

# Kinetic Digitally-Driven Architectural Structures as ‘Marginal’ Objects - a Conceptual Framework

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## Introduction

Although kinetic architectural elements and structures have existed since antiquity and in different cultures,<sup>1</sup> they were more widely recognised and developed throughout the second half of the twentieth century due to the rapid changes in the western way of life.<sup>2</sup> In particular, from the Second World War until recently, transformable lightweight structures and deployable, mobile or portable environments, built by architects and firms such as Buckminster Fuller, Hoberman associates and FTL Happold to name but a few,<sup>3</sup> have sought to resolve economical, practical or ecological problems<sup>4</sup> of the construction industry, and respond to issues of survival or nomadic dwelling.<sup>5</sup> On the other hand, in the 50s and 60s, the development of computers and cybernetic control systems, inspired the design of more experimental transformable environments - such as Price's *Fun Palace*, Archigram's *Living 1990* installation and Constant's *New Babylon* - able to respond to change and individuality. Such visionary projects would not result in realised architecture, yet they were precursors of the so-called 'intelligent environments', the applications that emerged, since the beginning of the 90s, from the ambient intelligence vision, i.e. the distribution of ubiquitous digital technologies in physical space.<sup>6</sup>

Lately, the merging of kinetic architectural systems and digital technologies has produced digitally-driven kinetic architecture, structures, environments or building components able to modify the shape, size or position of their physical form using embed-

ded computational technology. This is a vision for technologically-enhanced architecture with 'naturalised' capacities - that is, sensing and actuation abilities, intelligence, motion and pro-active behaviour. Although such applications are rather limited and exist mostly in experimental and academic contexts, there is indeed a growing interest in the potential development of digitally-driven kinetic architecture. As Michael Fox of the Kinetic Design Group argues:

*Architects need to design with an understanding of the current capabilities of embedded computation that have attained sufficient maturity to act as independent subsystems that can be beneficially incorporated into kinetic design.*<sup>7</sup>

It is widely accepted that the primary goal of digitally-driven kinetic structures is to provide flexible adaptation to constantly changing needs, desires,<sup>8</sup> and environmental conditions (optimisation and control).<sup>9</sup> A part of the online text in the *Muscle Room* (a kinetic space by the Hyperbody Research Group) website reads:

*The Muscle Room envisions a concept where the user can alter his surroundings to suit his every need. When the room is entered it is completely empty. One big, open space. By interacting with the room the user can get a different layout or appearance.*<sup>10</sup>

Similarly, Michael Fox and Bryant Yeh explain:

*This research develops a concept for the application of smart environments to kinetic systems in architecture. The goal is to create flexible and responsively adaptable architectural spaces and objects... Intelligent kinetic systems are an approach for utilising technology to create architecture that addresses today's dynamic, flexible and constantly changing activities.*<sup>11</sup>

Konstantinos Oungrinis, in his research on kinetic architecture, proposed a digitally-driven architectural environment - the 'Sensponder' - which optimises adaptability by integrating all the different operational capacities of kinetic systems in architecture. His 'Sensponder' architecture would be able to adapt to changing functional, environmental and structural demands by acquiring information from all available sources (through various sensors), and respond by performing local actions based on optimised decisions.<sup>12</sup>

Yet, behind the obvious functional reasons for designing and constructing such structures, there is, in my view, another equally important cultural aspect that drives these designs. In this paper I will show that the motivation lies in a culturally-defined human tendency to challenge the boundaries between the animate and the inanimate or the human and machine. Thus, I aspire to anticipate a conceptual framework through which to reflect on their value. In the following I am looking into the way digitally-driven projects are conceived. As I will show, they are not only understood as functional objects but also as 'social beings'.

### **Digitally-driven kinetic structures: The E-motive House and the Muscle Tower II**

Some of the most representative digitally-driven kinetic structures are those of the Hyperbody Research Group and its director Kas Oosterhuis at TUDelft as well as Oosterhuis' firm ONL.<sup>13</sup> Their projects Muscle Tower I and II, E-motive House, Muscle NSA, Muscle Body, Muscle Reconfigured

and Trans\_PORTS 2001, combine kinetic-mechanical systems with computer technologies. Other similar projects are those of the Design Research Lab at the Architectural Association exploring the potential of kinetic responsive structures in the urban context.<sup>14</sup> Maybe the most well-developed project in terms of feasibility, technical resolution and commercial potential is dECOi's Aegis Hyposurface, a moving responsive surface, a kind of kinetic information display, actuated by pistons. Although it is not an architectural space, it can be incorporated in architectural structures or urban areas to provide informational and advertising services as well as interactive sensory experiences.<sup>15</sup> Due to the limited scope of this paper I cannot examine the above examples one by one. Two of them, though, will be examined more closely here because they are highly illustrative of my argument: the E-motive House and the Muscle Tower II. Yet, the ideas discussed below apply to most of these projects.

Conceived as an information network node, the E-motive House [fig.1], designed by Oosterhuis and his ONL team, is a changeable structure (constructed by a complex combination of pneumatic and hydraulic cylinders, wooden beams and air chambers) able, in theory, to respond to the actions, needs and desires of both local and internet users. It will function in different ways: either as a space for work, food or sleep, thus realising something that would have seemed unconceivable in the past.<sup>16</sup>

However, besides the capacity to respond to changes of function, the description of the house includes a few other important characteristics. For Oosterhuis, the E-motive House is a 'being' with social skills and emotional states able to cooperate, learn, communicate and participate in social interactions with its residents. Because of the complex interactions between all the factors that affect its performance, the behaviour of the house will be unanticipated and seemingly unpredictable,

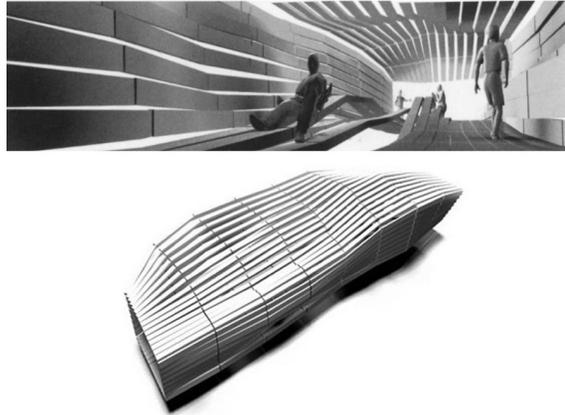


Fig. 1



Fig. 2

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Fig. 1: E-Motive House, 2002

Fig. 2: Muscle Tower II, 2004

giving the impression of an emotional entity. It will incorporate intelligence, which will allow it, through interaction with people, to gradually develop a character and express a predefined series of psychological states (e.g. entertainment or educational state), challenging the residents to adapt to such an environment.<sup>17</sup>

Apart from functional flexibility, a number of other issues is mentioned with regard to the E-motive House here: learning, intelligence, pro-activity and intentional behaviour as well as the capacity for social interaction and cooperation for the production of experiences. Describing the E-motive House Oosterhuis mentions the possible objects of discussion between its residents:

*What mood is your house in today? Isn't it feeling well? Why is your house behaving so strangely lately? Perhaps it needs to see a doctor? Did you care enough for your house? Is your house boring you? Are you neglecting your house? Is your house suggesting that you might be boring in the way you perceive it? These would be the sort of social conversation topics between the inhabitants of e-motive houses.*<sup>18</sup>

It seems that Oosterhuis attempts to attribute qualities beyond functional flexibility to the structure; he talks about it as if it is not just a soulless and inert environment but a 'living organism', a social, emotional being able to convey mood, a need for affection and communication. This attitude characterises the way he understands his other projects as well, for example the *Muscle Reconfigured* project:

*An intuitive interaction, opinionated towards seamless information exchange is initiated through the research experiment, hence transforming everyday utilitarian space into an inter-activating responsive organism.*<sup>19</sup>

It is important to note here that the physical characteristics of these structures (form and motion) should play a role in such attributions. For instance, Oosterhuis' Muscle Tower II project, developed and constructed by the Hyperbody, 'looks' very much like a 'living organism' [fig.2]. A flexible frame consisting of a network of pneumatic actuator cylinders can stretch or contract, thus making the whole structure bend, swivel or twist in different points along its height.<sup>20</sup>

The range of movements that it can perform is limited to left-right and front-back shifts responding to the presence of visitors detected by its proximity sensors. A visitor's presence will make it bend towards his or her direction for 30 seconds and then continue to perform its pre-programmed movements.<sup>21</sup> Video demonstrations of the structure in action, which can be found on its web site,<sup>22</sup> show that, although the set-up is simple and its behaviour is based on on-off commands, the structure appears to react to human movements with unpredictable position and posture changes. Here, the actual experience of the moving structure - its sudden shifts of direction and orientation along with its humanoid yet abstract form - may perceptually convey the sense of life.

It is true that seemingly autonomous self-generated motion, reactivity, as well as a number of other factors contribute to the perception of objects as alive, animate entities.<sup>23</sup> One can easily assume, then, that architectural structures able to move, react, interact or self-act, may sometimes be perceived as animate. I will argue, however, that the tendency to see digitally-driven structures as 'alive' cannot be explained merely in perpetual-psychological terms, because the idea of architecture as a 'living organism' has been part of the language and conceptualisation of architecture since the 19th century, and lately a recurring concept in the descriptions of intelligent environments and computationally-augmented architecture.

### Architecture as a 'living organism'

The use of biological metaphors and images within the architecture discipline is no recent phenomenon. Throughout the nineteenth century biological terms and metaphors (like 'circulation', 'structure' or 'function') were being used by architects in order to render aspects of architecture as objective categories that can be analysed with scientific methods.<sup>24</sup> However, the most important adoption of biological metaphors in architecture took place after the Second World War through the language and projects of the architectural avant-garde within the cultural, scientific and philosophical context shaped by cybernetics, Heisenberg's uncertainty principle and Karl Popper's attack on sociopolitical determinism.<sup>25</sup> For example, the avant-garde group Archigram, rejecting any conceptual boundary between the organic and the inorganic (echoing cybernetics),<sup>26</sup> designed architectural environments capable of responding to the indeterminacy of social and individual conditions<sup>27</sup> based on biological concepts such as 'transformation', a.k.a. 'metamorphosis'.<sup>28</sup>

While Archigram's approach to biological concepts in architecture was only iconographic, in Warren Brody's 1967 article 'The Design of Intelligent Environments', biological concepts such as complexity, self-organisation and evolutionary ability were regarded as inspirations for an active intelligent-responsive architecture able to learn from its users, self-act and anticipate behaviours based on acquired experience.<sup>29</sup> This relationship between architecture and life becomes even more literal today as the vision of ambient intelligence embedded in architecture has led to a rhetoric that describes intelligent environments that can move, perceive, interact, self-act and learn, as 'living', 'social' or 'intelligent'. In many cases intelligent environments are even conceived of and described as living entities and artificial beings. For instance, an article in *Wired* magazine mentions the ability of buildings to mimic living systems, perceive and react to environmental stimuli:

*What if buildings could function like living systems [...] A building that mimics a living system would be able to sense and respond appropriately to exterior conditions like varying winds, temperature swings or changing sunlight.*<sup>30</sup>

Kynan Eng et al.'s ICRA 2003 conference paper describes the intelligent room ADA as an 'artificial creature',<sup>31</sup> whereas in another point the authors mention that 'the project Ada: intelligent space is an exploration in the creation of living architecture',<sup>32</sup> explaining how this environment is perceived by its visitors as alive. Stephen Jones speaks even more literally about the relationship between intelligent environments and organisms:

*In developing intelligent environments we lose the distinction between organism and environment. The environment becomes an organism because it does all the things that an organism does except, perhaps, self-replication. The kinds of processes that must be operating in the integration of artificial organisms are analogous to those operating in biological organisms. These include complex self-regulatory processes enabled by substantial feedback circuits [...] These are the sort of things that a brain or nervous system does in response to its earliest experience.*<sup>33</sup>

Maria Luisa Palumbo points out that information technology links architecture to the living body:

*The question of sensitivity now indissolubly links the body, machines and architecture. If the distinguishing factor between living and inorganic forms is essentially the capacity to exchange information with the environment and, consequently, flexibility in terms of the capacity to learn and modify, the key innovation of architecture in the second half of the 20th century, characterised by its growing intimacy with machines, is the aspiration to give buildings the sensitivity and flexibility of living systems.*<sup>34</sup>

In the following section I will open up this field of

'alive' objects that have been challenging the boundaries between the natural and the artificial by examining their practices and their presence historically. In this way I will be able to contextualise digitally-driven kinetic architecture within a wider practice and discourse that sees 'living' artefacts as what MIT professor Sherry Turkle has termed 'marginal objects'. These are objects built to interrogate the boundaries between human and machine, the biological and the technological, because they stand on the boundary between the living and the non-living.

### **'Living' technological objects as marginal objects**

Although common sense allows us to distinguish between living and non-living objects and entities as belonging to different categories, this distinction is not as straightforward for computational objects that, because of their phenomenal attributes, stand on the boundary between these categories. Sherry Turkle names them 'marginal objects':

*Marginal objects, objects with no clear place, play important roles. On the lines between categories they draw attention to how we have drawn the lines. Sometimes in doing so they incite us to reaffirm the lines, sometimes to call them into question, stimulating different distinctions [...] Marginal objects are not neutral presences. They upset us because they have no home and because they often touch on highly charged issues of transition.*<sup>35</sup>

Turkle develops her argument by looking into the reactions of adults, children and scientists to the first appearance of computational artefacts in the wider society of the 1970s which gradually entered the social and psychological life of people, affecting the ways they understood and thought about life. It was difficult to classify such objects in terms of whether they were animate or inanimate (this will be examined further down). In this text I am using Turkle's concept to define digitally-driven kinetic

architecture, which presents characteristics of living organisms (interaction, self-initiated motion), also as a marginal object. What I am presenting in the following section is a history of creation of marginal objects, in other words a history of contestation and redefinition of the boundary between biology and technology. I will thus attempt to argue that digitally-driven structures can also be placed in this same context.

Although actual examples and descriptions of marginal objects go back as far as antiquity,<sup>36</sup> they have only been part of philosophical and cultural discourse since the seventeenth and eighteenth centuries. During that time, automatic machines, a.k.a. 'automata', became part of philosophical and scientific culture, because, contrary to vitalism, mechanistic (clockwork) explanations of natural phenomena were extended to biological systems by Descartes' mechanistic philosophy and his successors. More radical materialist philosophers of the period, such as Julien Offray de la Mettrie, would go as far as describe not only bodily processes but also mental functions in terms of mechanism.<sup>37</sup> Yet, in Jessica Riskin's view, eighteenth-century automata, such as Vaucanson's Defecating Duck made to simulate the animal's physiological processes, expressed the philosophical dispute between the mechanistic and the non-mechanistic interpretations of life, by attempting to determine the extent to which living beings could or could not be reproduced by mechanism. According to Riskin they resulted in 'a continual redrawing of the boundary between human and machine and redefinition of the essence of life and intelligence'.<sup>38</sup>

Although, during the nineteenth century, vitalistic views on life remained active even in scientific contexts, they were disputed by the development of the steam engine and the energy conservation law which showed that living organic phenomena - the production of heat and its conversion into mechanical energy, respiration and metabolism -

were also phenomena of machines.<sup>39</sup> Later, in the mid-twentieth century the advent of cybernetics as well as molecular biology pointed to the view that human and machine, the organic and the inorganic, are all information-processing devices, systems that adapt and adjust to their environment on the basis of the flow and control of a common unit called information.<sup>40</sup> This attempt was partly successful because of the way information was conceived and constructed in the scientific community and because of the electromechanical devices that were built by cyberneticists to demonstrate their ideas in reality.<sup>41</sup> In effect, the theories and machines of the scientific community of cybernetics, although constructed, resulted in a synthesis of humans and machines and became the means to challenge and blur the boundaries separating the living and the non-living.

This same attempt to equate the organic with the machinic was later led by the Artificial Intelligence (AI) community, which either regarded the human mind as an information-processing device, just like a computer, or the human brain as an emergent system, a model for the neural network of the connectionist approach to AI.<sup>42</sup> Within both approaches, however, traditional boundaries and distinctions between the natural and the artificial would dissolve because humans and computers were conceptualised as either rule-based devices or non-deterministic systems.<sup>43</sup> Yet at the same time both scientists and non-scientists would adopt a critical stance against this equation, arguing that AI suggests a flat mechanistic view of human nature; their critique, which Turkle calls 'romantic', would assume that what separates humans from computers is exactly that which cannot be coded, namely emotion and spontaneity.<sup>44</sup>

Human-machine boundaries are also challenged today in the practices and discourses of Artificial Life (A-Life), where digital entities are designed to simulate biological processes. In particular, since the end of the 1980s, the field of digital A-Life (also

called *soft A-Life*) has argued that life includes any possible form, either physical or digital, conceived only in terms of the self-organising complex processes (evolution, natural selection, adaptation, learning, physical interactions) that constitute it.<sup>45</sup> Such scientific conceptions and definitions of life, along with the way digital A-Life forms are represented and referred to, enhance the perception of biological and artificial life equations, constituting, as Hayles has put it, 'a multilayered system of metaphoric material relays through which 'life', 'nature' and the 'human' are being redefined'.<sup>46</sup> At the same time, however, some A-Life researchers have emphasised the importance of the material body - the physical structure of the organism - in the construction of artificial life.<sup>47</sup> Moreover, people's reaction to A-Life would emphasise sensuality and biological and physical embodiment as the basic constituents of life, separating them from A-Life objects.<sup>48</sup>

What seems to be dominant in this historical account of marginal-object production is the assumption that the boundary between human and machine is either unbridgeable - in the romantic reactions where there was always a parameter, like emotion, that enhanced those boundaries - or non-existent - in artificial-life practices or cybernetics where there were no ontological differences between the natural and the artificial. In other words, this boundary, although under controversy and dispute (sometimes blurred, sometimes clear-cut), was always present. As Warren Sack puts it:

*...such critiques assign a timeless, unchanging structure to what is better characterized as an on-going struggle to negotiate the ways in which the 'artificial' flows into the 'natural' and vice versa.*<sup>49</sup>

It seems to me that digitally-driven architecture can be considered to be part of such a tradition of marginal-object production. I have already mentioned the ways in which this kind of architecture is conceived

of or perceived in terms of human or biological attributes. Such attributes turn it into something more than a mere functional object; it becomes an object through which boundaries are interrogated, through which architecture acquires, once more, the status of an almost 'living' entity - a marginal object. But why do architects design digitally-driven kinetic structures endowed with such a status? To answer this question I will first have to answer the question why marginal objects are produced.

The most well-known reason for the production of artificial-life objects and images is the need to understand what is unique about man and what separates man from machines, as Bruce Mazlish<sup>50</sup> and Christopher Langton have explained.<sup>51</sup> It is, however, senseless to claim that the same reason applies for digitally-driven kinetic structures; although they present biological phenomena, like motion and interaction, they are not experimental simulations of biological processes, as is the case with A-Life objects. Digitally-driven kinetic architecture is not a scientific experiment but an architectural creation. Therefore, I think there is another reason driving the design of this kind of architecture that will become evident through the examination of the socio-cultural dimension of this phenomenon.

The following section attempts to respond to this problem and come up with a new conceptualisation of digitally-driven architecture, one which will no longer see it only as a functional object but also as a culturally-defined *quasi-object*.

### **The Nature-Culture separatism in modernity**

Since the 1980s the social studies in science and technology have been challenging the dissociation between the natural and the cultural, the scientific and the social, the object and the subject prevalent in the last two centuries, exposing the hybrid forms with which things are represented. For anthropologist Bruno Latour modernity is a double process of 'purification', that is, separation of Nature (and

science) from society and the self, and 'hybridisation', the mixing of nature and culture. Purification is what moderns pretend to be doing, Latour claims, because nothing is allowed to take place in-between nature and society (object and subject), the boundary that defines all reality, although in practice they produce all kinds of nature-culture hybrids (quasi-objects).<sup>52</sup> The modern accepts these hybrids but conceives them as mixtures of two pure forms, things and subjects or humans and non-humans, which he separates at the same time in order to extract from them the subject (or the socio-cultural) part and the object (or the natural) part.<sup>53</sup> This distinction is, for Latour, an imaginary construction because everything takes place between society and nature, in a 'middle kingdom' rejected by modernity - a central point of 'departure', not separation.<sup>54</sup> Modernity explained everything but left outside what was in the middle - the production of hybrid technological objects in a post-industrial era of information and 'smart' machines:

*...when we find ourselves invaded by frozen embryos, expert systems, digital machines, sensor-equipped robots, hybrid corn, data banks, psychotropic drugs, whales outfitted with radar sounding devices, gene synthesizers, audience analyzers, and so on [...] and when none of these chimera can be properly on the object side or on the subject side, or even in between, something has to be done.*<sup>55</sup>

A-Life is one of those intriguing practices where the modern subject-object distinctions are redefined. Lars Risan has noticed that although A-Life scientists construct artificial 'living' beings, at the same time they try to rid them of any subjectivity because they are considered to be scientific objects of inquiry. Yet, the difficulty in defining these distinctions, Risan thinks following Latour, is due to their use of everyday language which makes it difficult to draw subject-object boundary lines:

*In our everyday language we - 'moderns' - have*

*always been 'non-moderns'; 'witch doctors'; we do in practice endow our objects with a lot of subjective properties. Unlike, for example, physics, Artificial Life is a technoscience where it is hard to maintain a clear-cut boundary between everyday language and scientific models.*<sup>56</sup>

In his text, *Mixing Humans and Nonhumans Together: The Sociology of a Door-Closer*, Latour (using the nickname Jim Johnson),<sup>57</sup> discusses the problem of human-machine separation in the case of an automatic door-closer. He analyses how this purely technical object is clearly a moral and social agent, an anthropomorphic entity because it replaces humans and shapes human actions. He objects to the separating lines between humans and technological objects placed by sociologists; he sees only actors who are either human or non-human.<sup>58</sup> Such seemingly animate technological objects, social actors in Latour's view, especially apparent in the work of A-Life and the field of sociable robotics mentioned earlier, challenge modernity's human-machine distinctions. Lucy Suchman discusses A-Life within the wider philosophical problem of human-machine distinction and the autonomy of the machine:

*Having systematically established the division of humans and machines, technological imaginaries now evidence worry that once separated from us machines are rendered lifeless.*<sup>59</sup>

She further explains that the insistence on the human-machine distinction within the modern tradition drives the prospect of constructing autonomous anthropomorphic machines in order to be humanised, i.e. 'to be made like us - in order that we can be reunited with them'.<sup>60</sup> However, as Suchman points out, although aiming at the opposite, the actual production of intelligent robotic machines lies in the modern tradition of the post-enlightenment era which regards separation and autonomy rather than relation as characteristics of humanity.<sup>61</sup>

Bruce Mazlish locates this distinction and need for unification in a historical framework described by three discontinuities - artificial distinctions - in the western intellectual civilisation, which were overcome by three great scientists of the past: the first, which placed man in a dominant separate position over the cosmos was overcome by Copernicus, the second, which separated man from the rest of the animal kingdom, was overcome by Darwin, and the third placed man over the subconscious (overcome by Freud).<sup>62</sup> Mazlish explains that, as Copernicus, Darwin and Freud refuted these presumed discontinuities, now it is necessary to subvert the *fourth discontinuity*, that is, the fallacy that humans are different from the machines they make.<sup>63</sup> Examining the human-technology relationships through Darwinian theory, Mazlish argues that human nature includes both animal and machinic qualities, because tools and machines are inseparable from human evolution.<sup>64</sup> Human nature, then, is an evolving identity unfolding in terms of culture, our 'second nature', expressed in the form of *prosthetic* devices, either tools or machines - a subject elaborated by Freud, who called man a 'prosthetic god', and Norbert Wiener, who talked about devices like radars, jet engines and propellers in terms of prosthetic human or animal organs.<sup>65</sup>

Having said that, it now becomes clearer that there are cultural factors driving the conception of digitally-driven architectural structures, not unrelated to the philosophical discourse and practices of A-Life and marginal-object production. The machinic yet biomorphic and naturalised behaviour of these structures and the reference to them as if they are social entities, allowed me to place them within the discourse and practices of marginal objects in the history of A-Life. Such objects were understood as challengers of human-machine discontinuity as well as possible means to reunite humans with objects and machines. Similarly, digitally-driven kinetic architecture could also be regarded as a machine, an artificial marginal object, 'trying' to acquire life, to

become living organism in order to subvert Mazlish's fourth discontinuity. Its animate, seemingly human features, - motion, pro-activity and responsiveness - turn it into a prosthetic extension of humans and human functions (perception, action, intelligence), echoing the way Oosterhuis has conceptualised his E-motive House project: 'a social semi-independent extension of the human bodies of the inhabitants.'<sup>66</sup>

### Conclusions

By analysing the concept of the marginal object, its historical framework and the socio-cultural factors driving its construction, I have built a conceptual framework in order to support my view regarding the reasons behind the design of digitally-driven kinetic architecture. I have argued that these designs are led by a wider socio-cultural (and perhaps psychological) drive which can be observed in different artificial-life objects and 'living' machines. If the task of A-Life practices is to subvert the human-machine discontinuity pointed out by Suchman and Mazlish, then the design and construction of 'living' digitally-driven structures, like the E-motive house, the Muscle Tower II, or dECOi's Hyposurface must be part of this task to 'humanise' the machine-architecture, to undermine the nature-artifice boundary. Digitally-driven kinetic structures should not only be considered as functional objects but should also be seen as quasi-objects, which, in the context of Latour's nature-culture separatism critique, are constructed to challenge and reunite subject and object, human and machine. Yet, it should be clarified here that this bonding is not literal: it does not mean an actual unity between human and structure. It is only a conceptual interpretation of the possibility for prosthetic relations that such anthropomorphic structures generate due to the illusory perception that they are 'alive' entities. To achieve such a bonding, that is, an actual experience of unity between the human and the structure, one should look into other, more intimate devices, practices and discourses within fields such as human-machine interaction and the cyborg metaphor.

What then is the impact of the above observations and this alternative way of understanding digitally-driven structures? Are these observations obstacles to their actual functional potential and aim? Do designers have to change their attitude towards their conception and design? I think the answer to these questions is twofold.

On the one hand, designing and constructing such structures is indeed an important experiment for the evaluation of their behaviour, functional capacities and potential. Unlike closed deterministic machines, these 'naturalised' machines seem to open possibilities. They can be considered to be 'virtual machines', that is, architecture with undeveloped potential, awaiting the activation of possible functions and uses not yet actualised.<sup>67</sup>

On the other hand, we should not look at these structures as fanciful expressions of anthropomorphic qualities, which could obscure their real functional potential. Since functional flexibility and environmental adaptation are, and should be, the main reasons for designing and building such structures - otherwise they should not be considered architecture - it is important to acknowledge that sometimes simple approaches may lead to significant results. Flexibility and adaptation is not only a matter of mechanical and digitally-driven motion of structures but it can be a property of inert structures. Buildings can alter their environment and spatial organisation through the use of mobile elements (moving partitions, retractable roofs, kinetic panels or louvers on 'smart' building skins) which can achieve, with rather discrete motions, extensive changes in function and overall performance. For instance, think of the way that small motions of 'smart' façade louvers can result in significant changes in the building's environmental behaviour and interior conditions.

There is no space here for further elaboration of these ideas. However, the contribution of this

paper to the discussion on digitally-driven structures is that it raises questions about the criteria on which these designs are conceptualised and implemented. Although most digitally-driven structures are academic research projects with minimal professional and commercial application, in my view, their discussion through the conceptual framework presented in this paper is crucial for evaluating and anticipating the very possibility of their further exploration and implementation. In other words, by acknowledging the socio-cultural aspects of this kind of architecture, the designers of such structures are confronted with the demand to debate their status and significance, as well as re-examine the related concepts and practices.

#### Notes

1. Robert Kronenburg, *Portable Architecture* (Oxford: The Architectural Press, 1996).
2. Konstantinos Oungrinis, *Structural Morphology and Kinetic Structures in Transformable Spaces* (Thessaloniki: Unpublished Doctoral Dissertation Dept of Architecture A.U.TH., 2009), pp. 43-49, 36-37.
3. *Ibid.*, pp. 136-65.
4. See: Tony Robbin, *Engineering a new Architecture* (New Haven CT: Yale University Press, 1996), p. 38.
5. Konstantinos Oungrinis, *Transformations: Paradigms for Designing Transformable Spaces* (Cambridge: Harvard University Graduate School of Design, 2006), p. 7. For instance, in the work of Archigram nomadic kinetic structures are iconographic expressions of a modern technologically-enhanced lifestyle.
6. For instance, the Adaptive Home, the PlaceLab and the MavHome are some of the most representative examples of intelligent environments built to develop techniques - through information processing, memory, recognition and learning mechanisms, and decision-making capacities - to anticipate and adapt to personalised human desires and needs. See: *Intelligent Environments: Methods, Algorithms and Applications*, ed. by Dorothy Monekosso, Remagnino Paolo & Kuno Yoshinori (London: Springer, 2008).
7. Michael Fox, 'Beyond Kinetic', *Kinetic Design Group*, <<http://kdg.mit.edu/Pdf/Beyond.pdf>> [accessed 30 January 2006].
8. Antonino Saggio, 'How', in Francesco De Luca & Marco Nardini (eds), *Behind the Scenes: Avant-Garde Techniques in Contemporary Design* (Basel: Birkhauser, 2002), pp. 5-7.
9. For a review of environmentally-responsive buildings with kinetic smart building skins see: C.C. Sullivan, 'Robo Buildings: Pursuing the Interactive Envelope', *Architectural Record*, 194, 4 (April 2006), 148-156.
10. *Muscle Room*, <<http://www.protospace.bk.tudelft.nl/live/binaries/7c13c533-6f9b-4f0b-a113-0c0ad9aaa37a/doc/index.html>> [accessed 23 April 2008].
11. Michael Fox and Bryant Yeh, 'Intelligent Kinetic Systems', *Kinetic Design Group*, <<http://kdg.mit.edu/Projects/pap01.html>> [accessed 30 January 2006].
12. Oungrinis, *Structural Morphology*, pp. 359-360.
13. Hyperbody Research Group website, TUDelft, <<http://www.tudelft.nl/live/pagina.jsp?id=2e0eef38-3970-4fc0-8e0b-1ce04928c500&lang=nl>> [accessed 17 March 2006].
14. See the Responsive Environments projects from 2001 to 2004: *AADRL.net*, <<http://www.aaschool.ac.uk/aadrl>>.
15. *Hyposurface*, <<http://www.hyposurface.org>>.
16. Kas Oosterhuis, 'E-motive House', *ONL 2002*, <<http://www.oosterhuis.nl/quickstart/index.php?id=348>> [accessed 24 February 2008].
17. *Ibid.*
18. Kas Oosterhuis, *Hyperbodies: Towards an E-motive Architecture* (Basel: Birkhäuser, 2003), p. 54.
19. Nimish Boloria and Kas Oosterhuis, 'Envisioning the Responsive Milieu: An Investigation into Aspects of Ambient Intelligence, Human Machine Symbiosis and Ubiquitous Computing for Developing a Generic Real-Time Interactive Spatial Prototype', *CAADRIA '05 Proceedings* (New Delhi, 2005), 430.
20. *Muscle Tower II: An interactive and Kinetic Tower*, TUDelft, <<http://www.tudelft.nl/live/pagina.jsp?id=42d12e00-5d78-42d1-afe0-262352934565-&lang=en>> [accessed 17 March 2005].
21. Hans Hubers, e-mail to the author, February 10, 2009.

22. <<http://www.thegreatesthits.net/hyperbody/mov>> [accessed 11 October 2009].
23. There is a significant amount of research experiments in psychophysics, which study the perception of animacy in inanimate objects. See: Fritz Heider and Mary-Ann Simmel, 'An Experimental Study of Apparent Behavior', *American Journal of Psychology*, 57 (1944), 243-59, and Brian Scholl and Patrice Tremoulet, 'Perceptual Causality and Animacy', *Trends in Cognitive Science*, 4 (2000), 299-309.
24. Andrian Forty, *Words and Buildings: A Vocabulary of Modern Architecture* (London: Thames & Hudson, 2004), pp. 87-101.
25. See: Jonathan Hughes, 'The Indeterminate Building'; Simon Sadler, 'Open Ends: The Social Visions of 1960s non-Planning', in *Non-Plan: Essays on Freedom Participation and Change in Modern Architecture and Urbanism*, ed. by J. Hughes & S. Sadler (Oxford: Architectural Press, 2000), pp. 90-103; pp. 138-54.
26. Cybernetics, defined by its founder Norbert Wiener as the science of control and communication in the animal and machine, attempted to conceive of organic and inorganic systems as information exchange devices, systems able to adapt and adjust to their environment on the basis of the flow and control of information - a unit common to both.
27. Hadas Steiner, *Beyond Archigram: The Structure of Circulation* (London; New York: Routledge, 2009), pp. 13-20.
28. The term and its definition appear in their Archigram 8 periodical (Steiner, op. cit., p. 166).
29. Warren Brody, 'The Design of Intelligent Environments: Soft Architecture', *Landscape* (Autumn 1967), 8-12.
30. Lakshmi Sandhana, 'Smart Buildings Make Smooth Moves', *Wired*, August 31, 2006, <<http://www.wired.com/science/discoveries/news/2006/08/71680>> [accessed 23 March 2009].
31. Kynan Eng et al., 'Ada - Intelligent Space: An Artificial Creature for the Swiss Expo.02', *Proceedings of the 2003 IEEE/RSJ International Conference on Robotics and Automation (ICRA)* (Taipei, 2003).
32. Kynan Eng, 'ADA: Buildings as Organisms', *Game-setandmatch Conference Proceedings*, 2001, <<http://www.bk.tudelft.nl/hyperbody/conference/gsm>> [accessed 22 June 2005].
33. Stephen Jones, 'Intelligent Environments: Organisms or Objects?', *Convergence: The International Journal of Research into New Media Technologies*, 7, 2 (2001), 30.
34. Maria-Luisa Palumbo, *New Wombs: Electronic Bodies and Architectural Disorders* (Basel: Birkhauser, 2000), p. 76.
35. Sherry Turkle, *The Second Self: Computers and the Human Spirit* (2nd ed.) (London; Cambridge, Mass: The MIT Press, 2005), pp. 34-35.
36. See Sylvia Berryman, 'The Imitation of Life in Ancient Greek Philosophy', in *Genesis Redoux: Essays in the History and Philosophy of Artificial Life*, ed. by Jessica Riskin (Chicago; London: The University of Chicago Press, 2007), pp. 35-45.
37. See: Jessica Riskin, 'Eighteenth-Century Wetware', *Representations*, 83 (2003), 99.
38. Jessica Riskin, 'The Defecating Duck, or, the Ambiguous Origins of Artificial Life', *Critical Inquiry*, 29, 4 (2003), 601-33.
39. Evelyn Fox Keller, 'Marrying the Premodern to the Postmodern: Computers and Organisms after WWII', in *Prefiguring Cyberspace: an Intellectual History*, ed. by Darren Tofts, Annemarie Jonson, Alessio Cavallaro (Cambridge Mass; Sydney: MIT Press; Power Publications, 2002).
40. Darren Tofts, 'On Mutability', in *Prefiguring Cyberspace*, p. 3.
41. Katherine Hayles, *How we Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: The University of Chicago Press, 1999), pp. 62-65.
42. Margaret Boden, 'Introduction', in *The Philosophy of Artificial Intelligence* (Oxford; New York: Oxford University Press, 1990), p. 7.
43. Sherry Turkle, *Life on the Screen: Identity in the age of the Internet* (London: Weidenfeld & Nicolson, 1995), pp. 133-36.
44. Turkle, *The Second Self*, pp. 282-83; *Life on the Screen*, p. 84. The first computers and smart devices of the 1970s would challenge people's psychologi-

- cal reactions because of their opaqueness, real-time reactivity and unpredictable behaviour. Logic and intelligence, which have always been unique human attributes, were now attributed to machines, thus challenging human-machine boundaries. See: Turkle, *The Second Self*, p. 248.
45. Keller, op. cit., pp. 63-64; Christopher Langton, 'Artificial Life' in *Artificial Life: The Proceedings of an Interdisciplinary Workshop on the Synthesis and Simulation of Living Systems* (Redwood City: Addison-Wesley, 1989).
46. Hayles, op. cit., p. 224.
47. See: Rodney Brooks, *Cambrian Intelligence: The early History of the new AI* (Cambridge Mass.: The MIT Press, 1999). Robotics research in A-Life, for instance, has produced anthropomorphic artefacts, such as Cynthia Breazeal's Kismet, able to develop social and emotional relations with people. See: Cynthia Breazeal, *Sociable Machines: Expressive Social Exchange between Robots and People*, Doctor of Science Thesis (MIT, May 2000).
48. Turkle, *Life on the Screen*, p. 84.
49. Warren Sack, 'Artificial Human Nature', *Design Issues*, 13 (1997), 64.
50. Bruce Mazlish, 'The Man-Machine and Artificial Intelligence', *Stanford Electronic Humanities Review*, 1995, <<http://www.stanford.edu/group/SHR/4-2/text/mazlish.html>> [accessed 4 July 2008].
51. Langton, op. cit., p. 1.
52. Bruno Latour, *We Have Never Been Modern*, trans. by Catherine Porter (Cambridge Mass.: Harvard University Press, 1993).
53. Ibid., p. 78.
54. Ibid., pp. 78-79.
55. Ibid., p. 49.
56. Lars Christian Risan, 'Artificial Life: A Technoscience Leaving Modernity? An Anthropology of Subjects and Objects', AnthroBase.com, 1997, < [http://www.anthrobase.com/Txt/R/Risan\\_L\\_05.htm](http://www.anthrobase.com/Txt/R/Risan_L_05.htm) > [accessed 12 December 2008].
57. Jim Johnson (Bruno Latour), 'Mixing Humans and Nonhumans Together: The Sociology of a Door-Closer', *Social Problems*, 35, 3 (1998), 298-310.
58. Ibid., 303.
59. Lucy Suchman, *Human-Machine Reconfigurations: Plans and Situated Actions* (2nd ed.) (Cambridge: Cambridge University Press, 2007), p. 213.
60. Ibid., p. 214.
61. Ibid., pp. 213-14. Criticising robotic artefacts like Kismet, Suchman argues that these machines seem to be working autonomously and pro-actively because of the ways they are reproduced and depicted in media, thus restating traditional assumptions about human nature as autonomous (Ibid., p. 238).
62. Mazlish, here, follows Freud who, in his 8th lecture of the *Introductory Lectures to Psychoanalysis* given at the University of Vienna between 1915 and 1917, proposed a place for himself among Copernicus and Darwin. See: Mazlish, op. cit., p. 3.
63. Mazlish, op. cit.
64. Ibid., pp. 8, 216, 233.
65. Ibid., p. 198.
66. Oosterhuis, *Hyperbodies*, p. 55.
67. A rephrase of Alan Turing's 'Universal Machine' proposed in 1936, and understood in terms of Deleuze's concept of the 'virtual', the 'virtual machine', is a functionally underdetermined complex machine, never actualised as the totality of functions of which it is capable. See: Martin Lister et al., *New Media: A Critical Introduction* (London; New York: Routledge, 2003), pp. 360-64

**Biography**

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