Embedded and Interconnected Buildings: Toward Intelligent Architecture

As the concept of the universal machine—the computer—splits hardware (form) from software (function), so does the contemporary city separate its finely woven layers of meaning, use, and built form into quasi-autonomous strands. The meaning may no longer be the function of the form but is instead increasingly defined by usage patterns and contributing agents. It is culturally conditioned and crowdsourced with a quick refresh rate.

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Similarly, form may be a manifestation of temporal conditions driven by users and their momentary needs. It is no longer an inert landscape made of stone but rather a hybrid cyber-physical construct that materializes the dynamic connections of its agents. As such, static classifications and theories of urban form are no longer sufficient and need to be extended to include these new electronic and media-driven dimensions. Defining the image of the city as a result of five physical elements (Lynch, 1960) undercounts the virtual and emotional components and drives that are present in the environment. Operating within objectified and generalized categories cannot be extended into a quantum scale of urban habitation. Similarly, the assumption that these categories are commonly shared and agreed upon does not consider individual and subjective experiences. For example, all city dwellers know objects and places within their city that are considered culturally significant, but these places may have no bearing on their individual experience of the city. Quite often inhabitants choose to spend time in spaces that are not commonly shared so as to avoid traffic, to manifest individuality, or to relive personal and meaningful moments that happened in a certain location.

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Figure 1: Settlement distribution, night view, (NASA)

Behavioral patterns (patterns of habitation) as defined by Christopher Alexander in *The Pattern Language* are close to those of electronic networks and big data. They reflect human choices when traversing a city or mark points of social interactions (fig.1). However, even these patterns of habitation divide the built environment into active agents (people) and passive recipients of actions or inert objects (buildings and cities). While in the emerging Mediapolis many of the offline functions and activities are being ported into the virtualized worlds, this does not significantly redefine the structure of human habitation. Electronic social networks do replace or extend city squares or ancient agoras into new forms of social communications, as pointedly predicted by William Mitchell in *City of Bits: Space, Place, and the Infobahn*. However, the simple mapping of the city from the physical into the virtual misses a whole new class of users and possibilities. In a world of smart cities and autonomous objects, everyone and everything is an agent. While self-driving cars are obvious examples of energized matter, buildings and other elements start playing similar roles. Buildings can

start informing users what is the best route to go within it (Schwartz, 2013) in a similar way as interconnected drivers navigate the city using crowdsourcing apps such as Waze (fig.2). Furthermore, the combination of anonymity afforded by electronic existence and advanced functionalities of autonomous objects blurs the boundaries of what is outwardly projected by humans and machines. It may be difficult, if not impossible, to distinguish between these two groups of participants.

THE POSITION

What are current equivalents of Kevin Lynch's five elements? Are these elements still relevant? Do they need to be reconfirmed or perhaps upgraded? Does Christopher Alexander's pattern language based on outside observations of human behaviors apply to individual experiences? Applications of electroencephalogram (EEG) technology in architecture and urban studies (Mavros et al. 2012) provide opportunities to verify or reevaluate behavioral theories of the past that were derived through outside observations and intuitive thinking but did not have insight into brain imaging of behavioral patterns. The emotional impact of an architectural or urban space may be difficult to separate from the memories of past events associated with it.

This paper investigates how established models of the city, such as those discussed by Lynch (*The Image of the City*), Alexander (*A Pattern Language*), or Aldo Rossi (*The Architecture of the City*), intersect with a contemporary media framework using a new set of parameters such as networks, identities, and agents. It also looks at how the futuristic projections of William Mitchell (*City of Bits: Space, Place, and the Infobahn*) need to be expanded to include autonomous agents and remove humans as the only privileged participants of urban interactions. Emerging formative elements or drives such as **identity**, **addressability**, and **autonomy** become integral to what Félix Guattari defined as mental, social, and environmental ecologies in his seminal work *The Three Ecologies* (1989). Guattari's concept of ecologies (1) mental, (2) social, and (3) environmental, connects well with the urban theorists of the mid twentieth century such as Lynch and Alexander. The division between individual (mental), group (social), and context (environmental) ecologies is no longer satisfactory to explain the intricacies of the overall sociocultural mechanism of autonomous and media environments. Mental, and particularly social, ecologies should be seen as conditions that transcend only-human interactions and include inter-agent connections. The evidence and benefits of the new dimensions of wired cities—identity, addressability, and autonomy—cut across these pre-digital classifications and provide new ways to understand emerging constructs. This is already evident is some aspects expressed in the *City of Bits*, where Mitchell talks about human bodies morphing to cyborgs and buildings being embedded with telecommunication systems. However, environment, or a space where interactions occur needs to be included as an active and equal participant of these transformations.

Filled with individually addressable object-agents, the environment acquires new functionalities. It shifts from a simple backdrop or a context to an emancipated and equal player that interacts with other actors. Similarly, media—social ecology in Guattari's model—permeate through all scales of the landscape, corresponding closely to the vision outlined by Marshall McLuhan in *The Medium is the Massage: An Inventory of Effects* (1967). McLuhan's vision frames the symbiosis between culture and nature in acute and contemporary-relevant ways. Media become an intangible urban fabric connecting people and places as well as defining the patterns that form spatial identities. Electronic media components fundamentally redefine the very fabric of spatial habitation. The space-time continuity is being relaxed in lieu of cinematographic (narrative) spatial and chronological discontinuities. It corresponds to Lynch's observations regarding urban mental maps: "Most often our perception of the city is not sustained, but rather partial, fragmentary, mixed with other concerns. Nearly every sense is in operation, and the image is the composite of them all" (Lynch, 1960, p. 2). Fragmentation

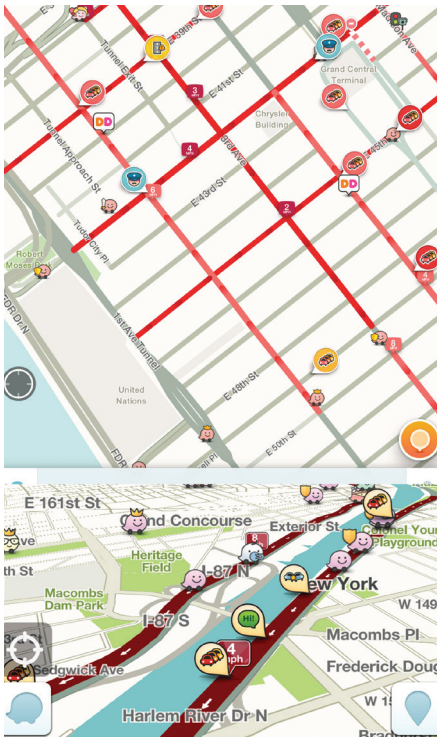

Figure 2: Crowdsourced apps like Waze allow for real-time adaptive urban navigation

and discontinuity of experiences and rebuilding them with partial memories into a spatial narrative are representative of both Lynch's urban mental maps and media environments. However, in the contemporary media city these mental maps not only are individual and perpetually self-informing but also refer to nonphysical constructs. A memory of the event shared by a group of people can serve as a *landmark* (one of Lynch's elements) that references social communication or as an *edge* (another of Lynch's elements) that defines constraints for a public discourse.

While the mental mapping framework is an effective vehicle to connect users' spatial experiences and broaden the understanding of behavioral dynamics within urban spaces, there seems to be unnecessary urgency in translating mental maps into tangible categories of physical objects. The qualities evoked by mental maps are lost in translation when ported into physically tangible urban elements such as buildings and city blocks. This is the major limitation of Lynch's urban form theory that tries to reconcile the immaterial and ephemeral into discrete physically defined topological rules. Particularly, considering that mental maps are the collection of subjective individual records, their resultant vector (socially agreed meanings) may have little to do with original components (personal references). The territory/topology dichotomy used by Mitchell continues to be relevant in media-enriched cities. Urban agent interactions register more explicitly through topological mappings, flow patterns, and interaction diagrams than through the typological approaches of a traditional city. Alexander's behavioral patterns correspond closely to this emerging way of urban mapping. Furthermore, with new electronic media, unrelated concepts—a building façade as an interface (Mitchell) and augmented reality as extension of Rossi's collective memories—begin to converse on a unified urban experience: experience that is well rooted in the needs of participants yet often unmaterialized, ephemeral, subjective, and crowdsource driven.

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Figure 3: Mobile augmented reality (AR) is just one of the platforms that provide customizable view of the city.

PUBLIC SPACE: PRIVATE ACCESS

Unlike the physical city, which by its shared nature is always "on" and WYSIWYG (what you see is what you get), virtualized worlds can be turned off and can be either WYSIWYG or non-WYSIWYG, allowing for privacy within the public realm (fig.3). This on-and-off transparency is characteristic of electronic networks and online culture. It also puts in question a number of architectural and urban form constants, such as Rossi's collective memory concept, or even Lynch's five elements that form mental maps.

The collective memories rely on shared experiences formed within an environment that is transparent to all participants and open for their consumption. The context- and location-awareness, characteristic of current electronic social networks, is the exact antithesis of the collective experience. It provides relevant information—here and now—filtered based on the needs of individual users. However, the endgame is not what is present in the environment or projected outward by its form but what a recipient (the general public) perceives and registers. The collective memories, those discussed by Rossi in *The Architecture of the City*, are not expressed and codified within buildings but by what consumers of culture walk out with from these experiences; what stays in their heads, not on the building walls.

In media-infused cities, elements such as *district*, *edge*, or *landmark* as defined by Lynch become mental expressions registered and shared by individuals without the need for broader compatibility or relevance within society. These mental maps become highly individualized, with strong references to nonphysical objects that go beyond Lynch's five elements and their projections onto the physical form of the city.

For example, for some New York City (NYC) is associated with September 11 events or with nineteenth-century immigration waves as repr esented by the Statue of Liberty. For others, it is associated with the iconic Central Park, with Woody Allen's movies, or with the Sex and the

City TV show. However, for most people NYC is a landmark that they will never visit, and the only image they have is the one informed by media.

TWO-WAY COMMUNICATION

> "Radio is one-sided when it should be two-. It is purely an apparatus for distribution, for mere sharing out. So here is a positive suggestion: change this apparatus over from distribution to communication." —Brecht

The Brecht expectation of two-way communication for then-emerging media such as radio or TV finds its implementation in current electronic networks. While it is still true that the loudest, most persuasive, or most viral prevail, new electronic media provide a potential voice to all participants. In this new scenario, cities are not only inhabited by people but also authored by them in the form of crowdsourcing. This authoring does not necessarily address changes in a broader physical form, but starts informing society functions by breaking established hierarchical structures and providing direct access to government. This becomes visible in the *BOS:311* mobile app [a] (previously *Citizen Connect*), where Boston residents have a venue to inform the city administration about broken streetlights, street potholes, or uncollected trash. The app allows users to share a photo and a message together with the geo-location data to situate the event. Similarly, other cities experiment with technologies like Twitter to improve civic engagement [b]. The next step is to bring residents into decision-making processes such as planning budgetary expenditures. This is part of the modest initiative in several Polish cities called "*Budżet Obywatelski*" (Civic Budgets), in which certain development and budgetary decisions are being voted on online by local residents [c]. While this is limited to relatively small projects, it is a meaningful step toward a better fit between citizens and their local government.

However, this streamlined and unfiltered communication between residents and city governments still relies on intentional actions of the concerned citizens to vote or to report a problem with the infrastructure. The future steps will involve an interface where users indirectly feed information and become sensors of a broader crowdsource network—without a need to devote time and effort to it. This approach raises valid privacy concerns, but in some instances the accompanying benefits could encourage users to participate in these networks. The *Waze* mobile app provides an effective case study of such balanced relationships between users as individuals and users as a group with shared interests. Self-described as the world's largest community-based traffic and navigation app, Waze harvests traffic data from its users by tracking their smartphone movements (car speed) and shares this information with other users. While it does potentially compromise privacy (tracking others while being tracked), it does provide enough benefits to participants to sustain the app's user base.

However, these resident empowerments and traffic navigation improvements are not the endgame for this communication progression. Ultimately, and it is already happening, the cities will be coauthored not only by their human residents but also by all autonomous agents, such as cars, drones, and buildings.

OTHER AUTONOMOUS AGENTS

Imbedded technologies extend to all aspects and scales of urban living. Items of urban furniture, such as trash bins, park benches, and vending machines, become agents of broader interconnectivity and autonomous networks. In some cases they are agents for more efficient and sustainable futures; in others, they serve as an extension of ever-present commercial or private interests.

Drones or self-driving autonomous vehicles will certainly redefine the way we perceive and inhabit cities. They will serve as an extension of human faculties with increased sensory and actuation bandwidths. However, more importantly, they will require a new virtualized spatial

framework that is highly collaborative and interconnected. They will become urban co-players competing for space and resources with human cohabitants. While autonomous vehicles may seem like isolated technological objects—an accessory—they will be seamlessly integrated with broader distributed sensor networks as continuous urban tissue. While driving activity could be implemented with a singular independent agent that is capable of interacting with its surroundings, the ability to adapt to or anticipate emerging situations can only be realized with a distributed sensor network.

While observing an autonomous (self-driving) car, one cannot help but notice that the vehicle is no longer a fully deterministic automaton resembling a manufacturing robot following a simple set of procedures, but rather an active, if not proactive, urban agent. It not only senses and adapts to changing conditions but also undergoes a decision-making process with often competing interests. The self-driving cars manifest not only autonomy but also a personality that is distinct from human actors. It directly relates to pre-programmed algorithms in an adaptive, not necessarily a prescriptive, way. It is also driven by its own senses (sensors) and bases its judgments on its own set of perceptions. For example, the perception of what is a safe distance or what constitutes a personal or private space is no longer governed by human cultural conditioning but rather by technological efficiency and instrumental precision. Electronic sensors interpret the environment differently from human senses and exhibit a latency—reaction to actuation time—that is very different from that of a human (fig.4). More importantly, these parameters are more quantifiable as compared to human agents, so they can be highly optimized and customized, and do not have to confirm to the lowest common denominator. For example, with human drivers the driving speed is benchmarked to the collective average or lowest common denominator, not the ability of individual agents.

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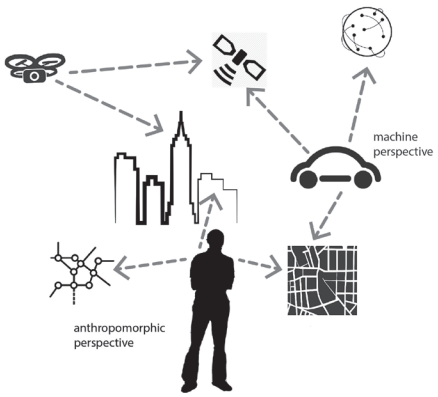
Figure 4: Autonomous vehicle with multiple sensing systems (*source: Jaehwan Kim, Intelligent Vehicle Platform Center, Advanced Institutes of Convergence Technology (AICT), South Korea*)

Autonomy and personality ultimately come into play when the society starts considering the decision making and the ethics of autonomous agents. An Atlantic article by Patrick Lin brings to our attention the ethical implications of an autonomous world, with the provocative question: “Sometimes good judgment can compel us to act illegally. Should a self-driving vehicle get to make that same decision?” [d] While this discussion refers to an automobile, its ethical query can be extended to all autonomous agents: vehicles, buildings, and networks. Ultimately the question of autonomy and participation must address whether autonomous agents should always be supervised by people or whether people should be subject to the judgment of autonomous agents. Should building systems override user preferences in case of power or water shortages to address collective interests? Can we trust people to act judiciously more than computers concerned with neither social mores nor personal gain? Is it still considered breaking the law if it is explicitly facilitated through a governing algorithm?

The current push for wirelessly interconnected cars, vehicle-to-vehicle (V2V), promises increased driver safety and eventually reduced fuel consumption and higher-speed travel [e]. In the V2V model, a car could reliably detect when another vehicle several feet in front is braking hard and adjust speed in anticipation of other cars following the same pattern. While actual data would need to be gathered and verified regarding the benefits of such a system, the conceptual shift is significant. A car’s sensory system is no longer different-from-but-similar-to human senses as discrete and connected to a particular autonomous object. It is distributed and shared among multiple active agents.

Autonomous objects also manifest alternative modes of perception (fig.5). Their sensory readings perceive broader spectral ranges with different tolerances and data processing speeds. Sensors are positioned differently, often distributed and integrated with the object’s materiality. What for humans is considered a continuous movement may for a machine be a series of distinct moments with separate time registrations. Their autonomous behavior will reflect differences in sensory and actuation abilities, leading to a different concept of spatial privacy and proximity—not unlike with various human cultures.

As acknowledged by William Mitchell in *City of Bits: Space, Place, and the Infobahn*, the most important task facing new electronic media cities is not "putting in place the digital plumbing" but "imagining and creating digitally meditated environments." The question of "what" and "why" is significantly more intriguing than "how." Digitally mediated environments provide a venue for the convergence of content and form in a way that blurs the physical with the virtual. They facilitate new forms of habitations and human relations. They are also governed by a new set of urban parameters—identity, autonomy, and connectivity—that unpack the current wired city.



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IDENTITY

Identity emerges as the primary qualifier of electronic social networks and virtual worlds. It reconnects us with a geographic and cultural context in a new and highly relevant way. It defines who we are in a more direct and authentic way. It gives us identities based on our location, preferences, and behavioral patterns rather than looks, family, or ethnicity. With embedded technologies, identity starts playing a central role tracking behavioral patterns of individual users (purchases, daily commuting paths, and health stats) and feeding to "big" data sets. The result is a highly granular understanding of individual user patterns without relying on some abstract, statistically weighted concept of a resident.

Paradoxically, these virtual worlds and electronic networks originated from scaleless and same-like digital matter disassociated from any aspects of physical reality. A digitally born identity becomes a counterpoint to its original implementation, where identities were blurred by perfectness and by the indistinguishability of digital copies. It also provides a new sense of privacy or the lack thereof. Individual users are identified not by their looks or names but by their slightly different behavioral patterns.

More importantly, identity is no longer an attribute assigned exclusively to humans. It also penetrates the world of everyday objects—static and mobile. With Internet of Things (IoT) and IPv6 protocol, everyday objects such as house appliances, furnishings, and health monitoring devices are individually recognizable and, more importantly, individually addressable. This interconnected network permeates to the cities and architecture, with the ability to control individual traffic lights in a city or individual building components in façade assemblies (e.g., the ICT building in Barcelona).

The ability to monitor and control various players in the urban environments is a direct contemporary implementation of Brecht's postulate about two-way communication. However, in Brecht's understanding, both parties of communication were humans. In the contemporary cities and architecture, this communication is between humans and machines (computer-human interactions [CHI] and machine-to-machine [M2M]). While the discussion of the emergence of identity among nonhuman agents is important, the very concept of identity may need to be rethought in the future. M2M or V2V communications with shared perceptual networks, as discussed earlier in the context of interconnected cars, may lead to the formation of a dichotomy between individual identities and shared identities. The very concept of identity may shift between that of an instance and of a group, or become as temporal and demand driven as it is unique.

IDENTITY → ADDRESSABILITY

Unless data is geo-located, there is no texture to the space and time. Situated data creates this texture, while distributed sensing provides a canvas to register this spatial modularity. Situated technologies not only contribute to an understanding of the relationship between an object and its immediate surroundings but also redefine what the field is—the place the objects operate within—by providing a reference plane. The identity of individual elements emerges out of this condition and paves the way for the bidirectional operabilities through

Figure 5: Autonomous objects operate with alternative modes of perception

ENDNOTES

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their addressability. The objects'/agents' identity and addressability deconstruct social and environmental ecologies with non-WYSIWYG qualities. Individual agent objects become equal players in the broader data marketplace, and the relationships they form have the potential to redefine what we consider a city. This individuality of agents with the unique addressability and the ability of always-online monitoring provides a new framework for understanding society and the way the collective subjectivity [f] of these individuals is transforming into objective measures.

IDENTITY + AUTONOMY = PERSONALITY

The behavior of autonomous object-agents is often seen as a direct and explicit implementation of the underlying algorithm. Machines do what they are programmed to do. We perceive their behavior as a deterministic consequence of a maker's intent. To keep track of our creations, we assign identities or IP addresses to them. This helps with their organization and the ability to access them at any given time. While addressability and identity alone do not imply personality, with the emergence of autonomous objects with adaptive behaviors it becomes apparent that personality is yet another dimension to consider. Through addressability, individual agents acquire identity. With autonomy, agents gain an opportunity to manifest their unique behaviors. The combination of both identity and autonomy forms the basis for the emergence of personality. This becomes evident with autonomous objects such as a self-driving car, which follows closely the algorithm it is assigned. However, algorithms enable such agents to solve for multiple, often competing criteria with bifurcating logic and scenarios. With machine learning as yet another variable augmenting the initial algorithm, resulting behavioral patterns may begin to manifest a unique personality. As in a human, a personality in an autonomous agent represents a combination of character traits that form a distinctive character and a coherent outwardly projected image. It distinguishes an object A from an object B not by an identification number but by its environmental responses and behavioral patterns. This personality may be a product of time-based experience (machine learning) and its context, registering responses and adapting its algorithms to specific localized circumstances. It is a part of the distributed intelligence framework that is defined as perceiving and acting autonomously while its activities are formed by its own experiences (Weiss, p. 1).

While this paper argues that the emergence of personality in autonomous agents is an unavoidable step in the integration of smart technologies and the emancipation of the environment from its present inert state, an equally important contributing factor is the human emotional response to robotic technologies. Humans seem to connect with robots in a similar way as they do with animals and other people by developing emotional attachments to autonomous objects [g]. This personification effect further enables and channels the emergence of personality within autonomous agents; however, it is not the main driver behind it.

CONTRIBUTION

This paper addresses the following three points regarding current urban theories in the context of contemporary cities:

1. New information and interaction layers change the ways people live in the cities. They create new expectations toward the built environment. On-demand functionalities, simulation anticipation, and real-time monitoring are only some of the expectations toward the physical world that are ported directly from virtual worlds and electronic networks. These information and interaction layers expand face-to-face communications with asynchronous exchanges, transforming a concept of interaction and identity established in the past—people are often increasingly known by their avatars and usernames, not faces—and form new social meeting grounds as anticipated by Mitchell (1996). This change is facilitated by location awareness enabled by mobile devices and user activity-tracking networks that feed directly into broader data systems.

2. There are new nonhuman players in the urban arena that assume similar roles to those of human agents. These nonhuman urban players no longer can be ignored nor often distinguished from people, partially due to the relative anonymity of electronic networks. Nonhuman agents bring a unique and highly valuable set of capabilities that society will have no reservation in adopting. This will inevitably redefine the types of interactions and the urban contract (the rules of the road) for all participants.

3. Consequently, the past and current theories of a city are no longer sufficient to deal with new forms of interactions and a broader participatory base that includes autonomous objects and adaptive buildings. While Lynch's elements can still have a bearing in media-enhanced worlds, they need to be expanded by nonphysical, temporal, and nonhuman phenomena. Similarly, with Alexander's language patterns, they need to step outside human- and history-rooted frameworks to include a new class of perceptions, identities, and social, yet nonhuman, behaviors (Cerulo). Mitchell's vision (*City of Bits*) is the most recent and the closest projection regarding future cities. The dualities he proposes—*façade/interface, synchronous/asynchronous, public space/public access, and spatial/antispatial*—start to define a set of operational criteria for future cities. However, these need to be expanded by *human/nonhuman or individual identities/shared identities*, just to continue the dialog. In this scenario, identity, autonomy, and connectivity form the baseline for better understanding and operability within urban habitats.

FINAL THOUGHTS

Cities are no longer defined by highly crafted inert forms and dynamic human contents conforming to an imposed framework, as they would have been seen in the past, but rather as exchange terminals facilitating human interaction. Urban software (agent interactions) functions independently of urban hardware (physical form). There is no direct correlation between form, function, and meaning. The semantics of space is defined by a continuously changing media culture subject to constant updates and memory lapses. The urban form is no longer the order maker. The focus on the physical appearance seen in postmodern town planning becomes a nostalgic reference—perhaps in lieu of an unreconciled relationship with the society as a democratic and spontaneous entity. It does not reflect the dynamically changing lives that occur within, but rather tries to confine them.

In the examples discussed earlier, traditionally isolated objects—buildings, cars, urban furniture—become active participants in a broader electronic network. While all of them continue to function for their original purposes, they increasingly are wired into the technological urban fabric, and start transcending their original designs. In some instances, their new role, such as marketing user-customized products to unexpected passersby [h], may become a primary function, using a host object as a justification for their placement.

The two critical ecologies of the current situated and technologically driven environments involve the synergy between narrative and locative media. Narrative media merge architecture with other immersive and emotionally engaging arts such as motion graphics, movies, and video games, while locative/imbedded media provide situated experience with autonomous, agent-like live responses. Users, human and nonhuman, merge with what was considered in the past an inert and static environment. Not only are contemporary cities increasingly inhabited by cyborg citizens [i] (Mitchell, 1996), but also an environment-context becomes a form of cybernetic organism that should be considered as an animated and responsive entity that anticipates and adapts to changing circumstances.

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i. As anticipated by William Mitchell in *City of Bits: Space, Place, and the Infobahn.*