Neurourbanism: from effective to affective computing in urban planning

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Abstract. This study stands interdisciplinarity at the intersection of computational sciences with neurosciences and urbanism that converge in the emerging field entitled neurourbanism. The generative ecosystem and ubiquitous computing in urbanism have reimagined urban planning that came with a range of implications, one of them being the fact that the design problem tends to be reduced to merely data manipulation and effective computing. This approach is simplifying in relation to many ineffable and incomputable dimensions that define the urban planning complexity and addressability. Consequently, affective computation has been identified as a direct manipulation mechanism of re-inserting the meaningful subjective human values and feedback into the generative designing processes as well as a tool for analyzing the implications that urban gestures modify or alter human perception and behavior. This paper nominates and analyses a series of studies that embrace neuroscience and affective computation in urban planning design, as well as author's own experimental journey in this regard, intending to serve as an introduction to practitioners of this new field of study.

Key words: generative design, neuroscience, emotion, EEG, literature review

1. Context: generative computation as a design method

The transition from CAD augmentative tools (that subordinately assist the design process) to generative-thinking tools (that not only endorse the design process, but become the design methods in themselves) are the main symptoms of what has been called the "second digital turn"[1]. Consequently, if the traditional design process starts with a blank sheet of paper[2], the generative ecosystem is moving towards an inductive bottom-up approach in which the designer no longer has direct control over the final form but over the parameters and the in-forming processes through which the totality of available solutions - the universe of possibilities - are suddenly brought to the surface through effective computation. In this framework, the designer's role resumes to a matter of searching for the right solution and curating the morphogenetical potential[3]. The main challenges of intensive use of solution generation software are related to the "paradox of choice"[4] derived from the oversupply of variable images which constitutes the solution space, that leads to a "decisional overstimulation"[5], that needs to be addressed through additional tools. One way to address this "paradox of choice" can be by narrowing the solution space by customizing solutions based on understanding user preferences.

[1] Carpo 2017
[2] Bolojan 2022
[3] Terzidis 2014
[4] Schwartz 2016
[5] Toffler 1970

2. Effective Computing

Computation is the fundamental level of everything that exists - whether we are talking about natural systems, human body systems or artificial systems. The idea of a universal mathematical logic as a key ("clavis universalis") to all problems has fascinated many thinkers over the ages. "Mathesis universalis" as promoted by Gottfried Wilhelm Leibniz and later taken up by Raimundus Lullus and René Descartes, see the universe as reducible to a common vocabulary and grammar that can explain everything in the universe. Effective computing is what can actually be computed through calculus, the universal mathematical ceiling of computability. Urban planning is known as one of the most complex fields of study as it involves the use and processing of an endless range of data, so computers are invited to do what they do best, i.e. the bringing forth the entire solution space based on the mathematical computation of all possible permutations. Today a whole category of tools uses effective computing, in urban planning, some of the well-known AI and data-driven tools being Urban SIM, Forma (by Autodesk), xkool. ai, PlanX, InFraRed, Delve, Urbanist AI, Sidewalk Labs, ARCHITEChTURES and so on.

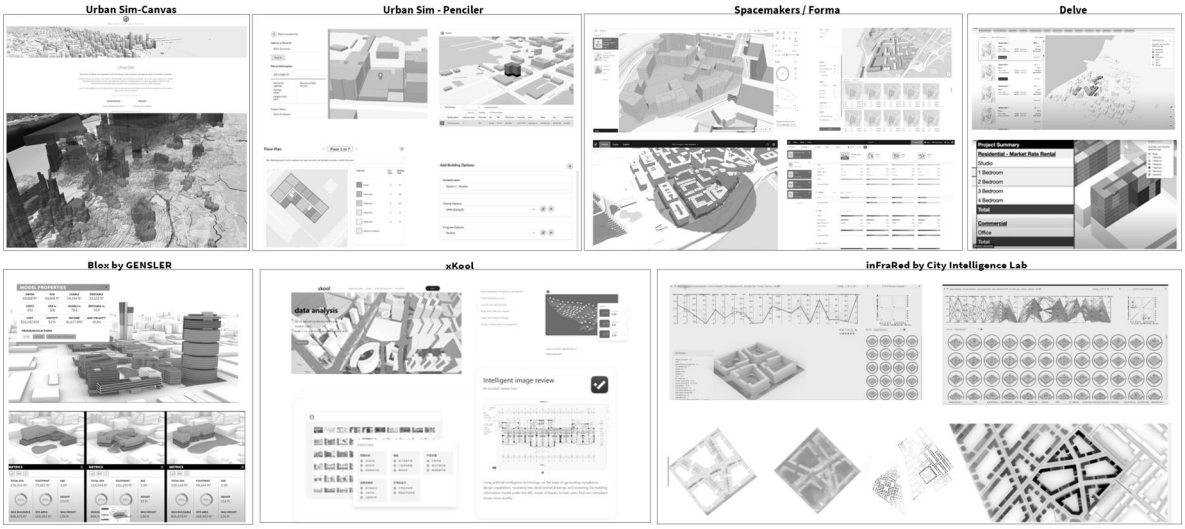

Fig. 1. Illustration of a series of tools based on Big Data and AI that have taken over the landscape of urbanism practice today.

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These data-driven tools aid urban planners to address the "tame"[6] dimension of the problem (which refers to its prescriptive and computable site), while the "wicked" it is still supposed to be difficult to be addressed through computation. Similarly Guoyan proposed a clear separation of design tasks between "quantitative" and "qualitative" tasks, the first being the easiest to automate[7], while the latter is still contingent on our human nature. Although an adamant supporter of computing, Christopher Alexander in his notes on the synthesis of form expressed also its deep concern about the possibility of fatal distortion of the nature of design by uncritical and uncontrolled entrustment of the architectural problem merely to

[6] Rittel and Weber 1973
[7] Guoyan 2009

computation[8], which motivates the need to identify mechanisms that allow this peer mediation of roles and capabilities between human and machine intro the design process.

3. Affective Computing in Urban Planning

3.1. Affective Computing

Architecture and urbanism are not only about form, rules and geometries, but they are also about human experience in space, which can hardly be quantified by numerical parameters as it needs a phenomenological projection in space. This experience can be mediated by affective computing. Therefore, in order to address the limitations of effective computing dealing with architectural and urban issues, this study propose the field of affective computing, a field of study pioneered by Rosalind Picard in 1995. Affective computing makes use of computers and hardware devices to track and decipher human's emotions that stand behind different mechanisms of approach / avoidance, reflexive reactions or decisions[9]. Emotions are messengers of subconscious information, signaling that an event has personal relevance to an individual, providing people with heuristic tools to make decisions and cope with all sheer number of possible options, which otherwise would be compelling[10]. Although high levels of emotional load can affect decision making, too little emotion can affect decision making too, therefore, the question that arises from this is whether intelligent machines can be “intelligent” without having emotions[11]. Emotions, perceptions and sensorimotor system are all part of our anchored cognition[12] that is grounded and corporally entangled with the world, which explains why the architecture extends beyond computation.

Affective computation can be employed by different technically mediated ways of affecting detection, as illustrated in Fig. 2. Over time researchers in neuroscience and psychology have used various psychophysiological measurement methods to study and recognize emotion (singularly or multimodally), the most used in research being:

- EEG (electroencephalography) that is an imaging technique that measures electrical activity generated by the brain through the scalp surface, using portable bio-sensors and amplification systems. This technique has the best resolution of response over time, up to ms. EEG assesses brain activity providing clues about the subject's cognitive engagement or overload, approach/avoidance, can provide insight about user’s emotions or motivation, stress or relaxation, positive/negative emotion like frontal-alpha asymmetry, the subconscious mechanisms behind decisions like ERPs, cognitive load from theta/beta ratio and so on. A new generation of non-invasive and non-clinical EEG systems has proliferated on the market in the last decade offering relatively comparable solutions to professional and laboratory-based systems at affordable prices like Emotiv EPOC X, Emotiv EPOC+, Emotiv INSIGHT, Unicorn Brain Interface, OpenBCI, NeuroSky MindWave, Imec EEG, NeuroFocus Mynd, Neurokeeper, Wearable Sensing etc.

[8] Alexander 1964
[9] Damasio 1991,1994,1996, Bechara et al. 1997, Elster 1996, 1998, Pfister and Böhm 2008
[10] Damasio and Verweij 2019
[11] Minsky 1985
[12] Barsalou 2008

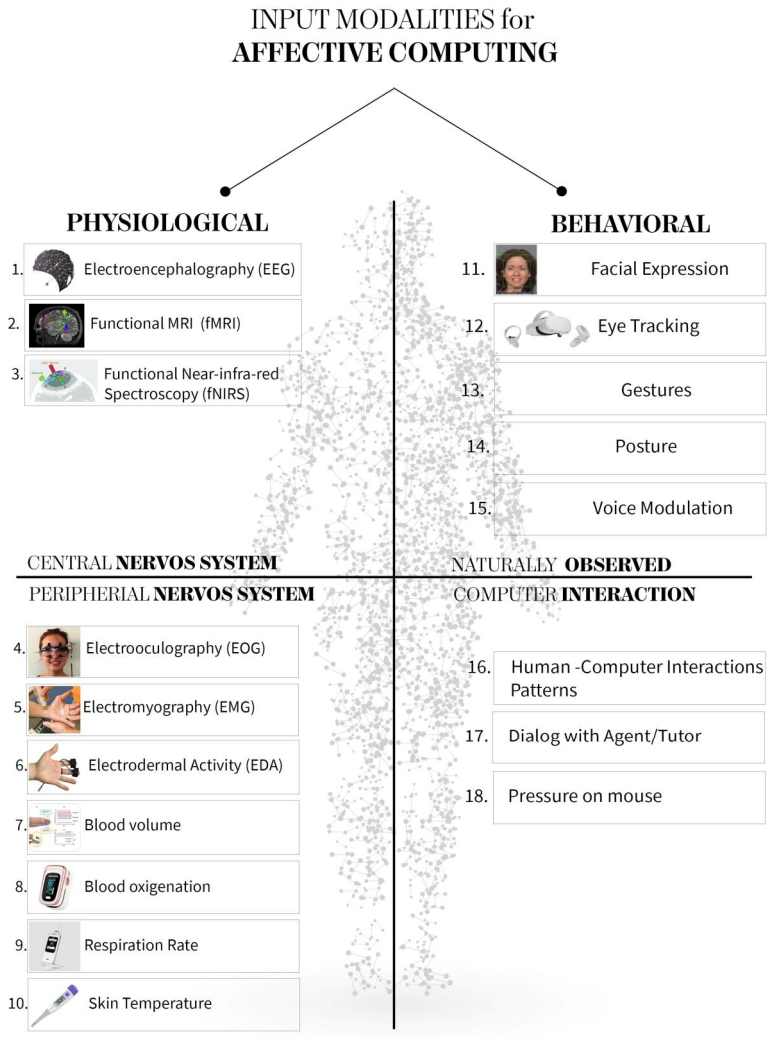

Fig. 2. Illustrative map of ways to capture emotions and affective states through affective computation.

- Galvanic Skin Response (GSR) and Electrodermal Activity (EDA) operates on the basis of a subconscious activation mechanism, measuring the sweating that occurs at a high stimulus arousal.
- fMRI (functional Magnetic Resonance Imaging) is based on the principle of magnetic fields and radio waves, providing a very good 3D spatial resolution view of the dynamics of neuronal activations in the brain.
- Respiration Rate ECG / EMG - measures depth, speed and regularity of breathing, heart rate (HR) and reflects emotional arousal in response to a stressful situation but cannot identify the positive or negative valence of a stimulus.
- Eye-tracking provides real-time metrics, related to gaze mapping and gaze position/points, gaze dilation or gaze fixation assessing engagement, motivation or the areas of interest for the subject.

3.2. Literature Review

Neurourbanism can be employed from two directions: (1) the first has to do with understanding how urban artefacts and urban life affects our human existence and our mental and psycho-emotional health and (2) the second refers to how should we design our cities and urban interventions to go beyond effective computation by integrating human values and the ineffable meanings of architecture into the design process.[13] Therefore, the first uses affective computation in understanding existing phenomena while the second approach is operational and proactive, using affective computation directly into the design process.

(1) The first dimension has been addressed in numerous studies that mirror the productive intersection between neuroscience, architecture and urbanism while assessing the impact of architectural styles on people[14], of lighting[15] or color [16] or the impact of urban façade quality on affective feelings[17]. Ruixuan used multimodal devices to rate the emotional data of urban users as indices to evaluate the overall quality of an urban space[18], regarding emotion as indicator of the design quality. Affective computing has been used for assessing the quality or urban lived experience like measuring the people's emotional bounds with places in the city [19] by measuring the real-time neural responses to different urban places. A campaign called ,,Affective City''[20] led by Federico De Matteis initiated the premise that cities are not made only of brick and stone but by affects, moods, atmospheres, as well as ineffable dimensions, that are sometimes deprived by urban planning strategies.

A subfield of study is neuroaesthetics that address the relation between form, proportions, height, materiality and emotion, several studies using a complex EEG headset with 128 electrodes while walking through architectural spaces to assess the impact of forms on human brain dynamics, reflecting non-architects' predilection for fluid, curved shapes over right-angled one[21]. Another study evaluated the impact of moving through the built environment on emotional and neurophysiological state[22] stressing the association between subjective evaluation and space qualities. Affective computing has been used also in environmental psychology to study the neuroscience of people-environment interaction. For instance, scientific evaluations based on EEG measurements confirmed that green spaces in cities have sanative and restorative values[23], based on a biophilia component of our human nature. Similarly, studies analyzed the preference for nature in urbanized societies[24], and the therapeutic values

[13] Küçük 2022
[14] Choo et al. 2017
[15] Shin et al. 2014
[16] Küller et al. 2009
[17] Hollander et al. 2020
[18] Li 2022
[19] Stals 2014
[20] Matteis 2021
[21] Banaei et al. 2017
[22] Maghool et al 2020
[23] Aspinall et al. 2015
[24] van den Berg et al. 2007

coming from the contact with nature or personal garden[25] as urbanicity is considered to challenge the pursuit of sustainability, by altering the psychological restoration desire that humans have towards the contact with nature.

(2) The second dimension employed affective computing constructively and operationally into design thinking since the concept phase Through BCI correlated with VR, two studies led by Barsan-Pipu[26] proposed a procedural immersion in a VR environment through which geometric shapes in an urban context were generated and modelled by thinking. In the Mindsculpt study[27] the authors used a non-invasive Brain–Computer Interface based on a supervised machine-learning approach that identifies patterns in neural activation and enable designers to create a wide range of hybrid geometries in Grasshopper in real-time, only by thinking about those geometries. This design workflow is supposed to shorten the latency between ideation and implementation compared to traditional CAD tools based on mouse and-keyboard paradigms. Similarly, a Japanese team at Osaka University[28] proposed a method based on functional magnetic resonance imaging (fMRI) and diffusion model (LDM) that suggests it might reconstruct high-resolution images with high fidelity, based on deciphering patterns of human brain activity activation using and artificial neural networks trained on an image-based model. The authors suggest that they would be able to reconstruct images only through the subject's mental visualization of them, thus establishing a link between the human visual system, mental imagery and computer vision.

As far as I am concerned, I have been involved in a study[29] that have used affective computing to discretize a solution space from a generative workflow in Grasshopper, using the ERP ("Event-Related Potentials") component from EEG that have access to unconscious decisions, based on a mechanism by which the brain generate specific electrical potentials when the subject is exposed to a visual or any stimulus that is relevant to him. Based on this component, the P300 spike reflected the changes in the EEG that occur within the first 300ms of stimulus onset, providing important clues about the subject's affective participation, preferences and decision while making choices and expressing preferences, that have been reinserted into the generative process. As illustrated in Fig.5 and Fig. 6 that illustrate the proposed workflow, the valuable human feedback has been fed back into the generative process in order to evolve the process in compliance with the user's preferences.

4. Discussions and conclusions

The aim of this study was to introduce affective computation as a tool that could be employed in generative urban design workflows in architecture and urbanism, both in retrospective studies as in operational ways of working. These research initiatives revealed the growing interest that designers and practitioners have in neuroarchitecture /

[25] Olszewska-Guizzo et al. 2022
[26] Barsan-Pipu, 2019, 2020
[27] Yang, Q et al. 2023
[28] Takagi and Nishimoto 2023
[29] Robu-Movilă and Țenea 2023

neurourbanism as a new tool for exploration, creation and understanding their design impact on mental and psycho-emotional health. In the evolving field of generative design, affective computing systems can create that "direct manipulation"[30] link, which is the necessary synchronicity that reduce the gulf of execution and gulf evaluation, because, "the closer we get to speaking directly to the machine, the more freedom of expression we have"[31].

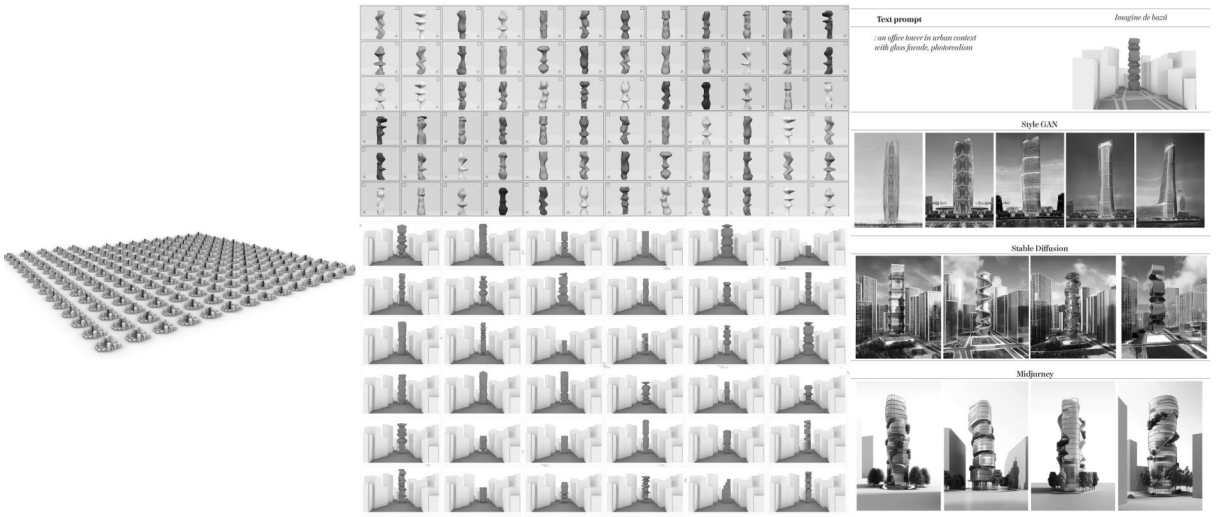

Fig. 5. The paradigm used in this study[32] used a generative software for a design task in an urban context, in parallel with the simultaneous use of an EEG-based affective computing system to control the generative phases while embedding the human feedback.

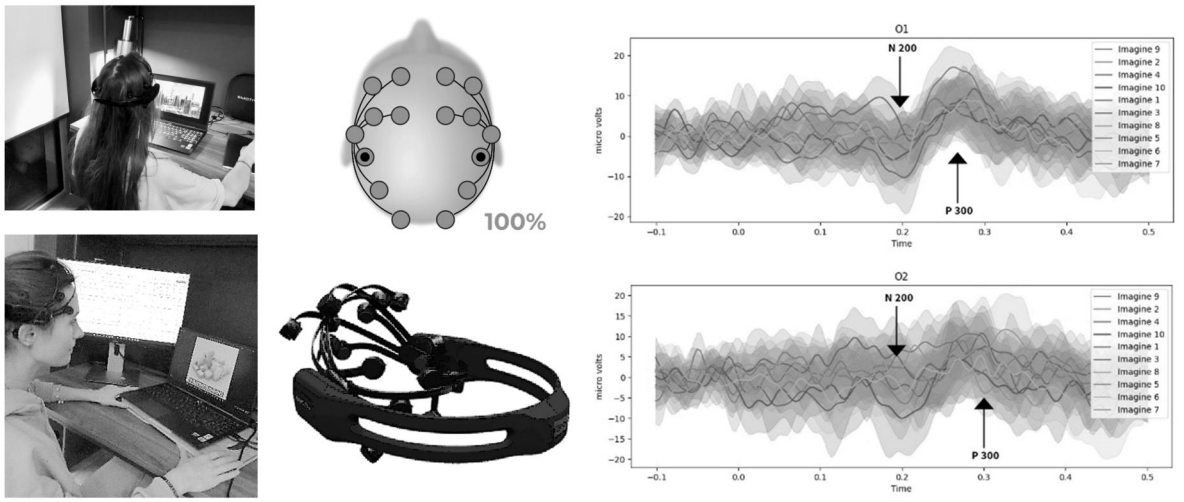

Fig. 4. Robu-Movilă and Țenea 's study have embedded affective computation to inform the generative effective computation process. The study used a commercial wireless EEG headset, called Emotiv EPOC X with 14 electrodes.

[30] Hutchins et.al 1985
[31] Coates and Derix, 2014: 37
[32] Robu-Movilă and Țenea 2023

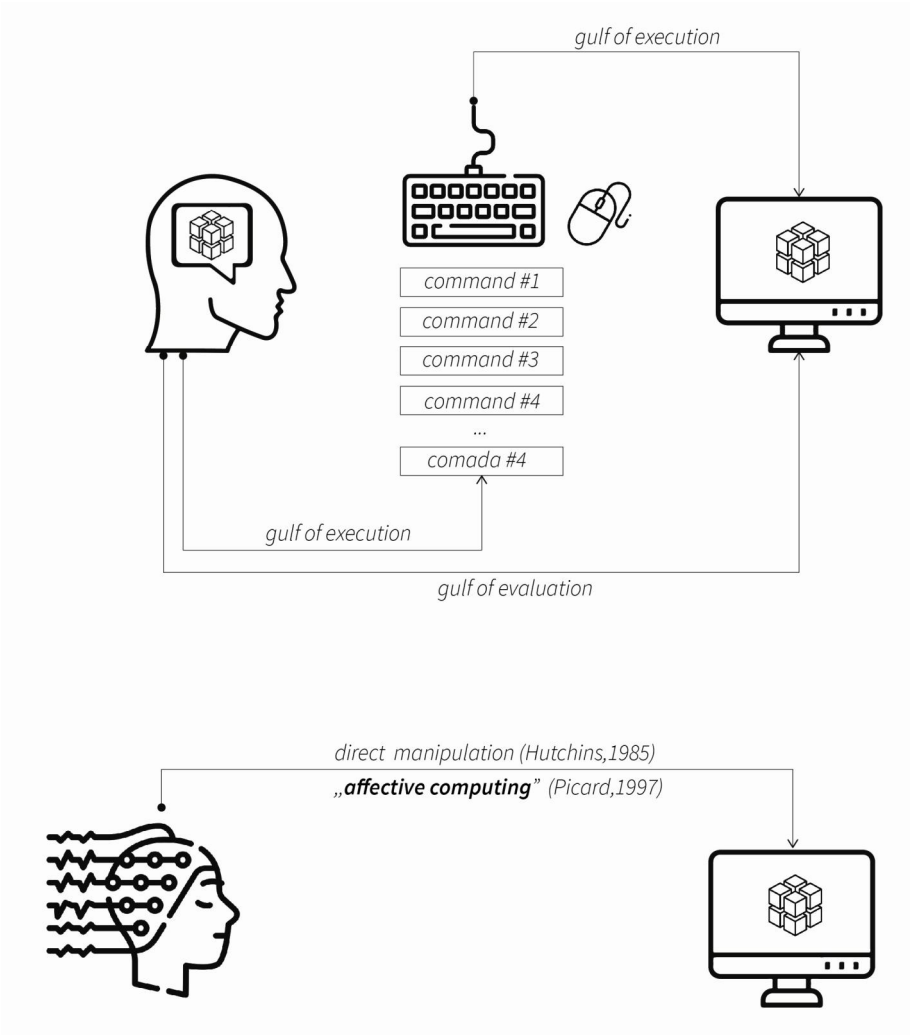

Fig. 5. Illustrating the traditional CAD loop vs. Affective Computing loop that reduces the gulf of execution and gulf of evaluation.

Like any other tool man creates for himself, technology is a Pharmakon and it is not good or bad in itself, but depends on how it is used. In order to find their own balance in mediating qualitative and quantitative, subjective and objective dimensions in evaluation, creators need to develop and customize their own strategies for evaluating/exploring the solution space, as the quality of solutions depends equally on both the generative and curatorial stages. This new context shifts the creator's attention from the direct design of form to the design of the formative structure and then to the critique and evaluation of their products. Architects are thus invited to become the creators of their own design tools because creativity is not only the search for new ideas but also the search for new tools through which these ideas can emerge.

The field of urbanism requires a level of complexity, depth and holistically approach that operates on the basis of big data but at the same time transcends effective computation. Many ineffable and incomputable dimensions of the architectural problem can only be fully perceived by a human cognition grounded in emotions and human perceptions. Thus, in the context of the generative practices that are taking over architectural and urban design, this

study situates itself in a humanistic restorative attitude concerned with keeping the level of control and decision in the sphere of the human factor, opening up future research direction, marking the transition from effective computing to affective computing.

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