UrbanMindscape: Bridging the Subjective and Objective Perception in Proximate Sensing

Keywords: Urban Perception; Semantic Segmentation; Street View Images; Convolutional Neural Network (CNN); Deep Learning

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BACKGROUND

Street View Images(SVI) have been a valuable resource in different contexts.

- Urban Analysis of the Built Environment
- Infrastructure Management
- Environmental Monitoring
- Real Estate and Property Management
- Public Safety and Security
- Social and Economic Research

BACKGROUND

Street View Images(SVI) have been a valuable resource in different contexts.

Urban Analysis of the Built Environment

Create visual representations of human perceptions and the physical characteristics of urban environments by leveraging deep learning techniques.

Objective

Subjective

A comprehensive understanding of urban spaces

Background

Subjective

Objective

(a) Safe (b) Lively (c) Beautiful

(d) Wealthy (e) Depressing (f) Boring

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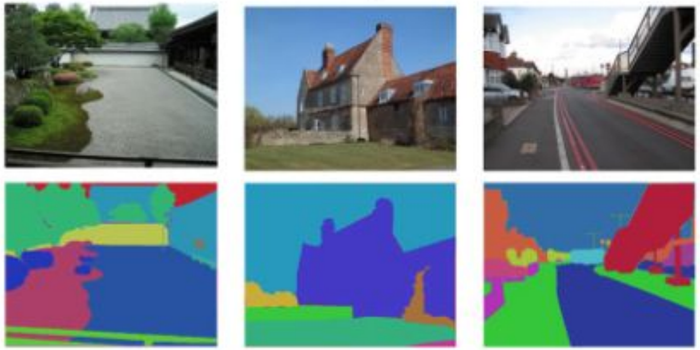


Urban Perception

Human Perception Score

Proximate Sensing

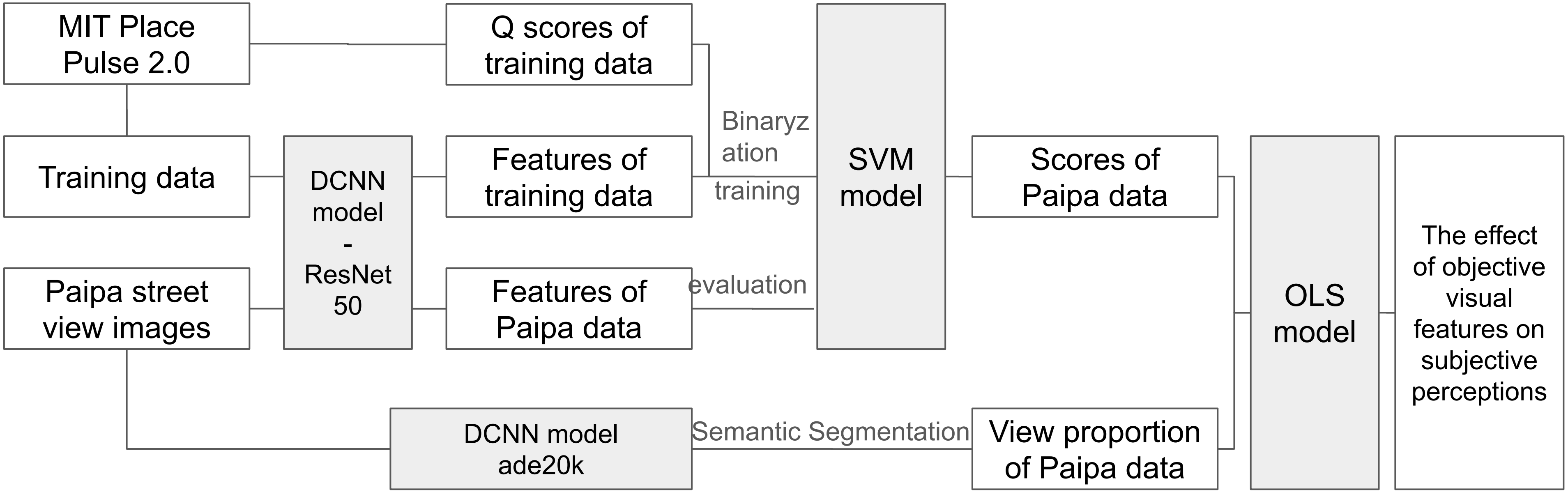
Background

MIT Place Pulse 2.0

Continent	#Cities	#Images
Asia	7	11,342
Africa	3	5,069
Australia	2	6,082
Europe	22	38,636
North America	15	33,691
South America	7	16,168
Total	56	110,988

The user interface of the MIT Place Pulse data collection platform. Participants are asked to choose one of the two images in response to one of the six questions. Millions of human perception responses for the images have been collected.

Methods


MIT Place Pulse 2.0
Q scores of training data
Training data
DCNN model - ResNet 50
Features of training data
Binaryzation
training
SVM model
Scores of Paipa data
Paipa street view images
Features of Paipa data
evaluation
OLS model
The effect of objective visual features on subjective perceptions
DCNN model ade20k
Semantic Segmentation
View proportion of Paipa data

Experiment

Study Area:

Train: MIT Place Pulse 2.0 dataset

Test: Paipa Town, Colombia

Dataset:

MIT Place Pulse 2.0 street view images across the world

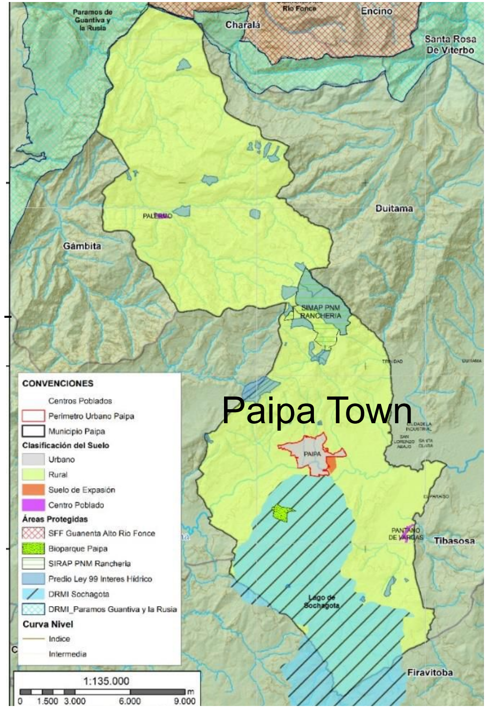
MIT Place Pulse 2.0 Q scores of SVI in six human perceptions

Paipa street view images(10m distance)

Bogota

Paipa Municipality

3hr Drive
From Bogota



Paipa Town

Experiment

To avoid introducing noise and error as much as possible, I followed the paper reference here and selected representative positive/negative samples from the whole dataset to use for the training task.

$$y_i^{\nu} = \begin{cases} -1 & \text{if} \quad Q_i^{\nu} < \mu_{\nu} - \delta\sigma_{\nu} \\ 1 & \text{if} \quad Q_i^{\nu} > \mu_{\nu} + \delta\sigma_{\nu} \end{cases}$$

Zhang, F., Zhou, B., Liu, L., Liu, Y., Fung, H.H., Lin, H., Ratti, C., 2018. Measuring human perceptions of a large-scale urban region using machine learning. Landscape and Urban Planning 180, 148–160. https://doi.org/10.1016/j.landurbplan.2018.08.020

• Safe	6.3	1
• Beautiful	5.3	1
• Wealthy	5.5	1
• Lively	6.0	1
• Boring	2.3	-1
• Depressing	1.6	-1

Binaryzation

	location_id	Q	trueskill.stds.-1	study_question	image_id	features	Q_label
0	513e6df2fdc9f0358700c383	20.592330	3.056702	safer	513e6df2fdc9f0358700c383	[0.22940833866596222, 1.0244624614715576, 0.01...	-1.0
4	5140cc3efdc9f04926002d59	28.707450	2.886764	safer	5140cc3efdc9f04926002d59	[0.12468238919973373, 0.5190224647521973, 0.04...	1.0
5	50f5ec0dfdc9f065f0008640	20.298309	4.895043	safer	50f5ec0dfdc9f065f0008640	[0.06582643836736679, 0.41787010431289673, 0.0...	-1.0
6	50f60121beb2fed6f80001b8	18.482701	4.151866	safer	50f60121beb2fed6f80001b8	[0.34781795740127563, 0.6622889041900635, 0.12...	-1.0
8	5142183ffdc9f04926008100	27.814428	5.197565	safer	5142183ffdc9f04926008100	[0.12155959755182266, 0.771874725818634, 0.020...	1.0
...	...	...	...	...	...	...	...
19993	50f5e70dfdc9f065f0007031	28.091575	3.007945	safer	50f5e70dfdc9f065f0007031	[0.4073934257030487, 0.5427781343460083, 0.159...	1.0
19995	50f439edfdc9f065f0002d42	16.917069	2.759283	safer	50f439edfdc9f065f0002d42	[0.2706283926963806, 0.8877367377281189, 0.329...	-1.0
19996	50f42eabfdc9f065f00022d3	33.181343	2.884191	safer	50f42eabfdc9f065f00022d3	[0.21051648259162903, 1.1483752727508545, 0.06...	1.0
19997	5140cc37fdc9f04926002d47	20.803571	2.217072	safer	5140cc37fdc9f04926002d47	[0.057956207543611526, 0.8228529095649719, 0.0...	-1.0
19999	513d5787fdc9f0358700319e	20.646238	2.397467	safer	513d5787fdc9f0358700319e	[0.3766400218009949, 1.0521074533462524, 0.068...	-1.0

10922 rows × 7 columns

Street Perception Analysis: Subjective Perceptions

Training data: 110,988 samples from 56 cities

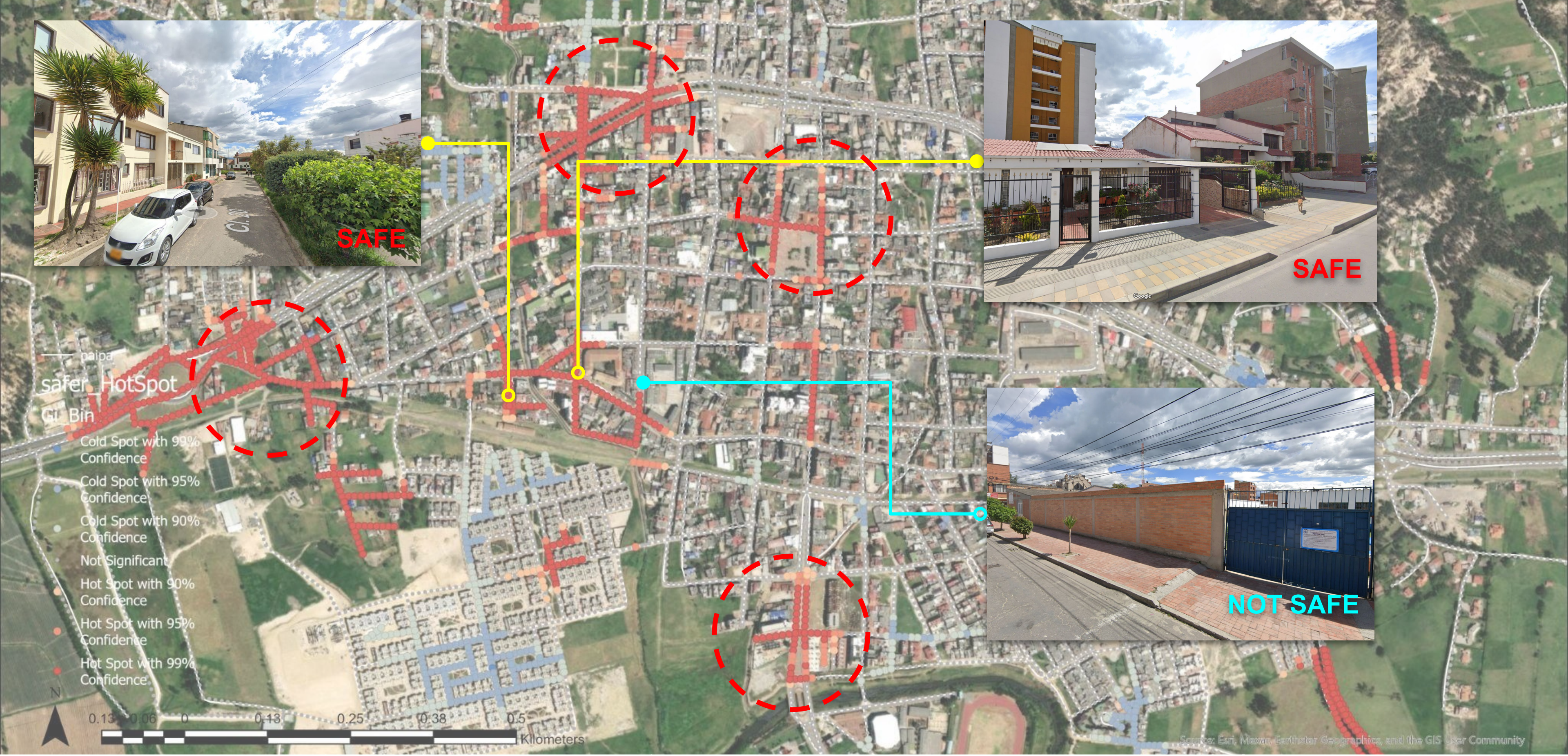
Dubey, A., Naik, N., Parikh, D., Raskar, R., & Hidalgo, C. A. (2016). Deep learning the city: Quantifying urban perception at a global scale. European conference on computer vision (pp. 196–212). Springer.

Testing data: 15,000 samples in Paipa

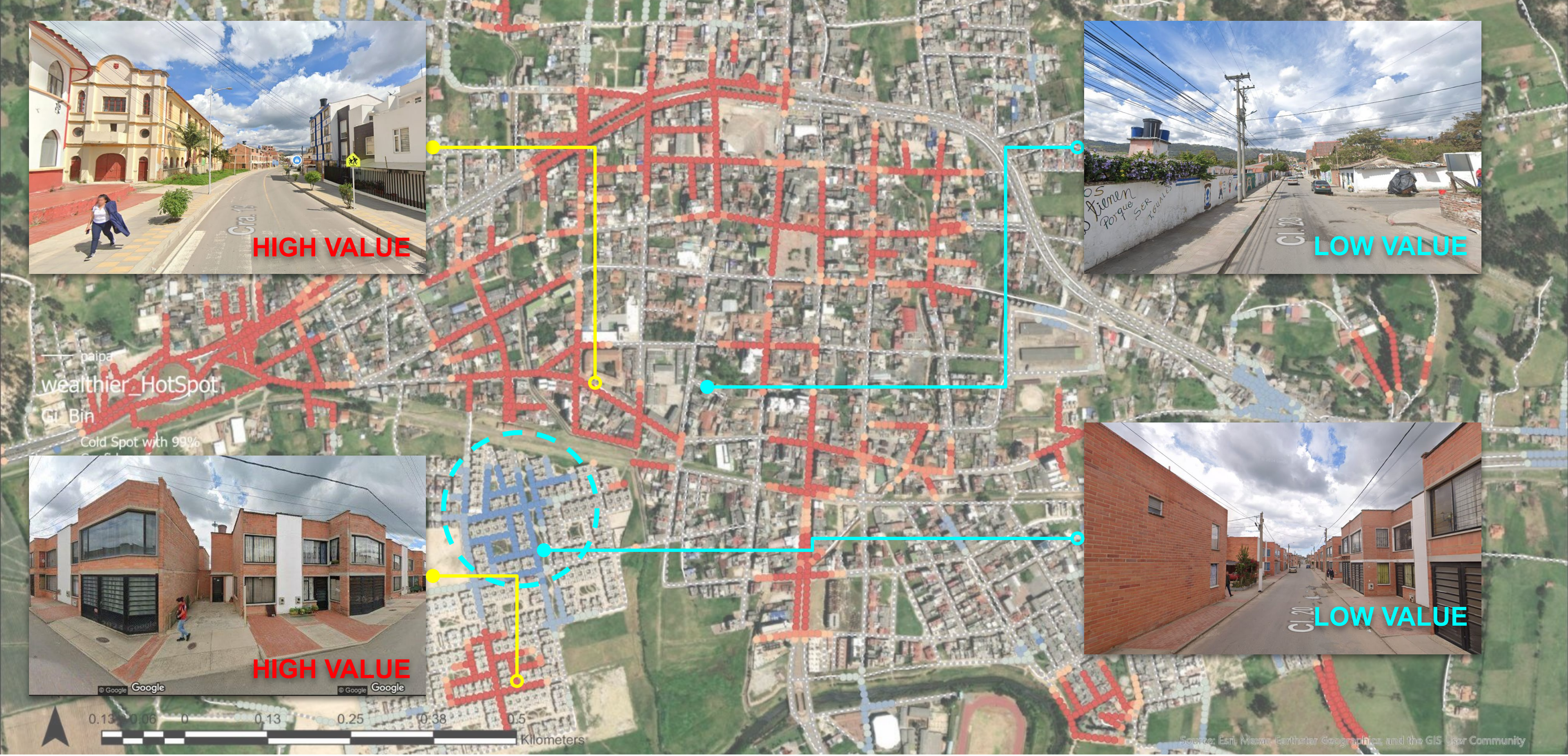
This model answers question:

Is this place safe/ lively/ beautiful/ wealthy/ boring/ depressing?

Street Perception Analysis: Safe

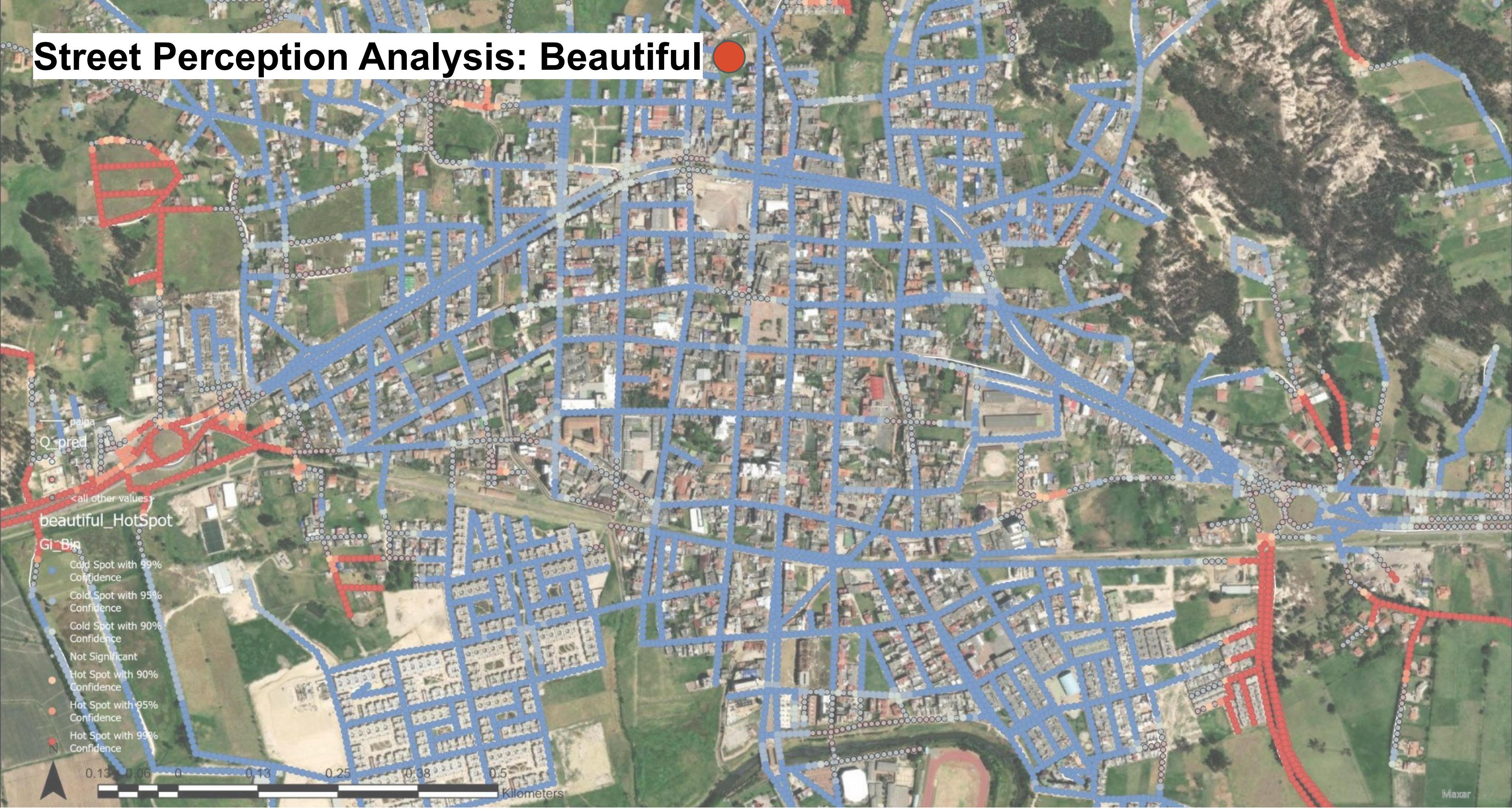


Street Perception Analysis: Wealthy



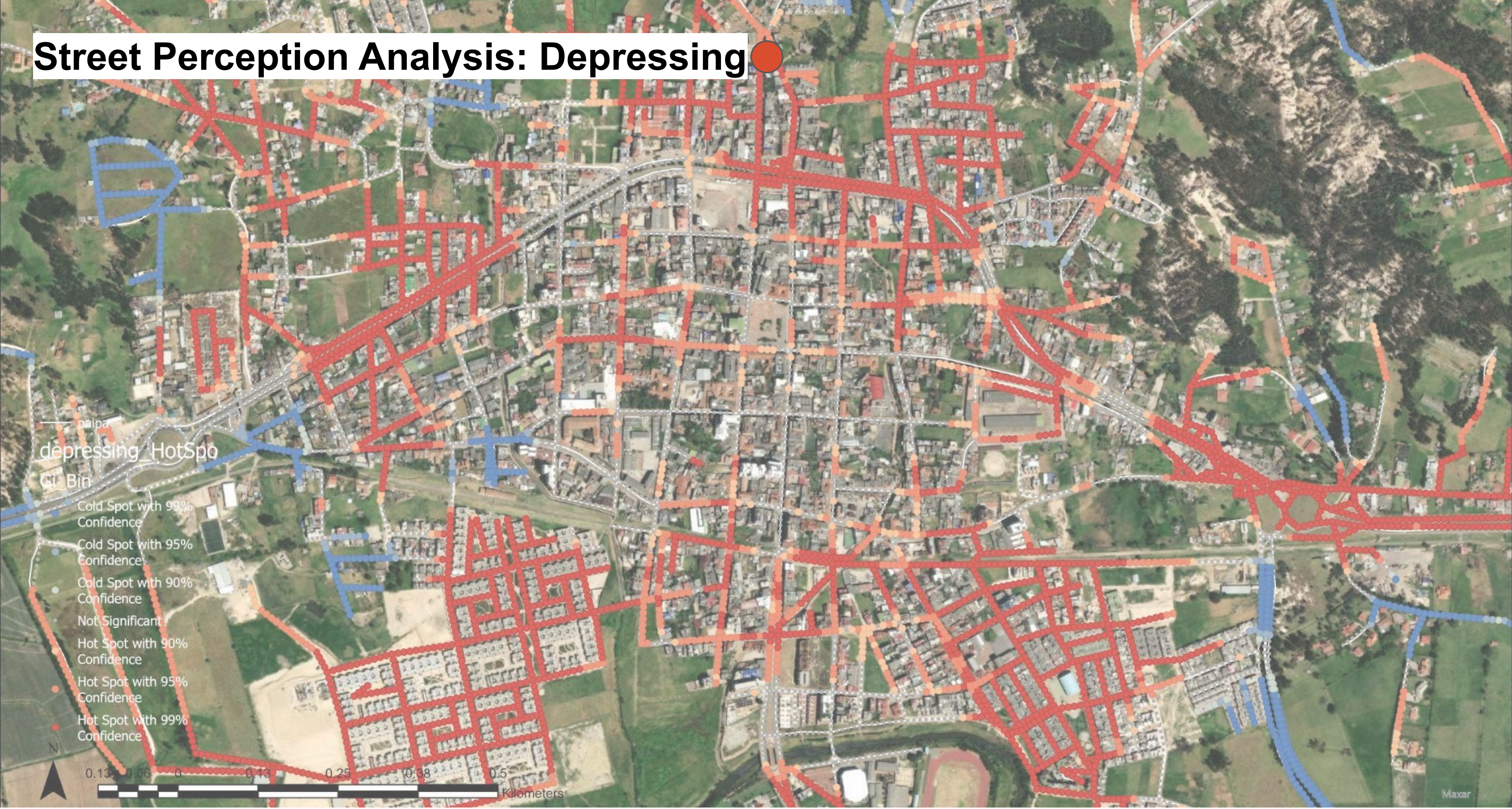
Street Perception Analysis: Lively

Street Perception Analysis: Beautiful

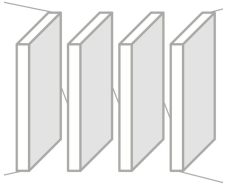


Street Perception Analysis: Boring

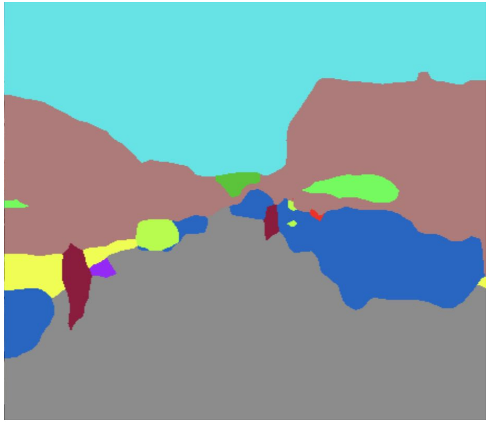
Street Perception Analysis: Depressing



Street Perception Analysis: Objective Perception



Semantic Segmentation



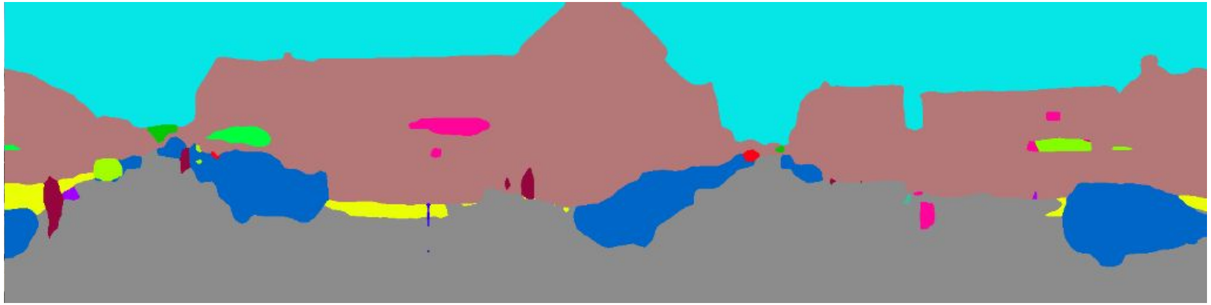
- wall 0.0013
- building 0.1071
- sky 0.1700
- tree 0.2843
- road 0.2251
- grass 0.1020
- sidewalk 0.0033
- plant 0.0001
- car 0.0973
- sign 0.0035
- stairs 0.0002
- van 0.0058

What percentage of the vision is building/car/tree/sky/road…?

Street Perception Analysis: Objective Perception

Classes related to urban space

Idx	Name
1	wall
2	building;edifice
3	sky
4	floor;flooring
5	tree
7	road;route
9	windowpane;window
10	grass
12	sidewalk;pavement
13	person;individual;someone;somebody;mortal;soul
18	plant;flora;plant;life
21	car;auto;automobile;machine;motorcar
26	house
44	signboard;sign
54	stairs;steps
103	van

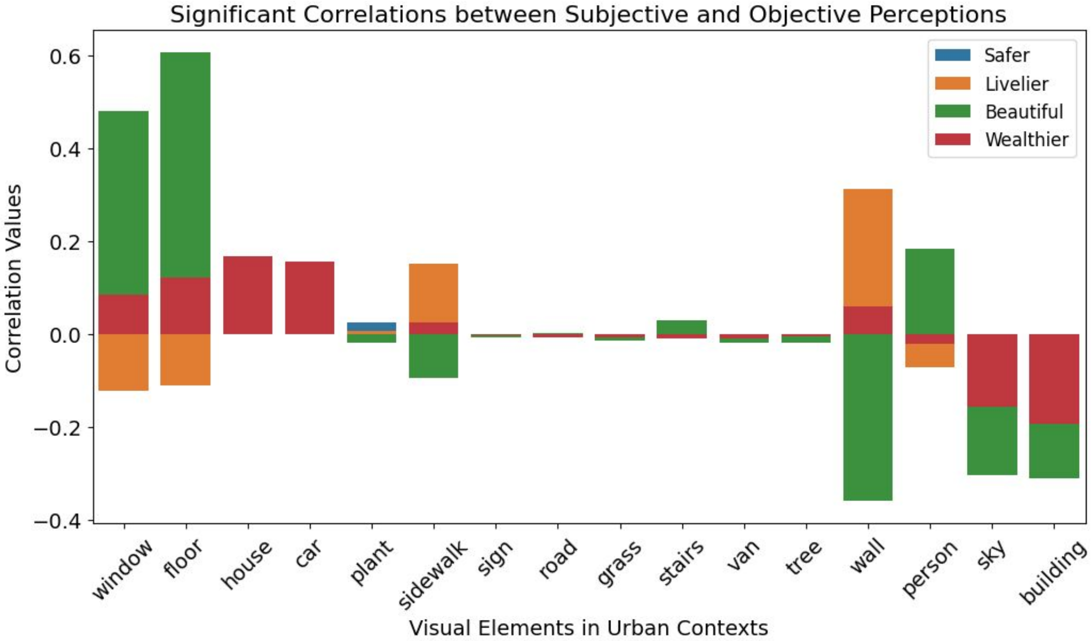


Street Perception Analysis: Objective Perception

Visual Proportion

Perceptual precognition

Multivariable Linear Regression Analysis



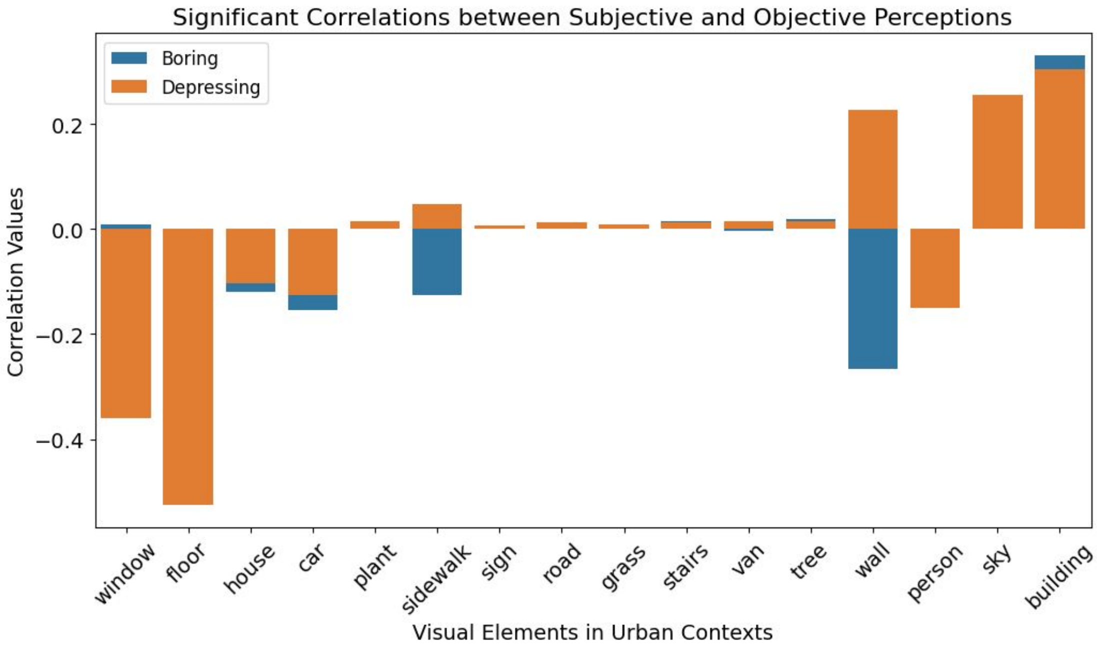
How does the proportion of building/car/tree/sky/road affect the feeling of safe/ lively/ beautiful/ wealthy/ boring/ depressing.

Street Perception Analysis: Objective Perception

Visual Proportion

Perceptual precognition

Multivariable Linear Regression Analysis

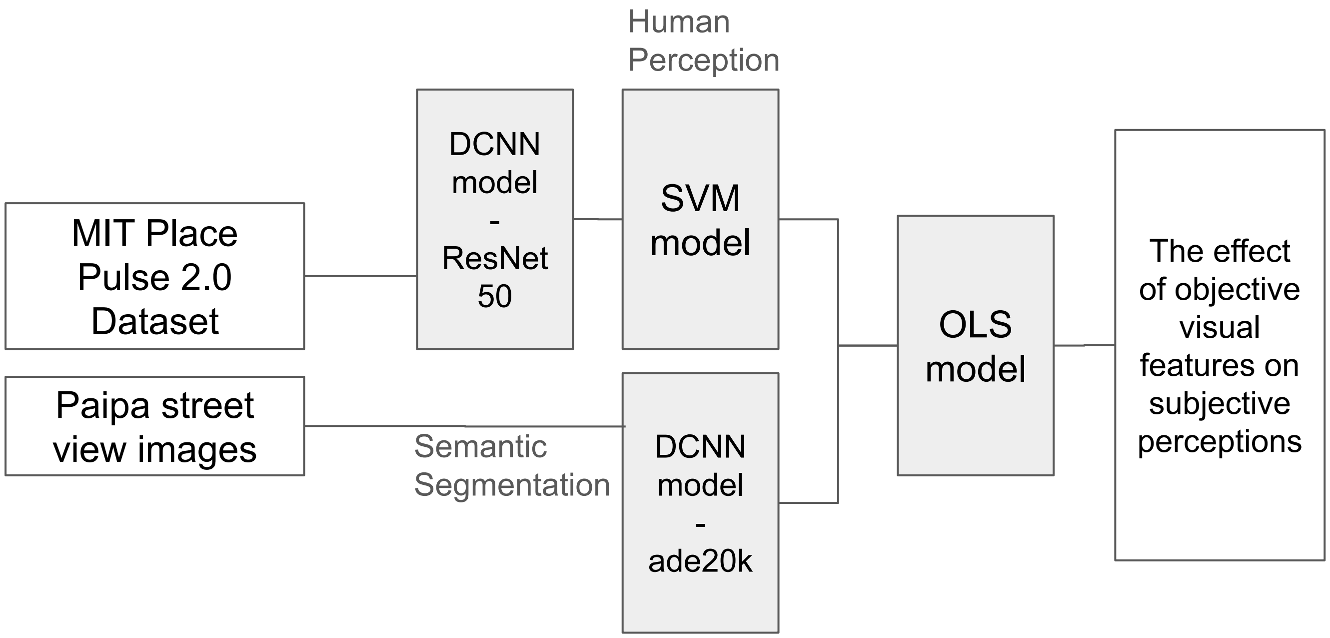


How does the proportion of building/car/tree/sky/road affect the feeling of safe/ lively/ beautiful/ wealthy/ boring/ depressing.

Street Perception Analysis: Design Solution Guidelines

Unsafe places	Enhancing green space
Unbeautiful places	Increasing open public spaces
Unlively places	Building Complete Streets
Low-value places	Promoting quality housing
Boring places	Enhancing street walkability
Depressing places	Reducing enclosed spaces

Conclusion



Next Step

Generate a real image of SVI that is a safe/lively/beautiful/wealthy /boring/depressing place

Select the image closest to the center of the custer of safe/lively/beautiful/wealthy /boring/depressing place