THE RELEVANCE OF INFORMATIONAL INFRASTRUCTURES IN FUTURE CITIES

Ricardo Alvarez
PhD Candidate and Researcher
DUSP / Senseable City Lab
Massachusetts Institute of Technology

Ricardo Alvarez is a PhD Candidate for the City Design and Development Group in the Department of Urban Studies and Planning and also a researcher in the Senseable City Lab, both at the Massachusetts Institute of Technology (MIT). His research focuses on the integration of large scale digital sensor networked architectures for the creation of future urban infrastructure systems and on the use of AR/VR media for spatial synthesis. He is also an entrepreneur in technology centered ventures in media and fintech industries. He worked for five years in the Mexican Federal Government where he was one of the founding members of ProMéxico (the country's trade and investment promotion Federal Agency) and worked as Senior Advisor to the CEO, Managed International Operations for North America, Europe, Africa and the Middle East and headed the Innovation and Strategic Projects Office. Prior to that he worked in the private sector in the retail, financial and media sectors.

KEYWORDS

- SMART CITIES
- DIGITAL INFRASTRUCTURE SYSTEMS
- IOT
- MACHINE LEARNING
- FUTURE SOCIETIES

"Building these programmable places is not just a matter of putting wires in the walls and electronic boxes in rooms... In the end, buildings will become computer interfaces and computer interfaces will become buildings."

William Mitchell (1996)

INTRODUCTION

Cities around the world are installing digital architectures of sensors, computational cores and telecommunications in the urban fabric, transforming existing infrastructure systems into multi-functional informational and services platforms in the process. The fast pace of digitization is often hard for cities to fathom, many of which are challenged by a silent privatization of the informational value of public spaces and the under-development of the potential of 21st century digital infrastructures due to a mono functional non-inclusive process of design. This is compounded by the power behind large-scale data ecosystems, which when paired with technologies such as machine learning will have profound impact over our future urban services and lifestyles. Cities need to adapt their design mentality and institutional models, but it is through social participation, and open technology standards that true inclusive synthesis of the future digital systems that enable our interactions with cities and allow for the myriad of new services and experiences can be achieved.

Cities are created through an accretion process by which urban artifacts are layered and appropriated over the course of history to become the "collective memory of man" (Rossi, 1982). Our infrastructure systems, from streetlights and traffic lights to sewers and roads are emblematic examples of this process. While we traditionally think about this accumulation of urban form in terms of bricks, it has become evident that in our contemporary societies the informational space mediated by digital technologies has created a parallel reality composed of bits that is no less important to our everyday lives. While we live in physical and social spaces, we are increasingly interacting with them through digital media. This convergence of bits and atoms (Mitchell, 1996) demands a similar process of imagination and reflection on the contemporary synthesis of urban physical-digital artifacts on which we will deposit our human biography in the 21st century.

The process of technological imagination in cities is not new. Influential thinkers and architects such as the likes of Howard (1902), Le Corbusier (1935) and Wright (1935), led this exercise roughly a century ago. They lived through a fast changing world, where inventions such as the automobile, the elevator and the telephone were demanding a change of urban form. Moreover, societies themselves were experimenting profound transformations that emanated from the industrial revolution. As such the fundamental question of their time was "what is the ideal city of the 20th century? The city that best expresses the power and beauty of modern technology and the most enlightened ideas of social justice" (Fishman, 1982, pp. 3). Today, we are living a similar transformation. As post-industrial societies change into information and knowledge societies, the coin of trade also changes from bits to atoms. The creation of digital or "smart" infrastructures is our exploration, our process of looking at cities through their informational lens. Given the rapid pace of change that digital technologies exhibit, Fishman's question remains as relevant today as when he first wrote it if not more; lest not forget that while previous technologies had a dramatic impact in our modern cities, they did so at an enormous energy and environmental cost.

Today we're gradually realizing this "digital city" of ubiquitous computers that are so prevalent that they are invisible, effectively melding into the background while having a profound effect in our everyday lives (Wieser, 1991). Although the digital city is often referred to as a "smart city" – a label widely adopted by marketing departments of corporations and cities alike – its scope is much greater. Beyond a reductionist view of discrete solutions centered on digital technologies aiming at improving urban efficiencies, the digital city encompasses a deeper evolution of our existing infrastructures transforming them into informational systems capable of dynamically mediating the interactions between humans and their environments. Its manifestations are everywhere, from simple things such as the doors that automatically open when we enter a building to systems of great complexity such as smart grids or the dynamic traffic management systems deployed in cities like Singapore, Stockholm, and London[1]. At its core the digital city is a combination of mass deployed digital sensors embedded into our urban fabric, on our personal devices, in our automobiles and homes. These sensors are interconnected by telecommunication networks that transmit massive volumes of collected data to distributed computational architectures for processing and storage. The processed data then used to perform actuation cycles on a variety of connected systems and eventually delivered to people through mediated infrastructures or locative media.

These assemblages are constantly generating troves of data about our environments and our behaviors in them. The data collected is not without context, but rather sensed from urban environments, aggregated and analyzed across varying scales of space and time to reveal invisible patterns, hidden dynamics of "actions, transactions and interactions" in the city (Batty, 2013, p. 115). When assembled, urban data can create real forms of knowledge capable of having an effect on social life (Kitchin, 2014); as such it can be used for a wide range of purposes; from achieving better governance and policy making to creating optimizations in critical infrastructure, developing new types of services and designing novel urban experiences. However, for the vision of the "digital city" to become real we need to merge the urbanscapes with the infoscapes into a coherent new urban synthesis that layers many new physical-digital urban artifacts. In short digital technologies, which McLuhan described as an extension of our nervous system (McLuhan, 1964), will be integrated into large "internet of things" architectures that will surpass the Internet of humans (Evans, 2011) to form "digital nervous systems" of urban, even planetary scales (Mitchell, 1995, 2000, 2003).

While some researchers characterize "smart city" projects as examples of outward-looking policy promotion for the globalized economy that propose benefits through a variety of digital augmentations (Wiig, 2015), and question the self-congratulatory rhetoric surrounding them, their fuzzy definition and overall ideology (Holland, 2005). The vision of the "digital city" is often questioned as if it is a choice, but the fact of the matter is that we cannot deny the constant permeation of digital technologies into our urban environments. Given the fast pace by which these technologies evolve in capabilities, accessibility and cost; their introduction into our daily lives and realities is an almost inevitable outcome and as such I think the more relevant question is not whether *if* it will or should happen, but rather *how* it will and should happen? The historical impact in cities of technologies such as the automobile, the elevator or the telephone should be a warning that pushes us to a greater degree of agency and inclusion in defining how the next waves of technology adoption should play out again in the future.

1 http://ops.fhwa.dot.gov/publications/fhwahop08039/cp_prim1_08.htm

This is a relevant matter since the ongoing digitization and "upgrading" of traditional cities infrastructures has created a '$100 billion jackpot' (Townsend, 2013, pp. 19), one that has fueled an industrial race for the transformation of the next generation of urban infrastructures. Many companies have been selling cities a large array of applications that leverage their respective domain of technological expertise to solve specific urban problems such as congested traffic, waste collection and energy optimization. These solutions are in high demand from public officials who desire highly visible solutions to show to their constituencies. Most of the time the technologies deployed work under closed, proprietary platforms that are essentially "black boxes" to the cities that purchase them through licensing arrangements aimed at creating technological dependencies and data silos. The closed nature of these platforms is critical for companies in their pursuit to strategically control the flows of bits, atoms and electrons of cities in the following decades of explosive urban growth and reconfiguration (Townsend, 2013).

The aforementioned dynamic poses the risk of allowing a greater degree of privatization of public systems than what is socially desirable. This is compounded by cities not thinking about their digital infrastructures in terms of multi-functional architectures and which are still purchasing digitally enhanced single purpose solutions that are a reflection of the 20th century mono-functional infrastructure design mentality. It is often difficult for cities to realize that unlike traditional infrastructures, which are designed to function on their own, digital infrastructures grow in value by working with others since the value captured from the data they generate can expand dramatically when combined with more data. The intangibility of the digital aspects of their new infrastructure systems makes it hard for cities to quantify or even comprehend their true value and makes it easy for companies to claim ownership of the data generated using proprietary technologies. In this sense public infrastructure systems can become privatized both in terms of functional and informational control, even when formal "ownership" resides in city hall. In 1748 Giambattista Nolli illustrated the distinctions between public and private physical space in his famous *Pianta Grande di Roma* map, unfortunately in the "Digital City" distinctions between the public and the private are much more difficult to delineate.

The 20th century infrastructure design mentality also leads to a skewed "*solutionist*" perspective aimed at fixing things and finding solutions to existing discrete problems. Its single-mindedness permeates a culture of development that focuses on optimization of efficiencies rather than on reframing of possibilities. For example, we tend to evaluate "smart" solutions for traffic mainly in terms of vehicular flows optimization or "smart" light projects in terms of a achieving a certain level of energy savings and higher quality of light; and while seeking to optimize existing systems is a worthwhile endeavor, many of the solutions offered don't take into account the nuances of human behaviors and needs outside of their one-dimensional focus and therefore miss on imagining other possibilities to improve their role in the city. Little consideration is given to how technological possibilities could challenge the typological definitions of our infrastructure systems in the future, or furthermore how society might use these new types of infrastructures to synthesize new uses and experiences that don't address any identified problem, but that still hold potential value for citizens.

Leveraging digital technologies for the evolution of current infrastructure systems will not only require investments in R+D but also efforts of design, imagination and planning. Even more so, it will require a good deal of social involvement. Here some lessons of the smartphone era become valuable since they demonstrate that through design showcases, standardization of hardware, data structures, development platforms and marketplaces, the larger population can be empowered into creating a myriad of applications. This won't happen overnight; a gradual process of experimentation and social contestation over this new informational space will be needed for the system to thrive.

Governments and companies can help kick start this social imagination when showcasing examples of applications and uses for the new platforms. Appropriate conditions for a creative ecosystem can be fostered, by providing standardized modular sensor and computational architectures flexible for adoption by cities, giving open access to data, helping education and training programs, developing application-programming interfaces (APIs) and streamlined marketplaces of information and services. All of this is required by the greater society if they are to use the city for processes of experimentation and creation. After all, cities around the world differ dramatically in terms of local challenges, urban form, social composition, institutional arrangements, cultural sensibilities and economic possibilities. The conditions and needs of cities such as New York, San Francisco and London are seldom the same from the likes of Nairobi, Tehran and Beijing; therefore a profound recognition in their differences and nuances will be needed to synthesize and create the multiple variations of experiences, solutions and services sought by their populations.

Many of these variations will not be in the form of hardware but in software. The uniqueness of each scenario will require a combination of grounded cultural values and practices synthesized in in the form of code and algorithms, which in turn will power the intelligence behind the next generation of informational infrastructures, but with a local flavor. Given the amounts of data being generated at urban scales by these infrastructures; techniques utilizing various forms of machine learning and artificial intelligence, such as convolutional neural networks and deep learning will increasingly become a critical component in the development of useful applications.

These machine-learning techniques leverage computers capabilities for detecting unique 'hidden' patterns in aggregated data of various kinds. Generally speaking, they do this by analyzing millions of data points used for 'training' purposes. Through this process computers gradually achieve the capability of calculating with a certain degree of probability the identification of basic patterns from raw data such as shapes, sequences, frequencies, order, color, etc. By stacking layers of patterns in a neural networked model, they are able to accurately identify patterns of greater complexity and so on. Some of these neural networks have so many layers that that we refer to them as 'deep' networks. They are capable of identifying patterns that even escape our human biology, which is why they are useful in the understanding of systems of great complexity. When computers utilize a type of recursive function commonly referred to as 'back propagation' they can integrate past results into their learning models as they sift through the data; in essence creating large probabilistic machines following a Bayesian model that continually learns and updates its 'beliefs' as it generates decisions based on the data inputs – the greater the data set, the more accurate the learning, the more powerful the decision –.

The patterns detected can range anywhere from extracting unique features that aid in the automation of humans tracking and face-recognition from video-data utilizing a variety of machine-vision algorithms; identifying unique sound signatures from audio to recognize speech patterns using natural language processing; detecting patterns of aggregated behaviors in traffic from GPS data or longer-term environmental change based on air quality data from particulate matter monitoring stations, to name a few. Machine learning technologies are at the moment creating a revolution in a wide array of data-intensive industries from media and finance to biotech, transportation and of course IT, they are behind many of the devices, interfaces and services that drive or digital lifestyles. However, technological shortcomings of machine learning must be acknowledged. For example, bias can be induced in machine learning models if the data is not representative enough, a known problem for example is video recognition algorithms that are very good at detecting persons of certain skin colors better than others simply because they were trained on data that didn't have enough representative samples from a general population. This is why properly curating of the data a core process. Also, it is important to recognize the conceptual and technological limitations of machine learning models for specific purposes. While there is a lot of speculative literature that romanticizes A.I., and while we have created machines that often surpass human beings in performing highly specific tasks (Bostrom, 2014) the truth is that we're far from creating truly intelligent computers capable of achieving human or near human level intelligence for a los of processes and scenarios.

Given the amount of data generated by our digitized urban environments, cities in the future will invariably leverage machine learning technologies to mine, understand and operationalize their data in order to maximize their benefits. But city hall cannot do it alone, as it often lacks the resources and knowledge to truly achieve this effort of conceptualizing the transformation of our traditional urban infrastructures into versatile intelligent cyber-physical artifacts for future cities, which is why involving enterprises and citizens in this task, is key. From history we learn ways to engage the public into appropriating and exploring the possibilities of a new typology of urban artifacts that mediate the connections between places and human activity, hopefully to help people exercise their right of collective power to reshape the process of urbanization (Harvey, 2003) in the informational space. In our era this collective process comes with a sense of urgency driven by information's natural tendency to grow (Hidalgo, 2015), which compounds the aggregation of power through monopolistic information control; a phenomena contemporarily exemplified by many of Silicon Valley's tech behemoths; lest we forget how often information has been misused as a social control tool by many companies, institutions and governments (Scott, 1998).

It is not my intention to signal that through technology alone the vision of the "digital city" will become a reality. For that, profound changes in institutional development, education, accessibility along with new business models and legal frameworks will be needed. To cite William Mitchell "As traditional cities have evolved so have customs, norms and laws governing rights to privacy, access to public and semi public places and exertion of control" (Mitchell, 1996, p.131) However I would argue that design exercises and technological demonstrations can be powerful instruments in triggering discussions that may be of relevance to the evolution of cities.

BIBLIOGRAPHY

- Batty, M. (2013). *The new science of cities.* Mit Press.
- Bostrom, N. (2014). *Superintelligence: Paths, dangers, strategies.* OUP Oxford.
- Corbusier, L. (1935). *La ville radieuse, éléments d'une doctrine d'urbanisme pour l'équipement de la civilisation machiniste: Paris, Genève, Rio de Janeiro, Sao Paolo, Montevideo, Buenos-Aires, Alger, Moscou, Anvers, Barcelone, Stockholm, Nemours, Piacé.* Éditions de l'architecture d'aujourd'hui.
- Evans, D. (2011). The Internet of things: How the next evolution of the Internet is changing everything. *CISCO white paper,* 1(2011), 1-11.
- Fishman, R. (1982). *Urban Utopias in the Twentieth Century: Ebenezer Howard, Frank Lloyd Wright, and Le Corbusier.* MIT Press.
- Hidalgo, C. (2015). Why information grows. *The evolution of Order, from Atoms to Economies.(Ebook) New York: Basic Books.*
- Holland, R. (2005). Will the real smart city stand up. *City,* 12(3), 3.
- Howard, E., & Osborn, F. J. (1965). *Garden cities of to-morrow* (Vol. 23). MIT Press.
- Kitchin, R. (2014). *The data revolution: Big data, open data, data infrastructures* and their consequences. Sage.
- McLuhan, M. (1964). *Understanding media: The extensions of man.* MIT press.
- Mitchell, W. J. (1996). *City of bits: space, place, and the infobahn.* MIT press.
- Mitchell, W. J. (2000). *E-topia:" urban life, Jim--but not as we know it".* MIT press.
- Mitchell, W. J. (2003). *Me++: The cyborg self and the networked city.* MIT Press.
- Rossi, A., & Eisenman, P. (1982). *The architecture of the city.* Cambridge, MA: MIT press.
- Scott, J. C. (1998). *Seeing like a state: How certain schemes to improve the human condition have failed.* Yale University Press.
- Townsend, A. M. (2013). *Smart cities: Big data, civic hackers, and the quest for a new utopia.* WW Norton & Company.
- Weiser, M. (1991). The computer for the 21st century. *Scientific American,* 265(3), 94-104.
- Wiig, A. (2015). IBM's smart city as techno-utopian policy mobility. *City,* 19(2-3), 258-273.
- Wright, F. L. (1935). Broadacre City: A new community plan. *Architectural Record,* 77(4), 243-54.