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Can we "see" the neighborhood-built environments from a UAV?

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Abstract

Health-related built environments in a neighborhood are significant to the health of the residents. In order to quantitatively examine built environments at the neighborhood scale, the operational unit *neighborhood* should be clearly defined in advance. This paper assessed a newly developed neighborhood concept, *sidewalk-homogenous neighborhood,* which corresponds to the economic profile and the health behaviors of residents. This study examined the applicability of the sidewalk-homogenous neighborhood in the process of detecting and evaluating built environments at the street level in four study sites. Sidewalks and greenery as the representations for built environments were classified on UAV images using the combined applications of geographic information systems (GIS) and deep learning. The study addressed that the sidewalk-homogenous neighborhood is a practical, operational unit to identify the spatial disparities of built environments at the neighborhood scale. In addition, the study revealed the inequality in Unmanned Aerial Vehicle (UAV) research opportunities between rich and poor neighborhoods.

1. Introduction

In quantitative analysis of neighborhood effects, census geography is often used as a surrogate neighborhood due to its simplicity and low cost (Clapp and Wang 2006). However, census geography can hardly respect the social and behavioral relationships among residents in the real world. Researchers may need to move beyond census geography and develop a neighborhood concept that maximizes sociological reality and statistical measurability for targeted research.

This study examined the applicability of *sidewalk-homogeneous neighborhood, a* newly proposed neighborhood concept for health-related built environment research. Four sidewalk-homogenous neighborhoods with different economic levels were used to examine the neighborhood effects in health-related built environments. Images captured by an Unmanned Aerial Vehicle (UAV) were processed with the combined applications of geographic information systems (GIS) and deep learning in the detection of spatial distribution of sidewalk and greenery at the neighborhood scale.

2. Method

This study was to further expand the concept of sidewalk-homogenous neighborhood, which had been initially proposed in Hong (2021) and Hong et al. (2022). The applicability of the proposed neighborhood concept was tested at four study sites in Northeast Ohio, USA. Sidewalks and greenery detected using the combined methods of GIS and deep learning on UAV imagery in Hong et al. (2022) were further utilized to examine the sidewalk-homogenous neighborhood concept in this paper.

2.1. Defining the sidewalk-homogenous neighborhoods

There are two defining criteria for a sidewalk-homogenous neighborhood: 1) house prices within the neighborhood are similar; and 2) all the streets of the neighborhood are residential (local) roads as defined by the road classification system in Ohio Department of Transportation (2020). The first factor suggests the economic component of a neighborhood, indicating that the residents are in a similar economic background. The second factor respects the habit of sidewalk usage.

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People are more likely to use sidewalks that are by local roadways due to a lower speed and less traffic (Teff 2011).

Four study sites in Northeast Ohio, USA with different economic levels were demarcated in Hong et al.'s (2022) study based on the criteria defined in the sidewalk-homogenous neighborhood. They were named *River Bend*, *North Cherry*, *Sandy Lake*, and *Summit Mall*. The ranges of house prices from the lowest to the highest and the area of each neighoboohd are listed in Table 1. The boundaries of the four neighborhoods and the UAV flight paths are displayed in Figure 1. The house price in each sidewalk-homogenous neighborhood is in the same level of price range and the roadways within the neighborhood are all residential roads where the speed limits are below either 25 or 30 miles per hour. The difference in the house price range between neighborhoods was to examine how sidewalk-homogenous neighborhoods with different economic components may differ from each other in terms of built environments.

Table 1. House prices and area of neighborhoods (Hong et al. 2022)

Neighborhood	House price (Thousand US $)	Area (sq km)
North Cherry	70 – 150	0.8
Sandy Lake	170 - 300	4.48
Summit Mall	220 - 500	1.13
River Bend	300 - 900	0.61

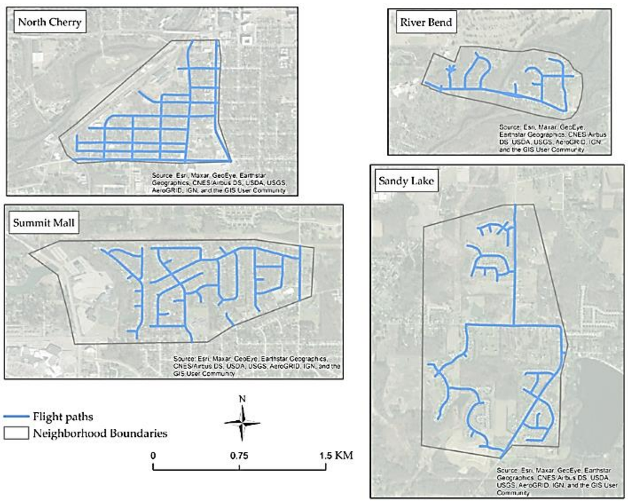

Figure 1. The boundaries of the neighborhoods and the UAV flight paths

2.2. The built environments revealed in the sidewalk-homogenous neighborhood

The densities of sidewalks and greenery in each street were detected and classified using deep learning methods and GIS in processing UAV imagery. Please refer to Hong et al. (2022) for details on the workflow.

3. Results and Discussion

Figures 2 and 3 demonstrate the sidewalk density and greenery ratio at the street level of each neighborhood, respectively. By visual observation, we may see that the neighborhoods at the higher economic level (River Bend and Summit mall) have greater sidewalk density and greenery ratio than the neighborhoods at the lower economic level (Sandy Lake and North Cherry). In addition, the intra-neighborhood differences are more remarked in the lower-economic neighborhoods.

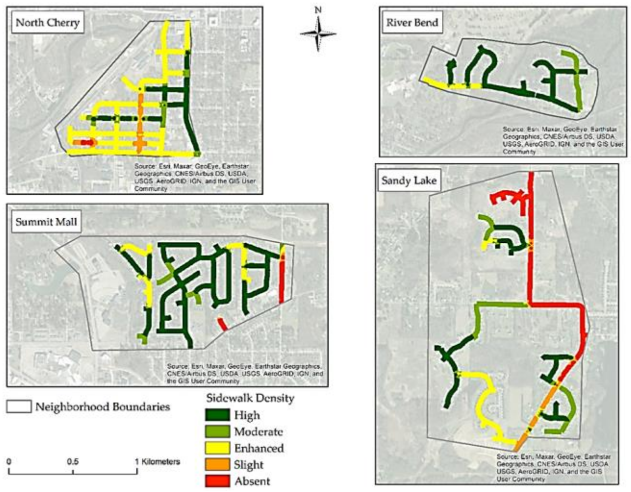

Figure 2. Sidewalk density at the street level of the sidewalk-homogenous neighborhood (Hong et al. 2022)

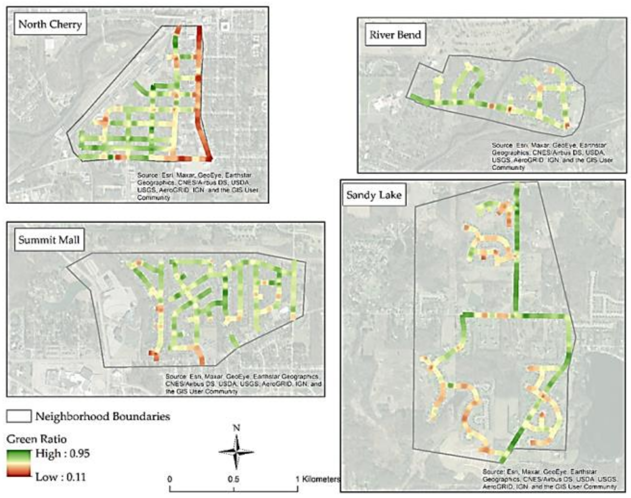

Figure 3. Greenery ratio at the street level of the sidewalk-homogenous neighborhood (Hong et al. 2022)

From the field experience of collecting images using a UAV, I realized that data collection over certain neighborhoods is restricted from autonomous flight mode over areas that are classified as either restricted, authorization, or warning zones by the Federal Aviation Administration (FAA). In the original plan for the study, two more neighborhoods with lower economic levels were planned as the study sites. However, they are located in the warning zone where the autonomous flight mode is not allowed. Although the manual flight mode is permitted, the scenes would be hardly captured with consistent configurations when flying the UAV manually. For instance, in the manual flight mode, it would be hard to ensure that the entire video or all the photos are captured at the same flying altitude, the same perspective, and the constant speed.

Figure 4 displays restricted/ authorization/ warning zones around my study sites (the Greater Akron region). Many marginalized neighborhoods in the Greater Akron region are within the warning zones of airspace (see yellow zones in Figure 4). The airspace from the ground of either an airport or a prison up to a certain distance is a warning zoom. It turns out that on one hand, most residential neighborhoods around an airport or a prison are economically marginalized. On the other hand, most neighborhoods with higher economic levels tend to be far away from those facilities and in airspace that UAVs are free to fly. The inequality in research opportunities between economically advantaged and disadvantaged neighborhoods may exacerbate the existing gap in built environment quality between the rich and the poor.

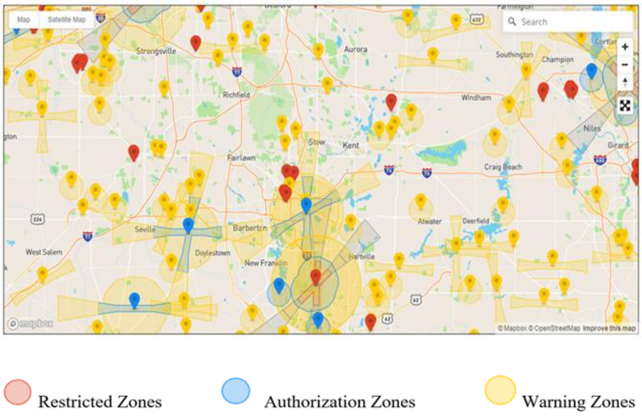

Figure 4. The restricted/authorization/warning zones in the Greater Akron region. Locators (in red, blue, or yellow) are the facilities (e.g., airports, prisons) that their airspace from the ground up to a certain distance are the restricted, authorization, or warning zones (DJI 2021)

4. Conclusion

This paper attempted to move beyond the traditional neighborhood concepts and examined applicability of the newly developed concept of sidewalk-homogenous n for health-related built environment studies at the neighborhood scale. The measurability of sidewalk-homogenous neighborhood was tested in four residential neighborhoods with different economic levels in Northeast Ohio, USA. Sidewalk density and greenery ratio at the street level in each neighborhood were examined and compared with the combined applications of deep learning and GIS in processing UAV imagery. The results indicated that the spatial differences between and within neighborhoods can be revealed in the spatial unit operated by the sidewalk-homogenous neighborhood. In addition, the results also addressed the inequality in research opportunity between the rich and the poor neighborhoods.

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