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# Architectural Styles through the Lens of Artificial Intelligence: A Review

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**ABSTRACT**

Architectural style is a topic with a long history. Different styles reflect the diversity of architecture, carry the imprint of the times and regions, and bear important aesthetic and cultural value. With the advent of artificial intelligence (AI), new methodologies for classifying these styles have emerged, offering a fresh perspective on architectural analysis. This article provides a review of the AI-based architectural style classification research, examining research topics, datasets, data types, and algorithms employed in the field. The core of the current architectural style classification algorithm is supervised learning, with convolutional neutral network most frequently used. Most research use images or graphs to represent architecture information. For future research, a larger standardized dataset is needed, and unsupervised learning should be given more attention. AI-based architectural style classification may be used in areas such as personalized architectural recommendations and new style generation, bringing a new perspective to architectural design.

## 1. Introduction

### *1.1 History of Classification of Architectural Styles*

Discussions about architectural styles have been around for a long time, and people refer to a group of architecture with similarities as the same style. In the field of art, words such as "style", "genre" and "ism" have similar meanings. A style may come from the induction of historians, or it may come from the manifesto of the art group itself.

The classification of architectural styles is of great value. First of all, architectural style is a name that provides a way of referring to a certain type of architecture. Secondly, each style has the imprint of the era and region, has important aesthetic and cultural value, and is also the basis for research on the evolution of architectural history. Thirdly, style provides people with a cognitive structure. The process of naming is the process of classifying architecture, which makes people's perception of architecture structured.

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Before the information age, the classification of architectural styles was mainly done by historians. Architectural historians and art historians summarized architectural styles, such as classifying architecture into Gothic, Baroque, International Style, Futurism, etc. In the book *Isms: Understanding Architectural Styles*, Jeremy Melvin summarized the history and extinctive features of many architectural styles [1]. In *Modern Architecture: a Critical History*, Frampton explains how each architectural style criticizes the architectural style before it and promotes the continuous development and change of architecture [2].

The greatest contribution of this traditional classification method of architectural styles is that it provides a clue to historical development, making it easier to comprehend the roots of their emergence in the cultural context of the times and the relationship between various styles. However, this style classification method also has certain limitations. Firstly, the classification of styles is not strict. For example, the International style and the Gothic style do not follow the same classification rule. The naming of a certain style only emphasizes the outstanding characteristics of the style, while ignoring other features. Secondly, there is no clear answer to "what is style" and "the nature of style". Style and content can be independent of each other. For example, a futuristic architecture can be a residence or a museum. Style and media can also be independent of each other. Style classification methods similar to those in architecture are also widely used in other art fields (such as painting and music), and there is often a phenomenon of style interoperability between art fields. For example, the futuristic style can be found in architecture as well as in painting. The independence of style from content and media shows that style has more essential characteristics. This characteristic may be a deeper and higher-dimensional cognitive characteristic, which requires more in-depth research.

### *1.2 Classification of Architectural Styles Based on Artificial Intelligence*

With the rise of artificial intelligence technology and its gradual application in the visual field, new methods of architectural style classification have emerged. Different from manual induction, this type of method is data-driven, using machine learning methods to extract architectural features and classify architectural styles.

The first question to be answered when using artificial intelligence to classify architectural styles is: what is the essence of style? Although there are still many unknowns about human style recognition, one thing certain is that style recognition is very similar to pattern recognition in artificial intelligence, that is, the process of extracting features and assigning different weights. In recent years, researchers mainly used methods such as convolutional neural network (CNN) and graph neural network (GNN) to classify various architectural styles, trying to establish useful tools to classify architectures or get to mimic people's perception and cognition of buildings.

Consistent with common sense, research shows that the representation of style and content in convolutional neural networks is separable [3]. Some scholars pointed out that style and elements are also different. Style is a spatial feature, while elements are some basic components [4]. The independence of style from content and elements shows that style is a characteristic of art and a high-dimensional feature encoding.

### *1.3 Aim of this Research*

Despite the rapid development of AI-based architectural style classification researches, trends and limitations of architectural style classification methods are still unclear. Therefore, this research aims to review architectural style classification methods based on artificial intelligence, summarize the research status and development trends, analyze the advantages and limitations of existing research, hoping to provide suggestion for future research.

## 2. Methodology

the research framework of this article is shown in Figure 1. First, we searched the literature on Web of Science and Google Scholar, which are two widely-used academic search engines. The search query was set as: (Architecture) AND (classification OR style OR genre) AND ("artificial intelligence" OR "machine learning" OR "deep learning"). Only literature written in English was included. Then the literature was screened to filter out articles that were irrelevant to the research topic of this article. The criteria for inclusion were: 1) The research topic is architectural style, which can include the exterior, interior or part of the building, excluding remote sensing information images; 2) Use Artificial intelligence algorithms for classification, including CNN, GNN, etc., excluding those that only use traditional classification methods and do not perform classification tasks. A total of 14 documents met the standard and were included.

Afterwards, these documents were systematically analyzed. The research objects, datasets, data types, and algorithms of each study were summarized. On this basis, the difficulties, advantages and disadvantages of existing research, and development trends are summarized. Finally, implications for future research are provided.

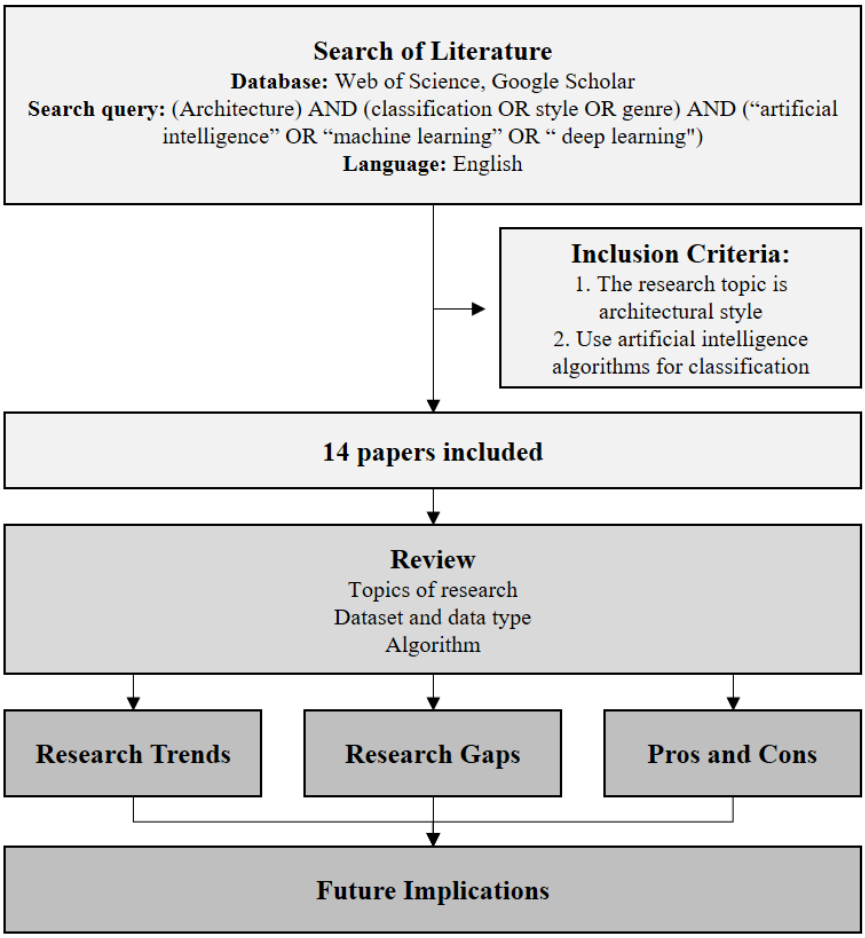


**Fig. 1.** Research Framework

# 3. Review of Literature

In order to provide a clear view of existing research, this paper extract the information in literature, including research objects, datasets, data types, and algorithms of each study. The information is listed in Table 1.

## *3.1 Topics of Research*

In terms of research topics, most studies classify the style of architecture as a hole. Some studies investigated a large number of style categories [5–7]. Some studies focus on buildings under certain constraints, for example, Mexican historic buildings [8], American houses [9], some specific architects' styles [4], etc. These studies usually use artificial labels as the standard for supervised learning.

Other studies classify parts of buildings, for example, classifying building facades [10], classifying facade windows [11], or classifying floor plans [12]. This type of research focuses on one aspect of architecture and can also capture certain characteristics of an architectural style.

## *3.2 Dataset and Data Type*

In terms of datasets, since there are no existing large-scale datasets, most existing studies have established their own datasets for their research topics [3,5,6,8,9,11–16]. Only a few studies have used previous datasets[7,10]. The amount of data in the dataset is not large, mostly ranging from a few hundred to tens of thousands of items.

Since architecture information is multi-dimensional, three-dimensional models, photos, videos, and drawings can all be used as representations of architecture. Due to the difficulty of calculating 3D models and videos and the immature development of algorithms, existing research adopts two strategies:

1) Use images to represent architecture

This strategy reduces the dimensionality of architecture into images, that is, photos of building architecture. In other words, this strategy transforms the architecture classification problem into an image classification problem. Then, methods such as CNN can be used for training and testing a model. The advantage of using image data is that the amount of data is large and easy to obtain, and the existing algorithm is relatively mature. The disadvantage is that each image can only reflect part of the architecture and cannot reflect the overall and spatial structure information of the architecture.

2) Use graphs to represent architecture

This strategy uses graphs for learning, that is, encoding of three-dimensional space or two-dimensional images according to certain rules, and then learning the encoded graphs. Among the literature included in this review, only two studies use graphs to represent architecture. The advantage is that it can clearly reflect the relationship between the various parts of the building. The disadvantage is that It requires more manual prior knowledge and manual annotation, and at the same time a lot of details are lost.

## *3.3 Algorithm*

Among all architectural style classification studies, most of the studies employee supervised learning, and the most commonly used algorithm is the CNN algorithm. This classification method mainly benefits from the rapid development of image classification in computer vision. Some research design their algorithm based on existing algorithms or pre-trained models. For example, a research utilizes the NASNet, a DCNN model to classify the works of 34 modern architects and achieves a classification accuracy of 73% [16]. Another study train their model based on the pre-trained Inception-v3 model [17]. Some studies also develop their own CNN in order to achieve better

performance. For example, a study designs and trains a network to classify images of three architectural styles of Mexican buildings [8]. The research finds that their relatively shallow network with only four convolutional layers achieves better performance than another deeper network with six convolutional layers, which demonstrate that the design of algorithm depends on the problem complexity as well as the amount of data. In addition to CNN, there are also studies using algorithms such as SVM and DPM, or a combination of multiple algorithms.

A few studies employee unsupervised learning methods. For example, in study [16] a clustering algorithm, principle component analysis (PCA) was conducted on architect styles, and it was found that three clusters were formed. The first and second categories are similar to the classifications of architectural historians, demonstrating that the machine's style classification is similar to human style perception in some aspects. But the third category is different from common cognition, which shows that the style classification of machines and people is also different.

**Table 1**
Summary of existing research

| Research | Topic | Dataset | Data type | Algorithm |
|---|---|---|---|---|
| **[12]** | Style identification and classification of floor plans | The floor plans of the works of 6 architects encoded in graphs according to certain rules. | graph | Q-SOM<br>Q-SOM：RF |
| **[11]** | Classification of three styles of building facade windows | 400 images of 3 architectural styles (Romanesque, Gothic and Baroque) | image | SIFT<br>k-means clustering |
| **[5]** | Classification of architectural styles | 5000 images in 25 categories | image | DPM<br>MLLR |
| **[6]** | Classification of architectural styles | over 10,000 architectural images in 9 categories | image | Hierarchical Sparse Coding<br>LDA<br>SVM |
| **[14]** | Infer the construction date and geographical location of a building based on architectural features | nearly 150,000 Google Street View images from Paris with a cadastre map | image | Nearest Neighbor Search |
| **[8]** | Classification of Mexican historical buildings | 16,000 style-tagged images (three architectural, one non-architectural) | image | CNN |
| **[13]** | Learn from graph-based 3D models and generate function-driven architectural concept designs | designs encoded as graphs | graph | DNN<br>GAN |
| **[7]** | Classification of architectural styles | Architectural Style Dataset [5] | image | DPM<br>DNN<br>IEP<br>SVM |

| | | | | |
|---|---|---|---|---|
| **[16]** | Classification of architectural styles concerning architects | Images of the works of 34 well-known architects + photos of typical residences, a total of 19568 pictures with author tags and indoor/outdoor tags | image | CNN<br>PCA |
| **[9]** | Classification of house styles in the US | 480 black and white images | image | CNN |
| **[17]** | Classification of architectural styles and estimate sale price | 25,000 Google Street View images in 7 categories | image | CNN |
| **[18]** | Classification of architecture age and interpret the architecture age and styles | Multiple publicly available datasets | images | CNN |
| **[10]** | Classification of building facade styles | Architectural Style Dataset [5] and AHE_Dataset [15]; | image | CNN<br>channel–spatial attention module |
| **[19]** | Classification of cultural heritage buildings in Athens | 6500 images in 4 categories | image | CNN |

# 4. Research Trends and Gaps

## *4.1 Research Trends*

Based on the previous analysis, it can be seen that the development trends of architectural style classification methods based on artificial intelligence are mainly as follows:

1) In terms of the topics: Early research often focused on parts of the building, such as plans, facade components, etc., and the number of classification categories was also very limited. With the development of research methods, the research objectives have become more holistic and the number of categories has also increased.

2) In terms of data types: images and graphs are the two most frequently used data types, but there are more studies using images. This may be because the current research on images is relatively mature. Overall, the amount of data in the architectural style dataset is relatively small.

3) In terms of feature extraction methods: Most studies use CNNs in machine learning for supervised learning, and a few studies use unsupervised learning.

## *4.2 Research Gaps*

Style recognition based on artificial intelligence has been widely used in fields such as painting [20], music [21], and movies [22], but its application in the field of architecture is relatively rare. There are two main difficulties in machine learning for architecture:

1) It is difficult to form a large-scale, standardized dataset.

For art types such as painting, music, and movies, media file data such as jpg, mp3 and mp4 can almost reflect the entire work. However, for architecture, it is very difficult to obtain data that can fully characterize architecture. The digital model file is high-quality architectural data, but there are still doubts about whether it can truly reflect the essence of architecture, because there may be many

differences between the real architecture and the model, and the digital model may miss some information.

Even setting this aside, there are still many difficulties: digital model files are rarely open source and difficult to obtain. In addition, there are great differences between models, making it hard to establish a standard to organize them. These factors have made it difficult for architecture to form a large-scale dataset as a benchmark like images.

2) Classification algorithms for high-dimensional data are not yet mature.

Most of the existing algorithms are aimed at two-dimensional image data, and algorithms for three-dimensional data are not yet mature. The architecture itself is a three-dimensional object, and the amount of three-dimensional calculations is already huge enough. If the time dimension (such as space roaming) is added, it will become higher-dimensional data, which poses a considerable challenge to the algorithm. This is why most existing research uses images or charts to reduce the dimensionality of architecture information for training and testing.

### *4.3 Pros and Cons of AI-based Style Classification*

The value of artificial intelligence-based architectural style classification is that it can provide a quantitative description of the style. In addition, it strips away historical, cultural, and aesthetic connotations and only extracts features from physical forms that people can feel, which reflects the cognitive process. In addition, by stripping away the influence of majors, its results may be closer to the perceptions of ordinary people who don't major in architecture.

However, this type of style classification method also has certain limitations. Because it strips away the historical context of styles, it makes it difficult to explain the relationships between styles. There may be various relationships between architectural styles, such as following, revival and opposition (Xu et al., 2014). The same style category may contain several subcategories, and the styles of each architect or even the same architect in different periods will have differences. However, current research cannot yet describe or explain the relationship between styles and the evolution of styles. Furthermore, although current computational models can output classifications, like most AI models, their interpretability is low.

## 5. Discussion and Future Implications

Based on the above discussion, this article believes that several points can be improved in future research, as summarized by the research stage in Figure 2.

### *5.1 Creation of Large-scale Standardized Datasets*

Most existing research is limited by the lack of large-scale, standardized datasets. In the history of the development of artificial intelligence algorithms, the establishment of large-scale datasets is crucial, which provides researchers with a basis for comparison and optimization. Taking the performance of various models on the ImageNet dataset as an example, the top 1 accuracy has increased from 58.9% in 2013 to 92.4% in 2024 [23], which demonstrates that a proper dataset is crucial for the development of algorithms. Therefore, in the future, one or more larger-scale and standardized datasets should be established to provide a benchmark for the field.

### *5.2 Supervised or Unsupervised Learning*

At the theoretical level, in the research on architectural style classification based on artificial intelligence, a question is particularly important, that is, should we use existing artificial style classification as labels for supervised learning?

The reason for supporting the use of manual labels as a standard is to make the machine as human-like as possible. Only when the machine learns artificial style classification can its classification be understood and used by humans, and it can be used to replace parts of humans.

The reasons for opposing the use of manual labels as a standard are: First of all, the human definition of style itself is ambiguous, and there is no reliable standard for classifying styles. The perceptual biases of different people, or even the same person, will affect classification, and the boundaries for dividing styles will also be different [12]. Limited by the human mind and language, previous definitions of style can only be as close as possible in description and metaphor, but cannot reach reality. In this regard, machines may be better than humans at discovering the essence of style and quantitatively describing it. Secondly, machines may discover patterns that humans have not discovered, which may challenge humans' existing cognition and trigger a new understanding of style.

This question once again asks about the nature of style, and even the nature of design. Style classification based on artificial intelligence is a disenchantment of the design process. It believes that style can be represented by mathematical structures. Design is not a sudden inspiration, it may just be a permutation and combination of existing design techniques. Most of the current research uses labeled data for supervised learning. In the future, more attention should be given to unsupervised learning methods to conduct a more in-depth exploration of the nature of style.

### *5.3 Theoretical Outlook*

With a larger dataset, more architectural research can be carried out based on style classification. For example, architectural history research can be carried out by analyzing the development of architecture according to the classification of architectural styles. Research can also study the relationship between architectural styles, preferences, and aesthetic values. Besides, researchers can also go deeper into the relationship between architectural styles on architectural cognition, etc.

### *5.4 Application Outlook*

At the application level, we can put forward several prospects for the application of this technology:

First, a personalized recommendation system can be designed based on architectural style classification. Studies have shown that people's preferences for different buildings are related to personality, gender, race, and artistic experience [24]. Therefore, style recommendations can be made based on user characteristics to facilitate them to choose their favorite architectural style. In fact, style recognition based on artificial intelligence has been well applied in the field of painting. The current algorithm can already achieve tasks such as style classification and style transfer well.

Additionally, architectural style classification can provide the basis for AI-generated new styles. Just like AI painting, after learning architectural styles, the machine may have the ability to create new architectural styles and expand the boundary of architecture design.

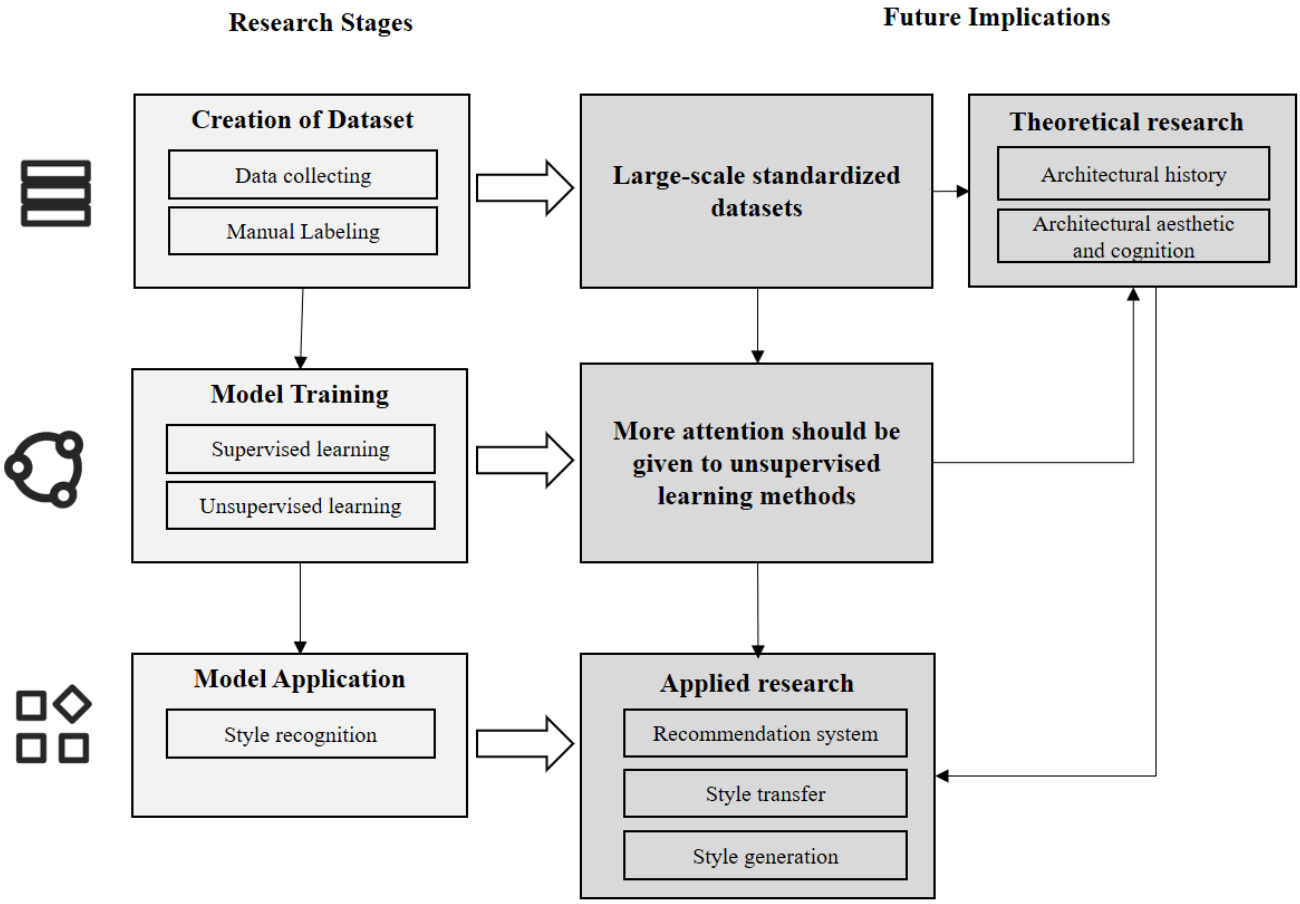


**Fig. 2.** Future Implications

## 6. Conclusions

This review examines the application of artificial intelligence (AI) in classifying architectural styles. After carefully analyzing the existing literature, it summarizes the research gaps and proposes future implications. In summary, the use of convolutional neural networks to analyze architectural images is still mainstream methodology. The paper identifies trends towards more holistic classifications, and underscores the need for large-scale, standardized datasets. It also recommends a shift towards unsupervised learning for deeper insights into the essence of style.

In conclusion, the integration of AI in the classification of architectural styles is a significant step towards a more data-driven approach to architectural research and practice. It is imperative for future research to address the existing gaps and expand the scope of applications. By doing so, the field can harness the full potential of AI to enrich our comprehension of architectural styles and their role in shaping our built environment.

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