Tracing the Shifts in Architectural Production through the Digital Turn

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Abstract. This research investigates the transformation of architectural practice through digital technologies since the 1990s, examining how computational design has reshaped spatial production and phenomenological experience. The study evolves into addressing broader technological revolution affecting architectural discourse. Drawing on Deleuze's (Deleuze, 1988) mathematical continuity, Shklovsky's (Shklovsky, 1988) estrangement theory, and Harman's (Harman, 2018) object-oriented ontology, the investigation traces three phases: blob architecture through folding geometries (1990s); collaborative parametric design challenging traditional authorship (2000s); and contemporary AI-generated architecture. The central thesis posits that digital architecture exists in productive tension between estrangement and familiarity, where technologies offer unprecedented creative possibilities while potentially alienating practitioners from embodied spatial experience. Key findings reveal "computational alienation" echoing Marx's critique of industrial separation and Berry's (Berry, 2014) digital alienation, where designers become distanced from tactile knowledge, and Srnicek's (Srnicek, 2019) "platform urbanism" that reifies social relations into algorithmic optimisation following Lukács' (Stahl, 2023) commodity fetishism. The research identifies a fundamental ontological shift from "possible to real" speculation toward Deleuze's "virtual to actual" processes, supported by Carpo's (Carpo, 2017) digital design analysis. The study concludes by proposing a critical digital practice advocating for "intimate algorithms" that remain phenomenological responses while embracing technological innovation.

Keywords: Digital architecture, urban futures, architectural alienation.

1 Introduction

This research began with a different question entirely, one rooted in the intimacy of everyday experience that has come to characterise the contemporary life. The initial inquiry centered on how everyday memory and the amplified consciousness of individual experience might inform architectural design, seeking to understand how the humanities could offer architecture new ways of engaging with the subjective dimensions of spatial experience.

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The late 20th century's intensification of individual consciousness what we might call the "amplified everyday" (Baudrillard, 2019) could reshape architectural practice. This approach was motivated by a growing sense that architecture has estranged from the lived, phenomenological dimensions of human experience, particularly as globalization and media saturation created new forms of individual awareness and memory formation.

However, as this research progressed, what began as an investigation into everyday memory and individual consciousness gradually revealed itself to be inseparable from the broader technological transformation reshaping architectural practice. The very technologies that were amplifying individual experience like the computers, networks, digital media, were simultaneously revolutionizing how architects conceived, designed, and constructed space.

This methodological shift from humanities-centred inquiry to digital architecture analysis reflects not an abandonment of the original questions, but their evolution in response to emergent conditions. Through the 1990s and into the 2000s, a parallel transformation occurring within architecture itself: the digital turn, I came to realize, was itself a response to the crisis of the everyday that had initially motivated my research. The parametric systems, algorithmic design processes, and AI-generated forms that came to dominate architectural discourse were not merely technical innovations but attempts to grapple with the same questions of individual agency, memory, and experience that had shaped my original inquiry.

Yet something was lost in this transition. The intimate scale of everyday memory, the lived experiences of the way light falls across a kitchen table, the quality of a stairwell's acoustics, the accumulated veranda that gives spaces their lived character, seemed to disappear beneath the smooth curves of blob architecture and the computational complexity of parametric design. The heightened individuality that had seemed so promising as a foundation for architectural renewal became subsumed within systems that, paradoxically, often eliminated individual agency in favour of algorithmic optimisation.

This tension between the amplified everyday and digital architectures underlies this research. While the explicit focus has shifted to examine the implications of computational design, artificial intelligence, and digital fabrication, the original questions about memory, individuality, and lived experience remain as a persistent undertone of what was left out in the process, and will continue to haunt the investigation.

2 Methodology

The Research employs qualitative interpretive research design combining historical analysis, conceptual analysis, and critical discourse analysis parallelly to excavates the layers of digital transformation and software innovations that occurred chronologically

since the 1990s (marking the digital turn, **Table 1**), with a focus on change in production and practice of architecture, examining what was preserved, what was transformed, and what was lost in the process.

Table 1. Phases of digital turn (Carpo, M. (2013b). Twenty years of Digital Design. In The Digital Turn in Architecture 1992-2012).

Period	Development	Analytical focus
1990s	Blob Architecture and folding geometries	Mathematical continuity and digital customization
2000s	Parametric and collaborative digital design	Authorship and scripting
2010s	AI driven architecture and platform urbanism	Algorithmic governance and computational alienation

Rather than examining empirically how the technological forces have changed the everyday life, the research undertakes the route of architectural theory, representative architectural projects, and technological advancements to map whether the technological transformation of architecture necessarily entails a loss of those qualities that make spaces truly inhabitable in a phenomenological sense.

Justifying the route, the analytical frameworks developed during the research enabled critical theory drawing from the philosophers to examine both technical and sociophilosophical implications of the digital architecture.(**Table 2**)

Table 2. *Conceptual Lens (Author).*

Lens	Key Theorists	Purpose
Digital design	Carpo, Lynn	Understand technological transformation
Phenomenology	Merleau-Ponty, Pallasmaa	Analyse embodied spatial experience
Critical Theory	Marx, Lefebvre	Examine alienation and platform urbanism

The central thesis that emerged from this methodological journey posits that digital architecture exists in a state of productive tension between estrangement and familiarity, where new technologies simultaneously offer unprecedented creative possibilities while potentially alienating both practitioners and users from the embodied, memory-laden experience that gives architecture its deeper meaning. This paradox manifests

across multiple scales and contexts, from the intimate space of the individual dwelling to the urban scale of algorithmic city management. (**Table 3**)

Table 3. Technological advancement and implementation (Author).

Digital tool	Digital architecture	Case	Scale
CAD/ BIM	Guggenheim Bilbao	Digital form generation	Architecture
3D printing	Grotto	Voxel based generation	Sculpture
Digital Platform	Sidewalks lab Toronto	Algorithm manipulation	City

What remains as a persistent research question throughout this investigation is how has digital architecture altered spatial experience of creating and living? and whether digital architecture can recover something of the intimate, memory-laden quality of everyday experience?

The research employs dialectical thinking to examine how digital technologies both fulfil and betray the promise of more responsive, individually-attuned architecture. However, the study only provides the conceptual insights into the philosophical and technological transformation of architecture, without empirical research but with a hope to inform future empirical research.

3 Mathematics as Object and the Image of Continuity

Who could have imagined? A point on a single click dragged to another click could give an image of a line. Accessibility to the computer gave more lines, line types, straight lines, and specifically curved lines, which could give a ‘folded’ drawing in the electronic media, and that held the capacity to reshape architectural discourse throughout the 1990s and beyond.

3.1 The Digital Turn: From Drawing to Problem-Making

The increasing affordability of computers in the 1990s enabled architects to embrace digital tools, though initially these technologies were used primarily to "make drawings and not to solve problems" (Carpo, 2023). This shift coincided with a remarkable philosophical convergence: the introduction of the spline command in CAD software appeared alongside Gilles Deleuze's influential text "The Fold: Leibniz and the Baroque" (1988) (Deleuze, 1988) and Architectural Design's seminal issue "Folding in Architecture" (1993) (Deleuze & Deleuze, 1993).

Deleuze argued for the "simultaneous invention of the 'Fold' in mathematics and in arts (painting, sculpture, architecture) in the age of the baroque" (Carpo, 2023; Deleuze,

1988). His fascination with smooth transitions from convexity to concavity in S-shaped curves proved intellectually contagious, catalysing a rational turn in architectural discourse.

The imagination of folded, curvilinear, and smooth objects transcended the "angular fractures of deconstructivist imagery" (Carpo, 2013b). Building on this, Greg Lynn's conception of folding and bending offered an alternative through "active involvement with external events", represented in curvilinear form. These forms were not merely exercises in "fluid tactics of topological geometry, morphology, morphogenesis, and computer technology," but "capable of complex deformations in response to programmatic, structural, economic, aesthetic, political and contextual influences" (Lynn, 2004), while simultaneously resolving the dialectical tensions between opposing contextual design approaches.

The dialectical tensions previously had architectural imagery trapped between the polarised contextual positions: the heterogeneous incongruity advocated by Venturi and Scott Brown's "Learning from Las Vegas," (Venturi et al., 1978) the homogeneous "architectural language through historical analyses" of Neo-Modernism, and the "consistencies resulting from indigenous climates, materials, traditions or technologies" of Regionalism (Lynn, 1993).

This new technical logic found its theoretical framework in Deleuze's concept of the "objectile" (Deleuze, 1988) and the computational capacity to manipulate mathematical continuity. (Carpo, 2013b) work in the late 1990s demonstrated that "mathematics has effectively become an object of manufacture," enabling architects to employ "calculus-based forms for the first time" (Lynn, 2004). Following Leibniz's analysis, Deleuze observed that "Leibniz's mathematics of continuity introduced and expressed a new idea of the object" (objectile), where "differential calculus does not describe objects, but variations (and variations of variations)" (Carpo, 2011). This corresponded to "a new concept of the technical object, no longer mechanically made and mass-produced but digitally made and based on variations" (mass-customised).

The mechanical age operated according to principles of "visual similarity and imitation as norm," where machine-led mass production created mass culture through imagery of visually identical objects and architecture. The digital age introduced a fundamentally different "technical logic of digital design and production that differs from the traditional modes of manufacturing by machines" (Carpo, 2011).

3.2 The Mathematical Revolution in Form

Mario Carpo emphasises how formal continuity in architecture, emerging partly as a reaction against the deconstructivist emphasis on fracture, intersected with the computer revolution of the mid-1990s and evolved into a comprehensive theory of mathematical continuity. Deleuze's concept of the fold draws from Leibniz's Baroque (Deleuze & Deleuze, 1993) Mathematics to propose "Unlike Platonic forms that exist

as eternal, unchanging essences, the fold suggests that architectural objects exist in states of perpetual becoming, defined not by fixed properties but by their capacity for transformation."

The mathematical philosophy underlying this approach draws from Alfred North Whitehead's process philosophy, which Deleuze frequently references. For Whitehead, reality consists not of discrete objects but of "actual occasions of experience" —events of becoming that are constantly prehending (grasping) and being prehended by other events. Applied to architecture, this suggests that buildings exist not as static objects but as complex assemblages of interacting processes: environmental flows, user movements, structural forces, material behaviours, and informational exchanges.

Lynn's "Folding in Architecture" marked a decisive shift from the "linguistic and representational focus of postmodernism and Derridean deconstruction" toward "spatial, artistic and mathematical models of Deleuze, Foucault, and Whitehead" (Lynn, 1993). The philosophical implications of this shift extend far beyond technological innovation, engaging fundamental questions about the nature of architectural objects and their relationship to space, time, and subjectivity.

The imagination of the "Blob," as Lynn termed it, was later appropriated by Patrik Schumacher as "parametric" (Carpo, 2023) became an architectural reality and remains a visible sign of the first major turn in digital architecture (Carpo, 2023). A new design environment dominated by blobs with embedded algorithms initiated the trend of "topological" architecture, characterised by roundness, continuous, seamless imagery of the objects. From the Guggenheim Bilbao to automotive design, web interfaces, and fashion magazines, this approach marked the emergence of a new digital design culture that continues to govern the contemporary imagery.

4 Collaborative Object and Imagination of the New Real

The early 2000s witnessed a convergence of digital design experimentation with the revolutionary expansion of internet connectivity, fundamentally transforming how architectural knowledge is produced, shared, and materialised. This period saw the emergence of new collaborative paradigms that challenged traditional notions of authorship while simultaneously raising profound questions about the nature of architectural reality in an increasingly digitised world.

4.1 The Migration to Cyberspace and Collaborative Design

Following the dot-com boom, the arrival of cyberspace facilitated a massive migration of human activities from physical to virtual space. The migration to cyberspace represents more than a mere technological shift it constitutes a fundamental transformation in how humans experience and inhabit space as virtual environments became increasingly "real" populated by varied objects and images. Digital design culture since the

1990s began addressing "the urban, economic and social consequences of the migration, also called 'despatialization' (Carpo, 2023). The "spatialisation" of the web opened new possibilities for creating and sharing knowledge globally through what became known as the participatory web, facilitating Carpo calls it "collaboration, interactivity, crowdsourcing and user-generated content."

Digital architecture quickly embraced these collaborative trends. Object variations could now be globalised while their representational images could be customised regionally. Collaboration between diverse stakeholders, individual coders, engineers, architects, developers, executors, and even end users enabled the development of increasingly complex architectural objects. This paradigm shift opened new possibilities for co-working while simultaneously raising critical concerns about authorship and creative agency.

The participatory web introduced what Karen Barad calls "agential realism" (Barad, 2007), an understanding that agency is not possessed by individual entities but emerges through material-discursive practices. In digital design collaboration, agency becomes distributed across human and non-human actors: algorithms, databases, servers, and users all participate in the ongoing becoming of architectural objects.

4.2 The Crisis of Authorship in Parametric Object

Mario Carpo explains that while "mass-customisation" (Carpo, 2017) and variability are inherent to digital design, the open-ended nature of parametric scripting inevitably challenges traditional authorial modes of design. Even when a machine or designer establishes parameters and produces variable scripts for object design, these can be altered during execution or construction by others, with or without the original script designer's consent.

Bernard Cache's intriguing collaborative project "Tables Projective" (2004-2005) obliged the end user to be the co-designer of a physical object (Carpo, 2023), thus reviving in part Negroponte's cybernetic vision of the late." (Carpo, 2023). This project exemplifies what Gilles Deleuze and Félix Guattari call "machinic assemblages" (Deleuze & Guattari, 1989) heterogeneous components (human, technological, economic) that function together without forming a unified whole. The end-user becomes what they term a "partial subject" within a larger assemblage of design production. Being just the "partial subject", the process of the project challenges traditional Western notions of individual authorship rooted in enlightenment concepts of the autonomous subject. While the democratisation of the process raises questions related to equal participation and power, the other initiatives, including the FabLab Movement (Neil Gershenfeld, 2001) (Carpo, 2023) and WikiHouse Foundation (2011) (Carpo, 2023), emerged with different social attempts to create what political theorist James C. Scott calls "seeing like a state" (Scott, 2020) forms of knowledge and practice that resist technocratic rationalisation while remaining technically sophisticated.

Including the Building Information Modelling (BIM) software further democratised the design process by enabling collaboration between designers and contractors to resolve construction-scale issues. These formal interactive tools provided "information exchange and coordination among scores of different agents and actors, human and technical alike each in charge of different parts or aspects of the project" (Carpo, 2013b). This new approach enabled the creation and organisation of form and space rationalised material attributes, time-based parametric capacities, building performance, and digital tectonics.

4.3 From Possible to Virtual: The Transformation of Architectural Reality

Acknowledging the BIM, theorists Sanford Kwinter and Manuel DeLanda (Carpo, 2013a) highlighted how digital processes reduced the gap between architectural objects and their construction. Objects became information datasets "information models" in professional practice. This marked a decisive shift from the speculative process of "possible to real" toward "virtual to actual." Where traditional architectural speculation remained predominantly cerebral, offering no guarantee that the architect's intentions would be faithfully represented in the built work, information models are "already digitally real," requiring no interpretation between imagination and realisation.

5 Voxel and Estrangement

5.1 From Possible to Virtual: The Transformation of Architectural Reality

The subtractive approach dominated manufacturing through the mechanical era of the 1950s and into the computational design era via CNC (computer numerically controlled) machines. However, additive fabrication technologies beginning with stereolithography in 1984, becoming marginally available in the 1990s, and spreading widely as 3D printing from 2008-09 onward fundamentally transformed material production (Carpo, 2017).

3D printing technology not only became the preferred choice of various designers and artists but also "went on to acquire deeper aesthetical, ideological and even sociopolitical significations" (Carpo, 2023). The technology fabricates small cubic units of matter called voxels, each unique and requiring specific data and machine time, scalable to any volume in any given density and material. As Carpo emphasises, "3D printing brings the logic of digital mass customisation from the macro scale of product design to the micro scale of the production of physical matter and at previously unimaginable levels of complexity and granularity."

Michael Hansmeyer and Benjamin Dillenburger's 3D printed model "Grotto" (Carpo, 2023) became seminal in this category. Representing an elaborate form of ornamentation, the model contained 260 million surfaces and 30 billion voxel spaces, each individually printed. Paradoxically, the detailed complexity made the grotto

cheaper to produce than a plain block of equivalent size and resolution, reversing the modernist equation of detail with labour, time, and expense.

5.2 The Challenge of Posthuman Detailing

While voxel-based 3D printing offered unprecedented possibilities, it also raised significant concerns about "the micro scale of production of physical matter." (Baudrillard, 2019) Detailing millions of voxels requires "inhuman or posthuman" levels of information management, big-data processing, and automated design control. This necessitates intelligent tool intervention for machinic or automatic control of design features.

Additional concerns emerged regarding human perception. The visual and tactile density of voxel-based objects often exceeded the capacity of human senses to perceive meaningful differences. The intricacies available through digital design will always pale compared to the natural world's organic and inorganic complexity. This raised crucial questions about digital style as a form of realism, excessive realism, or digital hyperrealism, where the overwhelming capacity of these objects to appear "real" challenges fundamental assumptions about architectural authenticity. (Baudrillard, 2019)

Voxel-based 3D printing has unlocked remarkable new potentials, yet it also introduces critical challenges related to the ultra-fine scale at which material is fabricated. Managing the vast quantities of data required to define millions of individual voxels demands levels of computational control that exceed typical human capabilities, approaching what might be described as posthuman design processes. As a result, these systems rely heavily on intelligent tools and automated workflows to manage, generate, and refine complex design features.

5.3 Real Unreal Estranged Object

Michael Young's pursuit of architectural knowledge through multiple strains of aesthetic realism emphasises that extreme digital resolution and overwhelming detail richness induce "feelings of discomfort, or estrangement" (Young, 2015). This "excessive resolution" serves as "a diacritical trait of the second digital style" and "the outward and visible sign of an inward and invisible excess of data that we may master or unleash but could never replicate, emulate or simply comprehend with our minds" (Carpo, 2017).

Mario Carpo draws parallels between industrial and digital revolutions: just as industrial technology extended natural bodily capacities, digital technologies extend natural intelligence. Following Marx's critique of industrial separation between the makers' hands and production tools (Carpo, 2013a), Carpo suggests a similar separation between thinkers' minds and computational tools. This separation partially explains why artificial intelligence in technology, objects, and the arts generates natural discomfort and alienation.

6 Artificial vs. Neural Object

Traditionally, architects used the estrangement theory to produce interest in the object that they created. The tactics of estrangement varied with different contexts and purposes defined by the architects. With the advancement of Artificial Intelligence, the neural object could not match the speed of the artificially obtained objects. Software like Mid-Journey and DALL-E created estranged objects that amazed the masses, thus fulfilling the theory of estrangement. Though the question of whether the artificially created object could be called real, is a debate.

6.1 Intelligent Objects

Matias del Campo's investigation into AI-generated architecture (Campo, 2022) raises the fundamental question: "What is real in AI?" He explains the AI creative process through statistical concepts of extrapolation and interpolation: "humans have an edge over machines in terms of extrapolation", while "machines are faster than humans in interpolation." Extrapolation constructs unknown data points outside discrete known sets, while interpolation constructs unknown points between known dataset points, like in the case of image-generating software Mid-Journey and DALL-E used extensively in the architecture schools (Campo, 2022).

Though faster machines "can generate less meaningful results and are occasionally prone to greater uncertainty," Campo argues that this uncertainty can produce surprising results in neural architecture, albeit from existing datasets rather than genuinely "new" creations that only humans can achieve.

Anna Abraham's neuroscientific approach to creativity reveals that discrete human knowledge and ideas derive from discrete memories of "semiotics and cognitive neural networks at play" (Abraham, 2018). Campo emphasises understanding cultural signifiers in "creative and new" ideas rather than debating whether AI or human brains are superior at creativity.

6.2 Architecture as Parafictional Project

Graham Harman's theory addresses the fundamental question, "What is real in architecture?" (Harman, 2018) By arguing that most philosophies either "undermine" objects (claiming they are less real than component parts) or "overmine" them (defining them as cognitive constructs with no independent reality). For underminers, reality occurs in analyzable part relationships; for overminers, reality occurs in human-constructed relations.

The aesthetics of architectural realism cannot collapse into building pragmatics but must maintain productive tensions through estrangement strategies. Michael Young proposes that "architecture be considered a parafictional project" that should "exploit its entire available media to propose ways in which the world can be made other" (Young, 2015). This approach embraces architecture's capacity for speculative world-

making while acknowledging the irreducible strangeness that emerges when digital technologies exceed human comprehension and control.

7 Digital Materiality of the Physical Objects

As architects now spend more time designing, testing, and visualising objects in the virtual environment, the question of materiality is challenging, whether digital capture of physical materiality could constitute a new reality, or is it just a representation of the physical-virtual.

The digital turns, beginning in the 1990s and extending through the 2000s, brought about a fundamental transformation in architectural discourse that continues to reverberate today. This transformation occurred across multiple waves, each introducing new ontological questions about the nature of physical-virtual reality through materiality. The first digital turn fundamentally altered how architectural objects were conceived, documented, and fabricated. Software like CAD/CAM systems revolutionised technical drawing from hand-drafted orthographic projections to precise digital geometries, enabling architects to manipulate form through mathematical relationships rather than intuitive sketching. The contemporary "second digital turn" has intensified these questions through AI-powered visualisation tools and machine learning systems trained on vast architectural datasets. These technologies can generate countless design variations, produce photorealistic renderings of unbuilt spaces, and create architectural proposals that emerge from algorithmic processes rather than human spatial intuition. This, Mario Carpo emphasises, is that the design profession has transitioned “from tools for making to tools for thinking” with the digital turn, and the digital materiality emerges as the interplay between architects, molecular materials, scripting, codes and programming language, mathematical algorithms, software, etc. (Carpo, 2017)

Architects Fabio Gramazio and Matthias Kohler suggest that materiality is increasingly being enriched with digital characteristics. The interplay between digital and material processes has enabled the transformation in the expression of architecture. They emphasise the shift from designing an object to computational design of processes, which will bring these objects into being in the physical world. (Gramazio & Kohler, 2008)

Deleuze and Guattari's framework of “assemblages” explains that these heterogeneous configurations of humans, algorithms, software interfaces, databases, and fabrication machines capture the emergent architectural possibilities. Deleuze explains that these assemblages are dynamic in nature, like a rhizome. Any component of the assemblage (physical or virtual, human or nonhuman) can connect any other to create objects, thus challenging the traditional hierarchical architecture making. (Deleuze & Guattari, 1989)

Jane Bennet's theory of vital materialism suggests that each element of these assemblages possesses its own agency and "thing-power," that it actively participates in the architectural possibilities. The elements possess their own material, tolerance, and capacities that shape outcome, creating what Bennett would recognise as 'vibrant matter' that exceeds human control and predictability. She emphasises recognising the active participation of nonhuman forces in events, enabling the vital materiality to run through and across bodies, both human and nonhuman (Bennett, 2010). The expansion of the theories about digital materiality is important in assuming the reality, whether it exists in architecture only through physical materialisation or could also exist as processes of computation and information.

8 Urban Alienation and Reification

The mediation by digital technologies has also transformed how residents experience, navigate, make choices, and understand the city. The threat of lived urban experience getting abstracted in quantifiable data reduces the urban processes according to market logic rather than social needs. This phenomenon creates a new form of urban alienation while neglecting social processes and relations that produce urban space.

Georg Lukács' critique of commodity fetishism explains how 'social relations between people appear as relations between things' (Stahl, 2023). In the urban digital context, this means having spatial social relations becoming mediated by algorithmic systems and treating urban complexity issues as computational parameter-based problems. This phenomenon creates urban reification, prioritising market efficiency over "democratic participation and social reproduction" (Lefebvre et al., 2013)

Henri Lefebvre's notion of space as simultaneously conceived, perceived, and lived helps to demonstrate and understand digital urban transformation. The conceived space refers to abstract frameworks used by the state in collaboration with architects, planners, and technocrats to organise spatial and urban development. (Lefebvre et al., 2013) Whereas digital tools have redefined the spatial conception through data visualisation, predictive modelling and algorithmic optimisation. The Smart City initiative exemplifies this transformation by turning complex cities into complex data, generated by data streams to be analysed and optimised. The perceived space refers to material routines, flows and discoveries that make urban life. Digital tools like navigation applications, ride-sharing services, etc., disrupt the neighbourhood character by algorithmic mediation, thereby controlling routing patterns and determining flows. The lived space refers to the symbolic, experiential, and affective dimensions of place that enhance everyday social practice. The digital tools transform and encourage individuation with the help of platforms like Instagram, which deceives the urban scape into the background for personal branding. The shareable digital content becomes the symbol of the urban spaces, reducing the local significance.

9 The Production of Digital Urban Space

Nick Srnicek calls the digital platform "extractive business models" that generate value by recording, analysing and optimising user data. In the urban context, this creates "Platform Urbanism" that shapes the organisation of the city space for data extraction and algorithmic optimisation for generating profits. (Srnicek, 2019) For example, travel-based platforms reorganise urban mobility around surge pricing and algorithmic dispatch rather than comprehensive public transit planning.

Louise Amoore calls it "algorithmic governance" when the city development by the urban governance system is governed by market mechanisms rather than democratic planning processes. The market mechanism manifests the decision-making processes that operate through automated data analysis rather than political deliberation. (Amoore, 2020). Toronto's failed sidewalk labs project was executed to integrate sensor networks with algorithmic management systems that would optimise vehicular and pedestrian flow, energy consumption, to even water management. (Goodman & Powles, 2019). Promoted to efficiently improve the infrastructure, but surfaced as the privatisation of urban governance, through a proprietary technological system controlled by global technology corporations.

Rob Kitchin describes how urban management depends on the "data urbanism" approaches to urban planning and governance. (Kitchin, 2017) The city drives on the data generated by transportation systems, utility networks, surveillance cameras, social media accounts, etc. This data becomes the reality of the urban conditions rather than a representation that reflects particular or state interests. For example, what Shoshana Zuboff calls "surveillance capitalism" (Zuboff, 2019), where digitally connected residents with smartphones and social media accounts generate data signals that draw attention of the data-driven management systems, while digitally disconnected areas experience service decline and further marginalisation.

The digital tools and algorithmic manipulations create alienation and reification of urban processes. The navigation apps affect the embodied spatial knowledge that comes from the enhanced understanding of the environment. The alienation affects what Kevin lynch called "imageability", mental maps that integrate landmarks, paths, districts, nodes, and edges into coherent spatial understanding. (Lynch, 1992) The temporal alienation makes the residents disconnected from both personal and collective temporal rhythms. Bernard Steigler calls "temporal disorientation" the loss of urban rhythm to algorithmic optimisation. (Crogan, 2019). The availability of food via the food delivery platforms disrupts the traditional meal times and quiet hours of the neighbourhood. The social alienation explains the commodification of social interaction through digital platforms also transforms urban social relations into market transactions. Robert Putnam calls it a decline in "social capital" because traditional urban social capital emerged in repeated interaction in the shared space, for example, neighbourhood stores. (Putnam, 1995) With the fast delivery grocery apps, the interaction that provided social support, information exchange, and collective efficacy for addressing neighbourhood problems

diminished. The digital apps represent the casualisation of labour that eliminates ethics and worker protection. Alexandrea Ravenelle's take on gig workers exposes the "entrepreneurial inequality" where the workers bear the market risks and losses, while the platform captures value through data analysis and algorithmic management (Ravenelle, 2019).

10 Conclusion

Each wave of digital transformation from the blob architecture of the 1990s through parametric design to contemporary AI-generated forms has offered unprecedented creative possibilities while simultaneously distancing both architects and users from the embodied, tactile knowledge that traditionally informed spatial experience. The investigation reveals that digital architecture exists in a state of productive tension what I have termed the dialectic between estrangement and familiarity. This tension manifests across multiple scales and contexts, from the intimate manipulation of mathematical curves through spline commands to the urban-scale implementation of algorithmic city management systems.

The most significant finding concerns what might be called the paradox of digital intimacy. As Mario Carpo observes, "The digital designer does not draw lines or model volumes. Instead, writes scripts that draw lines and model volumes." This mediation introduces "computational alienation," in which designers become distanced from tactile, embodied knowledge. Yet this alienation is not simply negative. The research demonstrates that estrangement of the overwhelming detail density of voxel-based 3D printing serves as a crucial architectural strategy for breaking habituated perception and opening new possibilities for spatial experience.

Central to this investigation is the question: what constitutes architectural reality in an age of digital mediation? The research traces a decisive shift from traditional "possible to real" speculation toward "virtual to actual" processes where information models are "already digitally real." This transformation challenges conventional distinctions between representation and reality. Urban-scale digital transformation reveals how technological forces reshaping architectural practice also transform urban citizenship and spatial democracy. The emergence of "platform urbanism" creates new forms of reification, where social relations become mediated by computational systems prioritizing market efficiency over democratic participation.

This research concludes not with a definitive answer but with a framework for critical digital practice that holds these tensions in productive suspension. The key insight is that opposition between digital innovation and lived experience represents a false choice. Instead, the challenge is developing digital practices that remain attentive to phenomenological dimensions while embracing technological transformation.

Such practice would cultivate "intimate algorithms" computational processes responsive to subtle, embodied dimensions of spatial experience while exploiting creative possibilities of digital design. This requires neither rejection of digital technologies nor uncritical technological solutionism, but critical engagement maintaining awareness of both possibilities and limitations.

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