Linguistic and Philosophical Investigations
ISSN: 1841-2394, e-ISSN: 2471-0881
Vol 23 (1), 2024
pp. 33–46

Drone-based Cultural Landscape Heritage Analysis using Computer Vision and Cultural Landscape Genes

Running short title: **Traditional Villages: Heritage Analysis**

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Abstract:

Huizhou traditional villages hold a lot of cultural and historical significance as they represent the rich architectural traditions and heritage of the region. These settlements pose unique challenges to management and conservation because of their intricate cultural landscape history. The main goal of this work is to use computer vision techniques in order to determine the genetic information inherent in traditional villages located in Huizhou for practical planning for their preservation. We propose Multi-Criteria Decision Making (MCDM) approaches that are intelligent have been employed, thus addressing decision-making complexities within cultural asset protection environments. Utilization of computer vision technology allows the research to automatically analyse and evaluate what constitutes genes of Traditional Villages' nationalities in Huizhou's cultural landscapes. This study presents the architectural features, spatial patterns, cultural artifacts as well as issue on historical context among others. Four approaches are compared: Convolutional Neural network (CNN), Recurrent neural network (RNN), CNN and RNN, and MCDM. The most accurate and consistent approach was shown by MCDM with accuracy being 0.88% while its CR equals 0.08%.

Keywords: Computer vision, Multi-Criteria Decision Making, Convolutional neural network, Recurrent neural network, Huizhou traditional villages.

Received: 22 April 2024 **Revised:** 12 June 2024 **Accepted:** 28 June 2024

1. Introduction

The Chinese Province of Anhui has remote traditional villages in Huizhou that are uniquely designed, intricately planned, and socially integrated to represent a significant cultural heritage. These are historical and architectural time machines of the region keeping alive customs and traditions dating back centuries. For instance, Huizhou architecture is characterized by graceful courtyards, whitewashed walls, horse head gables and intricate wood carvings. However, contemporary development trends threaten to destroy these remarkable cultural sites such as modernization, urbanization, population shift and weak conservation measures. Consequently, computer vision plays an essential role in assessing cultural landscape (Manimurugan et al 2024). Computer vision (CV) helps to detect the object and give its trace on real environment. Computer vision can go through numerous videos so as to get meaningful information from it quickly. This project aims at overcoming these issues using DNA analysis to document, analyse and conserve the cultural heritage of Huizhou traditional villages. The traditional villages in the region of China called Huizhou are hugely important historically and culturally. Notably among these are their distinctive spatial arrangements that characterize their towns' architectural traditions. The need for effective strategies to safeguard the cultural landscape heritage of Huizhou traditional villages is crucial to ensure their long-term preservation (Pasini, 2018; Chan, 2021; Sudhakar et al. 2022).

1.1 Motivations

It is vital to hold the cultural legacy of Huizhou's conventional villages to defend the history and identity of the location, in addition to inspire sustainable improvement and cultural tourism. Through their window into the beyond, these villages deliver essential insights into the social, economic, and architectural functions of the Huizhou area. It is possible to cope with the complex troubles associated with the control and renovation of those extraordinary cultural landscapes by way of developing novel techniques that combine pc imaginative and prescient strategies and Multi-Criteria Decision Making (MCDM) strategies (Pei et al. 2020; Utomo et al., 2023; Chen et al. 2020).

1.2 Problem Statement and Contextual Importance

Huizhou's traditional villages are in a paradoxical state due to population shifts, urbanization and rapid growth. This has been detrimental to the sustainability of these cultural landscapes that were preserved since time immemorial. These emerging trends present unique challenges in terms of their composition and preservation, given that Huizhou's cultural landscape is very intricate. Conventional methods of documentation and preservation are often inadequate for such cultural landscapes because they are dynamic and complex (Fernberg et al 2024).

MCDM and computer vision techniques can help address these issues. The aim of this research study is to develop an automated, systematic approach towards analysing and conserving the cultural heritage landscape features of Huizhou's ancient settlements with the help of machine learning as well as intelligent decision-making frameworks. In addition to identifying their historical worthiness, it includes recognizing and evaluating architectural elements, spatial layouts, and cultural items. This research contributes to the larger field of cultural heritage conservation by providing innovative strategies that could be applied to other similarly significant sites. For instance, in regard to Huizhou's traditional villages, In the context of Huizhou's traditional villages, the study shows the effectiveness of computer vision and MCDM methodologies, offering a useful model for the preservation of cultural heritage in various settings.

1.3 Challenges

Various intricate issues are there in the preservation and management of Huizhou traditional villages. This is because these settlements have different architectural styles, patterns of spatial organization and cultural artifacts which require a holistic approach. Cultural heritage conservation decision-making involves several criteria such as heritage value, sustainability, community involvement and economies viability. However, it is very challenging to achieve a balance between all these aspects of heritage preservation. The main difficulties image analysis faces include low quality images and documents that are difficult to analyse. Since drones cannot fly during rainy seasons or bad weather conditions usually the images generated from them might not be of good quality. Accurate training of computer vision models often necessitates large volumes of labelled data specifically for the task at hand thus making it impossible to train accurate computer vision model in a niche industry or on specific cultural heritage sites where labelled data may be scarce.

Computer vision algorithms can fail due to changes in lighting, weather, or objects obstructing the view (occlusions). These real-world variations make it difficult for the models to perform consistently. Furthermore, dynamic nature of cultural landscape heritage and lack of certainty involved in decision-making further compound preservation efforts. Additionally, the dynamic nature of cultural landscape heritage and the uncertainty surrounding decision-making further complicate the preservation efforts (Sarveshwaran et al. 2022; Li et al. 2023; Chen et al. 2021).

1.4 Objectives

The main goal of this research is to develop model that uses CV techniques and intelligent MCDM methodologies to protect Huizhou's ancient villages. The inventiveness efforts to automate the study and clarification of the cultural landscape genes characteristic in these reimbursements by taking into interpretation a variety of characteristics, with architectural traits, longitudinal patterns, social items, and ancient significance.

The machine learning and CV methodologies will accelerate the growth of an inclusive erection for production decisions and assessing various features pertinent to conservation and management. The particulars complicated in conserving cultural heritage will be tackled by this framework, which offers a methodical and expandable way to assess and rank preservation enterprises.

This research aims to solve the encounters accompanying with uncertainty in decision-making. The advanced analytical techniques and intelligent decision-making frameworks, the study seeks to develop a strong method to dynamic cultural landscape heritage of Huizhou's traditional villages. This comprises the facility to adapt to altering conditions and incorporate new data and insights as they become available, ensuring the long-term protection and sustainability of these culturally important sites.

The remaining papers are organized as follows. The related work is discussed in section 2. The methodology is presented in section 3. The results and discussion are described in sections 4 and 5. The conclusion and future research directions are discussed in section 6.

2. Literature Review

Wei et al. (2021) explored the impact of tourists' values lock-in on the development trajectories of traditional villages in Huizhou, specifically examining the cases of Hongcun and Xidi. The authors pointed out the importance of aligning the terms of deals done by tourists at these villages with the development and conservation goals of these areas. Gao et al. (2023) investigated the relationships between visitor behaviours and the land-based physical environment in core traditional Huizhou villages. The authors considered a case of Pingshan Village – being located in Yi County – and examined the influence of tourism on the spatial dynamics and conservation of traditional villages in Huizhou: it is noted by Gao et al. (2023) that. The landscape structure of a typical Huizhou district village was the subject of a case analysis conducted by Cheng et al. using Qizili Village as a material for an in-depth study.

Cheng et al. (2021) discuss the components and spatial structure constituting the cultural landscape of the town. The ideal ecosystem model and 3D landscape indices were utilized by Yao et al. (2016) while taking Chengkan Village as their example to analyze the spatial characteristics of Huizhou-styled villages to discover the geographical patterns and ecological processes enabling the preservation of Huizhou traditional villages.

Hierarchical Bayesian network modelling was first applied by Zheng et al. (2022) to examine how traditional Huizhou villages were geographically set in their locality. The aim of the study was to understand how various aspects in the two districts interacted with one another. The spatial arrangement of the regional settlement of building facades within its traditional Huizhou villages was then examined by Cheng et al. (2023) presents cultural and historical significance and how their spatial positioning contributed to the overall unique identification of all participants in the region. Cao and Mustafa (2023) investigated the paintings on doors. The observe centered on the super craftsmanship and cultural relevance of those ornamental elements. Using Xixinan Village in China as a case observe, Lu et al. (2022) investigated the phenomena of rural gentrification and its effects on traditional communities. The have a look at protected the problems and consequences of gentrification on traditional groups' social concord and cultural legacy. Huizhou merchant villages in southern Anhui Province had been tested by using Xue et al. (2021), who highlighted the merchant villages' one-of-a-kind qualities and historic relevance. The take a look at highlighted the sentimental and cultural factors of those settlements.

A method for producing counselled candidates by using predicting multi-criteria scores through the usage of Convolutional Neural Networks (CNN) and Bidirectional Long Short-Term Memory (BiLSTM) is provided with the aid of Kim et al. (2021). The authors need to solve the problem of making tips which are particular for each person while deliberating a variety of things. They create a version with the capability to capture and examine special functions related to candidate recommendations through utilising deep mastering techniques. According to Kim et al. 2021, the CNN-BiLSTM version well-known shows encouraging effects in forecasting multi-standards scores, consequently augmenting the precision and efficacy of tailored tips. The subject matter of clever forecasting in multi-standards choice-making (MCDM) is the focal point of Borysenko et al. (2020). The authors look into the application of clever forecasting techniques to forecast the outcomes of multicriteria selection-making methods.

By the usage of more than a few forecasting fashions and techniques, they hope to improve choice-making through offering specific forecasts for varied requirements. The paper emphasizes the price of clever forecasting in MCDM and gives steering on a way to use forecasting strategies to increase the precision of decision-making. A technique for multi-character multi-criteria choice-making (MP-MCDM) based on sentiment analysis, herbal language processing (NLP), and deep gaining knowledge of techniques is presented via Zuheros et al. (2021). The writers especially use TripAdvisor opinions to apply their techniques to the method of choosing restaurants. They try and extract applicable information to useful resource in decision-making in the context of many standards via inspecting the sentiment conveyed within the critiques.

Pan et al (2024) look at how semantic factor clouds can be converted into semantic Building Information Models (BIM) the usage of deep getting to know, with an emphasis on Taoping Village in Sichuan, China, to create a Heritage Digital Twin. Unmanned aerial cars and terrestrial laser scanning have been utilized to attain designated point cloud records of the agreement. The KP-SG neural network, which achieves 81 % and 83% reputation charges for buildings and plants, respectively, and a 2.53% improvement in mIoU over KP-FCNN, is the principle factor of the methodology. It is also splendid in accurately figuring out 11 categories.

According to Zuheros et al. (2021), the study shows how properly NLP and deep getting to know strategies paintings collectively in MP-MCDM to offer a smarter choice aid for selecting eating places based on purchaser opinions and evaluations. Understanding Huizhou traditional villages in terms of sustainable development, spatial organization, architectural capabilities, cultural importance, and the effects of tourism and gentrification has been aided via this in advance research. To create thorough protection plans for these cultural history locations, additional research combining computer vision methods and Multi-Criteria Decision Making (MCDM) strategies is essential.

Xu et al (2024) developed the classification model to classify the 3740 image of Slender West Lake travelers using SqueezeNet, a light-weight CNN. After upgrades, the original model had a validation accuracy of 85. 75%. This accomplishment ensures awesome accuracy within the class of tourism image at the same time as concurrently decreasing parameters. As such, it affords a extra methodologically sound framework for analysing tourism imagery and increases clean ideas for the creation and organization of tourism property.

Li et al. (2024) introduces the "tradition-panorama genes" concept and its double-chain version. Using traditional Tujia villages in Shizhu County, Chongqing Municipality, China as a case look at, the researchers identified, extracted, correlated, encoded, and comprehensively evaluated their way of life-landscape genes.

Based on these evaluations, safety and improvement techniques have been formulated. The findings spotlight that the identification and correlation of genes are critical for building an effective evaluation device and assessing protection degrees.

3. Methodology

Cultural Landscape Heritage (CLH) is analysed the use of, computer imaginative and prescient is progressive. It can construct complicated 3-d fashions of homes and landscapes, robotically understand and screen panorama features, and even discover harm. Better take a look at, maintenance, or even virtual tours of cultural heritage places are made feasible by this. Limitations in schooling information and environmental fluctuations are demanding situations, however the capability profits are greater than the drawbacks. Computer imaginative and prescient mixed with conventional techniques can assist us hold close these priceless cultural relics lots higher.

Three different types of data are used in the collection process: text input from village people, image data taken using drones, and gene data extracted from a database. While an RNN model extracts relevant information from the text data, a CNN model extracts features from the image data. Furthermore, a Genes Model creates feature information by using the village's historical gene data. The integrated features that are produced from concatenating or combining these three models are then used to inform MCDM techniques. To efficiently manage the complex nature of decision-making in the context of cultural heritage protection, MCDM is applied. The suggested system overview is shown in Figure 1.

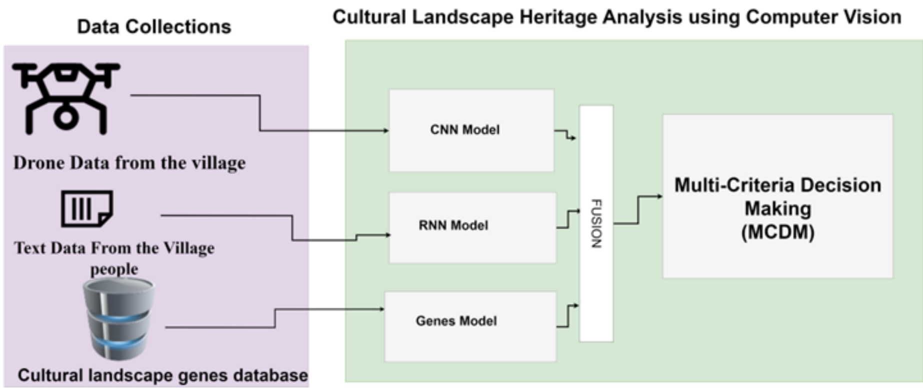

Figure: 1 The proposed system overview

3.1 Data Collections

Using satellite, aerial, and ground-based photography, high-resolution imagery of Huizhou traditional villages must be gathered in the first step. Local officials granted official authorization to our research to fly drones over the historic villages of Huizhou. After the drone was placed in these towns, it recorded nonstop video for three hours. Ten thousand photos were taken from this long movie recording. Of these, 8,000 were used to train our models, while the other 2,000 were saved for evaluating the model's functionality. Data was collected from April 2021 to February 2023. In our study project, the phrase "gene data database" refers to a structured repository that was established especially to store and organize data about the genes associated with the cultural landscape of Huizhou traditional villages. The information gathered from diverse sources, such as historical documents, architectural styles, construction materials, spatial arrangement, and interviews with locals, is centrally stored in this database. We have collected the local information from the 300 people. Together, these components create the "genes" of the cultural landscape, symbolizing the distinct qualities and history of these settlements. A key component of our research is the DNA data database, which makes it easier to analyze and preserve the cultural legacy connected to Huizhou traditional villages methodically. To hold this priceless legacy from being lost to time, it permits us to file and classify the minute components of the architectural and cultural additives of those communities (Fang & Li, 2022). Furthermore, information on architectural styles, construction materials, spatial employer, historic statistics, and cultural landscape genes may be acquired from nearby data, historical files, and interviews with citizens. To determine the type of village, textual content facts changed into additionally amassed from the villagers.

3.2 Image Processing and Feature Extraction

The collected image can be processed using CV strategies to extract pertinent functions. Building facades, roof kinds, windows, entrances, and other architectural components are a few examples of those traits. These traits could be recognized and categorized the use of sophisticated algorithms CNNs.

3.2.1 CNN Model

The CNN model for MCDM is meant to technique incoming statistics and generate predictions according to certain requirements. Convolutional layers are used to extract pertinent traits from the enter records, which permits the version to pick out essential correlations and styles. Starting with a sequence of convolutional layers, the model performs convolutions to perceive local patterns. Each layer within the series is made from a set of filters that slide over the enter information. The Rectified Linear Unit (ReLU) activation function is used to prompt those convolutions, adding non-linearity to the model. A max-pooling layer is used to down-pattern the characteristic maps after each convolutional layer, preserving the important data at the same time as lowering the spatial dimensions. This lessens the model's computational complexity whilst assisting in taking pictures the maximum pertinent records. The closing max pooling layer's output is then compressed into a one-dimensional vector, that is used because the completely linked (dense) layers' enter. These thick layers use the standards to inform their predictions and carry out additional processing on the obtained facts. The dense layers are given the ReLU activation feature to feature non-linearity and boost the expressive capability of the version. The SoftMax activation function, which offers chances to each magnificence within the MCDM trouble, is used within the closing dense layer. This enables the version to very well examine the numerous standards and offer the chance of each magnificence being selected. To train the model, the suitable loss feature—consisting of express pass-entropy—is selected to quantify the difference between the anticipated and real class labels. An optimizer, like Adam, optimizes the model by changing the community's parameters to reduce loss. By making use of a labelled dataset to represent the multi-standards selection problem, the CNN model may be trained to extract pertinent functions and generate particular predictions in step with the required criteria. After that, the version can be used to categorize new instances and guide decision-making across a range of industries.

3.2.2 RNN Model

The sequential information and temporal dependencies visible in the input statistics are supposed to be captured by means of the RNN model for MCDM. It sequentially approaches the standards and generates predictions based totally on the entire collection by using the recurrent nature of the version. The version is made from recurrent layers that facilitate records transfer across steps, allowing the model to keep song of standards which have already been analysed. Capturing the dependencies and patterns that emerge all through the selection-making manner relies upon in this reminiscence. As a form of reminiscence, the model creates a brand new hidden shape at every step through combining the enter representing a criterion with the previous hidden kingdom. Usually, this manner makes use of a particular recurrent unit, just like the Gated Recurrent Unit (GRU) or Long Short-Term Memory (LSTM). A collection of fully connected (dense) layers that further technique the obtained information and provide predictions based totally at the criteria are finally applied to the hidden nation on the cease of the technique. ReLU and different activation capabilities can add non-linearity and enhance the model's potential to symbolize difficult relationships.

3.2.3 Multi-Criteria Decision Making (MCDM)

The MCDM approach that determines a village's cultural degree by way of applying the Analytic Hierarchy Process (AHP). The algorithm takes under consideration numerous choice factors and assesses numerous options (villages) according to their cultural characteristics. The list of options (villages) in an effort to be assessed and the choice criteria, which stand for the factors used to determine the village's cultural degree, are enter into the algorithm. Furthermore, through a series of comparisons, a pairwise contrast matrix is shown that depicts the relative relevance of the options and criteria. To guarantee the consistency of the pairwise contrast matrix, the consistency ratio threshold is also designated.

The software determines each village's cultural level methodically. First, the relative weights given to the alternatives and standards are used to build the pairwise assessment matrix. Next, the matrix's consistency is examined to ensure it stays legitimate for in addition computations. The AHP computations are then accomplished. The pairwise evaluation matrix's column values are normalized so as to get the concern vectors for each criterion and opportunity. The relative weights of the wishes and picks are shown through those priority vectors. Then, the weighted matrix is calculated via multiplying the priority vector of the criteria by the corresponding members of the alternative vectors. In this level, the opportunity tests and the measure's weights are combined. After acquiring the weighted matrix, the entire scores for every alternative are calculated via summing the weighted columns. These rankings mirror the cultural stage of every village, with higher rankings indicating a higher artistic stage. Based on their cumulative ratings, the last selections are then arranged in descending order. Higher cultural ranges are thought to exist within the towns with the highest cumulative scores. Ultimately, the set of rules decides which hamlet or villages are great based totally at the assessed cultural stage. The algorithm's result is the village or villages which might be ranked maximum. It's essential to do not forget that the set of rules can be tailored to fulfill the particular requirements of a certain cultural assessment by using converting the selection criteria, options, and consistency ratio threshold. Algorithm 1 offers a way for Multi-Criteria Decision Making (MCDM) that determines a village's cultural stage by using applying the Analytic Hierarchy Process (AHP).

Algorithm 1 Multi-Criteria Decision Making (MCDM) using the Analytic Hierarchy Process (AHP)

Require: Decision criteria: A set of standards that will be used for evaluating the cultural level of the village.

Require: Alternatives: A set of villages to be evaluated.

Require: Pairwise comparison matrix: A matrix representing the pairwise comparisons of criteria and alternatives based on their relative importance.

Require: Consistency ratio threshold: A threshold value used to check the consistency of the pairwise comparison matrix.

Ensure: Best village(s) identified based on the cultural level determined by the AHP method.

1: **Construct the pairwise comparison matrix:**

2: Set up a square matrix representing the pairwise comparisons between the criteria and alternatives.

3: Populate the matrix by comparing the importance of each criterion and alternative against others using a scale, typically ranging from 1 (equal importance) to 9 (extreme importance). Use half-scale values for intermediate comparisons.

4: **Check the consistency of the pairwise comparison matrix:**

5: Calculate the consistency index (CI) by finding the principal eigenvector of the matrix and comparing it with the average eigenvector.

6: Compute the consistency ratio (CR) by dividing the CI by the random index (RI) value obtained from a predefined table based on the matrix size.

7: **if** CR exceeds the given threshold, **then**

Revise the pairwise comparison matrix until consistency is achieved.

end if

Perform the AHP calculations:

Compute the priority vector for each criterion and alternative by normalizing the column values of the pairwise comparison matrix.

Calculate the weighted matrix by multiplying the criteria's priority vector by the alternative vectors' corresponding elements.

Sum the weighted columns to obtain the total scores for each alternative.

Rank the alternatives:

Sort the alternatives based on their total scores in descending order to determine their cultural level.

Higher total scores indicate a higher cultural level.

Select the best village(s):

Choose the top-ranked village(s) as the best option(s) based on cultural level.

return the best village(s) as the output of the algorithm.

Implementation and Evaluation: A few traditional villages in Huizhou will adopt the suggested preservation techniques. Indicators including resident satisfaction, tourism revenue, heritage site status, and community participation will be used to assess how effective these measures are. Input from locals, specialists, and tourists will be gathered to evaluate the results of the preservation initiatives.

4. Results

An Intel i7 processor-based system running Windows 11 serves as the hardware and software configuration for the MCDM method's experimental setup. Python 3.8 is the programming language used for implementation; it offers flexibility as well as a large selection of libraries and tools for modelling and data analysis. The TensorFlow library is supposed to have the MCDM functions in this specific scenario. A well-liked and potent open-source library, TensorFlow is mostly utilized for deep learning applications. However, thanks to its powerful computational graph and numerical computing skills, it also provides MCDM capabilities. The experimental setup may make use of TensorFlow's powerful computing capabilities and user-friendly interface to successfully build and assess the selected MCDM approach. The Huizhou traditional villages are a group of traditional Chinese villages in the Huizhou region that are situated in Wuyuan County, Jiangxi Province, and Huangshan City, Anhui Province. It has been acknowledged that these villages constitute an important part of Chinese cultural history. The "Chinese Traditional Village List" spans the years 2012 to the end of 2023 and consists of 8,171 communities of exceptional historical, architectural, and cultural significance. Huangshan City's location map is shown in Figure 2. The Huizhou architecture sample is displayed in Figure 3.

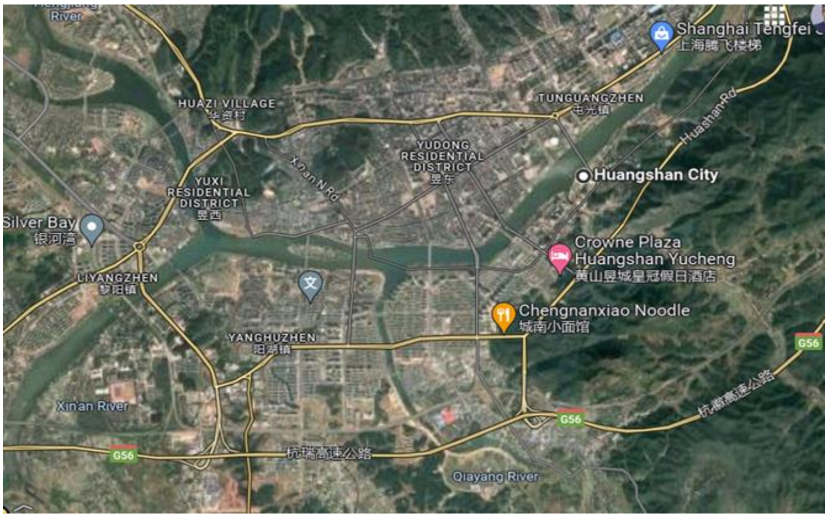

Figure 2: Our Location map of Huangshan City

Figure 3: Huizhou Architecture

4.1 Performances Evaluations

Several measures are used to evaluate how nicely the MCDM approach performs. These measures shed mild at the MCDM approach's efficacy, overall performance, and dependability. The following average overall performance signs are regularly employed to evaluate MCDM strategies:

Ratio of Consistency (CR): When using techniques which includes the Analytic Hierarchy Process (AHP), the consistency ratio is used to gauge how constant pairwise comparisons are. To determine the validity of the pairwise comparisons, it contrasts the actual consistency of the selections with a random consistency index. Better consistency is indicated via a decrease CR amount.

Weight Sensitivity Analysis: This evaluation seems at how touchy the selection's final results is to adjustments inside the weights of the standards. It aids in evaluating how changes to the burden distributions effect the remaining rankings or alternatives. Sensitivity evaluation offers statistics on the stability of

Accuracy: Accuracy measures the amount to which the MCDM technique as it ought to be presentations the ground reality or expert judgments. It can be assessed with the aid of comparing the MCDM effects with regarded benchmarks or professional reviews.

Rank Correlation: Rank correlation evaluates the connection among an professional's alternatives or a reference rating and the scores generated by means of the MCDM technique. It gauges how well the MCDM method adheres to the predicted rankings.

Stability: Stability gauges how continually the MCDM outputs maintain up if the enter statistics barely varies. It assesses the MCDM approach's resilience to minor adjustments in standards weights or opportunity assessments.

Sensibility: Sensibility is the MCDM technique's capacity to record modifications in selection results due to enormous shifts in the weights of the standards or possibility assessments. It gauges the approach's responsiveness to considerable changes within the furnished data.

The training and testing accuracy data consists of 50 epochs. The training accuracy starts at around 0.49 and gradually increases over the epochs. After some fluctuations, the training accuracy reaches a plateau of approximately 0.83, with minor changes. In the last 40 epochs, the training accuracy remains constant at 0.88. The testing accuracy starts at a low value of 0.32 and significantly improves over the initial epochs. It continues to increase, reaching a plateau of around 0.82. Like the training accuracy, the testing accuracy remains constant at 0.91 for the last 40 epochs. Overall, the training accuracy steadily improves, then plateaus at a relatively high value. In contrast, the testing accuracy shows a similar trend, indicating that the model generalizes well to unseen data. Figure 4 depicts the Training and Testing accuracy of the proposed method.

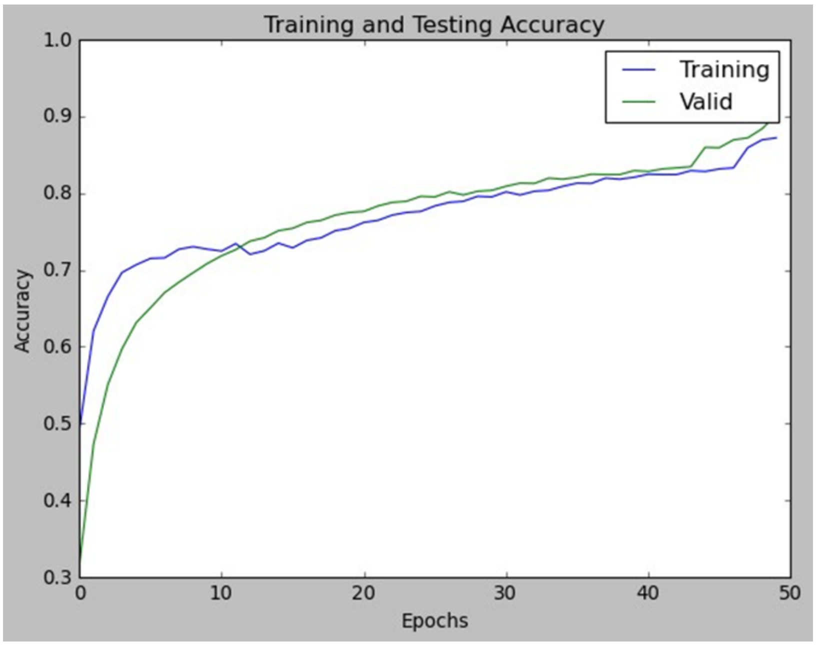

Figure 4: Training and Testing accuracy of the proposed method.

Table 1 compares four different methods: CNN (Xu et al 2024), RNN (Kim et al. (2021), CNN and RNN (Kim et al. (2021), and MCDM. The analysis includes three metrics: Consistency Ratio (CR), Weight Sensitivity Analysis, and Accuracy. Starting with the Consistency Ratio (CR), which measures the consistency of the decision-making process, we observe that MCDM has the lowest CR value of 0.08, indicating a higher character level than the other methods. CNN and RNN have similar CR values of 0.12 and 0.11, respectively, while CNN and RNN have the most elevated CR of 0.15. Therefore, MCDM demonstrates the highest level of decision consistency. The Weight Sensitivity Analysis assesses the sensitivity of the results to changes in the weights assigned to different criteria. In this analysis, MCDM has the highest weight sensitivity value of 0.85, suggesting slight variations in the consequences of the requirement can significantly affect the overall outcome.

CNN and RNN (Kim et al. (2021) show off moderate weight sensitivity with values of 0. 75 and 0. 72, respectively, even as RNN has the lowest sensitivity with a value of 0. 68. This means that RNN's overall performance is notably solid concerning changes in standards weights. Moving directly to Accuracy, which measures the performance of every method, we discover that MCDM achieves the best accuracy of 0.88. CNN and RNN comply with intently with a precision of 0. Eighty-four. CNN and RNN have an accuracy of 0.82 and 0. 79, respectively, displaying a relatively lower overall performance than the mixed technique. From these results, we will infer that MCDM offers the most consistent decision-making method and achieves the highest accuracy. However, it is also extra sensitive to changes in criteria weights. The blended method of CNN and RNN performs properly in phrases of accuracy, but its selection-making method may be greater regular. CNN and RNN have similar performances with slight accuracy stages. Figure 5 depicts the performance comparison of CR and Weighted evaluation.

Table 1: The performance comparison of Consistency Ratio (CR), Weight Sensitivity Analysis and Accuracy.

Method	Consistency Ratio (CR)	Weight Sensitivity Analysis	Accuracy
CNN (Xu et al 2024)	0.12	0.75	0.82
RNN (Kim et al. (2021)	0.11	0.68	0.79
CNN and RNN (Kim et al. 2021)	0.15	0.72	0.84
Ours	0.08	0.85	0.88

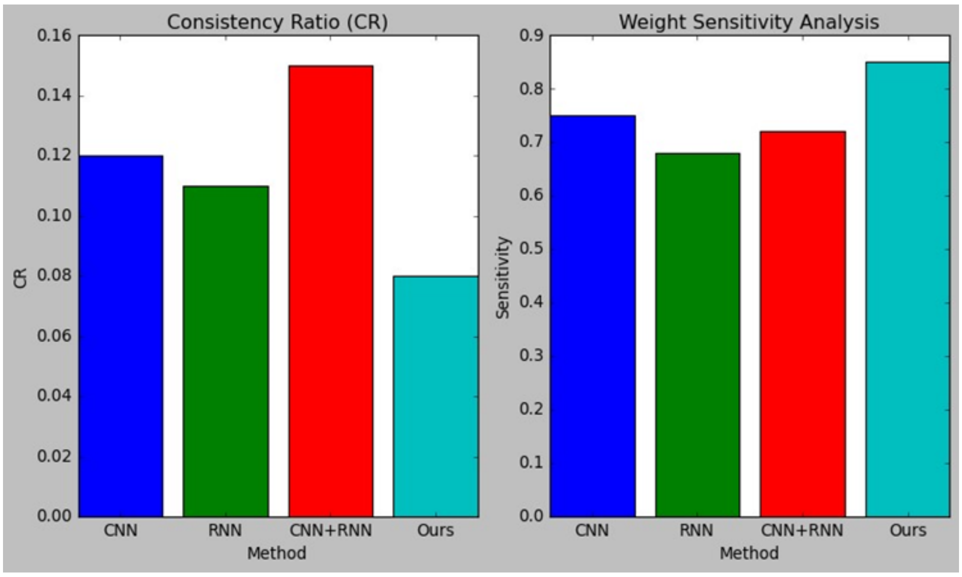

Figure 5: The performance comparison of CR and Weighted analysis

5. Discussion

Table 2 gives a comparative evaluation of four strategies: CNN (Xu et al 2024), RNN (Kim et al. (2021), CNN and RNN (Kim et al. (2021), and Multi-Criteria Decision Making (MCDM). The research includes 3 metrics: Rank Correlation, Stability, and Sensibility. Starting with Rank Correlation, which measures the consistency of the ranking produced with the aid of every technique, we take a look at that MCDM has the very best Rank Correlation price of 0.8. This indicates a robust and consistent rating performance whilst in comparison to the alternative procedures. With a price of 0.73, CNN and RNN are available 2nd, displaying a sturdy degree of rank correlation. Even with fairly lower Rank Correlation values—0.7 and 0.68, respectively—CNN and RNN nonetheless display a decent degree of stability in their rankings. Next, we study stability, which measures how strong the findings are after multiple tests. MCDM has the finest balance rating, at 0. 92. This indicates that the ratings generated via MCDM show off a excessive diploma of stability and consistency across many checks. CNN and RNN showcase strong stability as nicely, with a 0.88. Despite having truly lower stability values—0.85 and 0.82, respectively—RNN and CNN each show a decent diploma of energy. Sensibility, the final metric, assesses how responsive the results are to modifications in the input facts. With a Sensitivity score of 0.87, MCDM outperforms the other processes in phrases of sensitivity to changes in enter statistics. CNN and RNN are available in proper behind with a Sensibility score of 0.8. Despite having really decrease sensitivity values 0.78 and 0.75, respectively—CNN and RNN though display a decent degree of sensitivity.

These findings recommend that MCDM works well in phrases of stability and rank correlation, showing stable and consistent ranks. Additionally, it has a high Sensitivity, indicating that it's miles conscious of modifications within the enter records. CNN and RNN a reliable option seeing that they exhibit an amazing mix of Rank Correlation, Stability, and Sensibility. CNN and RNN have barely lower rankings but carry out well across all 3 metrics. Figure 6 suggests the performance comparisons of Rank Correlation, Stability and Sensibility.

Table 2: Rank Correlation, Stability and Sensibility

Method	Rank Correlation	Stability	Sensibility
CNN (Xu et al 2024)	0.7	0.85	0.78
RNN (Kim et al. (2021)	0.68	0.82	0.75
CNN and RNN (Kim et al. 2021)	0.73	0.88	0.8
Ours	0.8	0.92	0.87

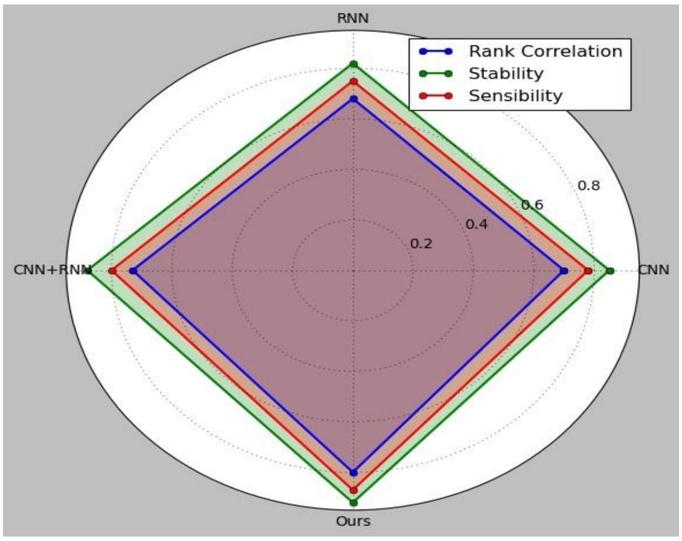

Figure 6: The performance comparisons of Rank Correlation, Stability and Sensibility

6. Conclusion

This research study uses computer vision methods and cultural landscape gene analysis to propose a comprehensive strategy for maintaining Huizhou's traditional villages. These villages' cultural legacy can be studied and documented to create sustainable preservation plans for them in the future. This research aims to contribute to cultural heritage preservation and serve as a model for preserving traditional villages in other regions facing similar challenges. The findings highlight the superiority of MCDM in decision consistency, accuracy, and stability, making it a robust approach for multi-criteria decision-making tasks. However, the combined CNN and RNN approach also demonstrates competitive performance in accuracy while exhibiting slightly less consistency. CNN and RNN show moderate performances in various metrics.

Limitations of the research:

The research methodology may be useful for a small number of villages, but it will need major modifications and more funding to be scaled up to include more sites or larger regions. Furthermore, the findings could not apply to other cultural heritage sites with distinct architectural styles and preservation issues due to the distinctive features of Huizhou's villages. Tailored approaches may be necessary for different contexts, impacting the broader applicability of the research.

In future this work can be extended to by addressing these limitations, the research can develop more robust, adaptable, and culturally sensitive strategies for preserving the rich cultural heritage of Huizhou and similar regions worldwide.

Statement of Declaration

Data Availability Statement: Data will be given on request email to the corresponding authors.

Conflicts of Interest: The authors declare no conflict of interest

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