

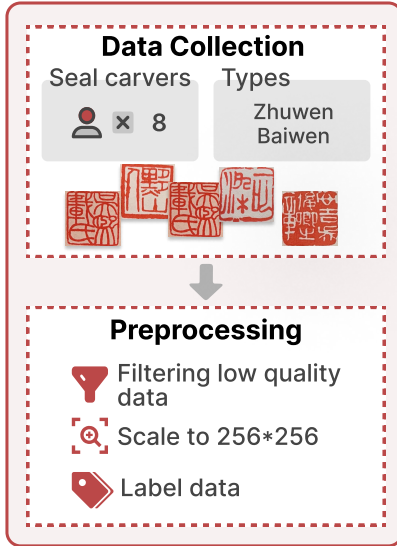
Chinese Seal Carving Aesthetic Evaluation

Ling Li
The Hong Kong University of Science
and Technology (Guangzhou)
Guangzhou, China
lli297@connect.hkust-gz.edu.cn

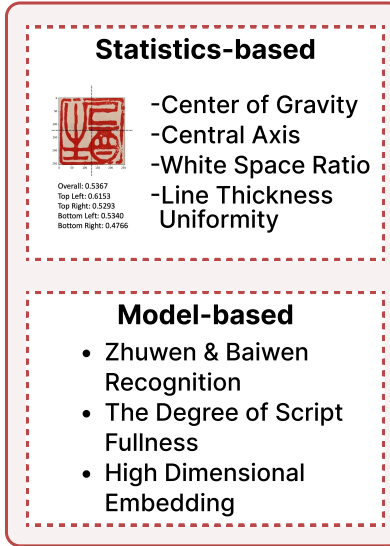
Manling Yang
The Hong Kong University of Science
and Technology (Guangzhou)
Guangzhou, China
myang838@connect.hkust-gz.edu.cn

Tiancheng Liu
The Hong Kong University of Science
and Technology (Guangzhou)
Guangzhou, China
tcliu767@connect.hkust-gz.edu.cn

Dataset Collection



Metric Calculation



Evaluation & Exploration

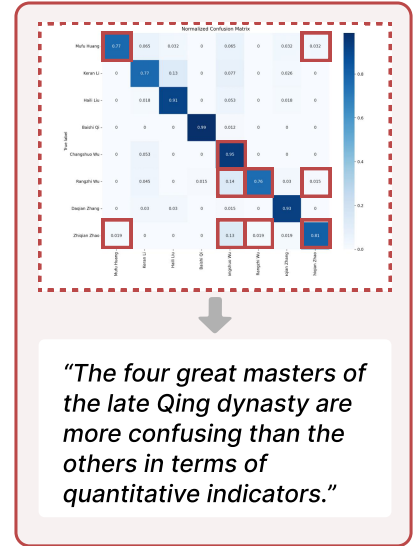


Figure 1: Pipeline of this paper. We first collect the seal carvings of 8 seal carvers in Zhuwen and Baiwen and filter the data to ensure the data quality. Then we use Statistics-based and Model-based methods to calculate the metrics. Finally, we analyze the quantitative results and explore the styles of different seal carvers.

ABSTRACT

This paper introduces a systematic framework for the aesthetic evaluation of Chinese seal carving, a traditional art form to be predominantly assessed qualitatively. For a more objective understanding and evaluation of it, we build a dataset of seal carvings from eight distinguished artists, including “the Four Great Masters of the Late Qing Dynasty” and four other renowned seal carvers. Our methodology combines statistical analysis and machine learning to calculate aesthetic metrics across five dimensions: Balance, Fluency, Layout, Fullness, and Similarity. Specifically, we employ statistical methods to determine the Center of Gravity, Central Axis, White Space Ratio, and Line Thickness Uniformity. Additionally, we utilize machine

learning to recognize Zhuwen and Baiwen scripts, assess script fullness, and analyze similarity through high-dimensional embedding. Our XGBoost experiments emphasize certain metrics’ importance in distinguishing artists’ styles. Moreover, the confusion matrix analysis illustrates master carvers’ influence on successors and Qi Baishi’s distinctive style. This study standardizes the evaluation of seal carving aesthetics and mitigates subjectivity in traditional methods. By offering a fresh perspective on this ancient art, our work contributes to its preservation and promotion in the digital age.

CCS CONCEPTS

• Applied computing → Arts and humanities; • Computing methodologies → Machine learning approaches.

KEYWORDS

Aesthetics Evaluation, Seal Carving, Machine Learning

ACM Reference Format:

Ling Li, Manling Yang, and Tiancheng Liu. 2024. Chinese Seal Carving Aesthetic Evaluation. In *Proceedings of Make sure to enter the correct conference title from your rights confirmation email (Conference acronym 'XX)*. ACM, New York, NY, USA, 8 pages. <https://doi.org/XXXXXXXX.XXXXXXX>

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.
Conference acronym 'XX, June 03–05, 2018, Woodstock, NY
© 2024 Copyright held by the owner/author(s). Publication rights licensed to ACM.
ACM ISBN 978-1-4503-XXXX-X/18/06
<https://doi.org/XXXXXXXX.XXXXXXX>

1 INTRODUCTION

Seal carving (*zhuanke*, Chinese: 篆刻) is a traditional art form of engraving Chinese characters on the surface of a seal [14]. The characters are mainly in "seal script", which is closely related to and very different from Chinese calligraphy in terms of artistic presentation and aesthetic style. The current research on seal carving art mainly includes the historical construction of seal carving art [11], the interpretation and appreciation of specific seal carvers from the professional point of view [19], and the creation of seal carving art in combination with generative technology [15], and so on.

These studies are important components of the theory and dissemination of the art of seal carving, but there is a gap in research on aesthetic assessment. Combining the qualitative style of seal carvers with the quantitative aesthetic assessment indexes can better help us understand and assess the seal carving art using automated methods. At the same time, a standardized quantitative method can avoid the bias of subjective judgment. In this study, we have selected six representative seal carvers as our subjects, namely Wu Ranzhi, Zhao Zhiqian, Huang Mufu, and Wu Changshuo, collectively known as "the Four Great Masters of the Late Qing Dynasty," as well as Qi Baishi and Zhang Daqian, recognized as "the Southern Zhang and Northern Qi."

We quantify the aesthetic indexes of the works of six seal carvers from five dimensions, namely balance, fluency, layout, fullness, and similarity, using both quantitative statistics and machine learning models. The quantitative statistics include the center of gravity, central axis, white space ratio, and line thickness uniformity, and the machine learning models include the recognition of Zhuwen's white text and its degree of script fullness and the similarity analysis based on high dimensional embedding.

Our research contributes to the field of seal carving art in several ways, benefiting both scholars and practitioners. By providing a quantitative method for aesthetic assessment, our study bridges the gap between the subjective, qualitative style of seal carvers and the objective, quantitative aesthetic assessment indexes. This not only aids scholars and researchers in better understanding and evaluating seal carving art, but it also provides practitioners with a standardized method for creating and assessing their own works. Additionally, the construction of a new seal carving image dataset, consisting of the works of the six representative seal carvers, will be a valuable resource for scholars, art historians, and enthusiasts, offering a comprehensive and diverse collection for further study and appreciation.

In summary, our contributions are enumerated as follows:

- *Seal Carving Dataset.* We construct a new seal carving image dataset consisting of the works of six representative seal carvers. It contains two types Zhuwen and Baiwen.
- *Quantitative Assessment Indicators.* We use statistical methods to calculate the Center of Gravity, Central Axis, White Space Ratio, and Line Thickness Uniformity, four important aesthetic indexes of seal carving.
- *Comprehensive Style Appreciation.* We combine quantitative indicators and qualitative conclusions to conduct a more profound and multi-dimensional excavation and appreciation of the artistic styles of the six chosen seal carvers.

2 RELATED WORK

Chinese Seal Carving. Seal carving has a long history of development, and a large portion of research has focused on the study of the history of seal carving and the stylistic characteristics of different stages. These include the basic theory and framework [2], the development and prosperity of specific stages [8, 16], and so on. This type of research usually starts from historical materials and works that have been handed down to us, and explores the artistic value and technical evolution of seal carving. A group of scholars also focus on an in-depth study of the style of a particular influential seal carver, encompassing unique techniques and blades, innovations and practices, etc [1, 18]. The art of seal carving has its unique concerns, such as the layout between characters, the overall visual effect and so on. Therefore it still has rich research space worthy of in-depth investigation.

Aesthetic Evaluation. Theories and methods related to aesthetic evaluation have been widely studied and applied in fine arts and calligraphy [4, 9, 13]. There are many different ways to automate aesthetic assessment, including measures of symmetry, coherence, complexity, contrast, and grouping [10]. For example, Fan et al. [5] used eye-tracking to measure and assess the visual complexity of Chinese ink paintings. With the development of artificial intelligence techniques, these assessment methods are no longer limited to computational modeling. For example, the convolutional neural network (CNN)-based model extracts aesthetic features [7] to rate pictorial aesthetics. Research on seal carving using a systematic approach to aesthetic assessment or stylistic exploration is still limited, so our study combines statistical methods of metrics computation and machine learning to analyze the works of six representative seal carvers stylistically.

3 METHODOLOGY

In this section, we will outline an overall pipeline for the aesthetic assessment of seal carving artworks and address the existing gap in their quantitative evaluation. Specifically, we will discuss the construction of datasets and the computation of different metrics to enhance the evaluation process.

3.1 Datasets

To gather ample and representative data, we conducted separate collections of seal carving works from the "Four Masters of Chinese Seal Carving in the Late Qing Dynasty" (WU Rangzhi, ZHAO Zhiqian, HUANG Mufu, and WU Changshuo), "Southern Zhang and Northern Qi" (ZHANG Daqian and Qi Baishi), as well as from equally renowned seal carving artists LIU Haili and LI Keran. The data selection process involved careful consideration and adherence to specific rules and criteria to ensure the inclusiveness and representativeness of the dataset.

In the data selection process, we implemented inclusive criteria to encompass a diverse range of artistic styles and historical significance. This included selecting works from each artist that exemplified distinct characteristics and artistic techniques, ensuring a comprehensive representation of their respective contributions to the art of seal carving. Additionally, we applied exclusive criteria to eliminate any potential biases or limitations in the dataset, such as excluding duplicate or derivative works, and prioritizing original

233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290

291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348

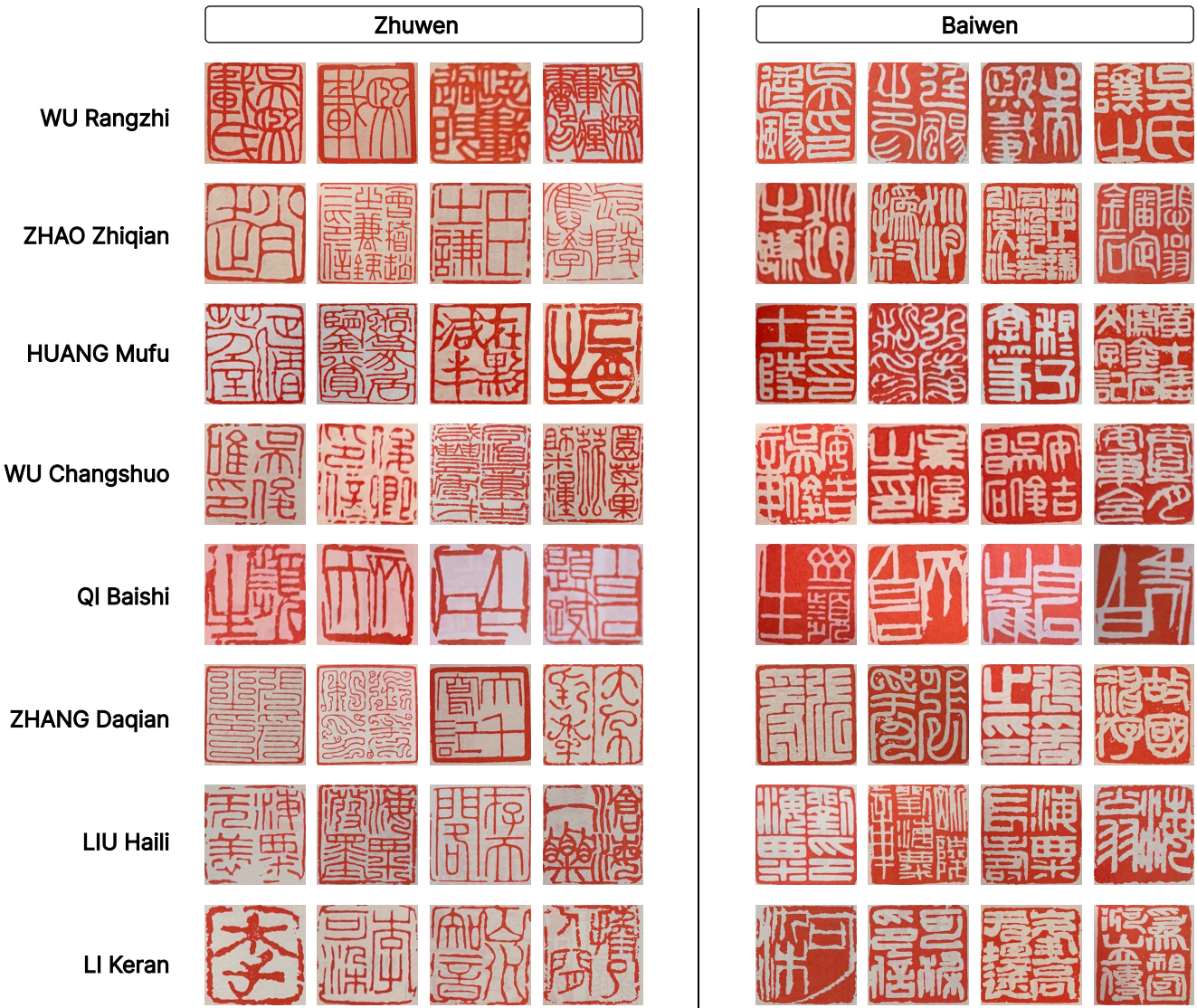


Figure 2: The samples from the proposed dataset.

and influential pieces that captured the essence of each artist’s unique style.

Furthermore, data collection was organized based on distinct artists and the types of seal carving works (Zhuwen or Baiwen), allowing for a comprehensive and systematic compilation of seal carving examples across different artists and seal types. The samples from the constructed dataset are illustrated in Figure 2. This meticulous approach to data selection and organization resulted in a robust and diverse seal carving dataset that serves as a valuable resource for comprehensive analysis and appreciation of this traditional art form.

3.2 Metrics

After gathering the necessary data, we proposed eight evaluation metrics for seal carving works, covering aspects of balance, fluency,

layout, fullness, and similarity. These metrics serve as quantitative indicators to assess the artistic quality and aesthetic value of the seal carving works. Four of the metrics rely on statistical methods, analyzing factors such as the Center of Gravity, Central Axis, White Space Ratio, and Line Thickness Uniformity to quantify specific aspects of the seal carvings. On the other hand, the remaining



Figure 3: The visual center of gravity is represented by black dots on the seal carving works.

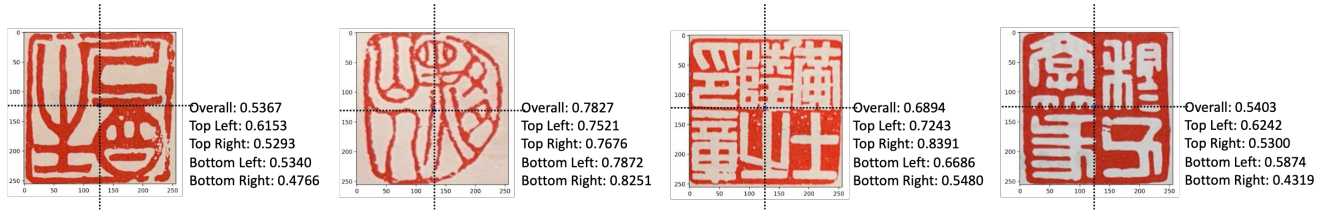


Figure 4: Examples of metrics on the center of gravity, central axis, and white space.

four metrics utilize advanced deep learning techniques, such as image recognition and high-dimensional embedding analysis, to provide a more in-depth assessment of the works. By defining these metrics and providing the corresponding computational methods, we aim to establish a comprehensive and objective framework for evaluating seal carving art, bridging the gap between traditional artistic evaluation and modern technological advancements.

3.3 Metrics based on statistics

Center of Gravity. The center of gravity in a seal carving refers to the point where the visual weight is most concentrated, influencing the overall balance and composition of the artwork. Given that seal carving often features multiple characters intricately arranged on a single seal, the placement of the center of gravity within this amalgamation of characters plays a crucial role in determining the visual impact and aesthetic appeal of the artwork. In a flat seal carving representation, the center of gravity can be thought of as a coordinate position that represents the average location of the visual weight distribution across the composition, calculated as follows:

$$\bar{x} = \frac{\sum_{x=0}^{W-1} \sum_{y=0}^{H-1} x \cdot I(x, y)}{\sum_{x=0}^{W-1} \sum_{y=0}^{H-1} I(x, y)}, \quad (1)$$

$$\bar{y} = \frac{\sum_{x=0}^{W-1} \sum_{y=0}^{H-1} y \cdot I(x, y)}{\sum_{x=0}^{W-1} \sum_{y=0}^{H-1} I(x, y)}. \quad (2)$$

This calculation is essential for understanding the spatial arrangement and harmonious distribution of elements within the confined space of the seal carving, providing insights into the artistic prowess and skill of the seal carver in achieving visual balance and coherence in their work. Figure 3 depicts the location of the visual center of gravity on the seal carving artwork.

Central Axis. The central axis in a seal carving is a theoretical line that runs through the center of gravity, effectively dividing the artwork into two visually balanced parts. This structural feature plays a fundamental role in achieving overall balance and stability in the composition, serving as a geometric metric derived from the center of gravity. As illustrated in Figure 4, we use two black dashed lines to represent the horizontal and vertical central axes. These lines serve to visually divide the seal carving into four balanced sections, providing a clear and objective measure of the artwork's equilibrium and harmonious layout. The central axis serves as a crucial reference point for evaluating the spatial distribution of visual elements within the seal carving, offering insights into the

artist's skill in achieving a well-balanced and aesthetically pleasing composition.

White Space Ratio. White space in seal carving refers to the area within the artwork that is not filled with lines or characters, playing a crucial role in creating a sense of "emptiness" that is highly valued in Chinese art for its aesthetic significance. In Zhuwen seal carving, the white space is defined as the area within the border outside the characters, emphasizing the importance of the empty spaces surrounding the characters in enhancing the overall visual impact of the seal carving. On the other hand, in Baiwen seal carving, the concept of white space refers to the area occupied by the characters themselves, highlighting the contrast between the filled and empty spaces within the composition. The calculation of white space in seal carving involves measuring the specific areas within and outside the characters, providing insights into the strategic use of empty spaces to create a harmonious and visually appealing artwork that conveys a sense of balance and elegance. The calculation is as follows:

$$\text{White space} = \sum_{x=0}^{W-1} \sum_{y=0}^{H-1} I(x, y), \quad (3)$$

$$\text{White Space Ratio} = \frac{\text{White space}}{W \times H}. \quad (4)$$

We calculated the ratio of white space in the entire seal carving artwork and the ratio of white space after dividing the central axis visually into four parts in Figure 4.



Figure 5: The line thickness uniformity metric is utilized to quantify seal carving works in both the horizontal and vertical directions.

Line Thickness Uniformity. This metric is designed to assess the thickness variation and overall consistency of the lines within

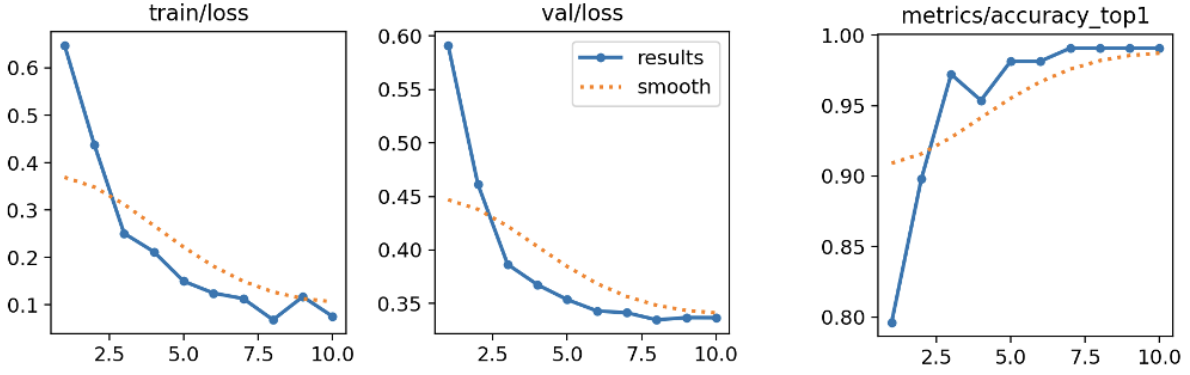


Figure 6: Training details in Zhuwen and Baiwen Recognition.

a seal carving. It utilizes a numerical scale ranging from 0 to 1 to represent the degree of uniformity, with lower values indicating greater unevenness and higher values indicating complete uniformity in line thickness. The calculation formula for this metric is as follows:

$$T_i = \frac{\sum_{j=1}^{N_i} I(x_i, y_{ij})}{N_i}, \quad (5)$$

$$S = \sqrt{\frac{1}{n} \sum_{i=1}^n (T_i - \bar{T})^2}, \quad (6)$$

$$E = 1 - \frac{S}{\bar{T}}, \quad (7)$$

where $I(x, y)$ represents the gray value of the pixel point (x, y) in the image, N_i represents the number of pixels in area i , x_i and y_{ij} represent the horizontal and vertical coordinates of the pixels in region i respectively, and \bar{T} represents the average stroke thickness across all areas. We also present the algorithmic flow for calculating line thickness uniformity as follows:

Algorithm 1: Line Thickness Uniformity Calculation

Data: Image I , Number of regions n

Result: Line Thickness Uniformity U

- 1 **for** $i \leftarrow 1$ **to** n **do**
 - 2 Extract region R_i from image I ;
 - 3 Calculate average intensity $T_i = \frac{\sum_{j=1}^{N_i} I(x_i, y_{ij})}{N_i}$;
 - 4 **end**
 - 5 Calculate the average line thickness $\bar{T} = \frac{1}{n} \sum_{i=1}^n T_i$;
 - 6 Calculate standard deviation $S = \sqrt{\frac{1}{n} \sum_{i=1}^n (T_i - \bar{T})^2}$;
 - 7 $U \leftarrow 1 - \frac{S}{\bar{T}}$;
 - 8 **return** U ;
-

It is important to note that unevenness is merely an objective evaluation of the seal carving and does not solely represent a measurement of its aesthetic appeal. Aesthetics is a complex interplay

of various elements, and while line thickness uniformity is an important factor, it is just one aspect of the overall artistic quality of the seal carving. Figure 5 illustrates the metrics of line thickness uniformity, delineating the variations between horizontal and vertical directions across various seal carving works.

3.4 Metrics based on models

Zhuwen and Baiwen Recognition. To categorize the seal carving works, we divided them into two distinct groups: Zhuwen and Baiwen. Using the Darknet[6] backbone for supervised training, we developed a highly accurate model that can effectively classify each seal carving work as either Zhuwen or Baiwen. The training process involved fluctuations in loss and recognition accuracy, which are visualized in Figure 6. This demonstrates the model's learning progression and its ability to differentiate between the two categories with precision.

The Degree of Characters Fullness (Zhuwen). We categorized the fullness of Zhuwen characters into three distinct levels, as illustrated in Figure 7. Each level represents a gradual shift in the thickness of character lines in seal carving works, from fine to thick. Our model was trained to accurately recognize Zhuwen character fullness based on these classification labels. This approach allows for a comprehensive understanding of the variations in line thickness within Zhuwen characters, enabling the model to make precise distinctions based on these classifications.

The Degree of Characters Fullness (Baiwen). We categorized the fullness of Baiwen characters into three distinct levels, as shown in Figure 8. This classification system allows for a detailed understanding of the variations in line thickness within Baiwen characters, similar to our approach with Zhuwen characters. We utilized annotated data to train a model that can accurately recognize the fullness of Baiwen characters, thus enriching the model with more intricate feature information. This comprehensive training approach enables the model to make precise distinctions based on the varying levels of line thickness within Baiwen characters.

High Dimensional Embedding. We utilized the same backbone to train the model on various seal carving works, using the artists as labels. This approach allowed the model to learn and understand the high-dimensional features that distinguish the artistic styles

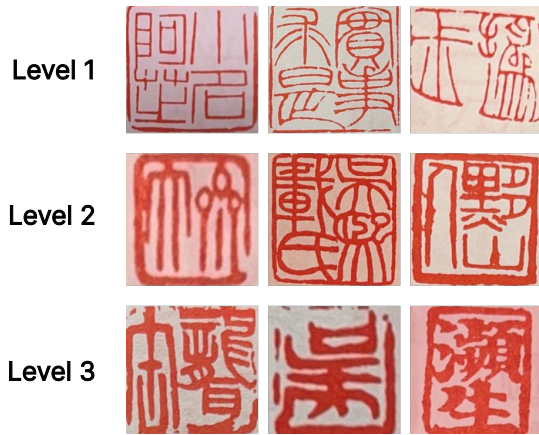


Figure 7: The degree of character fullness (Zhuwen) is classified into three levels.



Figure 8: The degree of character fullness (Baiwen) is classified into three levels.

present in the seal carving works. By training the model with the artists' labels, it gained the ability to differentiate and recognize the unique artistic styles exhibited in the seal carvings, thereby enhancing its accuracy and precision in classifying the works based on their respective artistic styles.

4 EXPERIMENT

In this section, we start by using XGBoost [3] to train on the extracted features, which proves to be effective in predicting the seal artists. This approach helps us determine the significance of various features and their impact on the identification process. Additionally, we utilize the confusion matrix of high-dimensional feature predictions to analyze the similarities and distinctions among different seal carving styles. This in-depth analysis provides valuable insights into the relationships between the extracted features and the unique characteristics of various seal carving styles, thereby enhancing our understanding of the artistic distinctions within the dataset.

Table 1: The significance of each feature in XGBoost classification prediction.

Feature	Importance
centroid(x)	0.064926
centroid(y)	0.065271
white space ratio (overall)	0.070373
white space ratio (top left)	0.063970
white space ratio (top right)	0.062518
white space ratio (bottom left)	0.086108
white space ratio (bottom right)	0.059698
line thickness uniformity (Horizontal)	0.057244
line thickness uniformity (Vertical)	0.071302
Zhuwen&Baiwen prediction	0.098839
Zhuwen&Baiwen prediction probability	0.06585
fullness prediction	0.148754
fullness prediction probability	0.085312

4.1 Findings with XGBoost

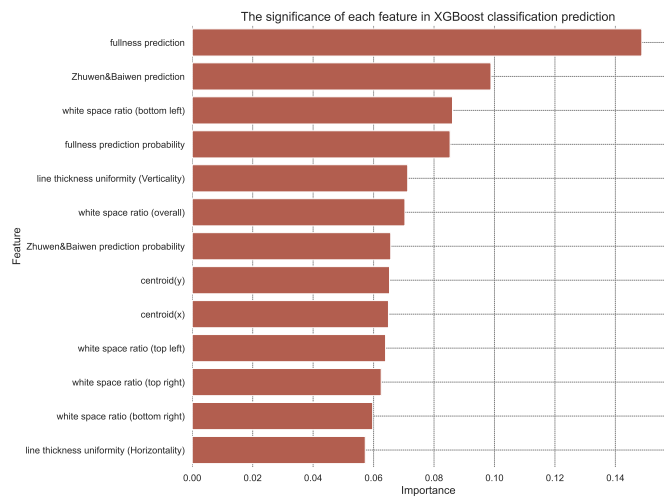


Figure 9: The ranking of feature significance.

The data presented in the table highlights the importance of certain metrics in distinguishing between seal carving works created by different artists. Specifically, metrics such as white space ratio, line thickness uniformity in the vertical direction, Zhuwen and Baiwen recognition, and fullness prediction emerge as key factors in the accurate identification of seal carving works. These metrics are instrumental in capturing the unique characteristics and stylistic nuances that define the individual artistic styles of the various seal carving artists. By focusing on these crucial metrics, our analysis gains deeper insights into the distinct features that contribute to the differentiation of seal carving works across different artists.

Additionally, our findings suggest that these key metrics reflect the intricacies of the artists' techniques and preferences, shedding light on the specific artistic elements that define their individual styles. For example, the white space ratio may indicate the balance

and composition within the seal carving, while line thickness uniformity could be indicative of the artists' attention to detail and precision. Moreover, the recognition of Zhuwen and Baiwen, as well as the fullness prediction, may reveal the use of traditional motifs and the overall aesthetic approach employed by the artists.

Understanding the significance of these metrics not only enhances the accuracy of identifying the seal carving works but also provides valuable insights into the artistic nuances and distinguishing features that characterize the works of each artist. This in-depth analysis of the key distinguishing factors can further inform the study and appreciation of seal carving art, offering a deeper understanding of the diverse artistic styles and techniques present in the dataset. Overall, these insights contribute to a more comprehensive comprehension of the artistic intricacies and variations within seal carving works, enriching the study of this traditional art form.

4.2 Findings with confusion matrix

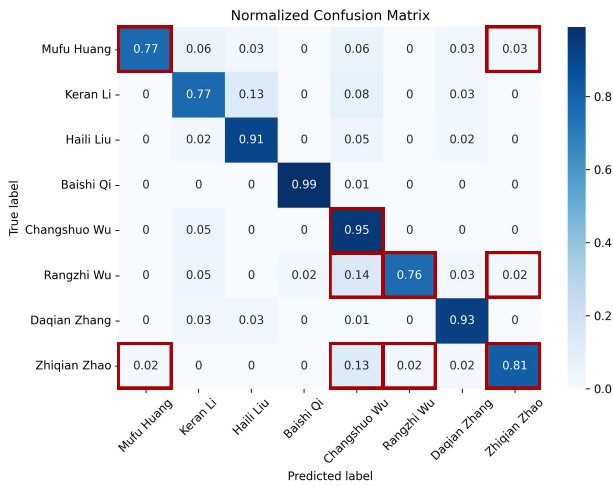


Figure 10: The intricate inspiration behind the works of various seal carvers.

We predict classification results using high-dimensional features and visualize the confusion matrix to illustrate the relationship between the predicted results and the ground truth values. The confusion matrix not only shows the correct and incorrect predictions, but also provides a representation of the probability of confusion, to some extent, which reflects the similarity between different classes of data.

In Figure 10, we highlight the confusing categories with a red rectangular box. These four easily confusing seal works were created by the prominent masters of seal carving during the late Qing Dynasty, also known as the Four Masters of Chinese Seal Carving in the Late Qing Dynasty. This designation underscores their esteemed status within the realm of seal carving, highlighting their significant contributions to the art form during that period.

Furthermore, the validation of this conclusion can be found in published papers, such as "吴熙载的篆刻风格对晚清及后世篆刻家产生了重要影响，如赵之谦、吴昌硕等都受到了他的启发，并在此基础上发展了自己的篆刻风格" (translated as "Wu

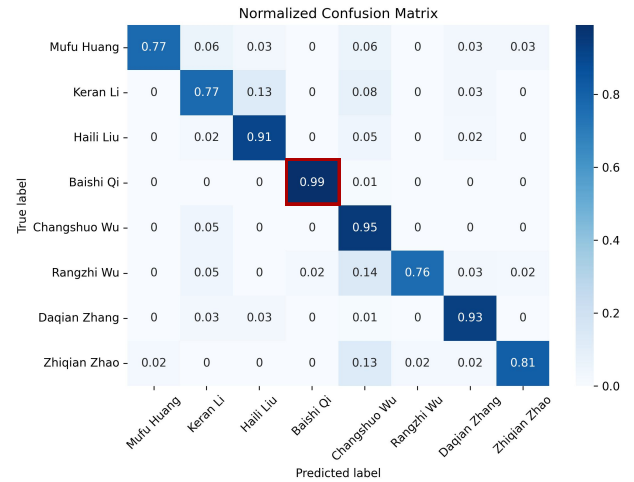


Figure 11: The distinctive style of numerous seal carvers.

Xizai's seal carving style had a significant influence on late Qing and subsequent seal carvers. Artists such as Zhao Zhijian and Wu Changshuo were inspired by him and developed their own seal carving styles based on his legacy." in [17].

This evidence reaffirms the enduring impact and influence of these four masters on subsequent generations of seal carvers, shedding light on the historical and artistic significance of their work. It provides valuable insights into the development and evolution of seal carving styles, as well as the broader impact of these prominent artists on the artistic landscape of Chinese seal carving.

We can clearly see in Figure 11 that the seal carver Qi Baishi is more easily distinguishable compared to other seal carvers, indicating that he possesses a more distinctive and recognizable style that sets him apart from his contemporaries.

This observation is consistent with the viewpoint presented in the published paper [12], which states "齐白石的篆刻作品具有很高的个性化特征，他的刀法和艺术风格独特，难以被他人模仿，这使得他的作品具有独一无二的艺术价值。". This passage emphasizes that Qi Baishi's seal carving works exhibit highly personalized characteristics, and his techniques and artistic style are so unique that they are difficult for others to imitate, thus endowing his works with unparalleled artistic value. This further underscores the exceptional and irreplicable nature of Qi Baishi's artistic contributions within the realm of seal carving.

The distinctiveness of Qi Baishi's seal carving style provides valuable insight into the realm of Chinese seal carving. It not only demonstrates the exceptional talent and creativity of the artist but also highlights the significance of individuality and originality in artistic expression. The fact that Qi Baishi's techniques and artistic style are perceived as unique and difficult to imitate emphasizes the importance of personal artistic expression and the value of creating works that stand out from the rest.

4.3 Summary of findings

In these experiments, we utilize XGBoost analysis and confusion matrix visualization to explore the significance of various metrics in identifying seal carving works by different seal carvers. The findings

shed light on the key distinguishing factors between artists and provide insights into the artistic nuances and stylistic variations within the dataset. Additionally, the analysis of easily confusing seal works by prominent masters of seal carving offers valuable historical and artistic context, highlighting their enduring influence on subsequent generations of artists.

Our findings are enumerated as follows:

- XGBoost analysis pinpointed key metrics such as white space ratio, line thickness uniformity, and Zhuwen and Baiwen recognition as crucial in distinguishing artists' works. Understanding these metrics deepens comprehension of artists' techniques and preferences, revealing nuances in artistic styles and aesthetic approaches.
- Confusion matrix analysis identified easily confusing seal works by Four Masters of Chinese Seal Carving in the Late Qing Dynasty. The influence of these masters on subsequent generations underscores their historical and artistic significance within the realm of seal carving. Qi Baishi's unique seal carving style exemplifies the importance of individuality and originality in artistic expression, emphasizing the enduring impact of exceptional artistic contributions.

5 LIMITATION

While our study offers significant insights into the evaluation of Chinese seal carving aesthetics, it is essential to acknowledge several limitations that could impact the generalizability and robustness of our findings.

Dataset Limitations. The dataset utilized in this study, although extensive, may not comprehensively represent the vast diversity of seal carvings across different periods and regions. Historical variations and regional styles may introduce nuances that our model may not fully capture. Future studies should aim to include a more diverse and representative dataset to enhance the model's applicability across different contexts.

Feature Selection Bias. The features selected for model training, such as line thickness and white space ratio, while significant, might overlook other potentially important characteristics. The importance rankings provided by XGBoost highlight certain features but may not fully capture the intricate details of seal carving styles. Future research could explore additional features, such as texture, ink density, and carving depth, to provide a more comprehensive analysis.

Historical Context and Influence. The study acknowledges the influence of historical figures and movements in seal carving, particularly the impact of the Four Masters of the Late Qing Dynasty. However, the historical context in which these works were created plays a crucial role in their interpretation and value. Our model does not account for the socio-political and cultural influences that shaped these artistic styles. Integrating historical context into the analysis could offer deeper insights into the evolution of seal carving art.

Our study presents a novel approach to evaluating Chinese seal carving aesthetics using machine learning techniques. However, it is crucial to address several limitations to enhance the model's robustness and applicability. Future research should aim to incorporate more diverse datasets, explore additional features, integrate

historical contexts, and build upon this preliminary exploration to develop more refined and comprehensive methods for assessing seal carving art.

6 CONCLUSION

This study introduces a framework for assessing the aesthetic qualities of Chinese seal carvings, a traditional art form that has received limited attention in quantitative research. By building a dataset featuring works from eight distinguished seal carvers and employing a combination of statistical analysis and machine learning techniques, we have significantly advanced the comprehension and admiration of seal carving art. Beyond establishing a standardized quantitative approach to evaluating seal carving aesthetics, our endeavor strives to mitigate the influence of subjective biases in judgment. By offering a fresh perspective on the appreciation and comprehension of seal carving art, our work becomes pivotal in fostering its preservation and propagation in the digital era.

REFERENCES

- [1] Yangtao Bai. 2021. Study of Huang Shiling's Seal Studies in the Late Qing Dynasty (in Chinese). (2021).
- [2] Guocheng chen. 2012. Study on the Theoretical Origin and Framework Structure of Ancient Chinese Seal Theory (in Chinese). (2012).
- [3] Tianqi Chen and Carlos Guestrin. 2016. Xgboost: A scalable tree boosting system. In *Proceedings of the 22nd acm sigkdd international conference on knowledge discovery and data mining*. 785–794.
- [4] Zhenbao Fan, Yixuan Zhu, Christine Yan, Yufan Li, and Kang Zhang. 2022. A comparative study of color between abstract paintings, oil paintings and Chinese ink paintings. In *Proceedings of the 15th International Symposium on Visual Information Communication and Interaction*. 1–8.
- [5] Zhen-Bao Fan, Yi-Na Li, Kang Zhang, Jinhui Yu, and Mao Lin Huang. 2022. Measuring and evaluating the visual complexity of Chinese ink paintings. *Comput. J.* 65, 8 (2022), 1964–1976.
- [6] Glenn Jocher, Ayush Chaurasia, and Jing Qiu. 2023. *Ultralytics YOLO*. <https://github.com/ultralytics/ultralytics>
- [7] Xin Lu, Zhe Lin, Hailin Jin, Jianchao Yang, and James Z Wang. 2014. Rapid: Rating pictorial aesthetics using deep learning. In *Proceedings of the 22nd ACM international conference on Multimedia*. 457–466.
- [8] Hongsheng Luo. 2004. Shuo Wen Jie Zi and the Art of Calligraphy and Seal Engraving in the Qing Dynasty (in Chinese). (2004).
- [9] Zhe Ma and Jianbo Su. 2016. Aesthetics evaluation for robotic Chinese calligraphy. *IEEE Transactions on Cognitive and Developmental Systems* 9, 1 (2016), 80–90.
- [10] Jon McCormack and Andy Lomas. 2020. Understanding aesthetic evaluation using deep learning. In *International conference on computational intelligence in music, sound, art and design (part of EvoStar)*. Springer, 118–133.
- [11] Weizu Sun. 2004. *Chinese Seals: Carving Authority and Creating History*. Long River Press.
- [12] Junjun Xie. 2017. Research on Qi Baishi's aesthetic thought of seal carving art.
- [13] Songhua Xu, Hao Jiang, Francis C.M. Lau, and Yunhe Pan. 2012. Computationally Evaluating and Reproducing the Beauty of Chinese Calligraphy. *IEEE Intelligent Systems* 27, 3 (2012), 63–72. <https://doi.org/10.1109/MIS.2012.46>
- [14] Yehang Yin, Zewen Chen, Yanji Zhao, Jiongqi Li, and Kejun Zhang. 2020. Automated Chinese seal carving art creation with AI assistance. In *2020 IEEE Conference on Multimedia Information Processing and Retrieval (MIPR)*. IEEE, 394–395.
- [15] Kejun Zhang, Rui Zhang, Yehang Yin, Yifei Li, Wenqi Wu, Lingyun Sun, Fei Wu, Huanghuang Deng, and Yunhe Pan. 2022. Visual knowledge guided intelligent generation of Chinese seal carving. *Frontiers of Information Technology & Electronic Engineering* 23, 10 (2022), 1479–1493.
- [16] Hong Zhao. 2003. An Experimental Study of the Development and Prosperity of Seal Engraving Art in the Qing Dynasty (in Chinese). (2003).
- [17] Jingci Zhou. 2021. Wu Xizai's Inheritance and Development of the Concept of 'Printing from Books.
- [18] Jingci Zhou. 2021. Wu Xizai's Innovation and Inheritance of Printing Series Publication Theory (in Chinese). (2021).
- [19] Qi Zhu. 2019. Techniques and Principles of Western Art Reflected in Huang Shiling's Paintings and Seal Carvings. In *5th International Conference on Arts, Design and Contemporary Education (ICADCE 2019)*. Atlantis Press, 381–388.