Digital Processes to Conscious Innovation in Built Environment

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Abstract. Some 15 years ago, the world's urban population surpassed the global rural population, an unprecedented shift in how and where we live. It is believed that by 2050 more than two thirds of the world's population will be living in urban settings. How can, and should we integrate such a population into the project methodology, aiming at their participation? There has been a growing interest in increasing user commitment in conception design processes for built space, moving against fully top-down approaches. In turn, Research Centres have become increasingly interested in the potential of computational technologies of AI, as well as digital fabrication, in design research projects. However, it should be noted that such research is limited in its social impact and influence over decision-making processes, namely in social, environmental, and urban settings. Furthermore, lack of more systematic information on emerging digital technologies, generating new forms of social innovation, is an obstacle to developing more conscious design strategies. In this context, this paper sets out to develop a set of European pilot projects produced in laboratories of technology and architecture, focusing on two guidelines: i) conscious innovation ii) inclusive participation. From this revision, a set of insights will result, which call for driving forces towards social cohesion, by implementing solutions based on digital technologies.

Therefore, this research will contribute to endow architects with theoretical and methodological references that drive conscious innovation and inclusive participation, in the name of a digital architecture that is more active, both politically and socially, and committed to greater spacial social justice.

Keywords: Architecture · Digital Design · Artificial Intelligence · Pilot Projects · Inclusive Participation

1 Introduction

We live in a world of rapid and deep change. Thus, the way we understand and interact with it has also been altered, so much so, that a great number of authors do not hesitate to speak of a fourth Industrial Revolution, in which technology has taken the central role. Technology in the age of information and its impact on architecture are undergoing a radical change, and the relationship between both areas calls for fresh concepts, wherein physical space interweaves with digital content. Therefore, developing increasingly functional and highly effective products will be the key to facing the challenges posed by the 21st century – global urbanization, economic unrest, and, especially, a growing awareness of the environmental crisis.

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In that sense, this research proposal draws on a double starting point:

Following the unprecedented challenges related to social, environmental, or economic aspects our world faces today, we architect, as protagonists in the creation of the built environment, are urged not only to research, but also radically apply new ways of designing, managing, and constructing the built space.

The community devoted to experimentation should adopt applied research and pilot projects as their main methodology, to promote cooperation with public organizations and the private sector, with the main industries and with administrative and municipal entities, to have a stronger influence on social, industries and with administrative and municipal entities, to have a stronger influence on social, environmental, and urban contexts.

A paradigm shift is underway, wherein the digital has become more material than ever before. It is then crucial that architects assume an active role, understanding and adapting to new settings, while guiding some of the transformations taking place and focusing on emerging technical paradigms.

In this context, this paper will map a set of pilot projects which draw from a systematic revision of study cases. Projects selected will be those using technology innovatively and guided by manifestos which are urban, social, environmental, economic, and political. They will strive to explore new methodologies aiming at a greater impact of their research, thus taking their work beyond laboratories, sterile and closed off, and promoting connection with different key stakeholders – local government, citizens, and industry.

In this context, the methodology used consisted of selecting projects that met the stipulated selection criteria: being based on intelligent digital design and/or construction processes; being a European pilot project; production in technology and architecture laboratories; focusing on conscious innovation and inclusive participation.

To explain and illustrate the various degrees of intersection between architecture, design-construction, and digital technologies, categorizations were immediately defined. We define seven levels, which increasingly illustrate this relationship.

The first constitutes the relationship at the level of thought (Thinking), in which the computer is not used, but there is computational thinking taking place. 2. The second level would be that of conception (Conception), in which thinking and computational tools are used in the process of designing the building. 3. The third level (Detail) would be that of Thinking in which computational tools are used in the process of generating building constructive details. 4. The fourth level (Analysis) reflects the thinking and computational tools used in the building "calculation" process. 5. The fifth designated level of partial fabrication, in which Thinking and computational tools are used in the digital fabrication process of building parts. 6. Manufacturing (F) in which the Thinking and computational tools are used in the digital manufacturing process of the entire building. 7. Assembly (M) in which the thinking and computational tools are used in the process of assembling the building components. In addition to this qualification grid, we have two types of relationship between these intersection levels: 1st, which consists of an integrated System, Design + Analysis + Partial Manufacturing; a 2nd that consists of a juxtaposed system that will be the Conception, Analysis, and Partial Manufacturing simultaneously.

This article will contribute to a construction of theoretical framework that will be created to put forward research models, action plans and guidelines making technological advances more suitable for the built space. Architects, cultural agents of construction, will also be equipped with reflective intellectual tools that allow them to be conscientious protagonists in the digital paradigm shift that we are currently witnessing, thus avoiding a criminous subordination in relation to the industry. This research will share insights and knowledge whose goal is to boost a conscious innovation in the field of architecture. It intends to promote a more abundant and sustainable course of action in line with the current needs of our habitat.

2 Context of a Computational Perspective in Architecture Research

All over the word, laboratories and architecture experts integrate the potential of computer-aided design technology and digital production in developing scientific projects. However, one can argue that these new projects wind up not actually influencing the decision-making process as they should, namely in social, environmental, or urban settings. Architects – agents in the creation of built space – are required to do research, but also to apply new modes of design, management, and building. The community devoted to experimentation should single out applied research and pilot projects as their main methodology. This would nurture cooperation with public agencies, administration, and local power, as well as the private sector. On the other hand, pilot projects must be carefully developed and widespread (Markopoulou 2019). Architects – agents of creation of the built environment – are obliged to carry out research, but also to apply new forms of design, management, and construction. The community dedicated to experimentation should adopt applied research and pilot projects as the main methodologies, to promote collaboration with public and private bodies, with the main industries involved, and with municipal administrative entities. In turn, pilot projects must be carefully developed and widely disseminated to contribute to the much-needed shift in mindset towards emerging futures. (Markopoulou, 2019).

2.1 Pilot Projects, Intelligent Processes and Practices

In this article we will cover the following projects: 1) IAAC, Super Barrio, Barcelona 2017; 2) IAAC, Fab Lab House, Barcelona, 2010; 3) Elytra Filament Pavilion. This selection of projects presents a different level of interaction between architecture and digital technologies that we will distinguish through the analysis carried out, defining different levels of interference.

Super Barrio, IAAC, Barcelona 2017

According to the site of IAAC, Super Barrio [1], is an open-source video game designed for smartphones and tablets. Initially developed as a pilot in the framework of the Master's in City & Technology from IAAC, it has been implemented in Barcelona (2017) to co-design the Superilla pilot project, etc. It empowers architects and public entities to engage citizens in participatory design processes for public spaces while promoting sustainability and inclusiveness. Users can visualize their neighbourhoods in 3D, customize elements, and incorporate functions and services related to ecology, energy, mobility, leisure, and culture. The game evaluates proposals based on accessibility, economy, productivity, ecology, and social interaction, enabling non-specialists to actively contribute to urban design and grasp the intricacies of decision-making. Super Barrio is a digital tool that aims to boost participatory co-design processes. This project is intuitive, and the navigation allows any citizen and various stakeholders to get involved in the design of the public space. Players can view icons representing different NBS and explore their possible use in their neighbourhoods. According to Areti Markopolou, whether the architecture of built space (or not) can be programmed for performance, the key question to be addressed is who the actuator of such performance is. This article engages the idea that responsive technologies, such as Virtual and Augmented Reality and User/Game Interfaces, can be used by architects and urban designers as a tool for enhanced participatory design and as a tool for prior evaluation or future design decisions. The latter is no longer seen only as the final aesthetic creator but as a mediator, creator and developer of open systems and participatory design of computerized interfaces. This creator carries responsibility for design processes that are fed by data collected before the participation event, as well as curating collective decisions through overlaying data collected before, during, and after the event. In terms of classification, this pilot project carried out in Barcelona, could include design and analysis using digital technologies (Fig. 1).

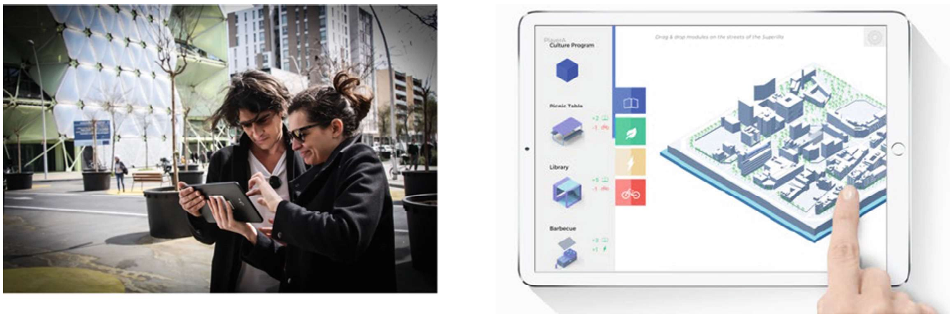

Fig. 1. Super Barrio.

Fab Lab House, Barcelona 2010

In 2010, The Fab Lab House thus became the first house entirely produced in a digital creation laboratory at an educational institution (Fig. 2). A group of professors, students, and collaborators from IAAC[1] manufactured a 60 m2 house inside one of the laboratories of the same institution, using just two medium-scale Computer Numerical Control (CNC) machines. The objective was to design an integral solar house using the technologies of the time, to generate maximum resources with minimum investment. A house built for people, committed to creating the city and connected to the entire world.

According to Vicente Guallart "Instead of building solar houses, we can create self-sufficient habitats capable of producing energy, food and other goods." [2] The Fab Lab House is a house designed as an active resource production center, rather than a

[1] Institute for Advanced Architecture of Catalonia.

passive consumption space. The house generates more than twice the energy needed to operate itself, through its own photovoltaic system; it produces food in its permaculture garden and fruit trees, and has a small fabrication lab, connected by videoconference to the global network of Fab Labs, for the manufacture of everyday objects. The Fab Lab House is based on optimizing computational design for solar energy capture and energy self-sufficiency; simultaneously, on the project website, users can access 3D files and customize the layout of the solar panels, as well as download production files and manufacture the product according to local resources and labour. The Fab Lab House was presented at Solar Decathlon Europe, having been built, exhibited, and evaluated in real environmental and living conditions [3].

In terms of classification, we can evaluate this pilot project carried out in Barcelona with a solution that relies on digital technologies in an integrated way covering design + analysis, detail + manufacturing.

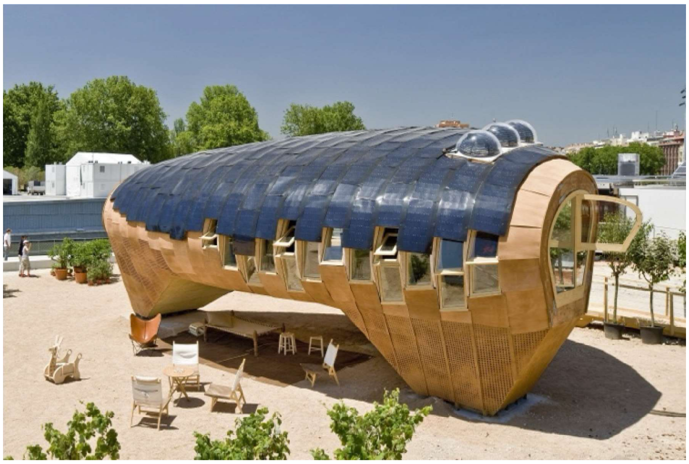

Fig. 2. The Fab Lab House Project.

Elytra Filament Pavilion Victoria and Albert Museum, by Achim Menges, London, 2016

The Elytra Filament Pavilion is inspired by lightweight construction principles found in nature, specifically the filament structures of the forewing shells of flying beetles known as elytra. The design, structural analysis, and adaptation of each cell in the pavilion is a fully digital process, allowing the machine control code for the robotic fabrication to be directly derived. The pavilion's cells are designed to be modular and evolve and grow over the course of the Engineering Season in response to data collected by embedded optical sensors, which trace the behavior and pattern of the canopy's inhabitants.

The production process is an innovative robotic winding process developed by the project team, which does not require any mould, thus reducing waste to a minimum. Each cell is made from the same load-bearing fibre material: transparent glass fibres and black carbon fibres. The robotic fabrication process enables an infinite range of morphological permutations of the cells, with each canopy cell adapted to its specific loading condition through a differentiation of its fibre arrangement, density, and orientation. The pavilion is a dynamic space and an evolving structure, with the cellular canopy growing from an on-site fabrication nucleus in response to patterns of inhabitation of the garden over time, driven by real-time sensing data.

The pavilion's capacity to be locally produced, to expand and to contract over time, provides a vision of future inner city green areas with responsive semi-outdoor spaces and thus extend the use of the scarce resource of public urban ground. In terms of classification, we can evaluate this pilot project that highlights the presence of digital technologies at the level of design + detail + analysis + manufacturing + and assembly, relating to an integrated system. The seemingly unfathomable complexity of the physical forms now created expresses a new form of artificial intelligence, outside the tradition of modern science and alien to the organic logic of our mind. This type of forms, of Achim Menges, is calculated structurally not through the calculation of traditional structures as it would be impossible in practical terms. Such is the number of "Filaments" we have here, it would take us years to solve the problem. Simulation and optimisation work by trial and error, carrying out many simulations until the correct solution is reached (Fig. 3).

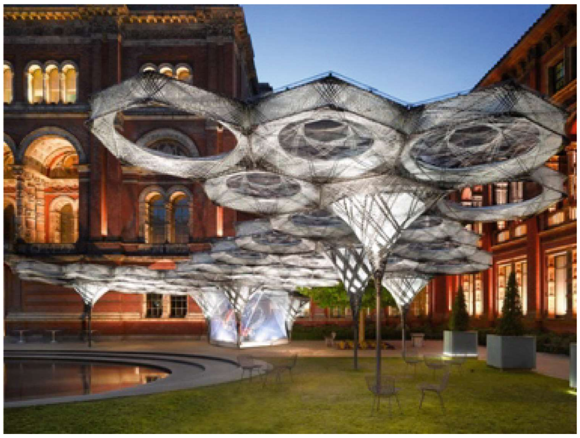

Fig. 3. Elytra Filament Pavilion Victoria and Albert Museum, by Achim Menges, London, 2016

3 Strategic Guidelines

In summary, how can digital technology positively impact decisions in architectural design and facilitate the design and construction phases? An active and synchronous role for architects is recommended in the paradigm shift we are witnessing, critically reflecting, and designing the use of innovative technologies in a responsible manner, contradicting the conservative nature that the discipline of architecture has historically demonstrated. As stated in JA[2], considering design through the lens of computation means realizing to what extent the intrinsic ability to computare (calculate), using the

[2] J–A Jornal Arquitectos https://arquitectos.pt/j-a/.

devices that characterize it, was used in the design process (latu sensu and not specifically limited to the exercise of architecture).

This selection of projects configures a framework that elucidates different levels of the digital in architecture. We consider computational thinking not so much as a materialization of computational technology, but rather as a way of thinking that has altered the understanding of design and the designer. Despite the formal manifestations that dominated the last decades, the most relevant effect of the digital in architecture has been a growing application, with progressive integration, of computation to the different steps of the process from design to production. In fact, the transformative potential of digital lies in the automation of the process that operationalizes the paradigm of mass customisation, originated outside the field of architecture and quickly embraced by the digerati of the 1990s. However, this paradigm enables both low-cost complexity generation and mass generation of contextual solutions (Neves, Brandão, Alves 2024).

The dissemination of the use of parametric design tools and digital fabrication has led to a new "material praxis" and a new field of exploration for building designers to take the role of meta-designer, developing meta-types for instance-designers – architects, builders, clients – to configure. To operate in this context architects must add to their skills the navigational instinct of entrepreneurs but also increasingly collaborate with other stakeholders in the design process.

On the other hand, how can research into digital technologies – developed in laboratories – positively impact user communities that inhabit urban spaces or the decision makers that eventually take decisions for it? A way to expand the capabilities of using computational and algorithmic design is to combine machine intelligence with cognitive and crowd intelligence that can be found in the arena of cities. Creating, therefore, design models that are based on circular feedback thinking that systemically merge bottom up and top-down processes while they are bidirectional; meaning models that allow designers to be educated about the citizen's desires and needs, but citizens, in their turn, can be educated about the impact of their desires, so that behavioral change can emerge [4].

Such processes could eventually bring radical positive impact and local custom solutions for the different urban environments. As Markopolou said, in the pilot projects developed by IAAC City & Technology program in the case studies of Barcelona (Superbarrio, 2017), low-cost Virtual Reality devices and open-source virtual gaming platforms, accordingly, have been used as new tools for participatory urban design, contributing to engage citizens in the design of the public space and the new buildings of their neighbourhood [5]. As stated in JA [4], in summary, "we conclude that technology certainly does not replace thinking, but it can change the framework in which this happens, for better or for worse.

In this context, teaching and research in architecture should not be oriented towards technology, but rather towards problem solving, with technology emerging, regardless of its sophistication, as a resource to be used in the search for solutions, with the nature of the problem and the designer's interpretation to determine which technology is appropriate. It is therefore essential for architects to be aware of the changes in digital technologies through critical discourse, theory, focusing on emerging technical paradigms that are profoundly reshaping the way we live, and promoting a more politically and socially active digital architecture. In this context, an active and synchronous role for architects is recommended in the paradigm shift we are witnessing, critically reflecting, and designing the use of innovative technologies in a responsible manner, contradicting the conservative nature that the discipline of architecture has historically demonstrated".

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