DLA 2021

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The Color Analysis of Building Façades: Based on the Panoramic Street View Images

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Introduction

The color scheme of a city is an essential element of the urban landscape and is related to the first impression of the city. It is also a reflection of the city's historical context.

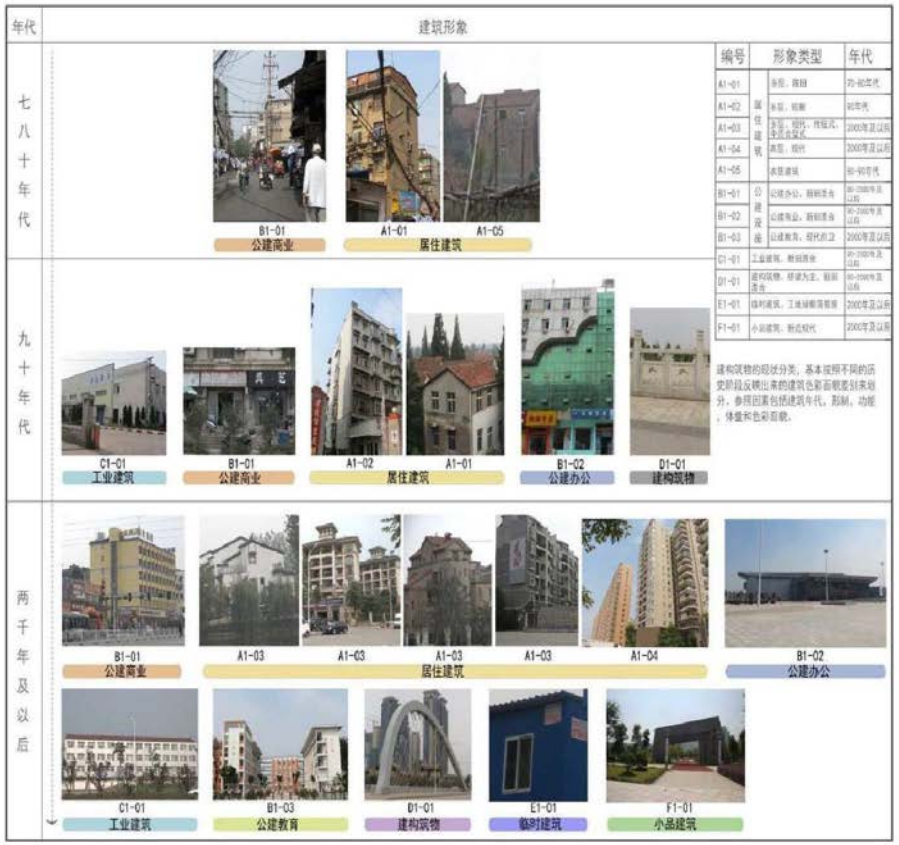
By analyzing the colors of the buildings, we can get a more objective and holistic view of the city and could provide a foundation for the regulations and ordinances for the color and texture usage of the building construction.

Historical and contemporary buildings in Wuhan

Research on building colors has a long history that could date back to the 1st century. Vitruvius, the Roman architect has described the natural color materials in his book “De Architectura Libri Decem”, known today as “The Ten Books on Architecture”. In recent years, the harmony of building color has been widely applied in urban color plans in a number of cities around the world.

Traditional research methods for urban color analysis include color card comparison, instrument color measurement and photograph recording. These methods are usually carried out by manual survey and sampling, which is limited by the number of color samples and the environment's accidental factors. Moreover, because the color sampling process is operated manually, it could take a lot of time and cost.

GB/T18922-2008 Chinese Building Color Card 1026

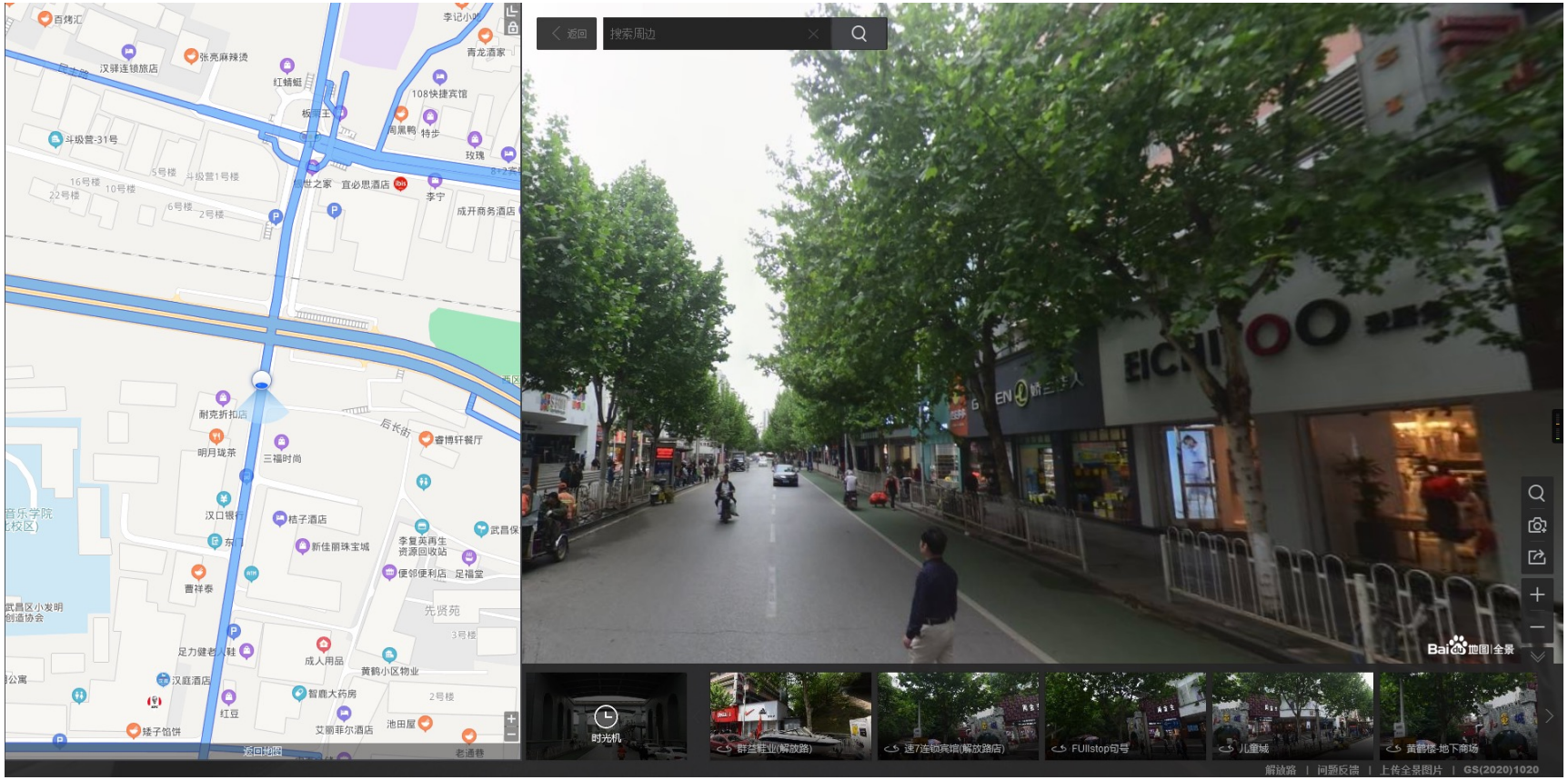


Building classification and color analysis

Color regulations

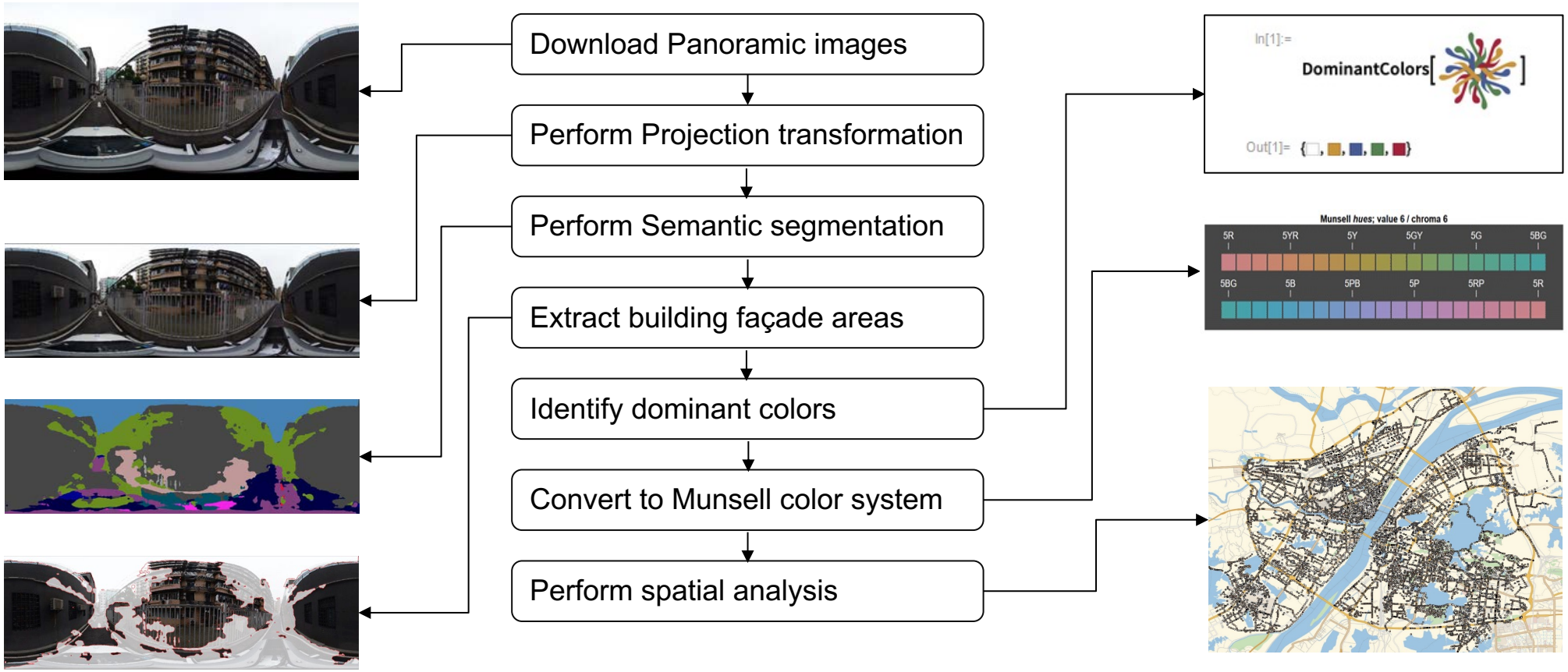
With the development of street view services by Google, Bing, Baidu, and other map service providers, the access to the realistic views of the urban buildings in most cities around the world has become available for everyone.

The panoramic images collected by the data recording vehicles could provide an intact and continuous illustration of building façade along the street. Compared to traditional sampling methods, using the large-scale street view images as the data source could significantly reduce the time costs, and is suitable for large-scale urban problems the study.

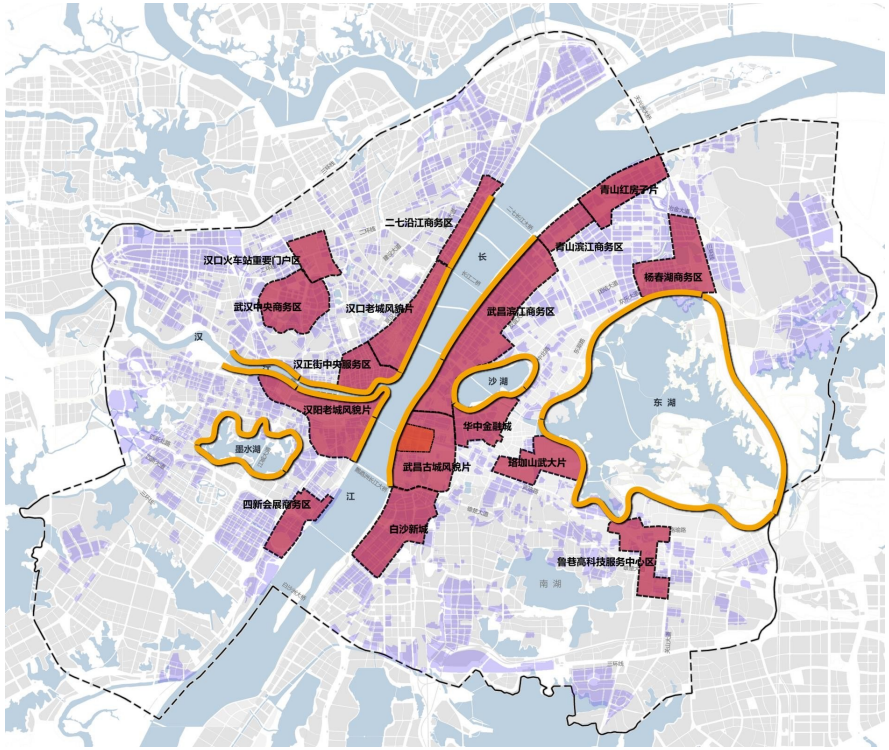


Baidu Street View Image Web Service

The Baidu street view images were downloaded as a data source and then semantically segmented them to extract the façade areas with the help of a convolutional neural network. Then the dominant colors of the building façades were identified and transformed to the Munsell color system for the analysis and composition between different districts. This can provide a repeatable and objective urban building color analysis method and offers a low-cost, high-efficiency analysis tool for urban color surveys.



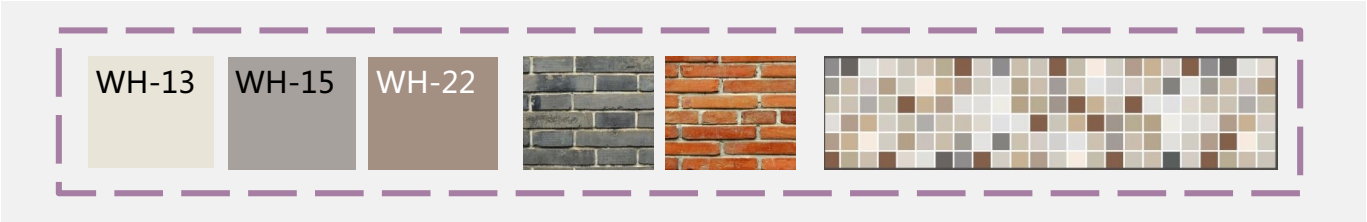
Introduction



Wuhan is a city located in the central part of China. The city's central urban area (678 km^2) was selected as the research area.

Since 2014, Wuhan Natural Resources and Planning Bureau has initiated a research project on the building color and material planning and management in response to the goal of "improving the living environment and creating a charming Wuhan."

Based on the city's historical context, the city government released the "Regulations on the Usage of Building Colors and Materials in the Main Urban Area of Wuhan" in January 2016.



Warm white

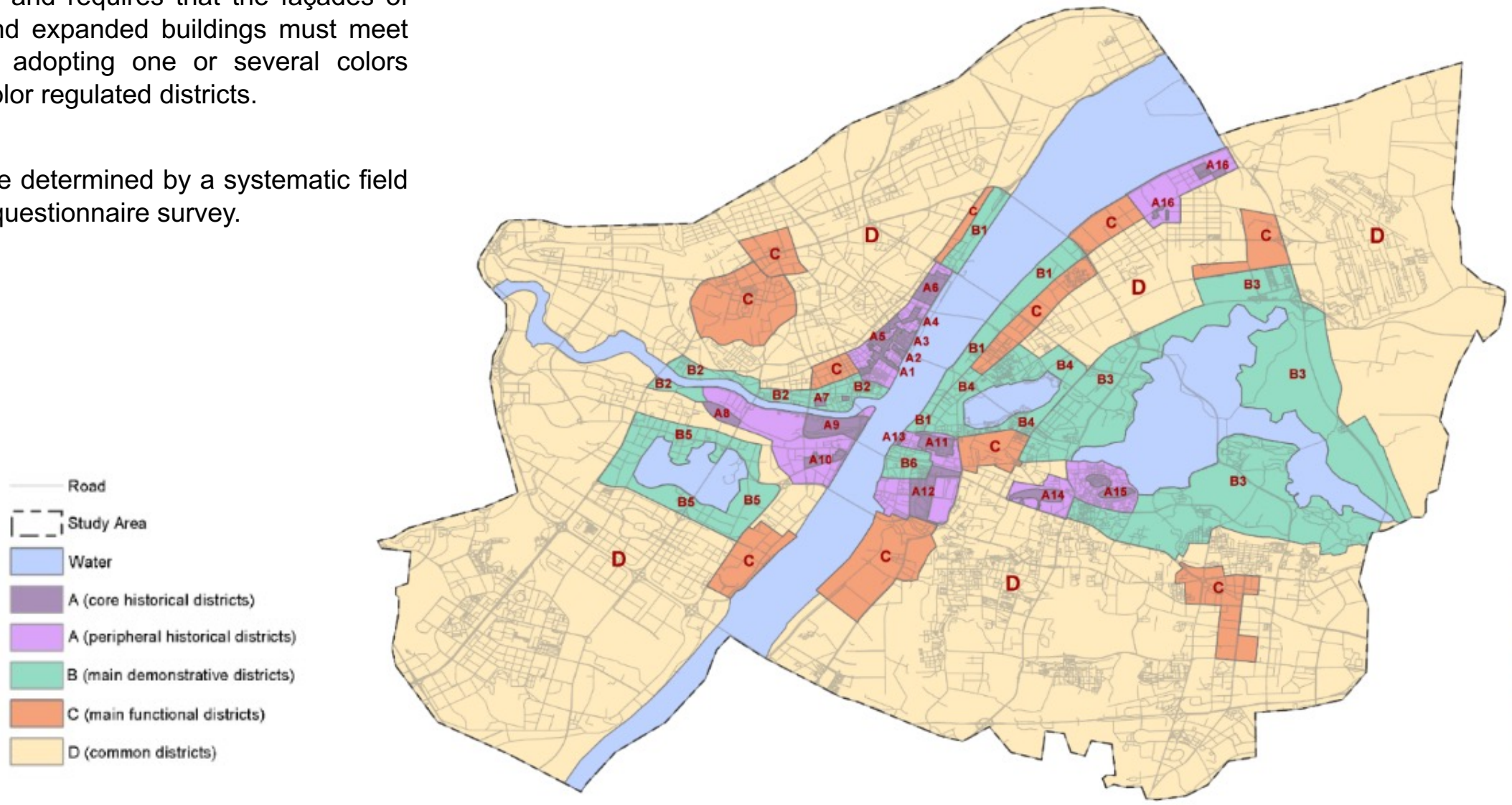
Bright gray

Brick orange

Study area

The regulation adopts the Munsell color system to describe the colors and requires that the façades of the new, rebuilt, and expanded buildings must meet the regulations by adopting one or several colors listed by different color regulated districts.

The listed colors are determined by a systematic field study and a public questionnaire survey.



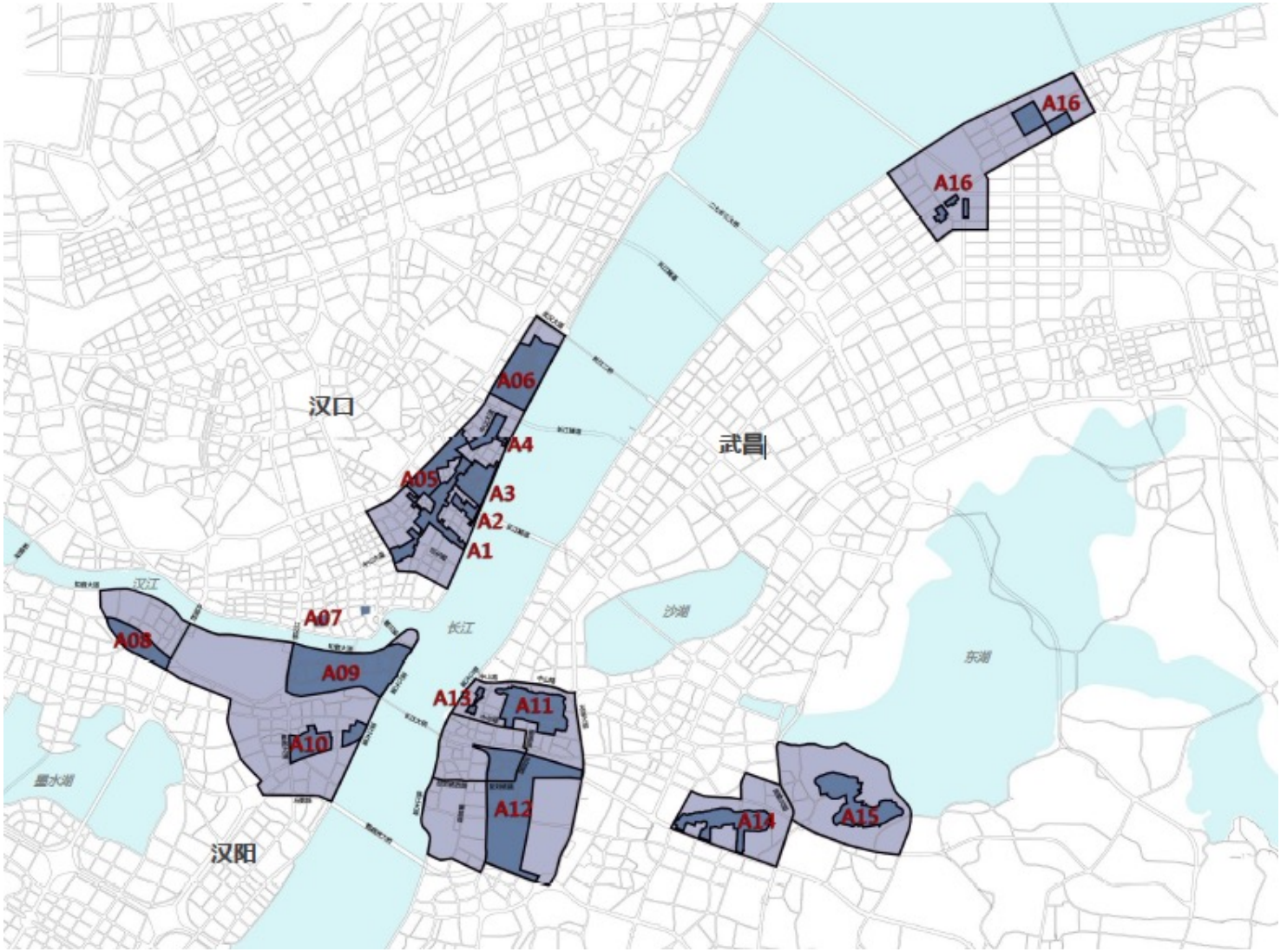
Districts listed in the "Regulations on the Usage of Building Colors and Materials in the Main Urban Area of Wuhan"

Study area

A Core historical districts

- A1 Zhongshan Avenue district
- A2 Qingdao district
- A3 August 7th Meeting Site district
- A4 Yiyuan road district
- A5 Dazhi road district
- A6 Liuhe road district
- A7 Hanzheng street district
- A8 Hangang district
- A9 Guishanbei district
- A10 Xianzheng street district
- A11 Tanhualin district
- A12 Shouyi district
- A13 Nongjiangsuo district
- A14 Hangshan district
- A15 Luojia Hill district
- A16 Qingshan Red Builcing district

A Peripheral historical districts



B Main demonstrative districts

B1 Waterfront of Yangtze River

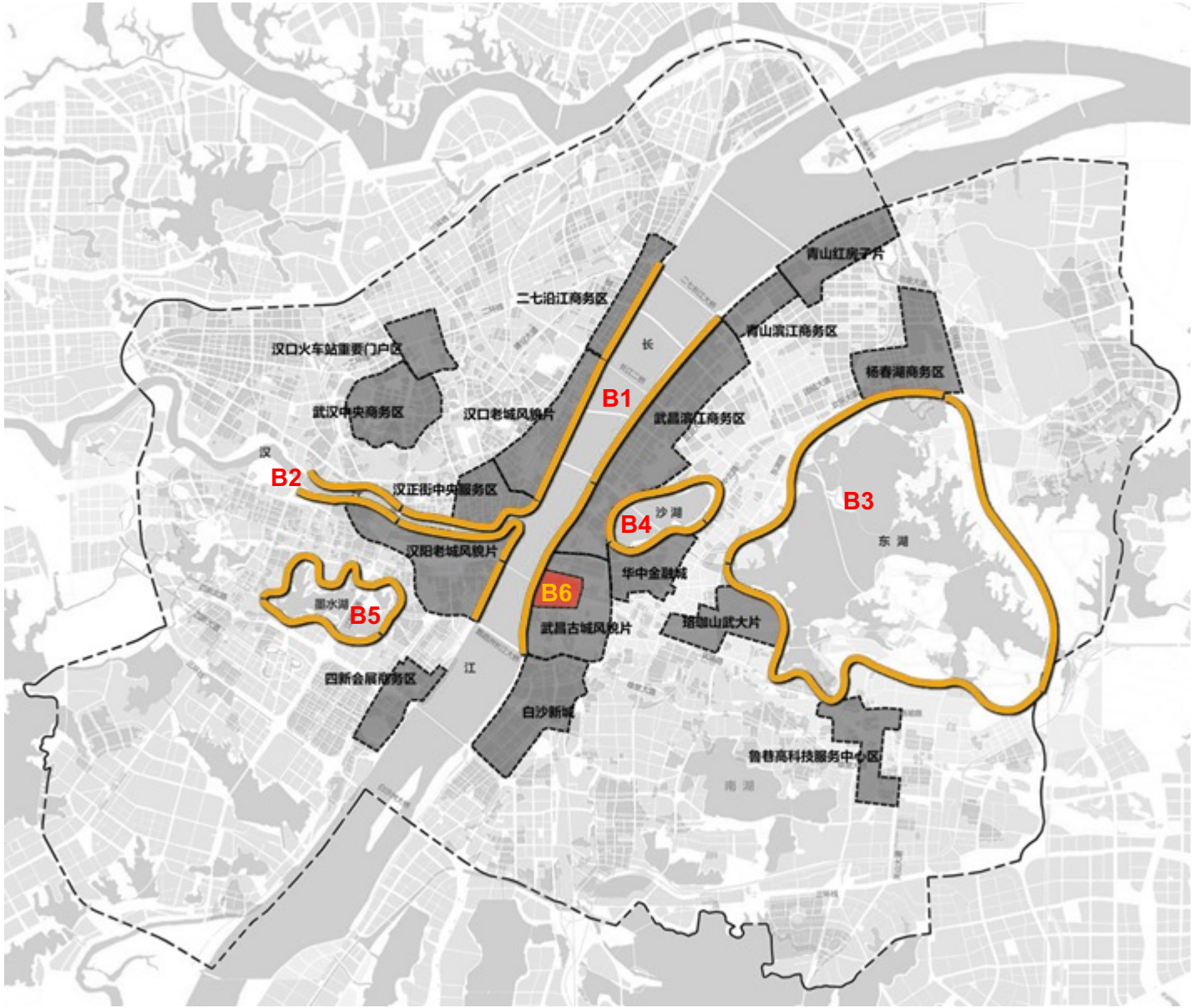
B2 Waterfront of Hanjiang River

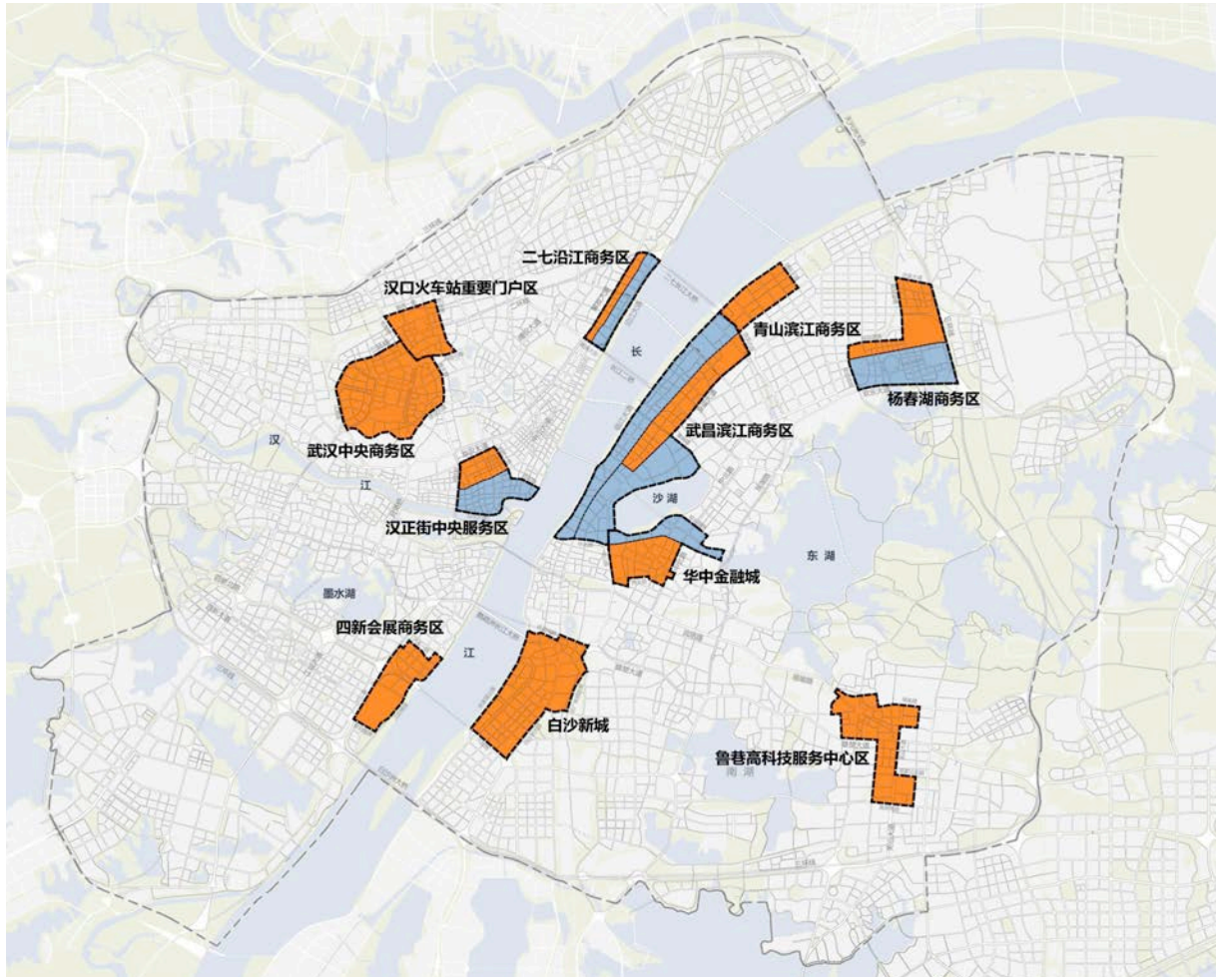
B3 Waterfront of East Lake

B4 Waterfront of Shahu Lake

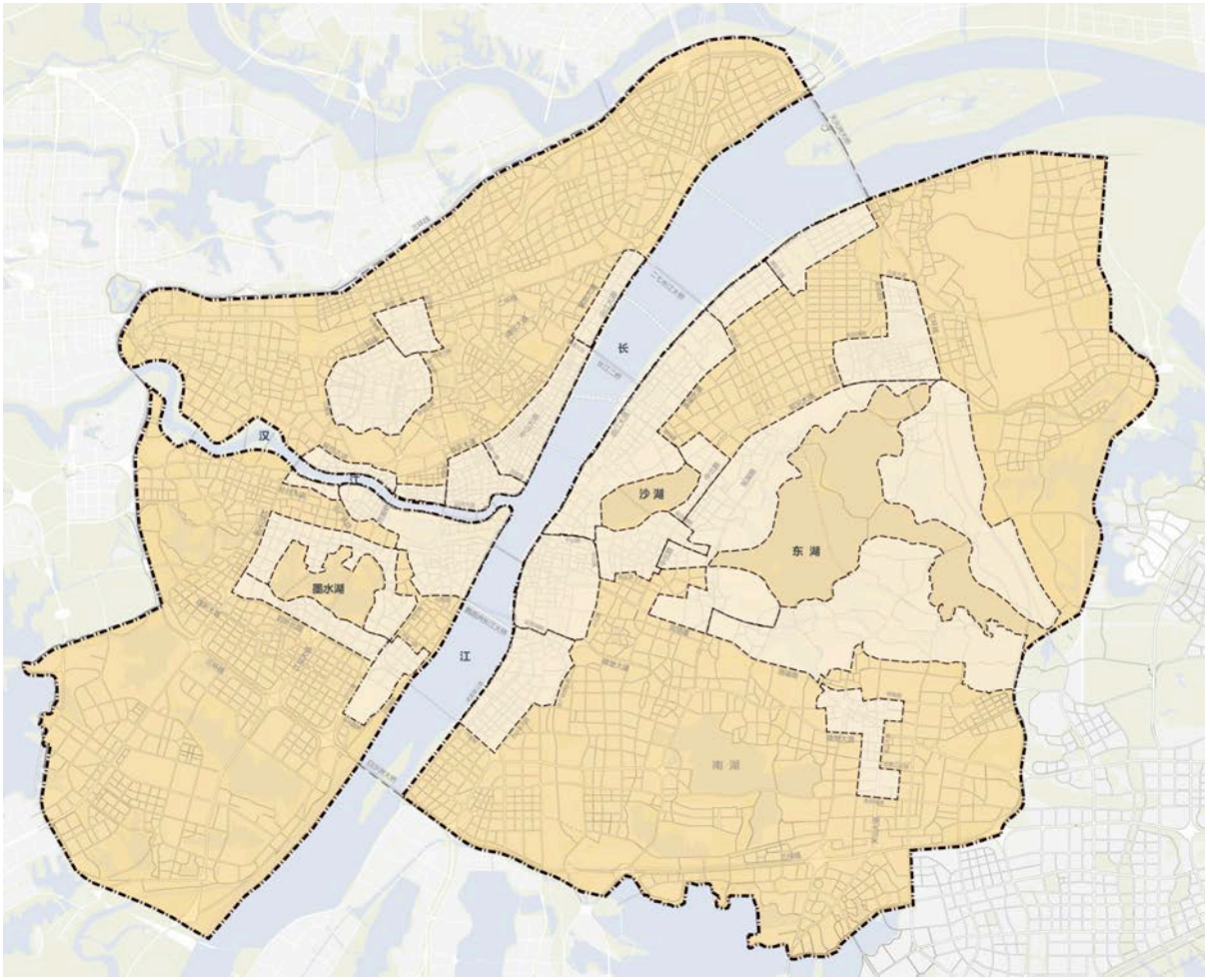
B5 Waterfront of Moshuihu Lake

B6 Yellow Crane Tower district



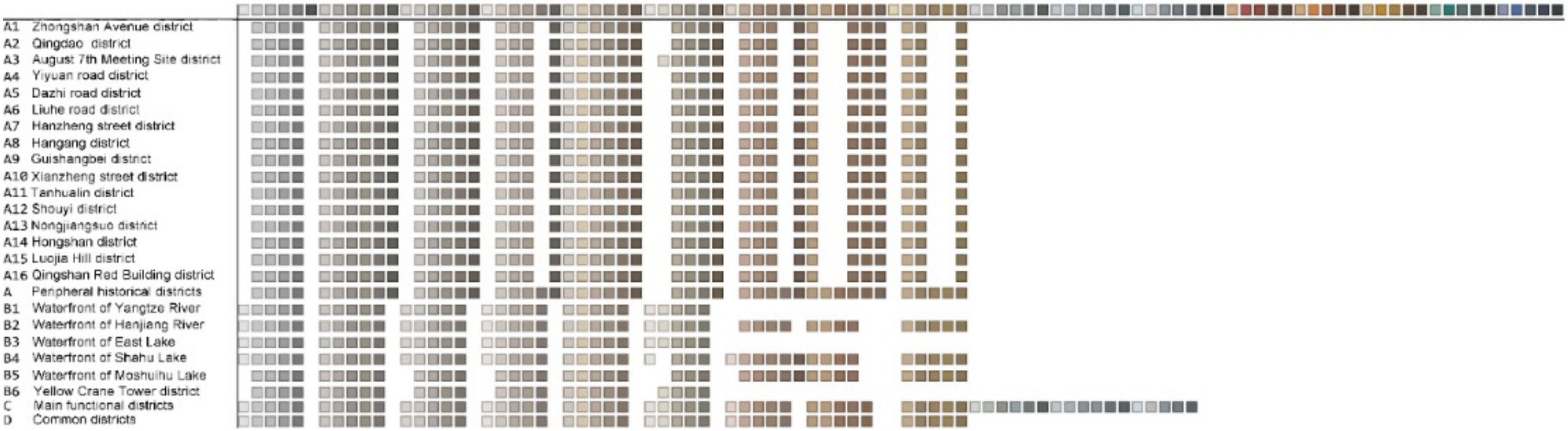


C Main functional districts



D Common districts

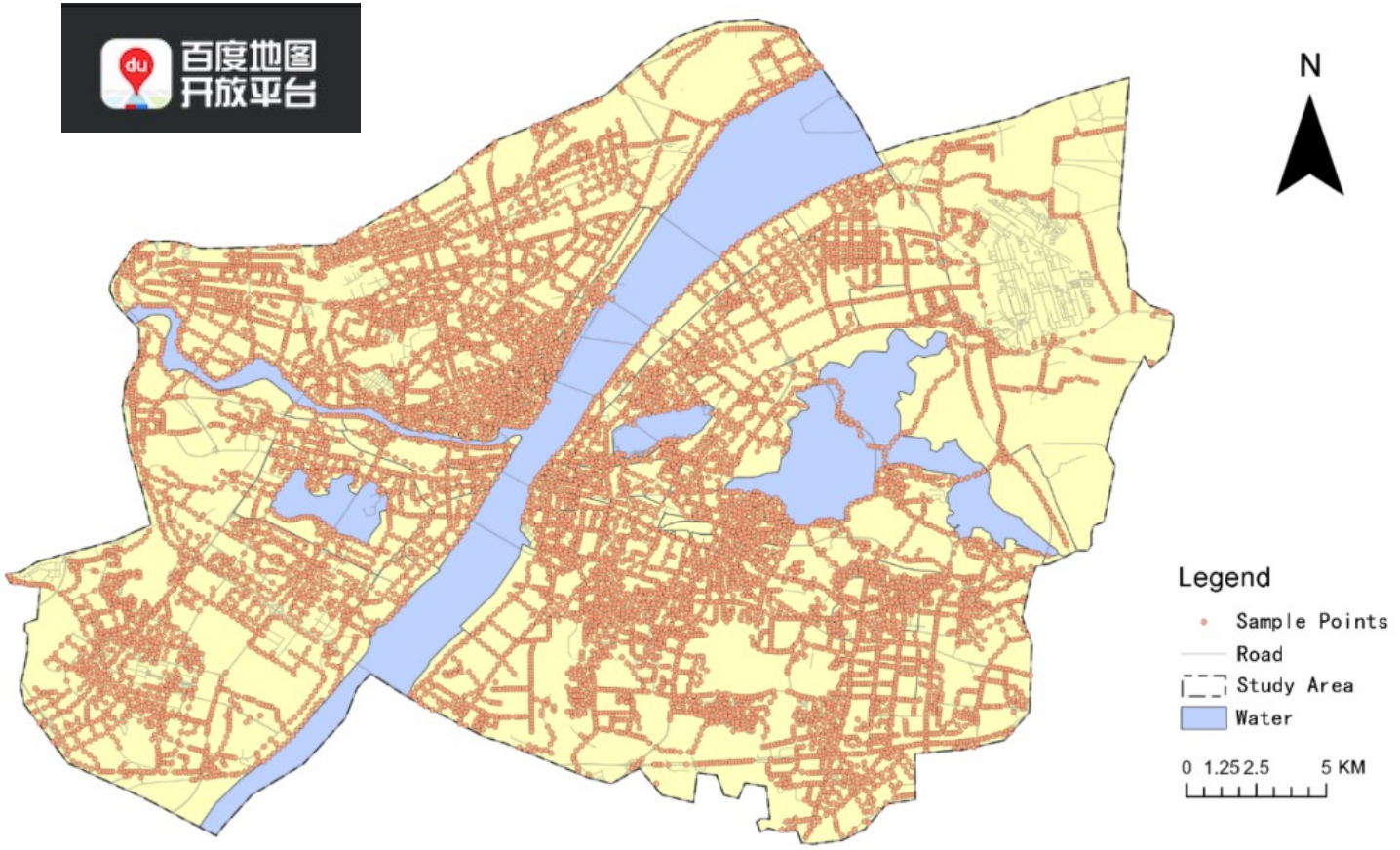
Each district‘s acceptable colors are shown in the figure below .



The acceptable colors of the building façades in different districts in the regulation

Acquiring Panoramic Images

The street vector data in the area are downloaded from OpenStreetMap. The roads and streets located on the ground were screened out by removing the viaducts, underground tunnels, and bridges based on the attributes of the vector data. Then the streets were divided into equal distances with 200m intervals to find the sampling points to acquire the panoramic images .



Sampling points of panoramic images in the main urban area of Wuhan

Projection Transformation

As different areas are not proportional on an equidistant cylindrical projected image, the equidistant cylindrical projected image was transformed to a cylindrical equal-area projected one with the following equations :

$$x_2 = \frac{\pi x_1}{2}$$

$$y_2 = y_0(\sin(\pi y_1 / y_0 - \pi/2)/4 + 1/4)$$

y_0 is the pixel height of the cylindrical equal-area projected image, x_1, x_2 are the corresponding x, y pixel coordinate of the equirectangular projected image, y_1, y_2 are the corresponding x, y pixel coordinate of the cylindrical equal-area projected image (ZHANG et al. 2020).

Equirectangular projected images

Cylindrical equal-area projected images

The transformation from equirectangular projection to cylindrical equal-area projection

Recognize and Extract Building Façade by Semantic Segmentation

The convolutional neural network Dilated ResNet-105 was used to identify and extract the building façade area in the cylindrical equal-area projected image. The training data is from the Cityscapes Dataset. The accuracy of semantic segmentation is measured by Mean Intersection-Over-Union (mIoU), which first computes the IOU for each semantic class and then computes the average over classes (QUAKNINE, 2019).

IoU is defined as follows: IoU = true positive / (true positive + false positive + false negative).

Dilated ResNet-105 achieves an mIoU of 75.6% on the Cityscapes dataset. After removing 917 images that did not contain building façade areas, the remaining 9377 images were binarized to the building façade areas and other areas. The binarized images were then used as masks to extract the building façade areas on the panoramic images .

Semantic segmented images

Extracted façade areas

Semantic segmented images and extracted facade areas

Extracting the Dominant Façade Colors

To reduce the influence of different lighting conditions and shadows cast on the façades, the façade areas which were excessively light or dark were removed before further analysis.

To analyze the dominant colors of the building façades, the color that covers the largest proportion on each image was extracted as the dominant color of the building.

```
In[ ]:= oriPic = ImageResize[  , 120];
        semPic = ImageResize[  , 120];

In[ ]:=

In[ ]:= (*biPic=ImageAssemble[{{ImageTake[Binarize[semPic,{0.274,0.275}],ImageDimensions[oriPic][[2]]/2]},
           {Image[ConstantArray[Black,{ImageDimensions[oriPic][[2]]/2,120}]]}}]*)

In[ ]:= biPic = Binarize[semPic, {0.274, 0.275}]

Out[ ]= 

In[ ]:= buildPic = Image[ColorConvert[SetAlphaChannel[oriPic, biPic], "HSB"], Magnification → 3]

Out[ ]= 

In[ ]:= DC = DominantColors[buildPic, Automatic, {"Coverage"}, "Dataset", Masking → biPic, Method → "KMeans", MinColorDistance → 0.1]

Out[ ]=
```

	Coverage
	0.0239035
	0.0175439
	0.0164474
	0.0100877
	0.00833333
	0.00789474
	0.00394737

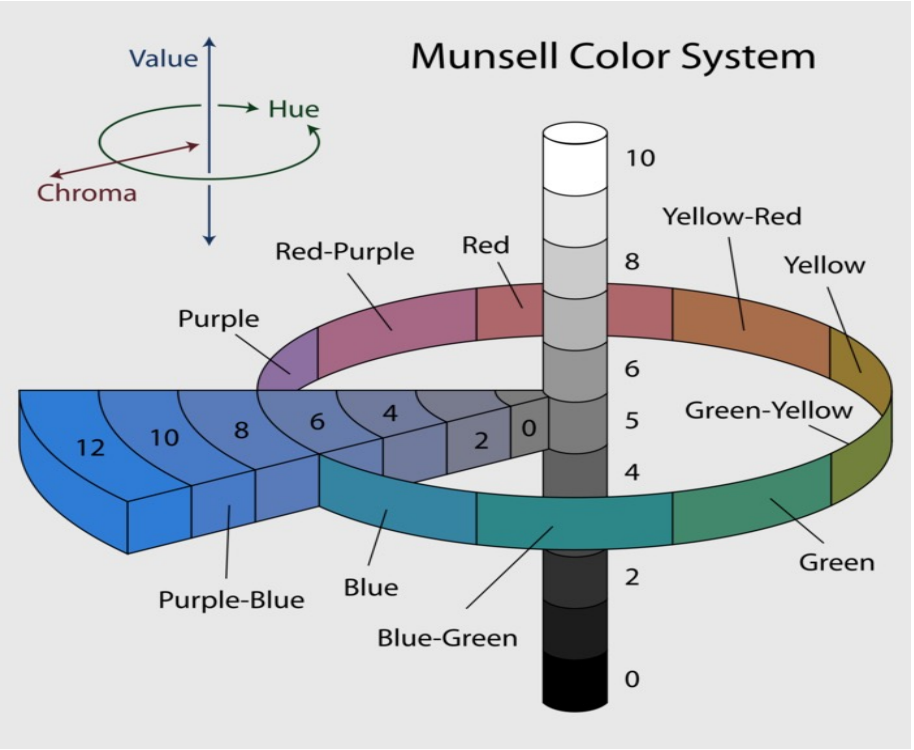
Conversion to the Munsell Color System

The Munsell color system is a color space system proposed by the American painter and art educator Albert H. Munsell in 1898.

This color system expresses the color relationship between Value, Color, and Chroma in a three-dimensional sphere.

It is based on human visual perception of uniform marking colors, making it a reliable scientific basis.

It is widely used in color representation and management, and also used as a standard and tool to define color relationships, evaluate color matching effects, and record color forms.

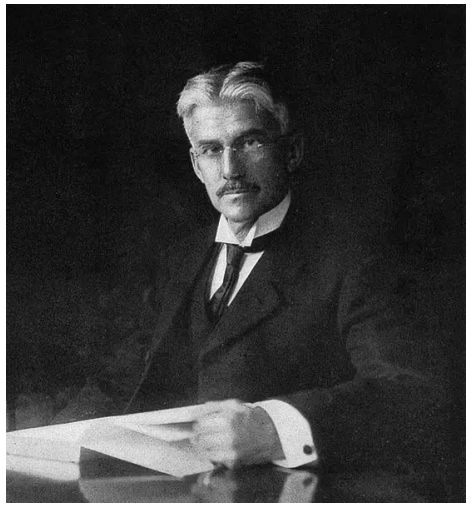


WH-01——Color code (Wuhan version)

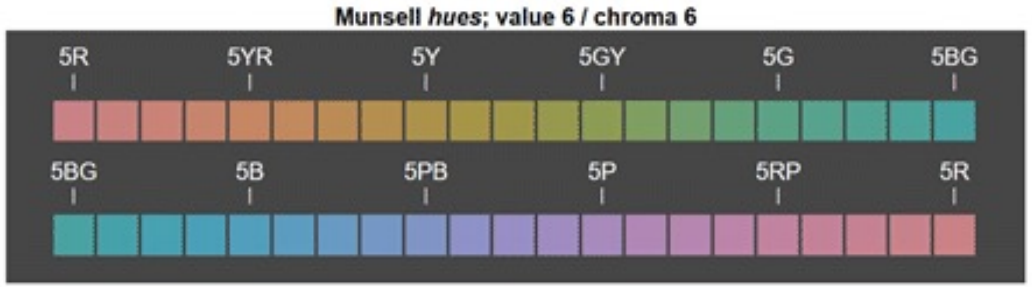
10YR 8/1—— Munsell color value (Reference)

10YR 8 / 1

Hue Value Chroma



Albert H. Munsell

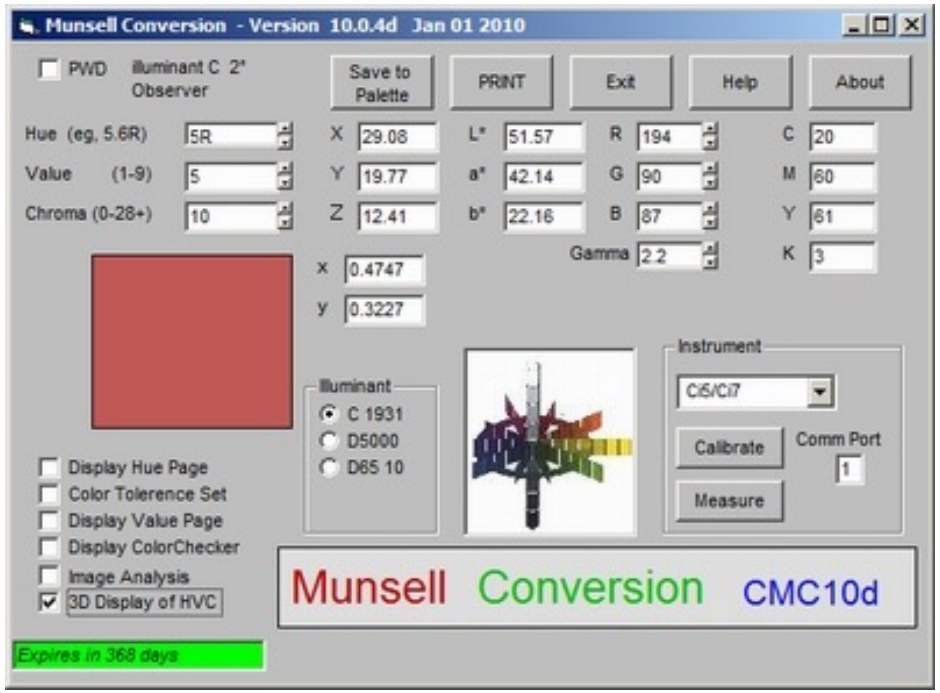


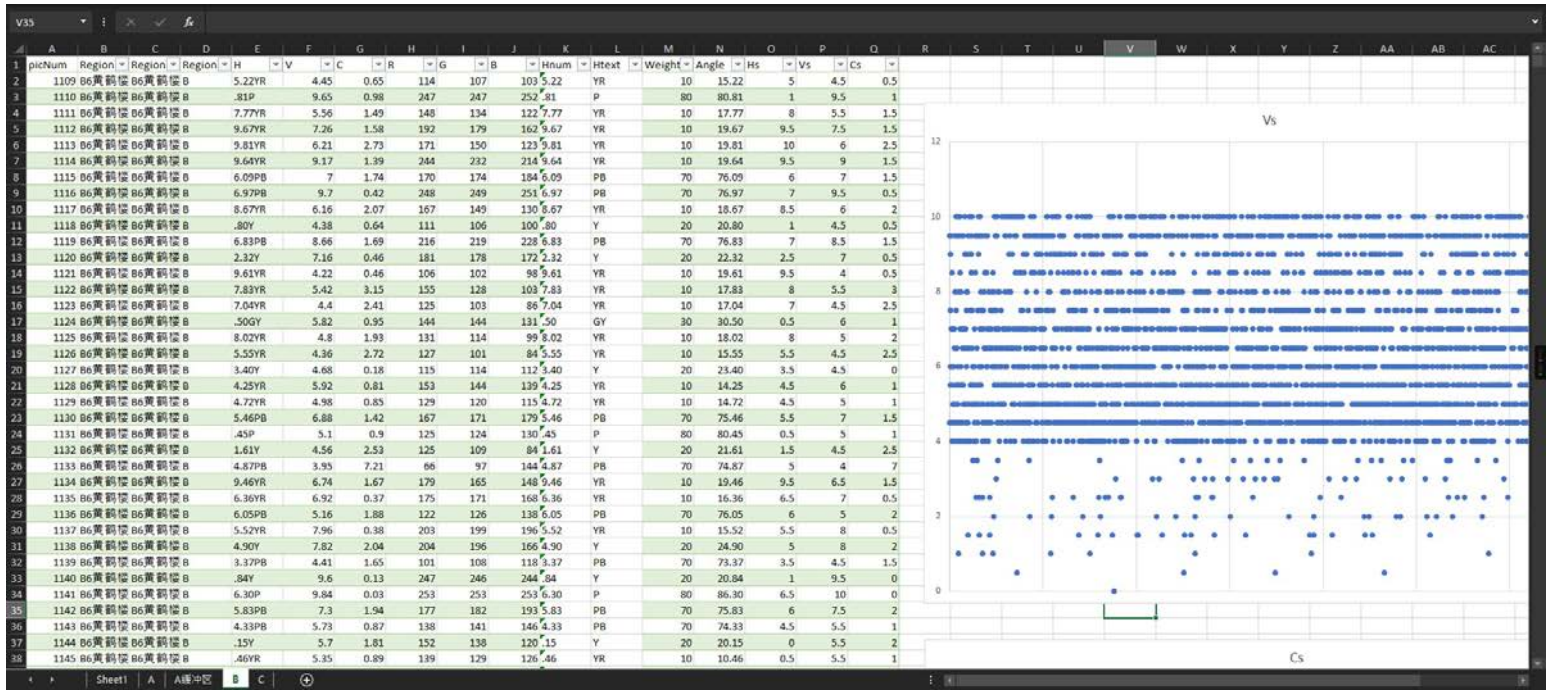
Conversion to the Munsell Color System

The "Regulations on the Usage of Building Colors and Materials in the Main Urban Area of Wuhan" was based on the Munsell color system.

The RGB colors of the façades were then transformed to the Munsell colors based on ASTM D1535 tables with the Illuminat C Observer.

The Munsell Conversion Software by WallkillColor was used to perform the color conversion.





Distribution of dominant colors of buildings

Conclusion and Outlook

The result shows that the dominant colors of the main demonstrative districts, the historical districts, and the waterfront districts are mainly warm.

The typical colors are pale white, slate gray and light brown.

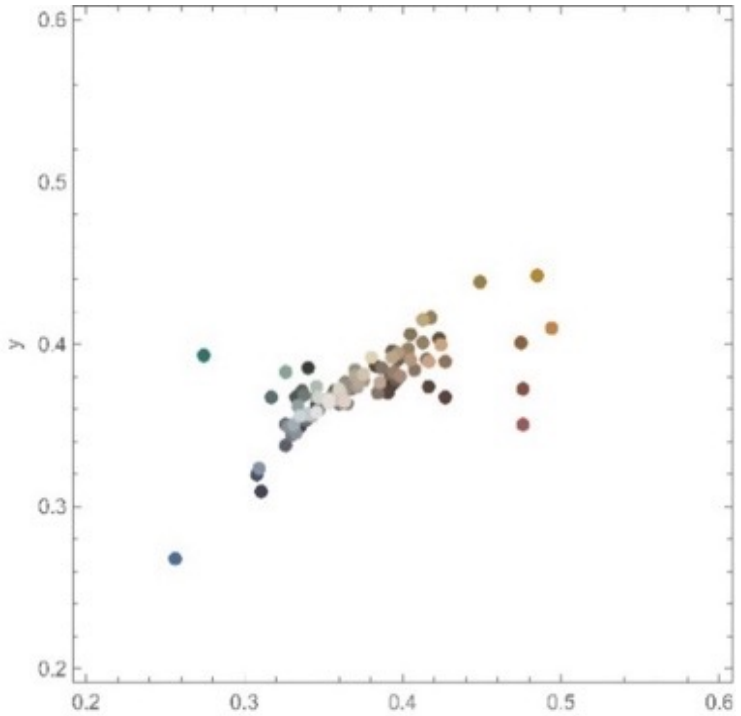
Compared to the requisite colors listed in the "Regulation on the Management of Building Colors and Materials in the Main Urban Area of Wuhan", the difference of façade colors between each district is not very significant.

Further coordination is still needed to highlight the characteristics of different districts in the city.

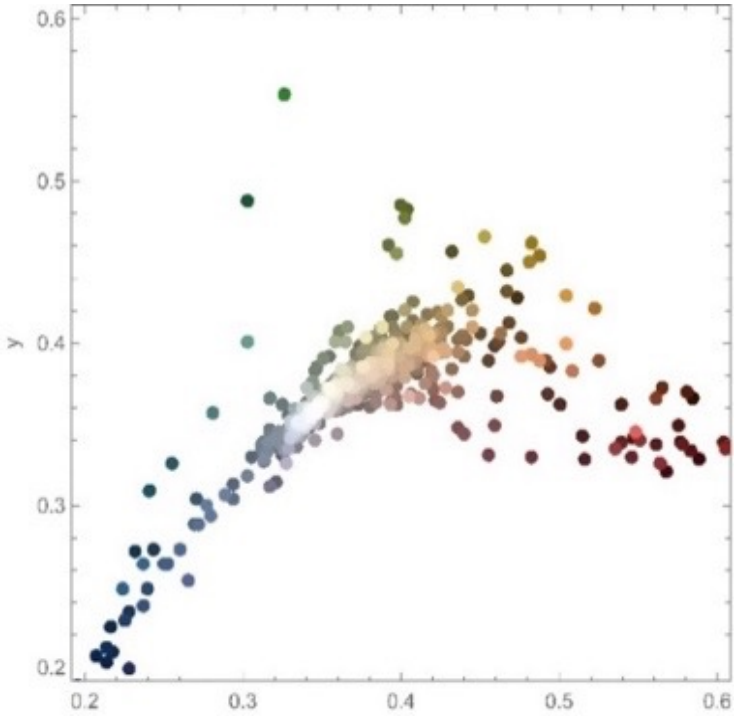
Results and Discussion

A comparison between the 98 Munsell colors recommended in the “Regulations on the Usage of Building Colors and Materials in the Main Urban Area of Wuhan” and the actual dominant colors of the city are illustrated in CIE-XYZ color space.

It can be seen that the colors of the building façades are mostly consistent with the regulations, and there are a few colors such as dark blue, medium green, dark orange, and saddle brown listed outside the regulated color area.



Regulated façade color space



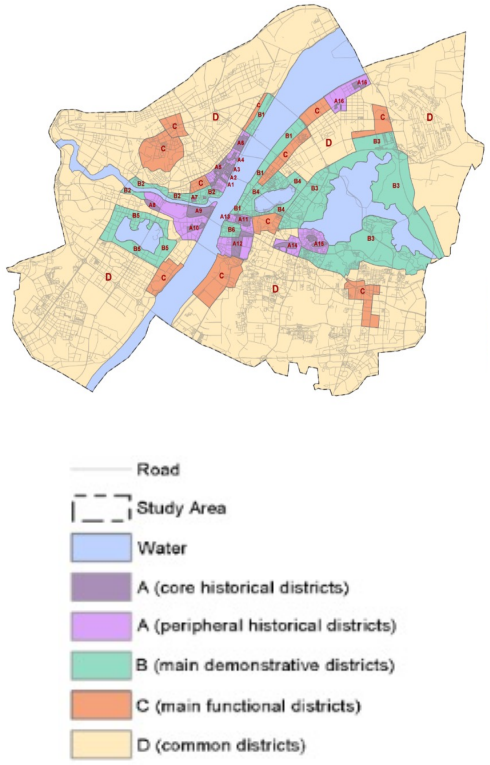
Actual façade color space

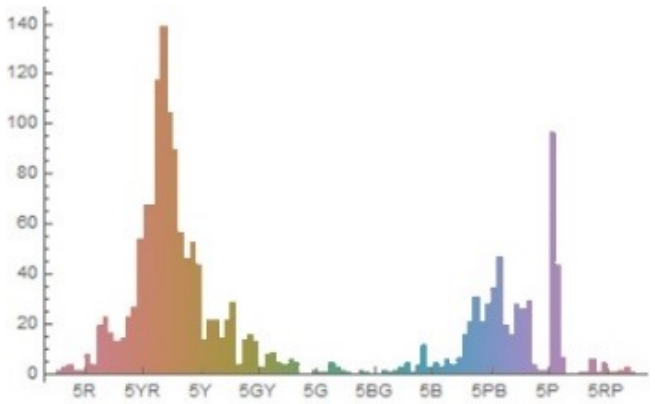
Comparison of regulated and actual façade colors in CIE-XYZ color space

4 Results and Discussion

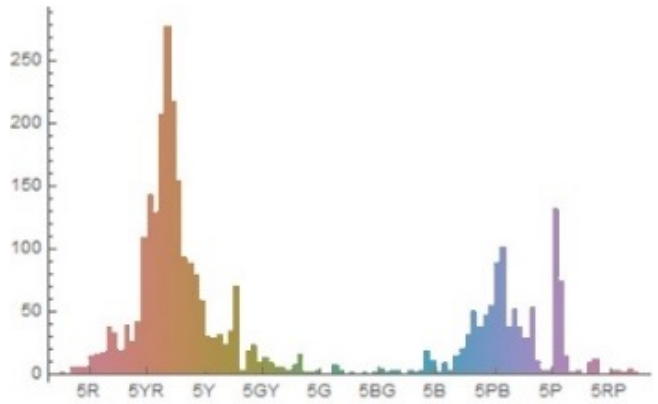
To reduce the complexity and visualize the hue distribution of the dominant colors, the Value and Chroma of each color were unified to 6, and the colors without a hue (pure white to grey) were dropped out. The color distribution of dominant colors in each region are shown in the figure below.

It can be seen that the colors in different districts are mainly distributed between 5YR-5Y with 2 other peaks at 5P and 5PB, which shows that the warm orange and blue-purple are in dominance.

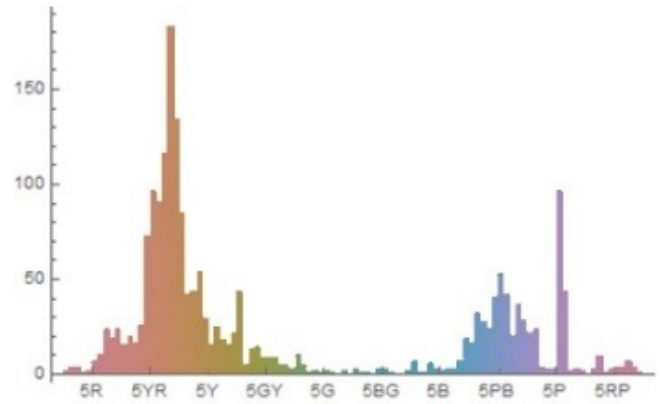




A (historic districts)



B (main demonstrative districts)

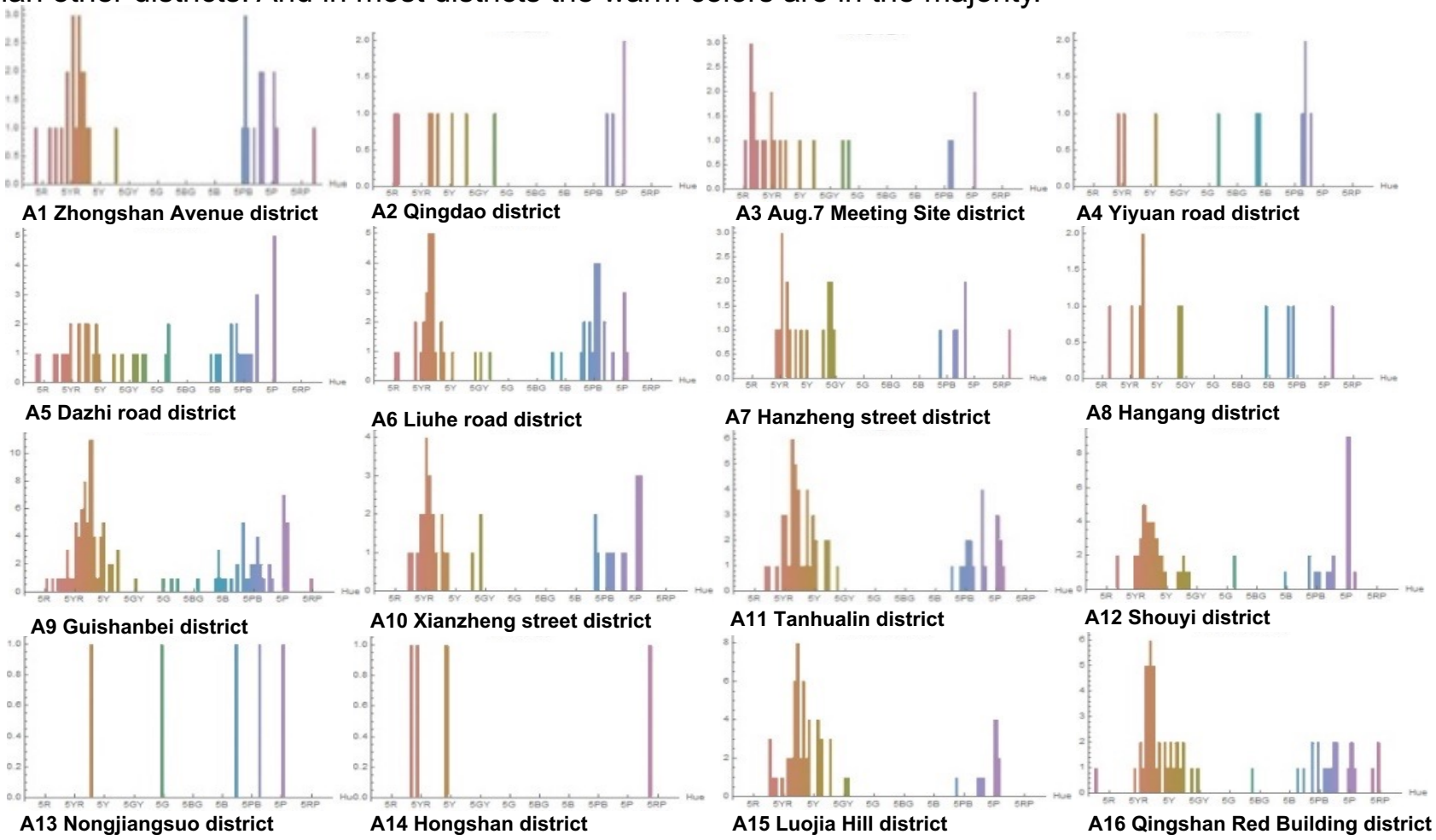


C (main functional area)

Color Distribution of the façades in different districts

The color distribution of historical districts

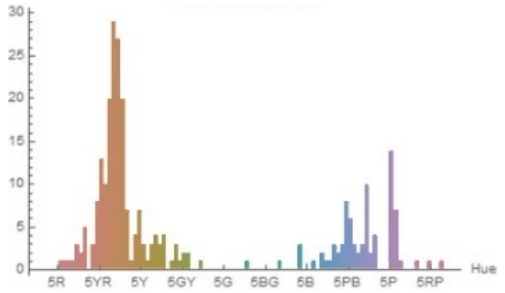
The city of Wuhan has a history of 3500 years. The historical districts of Wuhan contain a number of traditional Chinese and western buildings. Although the recommended colors in the regulation are almost the same in A1 – A16 districts, the hue distribution in different historical districts show that colors are variant. Districts such as A5, A9 and A16 have a wider hue distribution than other districts. And in most districts the warm colors are in the majority.



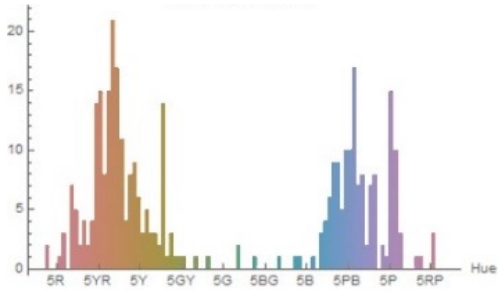
The color distribution of A1—A16 historical district

The color distribution of main demonstrative districts

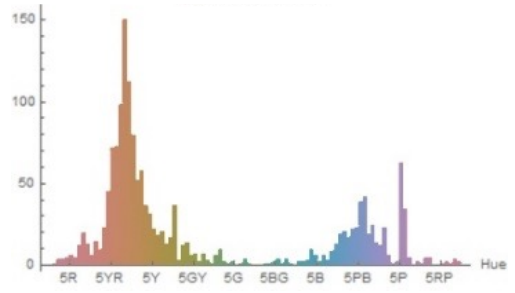
The B1 – B6 districts are the waterfront areas of Wuhan. Some of the districts such as B2 have a wide distribution cold colors from blue to purple while the warm colors are also significant. However, compared to A or C districts, the color difference is not very prominent.



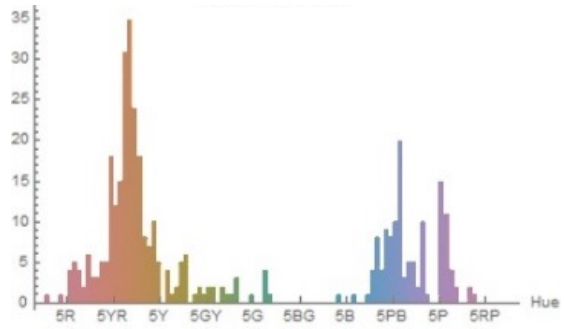
B1 Waterfront of Yangtze River



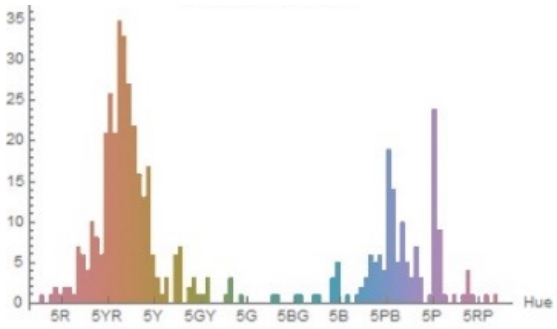
B2 Waterfront of Hanjiang River



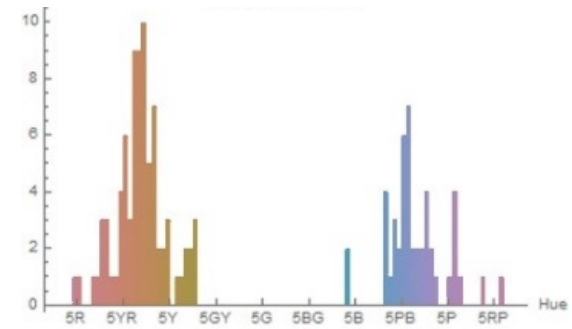
B3 Waterfront of East Lake



B4 Waterfront of Shahu Lake



B5 Waterfront of Moshuihu Lake



B6 Yellow Crane Tower district

The color distribution of main demonstrative districts

Potential Applications

The research proposed a method to automatically identify building dominant façade colors by recognizing and extracting the façade areas on the panoramic street view images.

- The method is suitable for analyzing building façade colors in large-scale areas.
- Compared to traditional manual color sampling and recognition, it can shorten the analysis time, reduce the labor cost, and improve the accuracy of color analysis.
- With the regularly updated panoramic images collected by vehicles, the dynamic change of building colors could be monitored, and the particularly popular/unpopular colors could be found.
- The regulation could be more flexible and adaptive to different developments.

2015-07 2017-06 2019-05

Time sequenced panoramic street view images

Limitations and Future Research

The accuracy of color recognition is influenced by a number of environmental factors.

Limitations of the panoramic images

The street trees and street furniture may block some part of the building façades and will affect the color recognition.

The colors on the panoramic image may deviate from the actual color for some factors such as the time difference of the panoramic street view images were taken and illumination conditions.

Limitations of the neural network model

The accuracy of the neural network model's semantic segmentation limits the accuracy of the recognition results.

Some elements such as cars or pavement that could be misidentified as the building façade area.

Casted shadows or light reflection may also affect the accuracy of color recognition.

More refinement is still needed to make the color analysis process more precise and adaptable to different urban areas.

Building facades blocked by trees

Low light condition

Overexposed

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Thank you!

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