Representing Interaction: From Static to Dynamic Spatial Environment

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REPRESENTING INTERACTION: FROM STATIC TO DYNAMIC SPATIAL ENVIRONMENT

REPRESENTANDO A INTERAÇÃO: DO ESPAÇO CONSTRUÍDO ESTÁTICO AO DINÂMICO

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ABSTRACT

Buildings are dynamic environments that change over time to accommodate diverse needs, flows, programs, and activities. The rapid adoption of digital technologies into buildings through ubiquitous computing creates a complex infrastructure of interaction between humans, the environment, and technologies that transform the design and operation of architecture. However, conventional architectural drawings fail to visualize the spatiotemporal dynamics of sensorial environments. This paper explores representations for designing human-building interactions. By investigating exemplary architectural drawings from the early 20th century to contemporary installations, it deconstructs the material and immaterial components of interaction through affordances, flows, footprints, behaviors, sensors, and feedback. Drawings highlight the potentials and constraints of building infrastructures to inform architectural design by representing layers of interactions. This approach addresses challenges related to automation, privacy, centralization, and surveillance in digitalized buildings and helps interdisciplinary collaboration for the critical adoption of technologies to balance human needs and environmental performance.

KEYWORDS: Human-Building Interaction. Architectural Representation. Infrastructure. Digitalization. Sensorial Environment.

RESUMO

Os edifícios são ambientes dinâmicos que mudam ao longo do tempo para acomodar diversas necessidades, fluxos, programas e atividades. A rápida adoção de tecnologias digitais em edifícios, através da computação ubíqua cria uma infraestrutura complexa de interação entre os seres humanos, o ambiente e as tecnologias que transformam o design e a operação da arquitetura. No entanto, os desenhos arquitetônicos convencionais falham em visualizar a dinâmica espaço-temporal dos ambientes monitorados por sensores. Este artigo explora representações de interações entre humano eedifício. Ao investigar desenhos arquitetônicos exemplares do início do século XX até instalações contemporâneas, este artigo desconstrói os componentes materiais e imateriais dessa interação por meio de “affordances”, fluxos, cobertura de monitoramento, comportamentos, sensores e feedback. Os desenhos destacam os potenciais e as restrições das infraestruturas dos edifícios para informar o design arquitetônico, representando camadas de interações. Esta abordagem aborda desafios relacionados à automação, privacidade, centralização e vigilância em edifícios digitalizados e ajuda a colaboração interdisciplinar para a adoção crítica de tecnologias para equilibrar às necessidades humanas e ao desempenho ambiental.

PALAVRAS-CHAVE: Interação Homem- Edifício. Representação Arquitetônica. Infraestrutura. Digitalização. Ambiente Sensorial.

1. INTRODUCTION

The spatial environment is surrounded by digital technologies, sensors, controllers, IoT devices, wireless networks, multimedia interfaces, home robots, virtual assistants, and smart gadgets. These decentralized devices, embedded software, and distributed intelligence become an integral part of architecture through ubiquitous computing, transforming the dynamic interactions of humans with buildings(Wiberg, 2015). Digitalization of buildings replaces basic interactions of switches, handles, and buttons with invisible sensors, data networks, and digital interfaces that unveil new affordances, mediums, and flows that require special architectural attention. However, the excess automation and optimization of building services "alienate" the relationships between humans, the environment, and technologies (Simondon, 2017). The centralized control of smart building services does not give users enough control, information, or responsibility over systems. Recent studies also demonstrate that human inputs in terms of behavior, control, interaction, and feedback complement automation to improve buildings' performance(O'Brien et al., 2020) and occupants' well-being and experience(Alavi et al., 2019; Nembrini & Lalanne, 2017; Park et al., 2019). Stalder(2019) emphasizes the inseparable relationship between humans and machines in prescribing behaviors, programs, and activities through comfort, control, and performance requirements. Beyond the quantitative performance analysis through standardization of users and programs researchers and designers also investigate how human-building interactions can advance the experience in this "spatiotemporally immersive" environment(Alavi et al., 2019).

Latour and Yaneva(2008) argue that a building is never static in either design or operation processes. They emphasize the consideration of architecture through dynamic processes and environments that evolve over time, responding to diverse needs, users, activities, and programs instead of mere objects and static forms. This conceptualization of architecture is repeated in the literature with alternating terminologies as a shift from "object forms" to "active forms"(Easterling, 2012), ''from artifacts to environments''(Alavi et al., 2019), from "passive objects" to "active producers"(Vrachliotis, 2022), or ''from static to cybernetic architectural systems''(Bali et al., 2019). Understanding systems, infrastructures, and flows of resources, people, and data through "their exchange over space"(Larkin, 2013) is essential for perceiving, experiencing, and designing architecture in action. The architectural project can be redefined as "Medium Design" shifting focus from objects to the design of a spatial interface that augments the active dialogue, continuous exchange, and emerging interactions(Easterling, 2021). This ensures the relationships between dynamic flows, systems, environment, and their visible and invisible components in the spatial environment.

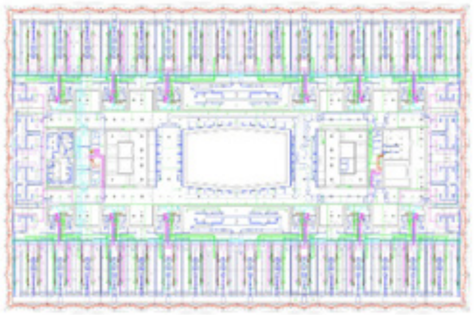
Representations are essential analysis, communication, collaboration, and design tools for architecture(Savaş et al., 2018). David Kirsh(2010) emphasizes external representations for an interactive cognitive process that enhances referencing, persistence, and collaboration in design for dealing with cost, organization, computation, and complexity. Representations can help to visualize the interplay between decentralized and centralized systems, static objects and dynamic scenarios, and autonomous and embedded agents. Making the invisible relationships and limitations visible can bridge perception and action for the "concretization" of technical objects(Simondon, 2017). As Juarrero(2023) highlights the capability of interaction in coherent wholes to generate novel properties and information in complex systems, representations can also emerge new interactions to communicate and exchange information for reinforcing the spatialization of technologies during architectural design.

This paper aims to focus on representations of human-building interactions at the intersection of architecture and building services to help interdisciplinary collaboration in the design process. By bringing distinctive architectural drawings from mechanization in the early 20th century to multimedia exhibitions, cybernetic projects of the 1960s, and interactive installations, the goal is to represent the spatiality of interaction to dissolve the traditional distinctions between material(visible) and immaterial(invisible) components. The examples deconstruct interaction through interconnected layers of affordances, flows, footprints, behaviors, sensors, and feedback to suggest a representation method for designing human-building interactions. This representational deconstruction helps to situate and responsibly integrate technologies, mediums, and digital systems into architecture through extended potentials as well as constraints of these system networks.

2. STATING THE OBVIOUS: VISUALIZING THE MATERIAL

Seminal books of Giedion(1948) and Banham(1969) provided an early architectural theory and history of environmental control systems and mechanical services starting from the mid-20th century. Since then, building services and mechanized interiors have found their ground in architectural research and practice. Starting with the use of services in buildings in the first machine age, new visualization and design methods are developed for their seamless integration into architecture(Banham, 1969). Building services and associated drawings are standardized through sets of mechanical, electrical, plumbing, and fire safety needs. Contemporary buildings are drawn and designed with all anatomical details presenting the materiality, equipment, and machinery of services in the buildings (Figures 1 and 2). CAD drawings and BIM models visualize the spatial allocation of services allowing clash detection, performance simulations, and optimizations in the design process to avoid problems during and after construction. Although conventional architectural drawings and information models are well-developed for the implementation of static systems and building services, they have shortcomings in representing the dynamic behavior of human and non-human agents in space, solidifying the inanimate perception of architecture. These drawings facilitate limited information to present flows, interactions, data processes, behaviors, and communications in buildings.

Data spreadsheets, system diagrams, or functional schemes, on the other hand, lack to present interconnections with actual spatial conditions. The continuous automation and digitalization of the built environment bring similar challenges to the machine age for designing, visualizing, and integrating new technologies. Representations can -once again- inform the design process by visualizing experiences and interactions.



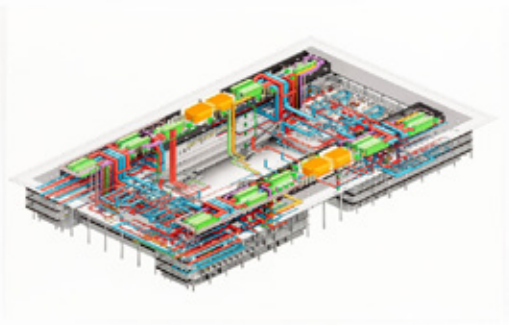


Figure 1. Adolf Krischanitz, Laboratory Building, Basel 2005-2008.
Source: Stalder(2017) from www.e-flux.com/architecture/history-theory/162450/an-elementary-proposition/ (2020)

Figure 2. Foster + Partners, coordination drawing, Cleveland Clinic Health Education Campus, Ohio, 2015. BIM drawing. DMC 2909.7. Source: drawingmatter.org/foster-partners/

3. VISUALIZING THE IMMATERIAL

3.1 Affordances

The term “Affordance” was coined by J. J. Gibson(1979) to explain the possibilities that the environment offers to humans, connecting the perception of the environment with affordances. In his seminal book “The Design of Everyday Things”, Don Norman(2013) adapts this concept for interaction design and states that “Affordances represent the possibilities in the world how an agent (a person, animal, or machine) can interact with something”. Affordances and signifiers are essential to conceptualizing the architecture of interactions to reveal the advantages, possibilities, and challenges of spatial elements and services. Koutamanis(2006) mentions that architectural affordances and their design representations not only help to understand users through their abilities and behaviors but also reveal the potentials and constraints of interacting agents in multiple resolutions and scales.

From the 1950s to the late 70s, “Cybernetics” became a significant inspiration for the theory and design in architecture. As Steenson(2017, p. 17) explains “With cybernetics, architecture became a mechanism of information exchange and provided the groundwork for architecture as an interactive practice.” The design process becomes “scientific problem-solving procedures” through the drawings of “circuit diagrams and feedback loops”(Vrachliotis, 2022, p. 13). The drawings of the Fun Palace (Figure 3) and Interaction Center (Figure 4) projects designed by Cedric Price represent the spatiotemporal affordances for alternating activities and dynamic programs instead of fixed architectural elements and forms. By bringing a set of flow diagrams, activity models, and organization charts, these experimental projects visualize how humans can utilize, adapt, communicate, transform, and interact with machines and spaces over time (Steenson, 2017). By shifting attention from appearance to experience, they celebrate affordances and continuous interactions between users and space.

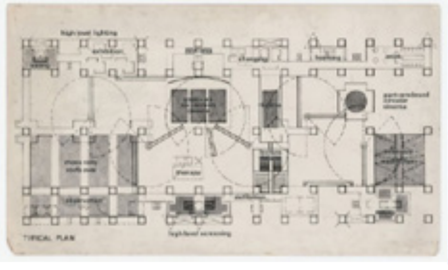
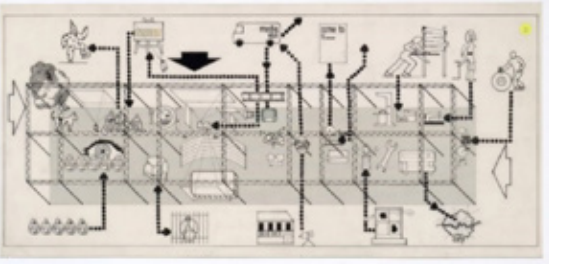



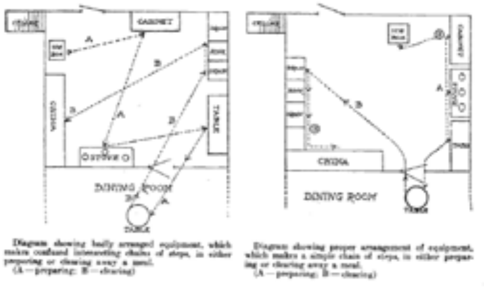
Figure 3. Typical plan of Fun Palace complex, 1964.
Source: Canadian Centre for Architecture, Cedric Price Fonds, DR1995: 0188: 710

Figure 4. Diagram mapping programme and community for Inter-Action Centre, London, England, 1977.
Source: Canadian Centre for Architecture, Montréal, Cedric Price Fonds, DR1995:0252:621

3.2 Flows

Flows are an integral part of the architectural design process for multiple reasons. Flows propagate architectural methods and concepts for emphasizing monumentality, ceremonial rituals, ambiances, or promenades as well as creating functional zonings, movement, and circulation patterns in buildings. Today, flows in complex projects can be simulated not just for circulation but also for air, water, and energy flows analyzing heating, cooling, or ventilation needs to optimize healthy environmental conditions. Flows connect nodes with networks in spatial topologies and provide a generative representational tool for designers to organize space with behaviors, movements, and environmental forces.

One of the early visualizations of flow studies dates to the beginning of the 19th century. Christina Frederick(1913) utilizes visuals to compare the kitchen layouts in terms of the arrangement and allocation of equipment for the efficient workflow of its users (Figure 5). These comparative diagrams represent how movement patterns for different activities and interactions can influence the effectiveness of a design. It ensures essential feedback on how architectural space can be further utilized and elaborated through associated movements. Northstar Medical Campus designed by ANONYMOUS Architects presents a contemporary example of how flow simulations facilitate optimization of the floor plan according to the circulation patterns of different user groups in alternative scenarios and times (Figure 6). The project highlights the relevance of representing flows in the design process for the interactions between humans and architectural space(Ansari, 2022).



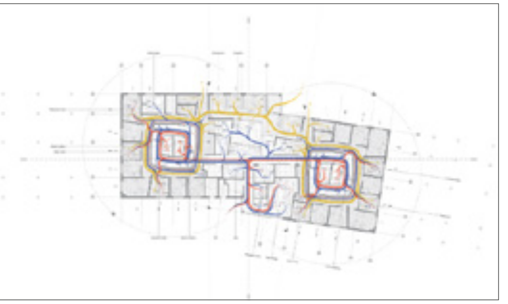


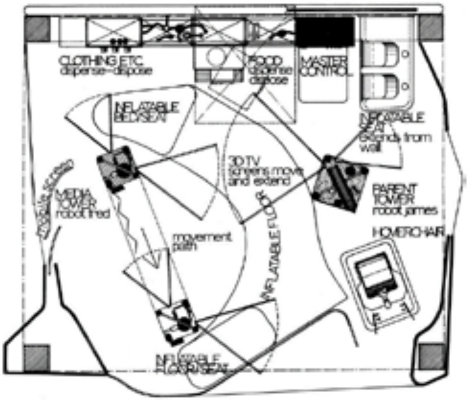
Figure 5. Diagrams showing the arrangement of equipment. Source: Frederick (1913)
Figure 6. Building 2 Circulation Diagram, Northstar Medical Campus. Source: Ansari (2022)

3.3 Footprints

Technological development in multimedia devices, speakers, high-resolution screens, and projectors for larger spaces after the 1950s creates new media infrastructure for artistic and architectural experimentations(Buckley, 2018). Archigram's "Living 1990" (Figure 7), "Living City Exhibitions" and "Light Sound Workshops" in the 1960s present early examples of benefiting from these technologies that juxtapose light, sound, and moving images in space to create multisensory ambiances. The harmony of dynamic colors, music, and patterns generates an audiovisual interplay of interactions with mobile audiences(Buckley, 2018). These networked experiences offer immersive modes of perceptions and expressions to engage with humans blurring the boundaries between media, arts, and architecture(Buckley, 2018). As a result, exhibition designs lead to challenges in visualizing the infrastructure of new equipment, control devices, and fields of media devices that interact with space and visitors. As Buckley states referring to Peter Cook:

> Cook noted that the integration of visible mechanical elements with invisible electronic control systems made the problem of representation especially difficult: "In a place where the hardware, software, and ephemera are all intermixed (and interdependent at any one time) there has to be a much looser hierarchy of parts. It becomes almost impossible to draw." (Cook, 1972, as cited in Buckley, 2018, p. 43)

The exhibition drawings of Archigram are innovative experiments bringing electrical control mechanisms and footprints of plug-in multimedia devices with their mobile placement and coverage within a spatial organization of this immersive infrastructure. These novel visualizations represent the topography of opportunities and affordances as well as the limits and constraints of control and multimedia. These footprint mappings engrave the fields of affordances for the interactions between multimedia devices, space, and humans. Contemporary buildings have similar drawings visualizing the CCTV systems that mark the coverage of cameras, sensors, or multimedia devices in buildings for ensuring constraints for security, safety, fire systems, or accessibility purposes (Figure 8). Although, it is underestimating to use these drawings for specific security purposes or safety regulations, utilizing these representations in the design process will become more important with the accumulation of digital technologies. These drawings can help with the growing concerns and protocols about surveillance, footprints, big data, cookies, and privacy in the smart environments served by private companies(Söderström et al., 2014).



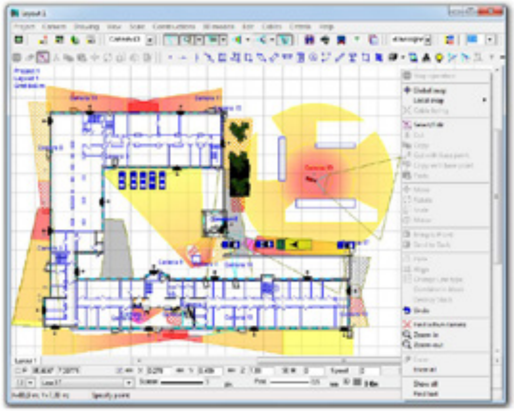


Figure 7. Plan, Living 1990 exhibit for the Weekend Telegraph constructed in Harrods department store, London, 1967. Warren Chalk, Peter Cook, Dennis Crompton, and Ron Herron. Copyright Archigram. Source: Buckley(2019)
Figure 8. CCTV CAD Software, Working with 2D projections, Source: www.cctvcad.com/VideoCAD-Versions.html (n.d.)

3.4 Behaviors

English illustration artist William Heath Robinson(1872-1944) illustrated many ironic yet intriguing drawings depicting people's struggle with the mechanization of living environments at the beginning of the 20th century. These visualizations concentrated on the swift evolution of daily activities through the integration of numerous gadgets and machines on the verge of the new lifestyle and comfort requests of society (Figures 9 and 10). His representations are imaginary examples of what extent the design of technologies can transform human behaviors, activities, and interactions. On the other hand, these drawings put criticality on the exaggerated utilization of machinery exemplifying a visual method to inform the design process for questioning our behaviors, never-ending needs, naive enthusiasm, and relationships with technology.

The "Becoming Animal" installation designed by "Minimaforms" is a contemporary example highlighting playful, sensorial experiences between people, space, and digital technologies. The installation reacts to various densities and movements of human agents through different combinations of colors, sounds, and facial expressions for creating "spatial environments that are adaptive, emotive and behavioural"(Spyropoulos, 2016, p. 38). The project diagrams map the parametric possibilities of dynamic interactions associated with different senses, times, emotions, actions, and movement states, visualizing a concrete example for programming interactive spatial environments (Figure 11). As Spyropoulos(2016) explains:

> Interaction understood as the evolving relationships between things allows a generative and timebased framework to explore space as a model of interfacing that shifts the tendencies of passive occupancy towards an active and evolving ecology of interacting agents. (Spyropolous, 2016, p. 38)

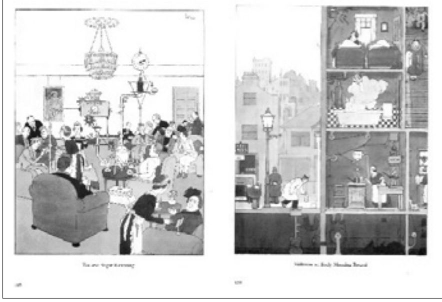


Figure 9 and 10 William Heath Robinson Illustrations, 1900s, Source: Robinson (1973)

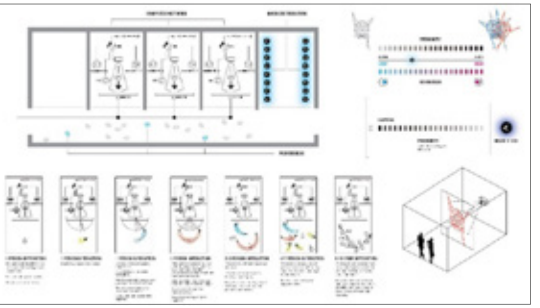


Figure 11 Becoming Animal Mapping, MoMA: Talk to Me, 2011, Minimaforms Source: Spyropoulos (2017)

3.5 Sensors and Feedback

Banham(1965) stresses the dissolution of architecture through its takeover by the "mechanical pudenda" of environmental control systems, in the mechanical turn. Kotsioris(2018) extends this shift with sensors and discusses the conceptual transformation of architecture from a protective shelter composed of thick components and strong materials to thin reflective surfaces providing an "indispensable medium" of signals, alarms, and ultrasonic waves for sensorial interactions (Figures 12 and 13). He recommends a deeper look into patent drawings and engineering visuals to investigate this invisible nature of sensing and control mechanisms. Kotsioris(2018, p. 234) notes that "filtering of bodies, once relegated to doors, windows, and locks, is singlehandedly made obsolete. Sensors and controllers defeat bricks and mortar." These visuals of early sensors exemplify a new representation mode that superimposes the perception of space with its afforded interactions.

Similarly, The Diffuse House by MAIO(2021) is a conceptual project created through the juxtaposition of floor plans generated by autonomous robotic vacuum cleaners (Figure 14). The drawings map the spatial medium afforded for robots' movement by visualizing the territory of the footprint of devices instead of conventional building plans. The drawings are composed of peculiar shapes and forms representing how these autonomous robots sense and interact with their environment. Both methods highlight alternative visualization methods for this shift from material forms to immaterial mediums of sensory interactions.

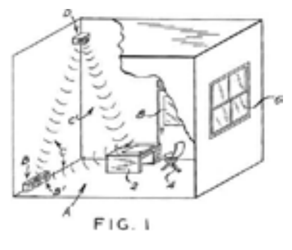


Figure 12. Patent drawing from Samuel M. Bagno's "Method and Apparatus for Detecting Motion in a Confined Space," 1947–53. Source: Kotsioris (2018)

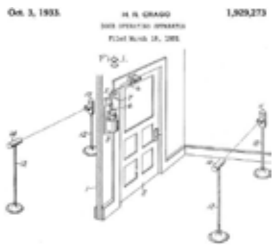


Figure 13. Patent drawing from General Electric's "Door Operating Apparatus," 1933. Source: Kotsioris (2018)

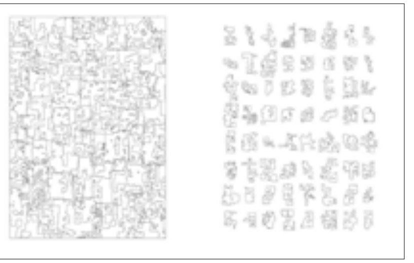
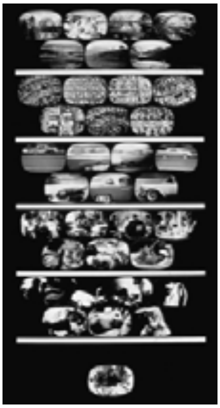


Figure 14. MAIO, The Diffuse House, 2020 Source: MAIO(2021)

Multimedia experiments of Charles and Ray Eames at the World's Fair in the 1950s set a precedent for the power of multiscreen devices. These exhibitions are significant for the early usage of media as a multichannel information source to generate narratives for their visitors(Colomina, 2001). Colomina(2001) notes that the simultaneous usage of multiple screens, films, signals, and sound intensifies the immersive ambiances and constructs time through feedback loops. The complete control of new communication modes regulates and conveys interactions and information flows between mediums superimposing architecture, information modes, and multimedia. The exhibition drawings represent design and storytelling methods through overlaps of simultaneous senses, devices, environments, and their narratives over time in multisensory environments (Figures 15 and 16).

The Power Exhibition at the CIVA Museum of Architecture in Brussels presented a progressive example of interactive building services. "Feel the Heat" installation designed by TU Delft Design, Data, and Society Group & The New Open project together with Meta Office showcases future potentials for data-driven building systems to decrease unnecessary consumption(The New Open, 2023). The integrated interface of the heating installation includes data visualizations of the timely operation of heating systems, available energy, and consumption levels combined with the territorial footprint and exchange of renewable energies around Brussels. The installation brings multiple times; personal, architectural, and territorial scales together and allows physical, sensory, and informational interaction, and exchange with visitors (Figures 17 and 18). Representational interface makes the relationships between services, times, scales, and humans visible to generate feedback loops and inform their occupants on performance and consumption to raise ecological consciousness.



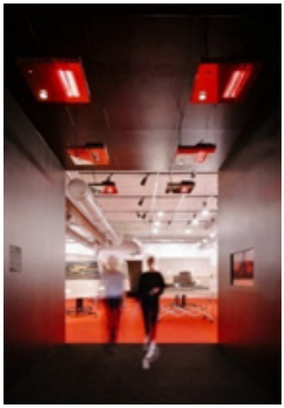
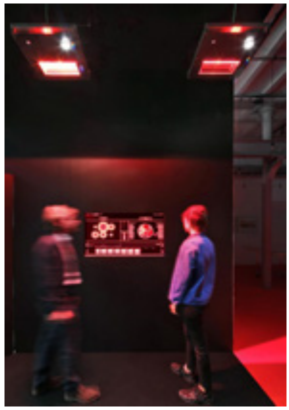



Figure 15. Charles and Ray Eames. Glimpses of the USA, 1959. Source: Colomina (2001)
Figure 16. Notation of timing of sequences for Glimpses of the USA, 1959. Source: Colomina (2001)
Figure 17 and 18. Feel the Heat, 2023 from "Power Exhibition, Project by TU Delft Design, Data and Society Group & The New Open project in collaboration with Meta Office, CIVA Brussels 2023, Photos by Filip Dujardin
Source: https://www.newopen.design/community/(2023)

4. DISCUSSION

Stan Allen(1999, p. 54) highlights the importance of architecture having the "capacity to actualize social and cultural concepts, it can also contribute something that strictly technical disciplines such as engineering cannot." By looking at the multiple modes of interaction between humans and technologies, this paper attempts to bring material and immaterial layers of interaction through architectural representation. The given examples of drawings can be read as clues, responses, or methods developed by architects and designers to deal with the de-spatialization of architecture through digitalization within the sensory landscape of buildings. The intention is to perceive, visualize, and design architecture by re-spatializing them as socio-eco-technical infrastructures of emergent dynamics and flows of interactions(Easterling, 2012). Representations have the capacity to bring the spatiotemporal, intermedial, sensorial, territorial, and behavioral relationships to reinforce theoretical, communicational, and critical grounds for architecting interactions.

Firstly, interactions open up alternative ways of architectural thinking regarding the theoretical position of complexity science associated with the definitions of *flows, causality, emergence, coherence, metastability, feedback, mereology,* and *catalysts* in complex dynamic systems(Juarrero, 2023). Norman(2013) also explains interaction design with overlapping terminologies of *affordances, signifiers, modalities, constraints, mappings, feedback, and paradoxes*. This extended understanding of the spatial medium helps to represent interactions through multiple layers, scales, modalities, and dimensions. The focus on interactions questions the relations between perception and action, individual and collective, living organisms and technical objects(Simondon, 2017) to differentiate technicities from technology (Gorny et al., 2024). This provides a better understanding of the relationships between animals and machines(Wiener, 2013), humans and non-humans(Latour, 1988), artificial and natural environment(Gibson, 1979) referring to diverse theories and ontologies about and beyond architecture.

Spatial representation of interaction augments the communication mediums and tools for collaboration. Visualizations facilitate the co-creation of multidisciplinary design teams of architects, engineers, and specialists by revealing the potential of services and datafication for human-building interactions. Drawing architecture as a cybernetic system of dynamic flows and interactions informs the design process for responding to the recent questions about designing intelligent environments. Building interfaces can also utilize representations for the operation stages of buildings to communicate with users. Spatial integration of interfaces enables multichannel sources of information and feedback for designing immersive experiences and behavioral interactions with humans and the environment.

Finally, representing the interaction underlines the drawing as a critical architectural design method for the responsible use of digital technologies in buildings. Understanding how immaterial layers of systems interact with the material ones refers to privacy, security, and surveillance challenges. This can also bring attention to putting equal emphasis on "individuation", isolation, and detachments as well as relations, networks, and interactions during the design(Simondon, 2017). Visualization can make the interconnectedness visible to evaluate, cultivate, and maybe limit digital, spatial, and ecological footprints within the growing hyperconnectivity in digitalized environments. Better visualization helps improve the integration beyond their optimization but also critical adoption of technologies regarding contemporary social, material, and ecological discussions.

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