Journal, 1991(04): 91-93.

[13]Sun Wenzheng Sun Ren. Construction Time of the Great Wall Fortress on the Northeast Road of Jin Dynasty[A]. Editorial Department of China Great Wall Museum. China Great Wall Museum, No.4, 2006 (Special Issue of China Qiqihar the Great Wall in Jin Dynasty Symposium) [C]. The Great Wall Society of China, 2006:12.

[14]Peng Zhanjie. On the Official Seals Unearthed from the Great Wall on the Northeast Road and the Great Wall Line of the Jin Dynasty[A]. Editorial Department of China Great Wall Museum. China Great Wall Museum, No.4, 2006 (Special Issue of China Qiqihar the Great Wall in Jin Dynasty Symposium) [C]. The Great Wall Society of China, 2006:15.

[15]Ji Yanhua. Garrison of the Great Wall in the Northeast Road of Jin Dynasty[J]. Theoretic Observation, 2006(03): 167-169.

[16]Zhang Gang. The Process of Mongol-Yuan Forces Entering the Nenjiang River Basin[J]. Journal of Qiqihar Junior Teachers' College, 2006(04): 92-96.

[17]Li Pihua. Functions of the Seven Sections of the Great Wall in the Area under the Jurisdiction of Zhaotaosi, Northeast Road of Jin Dynasty[J]. Northeast History and Geography, 2012(01): 55-62.

[18]Ning Bo. Research on the Great Wall on the Northeast Road in Jin Dynasty and Its Zhaotaosi, Northeast Road of Jin Dynasty[J]. Inner Mongolia Social Sciences (Chinese Edition), 2014, 35(03): 62-66.

[19]Zhang Boquan. Concise History of Jin Dynasty[M]. Liaoning: Liaoning People's Publishing House, 1984.

[20]Zhang Boquan. Historical Geography of Northeast China[M]. Jilin: Jilin People's Publishing House, 1981.

[21]Zhang Boquan, Wei Cuncheng. Archaeology and Territory of Ancient Northeast Ethnic Groups[M]. Changchun: Jilin University Press, 1997.

[22]Li Jiancai. Studies on Northeast Historical Geography[M]. Changchun: Jilin Literature and History Publishing House, 1986.

[23]Tong Dong. History of Northeast China[M]. Changchun: Jilin Literature and History Publishing House, 2006.

[24]Wang Yulang. Compilation of Research on Liao Dynasty Ancient Cities in Northeast China[M]. Heilongjiang: Harbin Publishing House, 2007.

[25]Wang Mingsun. Administrative Regions and Urban Development in Jin Dynasty Northeast and Inner Mongolia[J]. Collected Papers of History Studies, 2005(03): 56-74.

[26]Wang Yulang, Hao Bing, Liu Jiaming. Distribution and Preliminary Study of Liao-Jin Ancient Cities in Nenjiang River Basin[J]. Journal of Harbin University, 2013, 34(07): 1-15.