SPOOL

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VOLUME 7 . ISSUE 3

Cyber-physical Architecture #3

Actuated and Performative Architecture: Emerging Forms of Human-Machine Interaction

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Human-Machine Interaction is expanding its reach beyond displays and objects to its next frontier: the built environment. This involves not only known visions of ubiquitous computing and adaptive environments but sensor-actuator networks, large-scale interfaces, and the Internet of Things. More than and including these systems, Actuated and Performative Architecture renders the built environment as a cyber-physical system aiming to address challenges of everyday life. Embedding computation, including robotics, into the physical fabric of buildings fosters a potentially more intimate relationship between the built environment and people. Mixing the physical and the digital redefines the borders between types of spaces, the affordances and meanings of environments, and the sense of presence. Unlike a conventional space that has a limited range of responses to dynamic, changing conditions, Actuated and Performative Architecture is intimately interconnected with users and local conditions.

This Spool [CpA] #3 issue poses and attempts to answer questions on the nature of this intimate human-machine bond, encouraging the discussion of its potentials also in terms of individual and social resilience. This issue of Spool, moreover, attempts to explore the design of bio-cyber-physical systems, which requires integration of natural, physical, and virtual architectures with digital systems and social organizations. In designing interactions between the (augmented) human and cyber-physical environments, the collection and use of personal data, the management of a multi-layered design approach, and the ethics of such design activity require attention from experts in architectural design, interaction and UX design, civil and architectural engineering, mechanical and electrical engineering, computer and information science, sociology, psychology, education, ethics, philosophy, media arts, and science and technology studies.

The papers in this issue address some of the opportunities and challenges of Actuated and Performative Architecture by exploring concepts such as time-based and experience-based design paradigms, narratives as frameworks for enhancing human–machine social relations, immediate systems, augmented realities, and cyber-physically enhanced environments.

If Barbara's paper explores the directions taken by time-based design in order to identify new paradigms for contemporary spaces and their design, Nogueira et al. explore the digital reinterpretation of the architectural element window by means of image capture and future interactive projection aiming at expanding

experience in indoor environments. Pavlovic et al. outline the importance of mapping user experiences for cyber-physically enhanced environments by discussing design practices that can support this activity, while Friedrich proposes immediate systems in architectural research and praxis. Architecture as a Bio-Cyber-Physical System that is operating as part of a larger ecosystem aiming to address societal challenges with a broader understanding of sustainability in mind, is discussed by Pillan et al. In addition to these papers, the Dialogues on Architecture initiated in the first CpA issue are continued in this issue with a dialogue addressing the impact of computation and cyber-physical systems on architecture initiated by Nicolosi.

The attempt to answer questions related to the nature of the human-machine bond in architecture reveals some of the current achievements and even more future challenges. Cyber-physical architecture requires a multi-layered transdisciplinary approach that integrates humans and robots from design and production to operation of buildings.

DOI

Temporal dimensions in the mediation between machines, humans and spaces

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Abstract

This paper questions the need to introduce into the design methodologies and education, the temporal dimension in architectural design. It questions the need, to introduce methodologies and protocols to be able to define, design, and measure the variables involved in the actuation of spaces.

While in the history of design, spatial qualities have been central in the search for techniques and tools, temporal qualities have entered, with the advent of the digital revolution, as qualities capable of deforming, compressing, reconfiguring spaces and supporting new ways of living. The paper investigates various time-based approaches developed by scholars and designers from different disciplines, and the consequent proposals that have been developed so far.

The directions that time-based design has explored concern:

A   Spaces: Digital technologies of algorithmic design/production have made spaces and components adaptable in order to guarantee kinetic or sensorial performance over time through integration with robotic actuators.
B   Experience: Interactive technologies have made possible a continuous adaptability of spaces to human needs, through a continuous dialogue between humans and spaces via machines and computer systems that are able to formulate proposals for the customization of spaces.
C   Behaviours: Communication technologies, which have changed people's behaviours and their interaction with spaces. The spaces have been imbued with distributed digital media hosting the temporalities of real life. The times of 'online' life have introduced new configurations of experiential space.
    The paper explores the directions taken by design that can be considered time-based, to identify the cardinal points and the new paradigms for contemporary spaces.

Context

The research on the potential, that the digital revolution brought to architecture, began in the early nineties of the last century and the explorations, both in design, theory and construction, have been visionary and promising of spatial experiences. In contrast, there is a sense of inadequacy today related to the real estate market and the actual spaces where we live in. Built spaces static, insensitive to the new forms of living that the revolution of digital technologies introduced (Carpo, 2013).

During the extraordinary experimentations in the last 30 years, little has entered into the design of daily interior spaces, often leaving the task of meeting the need for flexibility, adaptation, mobility that the various forms of time involve only to the furnishings.

Today, we live in a multitemporal connection in a continuous and 'liquid' flow. When Zygmund Bauman (2007) introduced the concept of 'liquid modernity', he launched a deep reflection on the spatial-temporal morphology of places, on relationships and technologies, which is still ongoing.

From that moment, interior design could no longer be the same as before, because the fluidity of time would have reshaped the space as well. The spaces weren't the frame, the reference set, of human actions but instead became one of the possible media able to allow adaptability and flexibility, in a continuous flow of changes characterized by an endemic uncertainty.

The concept of liquid space was adopted by many scholars, architects and designers who adapted it to different contexts. Among these Marcos Novak, who claimed "*A liquid architecture is an architecture whose form is contingent on the interests of the beholder; it is an architecture that opens to welcome you and closes to defend you; it is an architecture without doors and hallways, where the next room is always where it needs to be and what it needs to be. It is an architecture that dances or pulsates, becomes tranquil or agitated. Liquid architecture makes liquid cities, cities that change at the shift of a value, where visitors with different backgrounds see different landmarks, where neighbourhoods vary with ideas held in common, and evolve as the ideas mature or dissolve.*"

Novak introduced the concept of 'liquid architecture' as an expression of the 'fourth dimension', incorporating the time alongside space among its primary elements. Novak's liquid architecture bended, rotated, and mutated in interaction with the person who inhabited it (Panahi, 2017).

Novak used the concept of liquidity to formulate what was called the *Transarchitecture*, where he began to explore the links between virtual spaces with materials, robotization, interactivity and communication through multimedia technologies and computer modelling.

A few years later, David Nelson Rose and the Future Arts Initiative expanded this definition to include the use of multi-sensory multimedia technologies. The reason was to increase brain function, as an act of the designer, to create a cohesive dialogue between the observer and the model. Liquidity was the cause, but also the effect, of a way of life that tried to thin the boundaries, mixing real life and digital presence; virtual proximity and physical distance, etc. but above all, that warped the spaces through media technologies and different forms of time.

Time-Based design

The definition of *time-based* design comes from a book, edited by Leupen, Heijine and van Zwol (2005), in which they began to investigate how the design of spaces should involve in time. Leupen acknowledged that *"the speed of modernization and the unpredictability inherent in the process makes it very difficult to establish reality for such a slow-moving medium as buildings".*

The term, borrowed from the videos, tried to describe the difficulty, for spatial designers, to establish a living relationship with the places, while the transformation was in progress.

The question had a genealogy in the thirties of the 20th Century, when Johannes van den Broek and Mart Stam began to experiment with forms of time-based architecture, in the attempt to make the most of the spaces, questioning the flexibility of the rooms during the hours of the day. The solutions were highly flexible and visionary, so much so that they became a reference, many decades later, when the masterplan and the project of the International Passenger Terminal (2002) in Yokohama was designed by FOA (Carpo, 2013).

While Leupen explored the temporal dimension of projects in lack of space, van Zwol dealt with the changed relationship between work and living, the potential mixtures and functional overlaps, considering the possibility of *"room for building with no specific ends".*

Their research was directed towards scenarios different from those of Novak, but they started from the same question: how could the temporal dimension be included in the genesis of architectural spaces?

It could be argued that the topic of time-based design was initially addressed by two sides: on the one hand, all those who explored the digital revolution as the possibility to modify spaces in time as did masters such as Eisenman, Lynn, Oosterhuis, and Novak, up to the temporal aspects of parametrically-driven architecture. On the other, all those who rooted the transformations within physical space, as a bottom-up need. The design of behaviours becomes the basis for the sharing economy applied to spaces.

Both approaches started from an assessment of the inadequacy of existing spaces, and sought through a time-based approach to:

- transform monofunctionality, by introducing the need to design spaces versatile in form and time;
- introduce customization of spaces;
- rethink the performance of components (walls, floors, ceilings, etc.);
- introduce new rhythms in the spaces (difference between day and night; variation between days, months, years; connections between different time zones);
- change the size/form of each space according to the changing needs;
- change the sense of privacy;
- etc.

These paradigm shifts in architecture produced entire strands of research and experimentation.

Some were rooted in the utopian strands of radical architecture, that considered that the temporal dimension would transform buildings into living machines, building scale vehicles, adaptable to inhabitants and contexts in a dynamic relationship with people and places (i.e. Walking City by Archigram, Generator Project by Cedric Price and John Frazer).

Others tried to make humans, and their spaces, interact through computers and robots able to accommodate the time they spent in the spaces.

The dynamic transformation of analogic spaces, following temporal instances, concerns structures, volumes and sub-systems as for instance:

– Sliding elements as showcased in the Domestic Transformer by Gary Chang' in Hong Kong, in which walls and furnishings move to accommodate various functions. The unused space is crushed and compressed to make room for the parts in use.
– From folding walls and doors such as Origami, designed by Michael Janzen to the Embryologic House by Greg Lynn that envisages a system of 9 steel frames and 72 aluminium struts, to support 2048 digitally fabricated panels facilitating changes in every individual component that can be transmitted throughout every other element in the system.
– Rolling volumes as for Transformer, the temporary pavilion designed by OMA in Seoul, which is rotated on its sides in order to become a theatre, a fashion show location or an exhibition hall;
– Pneumatic structures that can be inflated and easily transported, but also made possible by the use of new materials such as ETFE's film used for Allianz Arena by Herzog & De Meuron.

The dynamic dimension in buildings has been already explored William Zuk and Roger H. Clark, in Kinetic Architecture (1970). In time kinetics have been intertwined with robotics, to support interaction with the inhabitants. *"This ability to act may imply physical such as geometrical, material, or sensorial transformation and reconfiguration. Robotic building components (such as doors, walls, floors, etc.) may support daily life activities offering solutions for dealing with rapid increase of population and urban densification as well as contemporary inefficient use (25%) of built space"* (Bier, 2014).

The underlying consideration, of part of these projects, is that a person cannot live multiple real spaces simultaneously, so those empty spaces could be compressed until they are used again. With a compliant mechanism system a prototype was built to meet the needs of the inhabitants by reconfiguring 24/7. (Hyperbody, Pop-up Apartment, 2013).

Such architecture uses time to design components through actuated spaces (i.e. Aegis Hyposurfaces by dECOi), interactive spaces (i.e. Muscle Projects by Hyperbody); adaptive spaces (i.e. ADA, Intelligent Spaces by SPECS-lab).

Another original and experimental, less studied yet valuable contribution, was the one proposed by Physiological Architecture by Philip Rahm, who tried to explore the interaction of time with circadian and environmental qualities to modify physiological effects on the body. In Split Time Café he defined an intimate relationship between space and frequency of light, transforming space into an authentic natural clock, that induced those present in a state of sleep or wakefulness, depending on the excitement and inhibition of the visitor's endocrine system.

The revolution introduced by the smart technologies has led to a further possible scenario in the time-based design, related to the mediation, between humans and spaces, that these devices perform in acceleration, compression, time overlap. They are able to accommodate temporal and functional instances in continuous mutation within real spaces (Hassanein, 2017).

The smart technologies reshape spaces, interiors, architecture, buildings, infrastructures according to the needs, desires, environmental conditions, as well as customize experience (Carpo, 2017).

Temporal dimensions in the mediation between machines, humans and space

The implications on the design of spaces involves a reversal of the traditional paradigms of living spaces. It pays a greater attention to phenomena, that are in part already underway, such as space-sharing, adaptive architecture, etc.

A time-based design affects: the function itself; the change in the sense of privacy; the dimensions; time and its rhythms; the boundaries between offline and *'online'* spaces in a globalized room, etc. (Floridi, 2009).

The impact of digital technologies on time-based design affects not only the production and construction of spaces and their performance, but also the possibility that the space *"can be controlled, actuated, and animated by digital means"* (Bier, 2010).

The inadequacy of the spaces we inhabit, is accentuated by the most significant technologies today, which are those involving:

- mobility that is distorting the perception of space and time;
- communication, which is redefining the interaction between chronemics and proxemics;
- sharing, which is encouraging the flexibility, transformability and availability of spaces.

Mobility and coordination media

The mobility of high-speed transports, in territories and cities, produces some paradox: the closest spatially is not necessarily the nearest in actuality. This warps and bends spatial configurations.

Mobility, which is not necessarily movement, produces perceptual deformations, which configure space possibilities still unexplored (Barbara, 2012). In the field of mobility, telecommunications often play an average role of coordination between individuals located in distant areas (Castells, 1989).

To plan meetings and travels is a continuous action that users carry out, in their urban movements. It is a form of tele-cocoon that allows people to stay in constant touch with theirs contacts, solving micro-coordination problems. Mobile telecommunication cannibalizes 'dead times' and allows the in-between time to be manned. Paradoxically, the time of the displacement - which is different from the time of the journey- typical of the commuter, becomes an ideal time-space to leave as a phenomenology and to connect elsewhere (Barbara, 2012).

Through this *'connected presence'*, all the places, where we pass through, are pervaded by a sense of intimacy, but also of separation from context and absence (Perry, 2001).

Communication media have become indispensable tools to create a sense of proximity in distance, or absence, helped by a simultaneous, and not delayed, interaction. The asynchronous media have a lower degree of involvement than those of sharing, of the experience embedded in the space of places (Castells, 2001).

Simultaneous communication, compared to the asynchronic one, has completely changed the ways of establishing communities or simply supporting them. It has allowed the sharing of the daily experiences, by

the emigrants with their families and their countries of origin, of the visiting or exchange students, revealing the emotional nuances of relationships and not only the essential information.

These media have developed 'trans-national' families, whose multi-territorial lives are hosted in the country where they stay but live virtually in the continuous connection with the countries of origin. Their daily communications go beyond the boundaries of states and cultural limits, drastically reducing the sense of homesickness, of distance and the incidence of repatriation (Ling, 2008).

Communication and media for location and presence

The studies about chronemics -often combined with the proxemics ones- which analyse the relationships with time in its various manifestations, show that the temporal dimension is extremely personal, social and cultural and the failure of synchronicity, causes dystonia, misunderstandings, inconvenience (Zucchermaglio, 2013).

Cell phones and media have changed our relationship with physical space and with people. They change the forms of time by encouraging multi-temporality, simultaneity, etc. but above all, they manipulate the distances between things and people, they redefine the organization of time in the spaces, in the relationships and in the processes.

 Depending on the involvement, the experience can be:

— immersive, if it involves only the user but excludes those present;
— pervasive, if it pushes those present in the background;
— conjunctive, if it involves all those present.

Even today, smart devices are mainly used:

— to protect and to build a cocoon, around yourself, to be able to exclude the context and to ensure a portable reality consistent with your emotional state, with your needs of the moment;
— to connect to a network of digital belongings, occupying temporarily the spaces, camping, setting up and using smart infrastructure able to rebuild anywhere our digital, productive, existential habitat;
— to share information and traces of our movements and lives, leaving a footprint, able to increase our visibility, orientation, but also, from the point of view of the network, to control our lives and those of others (Ling & Campbell, 2010).

Cocooning media are used to build protection against the intrusion of other people or circumstances. One of the primary functions of these technologies is to provide a personalized space, connected to a person and not to a physical place, to protect themselves from the involvement of places or the co-presence of others.

These technologies create a private territory within the boundaries of an urban space. Cocoons are micro-places, built by private, controlled infrastructure, which temporarily occupy public spaces for personal use.

Often it is related to audio media, because through headphones, people try to establish a personal boundary between own soundscape and the environment around them. These technologies are often used by commuters.

Camping media are used to settle in public spaces in order to build their own digital camp. As in some cafés, parks or co-working. Compared to the cocooning effect typical of commuters, who make a simple crossing from place to place, camping involves a staying, albeit temporary. Rather than *'killing time'* in passing places, camping *'spends time'* and *'schedules'* time in locations outside the home and office. A digital camping site usually is a highly social environment.

Footprint technologies are those that require to leave a trace. These media are portable objects used to make purchases, to navigate, to interface with urban environments. They include objects such as smart phones, tablets, loyalty cards, credit cards, digital wallet, membership cards (Ling, 2008).

Media for time-based spaces

The time-based space, configured by the new media, replaces or adds new possibilities, but above all, it intensifies the social presence. Mobile media have increased space-time flexibility in social interactions. Time and space have amplified the degrees of freedom requiring more flexibility, negotiation and reconstruction of roles and rules, both in the private and in the public areas.

Communication makes many activities shareable. When we are connected, we experience a co-presence because, in Heideggerian terms, the physical space in which we are, is juxtaposed with the phenomenological one.

It is a negotiation based on a subjective sense of space and time that, to ensure the process of interaction, requires maximum involvement and identification. The greater the inclusion and involvement, the better the interaction. The context, the space in which the body is physically present, becomes the background and not the stage of the action (Light, 2006).

However, media communication does not make us free from spaces, places and practices, but makes them available for other networkers.

This not only gives us extra space, but also makes us open, in real time, to monitor, control and, above all, to be available. The high responsiveness to stimuli, that communication media requires, is an important stress factor, because the mobile communication society always and everywhere makes a representation of the self, become seamless between private and public.

The flexibility of mobile communication can make some relationships more informal, but sharing times increases the feeling of control and acceleration. The time of mobile networks is unforeseen, volatile, chaotic, allowing intimate connections in every moment of social life and making us ubiquitous. Places and times of disconnection are more and more rare: everything you can do online is open 24/7 (Barbara, 2012).

So private space and public space blend into each other. Private space seems to become more open and global as the public becomes more intimate and local (Augé, 2009).

The space-time changes as a result of the adoption and use of wireless technologies, which had ensured *'space flows'* and *'timeless time'* based on a shift, in the social and economic order characterized by decentralized and flexible nodes, based on the sharing of interests, the need for information, as well as shared places (Castells, 2007).

The expansion of space and time allows different forms of social practices at work, in education and in relationships. Many of these practices are hybrid, merging together recognizable structures within liquid forms.

A revolution in spaces based on mobile workplace and virtual teams, which even during the recent lockdown, has guaranteed work, teaching, communication and adaptation of living and working spaces *"instead of thinking of places as areas with boundaries around, they can be imagined as moments articulated in a network of established social relations"* (Massey, 1994).

Conclusions

The liquidity that Bauman was writing about, adopted by Novak and the designers inspired by the digital revolution, is therefore mixed with the temporal revolution introduced by the media of communication in our daily lives. These are all the elements for starting a time-based design of the spaces in which we live.

It is therefore necessary, for the design disciplines, to adopt the new paradigms, make a synthesis of existing approaches and define criteria for the measurability of the results achieved.

Above all that they graft the know-how and the results of these experiments into the profession, even the most ordinary design, and into the spaces of our everyday life.

It is necessary to build analysis and representation tools (chronotopes) to understand the new relationships between real and virtual times and spaces; introduce in architecture and architectural education methodologies and software able to model through time spaces (Grasshopper, etc.). With regard to the production and construction of dynamic forms of space, robotics would continue to intervene in the customization of shapes, dimensions, possible interactions as it has already been doing for decades. Finally, for the design of the experience, an interactive dimension would be able to manage spaces in an adaptive way according to the demands of an increasingly diversified society.

These conclusions are not the destination, they are the result of exercises carried out in the laboratory of spatial design that I hold at the Politecnico di Milano. They are the beginning of a process of systematization of what exists, which has as a mandatory goal to train designers able to include the temporal qualities in future projects and spaces.

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