

Using Eye-tracking and Deep Learning Approach to Promote Naturalness in Urban Landscape

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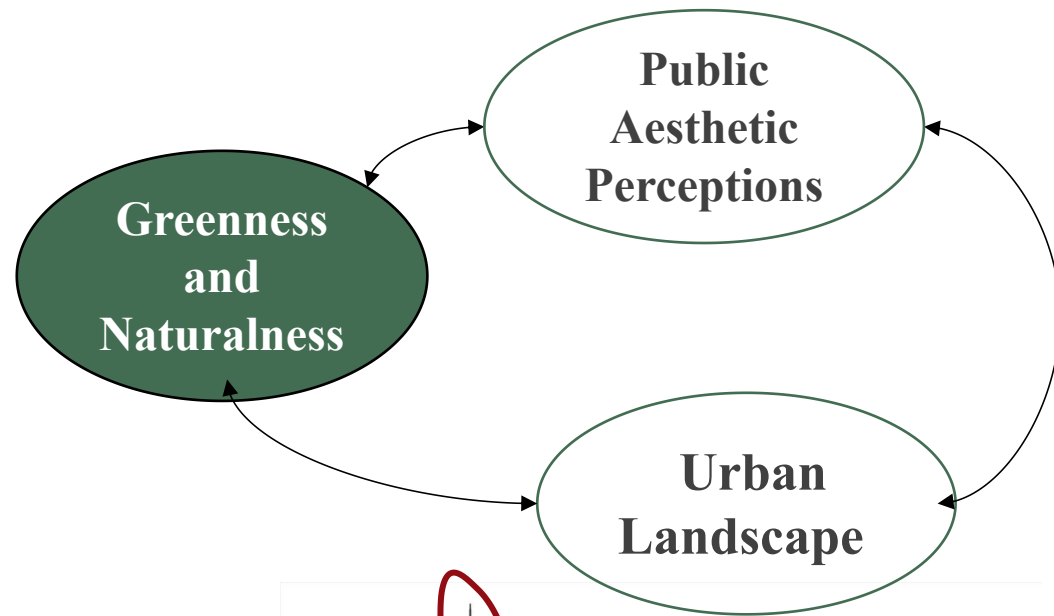
SHANGHAI JIAO TONG UNIVERSITY

MAY 05, 2020



Research question:

How to explore the cognitive conceptual mechanism of urban landscape aesthetics (Naturalness) from the perspective of the public?



GAP:

- Urban naturalness needs to be improved;
- Current measures of plannings and designs separated naturalness from public appreciation and acceptance;

Method:

- Deep Learning image segmentation and eye tracker;
- Bayesian networks aesthetic modelling;
- Public questionnaire and data analysis;

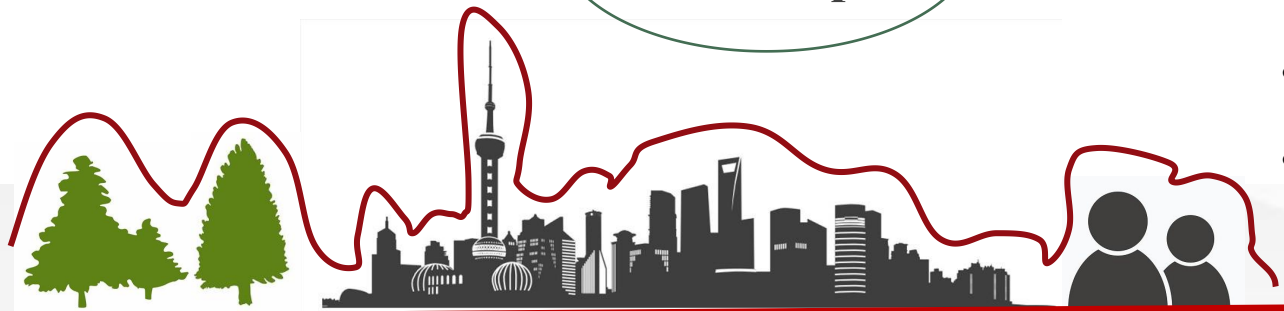
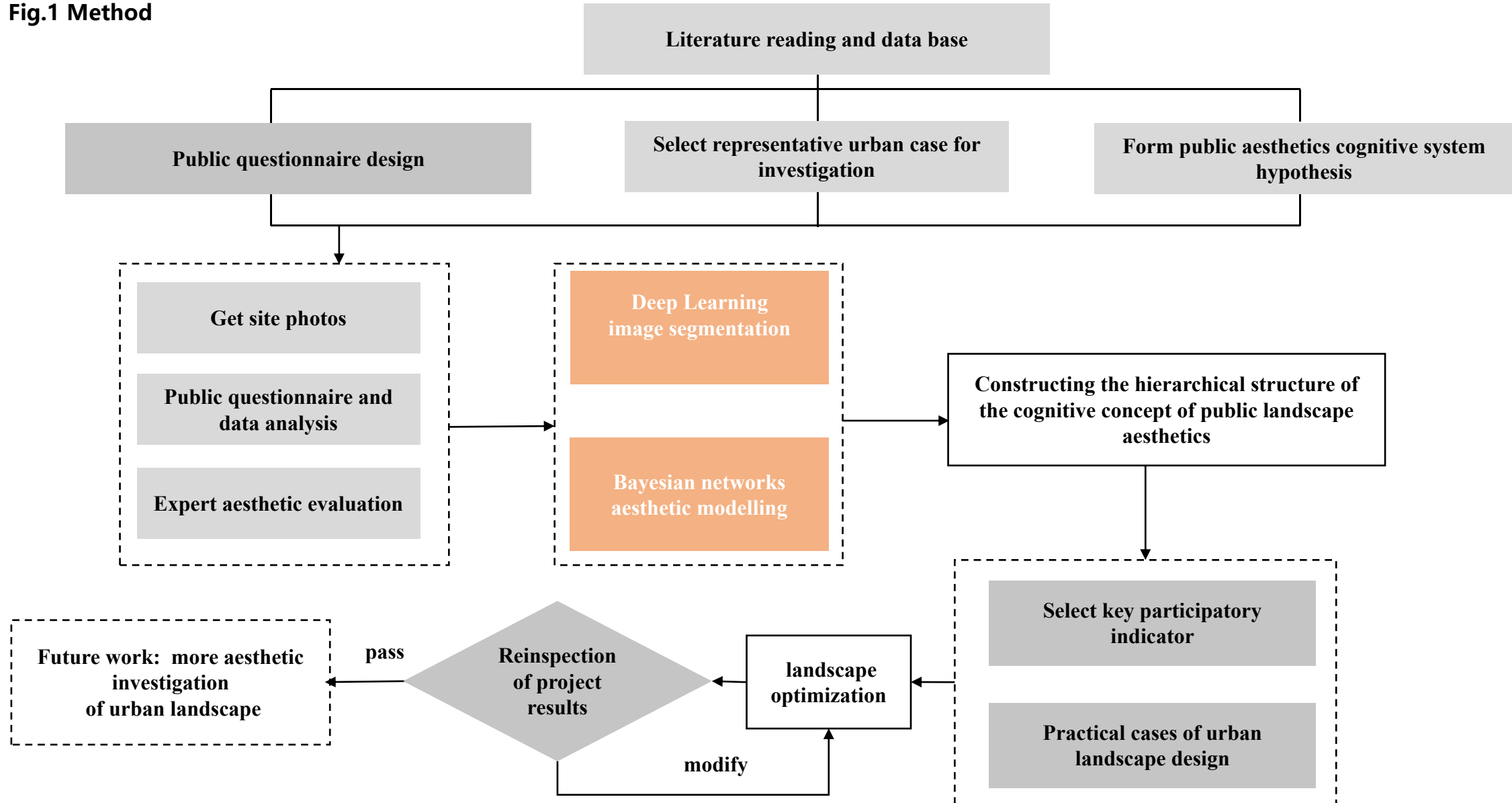




Fig.1 Method



Select research case and start investigation

- Choose **Guangzhong road and Pingxingguan road** in Shanghai as research case to take photos
- **Semi-structured cognitive interviews** were conducted to the surrounding public (38 valid questionnaires were collected).
- Recruit the public to evaluate the urban landscape through **Internet**, (269 valid questionnaires were collected)



Fig.2 Study site location

4. 请选择以下20张图片中您认为最喜欢的五张图片。
Please select five of the following 20 pictures that you like most.

L1 L2 L3 L4 L5

H1
H2
H3
H4

[矩阵多选题] *

请在图片对应的位置上进行勾选 (L1代表第一行, H1代表第一列)。
Please select the corresponding position in the picture (L1 represents the first row, H1 represents the first column).

如果您认为存在选择困难, 可以选取多于5张图片, 但不能少于5个。
If you think it is difficult to choose, you can choose more than 5 pictures, but not less than 5 pictures

	L1	L2	L3	L4	L5
H1	☐	☐	☐	☐	☐
H2	☐	☐	☐	☐	☐
H3	☐	☐	☐	☐	☐
H4	☐	☐	☐	☐	☐

Fig.3 Questionnaires

6. 请选择以下20张图片中您认为视觉对比度最高的五张图片。
Please select five of the following 20 pictures that you think have the highest visual contrast.

请在图片对应的位置上进行勾选 (L1代表第一行, H1代表第一列)。
Please select the corresponding position in the picture (L1 represents the first row, H1 represents the first column).

如果您认为存在选择困难, 可以选择多于5张图片, 但不能少于5个。
If you think it is difficult to choose, you can choose more than 5 pictures, but not less than 5 pictures

	L1	L2	L3	L4	L5
H1	☐	☐	☐	☐	☐
H2	☐	☐	☐	☐	☐
H3	☐	☐	☐	☐	☐
H4	☐	☐	☐	☐	☐

序号	提交答卷时间	来源详情	来自IP	您的性别: Your	2. 您的 年龄: Year	3. 您的 学历: 学历	4. 请选 择以下下 20张图片	4、H1(L2/4、H1(L3/4、H1(L4/4、H2(L1/4、H2(L2/4、H2(L3/4、H2(L4/4、H3(L1/4、H3(L2/4、H3(L3/4、H3(L4/4										
1	2020/1/9 0:42 N/A	223.104.2	2	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0
2	2020/1/9 11:00 N/A	117.160.1	2	2	3	0	0	0	0	0	1	1	1	0	0	0	0	0
3	2020/1/9 11:02 N/A	222.137.2	2	2	3	1	0	0	0	0	0	0	0	0	0	1	0	0
4	2020/1/9 11:08 N/A	125.37.18	2	1	2	1	0	0	0	0	0	0	1	0	0	1	0	0
5	2020/1/9 11:10 N/A	112.17.23	1	1	2	0	1	1	0	0	0	0	0	1	0	0	1	0
6	2020/1/9 11:13 N/A	140.243.1	2	1	2	1	0	0	0	0	0	0	1	0	0	0	1	0
7	2020/1/9 11:14 N/A	222.244.1	1	1	3	1	0	0	0	0	0	0	0	1	0	1	0	0
8	2020/1/9 11:23 N/A	223.104.6	2	2	2	0	0	1	1	0	0	0	0	0	0	0	0	1
9	2020/1/9 11:23 N/A	39.189.45	2	1	2	0	0	0	0	1	0	1	1	0	0	0	0	0
10	2020/1/9 11:26 N/A	202.167.2	2	1	3	0	0	167	2	1	0	0	0	0	1	1	0	1
11	2020/1/9 11:27 N/A	218.193.1	2	1	3	1	0	1	0	0	1	0	1	0	0	0	0	1
12	2020/1/9 11:28 N/A	112.54.33	2	1	3	1	0	0	0	0	0	0	0	0	1	1	1	1
13	2020/1/9 11:29 N/A	218.193.1	2	1	3	0	0	0	0	0	1	1	0	0	0	0	1	0
14	2020/1/9 11:30 N/A	58.247.22	2	1	3	0	0	0	0	1	0	1	0	0	0	1	0	0
15	2020/1/9 11:30 N/A	223.104.5	2	1	3	0	0	0	0	0	0	0	0	1	0	0	1	0
16	2020/1/9 11:30 N/A	223.104.2	1	2	3	0	0	0	0	0	0	0	0	0	0	0	1	1
17	2020/1/9 11:31 N/A	140.207.2	2	1	3	0	0	1	0	0	0	0	0	0	0	1	1	0
18	2020/1/9 11:31 N/A	58.247.22	2	1	3	0	1	0	0	0	0	1	0	0	0	0	1	0
19	2020/1/9 11:32 N/A	61.148.57	2	1	3	0	0	0	0	0	1	0	0	0	0	0	0	1
20	2020/1/9 11:34 N/A	61.131.11	2	1	3	0	1	0	1	0	0	0	0	0	0	0	0	0
21	2020/1/9 11:38 N/A	58.247.22	2	1	3	0	1	0	1	0	1	0	0	0	0	1	0	0
22	2020/1/9 11:38 N/A	58.247.22	2	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0
23	2020/1/9 11:38 N/A	202.120.1	2	1	3	0	0	0	0	0	0	0	1	0	0	0	0	0
24	2020/1/9 11:40 N/A	218.193.1	2	1	3	0	1	0	0	0	0	0	1	0	0	1	0	0
25	2020/1/9 11:41 N/A	111.186.5	2	1	3	0	0	1	0	1	0	1	0	0	0	0	0	0
26	2020/1/9 11:42 N/A	123.139.8	2	1	3	0	0	0	0	0	0	0	0	0	0	0	1	1
27	2020/1/9 11:42 N/A	223.104.2	2	1	3	0	0	0	0	0	0	0	0	1	0	1	0	0
28	2020/1/9 11:42 N/A	223.104.4	2	1	3	0	1	0	0	0	0	0	0	0	1	1	0	0
29	2020/1/9 11:42 N/A	112.54.33	2	2	-2	1	1	1	0	1	1	2	0	1	1	0	1	0
30	2020/1/9 11:46 N/A	113.7.40.1	1	1	3	1	1	0	0	0	1	0	0	0	0	0	1	1
31	2020/1/9 11:47 N/A	218.193.1	2	1	3	0	1	0	0	0	0	1	0	0	0	1	0	0
32	2020/1/9 11:48 N/A	58.247.22	2	2	3	1	1	0	0	0	0	0	0	0	0	0	1	0
33	2020/1/9 11:48 N/A	223.104.2	2	1	2	0	0	0	1	1	23	104	2	0	0	0	1	0
34	2020/1/9 11:48 N/A	219.154.4	2	4	1	0	0	0	0	0	1	0	0	0	0	0	0	0

Fig.4 Data collection

Street view image segmentation through the convolutional neural network (CNN)

- **Tensorflow** (Martin, Ashish, & Paul, 2015) and **Keras** (Chollet et al, 2015) model framework
- **ADE20k** open dataset (Zhou et al, 2016) containing a large number of annotated object categories (such as sky, tree, car, etc.) are used.

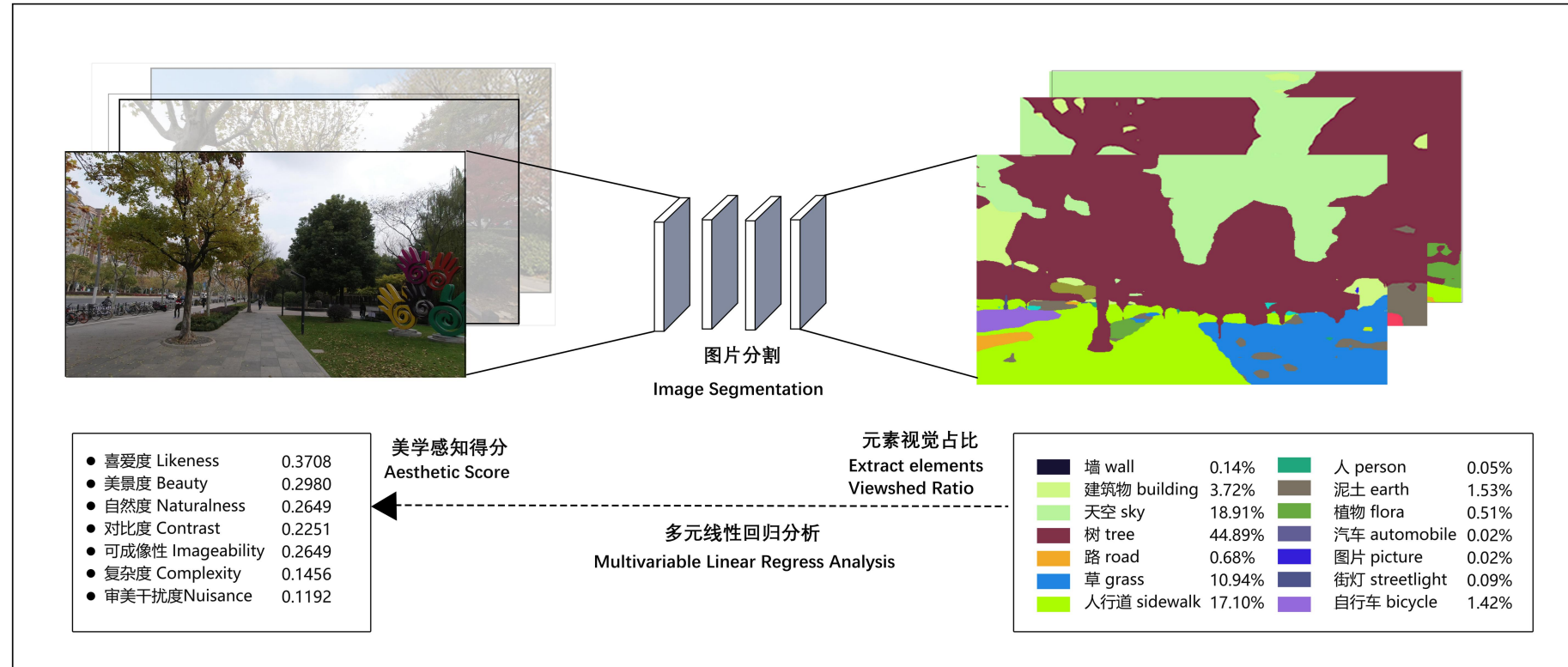


Fig.5 Street view image segmentation through the convolutional neural network (CNN)

- Using **ADE-20K model** for feature analysis and element extraction of 20 street scenes

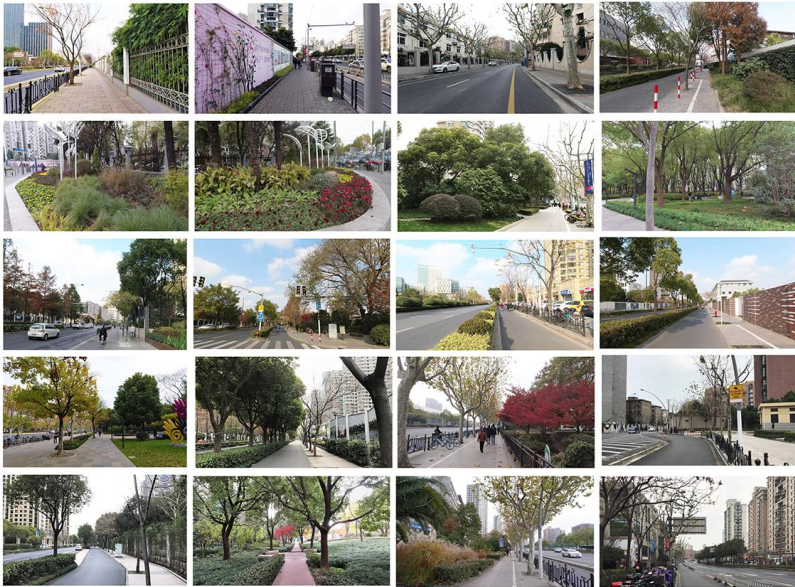
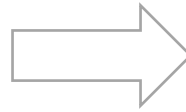


Fig.6 Site photo collection



wall	0.000259	
building	0.024945	
sky	0.035194	
tree	0.551042	
grass	0.104989	
earth	0.089237	
plant	0.132652	
water	0.00046	
path	0.061221	

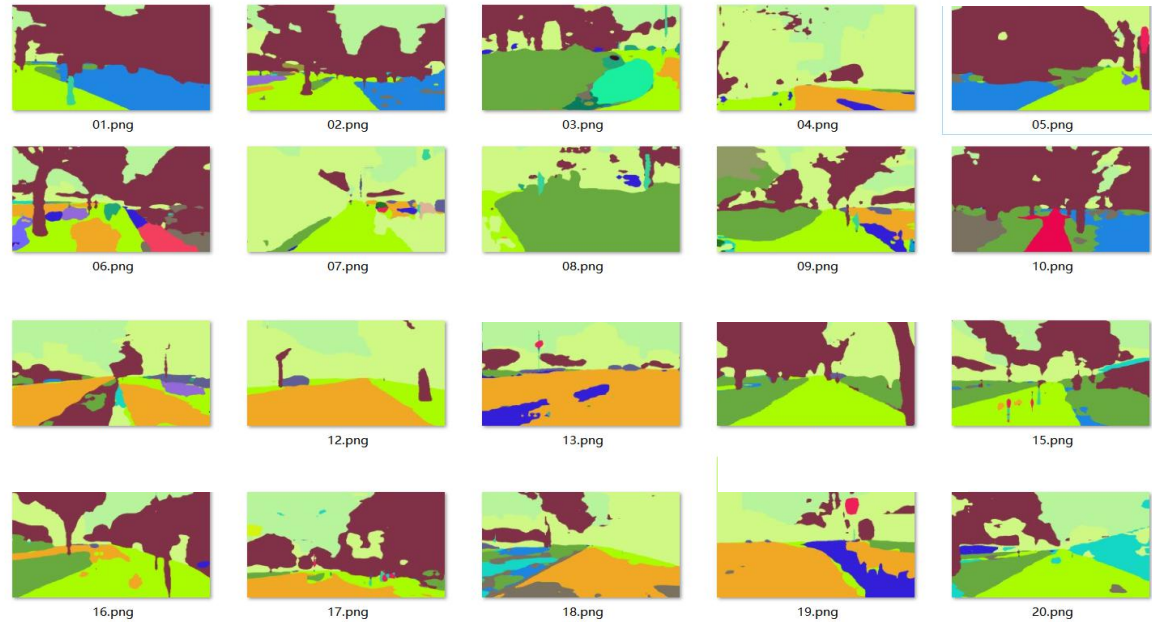


Fig.7 Site photo segmentation

Bayesian networks aesthetic modelling

- Landscape elements extracted by machine learning and the evaluation of public questionnaire : **"Posterior Probability"**;
- Proposed hierarchical structure of the cognitive concept of public landscape aesthetics : **"Prior Probability"**;
- **Data analysis** : test the significant correlation between the elements.

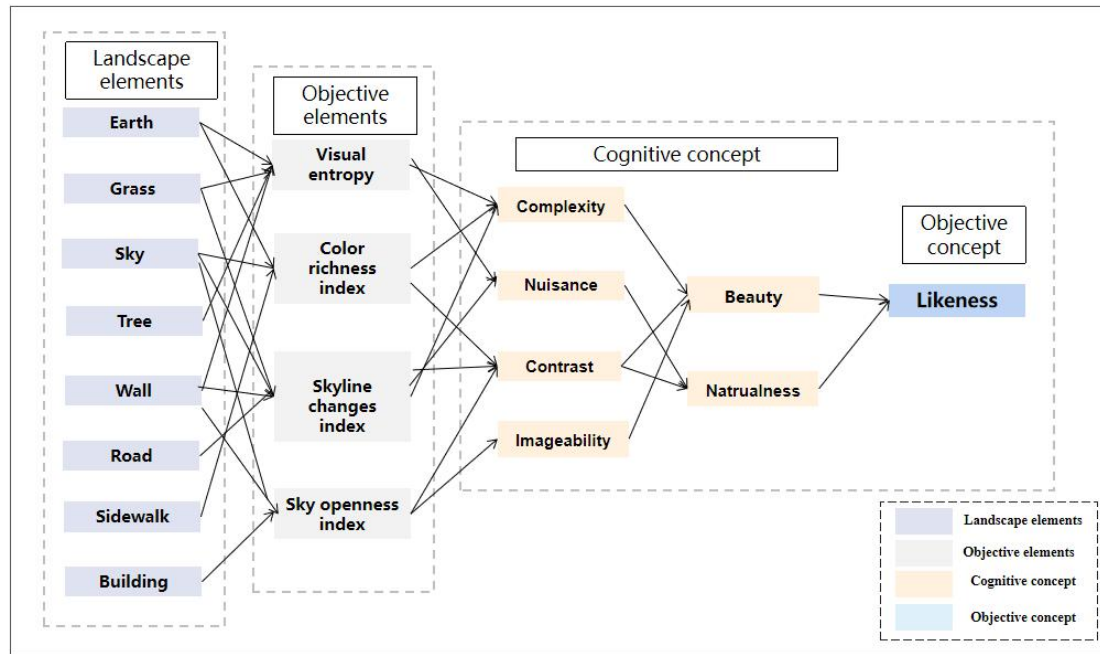


Fig.8 Cognitive concept hierarchy hypothesis of public landscape aesthetics

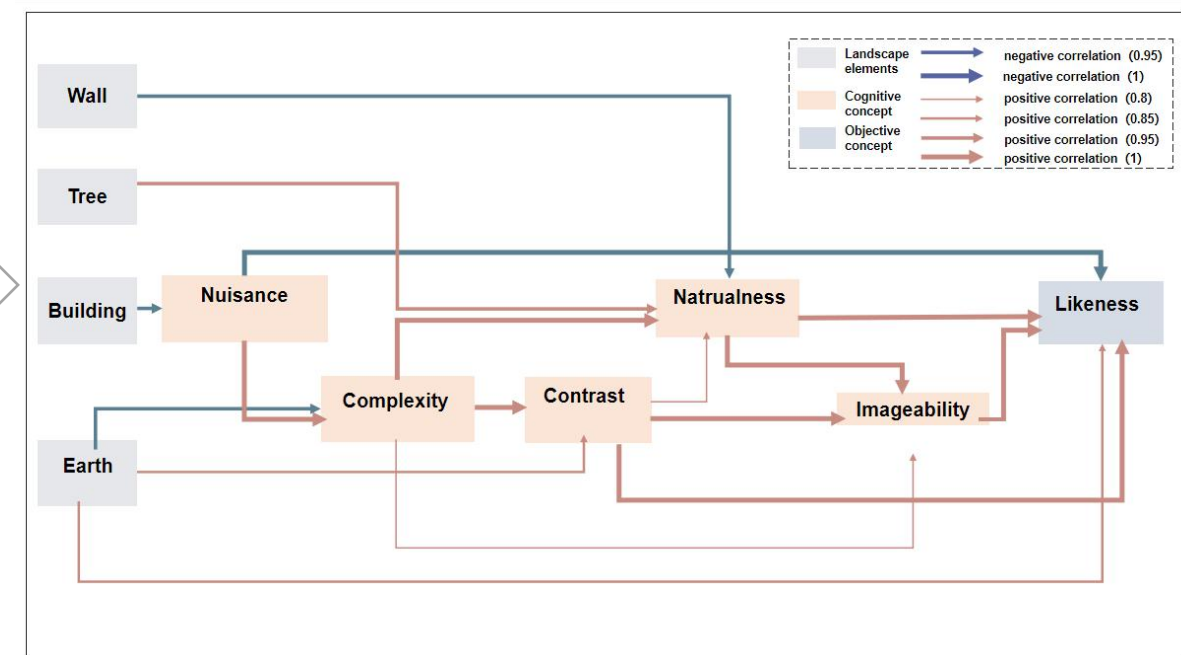
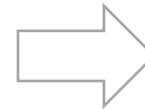


Fig.9 Cognitive concept hierarchy of public landscape aesthetics

Analysis of aesthetic perception scores of landscape pictures:

- High comprehensive aesthetic perception: H5L2,H3L2,H4L3;
- Low comprehensive aesthetic perception:H5L4 (high score in Nuisance), H4L4 (low score in Naturalness);
- The scores of each picture are quite different.

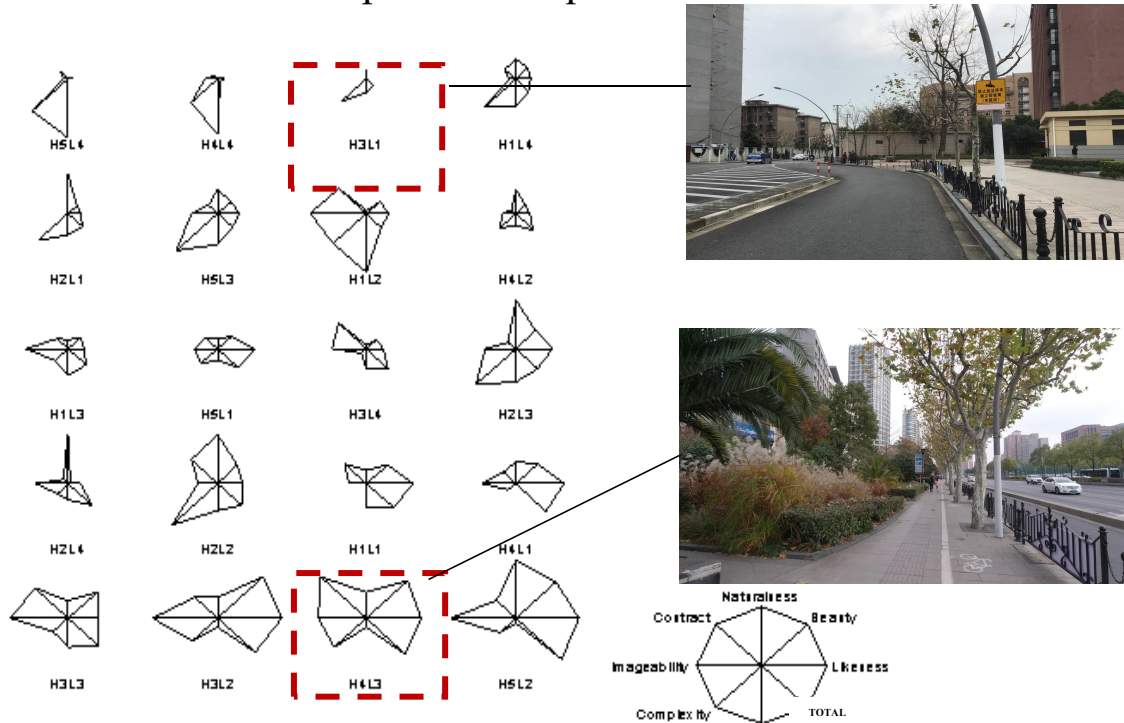


Fig. 10 Comparison of scores of perception indexes of 20 pictures in the study plot

Correlation analysis among indicators:

- Positive correlation: Likeness, Beauty, Naturalness, Imaginability, Contrast and Total(comprehensive index);
- Negative correlation: Nuisance with other indicators;Complexity with other indicators .

	Likeness	Beauty	Naturalness	Contract	Imageability	Complexity	Nuisance	total
Likeness	1	0.92	0.35	0.56	0.68	-0.18	-0.52	0.89
Beauty	0.92	1	0.36	0.68	0.75	0	-0.47	0.89
Naturalness	0.35	0.36	1	0.04	0.18	0.19	-0.43	0.54
Contract	0.56	0.68	0.04	1	0.65	-0.05	-0.1	0.62
Imageability	0.68	0.75	0.18	0.65	1	-0.18	-0.2	0.75
Complexity	-0.18	0	0.19	-0.05	-0.18	1	0.45	-0.29
Nuisance	-0.52	-0.47	-0.43	-0.1	-0.2	0.45	1	-0.68
total	0.89	0.89	0.54	0.62	0.75	-0.29	-0.68	1

Fig. 11 Pearson correlation coefficient between perception scores of 20 pictures in the questionnaire

Pearson correlation analysis:

- **Positive correlation:** "Likeness - Trees", "Naturalness - Trees", "Naturalness - Likeness", "Sidewalk - Trees".
- **Negative correlation:** "Likeness - Building", "Earth - Sidewalk", "Building - Tree" and "Building - Earth".
- More space should be reserved for **natural vegetation** in urban planning and design.

MeanDecreaseGini:

- The high-level Abstract index may have a greater impact on landscape preference than the concrete landscape element index.
- The three influential factors are walls, buildings and **trees**.

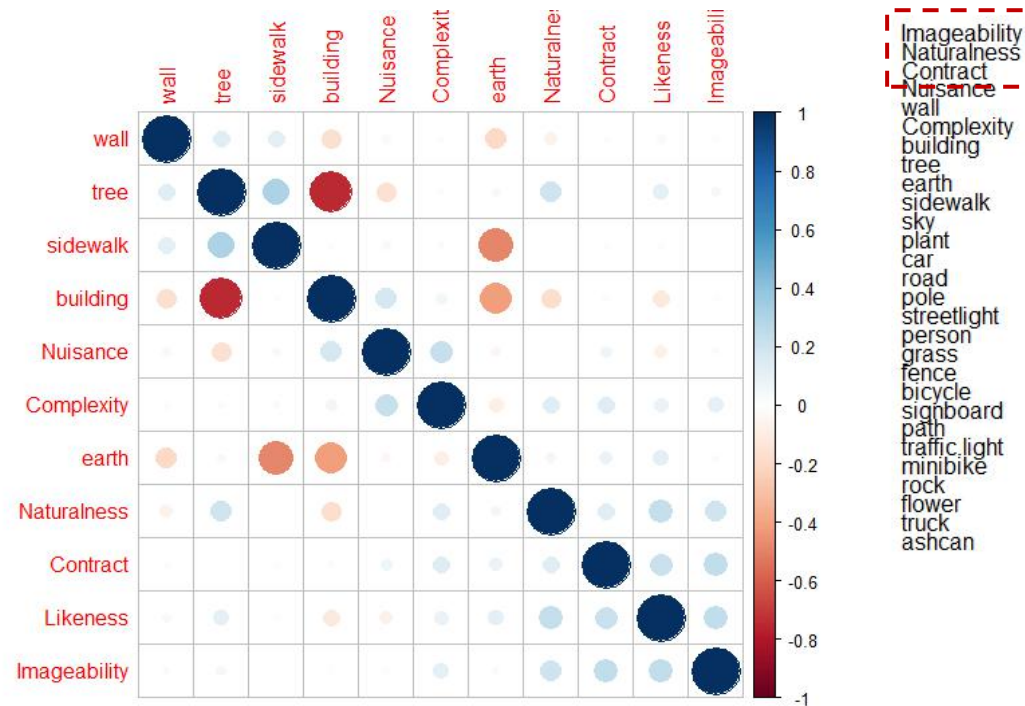


Figure 12 Pearson correlation coefficient analysis among elements of Bayes aesthetic concept level

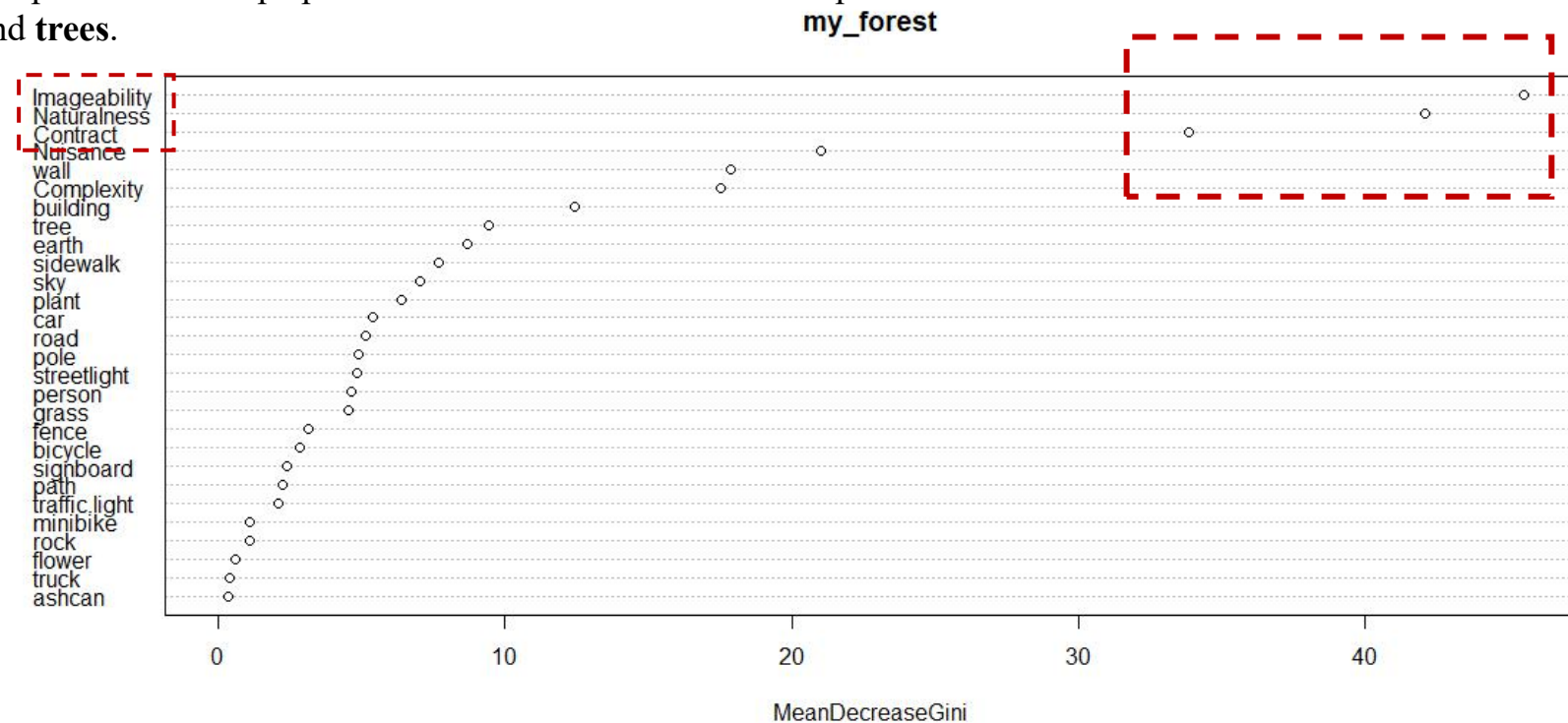


Fig 13. The importance of random forest on the independent variables influencing the public's aesthetic perception

*Mean decreasegini calculates the influence of each variable on the heterogeneity of observations on each node of the classification tree through Gini index, so as to compare the importance of variables. The higher the value, the more important the variable is.

■ The application of deep learning in landscape element identification is feasible

- Image segmentation brought by deep learning can be used to support the construction of public aesthetics cognitive hierarchy .

■ Analysis on the relationship between landscape elements and public preference aesthetic indexes

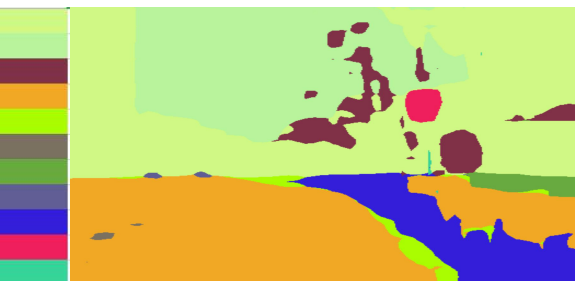
- Strong positive correlation among indexes : factors affecting the public preference may have comprehensive influence;
- The distribution and growth of **natural vegetation** in the city have a significant impact on Naturalness and Beauty;
- Plants with obvious color contrast may get more favorable comments from the public.

wall	0.000259
building	0.024945
sky	0.035194
tree	0.551042
grass	0.104989
earth	0.089237
plant	0.132652
water	0.00046
path	0.061221



H5L2: 65.6% of total plant element area
High score in Total and Naturalness

building,	0.340358
sky	0.20962
tree	0.046042
road	0.281282
sidewalk	0.015443
earth	0.001073
plant	0.014151
car	0.00105
fence	0.083418
signboard	0.007093
pole	0.000469



H4L4: 4.60% of total plant element area
Low score in Total and Naturalness



H4L3: Red leaves feature proportion (27.43%)
High score in Contrast and Beauty

■ The credibility and application value of Bayesian network model

- **Bayesian network statistics and landscape aesthetics conceptual framework integration method** can be used to explore the public's cognitive mechanism of urban landscape aesthetics .
- The intelligent assessment model of public aesthetic behavior can be developed to realize a **large-scale, fast and accurate** public cognition survey of urban landscape aesthetics (naturalness).

Supplement eye tracking experiment:

- Invite the subjects to observe the street view pictures with eye tracker
- Collect and analyze the thermal distribution data of eye tracker

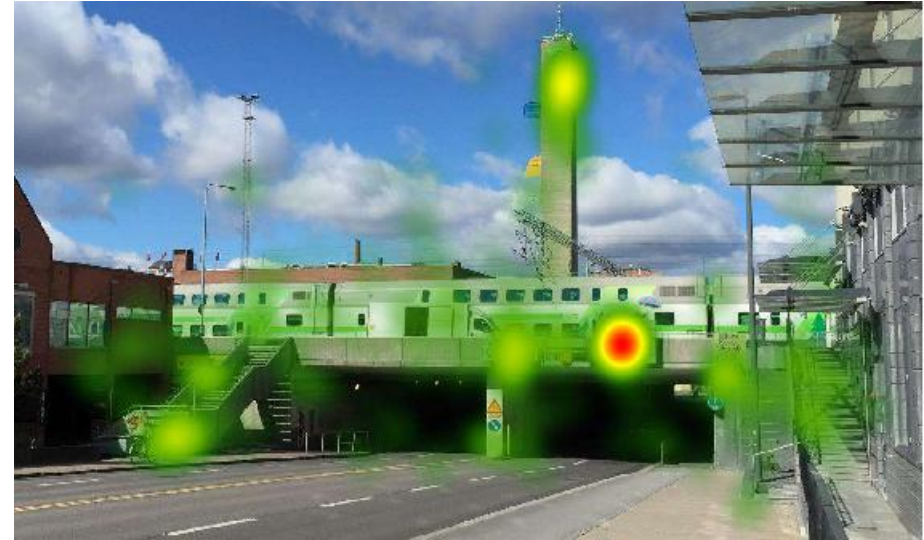


Figure 14: A heat map describing a street view (photo credits T.Vainio)
Figure from: Towards Novel Urban Planning Methods -- Using Eye-tracking Systems to Understand Human Attention in Urban Environments (Teija Vainio, 2019)

Thanks for watching !

To learn more about our work, please contact
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