Interaction Design and Architecture(s) Journal - IxD&A, N.20, 2014, pp. 61-71

The image of the algorithmic city: a research approach

Kevin Hamilton[1], Karrie Karahalios[1], Christian Sandvig[2], Cedric Langbort[1],

[1] Center for People and Infrastructures, Coordinated Science Laboratory
University of Illinois, Urbana-Champaign
1308 West Main Street, Urbana IL 61801 USA
{kham, kkarahal, langbort} @illinois.edu
[2] School of Information, University of Michigan
4322 North Quad, 105 S State St
Ann Arbor, MI 48109
csandvig@umich.edu

Abstract. Design for civic participation in the "smart" city requires examination of the algorithms by which computational processes organize and present geospatial information to inhabitants. How does awareness of these algorithms positively or negatively affect use? A renewed approach to one popular twentieth-century model for city design reveals potential paths for answering this question. The paper examines the contemporary "algorithmic" city using Kevin Lynch's prescriptions for livable urban design, and identifies several paths for future research.

Keywords: Perception, Cognition, Control, Participation, Open Data, Software, Governance, Design, Geospatial Annotation

1 Introduction

Decades ago, city planners and designers idealized the *legible* city, a polis whose construction facilitated a clear cognitive image for inhabitants and visitors. Today, largely relying on an ethos of "Open Data," many discussions about the computationally-augmented or "smart" city focus not on legibility but *transparency* [16]. Where the legible city waited to be *read*, the transparent city of data waits to be *accessed*. Key here is that for contemporary citizens, the act of reading, filtering, and interpreting the city is increasingly performed by software.

Today computational processes sort geo-located data and present relevant information to the walker, the voter, the consumer, and media interfaces are the dominant interfaces to a city. As early as 2001, Matei et al. asked residents of Los Angeles to highlight a map to indicate areas they thought were dangerous, then found that the differences among the shapes people drew could be predicted by which media

outlets they watched [13]. How might similar effects take place in today's era of mobile devices?

Despite growing emphasis on transparent and shared processes of composing the databases on which mobile computation depends, the algorithms that sort and deliver this data take place largely in the dark. For a city to be truly shared, participatory, and shaped by a public, do our very processes of retrieving data need to happen in as bright a light as the composition of the databases themselves? Or, do such processes actually impede use when they are too present and available? In a "people-centered" city of data, how legible should our algorithms be?

2 From Open Book to Black Box

Twentieth century adherents of the legible city saw beneath all cities the potential for universal, abstract concepts of order, structure, and flow. To such parties, the livable city should be a memorable image, one available to all in "the mind's eye." To this end, they set about studying human perception in order to develop design principles for wayfinding and navigation. Based on these principles, city designers either ordered new neighborhoods to maximize the potential for the formation of "cognitive maps," or augmented existing cities with signage or other mechanisms to aid in that process.

This approach to understanding and designing for the human experience of cities held sway for much of the twentieth century, before giving way to other theories and design strategies. Among the new approaches, human perception fell from favor as a key matter of concern for designers and students of urban space – not least due to the rise of augmenting technologies such as GPS-enabled devices, which, as typically implemented and celebrated, "pull" citizens through space while "pushing" relevant location-based information to their screens. In such technologies, the perception and navigation of geospatial volumes often seem to be less a factor than the perception and navigation of screen interfaces and databases. For many, the database rose in importance over the geospatial map in the quest for use-able cities.

Algorithms are as significant as databases within such approaches to urban navigation – as they are in so many other aspects of contemporary information and communication technologies. As computational, mathematical functions, algorithms gather relevant inputs - such as location, history of visits, or construction updates - and provide outputs – such as suggested routes, recommended destinations, and estimated travel times. In urban spatial applications, just as in web search, online shopping applications, or social network services, these processes largely take place in the "background" of user experience, legible only as effects, and not as processes.

In the field of Human Computer Interaction, opinions differ on when, how or why such processes should be visible to the user - if ever. [7,12] At least some recent work has shown that human understanding of algorithmically-constructed datasets is radically skewed, though few have firmly established the positive or negative effects of such misperception. [3] Popular debates over the effects of search engine "filter bubbles" reveal at least some of the stakes in such matters. [15] Many histories of technology have also offered that as a technological process moves from early,

experimental and highly visible stages to later ubiquitous and invisible implementation, matters of contention and debate often move into firm definition and intractability [8].

Precedent in urban design, interaction design, and history of technology would seem to argue for the necessity of research into the value of visibility, legibility and transparency in the implementation of algorithms as a component of cities. Should designers of "people-centered" cities pay attention to perception not only of interfaces or of spaces, but of the processes that bridge the screen and the street?

One path to answering this question might lie in a renewed approach not only to the study of perception and cognition, but to the body of work most concerned with designing cities according to the patterns of human sensation – that of city theorist Kevin Lynch. Lynch's principles, as outlined in his 1962 book *Image of the City*, might bear application in the study of geographic spaces constructed by software in real time for our mobile devices. (Indeed at least one group has done so, though with an eye more to databases than to algorithms [17].) People-centered cities require new attention to the "image of the city" – in this case the algorithmic city.

3 Lynch's Elements of Legibility

More than half a century ago, Kevin Lynch revolutionized the architecture of cities through asking a new kind of question: how can a city be more legible? Though the word legible suggests a comparison of cities to texts, Lynch's pioneering work actually treated city plans not as texts, but rather as images for use in human memory.

Through interviews with passersby, Lynch determined some of the key elements necessary to the design of legible cities – cities for which inhabitants can form a clear mental image. Such a clear mental image, argues Lynch, is necessary to a high quality of life, and especially one wherein citizens are able to imagine the possibility of a shared public space.

Lynch considered five distinct elements to be necessary to forming a clear mental image of a city [11]:

Paths are the channels along which inhabitants or visitors move.
Edges are the linear boundaries, breaks, or barriers, which arrest movement, or require crossing.
Nodes are the junctures or points of convergence for movement, including entryways and exits.
Districts are the sections of the city one can be inside of or outside of.
Landmarks are useful points of reference that are visible from afar.

According to Lynch, cities should be organized around clear creation of such elements, or augmented as necessary to facilitate mental imaging.

4 Legible, Semiotic, Algorithmic

Since Lynch's early book, some have suggested that his emphasis on perception in urban experience betrayed a short-sighted preoccupation with the cognitive and the abstract [17, 23], and a neglect of the semiotic in cities navigated as much by signage as by sight. Lynch's critics wondered whether a cognitive map is eally necessary, or even possible, in a city composed not only of proliferating signage but of buildings that themselves function as symbols through style? Contemporary cities, argued Venturi, Scott Brown and Izenour in their 1972 book *Learning From Las Vegas*, required "an architecture of bold communication rather than one of subtle expression. [23]" In their view, styles and signs make the connections between elements, so that the driver's mind doesn't need to do the cognitive work.

Perception of space and cognitive mapping of cities has only lessened in importance for many since then, with the initial availability of consumer-grade GPS technologies, followed by the proliferation of geo-located annotation applications for smartphone platforms. Spatial orientation itself, many argue, is less important when navigating with such tools [21] (even leading, by some accounts, to a weakening of the human hippocampus [14]). As in the postmodern semiotic city, geo-spatial annotation applications remember the edges, nodes, and districts for the user, and alert her accordingly. As algorithms generate maps dynamically for the traveler, the user arguably has no need of a cognitive map at all, and potentially needs only attend the navigational device, not the environment.

Both criticisms and celebrations of this vision tend to dwell on the databases on which such technologies rely, and less on the weakened role of spatial perception in this scenario, or on the algorithmic processes by which data reaches the user. In other words, arguments over how "people-centered" the annotated city will be tend to resemble arguments about the nature of authoritative knowledge on a site like Wikipedia. Though there is much merit to discussions about the value of "top-down" or "bottom-up" approaches to knowledge production, when applied to civic design they tend to treat the city as a browser-screen, and overlook large aspects of human experience. In reality, the algorithmic city is full of the same elements as Lynch's abstracted city, and merits a new examination through that old lens. In such a view, the algorithm comes into sharp focus as an area of needed study and research.

5 Research Questions for the Algorithmic City

Two questions await researchers and designers who would explore the processes behind the dynamically-constructed interfaces and representations of cities that appear on today's mobile screens.

First, how do these processes affect the cognitive images of inhabitants through use, and are such mental processes even as prevelant, or useful as they once were?

Second, how does common knowledge of these processes – either through detailed understanding of the algorithms in play, or through mere awareness of their existence – affect use of these technologies, and ultimately a person's approach to the city?

Even those who, like the semioticians Venturi and Scott Brown, reject the need for,

or even possibility of, a "mental map" held either individually or in common face the latter question as a basic matter of designing systems, interfaces, and experiences for the geo-spatial web.

A user's awareness of the algorithm at work in path-determination could affect use in many ways. A traveler's "inputs" to such an algorithm might include not only searched-for destinations and travel histories, but records of previous decisions to deviate from paths. The paths of others in a user's social network might also function as inputs to these processes.

As users begin to notice such algorithmic structures, either through direct observation or media coverage, might they not begin to change their behavior to achieve desired outcomes? For example, recent media coverage has suggested that certain algorithms for determining consumer credit ratings might be taking Facebook friend networks into consideration [10,19]. ("Choose your Facebook friends wisely; they could help you get approved -- or rejected -- for a loan," read one CNN tag line.) As users begin to take such advice and act to anticipate or "game" the system, might such efforts begin to multiply into overcompensation, and produce results far afield of the desired effect?

As in other interfaces wherein both passive and active inputs affect outcomes, or where some degree of machine intelligence is at work, designers will need to consider which aspects of the algorithm to make explicit for the user -and how- in order to create a relationship based on both trust and control.

The significance of trust within these processes takes the design of algorithmic interfaces in general, and geospatial algorithmic interfaces in particular, into territory that is somewhat less common for interaction design or city planning, though more famliar for artificial intelligence and security systems. For such systems – as in, for example, some medical devices or voting machines - research has demonstrated that explanation of machine decision-making processes is essential to establishing trust, and therefore to effective use [18]. In such situations – and unlike many other everyday machine interactions – either the designers or the machine itself need to reveal the decision process by which a process produces a particular result, or risk loss of confidence in the device [18].

Loss of confidence has, in fact, played a significant part in the introduction of new technologies into urban infrastructure. Anthony Townsend describes how cities grow more brittle with the addition of each new layer of software, and how failure in these layers usually triggers protocols that enact strict hierarchies of ownership and belonging for inhabitants [22].

A variety of approaches and theories exist for approaching the problem of establishing trust in such cases; designers of algorithmic cities will likely need to avail themselves of such precedent in order to guarantee utility, safety, and a sense of shared space.

6 Five Elements of the Algorithmic City

To reconsider the city today in Lynch's terms is to ground what for some critics was an overly abstract and universalizing approach in the specifics of individual citizen

experiences. A view of each of Lynch's elements in light of algorithmically-generated spaces reveals a bounty of new areas for research into the effects of geospatial interfaces on mental imaging of cites, and into the question of how visible urban algorithmic processes should be.

6.1 Paths

Paths are, in Lynch's view, among the most predominant elements in a city's image. They gain prominence through special activity or use, and specificity through dramatic changes in size or shape over the course of movement. Where a city has few distinguishable paths, Lynch found that few inhabitants could conjure an image of the city at all, and most had frequent trouble navigating. In Lynch's findings, repeated use of a path also played a role in that path's specificity [11].

Today's navigational aids have certainly had an effect on paths as shared or regularly-occurring elements for travelers. Anecdotal evidence would suggest that as applications such as Google Maps compute and prioritize routes based on real-time estimates of travel-time, once secondary or even tertiary roads might find new use.

When relying on such aids, the same traveler is also likely to take multiple routes between the same two points in the city over time. Though common sense would argue that route-variation has always been a part of urban navigation, algorithmic route-mapping software would seem to diminish the "central path" as an orienting device. Within such algorithms, what was once a central path is now but one more potential route, or fragment of route, to include in estimated travel times.

In addition, such technologies have already seen the growth of user-specific route construction based on demographic data, account preferences, or social media. An existing application called Waze allows users to navigate around "public events" indicated by users. Microsoft and Apple and both filed patents for similar features in their own navigation software, earning Microsoft some negative attention for anticipating an option for navigation around "high crime neighborhoods [4]." Apple's patent includes "protesters" as a possible detail for users to report toward the re-figuring of routes for other customers [5]. Both early efforts such as the Institute for Applied Autonomy's iSee application, which allowed travelers to map paths of "least surveillance," or more recent mapping tools such as MIT Senselab's Safecast present opportunities for specialized, algorithmically-constructed routes. Today, custom paths proliferate based not on any visible cues in the landscape, but rather on geo-located data generated by a user, a group of users, or the state.

The definition of the path as an element of the city bears re-examining in these instances. What paths emerge in a city's image under these dynamic circumstances, and for whom? If different paths emerge as predominant for different users based on demographics, what distinct and simultaneous images of the city emerge, and for whom? Where do these disparate images conflict or interact, and what are the effects of this fragmentation on shared citizenship?

6.2 Edges

Edges, though linear, function more as lateral reference points in Lynch's theory than as paths. In a city of algorithmically-constructed paths, edges might in fact be less apparent, given the tendency of GPS software to re-route for obstacles without alerting users to the change, or to guide travelers without regard for edges at all.

That said, the algorithmic city is full of new boundaries that range from difficult to impossible to cross. These boundaries can also shift in similar ways to paths. Edges in these situations could appear through RFID-triggered physical access points, pay-wall or password-protected information gateways, or even where network access itself ceases due to limited power, service contract limitations, or changes in protocol.

Lynch originally referred to Chicago as a city where an edge – that of Lake Michigan's coastline – featured more prominently than any other element in the cognitive image of inhabitants [11]. In such situations, most people navigate according to the edge without ever crossing it. Might a similarly dominant edge organize future cities through, for example, geographically delimited access to particular features of networked life? Already, lack of cellular or GSM coverage in remote areas functions this way for some. Might future manifestations of such barriers also occur through, for example, differences in which service providers are known to share data with law enforcement or government monitoring agencies? Apple has also filed patents for disabling particular technologies – such as audiovisual recording applications – in their devices within certain bounded areas [2]. Inhabitants might very likely begin to orient their life to such new boundaries – if they can even find them.

As such edges of technology, property or law shift over time according to changes in policy, protocols, standards or contracts, how is the inhabitant of the city to know where the edges exist without first crossing them, and possibly incurring penalty or prosecution? Here is surely a case where an important element of the city has grown both less legible and more important to observe and circumnavigate. If the shifting edge itself can't be visualized, then perhaps the explanation of the algorithms that determine such edges can be made more visible or legible instead.

6.3 Nodes

In Lynch's city, nodes are typically the town squares, the junctions, the "strategic foci" into which the citizen could enter, or from which she could leave [11]. As such, nodes are places of heightened attention and decision-making, perhaps also serving as places to change modes of conveyance.

In the algorithmic city, nodes, like paths, are user-specific, and often travel with the user in the form of applications on mobile networked devices. What distinguishes one node from another in algorithmic space is not its location in space, but its particular, often proprietary collection of potential entrances or exits. Paired with a mobile device and the right user account, any geo-location can be a node in the algorithmic city. Within spaces facilitated by proprietary accounts, entrances and exits appear according to user history, preferences, paid levels of access, or collective voting and ranking.

As such, nodes bring some of the same challenges as paths and edges to establishing a shared civic image among inhabitants. As with paths, nodes have now moved into the realm of individualistic preferences and histories, and context-specific revelations. Here, however, the algorithms at work are at least partly visible in the form of branded identities. Rival companies such as TripAdvisor, Yelp or Groupon compete to offer not only a dataset tailored for users, but algorithms that seem to slant in ways that suggest a desirable authority or identity. In some cases, branding strategies in such products obscure the algorithmic processes by which portals appear to a user, while in other cases they might help reveal such processes. Researchers will need to examine the effects of both approaches.

Nodes in the algorithmic city can also be somewhat diffuse given the relocation of many official portals into the very space of origin for travelers. A user who routinely "checks in" to her flight at home before departing for the airport will likely no longer see the airport ticket counter as a crossroads, just as political borders are not as visible from the perspective of shipping containers whose contents are checked and officially sealed by embedded customs agents at their site of origin.

New nodes could also emerge at the junctures of different coverage areas for wireless infrastructure, or different jurisdictions for policy and protocols. As with edges, however, visibility of such junctures is not always a straightforward matter. Designers of the people-centered city will need to examine the role of the new "mobile nodes" in establishing shared spaces of meeting, transition, and access, while also attending to potential needs for increased visibility for vital nodes that appear unexpectedly, or vanish into infrastructure.

6.4 Districts

Districts in the algorithmic city will in some ways diminish, and in other ways proliferate. They diminish in importance as mobile guidance systems direct travelers without regard for boundaries, while re-emerging as a new set of choices between which not only a traveler but a public offical might make crucial decisions. These new, less visible but no less effective districts, will appear with great simultaneity and fragmentation.

As areas which, according to Lynch, "one can mentally go inside of [11]," districts often surpass paths for their prominence in a city's image. Algorithmically constructed districts occur through software-identified regions, and could include everything from a map of Manhattan according to Netflix rentals (as conducted by the New York Times in 2010 [1]) to the pioneering work of Laura Kurgan's Spatial Information Design Lab at Columbia University, which has conducted a study of America's "Million Dollar Blocks," city blocks with enough registered residents currently away and incarcerated to cost over a million dollars a year in federal funds [6].

Such approaches to region or districting will often appear only to the person with the right device or software – though in this case, perhaps more than in other Lynchian elements, the digital stands to leave lasting visible effects. As cities largely govern, police, and resource based on geographic zoning, algorithmic districts unseen in everyday space could ultimately end up informing the future of a neighborhood

without announcement or rationale. Historians of zoning law, taxation or finance have shown that relatively invisible and seemingly value-free computational processes can have lasting effects, as in the American "redlining" of districts deemed undesirable for home loans because of racial composition in the 1930s [9].

Here again, invisible algorithmic processes bear examination for how explanation of their presence and structure will effect not only navigation and identity, but the very material composition of a city through investment, legal enforcement, and economic planning.

6.5 Landmarks

Lastly, landmarks may be the most likely of Lynch's elements to retain their function as spectacular and even iconic reference points in the city, especially with the contemporary turns toward city-branding through "star architecture" and spectacle. Such landmarks may even acquire new use in the algorithmic city; their relative pictorial stability and high contrast make them well-suited to photographic capture in augmented reality applications.

That said, it must also be acknowledged that the definitive reference point or landmark in the algorithmic city is the self, as mobile devices orient all things to a user's current location, history and preferences. This definitive change in the city is both the largest reason why cognitive imaging of cities may not even be a significant part of urban experience, and the source of greatest concern for those who wish to make cities truly "people-centered" and not merely "person-centered." If the augmented city is largely a self-referential city, then the visibility of algorithms is a less immediate question than the very visibility of other citizens. How important is our awareness of not only fellow inhabitants, but of their different spatial constructions of the city?

7 Conclusion

It must be said that even Lynch was less concerned with individual subjectivity and variation than with establishing images to be held in common. More recent scholarship has shown the ways in which such easily image-able city spaces exclude some groups through the very solidity and coherence of the image, leading some to embrace a more heterogenous approach to space, such as that found in de Certeau's vision of the city.

But therein lies the same trap as that of the most tired arguments over Wikipedia as a reliable authority. Arguments over "top-down" vs "bottom-up" approaches to knowledge construction tend to treat the mere existence of databases as the most important aspect of digital life, when good or bad governance can often take place in full ignorance of such data.

As Dietmar Offenhuber argues in his essay "Legibility from Below," transparency and accountability are not only less linked than often imagined, but necessarily considered as separate features and entities [20]. Accountability, Offenhuber argues,

"goes beyond transparency and questions of information access" to guarantee answerability and enforcement. Quoting political scientist Andreas Schedler, he explains how agents of such accountability make their primary area of competence "the unobserved and unobservable actions."

Making algorithms more visible to users, travelers or citizens will not always result in a more safe, inclusive, or livable city. Such revelations could even very well serve as a detriment to participation or even health. But until we move beyond the study and design of "smart" cities based on their composition as databases to examine the processes by which such augmented spaces appear to users in the first place, we will be missing a key feature of contemporary civic life.

References

1. A Peek Into Netflix Queues - Interactive Graphic - NYTimes.com, 14 Jan (2014)
2. Bell, Michael, Lovich Vitali, and CA.: United States Patent: 8254902 - Apparatus and Methods for Enforcement of Policies Upon a Wireless Device, 28 Aug (2012)
3. Bernstein, Michael S. et al..: Quantifying the Invisible Audience in Social Networks, in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, New York, NY, USA: ACM, pp. 21–30, (2013)
4. Bishop, Todd.: New Microsoft Patent: Walking Directions That Avoid Crime-ridden Neighborhoods, for GeekWire.com, 3 Jan (2012), http://www.geekwire.com/2012/new-microsoft-patent-walking-directions-that-avoid-bad-neighborhoods/
5. Campbell, Mikey.: Apple's Waze-like Navigation System Creates Routes Based on User Ratings, Real-time Accident Reporting, for Appleinsider.com, 13 Jan (2014), http://appleinsider.com/articles/13/07/04/apples-waze-like-navigation-system-creates-routes-based-on-user-ratings-real-time-accident-reporting
6. Kurgan, Laura, and Cadora E.: Architecture and Justice, New York: Spatial Information Design Lab, Columbia University, (2005)
7. Harrison, Steve, Sengers P, and Tatar D.: Making Epistemological Trouble: Third-paradigm HCI As Successor Science, in Interactive Computing 23.5, pp. 385–392, (2011)
8. Latour, Bruno.: Pandora's Hope: Essays on the Reality of Science Studies, Harvard University Press, (1999)
9. Light, Jennifer.: Discriminating Appraisals: Cartography, Computation, and Access to Federal Mortgage Insurance in the 1930s, in Technology and Culture 52.3, pp. 485–522 (2011)
10. Lobosco, Katie.: Facebook Friends Could Change Your Credit Score, for money.cnn.com, 26 Aug (2013), http://money.cnn.com/2013/08/26/technology/social/facebook-credit-score/
11. Lynch, Kevin.: The Image of the City, Cambridge [Mass.]: Technology Press, (1960)
12. Mark, Gloria, and Norman Makoto Su.: Making Infrastructure Visible for Nomadic Work, in Pervasive and Mobile Computing 6.3, pp. 312–323, (2010)
13. Matei, S., Ball-Rokeach, S. J., Qiu, J. L..: Fear and Misperception of Los Angeles Urban Space: A Spatial-Statistical Study of Communication-Shaped Mental Maps, in Communication Research *28*(4), pp. 429—463, (2001)
14. Maxwell, Rebecca.: Spatial Orientation and the Brain: The Effects of Map Reading and Navigation, for GISlounge.com, 8 Mar (2013), http://www.gislounge.com/spatial-orientation-and-the-brain-the-effects-of-map-reading-and-navigation/
15. Morozov, Evgeny.: Book Review - The Filter Bubble - By Eli Pariser, in The New York Times, 10 June (2011)

16. New Cities Summit 2012 - The Annotated City - 14 May 2012 – YouTube, 14 May (2012), http://www.youtube.com/watch?v=Yu8U_6V_uq8
17. Offenhuber, Dietmar, and Ratti C.: Reading the City — Reconsidering Kevin Lynch's Notion of Legibility in the Digital Age, in The Digital Turn - Design in the Era of Interactive Technologies, ed. Zane Berzina, Barbara Junge, Wim Westerveld, and Carola Zwick. Zürich: Park Books (2012)
18. Pieters, Wolter.: Explanation and Trust: What to Tell the User in Security and AI?, in Ethics and Information Technology 13.1, pp. 53—64, (2011)
19. Salyer, Kirsten.: That Facebook Post Could Ruin Your Credit, for Bloomberg Opinion, 9 Jan (2014), http://www.bloomberg.com/news/2014-01-09/that-facebook-post-could-ruin-your-credit.html
20. Schechtner, Katja, and Offenhuber D, eds.: Accountability Technologies: Tools for Asking Hard Questions, Ambra, (2013)
21. Thielmann, T.: 'You Have Reached Your Destination!' Position, Positioning and Superpositioning of Space through Car Navigation Systems, in Social Geography 2.1, pp. 63—75, (2007)
22. Townsend, Anthony M.: Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia, New York: W. W. Norton, (2013)
23. Venturi, Robert. *Learning from Las Vegas*. Cambridge, Mass: MIT Press, 1972.