Generative design principles and algorithmic thinking in architectural plan variations: human to machine approach

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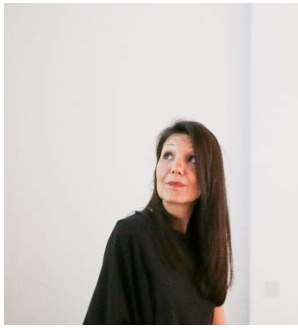

Abstract

The design process based on analogue architectural plan variations has been analysed in order to determine generative principles for its automation. It has been presumed that the limitations of the current artificial plan generator models could be mastered and overcome by establishing a closer relationship between the natural design process and the artificial one. Since it has been claimed that artificial models are still incapable of having real-person insight and consequently completely autonomously and critically present and decide upon high-quality architectural design proposals in regard to presented spatial tasks, no matter the number of examples which they have been trained on, the author aimed to document and deconstruct her own design process so as to determine the main reasons based on which human-controlled processes deliver better results in certain aspects when compared to their artificial (AI) counterparts, as well as how they can be measured, parametrized, and transferred into the algorithmic patterns. Some aesthetic aspects of both approaches will also be examined.

The case study has been chosen from the author's practice. Simple in terms of the programmatic requirements and additionally highly constrained by urban locational parameters considering formal boundaries, this case appeared to be appropriate for examining possibilities of internal morphing and variation based on values defined by the architect herself from both professional and critical perspectives while also following the standard contextual parameters. The study of the design process grounded on architectural plan variability, versioning, and optimization, had a specific focus on decision-making during these operations. Having been of the key importance for determining protocols for the contrasted artificial behavior, the act of decision-making and architectural design intentions have been taken for central concerns within the debate on differences in design performance of humans and machines.

Design options have been documented in an elaborate map-diagram. The applied model utilized the branching logic of variations alongside main arguments that directed their course of development. Through such representational and analytical forms, the complete evolutive footprint of the investigated design and different architectural scenarios have been recorded within a common scene or an image, following dynamic changes and adaptations to the bounding conditions and design parameters toward the final solution that best responds to all of them and to the architect's design intentions. The main objective of the procedure, which can be situated in the field of algorithmic thinking, has been to convert this map into the set of instructions for an artificial architectural plan generator, or, in other words, to determine possible generative formulas in the recorded design process pattern that can properly address spatially expressed programmatic aspects besides the formal and structural features that have up to date taken the dominant position in similar kinds of research.

Keywords: generative design, architectural design, design process, mapping, diagramming, automation, variations, human-machine relations, algorithmic thinking and architecture

1. Introduction

As it has been indicated in the abstract, the presented investigation addresses the problem of the analytical framework for main formative parameters, values and standards, creative inputs and decision-making that all direct the course of design's development within the architectural design process. The analysis of a process marked by variation places the emphasis on extensive transformations of possible design solutions during the course of the project's research phase and proposals' optimization. Behind the aim to document and deconstruct all the elements involved in a design process and clarify dynamic and frequently unfathomable relations between them, there is an aim, firstly to better understand human constructive and inferring cognitive processes, secondly to compare their logic and algorithmic regularity and irregularity to the existing artificial modalities and behaviour, and lastly apply it in new automated ways in order to test the possible effect and successfulness in terms of quality of architectural designs. Artificial intelligence, having been perceived "as a set of technologies that externalize certain rational and logical qualities of human reasoning" [1], according to A. Bava hasn't addressed all important aspects. Besides the formal logic and the aim of new design methods based on computation in relation to it, those parameters that make architecture "a habitat-making practice" [1] haven't been completely elucidated. In that respect, generative principles and variations have been applied and tested on architectural plans, as well, all towards, once the aims of this effort have been achieved, the better integration between the structural and formal, and programmatic qualitative properties alongside other external features. In order to set the research standards and objectives beyond the pure style (e.g. such that has been claimed through the notion of *parametricism* [2] or asserted by the term *digital style* [3]) and formal-structural optimization, this study will try to add its findings to this other cluster of

inquiries through defined experiments and practitioner's reflections. To that end, having awareness of all precedents - from those regarded as founders of the traditional approaches to this issue in architectural history (e.g. Le Muet, Briseux Durand in [1], but also other architects and architectural theorists devoted to similar problems [4]), across the authors that pioneered or enabled the transition from traditional to digital approaches and modalities in both architecture and arts with specific perspectives in the field of generative design (Alexander, Wurman, Price, and Negroponte, in [5], Doxiadis [1], Molnar in [6], Soddu and Colabella [7], etc.), to those whose theoretical, critical and design research pertains to better understanding of consequences of intelligence, algorithmic and digital turns in architecture [8-10] and the most recent experimentations with neural networks and artificial intelligence in general [11-19] - the specific focus will be placed on interior morphing of the architectural space and programmatic variations within the architectural design process [1, 20, 21, etc.]. The existing publications on *variation* and *versioning* [22-24] have also been consulted, while some of the previously published personal studies [25-27] provided substantial knowledge of relevant references and design research methodologies, establishing thereby conditions for a move from theoretical reviewing to application in practice and experimentation along with original innovative contributions.

Having still been in the first research phase, this open and unfinished project and research attempt will be discussed in terms of its prospects and possible contribution to the existing set of similar investigations and experiments, all dealing with generative principles and algorithmic variation in architectural plan design. We will be looking for the regularities and irregularities in decision-making during the design process, the main difference between the human and machine capabilities and expressions, the required language of instruction, design protocols, and above all, for the algorithmic interpretation and a map of the analysed processes as a potential input for machine automation.

2. Human to machine/artificial Intelligence

The structure of the analogue design process and decision-making have been mapped and organized to enable easier transition or conversion of hereby documented procedures and out comes to the language of the machines. It has been presumed that through several analytical and refining iterations the material can be properly formatted to correspond to algorithmic machine logic. This relation – between the human and artificial inferring processes, or procedural instructions – has been subjected to scrutiny in the following paragraphs, suggesting in particular graphic ways of doing so.

2.1. Human logic – algorithmic form

By taking into consideration all design-informative and design-guiding parameters that might be constructing the conceptual lattice or framework, the analogue design conduct has been documented and catalogued including all its steps and development phases. The mapping method followed the logic of rhizomatic branching (Fig.1) implicating

openness of each temporary consolidated proposal or probable solution. The first map represents the free course of decisions made in terms of change in variant types, and it shows the attempt to simultaneously lead several parallel processes and variants' adjustments. The second map displays the post-antes ordering, rearrangement, and classification of all produced variants, whose footprint has also been represented through another 3d structure.

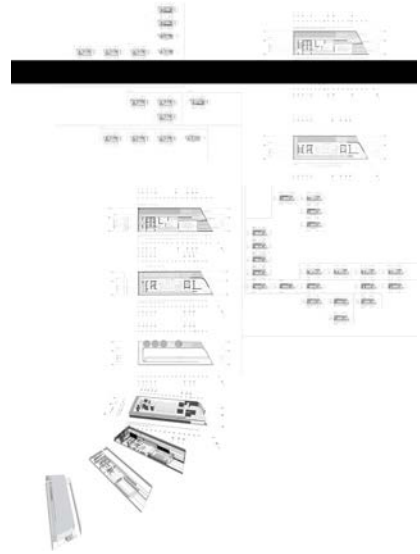

Figure 1.

The 3d model contains variants and their subvariants, along with graphic remarks on specific elements that have been subjected to transformation and representation of these through sequences (multiple phases of development between several kinds of solutions). The graphic intervention leaves spatial traces of branching and thus forms a connecting structure between the variants, solidifying in a certain way the relations made between design options and r efinements of each at the smaller interior scale (Fig.2).

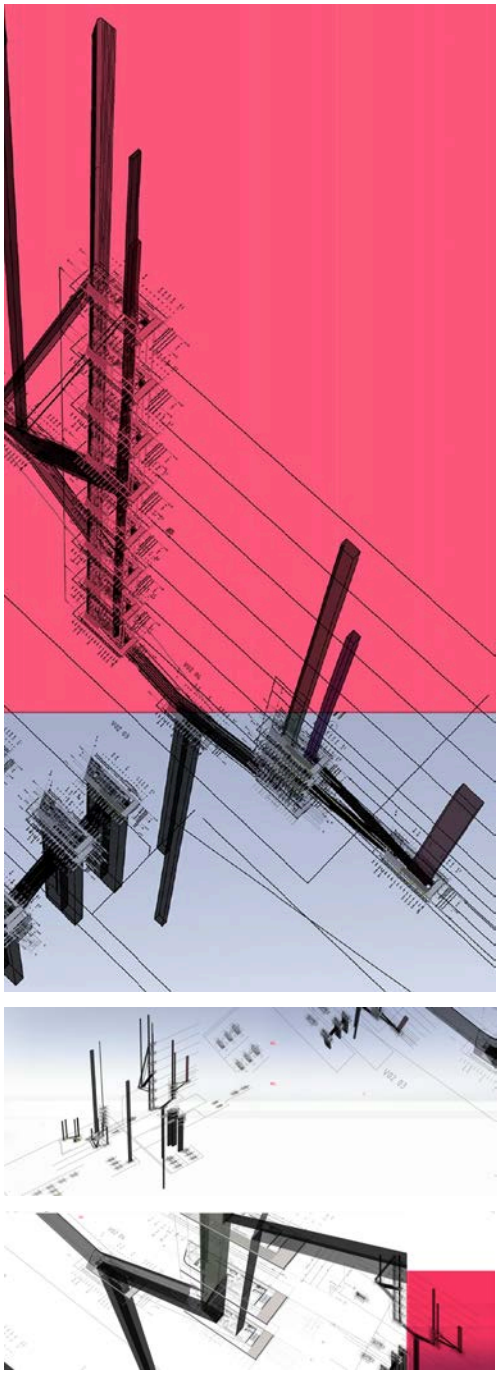

Figure 2.

2.2. Machine logic

In a continuation of the explained plan, several existing variation-based machine algorithms have been analysed in terms of their operation and l ogic behind the processes they perform. The successfulness of the conversion process rests on substantial knowledge of differences between human performance and behaviour and that of the machines, and nec essary adjustments. It has been as sumed that the former (human) performance is frequently non-linear, less predictable if left to individual conduct and w ithout the schedule, as well as possibly

inconsistent regarding the strict order and mathematical rigour of the organization phases depending on the course of research and unexpected occurrences. Being also relatively prone to errors and creative changes or interventions, human conduct has been considered as usually opposed to that of machines' clean and simple performance, more easily discerned in terms of the precision or numerical values of parameters by which it can be measured. But such a clean cut between the two cognitive modalities hasn't been the aim of the research and development programs and agendas, even though the distinction tests still trace differences similarly based on everything stated. Such does the Alan Turing's test from the 1950s, originally called *the imitation game*, or simply *the Turing test*.

A number of authors have been interested in the relationship between architecture and machines, considering them to include different forms and varieties of objects that qualify for machine designation (review in Ciric, 2020). Among them, computers and artificial sensory infrastructures have only been some of the most recent ones. Computing and artificial intelligence stand out as the most relevant of all machine technologies in the current moment and for the future of the development of the architectural discipline. As important research areas, the fields of architectural intelligence and design intelligence, architectural artificial intelligence, and neural architecture have finally been given contemporary critical and theoretical support and views [8-21]. In reference to such contribution, navigation within the field becomes much easier.

One particular instance regarding machine or algorithmic operation can be singled out to make a critical argument that will support the research proposed in this report. It has been asserted that machines, or algorithms mostly "learn how to see" - their performance and creative work are based on visual training and parameters they identify through this one sensory framework - but they "cannot learn how to plan" (Del Campo in [19] (1.02.15), or this and other higher cognitive performances still haven't been refined. The semantic or programmatic content and prediction (having been translated into the required language), combined with visual material, parameters and structure, represent important elements in planning or design. And if the *tame problem* (structural and formal optimization) has been resolved, the *wicked problem* (cultural aspects, multisensory observation and experience present in humans, as well their specific judgement, values, assessments, and practice), still hasn't been completely resolved (the tame-wicked problem relation as formulated by Del Campo in [19] and extended through personal elaboration and towards the posed research objectives).

3. Methodology

3.1 Algorithmic performance and human cognitive input

A discussion can be started over the way in which variations have been organized, structured, or selected, and if this pertains to the artistic or scientific approach, as well as if the authorship over the process could be claimed or it represents an external contribution. If the aim is to precisely determine the logic by which human thinking and decision-

making processes have been made, then the course of the variations' development and the rules that have shaped their final architectural design configurations (alongside parameters that introduced or demanded them), would have to be carefully and meticulously recorded with no space for errors or omissions regarding any possible detail. On the other hand, if following the artistic approach, the rigour of mathematical precision might be loosened and left to subjective decision-making apparatus or to "the last word of the artist" (Molnar in *section 003: On View: Hommage à Barbaud* [6]). Randomness or desultory behaviour has long been given great attention, as well as conscious and reasonable thinking and action, referring to the former as something not easily discernible in human behaviour. Both have been present in the design and other creative processes – at times predetermined, at times unpredictably occurring – but the consciousness of the approach taken and its explanation have always been of key significance for claims of original and specific contribution, whether of artistic or scientific origin.

We find similar questions in debates over authorship in cases where both human and machine interventions are present. There is a question of the degree of human involvement when working with algorithms, and that of particular phases in a design and creative process which human intervention is invested in. As it has been simplified "the difference between messing with a program and messing with its results, changing the algorithm or changing the outputs" is what actually makes a major difference and implies the exact place of the author's intervention within the design process, methodology, and use of available techniques. The noted problem appeared within the field of generative art, but the similar applies to any kind of work with algorithms, especially regarding the most recent conditions related to artificial intelligence and claims of its creative and decision-making autonomy. For these reasons, the process should be well understood and it is eventually the main component that can warrant the specificity of both method and the output, making results and the work itself original and unrepeatable. One more argument could be added in support of such claims and that places the process as design research method at the centre of the resolution of the situation which does not have any more such fixed rules (or prefixed codes) and procedures of transferring data into architecture [22] (p.7). In such conditions, the process is *invariant* in the formula of design as a complex dynamic system – the property of recognition and the carrier of the work's identity.

3.2 Variation

Variation, variety, and uniformity have been thoroughly investigated in architecture by several authors [22, 8, 10]. We also encounter a number of its modalities and related concepts throughout the architectural literature (versioning, evolution, and evolvability being only a few), and it can be stated that the concept cannot be investigated aside from such context and relational approach to its meaning and use. Yet, for the reasons of the text's economy, only some of them will be directly addressed.

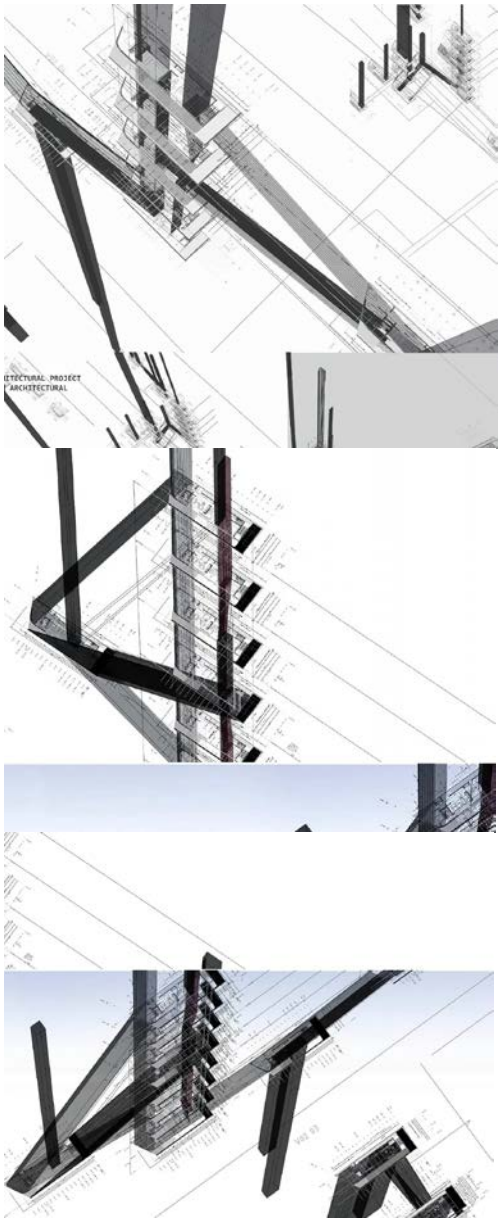

Figure 3

Variation represents a method that implies a design of not only *a single object* but of a *range of objects* [22] (p.7). Multiplicity and difference between all entities within the achieved range contained in this approach distinguish it from other design approaches. Further on, such multiplicity has its own specific rules that determine the method's identity within the domain of methods based on a larger number of probable outcomes and design solutions. It can be said that they provide necessary deviation or difference which ensures that the solution will be both optimum in terms of predefined requirements (quantified or qualitatively expressed; *extensive* or *intensive* [28] (p.12)) and original/unique in terms of the value it adds as compared to contributions of the existing referential examples and elements it draws certain qualities from. The feature of *irreversibility*, or the inability to return to previous less-adequate or discarded stages while undergoing the constant progressive transformation from moment to moment [29] (p.42), explains the kind of differentiation that marks variation as a specific kind or a class of transformation. Still, the kind of process that has been here described, can retain some of the iterations, return to them, and restart the process from it as another primitive or its evolved variant if the situation implies. Originating from the field of biology or biotechnology (genetics or evolutionary biology), variation and v ariability are likewise explained in their terms. Morphogenesis has frequently been referred to [28], but the variation that results not only in morphological but also systemic, operational, or anatomy-related transformations and specific outcomes (to use the analogy related to genetic evolvability) is what should be pr operly addressed when analysing the effects on architecture and ar chitectural design research. In terms of the relational complexity between all the variables and the invariants, as well as capacities that

their degree implies along with results of intricate mutual contingency, it must be said that variation might not always be so easily controlled or known in advance – it usually demands trials, but it also reveals what has been imagined or conceptualized, and can be expected. Its modelling and analysis, however, are at the core of this short study, seeking the best way to explain the variation concept through graphic architectural transformations.

Another feature that is related to digital variations is that almost automatically indicates the design not only of the final product but *the design itself* [22] (p.7) – the *design formula*, or the whole design process and the order of procedures alongside standard disciplinary laws of architectural design. To opt for such kind of a design process and its design indicates openness to external feedback and constant interaction and responsiveness to elements that might affect the process and its object. It also incorporates *perpetual feedback between the analysis, intervention, and exchange with the environment* [29] (p.41) in terms of the very architectural practice. From such perspectives, we can easily infer their references in the theory of complex adaptive systems, or dynamic systems [29] (pp.43-44), and recognize the transfer of such systemic thinking and relations to both architectural object design and the design of a design process.

Versioning appears as another *approach of architects and designers to technology that enables open, gestural, procedural design methodology based on recombinant geometry* [24] (p.132). Such open geometry permits influential (internal or environmental) factors of formal, programmatic, and structural shaping to "affect the system without losing the precision of numerical control or the ability to translate these geometries using available construction technology" [24] (p.132). The use of "vector-based information over pixel-based simulation and representation" has been advocated due to the fact that "vector-based information allows immediate results to be transformed and refined as the previous tests feed additional data through the framework of intentionality" [24] (p.132). Diverging from the traditional meaning, which implies copying of a type or original, versioning involves variations and evolutions not of one specific source or a prototype but a set of conditions organised in a menu or a nomenclature capable of being configured to address particular design criteria" [24] (p.133). This menu, containing the set of types and specific actions capable of evolving parametrically, represents the primary source of applied transformations - "…design decisions are based on an organisational strategy capable of responding to the change of variables so as to create a fluid movement" [24] (p.133). In such a process the relation between the original or reference and a copy or developed entity no longer exists since the first category has been replaced by the set of attributes of variable value that does not imply any specific object whatsoever, but elements of a certain type, along with possible actions, or capacities.

In terms of the change that variation brought into the sphere of manufacturing, the enabling of mass-customization has been one of the most important ones [11]. It has been claimed that the use of

digital tools to mass-produce variation moved the paradigm from overly criticized reproducibility of uniform and generic solutions towards the be-spoke design and enhanced diversity. This has enlarged the scope of possible answers to architectural design tasks while being much more capable of processing each requirement and constitutive parameter.

The weaknesses that have existed in explained approaches so far have been reflected in the fact that the major focus on variation and opt imization has been on formal and structural features, at least to the certain point in time when programmatic and architectural plan algorithms have been more publicly introduced. Programmatic generative algorithms, however, were still either of highly restrictive access or underdeveloped in terms of the all quality requirements expressed by many architects. In addition, some had as their creative goal “the approach to floor plan design solely from the perspective of optimization and w ithout regard for convention or constructability” [21] (also in [20]). The key formative parameters that comprise the system in programmatic terms – the architectural semantic programmatic content – was what has been missing in highly anesthetized and compelling visual results. Not even the narrative or textual inputs available and appl ied in image-generating algorithms were satisfactory in architectural terms and in terms of a problem of semantic content, and therefore necessary improvements have been required. The spatial configuration of the narrative and its technically literate representation, aside from the geometry and the atmosphere that could have been visually achieved and conveyed, is what should have been rethought and developed. For these reasons, while all aspects should work in concert, the registered underdeveloped issues have been subjected to scrutiny.

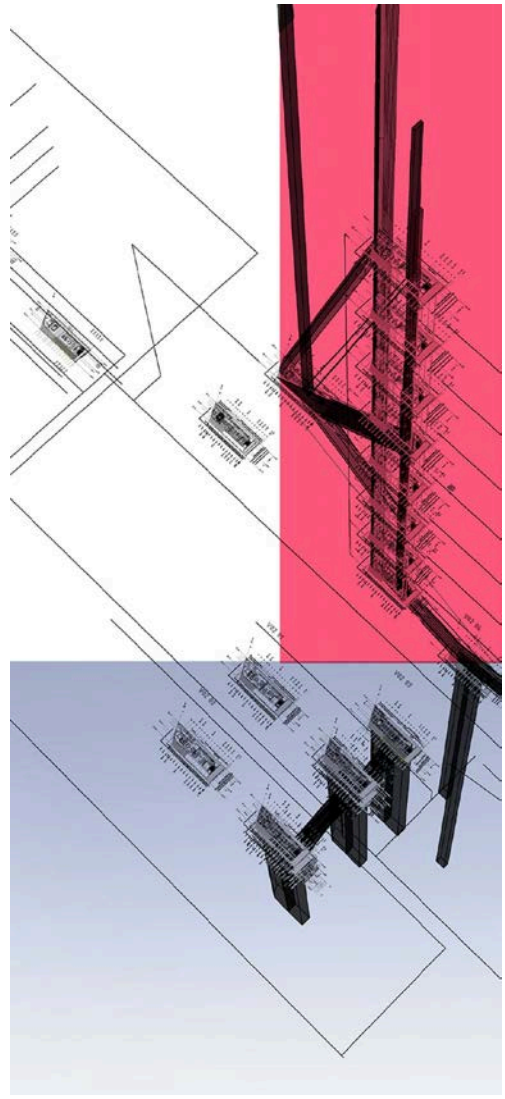

Figure 4

3.3. Process

Documentation of the design process and its thorough understanding provide

the basic material that could be used for the purposes of algorithmic translation. The elements have to be organized in the exact way they have been performed, with a careful notation of temporal determinants. The intervals and successive actions can be further subjected to optimization or different transformative strategies in regard to the design process and its representation, as well as formatted according to the requirements of machine performance as a second cycle of optimization, but at this stage, the correct mapping of the process and variants themselves has to be properly documented.

4. Conclusion

In a conclusion, it is important to assert that the text represents the collection of starting observations and thoughts on the topic. It has been expected that the chosen content will assist in shaping the next phase of the research proposal and in that respect either completely explain the actions accomplished so far, facilitate their understanding while situating them in a wider context of historical precedents, or open up new fields of research and new questions in order to complement and appropriately ground all objectives that have been aimed at. In addition to that, the position that has been taken by the author claims the important role of graphic material, as well, both in the deliverance of necessary proofs and as a confirmation of followed methodology and a narrative of a design process. The illustrations, even though not completely finished, represent a direct reflection of each step of the process analysis and its conversion to the algorithmic mode.

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