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Article

Application of multimodal metaphor strategies and biomechanics knowledge in shaping the urban image of the Guangdong-Hong Kong-Macao greater bay area

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Abstract: The purpose of this paper is to explore the strategic application of multimodal metaphor and biomechanics knowledge in enhancing the image of Guangdong-Hong Kong-Macao Greater Bay Area (GBA). In the urban planning of GBA, the building structure can be designed by imitating the skeleton system of organisms, and the load-bearing columns and beams can be reasonably arranged to resist external forces, such as wind or earthquake activities. The "muscles" of a city, such as active transportation systems such as subways and buses, can work together to promote the flow of people and goods, similar to the muscles of organisms that drive movement through contraction and relaxation. This study focuses on this field, and comprehensively uses theoretical analysis and experimental verification methods to explore the underlying operating mechanism of biomechanical knowledge in the field of regional image communication, and focuses on exploring the collaborative integration mode of biomechanical knowledge and multimodal elements. Taking fluid dynamics in biological system as an example, the efficient flow of blood circulation system can inspire the design of GBA water supply and drainage network. In this study, an image communication model suitable for Greater Bay Area city is constructed. The model is based on multimodal metaphor strategy and deeply integrates biomechanical knowledge to realize the organic embedding of the two. After the model is built, the parameters of the model are refined and optimized based on biomechanical principles, and then the comprehensive performance of the model is comprehensively and systematically evaluated. The results show that the combination of multimodal metaphor strategy and biomechanics can guide the audience's cognition and evaluation of GBA city image more accurately, and verify its unique advantages in improving the efficiency of regional image communication.

Keywords: Guangdong-Hong Kong-Macao great bay area; international image; multimodal metaphor; biomechanics; performance assessment

1. Introduction

With the deepening of globalization, the international spread of regional image has become an important indicator to measure the comprehensive strength and international influence of a region [1]. GBA is one of the regions with the highest degree of openness and the strongest economic vitality in China. The shaping and dissemination of its international image is not only related to the coordinated development within the region, but also an important window for the external display of the national image [2]. With the in-depth implementation of the "Belt and Road Initiative" and the increasing global attention to GBA, how to effectively build and spread a positive, pluralistic and open international image has become an urgent

problem [3]. Based on the unique perspective of biomechanics, this study focuses on the multimodal metonymic complex that integrates biomechanical principles in the construction of the international image of the Greater Bay Area, and probes deeply into the complex and subtle communication mechanism formed under the action of biomechanics. For example, the principles of biomechanics can be used in the design of urban transportation buildings in the Greater Bay Area. The streamline design in traffic planning can be compared to the blood circulation system in organisms. By rationally planning traffic routes and nodes, the smoothness and efficiency of traffic can be improved, congestion can be reduced, and the image of efficient and convenient transportation in the Greater Bay Area can be displayed. At the same time, the appearance of architectural design can also refer to the form of organisms, such as imitating the arc structure of shells, which is not only beautiful, but also can achieve better load-bearing and wind resistance in mechanics, so that the building can not only reflect the integration with nature, but also show the intelligent application of biomechanics, and enhance the architectural image of the cities in the Greater Bay Area. Moreover, it reveals the key value and potential influence of biomechanics in the field of regional image communication, and provides innovative theoretical support and practical guidance for the precise shaping and efficient communication of the international image of the Greater Bay Area.

GBA, covering nine cities in Guangdong Province and two special administrative regions of Hong Kong and Macao, is gradually becoming a world-class urban agglomeration and a new engine of global economic growth by virtue of its unique geographical location, profound historical and cultural heritage and highly developed economic system [4,5]. Under the background of global information explosion, the shaping and dissemination of regional image is facing unprecedented challenges. On the one hand, the mass and fragmentation of information make it particularly difficult to screen and transmit effective information [6]. On the other hand, there may be significant differences in the interpretation of the same information by audiences in different cultural backgrounds, which undoubtedly increases the complexity of international image construction [7]. Multimodal metonymy complex can cross the boundaries of language and culture by comprehensively using various symbol systems such as images, sounds and characters, and build a rich and infectious information dissemination system, so it shows great potential in the construction of international image [8]. Multimodal metonymy complex can not only effectively integrate all kinds of communication resources, but also stimulate the audience's emotional resonance and cognitive association with the help of metaphors, symbols and other rhetorical devices [9].

The theory of multimodal metonymy complex originates from the cross field of cognitive linguistics and media research. It emphasizes the interaction and meaning transformation between different modes in the process of information transmission [10]. Metonymy, as a basic cognitive mechanism, helps people to understand and express complex concepts by means of "part generation whole" or "concrete generation abstraction". When metonymy is combined with the multimodal characteristics of multimedia technology, a multimodal metonymy complex is formed [11]. This complex can use a variety of sensory channels to transmit information in a more vivid and intuitive way, and enhance the attractiveness and

persuasiveness of information [12]. In the context of GBA international image construction, the application of multimodal metonymy complex is particularly critical. It can display the natural scenery and urban features of the region with the help of visual images, and also convey the cultural characteristics and development concepts of the region with the help of sound, text and other modes [13]. Multimodal metonymy complex can skillfully visualize the abstract concept of regional image, for example, with the help of "bridge" to symbolize connection and cooperation, and "lighthouse" to symbolize guidance and hope, thus building a profound cognitive framework for GBA in the hearts of the audience [14,15].

From a practical point of view, studying the mechanics of biomechanics in information dissemination, audience biofeedback and dynamic changes in communication effects, we can customize biomechanically oriented and innovative communication strategies for all parties. Biomechanics involves specific knowledge of kinematics, dynamics, and biomaterials, which helps us to understand the differences in audience's biological characteristics in different cultural contexts. For example, biomechanical analyses can reveal the physical responses and emotional resonance of different cultural groups when receiving messages, thus optimising the content and form of communication. By analysing the audience's physiological responses (e.g., heart rate, EMG, etc.), it is possible to monitor in real time their reactions to the message, which in turn guides the adjustment of communication strategies. Using this data, communicators can design more targeted content to trigger a stronger sense of empathy and engagement. In addition, dynamically changing communication effects can be evaluated through biomechanical modelling, ensuring that messages are delivered both accurately and efficiently. Ultimately, through the application of biomechanics, the Guangdong-Hong Kong-Macao Greater Bay Area is able to create a unique city image and enhance its recognition and influence in the public mind. This biomechanics-based communication strategy not only promotes the shaping of the region's image, but also enables effective communication and transformation between cultures.

Theoretically speaking, this study will expand the application field of multimodal metaphor strategy cooperated with biomechanics knowledge. With the help of constructing a corresponding multimodal communication model, and making empirical analysis and verification, this study aims to confirm the effectiveness of the theory and reveal the unique laws and mechanisms of the combination of multimodal communication and biomechanics in cross-cultural communication.

2. Literature review

2.1. Multimodal metonymy complex theory

Multimodal metonymy complex theory is the cross product of cognitive linguistics, media research and communication. It deepens people's understanding of multimodal interaction in information dissemination [16]. Metonymy refers to the cognitive process of using one concept or thing to understand and express another related concept or thing, which embodies the creativity and economy of human thinking [17]. In the field of communication, metonymy is widely used in many

fields, such as advertising, brand building, movies, bio-science, and so on, in order to construct symbolic and emotional information.

Nowadays, information dissemination is no longer limited to a single mode, but the comprehensive application of images, sounds, words, actions and other modes [18]. Multi-modal metonymy complex came into being under this background, which emphasizes the synergy between different modes and how to realize the trans-modal transmission of meaning with the help of metonymy mechanism [19]. For example, in advertising, the image of a product may be associated with a positive emotion or lifestyle, and the combination of vision and hearing can stimulate consumers' desire to buy [20]. This multi-modal metonymic expression is more vivid and powerful than a single mode, and can touch the emotions of the audience more effectively.

2.2. Construction of GBA international image

As a new regional concept, the construction of GBA's international image is a complex and multidimensional process, involving political, economic, cultural, bio-science, and other levels [21]. In terms of international image-building, GBA faces the challenge of how to effectively convey its own historical background, economic vitality, cultural diversity, bio-science development, and open and inclusive attitude to the global audience [22].

The existing research mostly starts from the angles of city brand marketing, city visual image design, tourism image perception, and science development. Urban brand marketing emphasizes the promotion of regional visibility and attractiveness by means of brand positioning and story telling [23]. Urban visual image design focuses on how to build a unified and recognizable regional image with the help of visual elements such as signs, colors and fonts [24]. The study of tourism image perception focuses on the analysis of tourists' perception and assessment of regional tourism resources and how these factors affect the overall image of the region [25]. Nowadays, biomechanic science's development also becomes an attractive point.

Current research is often limited to unimodal or unidimensional analyses, failing to emphasize the critical importance of multimodal communication in shaping the region's international image in the context of the information explosion era. However, biomechanics knowledge can give new energy to multimodal communication. Multimodal metaphors make the city image easier to understand and remember, while the integration of biomechanics increases the scientific nature and credibility of the image. From a point together with biomechanical knowledge, the use of multimodal metaphoric complexes, combined with human physiological perception mechanisms, and the use of sensory channels to synergistically build an international image that resonates with regional and global audiences is a new academic field that needs to be explored urgently.

2.3. The combination of multimodal metonymy complex and GBA international image construction

Although there have been many studies on the application of multimodal metonymy complex in advertising, movies and other fields, there are still relatively

few studies on its application in the construction of regional international image, especially in the specific context of GBA. It is worth noting that research that cuts through from a biomechanical perspective is missing in existing explorations, but this also provides a new opportunity for follow-up research. This is expected to leverage the power of biomechanics to deeply excavate its application potential in the construction of the international image of the Greater Bay Area.

Fu et al. [26] pointed out that with the help of multimodal metonymy expression, the economic development achievements of GBA can be combined with symbolic elements such as “bridge” and “lighthouse” to convey the image of the region as a global economic hub and leader. Li et al. [27] believe that using visual images to show the unique charm of Lingnan culture in cultural tourism promotion, and telling the story of the Bay Area in combination with music, words and other modes can enhance the cultural identity and emotional resonance of tourists. It is believed that bio-science, such as biomechanics, will help to attract more people.

Although these studies are preliminary, they have shown the great potential of multimodal metonymy complex in the construction of GBA international image. They show that with the help of well-designed multi-modal communication strategies, the attractiveness and recognition of regional images can be enhanced, and a positive regional image can be constructed on a global scale to promote international exchanges and cooperation.

There are still some shortcomings in the existing research. On the one hand, the application mechanism of the multimodal metaphoric complex in regional image construction with biomechanics knowledge lacks in-depth theoretical study, and its unique action principle is unclear. On the other hand, empirical research with biomechanics knowledge is scarce, and the research on the acceptance effect of audiences from different cultures is insufficient. This makes it hard to understand the audience’s cognitive pattern under biomechanical influence. Also, the formulation of innovative and practical multi-modal communication strategies based on biomechanics in the Greater Bay Area needs further exploration and breakthroughs. Finally, how to work out an innovative and practical multi-modal communication strategy based on the actual situation of GBA is still an urgent problem.

3. Methodology

3.1. Research design

In order to explore the role of biomechanics-enabled multimodal metaphoric complex on the construction of the international image of the Greater Bay Area, and to construct a communication model, this study adopts a comprehensive research method, integrating the advantages of quantitative and qualitative analysis. This research focuses on the impact of biomechanics knowledge on information dissemination, audience perception, and image construction, and collects and organizes the data from this perspective, to ensure that the results accurately reflect its role, and to provide a basis for and guidance on the shaping of the image of the Greater Bay Area.

3.1.1. Sample selection and data collection

Firstly, the official propaganda films, news reports and social media content released by GBA on international platforms in recent years are selected as the research objects. These materials cover various modes such as video, image and text, and can fully reflect the practice of GBA in international image construction. The selection of samples follows the principles of representativeness, diversity and timeliness to ensure that the research data can truly reflect the current situation.

In the data collection phase, based on biomechanics principles, use adapted video analysis software to do frame-level analysis of promotional scenes. Focus on extracting key visual elements like movement trajectory and intensity, plus sound effects and voice-over text that trigger physiological responses. For news and social media content, use text mining for keyword extraction, sentiment analysis and theme modeling, filtering biomechanics-related info to integrate multidimensional data for follow-up research.

3.1.2. Data preprocessing and biomechanical feature extraction

In the study of using biomechanics to build the Greater Bay Area's international image, data processing matters. First, after gathering raw data, preprocess based on biomechanics. Remove irrelevant info precisely and unify the format for effective analysis. Then, design a coding scheme following the multimodal metonymic complex with biomechanical traits. Categorize visual elements like nature scenes for visual comfort, buildings reflecting movement adaptability, and people's activities related to behavior patterns, marking metonymic meanings. Code sound effects by emotional feedback and music type, and analyze text's rhetoric and themes in the biomechanics context to underpin further research.

3.1.3. Data analysis and model construction preparation

In the data analysis stage of biomechanics-based exploration of the construction of the international image of the Greater Bay Area, the biomechanically encoded data are manipulated by using appropriate statistical software, and descriptive statistics, correlation analysis and clustering analysis are carried out to fully explore the rules of the multimodal metaphorical complex and its effectiveness under the empowerment of biomechanics. Video analysis software is chosen because it can accurately extract key visual elements, such as motion trajectory and intensity, which is very important for analyzing urban dynamic scenes. Text mining technology is used to mine the information needed for sentiment analysis and theme modeling in text data. In the process of use, the video analysis software first processes the video of the city scene and extracts the key visual features; Then, text mining technology mines text data such as social media and news reports to obtain the public's cognition and attitude towards the city image. For unstructured data, natural language processing technology is used for preprocessing and structuring to improve the availability of data and the repeatability of methods. In particular, the social network analysis technology should be used to construct a multimodal elemental relationship network incorporating biomechanical perception factors, and visualize the interaction of different modalities based on biomechanics as well as the metaphorical paths, so as to accurately demonstrate the key role of biomechanics.

3.2. Communication model construction

Based on the data collection and analysis of the above research design, a GBA international image communication model based on multimodal metonymy complex is constructed. The goal of this model is to reveal how multimodal elements interact with each other by means of metonymy mechanism, thus affecting the audience's cognition and assessment of GBA's international image. In the interaction between multimodal metaphor and biomechanics, taking the urban planning of GBA as an example, we can see how biomechanics principles are integrated into architectural design. The structural design of buildings can imitate the skeletal system of organisms, and resist external forces such as wind or earthquake activities by rationally arranging load-bearing columns and beams. Urban transportation systems, such as subways and buses, can work together to promote the flow of people and goods, and muscles similar to organisms drive movement through contraction and relaxation.

3.2.1. Integration of model architecture and biomechanics

The model framework consists of three core parts: static fusion module, dynamic fusion module and influence fusion prediction module. Together, they support the complex mechanism of multimodal metonymy complex in international image communication. On this basis, from the perspective of social network research, each element in the model is regarded as a "node" in the network, and the relationship between elements is regarded as a "connection line" between nodes, which carries the specific content of the relationship and reflects the substantive realistic interaction.

In this network structure, multimodal elements (such as visual images, sound effects, text content) serve as nodes. The metonymic relationship between them constitutes the connection between nodes. These connections may be directional, indicating a one-way influence or propagation path. For example, a visual element may guide the audience to understand the content of another text by means of metaphor; It may also be undirected, indicating the correlation and resonance between elements, such as the emotional echo between images and music.

In particular, the concepts of directed network and undirected network are introduced to distinguish different types of metonymy relations. In a directed network, nodes have degrees of access, which reflects the position and function of elements in the metonymy chain. For example, a core visual element may have a high degree of access, which means that it is quoted or explained by many other elements. Extent indicates the influence of the element on other elements. In an undirected network, the relationship between nodes is more equal and reciprocal, for example, two elements complement each other in content and together form a complete metonymy complex.

As shown in **Figure 1**, the directed topology and the undirected topology directly show the different characteristics of these two network structures. In our model (as shown in **Figure 2**), this network structure is dynamic, and with the passage of time, the increase or decrease of members within the group and the change of relationship will be captured and reflected in the dynamic feature sequence of the model. With the help of time series analysis and dynamic modeling of

complex networks, we can more accurately grasp the evolution law of multimodal metonymy complex in international image communication.

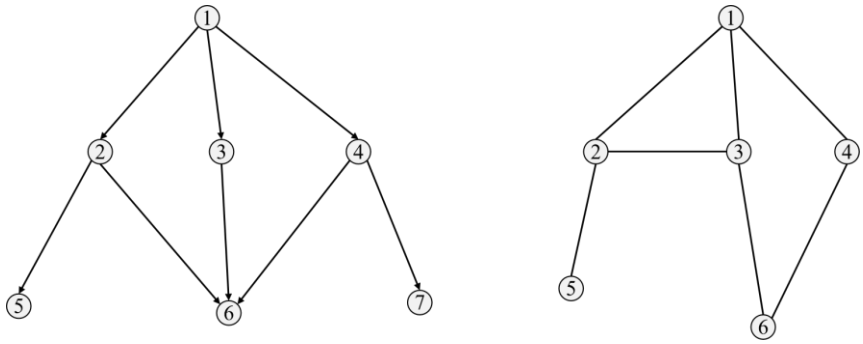

Figure 1. Directed and undirected topology diagrams.

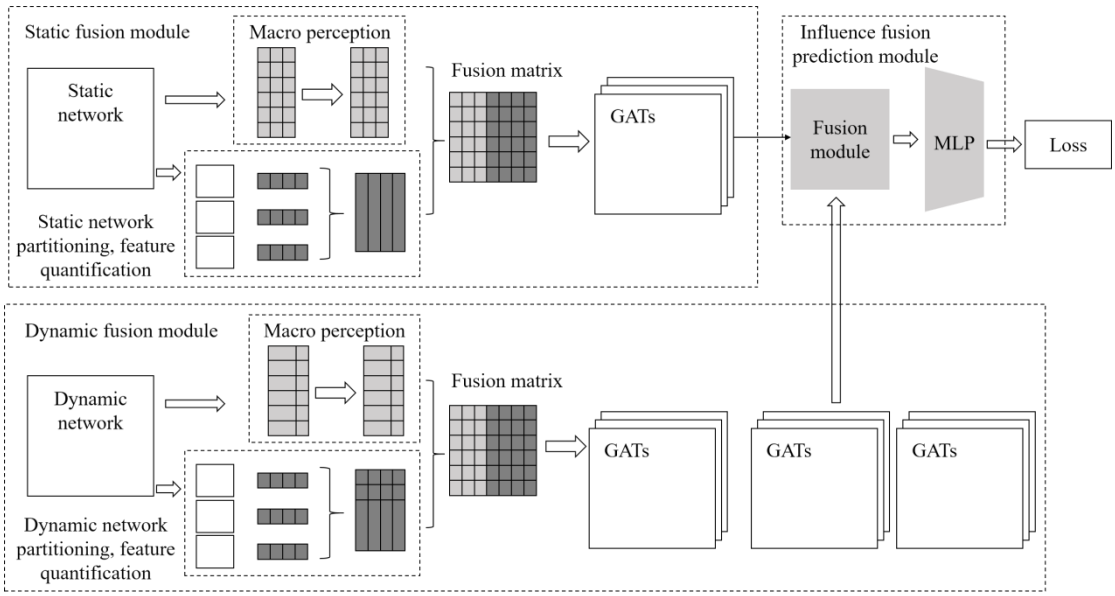

Figure 2. Model structure.

3.2.2. Model operation mechanism and optimization strategy

During the operation of the model, multimodal elements, as network nodes, are connected with each other by metonymy to form a complex communication network. This network not only shows the relationship between elements statically, but also dynamically reflects the changes and influences in the process of communication. The static fusion module is responsible for integrating elements of different modes to form a preliminary metonymic complex. The dynamic fusion module captures the dynamic changes of members and relationships within the group and updates the network structure. The influence fusion prediction module predicts the influence of multimodal metonymy complex on audience's cognition and assessment based on the network structure and analysis results.

The neural network model of multimodal cultural information dissemination represents different network structures through the connections between different nodes. In a network of N nodes, consider two nodes, i and j. The shortest path length between these nodes, originating from node i and terminating at node j, is defined as $l(i, j)$. For undirected graphs, the average path length is defined as:

$$i = \frac{1}{\frac{1}{2}N(N-1)} \sum_{i>j} l(i,j) \tag{1}$$

The clustering coefficient C_i of node i pertains to the connectivity among nodes directly linked to node i within the network. It represents the proportion of actual edges between nodes i, which are directly connected, relative to the maximum potential number of edges. C_i is defined as:

$$C_i = \frac{2e_i}{k_i(k_i-1)} \tag{2}$$

k_i represents the degree of node i, while e_i denotes the number of edges connecting node i to other nodes. C_i provides local insights. Hence, the clustering coefficient C_i of a complex network is the average clustering coefficient across all nodes.

$$C = \sum_{i=1}^{N} C_i \tag{3}$$

Weight attenuation is a widely-used regularization technique that involves adding a regularization term to the cost function. The resulting cross entropy, after applying this regularization, is:

$$c = -\frac{1}{n}\sum_{xj}\left[y_j \ln a_j^L + (1-y_j)\ln\left(1-a_j^L\right)\right] + \frac{\lambda}{2n}\sum_{w} w^2 \tag{4}$$

The first term represents the standard cross entropy, while the second term is a regularization component, summing the squares of ownership values in the network. This is modulated by parameter $\lambda/2n$, where $\lambda > 0$ denotes the regularization parameter and n the training set size. For the training document set, compute vector distances to obtain the most recent k texts of the test document:

$$Sim(T,D) = \frac{\sum_{i=1}^{N}(T_i \times D_i)}{\left\{\left(\sum_{i=1}^{N} T_i^2\right) \times \left(\sum_{i=1}^{N} D_i^2\right)\right\}^{1/2}} \tag{5}$$

where T is the test document and D is the training document set, compute the weights of k documents.

$$P(T,C_j) = \sum_{d_i \in K} Sim(T,d_i) \times I(d_i \times C_j) \tag{6}$$

where T is the test document, d_i is the i in the chosen training document, $I(d_i \times C_j)$ is the indicator function, and d_i is 1 if it belongs to class C_j, otherwise 0.

The diffusion rate of multimodal cultural information signifies the change in imperceptible attribute S nodes within the unit time of the public opinion dissemination network, or the rate of decrease of such nodes. Given an interception duration of x, its expression is:

$$\frac{\Delta S(t_n)}{x} = \frac{S(t_{n-x}) - S(t_n)}{x} \tag{7}$$

Consider a combined classifier comprising N binary classification models, each with an error rate of P. When employing a majority voting strategy for the final decision, the overall error of this classifier can be determined using a specific formula:

$$p_{error} = \sum_{k=0}^{N/2} \binom{N}{k} (1-p)^k p^{N-k} \tag{8}$$

when p is below 0.5, the error rate p_{error} decreases as N increases. Information entropy is a measure of uncertainty, calculated using the probability of information occurrence. It describes the relationship between information content and its probability.

$$E(S) = \sum_{i=1}^{c} -p_i \log_2 p_i \tag{9}$$

where S is a random variable, c denotes the number of measurement outcomes, and p_i represents the probability of outcome i. The conditional entropy is given by:

$$E(S, X) = \sum_{x \in X} p(x)\, E(S|X = x) \tag{10}$$

where X is an information attribute and $p(x)$ is the probability of value $X = x$. For a new sample x, the random forest prediction $\hat{y}$ is given by:

$$\hat{y} = \frac{1}{T} \sum_{t=1}^{T} \hat{y}_t(x) \tag{11}$$

$\hat{y}_t(x)$ is the prediction for sample x by the t tree, out of T trees in the forest, for a classification task.

$$\hat{y} = \text{majority\_vote}\left(\hat{y}_1(x), \hat{y}_2(x) \ldots, \hat{y}_T(x)\right) \tag{12}$$

where: majority_vote denotes the majority voting function, selecting the category with the highest prediction frequency across all trees.

After receiving these complexes, the audience will decode and interpret them according to their own cultural background and cognitive framework. Multi-modal metonymy and visual pun in the processing layer can stimulate the association and imagination of the audience and guide them to understand and evaluate the international image of GBA at a deeper level. Finally, at the output level, the audience's cognition and assessment will be fed back as the overall impression and attitude tendency of GBA's international image.

4. Results analysis and discussion

4.1. Experimental result

After completing the construction of GBA international image communication model based on multimodal metonymy complex, it entered the stage of experimental verification, with the goal of evaluating the prediction accuracy and practical

application potential of the model with the help of rigorous tests. This process not only includes the test of the basic prediction ability of the model, but also involves the exploration of further improving the performance of the model by means of parameter optimization.

Firstly, the model is tested comprehensively on the test set. The test set contains a variety of GBA international image communication materials, covering different media forms and various communication channels. By comparing the predicted results of the model with the actual audience feedback data, the accuracy of the model in predicting the audience's cognition and assessment of GBA's international image is evaluated.

Figure 3 shows the comparison between the predicted results and the actual results. There is a high degree of consistency between the predicted values of the model and the actual audience feedback data, and both the overall trend and the specific values are quite close. This result proves the reliability and effectiveness of the model in practical application, and shows that the communication model based on multimodal metonymy complex can accurately capture and predict the audience's complex cognitive process of GBA international image.

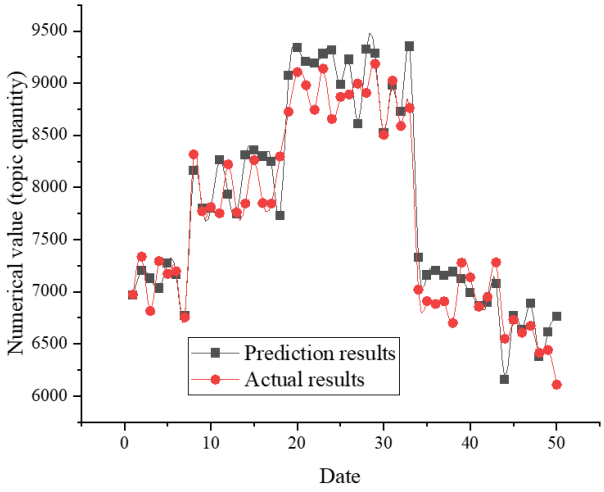

Figure 3. Comparison between predicted results and actual results.

Parameter optimization is a key step to improve the performance of machine learning model, which involves systematically adjusting multiple parameters in the model to find the best configuration combination. In the process of parameter optimization, two key parameters, the number of feature selection and the number of trees, are focused on. The number of feature selection determines the amount of information processed by the model, while the number of trees affects the complexity and generalization ability of the decision tree. With the help of many iterative experiments, the search range of parameters is gradually narrowed, and the optimal parameter combination is finally determined.

Figure 4 shows the influence of the number of feature selections on the model performance. With the increase of the number of feature selection, the performance of the model first rises and then falls, and there is an obvious optimal value. When the number of feature selection is set to 10, the model performance reaches the peak.

This shows that too many features may introduce noise, while too few features may lead to insufficient information.

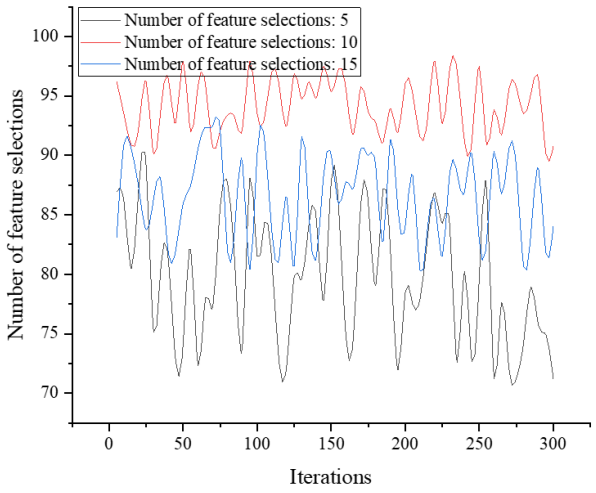

Figure 4. Parameter optimization (number of feature selections).

Figure 5 reveals the relationship between the number of trees and the performance of the model. With the increase of the number of trees, the performance of the model is gradually improved, but when the number of trees exceeds a certain threshold, the performance improvement becomes no longer significant, and even overfitting may occur. After repeated tests, it is found that when the number of trees is set to 150, the model performance reaches the best state.

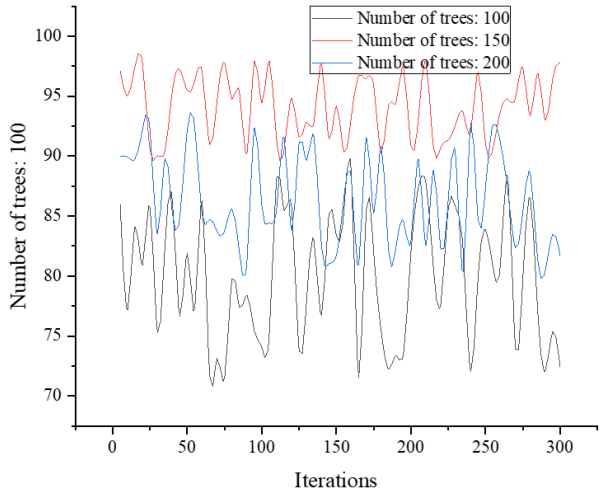

Figure 5. Parameter optimization (number of trees).

It is not difficult to find from **Figure 6** that the prediction accuracy of the optimized model has been significantly improved, reaching 96.7%, which is a qualitative leap compared with the model before optimization. This result verifies the effectiveness of parameter optimization, and further proves the potential of communication model based on multimodal metonymy complex in GBA international image construction.

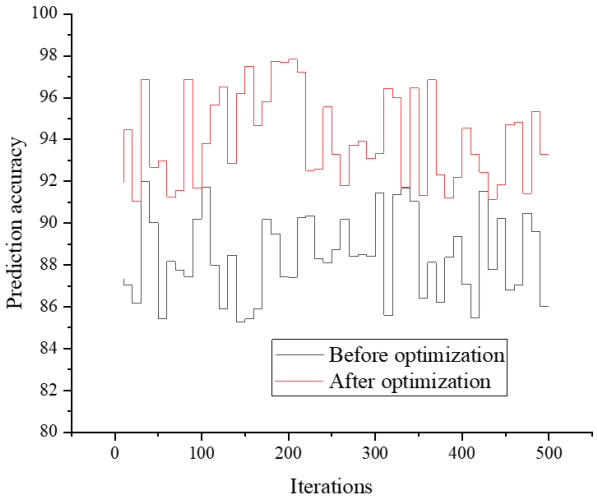

Figure 6. Comparison of model prediction accuracy before and after optimization.

It is not difficult to find from **Table 1** that the prediction accuracy of the optimized model in different media forms has been significantly improved. Especially in the two visual media forms, pictures and videos, the improvement is more significant. This further proves the effectiveness of multimodal metonymy complex theory in the analysis and prediction of visual elements.

Table 1. Comparison of model prediction accuracy across different media forms.

Media Form	Prediction Accuracy Before Optimization	Prediction Accuracy After Optimization	Improvement
Video	85.2%	97.1%	+11.9%
Image	82.3%	95.6%	+13.3%
Text	88.7%	98.2%	+9.5%
Overall	85.6%	96.7%	+11.1%

Table 2 shows that the prediction accuracy of the optimized model in different communication channels has also been significantly improved. It is worth noting that in the channel of media coverage, the prediction accuracy of the model has improved the most. This may be related to the diversity and complexity of media reports, and the optimized model better captures these characteristics.

Table 2. Comparison of model prediction accuracy across different communication channels.

Communication Channel	Prediction Accuracy Before Optimization	Prediction Accuracy After Optimization
Official Propaganda	87.6%	98.5%
Media Reports	83.1%	94.7%
Social media	86.2%	97.3%
Overall	85.6%	96.7%

Table 3 reveals the improvement of the prediction accuracy of the optimized model in different audience groups. The prediction accuracy of the model has been significantly improved in all audience groups, especially in the two relatively special groups, the elderly and the international audience. This shows that the optimized model has better cross-cultural and cross-age adaptability.

Table 3. Comparison of model prediction accuracy across different audience groups.

Audience Group	Prediction Accuracy Before Optimization	Prediction Accuracy After Optimization	Improvement
Young Adults	84.5%	96.8%	+12.3%
Middle-Aged	86.7%	97.2%	+10.5%
Senior Citizens	82.1%	95.3%	+13.2%
International	85.9%	96.9%	+11.0%
Overall	85.6%	96.7%	+11.1%

In order to verify the adaptability of the model in different cultural backgrounds, cross-cultural experiments were carried out and relevant data were collected. **Table 4** shows the performance differences of the model in three different cultural groups (group A focusing on collectivism, group B focusing on individualism, and group C with mixed cultural background).

Table 4. Cross-cultural experiment data.

Cultural Group	Model Accuracy (%)	Model Response Time (s)	User Satisfaction Rating (1–5)	Theme Consistency Rating (1–5)
Group A	85	2.3	4.2	4.5
Group B	78	2.7	3.8	4.0
Group C	82	2.5	4.0	4.2

The model is the best in the group that pays attention to collectivism culture, with high accuracy, high user satisfaction and strong theme consistency. In the group that pays attention to individualistic culture, the performance is slightly poor, the accuracy and user satisfaction are relatively low, and the theme consistency is also slightly reduced. In the group with mixed cultural background, it is somewhere between the two. This shows that the model has strong adaptability in different cultural backgrounds, but it still needs to be further optimized to meet the needs of individualistic cultural groups.

4.2. Discussion

By constructing and verifying the GBA international image communication model based on multimodal metonymy complex, this study reveals the important role of multimodal elements in the construction of regional image, and also provides new ideas and methods for improving the international communication effect of regional image. However, the study also has some limitations, such as the limitation of sample selection and the difficulty of obtaining audience feedback data, which may affect the generalization ability and prediction accuracy of the model.

In the future, we will continue to deepen the study of multimodal metonymy complex theory and explore its application potential in more fields and scenarios. At the same time, we will actively seek opportunities to cooperate with the industry and apply the model to the actual regional image communication project to verify its effect and value in actual operation. In addition, we will also pay attention to the development of new technologies, such as artificial intelligence, biomechanics, and big data, in order to integrate these technologies into the model and further improve the intelligent level of the model.

In addition to urban planning and transportation system, biomechanics is also widely used in architectural design and public facilities layout. In architectural design, we can learn from the principle of structural optimization of organisms to design beautiful and practical buildings. For example, by imitating the morphological and structural characteristics of organisms, buildings with better seismic performance and energy-saving effects can be designed. In the layout of public facilities, the principle of biomechanics is also helpful to optimize the location and layout of facilities, improve the efficiency of facilities and public satisfaction. In the future research direction, we need to pay attention to some specific research gaps and technical challenges. For example, how to further integrate artificial intelligence and big data technology to improve the intelligence level of the model; How to maintain the stability of the model in a more dynamic environment; And how to better apply biomechanical principles to the practice of urban planning. These research gaps and technical challenges provide a clear direction and motivation for the follow-up research.

5. Conclusions

This study explores the application and effect of multimodal metaphor strategy and biomechanical knowledge in shaping the image of regional cities. By constructing a new image communication model of GBA city based on biomechanical principles, combined with experimental verification and parameter optimization process, the following main conclusions are drawn:

As an innovative communication strategy, the combination of multimodal metaphor strategy and biomechanics can improve the shaping effect of GBA city image. The model shows high accuracy and stability in predicting the biomechanical characteristics of the audience. This fully verifies the key role of multimodal elements and biomechanical knowledge in the construction of regional image. Through careful parameter optimization, the performance of the model has been significantly improved, and the prediction accuracy in different media forms, communication channels and audience groups has been greatly improved. This further proves that the communication model based on multimodal metaphor strategy and biomechanics has wide applicability and strong flexibility.

This study provides new theoretical support and practical guidance for the shaping of GBA city image, and also opens up a new perspective for the research in related fields. Future research will continue to deepen the combination theory of multimodal metaphor strategy and biomechanics, and expand its application prospect in more fields.

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