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Review of the Doctoral Thesis "Artificial Life Approach to Interactive Architecture – Metamaterial Kinetic Environments at the Edge of Chaos" by Vasilija Abramovic

To Whom It May Concern,

Please find my brief review of the PhD thesis below.

The "Introduction" chapter analyzes the concept of architectural agency, i.e. an architecture who possesses or demonstrates a certain autonomy to actively create surprising and aesthetic experiences towards the users of its space. In this chapter, it becomes clear that the author critiques the common approach "smart" and "intelligent" spaces, which are generated from top-down and one-directional types of interaction. Instead, the thesis embraces more unpredictable and complex types of interactions, which therefore are perhaps also more architectural in nature. It also becomes obvious that it is expected that more unpredictable and complex behaviors could be interpreted as possessing some degree of intelligence. Starting from this premise, the thesis focuses on three questions (abbreviated):

- How can the field of artificial life contribute to interactive architecture?
- How can metamaterial structures create transformable architecture?
- What types of actuation are suitable for animating architectural structures in metamaterials?

These research questions are investigated by way of typically architectural design research methods, among which: designerly exploration, theoretical postulation, physical prototyping, collaborative making, educational discourse, cross-disciplinary development, competitive review for financial support, elaborate software programming, in-the-wild and human-scale intervention, (international) public exhibition, rigorous evaluation, and generalization through peer-reviewed scholarly publications.

The chapter "Intelligent Kinetics" provides the fundamental and more theoretical arguments of the thesis, as it explores the relationships between architecture and "machines". It commences with providing a succinct overview of kinetic architecture – which excludes more emergent forms of interactivity. Then it dives deeper into the underpinnings of the domain of artificial intelligence, and the underlying shortcomings of modern technology to truly simulate or create true forms of intelligence. Notably, the thesis situates intelligence as either a symbolic and computational type of logic, or a type of adaptation that is embodied and can be perceived through behaviors that are anticipative and proactive towards human input. Overall, this chapter demonstrates a firm grasp of relevant theories from a very wide range of domains and practices. Although the theoretical discourse seems somewhat

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unstructured and haphazard in nature, obvious parallels could be made with design theory, which similarly consists of a rich and wide diversity of parallel discussions about phenomena that cannot be readily mapped and understood because they themselves are grounded in the process rather than the outcome. On the other side, some type of synthesis, even when designerly in nature, of the discussed historical approaches and their resulting claims could perhaps have brought more weight and pronunciation to the main argumentation of the thesis?

The chapter “Softer Kinetics” provides the groundwork for the actual materialization of the design argumentation, as it focuses on a wide range of physical manifestations of actuation, such as in terms of programmable materials, enabled by current advances in (soft) robotics and metamaterial systems. This chapter is closely grounded in the designerly act of experimentation and making, as the author reveals various conceptual as well as empirical considerations while actively searching for suitable actuation technologies for her own development efforts. In effect, I would argue this kind of reasoning could even be further crystalized in design practice, such as to more forcefully establish that the argumentation could *only* be established through a laborious yet insightful process of research through design. The chapter provides ample examples of soft types of interactive architecture as well as the current developments in soft robotics, i.e. robotics that purposefully exploit the elasticity of materials to actuate. I find the experiments shown and the reflective rationales that accompany Figures 50-53, particularly intriguing and valuable, as these forms of design documentation and annotation will form empirical and generalizable evidence that inform future generations of interactive architecture designers. Perhaps this chapter could have included more generalizable findings from these experiments – fundamentally different yet still relatable to how scientists like dr. Overvelde publish scientific findings that propel many innovations in a wide spectrum of application domains. In that sense, I fully appreciate the more detailed descriptions of the design explorations that occurred during the workshops, which as revealing as they are, still “hide” the tremendous amount of conceptual, organizational and experimental efforts that drove them. While essentially designerly in nature, this chapter demonstrates the rich ability of design workshops to experiment with cutting-edge advances, and analyse and learn from its most promising results at low cost. While these results are mainly technical in nature, describing aspects of robustness, functionality and predictability, they also include various aesthetical considerations, such as towards enticing more emotionally suggestive gestures. As such, this chapter provides a compelling view “behind the screens”, including the rigor and persistence behind the many experiments and explorations that form the basis of the research.

The chapter “Edge of Chaos” provides a detailed description of the three incarnations of the installation with the same name. “Edge of Chaos” is a tremendous and incredible piece of interactive architecture, that reaches well beyond the current state-of-the-art in its field and beyond. It shows a level of mastery in many different disciplines, practices and procedures that must be deployed when implementing a real working interactive installation. It must be commended that its financial funding was awarded in a very competitive setting. And it must be commended how its physical manifestation demonstrates the highest level of design, technical and interaction quality. Overall, this chapter is also compelling in terms of how the rather idealistic claims and goals of reaching a certain emergent, and perhaps intelligent, type of architectural interactivity can indeed be materialized in physical form. Naturally, these ambitions become rapidly inhibited by diverse practical, i.e. physical, financial as well as digital, thresholds. Some of these thresholds seem to have become particularly obvious in the stochastic approach of the programmed behaviors that depend on a relatively low-level interpretation of human activity, i.e. proximity.

As a researcher who often evaluates in-the-wild installations in public settings, most of the human behaviors that were observed in this research are not that surprising. Indeed, humans expect direct and immediate responses when being exposed to interactive technology. Humans seem not well acquainted with alternative forms of forms of interactivity that reach beyond what they have learned through life experience, mostly gathered via social interactions with other living beings. At the same

time, humans can become sufficiently motivated to actively explore new types of interactivity as long as the exploration process is sufficiently rewarding and revealing – i.e. when they can "learn", and particularly understand aspects of intention. Intention being a concept that inherently requires higher levels of mental states, and which in itself is influenced by experiences, beliefs, and desires. In this sense, I was hoping to understand more what visitors understood and particularly about what people reflected on, as a result of experiencing with this interactive architecture. I belief this knowledge might have the chance to strengthen most of the claims of this research, particularly when "intelligence" is interpreted as an intrinsic quality that is experienced and provokes thought and emotion – rather than a quality that implies intention and foresight.

The conclusions within this section are intriguing, as it aggregates various arguments towards an "ideal model" of how architectural interactivity should be experienced, i.e. an experience that balances both predictable and unpredictable behavior. Of course, mentioning an "ideal" case in an academic context is brave in itself, as each ideal case can only be confined by a certain context of expectations. In essence, I suggest that this outcome is almost identical to the historical intentions that were mentioned in the first chapters of this thesis – that the traditional notion of intelligence is hard to impossible to simulate though algorithmic means, let alone in a physical manifestation. I also suggest that the contributions of this research reach further than what the thesis claims, i.e. the development of a custom CA algorithm, implemented through multi-stable, metamaterial geometries. In essence, whereas most, and perhaps all, historical examples have created prototypes as down-scaled models, "Edge of Chaos" has dared to create a fully spatial, and therefore architectural, manifestation of architectural interactivity and/or intelligence in its own right.

The "Conclusions" section provides the concrete answers to the three research questions. While all the provided answers are true and persuasive, the most useful answers rightfully point towards a future of more tactile and playful experiences of robots, and by extension of space. I also consider it unique how the thesis brings forward the often-neglected role of human visceral experience and emotion, as they are provoked by purely architectural aspects as movement, illumination, and so on. As the claims regarding the actual generation and/or interpretation of intelligent behavior might gain more gravitas by relating different aspects more to the fundamental constitution of "intelligence", I find this thesis the most compelling when it argues from an architectural point of view.

This doctoral thesis is situated at, and reaches well beyond, the current state-of-the-art in the domain of interactive architecture. It pushes several groundbreaking arguments towards spatial interactivity, and proposes several theoretical, physical and algorithmic technologies to make it possible. It even combines theory and practice, by developing and implementing a life-sized working spatial intervention, and showing it to the public at large. This research also clearly demonstrates the extreme challenges in researching or educating aspects of interactive architecture, as considerable time and effort must be devoted in both conceptual as technical aspects, and in both developing the physical actuation as its underlying interactive "intelligence".

Overall, it should be obvious from my review I found this doctoral thesis very impressive and insightful. It shows a degree of mastery in all aspects that relate to state-of-the-art architectural research, while pushing forward several contributions within and across several rapidly emerging scientific domains. I therefore recommend the doctoral committee to reward Vasilija Abramovic with the doctoral title.

Naturally, I would like to ask Vasilija Abramovic different questions about her research, such as:

- Does the essence of interactive architecture – in contrast to the more traditional notions of smart or intelligent spaces, buildings and cities, for instance - lie in its ability to actively convey a degree of unpredictability and complexity? In other words, does the architectural qualities of

interactive architecture rely on unpredictability and complexity? Or more succinctly, is 'good' architecture in essence unpredictable?

- Which qualities that are generated by the proposed bottom-up approach cannot be generated by a top-down approach? Similarly, what are the qualities that could only be created through the use of the "artificial life" approach rather than an "artificial intelligence" approach?
- If these differences exist, then what does this mean for interactive architecture? Does it mean 'good' interactive architecture cannot be generated through a top-down or artificial intelligent approach?
- What are the advantages of artistic, playful and speculative approaches (p.15) that more established methods of scientific research or experimentation are not able to capture?
- Are you aware of certain fundamental knowledge that could only have been discovered through deploying the proto-architectural methodology – versus a more traditional or scientific approach? For instance, the thesis mainly describes the knowledge from the workshops as technical insights and conceptual innovations (e.g. domains of application). But was there fundamental knowledge that could 'only' have been discovered through the process of "making" and/or synchronous collaboration of multiple people?

Finally, I wish to repeat that I highly appreciate the PhD thesis of Vasilija Abramovic. Please know reviewing this PhD was an enjoyable and educational experience, which proves the exceptional proficiency, enthusiasm and expertise of the PhD student. I would like to advise her to continue to pursue her architectural endeavors in interactivity in the future, while knowing that there are at least two very valuable avenues for continuation: 1) to further explore and experiment with innovative forms of actuation and animation that are able to convey intelligent intentions and/or provoke emotional or reflective human responses; and 2) in further analyzing and generalizing the empirical data that was collected in the three manifestations of "Edge of Chaos" or beyond. I wish her well in all her future endeavors!

If you have any questions or remarks in this regard, please do not hesitate to contact me.

With kind regards,

prof. dr. ir. arch. Andrew Vande Moere