Landscape and Urban Planning 169 (2018) 148–159

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Using unmanned aerial systems (UAS) for remotely sensing physical disorder in neighborhoods

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ARTICLE INFO

Keywords:
Spatial analysis
Unmanned aerial systems
Physical disorder
Remote sensing
Drones
Urban

ABSTRACT

Place and local milieu have always been important considerations in the study of human behavior. However, place is typically measured with secondary data in aggregate form, obfuscating crucial, hyper-local information on neighborhood ecological conditions contributing to larger social, criminological, and public health processes. Hyper-local information, which is rarely available via traditional neighborhood audits or secondary data, should include information on neighborhood aesthetics (e.g., architecture, trees, public art), physical disorder (e.g., litter, unkempt lots, building decay), pedestrian safety (e.g., lighting, curb cuts), and related street characteristics. When this information is absent, the ability to connect and interpret the underlying effects of place on social problems is severely compromised. Using two neighborhoods in Phoenix, Arizona as case studies, we employ a novel strategy to collect hyper-local ecological information on physical disorder using unmanned aerial systems (UAS). We compare the collected data to more widely available sources and methods, including systematic social observation, as well as the use of satellite and street imagery. Finally, we discuss the operational challenges, constraints and data quality issues that emerge from implementing a UAS-based approach.

1. Introduction

In almost any context where urban and regional issues are considered, place matters. Local milieu is fundamental for understanding and explaining why a neighborhood might be plagued by poverty and crime, just as much as it underscores good public education opportunities, positive health outcomes and emotional wellbeing. Opportunities for examining and characterizing local milieu have grown dramatically over the past several decades as socio-economic, planning and health scientists have embraced the use of GIS and spatial data. Unfortunately, although many empirical studies are focused on the influence of place on outcomes (e.g., health, crime, development), place is often examined through its residual influence after individual-characteristics have been accounted for in statistical models. This is problematic since "place" embodies much more than absolute geographic location (e.g., latitude and longitude coordinates) or simple spatial autocorrelation (Cummins, Curtis, Diez-Roux, & Macintyre, 2007; Kearns, 1993; Kearns & Moon, 2002). Place includes the physical characteristics of a location, as well as the cultures, institutions, traditions, and lifestyles to which people are exposed to, participate in, and build upon on a daily basis (Cresswell, 2004). Consequently, scientists are progressively incorporating new concepts and methods for including a fuller conception of place and analyzing neighborhood variations in health (Kawachi & Berkman, 2003), disorder, collective efficacy, and crime (Sampson, Raudenbush, & Earls, 1997).

One critically important gap in ecological studies of place is the lack of hyper-local information – extremely detailed information regarding a small unit of space – on ecological conditions contributing to larger social and public health processes. For example, neighborhood aesthetics (e.g., architecture, trees, public art), physical disorder (e.g., litter, graffiti, abandoned buildings), pedestrian safety (e.g., level sidewalks, street lights, curbs), and street characteristics (e.g., crossing aids, traffic-calming elements and speed limit signs) can all play an important role in facilitating or inhibiting individuals' interactions with their neighborhood through perceptual barriers, physical obstructions and the like. Much of this ecological information can be collected through systematic social observation (SSO) or neighborhood audits of public spaces (Sampson & Raudenbush, 1999). However, SSOs are inherently expensive, time consuming, typically provide only a single snapshot in time, and are often dangerous; as a consequence, gathering hyper-local information is typically not pursued. Furthermore, to reduce the time and monetary costs of data gathering, SSOs are usually

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http://dx.doi.org/10.1016/j.landurbplan.2017.09.001
Received 21 November 2016; Received in revised form 31 August 2017; Accepted 3 September 2017

limited geographically to the "block face" or the portion of a city block that faces the street. This technique excludes a significant portion of space that individuals reference during their interactions with their neighborhood (Wallace & Schalliol, 2015). There are alternatives for such audits, including neighborhood specific "windshield tours" (Eng & Blanchard, 1990; Farquhar, Parker, Schulz, & Israel, 2006; Kruger, French-Turner, & Brownlee, 2013), the use of Google Street View for collecting contextual information on the local environment (Mooney et al., 2014; Rundle, Bader, Richards, Neckerman, & Teitler, 2011; Wilson et al., 2012) or more general approaches using remotely sensed imagery from satellite sources (Mesev, 2003; Patino, Duque, Pardo-Pascual, & Ruiz, 2014; Wolfe & Mennis, 2012). As detailed below, all three alternatives are imperfect, with limitations including temporal and/or frequency constraints, safety concerns, cost, and antiquated data.

The purpose of this research is three-fold. First, using Phoenix, Arizona as a case study, we detail an alternative, cost effective, safe, and accurate approach for capturing hyper-local information and the ecological characteristics of neighborhoods in the auditing process. Specifically, we explore how an unmanned aerial system (UAS) can be used for capturing imagery that documents physical disorder in neighborhoods. The use of UASs allow for the collection of hyper-local information at great frequency to both supplement and potentially improve traditional approaches, including classic systematic social observation, windshield tours, and virtual tools such as Google Street View. This information is critically important for scientific endeavors seeking to deepen our understanding of place and its influence on health, housing, disorder, crime, and many other social outcomes that are context-driven. Second, we compare the collected data to more widely available sources, including satellite and street imagery. Finally, we discuss the operational challenges, constraints and data quality issues that emerge from implementing a UAS-based approach.

2. Background

Place matters for many reasons. There has been a considerable amount of work detailing the need for the ecological analysis of neighborhoods and the importance of capturing the contextual drivers of crime, violence, health outcomes and many other socioeconomic processes (Cunradi, Mair, Ponicki, & Remer, 2011; O'Campo, Burke, Peak, McDonnell, & Gielen, 2005; Susser, 1994; Sampson & Raudenbush, 1999). However, the literature dealing with the conceptual foundation(s) of neighborhood audits and their orchestration is widely scattered across disciplines, including public health (Badland, Opit, Witten, Kearns, & Mavoa, 2010; Clarke, Ailshire, Melendez, Bader, & Morenoff, 2010; Farquhar et al., 2006; Griew et al., 2013), computing (Hara, Le, & Froehlich, 2013; Hara et al., 2015), urban planning (Ben-Joseph, Lee, Cromley, Laden, & Troped, 2013), geography (Curtis, Curtis, Mapes, Szell, & Cinderich, 2013), and agronomy (Rousselet et al., 2013), to name a few. Because of the breadth and diversity of the ecological analysis literature and its applications, this background section is necessarily limited to providing an overview of approaches used to capture neighborhood physical disorder. Specifically, we focus on the critical subconcepts of neighborhood aesthetics, decay, decline, blight, and their relative dynamism, as well as the three major frameworks for conducting neighborhood audits for evaluating physical disorder, highlighting their relative strengths and weaknesses. While we acknowledge the social disorder literature and its importance for deepening our understanding of urban context (O'Brien, 2015; O'Brien, Sampson, & Winship, 2015; Sampson & Raudenbush, 1999; Skogan, 1990), space limitations restrict us to primarily discussing physical disorder.

2.1. Neighborhood disorder, crime and outcomes

Neighborhood disorder centers on the violations of norms that govern public space and behavior (Hunter, 1985; Skogan, 1990). The presence of disorder cues signal to both individuals and offenders that "no one cares" about that neighborhood, including the police and local government (Wilson & Kelling, 1982), and residents are unable or unwilling to intervene (Pattillo, 1998). Disorder also indicates the potential for crime and victimization (Wilson & Kelling, 1982), which in turn generates fear of crime and victimization for both residents and outsiders (Permentier, Matthieu, Gideon Bolt, & Maarten van Ham, 2007; Wallace & Louton, 2017, in press; Wutich, Ruth, Brewis, & Boone, 2014). Again, to offenders, there is a perception that police and resident intervention is unlikely, further catalyzing crime (St. Jean, 2007; Wilson & Kelling, 1982).

Disorder can be categorized as social or physical. In short, social disorder cues include public behavior that conveys an immediate criminal threat (Sampson & Raudenbush, 1999) and is rooted in the behavior of people in public spaces. This includes people arguing on the street, loitering, and drug sales and/or use (Sampson & Raudenbush, 1999; Skogan, 1990). Physical disorder consists of signs of neighborhood neglect and dilapidation, such as broken sidewalks, vacant lots, dilapidated homes, litter, and broken windows (Sampson & Raudenbush, 1999; Skogan, 1990). Physical disorder can also be an artifact of prior criminal behavior in the area. The unmitigated presence of physical disorder in a neighborhood begins a process of neighborhood decay (Skogan, 1990). The "spiral of decay" commences when disorder precipitates additional disorder, often pushing neighborhoods into a state of malaise (Ross & Mirowsky, 1999), changing residents' perceptions and attitudes regarding the use of physical and social space. In turn, this affects how individuals interact with their neighborhood.

Both types of disorder are linked to a multitude of negative outcomes for both individuals and neighborhoods. In addition to fear (Garofalo & Laub, 1978; Wilson & Kelling, 1982) and mistrust (Ross & Jang, 2000), high levels of neighborhood disorder are associated with poor individual health outcomes: coronary risk factors, heart disease mortality, low birth weight, smoking, morbidity, psychological stress, heavy drinking, feelings of powerlessness, physical decline and depression (Cutrona, Russell, Hessling, Brown, & Murry, 2000; Geis & Ross, 1998; Hill, Ross, & Angel, 2005; Linares et al., 2001; Lowenkamp, Cullen, & Pratt, 2003; Ross & Jang, 2000; Ross & Mirowsky, 2001).

For neighborhoods, physical disorder and the spiral of decay can accelerate the downward trajectory of a neighborhood. Residents have a differential ability to exit disorderly neighborhoods such that households with greater economic resources are more likely to move out (Crowder, 2001; Dugan, 1999). In time, this reduces levels of wealth and resources in a neighborhood. As a result, businesses also turnover, with desirable retail and services such as grocery stores, pharmacies, and banks, gradually replaced with nuisance retail and services such as liquor stores or check cashing stores (Greenbaum & Tita, 2004; Small & McDermott, 2006).

Finally, both types of disorder have been linked to crime, although empirical evidence has been mixed. Research by Kelling and Coles (1996) and Skogan (1990) support this premise, while studies by Harcourt (2001), Sampson and Groves (1989), Sampson and Raudenbush (1999) and Taylor (2001) do not. One explanation for these mixed findings is the use of flawed disorder measurements. Objective measurements of disorder, such as SSOs, while touted as the gold standard, are severely restrictive in the space they measure. During a typical neighborhood audit using SSO, large portions of a neighborhood remain hidden from view and are left unaccounted for. These areas may be highly susceptible to crime, but their associated disorder cues are missed using traditional approaches. With few exceptions (see Wallace & Schalliol, 2015), sociologists, criminologists, and geographers have uniformly ignored any disorder that does not fall within the "block face." As such, large swaths of neighborhood disorder remain unmeasured. In the next section, we detail *how* and *why* such large portions of a neighborhood can be missed during the evaluation process by discussing the three dominant measurement techniques for capturing physical disorder in neighborhoods and highlighting their relative strengths and weaknesses.