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A novel framework for modelling people's perceived scene complexity of navigation environments based on street-level imagery and open geodata

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Abstract:

Scene complexity refers to the difficulty of human perception and understanding of a specific environment (Tapiro et al., 2020). An environment is complex when it has many parts or components, and those parts or components interrelate with each other in multiple and random ways. People's behaviors and spatial activities are strongly affected by such complexity environments (Montello, 2018). Moreover, wayfinders require more time to make decisions in complex environments and suffer from a higher probability of making wrong decisions and getting frustrated, sometimes leading to navigation failures or bringing road safety problems (Richter, 2009; Tapiro et al., 2020). As a result, it is fundamental to the disciplines of psychology, geography, and transportation and computer science to assess the perceived scenario complexity of the environment.The existing computational methods for modelling the perceived scene complexity of humans primarily focus on either visual or structural characteristics of the environment.

This work presents a computational method (Figure 1) to quantify the scene complexity of real-world environments comprehensively based on the visual, structural, and semantic characteristics, and assesses the performance of the technical approach with human-labelled "ground-truth" data. Specifically, we proposed a set of features (Table 1) to model the visual (e.g. color, shape, texture, and field of vision), structural (e.g. branches and nodes), and semantic (e.g. the number of POIs and their spatial patterns, well-known signs) aspects, based on street-view panoramas, road network data, POI data, and building footprint data.

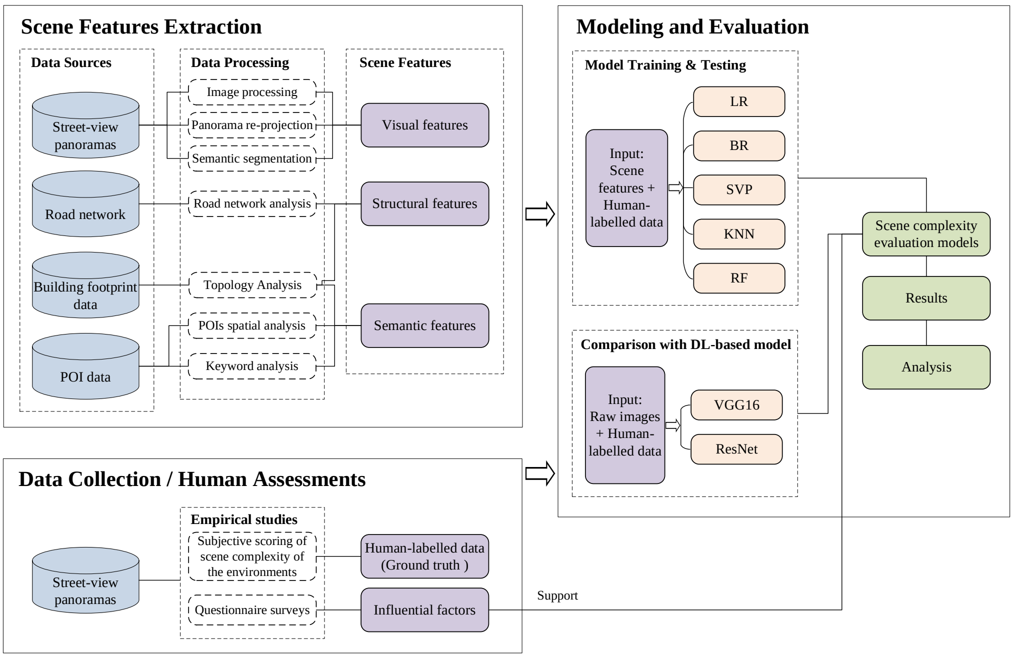

Figure 1. Overview of the methodology.

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Dimension	Scene feature descriptions
Visual features	Entropy of color (*vis_color)*
	Spatial distribution of color *(vis_color_spatial*)
	Texture (*vis_texture*)
	Shape (*vis_shape*)
	Percentage of visible sky area (*vis_sky_pct*)
	Percentage of building areas (*vis_building_pct*)
Structural features	Distance to the nearest street intersection (*str_dist_intersection*)
	Branch of the nearest street intersection (*str_branch_intersection*)
Semantic features	Number of POIs (*sem_POI_number*)
	Spatial distribution of POIs (*sem_POI_distribution*)
	Number of well-known POIs (*sem_POI_wk*)

Table 1. Complexity features of each real-world street scene.

The results of the evaluation show that the proposed computational method is feasible to predict the perceived scene complexity of street-view environments, with an excellent Mean Absolute Error (MAE) of 0.1108 (on the scale of 1 to 5). The evaluation results on two additional cities further illustrate the high robustness of the proposed computational method. Regarding all conceivable combinations of the visual, structural, and semantic dimensions, considering all these three dimensions provides the best regression performance. In addition, the top-4 most important features for the modelling of scene complexity were: Spatial distribution of POIs, Number of POIs, Percentage of visible sky area, and Distance to the nearest street intersection. Interestingly, these 4 features all appeared in the top-5 feature list reported by human participants in the empirical studies. This work proposes a set of visual, structural and semantic features to quantify the complexity of street scenes, and computational methods for extracting these features from open source data are also mentioned. In addition, the complexity labeling data needed for modeling can be collected through empirical studies. As a consequence, the method can be widely applied in many different cities around the world.

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