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Original scientific paper

Research on Reconstruction Factor Model of Old Residential Area Based on Multi-Modal Data Fusion

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Abstract: The green transformation of old residential areas is a major livelihood project and development project to promote urban renewal and meet the needs of the people for a better life, and an important way to realize the sustainable development of stock buildings. Firstly, in the transformation elements, an adaptive modal weight updating mechanism is designed to dynamically adjust the modal weights in the process of coclustering fusion, so as to meet the dynamic change requirements of the modal influence on the fusion results and improve the scalability of the algorithm. Secondly, the evaluation index system of comprehensive elements of green transformation in old residential areas is established and improved, and the attribute hierarchy model is used to determine the index weights. Finally, taking the reconstruction elements of old residential areas as the basic unit of matters-element extension theory, the multi-modal data fusion reconstruction element model is constructed, which provides a new perspective and new ideas for the formulation of old residential areas reconstruction plan.

Keywords: comprehensive factor evaluation; data fusion; element model; multimodal; renovation of old residential areas

1 INTRODUCTION

At present, urbanization rate has exceeded 60%, and urban development has entered a new historical period. The implementation of urban renewal action is the only way to adapt to the development of the Times [1]. As the most important part of urban renewal action, the reconstruction of old residential areas has gradually become a hot topic in recent years. At present, many old residential roads are seriously damaged; lack of streetlights, parking spaces and other infrastructure; residents travel is very inconvenient. In a large number of old residential areas also appear exposed wires, insufficient fire facilities and other chaos, there is a greater security risk. Therefore, the renovation of old residential areas is not only conducive to improving the living environment and quality of life, but also to protecting the life and health of residents, and is an important measure to improve people's livelihood [2].

So far, the supporting policies, standards and technologies for the renovation of old residential areas have been quite mature. Some domestic scholars have also carried out corresponding research on this basis. Based on the new public management theory, the whole performance evaluation model process of the renovation project of old residential areas is constructed, which provides a new angle for performance evaluation of old residential areas [3]. It puts forward the participation of real estate enterprises in the renovation of old residential areas and its operation mode [4]. The process of urbanization in developed countries is relatively early, and the research on urban renewal and the reconstruction of old residential areas is also in the forefront. The open architecture theory is proposed, which divides the building space into levels and distributes the building control rights according to the levels [5], making it easier for buildings to adapt to social development and change. The concept of "architectural regeneration" is proposed, which covers all architectural behaviors except new buildings [6] and provides ideas and experience for the renovation of old residential buildings. The above research includes the performance evaluation, reconstruction mode, livable evaluation and building reconstruction of the old residential area, but there is a lack of relevant research that introduces the system engineering model into the whole process of the old residential area reconstruction.

As an interdisciplinary discipline, systems engineering has been widely applied in many fields, and has been introduced into the field of green building to guide the whole process of green building [7]. System engineering was introduced into the field of foundation pit construction, and a series of methods such as grey line control excavation method were proposed according to the methodology of system engineering [8], which effectively improved the problem of foundation pit deformation. The system engineering methodology is introduced into the field of railway tunnel engineering construction management [9], aiming at improving the ability to solve complex problems in international engineering. The system engineering methodology is applied to enterprise development strategy, and the idea of system engineering is explored in a beneficial way [10]. Based on the proposed four-dimensional structure system and the reconstruction elements of the old area, this paper proposes an incremental coclustering fusion algorithm for non-parametric multimodal data. A new multi-modal data similarity metric is designed to perform incremental clustering fusion on multi-modal data. At the same time, an adaptive modal weight mechanism is designed to dynamically adjust modal weights in the process of coclustering fusion, and the whole process model of the old community transformation is constructed. The systematic engineering thought which should be followed in the whole process of rebuilding old residential area is discussed in many aspects.

2 RELATED WORK

This paper probes into the reconstruction strategy of the old residential area from the aspects of reconstruction content and reconstruction plan decision. For example, from the perspective of aging, it is believed that the reconstruction content should not only consider the transformation and renovation of the material conditions of the building [11], but also consider the living needs of the elderly and the protection of cultural heritage in the community. Aiming at livability and urban repair, the reconstruction content is summarized into two items:

essential projects and expansion projects [12]. Based on the concept of micro-renovation of old residential areas, the renovation content is divided into three parts: renovation of building appearance, renovation of public infrastructure and upgrading of community management [13]. Some scholars summarize the contents of transformation through typical cases to provide reference for the development of transformation work [14]. The contents of the old residential area are varied and complicated, so it is necessary to reasonably determine the specific contents of the reconstruction according to the local policies. In terms of renovation plan decision-making, a building renovation case base is established based on actual renovation projects, and a case-based reasoning method is proposed to support the renovation plan decision-making [15]. Based on the survey data, the relationship between the renovation content and residents' satisfaction is analyzed, and the priority of the renovation content is determined, providing a reference for the decision-making of the renovation plan [16]. In addition, there are also scholars from the perspective of transformation potential, to explore the renovation of old residential areas. The renovation potential of the old residential area is evaluated from the aspects of infrastructure, external conditions, residents' wishes, expected benefits, etc., and the optimal renovation plan of the old residential area is explored [17, 18]. In general, the transformation of the old residential area not only includes the transformation of the external material conditions of the residential area, but also includes the upgrading and reshaping of the internal humanistic spirit of the residential area, and the specific transformation content needs to be reasonably determined according to the residents' wishes and regional planning.

At present, the renovation of old residential areas is faced with many obstacles and influencing factors, including imperfect policies [19] single source of funds, difficult communication and coordination of stakeholders [20], insufficient participation of residents [21], and lack of long-term management mechanism [22]. This paper reviews the existing renovation policies in China, identifies the obstacles existing in the renovation of existing buildings, and puts forward the relevant policy suggestions to solve these obstacles. Fuzzy-DEMATEL method was used to verify the action path among various influencing factors in the renovation of old residential areas in China [23], and the research results revealed 13 key obstacles, among which the lack of effective supporting policies and the lack of public-private cooperation mechanism were the most important influencing factors. Some scholars also analyze the obstacles faced by the renovation of old residential areas from the perspective of project risk. For example, the study conducted an in-depth analysis of Singapore's green transformation projects [24], summarized 20 common risk factors, and identified key risks through a questionnaire survey. Risk factors faced by renovation projects of old residential areas are summarized from five aspects: economy, technology, society, environment and management [25], and corresponding risk countermeasures are put forward. In the reconstruction of old residential areas, the intention of residents is the key point restricting the progress of the reconstruction. For example, in the process of rebuilding old residential areas in Shanghai, residents have low willingness because they do not understand the reconstruction policies [26]. The study of residents' participation in spongy transformation and governance found that most residents "do not intend to participate" seriously restricts the level of transformation. Due to regional differences, factors affecting residents' willingness and solution strategies cannot be copied, and the current living environment of residents is not ideal, with various security risks. Therefore, it has become a top priority to promote the renovation of old residential areas [27]. The transformation of old residential areas has the overall, strategic and forward-looking nature, which is not only the first choice and necessary option to keep up with the development boom of The Times, but also the real completion of the final realization of China's ecological civilization construction and the development goal of low-carbon environmental protection project management has outstanding contributions and practical significance. However, few scholars have explored the specific factors that affect the reconstruction intention of residents in different regions and types, thus affecting the process of the reconstruction cause, found the common problems and studied the countermeasures of the reconstruction intention of residents in existing old residential areas in different regions and types.

The main goal of multimodal data coclustering is to improve the accuracy of clustering results by fusing multi-data feature set learning [28]. In recent years, the problem of multimodal coclustering has received extensive attention, and some effective coclustering fusion algorithms have been proposed accordingly [29]. Latent subspace-based learning is a representative algorithm, which learns the unified latent subspace fusion representation of cross-modal data through multi-modal sharing, and then completes the co-clustering of multi-modal data in the shared space by using the single-modal clustering algorithm. For example, in literature [30], the CCA (Canonical Correlation Analysis) was first used to maximize the correlation between the two modal data in the projection space, to learn the low-dimensional shared subspace of cross-modal data, and then to complete the coclustering analysis of the data based on the shared features. Recently, some multi-modal latent subspace learning methods based on matrix decomposition have been proposed, which complete the multi-modal data coclustering by learning the consistent coding matrix shared by all modes [31]. Based on the theory of planning behavior, this paper constructs a theoretical model of the factors that affect residents' willingness to transform, collects data through questionnaires, analyzes reliability and validity, multi-group data and structural equation model, and puts forward specific suggestions in a targeted manner, hoping to provide strong theoretical support and reference value for the formulation of policies to promote high-quality urban development [32-36].

3 RESEARCH ON RECONSTRUCTION FACTOR FUSION MODEL OF OLD RESIDENTIAL AREA BASED ON MULTI-MODAL DATA FUSION

3.1 Multimodal Data Fusion Algorithm Based on Deep Semantic Matching

Aiming at the problem that the existing incomplete multimodal analysis fusion algorithm is difficult to effectively learn the semantics of cross-modal data sharing, an incomplete multimodal data fusion algorithm based on deep semantic matching is proposed in the research on the reconstruction elements of old communities. This algorithm uses the correlation of high-level semantics of multimodes to design a unified deep learning model that integrates the private deep network of modes and the features of modal sharing. The deep correlation fusion of incomplete multimodal data is realized, and the semantic deviation of modal sharing features is reduced. Based on the spatial geometric characteristics of the modes, the regularization factors of the mode local invariant graphs are designed, and the deep-sharing features and original modal features are coupled to further improve the accuracy of the fusion results. The experiment verifies that the deep incomplete multimodal data fusion algorithm proposed in this paper can effectively correlation match incomplete multimodal data through deep semantic abstraction, and ensure the accuracy of fusion results. The architecture diagram is shown in Fig. 1.

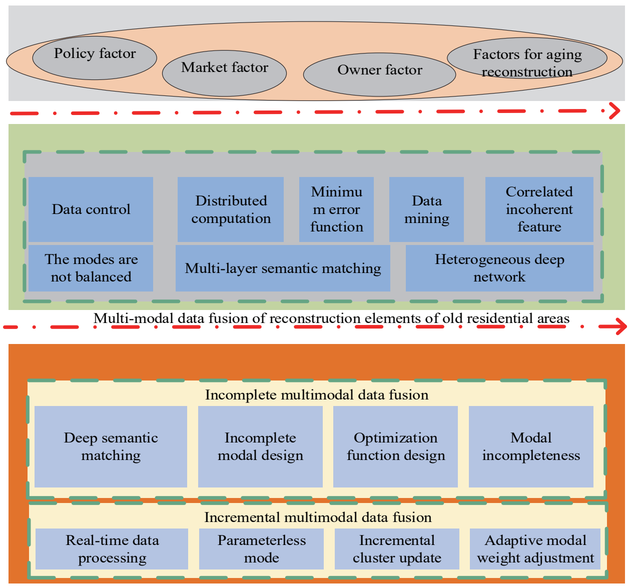

Figure 1 Multi-modal data fusion model framework of reconstruction elements of old residential areas

As shown in Fig. 1, in order to learn the sharing characteristics of incomplete multi-modal data of reconstruction elements of old residential areas, a cross-modal deep semantic matching mechanism is proposed. Different from the existing incomplete multimodal data fusion algorithms, this algorithm constructs the shared feature subspace between modes through the multi-layer nonlinear correlation between modal data. Invariant graph regularization factor is designed to ensure local similarity of modal data in shared subspace. A new objective function is designed to describe the deep semantic matching model of incomplete multimodal data, and its optimization process is derived in detail.

3.2 Multi-Modal Deep Semantic Matching Algorithm Within Complete Reconstruction Elements of Old Residential Areas

Accordingly, the incomplete multimodal deep semantic matching model can be expressed as:

$$\min \sum_{i=1}^{v} (H_c^v - U_i^v) + \alpha^i Tr(p^i L^i) \tag{1}$$

where H is the characteristic output of the modal private deep network, I is the nonlinear activation function, and p and L are the corresponding weight matrix and bias vector, respectively. The multi-modal data features can be fused and analyzed in the obtained subspace.

Given a uniform coding matrix P for each mode and a modal deep network R, minimizing the objective function via the basis matrix U can be further written as:

$$\min \| H^v - U^v P^v \|_R^2 \tag{2}$$

When fixing the basis matrix U and the uniform coding matrix P for each mode, the updating of the modal network R can be described as a subproblem of minimizing the scale function, as follows:

$$\min \theta^i = f(W_v x^v + b_v) - U^V P^V \tag{3}$$

The update of the L-layer network weight W and bias vector b is as follows:

$$W_v^l = W_v^i - u^v \frac{\partial \theta^v}{\partial W_v^l} \tag{4}$$

$$b_v^l = b_v^i - u^v \frac{\partial \theta^v}{\partial b_v^l} \tag{5}$$

The optimization and updating process of the entire incomplete multimodal deep semantic matching model is shown in Tab. 1.

Table 1 Deep incomplete Multi-Modal Document Frequency (MMDF) semantic matching model optimization

Input: Incomplete multimodal data set X, regularization parameter a, deep learning network parameters for each mode.
Output: Each mode depth matching network R, basis matrix Mai U and uniform coding matrix P.
Steps:
1: Randomly initialize each modal depth matching network parameter R, and use modal data X and stack automatic coding machine to pre-train the modal depth network layer by layer;
2: Initialize the modal basis matrix U and the shared feature matrix P by minimizing the objective function;
3: Randomly initialize the private feature matrix $P > 0$ in the shared space of each mode;
4:Repeat
5: Through the forward propagation of each mode deep network R, the depth conversion output feature H of each mode input data X is obtained;
6: Update the consistent coding matrix P between modes and the private feature matrix P in the shared space of each mode;
7: Update each mode basis matrix U;
8: In the process of back propagation, jointly fine-tune each mode depth matching network R;
9:Until the objective function converges;
Output P;

In Tab. 1, the deep transformation feature H of the incomplete modal input data is generated by the deep neural network of each mode in the forward propagation process. Compared with other incomplete multimodal data processing algorithms, complete modal data is used to construct semantic relations between modes, and the shared feature subspace of incomplete modes is obtained by coupling learning between modes, MMDF (Textual algorithm), NFM (Neural Factorization Machines) [4], PVC (Persistent Volume Claim) [12], MVG (Multiple View Geometry) [17], IMSL (International Mathematics and Statistics Library) [18], DIMC (Digital Internal Model Control) [21]. As a result, it is better clustering performance than those based on missing modal data, as shown in Fig. 2.

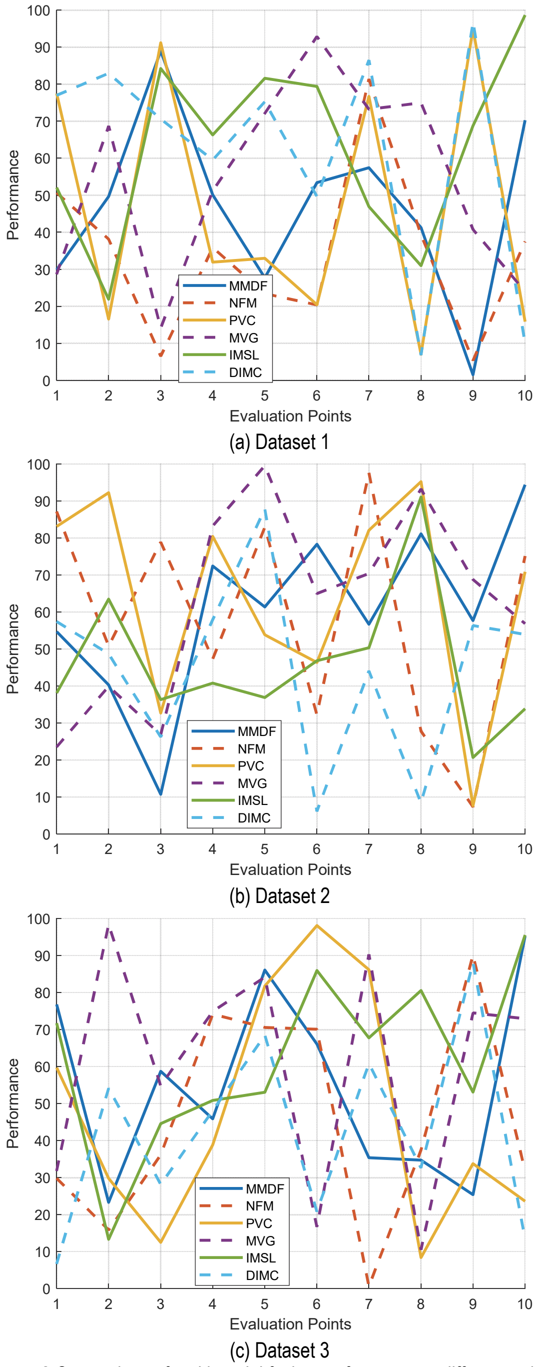

Figure 2 Comparison of multi modal fusion performance at different ratios on four data sets

3.3 Analysis of Key Elements of Reconstruction of Old Residential Areas

As a systematic livelihood project, the renovation of old residential areas has different models in different regions when facing the actual situation. For example, Chengdu adopts the model of government guidance and residents' participation to carry out residential renovation; In Shanghai, residents jointly funded by the government led the way to carry out residential renovation. It is difficult for Guangzhou to carry out residential renovation in the way of government residents co-funding and residents leading. These models involve multiple levels of influencing factors, and there are correlations among these factors, as shown in Tab. 2.

Table 2 Multi-level influencing factors

Primary index	Secondary index	Indicator specification
government	Policy system *P*1	Relevant policies for the renovation of old residential areas.
	Transformation scale *P*2	For the selection of the size of the old residential area transformation, such as micro transformation or suitable for aging transformation.
	Monitoring mechanism *P*3	The government aims at the supervision mechanism of the whole process of renovation of old residential areas, such as the establishment of relevant working groups to supervise.
	Operation mechanism *P*4	Work with social capital to transform old residential areas and operate subsequent profit models.
	Laws and Regulations *P*5	A series of relevant laws and regulations have been introduced for the renovation of old residential areas.
marketplace	Financial support *P*6	The degree of financial support for the renovation of old residential areas.
	Planning arrangement *P*7	The degree of planning for the renovation of old residential areas.
	Organization Management *P*8	Ability of construction organization and late operation management.
	Periodic return *P*9	Period of return on investment for renovation of old residential areas.
	Renewal potential *P*10	Investment potential and profit potential of old residential renovation enterprises.
proprietor	Construction affects *P*11	The influence of the renovation of old residential areas on residents' daily travel.
	Convenient service *P*12	The transformation of old residential areas changes the subsequent life services of residents.
	Participate in communication *P*13	Residents participate in the exchange of opinions on the renovation policies of old residential areas.
	Space place *P*14	Old residential renovation space enhancement ability.
	Property rights *P*15	Public facilities infrastructure and renovation to increase the property rights of facilities.
	Community advocacy *P*16	Community transformation policy publicity efforts.
	Retrofit *P*17	Whether the community renovation is suitable for the elderly to live in

The adjacency matrix is constructed according to the relationship between each factor. On the basis of determining the correlation of each factor, adjacency matrix is applied to describe the logical relationship between each factor, and the adjacency matrix *A* of each index is obtained. The matrix calculation formula is as follows:

$$R=(A+I)^k \tag{6}$$

where: I is the identity matrix; k is the number of reachable matrix transformations.

The influencing factor system of the renovation mode of old residential areas can be divided into 7 levels, as shown in Fig. 3. These seven levels mainly reflect the relationship between the influencing factors of the transformation mode of the old residential area, and combined with the actual situation of the transformation mode of the old residential area, it is divided into three levels: surface influencing factors, middle influencing factors and deep influencing factors. The surface influencing factors directly affect the transformation mode of the old residential area, the middle influencing factors indirectly affect, and the deep influencing factors are the key factors of the root influencing the transformation mode of the old residential area.

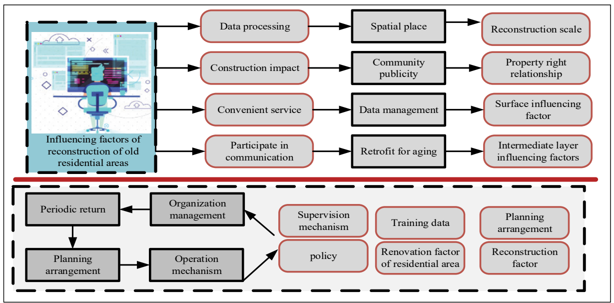

Figure 3 Hierarchical structure of influencing factors in the reconstruction mode of old residential areas

Given two multimodal data instances X with V feature sets, the weighted similarity between them is defined as follows:

$$Dis(X_i,X_j)=\frac{1}{2}\sum_{v}\alpha^v\frac{X_i^v-X_j^v}{\|X_i^v\|} \tag{7}$$

In multimodal data sets, some data feature sets contain only sparse representation instances [0, 1]. For example, the instance feature representation of whether different label text meta information exists in network image data sets.

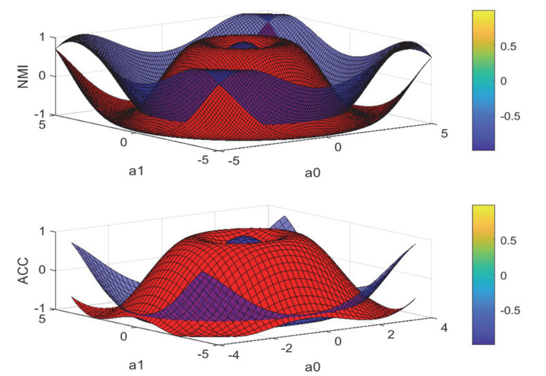

Figure 4 Influence of transformation factors of old residential areas on the clustering results of multi modal fusion

Based on this, we use the probability distribution of labels to construct a modal structure description, that is, the central point representation of the result cluster of modal clustering. The average ACC (Accuracy) and NMI (Normalized Mutual Information) clustering performance under different data instance missing ratios (10%, 30%, 50%, 70%, 90%) is given by incomplete two-module in Fig. 4.

The application of the whole process model of old residential renovation is not limited to a specific type of old residential renovation project, but is suitable for various types of old residential renovation. It focuses on the overall guidance of different professionals in different objective environments: what technology, knowledge and management methods is a systematic, dynamic, hierarchical theoretical guidance framework.

4 RESEARCH ON THE INFLUENCING FACTORS OF SUSTAINABLE DEVELOPMENT OF OLD RESIDENTIAL AREA RECONSTRUCTION BY MULTI-MODAL DATA FUSION

4.1 Establishment of a System Model of Influencing Factors in the Reconstruction of Old Residential Areas

The essence of old residential area reconstruction modelling is to treat the system as a weighted directed graph, which corresponds to the direct influence matrix. Therefore, after setting the scoring rules, as shown in Tab. 3, six experts in this field were invited to evaluate the strength of the relationship among various influencing factors in the process of sustainable promotion of the renovation of old residential areas, and to quantify the mutual relationship among various factors.

Table 3 Evaluation scale of influence relationship

Influence relationship	Have no effect	Little influence	Medium impact	Big difference
Evaluation scale	0	1	2	3

Direct influence matrix A is determined by taking the average scores of 6 experts, and a represents the degree of direct influence of factor s_i on factor s_j. If $i = j$, then $a_{ij} = 0$, regardless of the effect of the factor on itself.

$$A=\begin{pmatrix} 0, a_{12}\dots a_{1n} \\ \dots \\ a_{n1}, a_{n2}\dots 0 \end{pmatrix} \tag{8}$$

Through the normalization of the direct influence matrix A, the normalization of the direct influence matrix B is obtained. In addition to the direct influence among the influencing factors, the indirect influence among the influencing factors should be considered. The comprehensive influence matrix E is the cumulative sum of direct influence and indirect influence, where I is the unit matrix.

$$B=\frac{1}{\max\sum_{j=1}^{n}a_{ij}}A \tag{9}$$

Based on the comprehensive impact matrix E, calculate the influence degree D_i, influence degree C_i, center degree M_i, and cause degree R_i of each influence factor. Impact degree D_i is the sum of the rows corresponding to factor s_i in E, and impact degree C_i is the sum of the columns corresponding to factor s_i in E. The center degree M_i is the sum of the impact D_i and the impact C_i, and the cause degree R_i is the difference between the impact D_i and the impact C_i.

$$D_i = \sum_{j=1}^{n} e_{ij}, C_i = \sum_{j=1}^{n} e_{ji} \tag{10}$$

According to the multimodal data fusion algorithm and the adjacent binary relationship shown in the skeleton matrix, as shown in Tab. 4, a group of adversarial hierarchical structure model diagrams is drawn.

Table 4 Results of multi modal data fusion algorithm

Hierarchy	Result priority-UP extraction process	Cause Priority-Down extraction process
Floor 1	S12, S16, S18, S19	S12, S19
Floor 2	S4, S5, S9, S10, S11, S17	S5, S9, S11, S17, S18
Floor 3	S2, S13, S14, S15	S15
Floor 4	S3, S6, S7	S2, S7, S13, S14, S16
Floor 5	S1, S8	S1, S3, S4, S6, S8

4.2 Multi-Modal Data Fusion Reconstruction Element Model Establishment

As a unit of matter-element extension theory, the reconstruction elements of old communities are triples composed of elements, element characteristics and eigenvalue, expressed by $R = (N, C, V)$. There may be the same characteristics between different elements. For the validity of the results, the characteristic matter elements can be expressed as follows:

$$R_m = (N_m, C, V_m) = [N_m, C_1, V_{im}] \tag{11}$$

where: N is the name of the thing; c is the eigenvalue of things; V is the quantity corresponding to the eigenvalue.

The classical domain matter-element matrix R of the comprehensive benefit of green transformation in old residential areas is expressed as:

$$R_0 = [N, N_1, N_m, C, V_1, V_m] \tag{12}$$

The segment domain matrix R_p of the comprehensive benefit of green transformation in the old residential area is expressed as:

$$R_p = \begin{bmatrix} P, C_1, V_{1p} \\ .... \\ P, C_n, V_{np} \end{bmatrix} \tag{13}$$

where: p is the total composition of the comprehensive benefit evaluation grade; c is the eigenvalue of p; V is the magnitude range of nodal matter element with respect to feature c, that is, nodal domain.

The correlation function of comprehensive benefit index of green renovation in old residential areas is:

$$K_j(v_{kj}) = \frac{\tau(v_{ik}, v_{kj})}{\tau(v_{ik}, v_{pi}) - \tau(v_{ik}, v_{ij})} \tag{14}$$

The selection of shared feature dimensions of the old cell reconstruction factor model algorithm for multi-modal data fusion is further verified. As shown in Fig. 5, when the shared feature dimension is smaller than the number of data instance classifications, the values of the algorithm's three clustering indicators, NMI and ACC, all increase with the increase of the shared feature dimension. When the shared feature dimension exceeds the number of categories, with the increase of the shared feature dimension, the values of the three clustering indexes of the multimodal data fusion algorithm tend to be stable. In the learning of multi-modal data, the higher the shared feature dimension is, the more system overhead will be incurred. Therefore, the dimension of shared feature in the multi-modal data fusion algorithm is also set to be the same as the classification number of data instances.

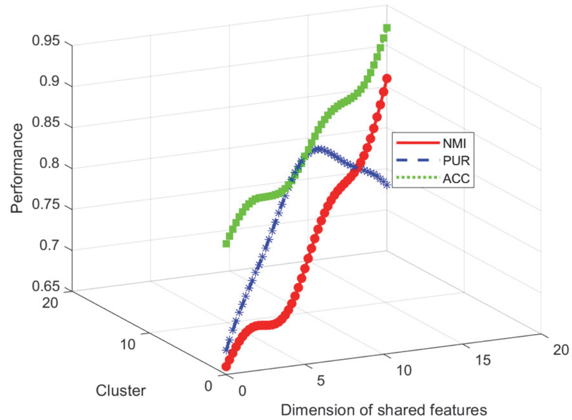

Figure 5 Influence of shared factors on the clustering performance of old residential areas

Firstly, the modal data is projected into the potential feature subspace by using the projection matrix of the old element transform mode shared feature and mode private feature. Then, combined with the cross-modal common feature matrix in subspace, the joint optimization objective function of each mode is established, and the modal invariant graph regularization and projective matrix sparsity are used to assist the model optimization process. Finally, through iterative co-learning of inter-modal correlation and uncorrelation features, robust cross-modal data sharing features in the potential subspace are obtained, and the final fusion clustering is completed. The proposed old cell reconstruction factor algorithm for multi-modal data fusion can effectively fuse and analyse high-dimensional multi-modal data in low-dimensional subspace, and obtain better clustering performance than all comparison algorithms. All the variables in this article are shown in Tab. 5.

Table 5 Symbol

Symbol	Meaning
H	Characteristic output
I	non linear activation function
P	Uniform coding matrix
U	Basis matrix
W	L-layer network weight
A	the adjacency matrix
k	the number of reachable matrix transformations
X	multimodal data instance
V	The quantity corresponding to the eigenvalue

5 SIMULATION VERIFICATION

Take an old residential district in a city as an example. Built in 1999, the district covers an area of 91800 square meters, with a residential construction area of 190000 square meters. There are 18 houses and more than 2040 households. First of all, the existing performance of the building is tested. After the test, it is found that the community has exceeded the reasonable service life, the roof leaks rain, the insulation is poor, the heating performance is poor, the wall is frosted and hairy, the pipe network has drip, the heating energy is large, the user's tap water is large, the external wall water pipe breaks, the water resources are seriously wasted, and the public facilities in the community are aging and seriously damaged. The lack of maintenance and management of greening on both sides of the road and in the recreation area, the indiscriminate parking of the owners' vehicles and the absence of corresponding above-ground and underground parking lots have seriously disturbed the landscape of the community, and the absence of street lights on the main and secondary roads has caused security risks. According to the above problems, the green comprehensive transformation of the existing community with the goal of comprehensively improving the quality of the community and enhancing the convenience, safety and comfort of residents' life includes the transformation of environmental greening and site, the transformation of building functions, the transformation of the enclosure structure, the transformation of water supply and drainage system and the transformation of HVAC system. Green construction, electrical intelligent transformation and operation management transformation and many other aspects.

According to the constructed comprehensive benefit evaluation system for green transformation of old residential areas, from five aspects of cost, technical benefit, economic benefit, ecological benefit and social benefit, the impact and effectiveness of green transformation on all aspects are comprehensively considered, and the evaluation levels are divided into four levels according to the transformation standards and requirements. Is excellent program N, good program N_2, general program N; , inferior program N_4:

$$R_0 = \begin{bmatrix} N, N_1, N_2, N_3, N_4 \\ C_1, (1,0.8), (0.8,0.7), (0.7,0.5), (0.5,0.3) \\ .... \\ C_{19}, (1,0.8), (0.8,0.7), (0.7,0.5), (0.5,0.3) \end{bmatrix} \tag{15}$$

For different risk factors, the negotiation loss coefficient of both sides is a continuous random variable with the characteristics of interval uniform distribution, while the transfer probability and transfer share of a certain risk by government departments conform to the characteristics of normal distribution. Based on the actual situation of the case, the numerical interval and parameter distribution of the relevant parameters of the game are determined, as shown in Tab. 6.

Define the value interval and distribution of input variables X_1 (negotiation consumption coefficient of government departments), X_2 (negotiation consumption coefficient of social capital), X_3 (transfer probability), X_4 (transfer risk share a), and then define the calculation relationship of output variable Y (risk sharing ratio k), and determine the simulation times as 2000 times, and run the simulation to get Fig. 6. Simulations of Fig. 7 and Fig. 8.

Table 6 Value ranges of game related parameters

Correlation parameter	Section	Probability distribution
Transition probability	[0.5 - 1.0]	Normal distribution
Government bargaining loss	[1.0 - 1.25]	Uniform distribution
Bargaining loss of social capital	[1.0 -1.25]	Uniform distribution
Transfer share	[0 - 0.25]	Normal distribution

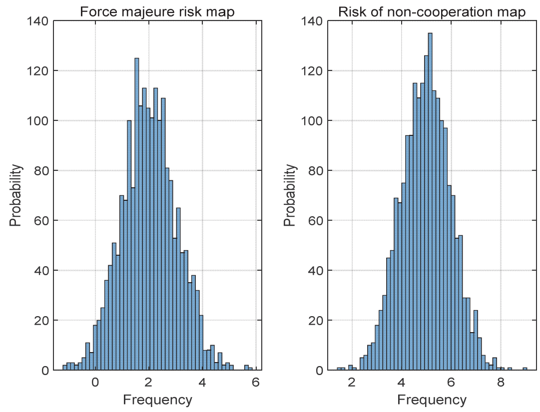

Figure 6 Simulation diagram of residents' non-cooperative risk sharing ratio

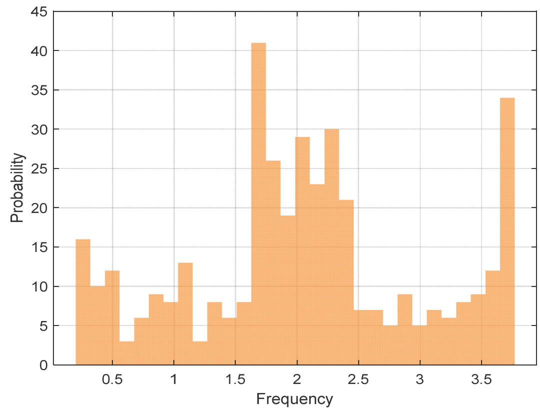

Figure 7 Simulation diagram of risk sharing ratio of unclear property rights relationship

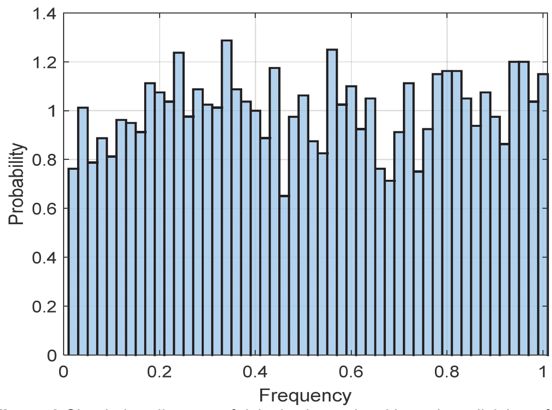

Figure 8 Simulation diagram of risk sharing ratio with unclear division of rights and responsibilities of stakeholders

In addition, the convergence of the multimodal data fusion algorithm is proved. In this section, the convergence is further verified on the data set Multiple Features and

NUS-WIDE (National University of Singapore Wide Dataset). As shown in Fig. 9, with the increase of the number of iterations, the objective function values of the algorithm on the two data sets are monotonically decreasing, and effective convergence results can be achieved after 12 iterations, and better NMI, PUR (Per Unit Value) and ACC clustering performance can be obtained.

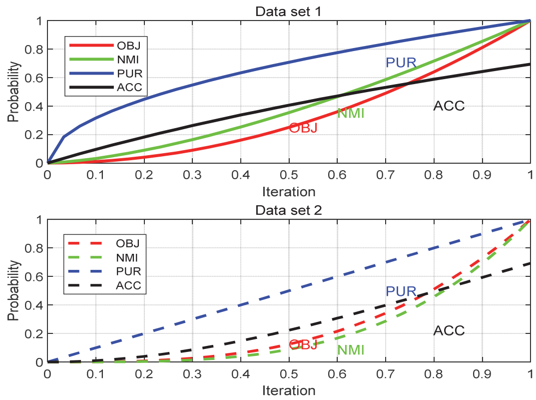

Figure 9 Algorithm convergence verification on each data set

Among existing feature learning algorithms for multi-modal data sharing based on non-negative matrix decomposition (NMF), most of the algorithms are set the same as this one, and their effectiveness has been verified. In the following, the selection of shared feature dimensions of the old cell transformation factor algorithm for multi-modal data fusion will be further verified on Multiple Features dataset.

Figure 10 Influence of shared feature dimension on clustering performance

As shown in Fig. 10, when the shared feature dimension is smaller than the number of data instance classifications (1 on Multiple Features dataset), with the increase of the shared feature dimension, the values of the three clustering indicators NMI and PUR of the old cell transformation factor algorithm of multi-modal data fusion are constantly rising. When the shared feature dimension exceeds the number of categories, with the increase of the shared feature dimension, the values of the three clustering indexes of the old cell reconstruction element algorithm of multi-modal data fusion tend to be stable. In the learning of multi-modal data, the higher the shared feature dimension is, the more system overhead will be incurred. Therefore, the dimension of shared feature in the old cell reconstruction element algorithm of multi-modal data fusion is also set to be the same as the classification number of data instances.

For social capital, the transaction cost is too high and the capital recovery cycle is too long in the existing transformation practice. Only by reducing the overall cost of social capital's participation in the transformation and increasing the depth of social capital's participation in the transformation can the possibility of social capital's participation in financing be increased. Allow social capital to participate in the transformation as investment entities, appropriately empower them, focus on building a governance community of "government, market, and residents", and focus on sharing responsibilities instead of fighting for rights and interests, so as to reduce the uncertainty of cooperation. The operating income of the new facilities will supplement the renovation costs, such as adjusting the use function of inefficient land transforming it into supporting facilities that meet the strong needs of residents such as elderly care. The multi-agent participation diagram of the multi-modal fusion element model is shown in Fig. 11.

Promoting the continuous renovation of old residential areas is the key to save the cost of reconstruction. Encourage the adjacent residential areas to transform according to the area, and integrate and renovate scattered old residential areas by rationalizing the road network and improving the functions, which not only solves the problem of backward basic facilities of scattered residential areas but also reduces the property operation costs of residential areas that do not have the condition of capital balance. To divide the transformation sequence with the level of "one district and one project in the city", promote the continuous transformation of old residential areas, and maximize the government investment benefits as much as possible.

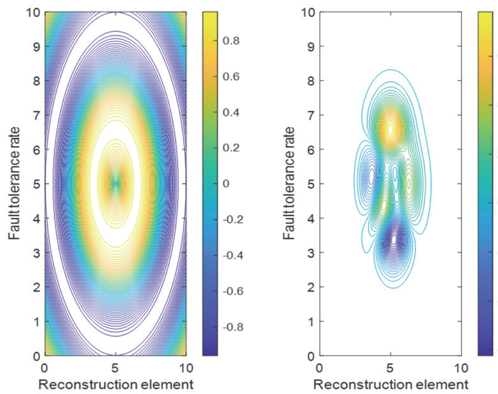

Figure 11 Multi-agent participation diagram of the reconstruction element model of the old residential area with multi-modal fusion

6 CONCLUSION

As an important project for urban renewal and satisfying people's demand for a better life, the green transformation of old residential areas should pay attention to sustainable development. Firstly, an adaptive modal weight update mechanism is designed in the transform element. By dynamically updating and adjusting the cluster structure and modal weight, non-parametric incremental fusion of multi-modal data is carried out to maintain the clustering fusion accuracy of newly added modal data and improve the performance and scalability of the clustering fusion algorithm. Secondly, on the basis of the reconstruction factor model of the old residential area based on multi-modal data fusion, the hierarchical structure model is divided into three levels, and the factors are analyzed to find the fundamental factors affecting the old residential area and the influencing path, so as to promote the reconstruction and development of the old residential area and provide help for the construction of the old residential area. Finally, according to the multi-modal data fusion model of the reconstruction elements of old residential areas, the multi-modal data fusion model is established based on the triplet composed of the elements, factor characteristics and characteristic values, and it is found that promoting the marketization of the reconstruction of old residential areas is the fundamental way to improve the reconstruction effect of old residential areas, which can provide references for relevant departments to improve the transformation mode of old residential areas. There are many complex risks in old residential areas, and some risks may change significantly with the implementation of the project. How to deal with them, the dynamic monitoring of the shared risks and the timely adjustment of the risk sharing plan need to be further improved.

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7 REFERENCES

[1] Wang, H., Zuo, H., & Liu, Z. (2021). Research on 3D reconstruction method of wear particle dynamic image based on multi contour space mapping. *IOP Conference Series: Materials Science and Engineering, 1207*(1), 12017-12028. https://doi.org/10.1088/1757-899X/1207/1/012017

[2] Li, F., Liang, H. D., & Wang, F. G. (2023). Remote Sensing Monitoring Research of Multi-Temporal Desertfication Based on Spectral Mixture Analysis: A Case Study of Wuda, Inner Mongolia, China. *Advanced Materials Research, 1065-1069*, 2282-2286. https://doi.org/10.4028/www.scientific.net/AMR.1065-1069.2282

[3] Qu, F., Qin, Z., & Zhao, C. (2021). A high resolution InSAR topographic reconstruction research in urban area based on TerraSAR-X data.*Proceedings of SPIE - The International Society for Optical Engineering, 8286*(4), 393-403. https://doi.org/10.1117/12.912433

[4] Ye, Y. & Bill, P. (2021).Buckles.Residential Building Reconstruction Based on Data Fusion. *Acta Electronica Sinica, 42*(002), 250-256.

[5] Zhang, G., Zhu, Y., & Zang, L. (2022). Spatial reconstruction evaluation and partition of rural residential areas in Changli county under background of new-type urbanization. *Transactions of the Chinese Society of Agricultural Engineering*, *4*(3), 34-56.

[6] Choi, J. W., Park, S., & Sohn, J. (2024). Automated digital oncologic data review for breast cancer research: AI-enabled mCODE and field-of-interest extraction framework. *Journal of Clinical Oncology*, *42*(16_suppl), e12647-e12657. https://doi.org/10.1200/JCO.2024.42.16_suppl.e12647

[7] Yuan, Y., Tao, G., & Jiaqi, B. (2019). Research on Three-dimensional Reconstruction Model of Power Line Based on Point Cloud Data. *Journal of Clinical Oncology,* 34829-34845. https://doi.org/10.1109/ICPRE48497.2019.9034829

[8] Yang, D., Yang, H., & Liu, D. (2024). Research on automatic 3D reconstruction of plant phenotype based on Multi-View images. *Computers and Electronics in Agriculture,* 220-266. https://doi.org/10.1016/j.compag.2024.108866

[9] Zhang, Q., Zhang, F., & Lu, X . (2021). Study on Layout Model of Cold Residential Area Based on Computer Microclimate Optimization. *Journal of Physics: Conference Series, 1915*(2), 22034-22056. https://doi.org/10.1088/1742-6596/1915/2/022034

[10] Yang, R., Liu, Y., & Long, H. (2022). Spatial-temporal characteristics of rural residential land use change and spatial directivity identification based on grid in the Bohai Rim in China. *Geographical Research, 34*(6), 1077-1087.

[11] Liuyang, D. (2021). Research on Quality Improvement and Reconstruction of Mixed-Function Urban Villages Based on Green View Index and Space Syntax. *Sustainable Development, 11*(4), 531-539. https://doi.org/10.12677/sd.2021.114065

[12] Song, Y. & Cao, P. (2021). Research on the Construction of Virtual Three-Dimensional Model of Aging Housing Transformation in Northeast China Based on Mobile Communication Technology. *International Journal of Wireless Information Networks, 28*(3), 297-307. https://doi.org/10.1007/s10776-021-00514-x

[13] Wei, C. & Yan, S. (2023). Reconstruction design of drainage system in residential area at low-lying area in old town. *Water & Wastewater Engineering, 3*, 84-96. https://doi.org/10.1016/j.breast.2013.05.001

[14] Yanbo, Q. U., Guanghui, J., & Ran, S. (2023). Type Classification of Rural Settlements and Its Consolidation Models Based on the Coupling of System Factor Characteristics. *Acta entiarum Naturalium Universitatis Pekinensis, 7*, 38-46.

[15] Sun, W., Li, H. G., & Xu, X. (2021). Research on Key Technologies of Three-dimensional Digital Reconstruction of Cultural Heritage in Historical and Cultural Blocks. *IEEE,* 54-68. https://doi.org/10.1109/CTMCD53128.2021.00054

[16] Komolafe, T. E., Wang, N., & Tian, Y. (2024). MDUNet: deep-prior unrolling network with multi-parameter data integration for low-dose computed tomography reconstruction. *Machine Vision and Applications, 35*(4), 1568-1574. https://doi.org/10.1007/s00138-024-01568-6

[17] An, W., Liu, K., & Wang, J. (2024).Research on Multi-hypothesis Residual Reconstruction Algorithm Based on Adaptive Sampling. *Acta Automatica Sinica, 43*(12), 2190-2201.

[18] Shen, L., Deng, L., & Wang, Y. (2024). PCSAGAN: a physics-constrained generative network based on self-attention for high-fidelity flow field reconstruction. *Journal of Visualization, 27*(4), 661-676. https://doi.org/10.1007/s12650-024-00987-x

[19] Wilson, H. H., Ma, C., & Ku, D. (2024). Deep learning model utilizing clinical data alone outperforms image-based

model for hernia recurrence following abdominal wall reconstruction with long-term follow up. *Surgical Endoscopy, 38*(7), 3984-3991. https://doi.org/10.1007/s00464-024-10980-y
[20] Du, J. (2020). Research on Optimization of Portrait Sculpture Data Based on 3D Image and Mobile Edge Computing. *IEEE Access, 8*(99), 3010-3023. https://doi.org/10.1109/ACCESS.2020.3043010
[21] Fenghe, W., Xiaofeng, Z., & Shi, F. (2021). Research on 3D Reconstruction Method Based on Single Image Data. *China Mechanical Engineering, 18*(17), 2071-2075. https://doi.org/10.1016/S1874-8651(08)60023-X
[22] Sun, X., Zhang, R., & Chen, X. (2020). Impact of nanotechnology patents on green development of China's building industry. *Recent Pat Nanotech*, *14*(2):141-152. https://doi.org/10.2174/1872210513666191205123449
[23] Seki, H., Ogiya, A., & Nagura, N. (2024). Prognosis of locoregional recurrence after early breast cancer with immediate breast reconstruction. *Journal of Clinical Oncology, 42*(16_suppl), e12595-e12605. https://doi.org/10.1200/JCO.2024.42.16_suppl.e12595
[24] Yan, W., Wang, D., & Wang, Y. (2024). Metatranscriptomics-guided genome-scale metabolic reconstruction reveals the carbon flux and trophic interaction in methanogenic communities. *Microbiome, 12*(1), 1830-1845. https://doi.org/10.1186/s40168-024-01830-z
[25] Quang-Huy, T., Sharma, B., & Theu, L. T. (2024). Frequency-hopping along with resolution-turning for fast and enhanced reconstruction in ultrasound tomography. *Scientific Reports, 14*(1), 66138-66143. https://doi.org/ 10.1038/s41598-024-66138-2
[26] Wehrli, L. A., Harris, K, T., & Wood, D. T. (2024). Urological outcomes in adult females born with anorectal malformation or Hirschsprung disease. *Pediatric Surgery International, 40*(1), 5766-5778. https://doi.org/10.1007/s00383-024-05766-1
[27] Zenk, F., Fleck, J. S., & Jansen, S. M. J. (2024). Single-cell epigenomic reconstruction of developmental trajectories from pluripotency in human neural organoid systems. *Nature Neuroscience, 27*(7), 1376-1386. https://doi.org/10.1038/s41593-024-01652-0
[28] Xu, Q., Lu, H., & Zheng, Z. (2024). Challenges and opportunities in Quaternary palynology. *Science China Earth Sciences, 67*(7), 2148-2161. https://doi.org/10.1007/s11430-023-1310-4
[29] Meena, A., Das, S., & Runer, A. (2024). Revision ACL reconstruction in female athletes: current concepts. *Journal of ISAKOS, 9*(3), 464-470. https://doi.org/10.1016/j.jisako.2024.02.007
[30] Tian, Y., Chen, P., & Lu, P. (2024). Basin-scale reconstruction of late Pleistocene-Holocene fluvial landform evolution and its mechanisms in transitional areas between Taihang Mountain and North China Plain. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 634-645. https://doi.org/10.1016/j.palaeo.2023.111944
[31] Figueroa, D. & María, F. F. (2024). Return to sports in female athletes after anterior cruciate ligament reconstruction: A systematic review and metanalysis. *Journal of ISAKOS, 9*(3), 378-385. https://doi.org/10.1016/j.jisako.2024.01.008
[32] Sun, X., Zhang, R., & Yu, Z. (2024). Revisiting the porter hypothesis within the economy-environment-health framework: Empirical analysis from a multidimensional perspective. *J Environ Manage, 349*, 119557. https://doi.org/10.1016/j.jenvman.2023.119557
[33] Sun, X., Zhu, S., & Guo, J. (2024). Exploring ways to improve China's ecological well-being amidst air pollution challenges using mixed methods. *J Environ Manage, 364*, 121457. https://doi.org/10.1016/j.jenvman.2024.121457
[34] Yang, R., Liu, Y., & Long, H. (2022). Spatial-temporal characteristics of rural residential land use change and spatial directivity identification based on grid in the Bohai Rim in China. *Geographical Research, 34*(6), 1077-1087.
[35] Sun, X., Meng, Z., & Zhang, X. (2024). The role of institutional quality in the nexus between green financing and sustainable development. *Res Int Bus Financ, 73*,102531. https://doi.org/10.1016/j.ribaf.2024.102531
[36] Zhang, X., Gou, P., & Huang, Y. (2023). Reconstruction of all-weather land surface temperature based on a combined physical and data-driven model. *Environ Sci Pollut R, 30*(32), 78865-78878. https://doi.org/10.1007/s11356-023-27986-z

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