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THE VISUAL QUANTITATIVE ANALYSIS AND EMPIRICAL RESEARCH OF COMMERCIAL PEDESTRIAN STREETSCAPE

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Abstract

Commercial pedestrian streetscape is a corridor with highly artificial visualization, tending to be more rich and diverse as the business center is gathering gradually. To optimize streetscape design and evaluation, it is necessary to propose a measurable quantitative index of landscape visual complexity. In this paper, the visual entropy has been introduced to measure the visual complexity of commercial pedestrian streetscape, the data of which have been calculated by means of MATLAB digital image processing module. And the data have been correlatively analyzed with the evaluation conclusions of a group of interviewers (105 people) by SPSS analysis software. The analysis has indicated a significant correlation between visual entropy and evaluation conclusions, so the visual entropy can be used as a quantitative index for evaluating commercial pedestrian streetscape visual complexity.

Keywords: *Commercial Pedestrian Streetscape;Visual Entropy;Correlation*

1. INTRODUCTION

Roads are important elements of the city, and especially commercial pedestrian streets featuring walking and shopping are important places to appreciate and perceive the visual landscape of the city[1].As a highly artificial visual corridor, commercial pedestrian streets tend to be more rich and diverse as the business center continues to be gathering gradually. The street linear, facades of buildings along the street, shop advertising signs, street skyline, street paving, lighting, planting and so on are all important parts of its visual contents. At the same time, the visual characteristics become more complex because of the three-dimensional and staggered tendency of streetscape as a result of growing number of surrounding high-rise buildings[2].(Figure 1). For the moment visual evaluation of landscape is mostly focused on the qualitative analysis and evaluation，while with the systematization, platform and technicalization of landscape evaluation, quantitative assessment is becoming more and more important.

Figure.1 Typical Commercial Pedestrian Streetscape Picture

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2. VISUAL ANALYSIS OF COMMERCIAL PEDESTRIAN STREETSCAPE

Commercial pedestrian streets are usually located in a business center, the both sides of whose frontages are transformed into various shops and commercial space and whose facade is also focused on commercial signs. Because of the characteristics of commercialization and walking, a series of characters have been developed in the street pavement in the following aspects:

2.1Restricted Sight

With the increase of high-rise buildings surrounding the pedestrian streets, the distance and angle of sight are significantly restricted. In the horizontal direction, the searching route of pedestrian vision are more affected by the shape of streets,and their signt focuses on the store and the traveling direction of the both sides; In the vertical direction, the vision mostly contain lower portion of the street construction because of the vertical angle limit of human head. Affected by pedestrian traveling lines, the visual features have relationship with the ratio of linear and aspect, showing the significant restricted sight.

2.2 The Diversification, Complexity And Fragment Of Landscape Elements

Attracted by commercial positioning and crowd together, many businesses and brands will compete for settlement. With high load commercial presence in a limited space, settled merchants will maximize the commercial effect in smallest business area inevitably. The facade of the building are seriously obscured by shop signs perpendicular to the street. Thus small landscape elements will have been damaged seriously, showing the characteristics of complication and diversity.

2.3 Paved Ground

Without vehicle load, grounds are paved with more abundant kinds of materials of color and texture such as multi-stones translucent glass, copper decorative patterns and parquet and systematic design. Paved grounds have become another important addition visual contents besides the building facade and sky background.

2.4 The Visual Features Of Slow Walking

Different from those in urban main roads, the pedestrians walk at the speed of 5km/h in pedestrian shopping streets, whose visual axis is biased downward about 10 °.Thus people pay more attention to the ground and the street construction bottom. In slow walking, pedestrians have a stronger ability of capturing, searching and processing information, and they will pay more attention to the surrounding shops decoration, exhibits and other details. Therefore, the design of the street should be beneficial to the walking scale and it's more important to deal with details [3].

3. RELATED RESEARCH

In recent years, with the progress of China's urbanization, the mode of urban construction is being transformed from quantity growth to quality promotion. There is an increasing number of researches on urban landscape and streetscape visual evaluation. Summarizing the published documents, the research is mainly divided into two areas:

(1) Research on evaluation methods of the urban streetscape.

In this ares the Analytic Hierarchy Process and Multi-factor Analysis are often studied. For example, Li Kunlun specifically has calculated the weight of urban road landscape evaluate index system with Analytic Hierarchy Process [4], and Wang Junhong has estimated weight of the urban expressway landscape impact evaluation with Analytic Hierarchy Process[5].

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Qin Qing has studied the evaluation method of landscape of a Xi'an street by Multi-factor Analysis method, and proposed the measures at different levels [6];etc.

(2) Research on quantitative methods of index.

For example, Jia Zhirong has evaluated the visual effects of seven different cutting slope with the SD method. The research results showed that the visual effects of the Road slope Landscape was composed of three evaluation shaft, and through the analysis Jia proposed the method of how to improve visual quality of landscape[7]. Lv Hongliang has proposed a set of landscape assessment methods of operability, in which the concept of indicators and standardized approach are improved, and the compatibility of the road and surrounding landscape is investigated[8]. Yuan Feng has studied the urban landscape quality evaluation models and classified them. He believes that quantitative evaluation is an ideal method especially in a computer aid-ed model and more complete evaluation conclusions will be achieved with the combination of qualitative and quantitative evaluation [9]. At the same time some researchers has begun to focus on quantitative evaluation that is different from traditional qualitative evaluation, and proposed some valuable evaluation indicators. Chen Wei has made a quantitive comparison between traditional commercial streets and modern commercial streets with the help of fractal geometry quantitative methods and entropy value calculation [10]. Wang Jianfeng has analyzed urban heterogeneity, streetscape and skyline with information entropy and spatial scale quantitative indicators[11], which is innovative to some extent. Besides some landscape designers and researchers have studied the streetscape deeply in the aspects of street space characteristics, human visual characteristics and landscape sequence organization [4,12].

In conclusion, qualitative analysis is focused on in most of the mentioned evaluation methods on the visual features of streetscape with descriptive words to expressions, which is in conformity with the viewers' thinking and expressing habits and simple in terms of operation. However, by the method of qualitative evaluation no firm generalization of inherent properties of landscape can be made and it is not accurate and scientific enough to make relative policies and regulations. In recent years, some researchers have found that the information entropy is a more effective quantitative indicator in the description of the richness and complexity of the function space in their study on urban spatial structure[13]. In the study of the urban landscape vision, some researchers have used visual entropy as an indicator for describing urban plane shape and space facade richness , and acquired some exploratory academic achievements [14].

However, there exist few studies on the relationship between the quantitative indicators of landscape and people's subjective evaluation. This paper has focused on whether there is a certain correlation between the visual attributes of landscape and people's subjective evaluation conclusions and the strength of the correlation .

4. DEFINITION OF VISUAL ENTROPY

In 1850, Rudolf Clausius proposed the concept of entropy which is mainly used to describe the degree of disorder in thermodynamics[15]. Later, entropy was used as a basic and important concept in different disciplines. At the moment in the field of image process, researchers have described human subjective measurement for visual information with the visual entropy , which is consistent with the human visual characteristics and easy to quantify analysis [16][17].

Theoretically, visual entropy is defined in

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accordance with pixels order of the gray image, which reflects the degree of information richness and distribution of noise. Although entropy can not reflect the details of the image, it is significant to reflect the richness of images[18].

When there are N significant boundary regions or units in one visual object of landscape, the probability of occurrence of the i-th area is Pi(i=1,2,3,n)，and the information amount is $H = -\log P_i$, so as a whole visual object including N regions, its information amounts to ： $H = -\sum_{i=1}^{n} P_i \log P_i$, which can reflect the complexity degree of a visual object we can name as visual entropy[19].

5. THE COMPUTER ANALYSIS PROCESS OF VISUAL ENTROPY

Although as an important indicator visual entropy can reflect the visual complexity and richness of landscape, it is still impossible to have manual measurement and analysis and calculation of physical landscape or optical photos because of complexity of landscape itself and measurement difficulty in geometric parameters. With the help of digital photography and image processing technology which have been mature, it may be realizable to take visual entropy analysis of real digital images of landscape. The landscape evaluation method with real images has been widely recognized by the psychophysical school for its high reliability and validity[20].

5.1 Format Of The Image

The digital images for this research are taken with digital cameras at an angle simulating that of human observation. Most of them are in the format of JPEG, which is one of the most widely used formats of digital images and used as a common format in digital cameras on the market currently and one of the important image formats on the network and CD-ROM reading.

5.2 Calculation Process Of Visual Entropy

There are many software tools for digital image process, one of which is MATLAB with the significant advantages of high computing efficiency, better interface and being more generic. A dedicated toolbox has been launched for digital image processing in MATLAB, containing a series of image processing operations functions[21][22].

On MATLAB platform, visual entropy calculation process includes:

(1) reading and grayscale of the images;

(2) improving the contrast of image grayscale with the method of histogram equalization ;

(3)segmenting the images with the method of the region growing;

(4) calculating the area of each divided regions;

(5)calculating the visual entropy results, and output them.

The key algorithm is as follows:

```
   x1=round(1+rand(1,1)*(M-1));
   y1=round(1+rand(1,1)*(N-1));
[suit1,Y]=unitregiongrow(I,M,N,threshold,x1,y1)
;
   A(1)=suit1;
   Entropy=Entropy-(suit1/S)*log(suit1/S);
   imtool(Y) ;
     for p=2:k
       x2=round(1+rand(1,1)*(M-1));
y2=round(1+rand(1,1)*(N-1));
[suit2,Y]=unitregiongrow(I,M,N,threshold,x2,y2)
;
fprintf('The number is %3.0f\n',p)
  if suit2==A
          suit2=S;
          else
            A(p)=suit2;
            Entropy=Entropy-(suit2/S)*
log(suit2/S);
```

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```
        imtool(Y);
      end
```

The cycle function key algorithm is as follows:

```
   function
[suit,Y]=unitregiongrow(I,M,N,threshold,x,y)
   while count>0
     gray=0;
      count=0;
      for i=1:M
        for j=1:N
          if Y(i,j)==1
  if (i-1)>0 && (i+1)<(M+1) && (j-1)>0 &&
(j+1)<(N+1)
   for u= -1:1
   for v=-1:1
     if Y(i+u,j+v)==0 &
abs(I(i+u,j+v)-seed)<=threshold &
1/(1+1/15*abs(I(i+u,j+v)-seed))>0.1
   Y(i+u,j+v)=1;
     count=count+1;
     gray=gray+I(i+u,j+v);
               end
             end
            end
         end
      end
    end
   suit=suit+count;
  end
```

5.3 The Result Of Image Analysis

In this paper 10 famous pedestrian streets are selected as the research objects (Figure 2), the images of which have been processed and analyzed.

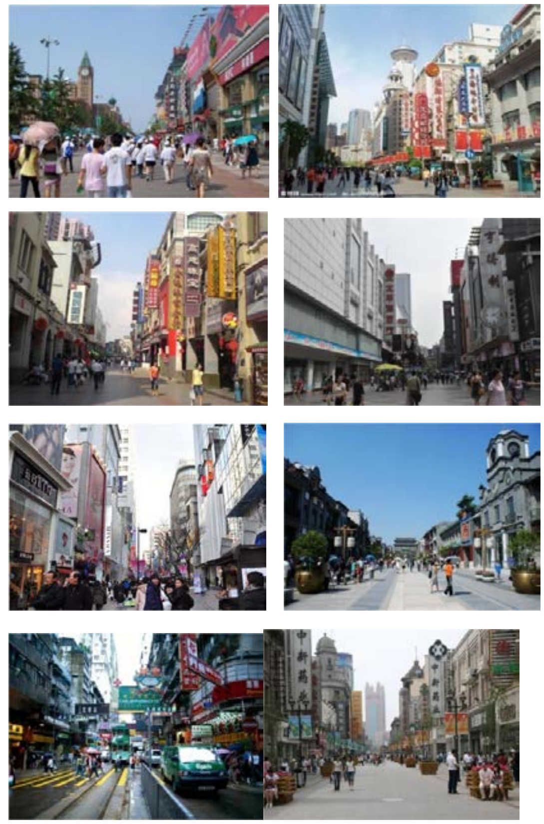


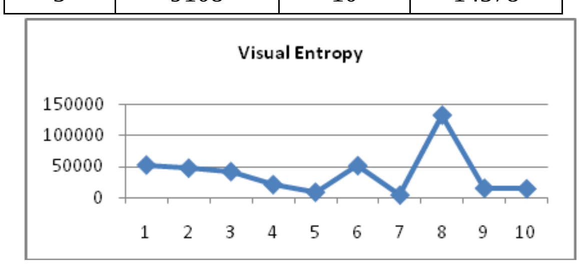
Figure 2. Real Pictures Of Commercial Pedestrian Streetscape

5.4 The Calculation Results Of Visual Entropy

The calculation results and line chart about visual entropy of each image are as follows.

Table 1. Visual Entropy Calculation Results

Image No.	Visual Entropy	Image No.	Visual Entropy
1	52856	6	51853
2	47869	7	4484
3	42323	8	133191
4	21317	9	15461
5	9108	10	14578



Figuer 3. The Line Chart Of Visual Entropy

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6. THE SUBJECTIVE EVALUATION OF VISUAL COMPLEXITY OF PEDESTRIAN STREETSCAPE

In this process, 10 JPEG images of pedestrian streetscape have been showed on the projection slides as the evaluated objects to the respondents who are sophomores from school of architecture in a domestic university, with good ability of evaluation and aesthetic standard. In total there are 112 copies of questionnaires, of which 105 copies are valid.

The questionnaire was designed in SD method [23][24]. The evaluation table used in SD method is a collection of odd-stage scales. Each scale marks out a visual attribute of the measured landscape. Such as openness or closure, brightness or darkness, etc. The degrees on each direction are, in order, "general", "preferable", "still more" and "very", corresponding to the quantized values of 0, 1, 2, 3, with 7 degrees in all. The questionnaire of relevant semantic differentiation is shown in Figure 4.

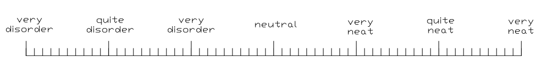

Figure 4. Semantic Differentiation Questionnaire On The Visual Complexity Of Pedestrian Streetscape

The average evaluation conclusions are as follows:

Table 2. Average Rating Of Evaluation Values

Image No.	Evaluation Value	Image No.	Evaluation Value
1	0.700	6	0.070
2	0.248	7	-0.195
3	0.466	8	1.606
4	-0.264	9	-1.800
5	-0.237	10	0.060

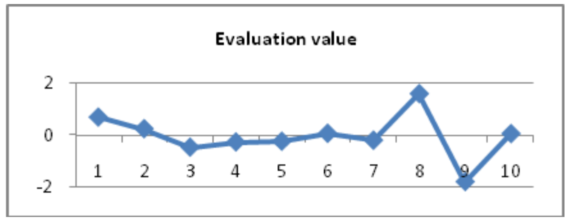

Figure 5. The Line Chart Of Average Rating Of Evaluation Values

7. RESULTS AND DISCUSSION

Visual entropy and Average rating evaluation value are analyzed by IBM SPSS software, and the bivariate scatter plot and related analytical values are shown in Figure 6 and Table 3:

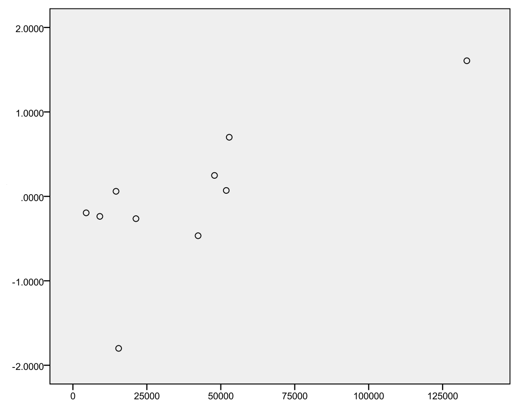

Figure 6. Evaluation Value—Visual Entropy Variable Scatterplot

Table 3. Table Of Correlation Analysis Results

		Visual Entropy	Evaluation value
Visual Entropy	Person correlation	1	0.753**
	Significant(bilateral)		0.012
	N	10	10
Evaluation value	Person correlation	0.753**	1
	Significant(bilateral)	0.012	
	N	10	10

**. Significantly correlated at the 0.01 level (bilateral).

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According to the bivariate Pearson correlation test, the correlation coefficient between the visual entropy and the visual complexity was 0.753 at the 0.05 level (bilateral) , P = 0.012, showing that there is a significant correlation between the visual attributes of a landscape and people's indicator to measure the visual complexity of landscape, and thus provides a reference for the evaluation of visual orderliness.

When an image have a bigger visual entropy, its degree of orderliness is higher; when an image have smaller visual entropy, its degree of orderliness is lower. This result is not consistent with the common sense of daily life and further research is needed to explore its own rules;

In this study, the amount of objects (ten streets) is small, resulting in less data gathering; the sample size should be enlarged for a more clear result in further study;

The studied digital images of streets are not shot under similar weather conditions; the difference of the image brightness may give rise to deviation of visual entropy calculation because of the boundary recognition differences. Further research is required to make use of the photographs under the same or similar weather conditions.

The calculating method of visual entropy is available for some improvement, such as adding the color values or brightness values of the images, which may be conducive to find out other possible correlation between the visual entropy and visual complexity;

Based on the definition and calculation of the visual entropy, the differences in the fineness of the image cannot produce a significant impact on information entropy values.

8. Conclusions

This paper introduces the visual entropy to weigh the visual complexity of the commercial pedestrian streetscape, calculates the visual entropy by means of MATLAB digital image-processing module and makes a correlation analysis between subjective evaluations and the visual entropy from the questionnaires of a group of 105 respondents by SPSS software. The analysis indicates that a significant correlation exists between the visual entropy and evaluation conclusions and that the visual entropy can be applied as a quantitative index for the visual complexity of pedestrian commercial streetscape.

The principle of measuring the visual complexity by visual entropy can also apply to other types of landscape. Further relevant studies are needed.

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