Why Make the World Move?

Motivations for Adaptive Environments, a Next Horizon of Human Computer Interaction

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Abstract

The next horizons of human-computer interaction promise a whirling world of digital bytes, physical bits, and their hybrids. Are human beings prepared to inhabit such cyber-physical, adaptive environments? Assuming an optimistic view, this chapter offers a reply, drawing from art and art history, environmental design, literature, psychology, and evolutionary anthropology, to identify wide-ranging motivations for the design of such "new places" of human-computer interaction. Moreover, the author makes a plea to researchers focused in the domain of adaptive environments to pause and take a longer, more comprehensive, more self-reflective view to see what we're doing, to recognize where we are, and to possibly find ourselves and others within our designed artifacts and systems that make the world move.

Keywords

Adaptive environments; Architectural robotics; Interactive Environments; Theory; Human-Machine Interaction; Intelligent Systems; Internet of Things [IoT]; Cyber-Physical Systems [CPS].

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1 Introduction

It is well recognized that human-computer interaction (HCI) today is no longer bound by computer displays ("one human–one computer") or by Weiser's vision of ubiquitous computing ("people connected by an invisible web"). Today, the horizons of human-computer interaction are defined, in part, by physical scale. At one end of the physical spectrum. where HCI approaches nothingness, computing resides not only around us but also *on* us and *in* us, embedded notably as a bionic second-skin forging a connection between our bodies and the external world.[1] At the other end of the physical spectrum, computing is embedded in the very fabric of our everyday living environments, manifested as networked smart appliances (the Internet of Things [IoT]), physical and tangible computing (Tangible User Interface [TUI]), assistive, humanoid robots (Human-Robot Interaction [HRI]), and as shape-shifting furniture, rooms (figure 1), building façades, and urban infrastructure that include Architecture Robotics [AR]).

The umbrella term for this grander scale of the physical spectrum assumes the namesake of this journal, Adaptive Environments (AE) or, alternatively, Intelligent Environments (IE). Characterized as computing hardware made spatial and inhabitable, Adaptive Environments are meticulously designed, inhabitable environments made interactive, adaptive, and at least partly intelligent. A key behavioral trait of Adaptive Environments is their capacity to respond and adjust to external, often dynamic input, whether this input be the needs and wants of human inhabitants, or changes in environmental or climactic conditions, or updated information supplied by the internet. The response of Adaptive Environments to external input can manifest itself as a change in colors, sound, and shape. In the author's *Architectural Robotics Lab* at Cornell University, previously established in 2005 with collaborator Ian Walker at Clemson University, Adaptive Environments have assumed the form of: an Assistive Robotic Table (ART)[2] enabling, in particular, post-stroke patients; an Animated Working Environment[3] that re-conforms to support the working life of co-located, information Age workers working at once with digital and analog materials and tools; and a LIT ROOM[4] cultivating literacy in children (figure 1) by transforming the everyday space of the public library into the imaginary space of the book.

1 Someya, T. (2013). Building bionic skin. IEEE Spectrum, 50(9), pp.50-56.

2 Houayek, H., Green, K., Gugerty, L., Walker, I. and Witte, J. (2013). AWE: an animated work environment for working with physical and digital tools and artifacts. Personal and Ubiquitous Computing, 18(5), pp.1227-1241.

3 Threatt, A. L., Merino, J., Green, K. E. and Walker, I. D. (2014). An Assistive Robotic Table for Older and Post-Stroke Adults: Results from Participatory Design and Evaluation Activities with Clinical Staff. Proceedings of CHI 2014: the ACM Conference on Human Factors in Computing Systems, Toronto, Ontario, Canada, pp. 673–682.

4 Schafer, G., Green, K. E., Walker, I. D., Fullerton, S. K. and Lewis, E. (2014). An Interactive, Cyber-Physical Read-Aloud Environment: Results and Lessons from an Evaluation Activity with Children and their Teachers. Proceedings of DIS 2014: the ACM conference on Designing Interactive Systems, Vancouver, B.C., pp. 865–874.

FIGURE 1 Adaptive environment from the author's ARCHITECTURAL ROBOTICS LAB at Cornell Univeristy: The LIT ROOM (photos by author). Delighted young users within the author's cyber-physical LIT ROOM at a public library prompted the author to dwell on the significance of such "new places" in HCI.

Across the physical spectrum, recent triumphs in these new horizons of HCI nevertheless remind us of that old, unsettling adage: *Just because you can, doesn't mean you should*. The same sentiment has been attributed recently to assistive humanoid robots and Artificial Intelligence (AI), the latter which will form, likely, the glue that binds together the various scales of next horizon HCI artifacts to form cyber-physical (eco)systems [CPS] of smaller and larger, interactive and intelligent, computing artifacts. In this expanded CPS, the human users in HCI become inhabitants of a whirling world of physical bits, digital bytes, and their hybrids. This "world on the move" begs the question (borrowing words from Science on the future of AI), "What will the world be like if [this kind of computing] comes to coexist with human kind?"[5] While the AI community addresses this question, some with fear, others with anticipation,[6] the HCI research community appears more satisfied with reporting on research triumphs, neglecting meanwhile to consider the meta question, What is it about human beings and being human that compels these next horizons of HCI?—*Why make our world move?* Offered as an impetus for much needed self-reflection, this short paper is an effort to address this core question from a cautiously optimistic stance. While the philosophical (i.e. phenomenological) dimension has been addressed for HCI, adeptly, by Dourish,[7] the response here draws instead from art and art history, environmental design, literature, psychology, and evolutionary anthropology.

5 Stajic, J., Stone, R., Chin, G. and Wible, B. (2015). Special issue on artificial intelligence. Science. 349(6245). pp.248-278

6 IEEE Spectrum: Technology, Engineering, and Science News. (2015). Special Report: The Singularity. [online] Available at: http://spectrum.ieee.org/static/singularity [Accessed 18 Dec. 2016].

7 Dourish, P. (2001). Where the Action Is: The Foundations of Embodied Interaction. Cambridge, Mass.: MIT Press.

2 Drawing from art and art history

Imagine a collection of appliances (IoT) or a robotic workplace (IE) that intelligently reconfigures to support changes in the workflow, recognizing the need for a particular adaption or reconfiguration that will better support it. The design of such systems requires the design team to envision (theoretically) innumerable pathways to adaption and reconfiguration: to essentially recognize in one form still other forms. This is a very different way to think about form for designers where convention assumes that form is singular and stable. Art historian Henri Focillon thought other than conventionally, grappling with the notion that a single form is neither singular nor stable but rather has within it a multitude of forms. “Although form is our most strict definition of space,” wrote Focillon, “it also suggests to us the existence of other forms.”[8] We must “never think of forms, in their different states, as simply suspended in some remote, abstract zone; they mingle with life, whence they come; they translate into space certain movements of the mind.”[9] As forms are conceived and engaged by their users, “each form,” writes Focillon, “is in continual movement, deep within the maze of tests and trials” to which their users submit them.[10] In art, perhaps the clearest statement of this reciprocity between the dynamism of form and human perception is found in Italian Futurism, the artistic movement of the early 20th century, evidenced by the words of the movement’s founder, F. T. Marinetti: “A house in construction symbolizes our burning passion for the coming-into-being of things. Things already built and finished, bivouacs of cowardice and sleep, disgust us! We love the immense, mobile, and impassioned framework that we can consolidate, always differently, at every moment.”[11] The thinking of Focillon and Marinetti suggest to the designers of the next horizons of HCI that an artifact is not singular and isolated but an “open work,” a kind of “hypertext,” an artifact open to users’ interpretations as imparted by memory and by the physical, virtual, and cultural contexts in which the artifact resides.[12]

3 Drawing from environmental design

With few exceptions, designing the built environment for movement, for *reconfigurability*, has been resisted by designers throughout history. Resistance to reconfigurability is motivated by the requirement of buildings to maintain continuity, to defy or at least to resist the impositions of nature and unfamiliar humankind. Curiously, today’s homes and workplaces remain largely incapable of responding to changes occurring in their inhabitants as these inhabitants grow, grow old, and sometimes grow sick, and as groups of inhabitants grow and shrink in their numbers and exhibit varied and fluctuating needs and wants. Environmental design (mostly equated with architecture) has mostly ignored this flux endemic to life.

8 Focillon, H. (1989). The life of forms in art. New York: Zone Books, pp.97-98.

9 Ibid., 60.

10 Ibid., 123-124

11 Marinetti, F. T. (1991). The Birth of a Futurist Aesthetic. In Let’s Murder the Moonshine. Los Angeles: Sun & Moon Press.

12 Eco, U. (1989). The open work. Cambridge, Mass.: Harvard University Press.

From the aesthetic, formal side, resistance to reconfigurability is motivated by the quest for a universal standard for measuring it: in designing its parts, and in organizing these parts to constitute the whole work. From architects Vitruvius to Le Corbusier—two millennia between them—the dimensional and proportional systems of buildings and other aspects of the built environment were modeled on an idealized and yet motionless human body: Vitruvian and Modular men. Maintaining the continuity bridging these two figures is the Renaissance ideal of a "timeless" and "beautiful" building in which "nothing may be added, taken away or altered."[13]

This "immobility" of architecture has its historical exceptions. It is not entirely novel for a piece of furniture or even a building interior to permit changes to its physical form to afford different functions supporting different human objectives or activities. These kinds of mechanical affordances or *action possibilities* date back centuries, for example, in the form of tatami mats and sliding shoji screens found in traditional Japanese houses. Most notably in architecture, the Rietveld Schröder House (1924, Utrecht), designed by cabinetmaker and architect Gerrit Thomas Rietveld, extended the concept of the sliding screen to permit the manual reconfiguration and repositioning of various components of the home's second story. Carlo Mollino, a mid-twentieth century architect known for his own reconfigurable architectural contrivances, imaginatively characterized the manually reconfigurable house as "a jack-in-the-box, a play of easily changeable rooms and furnishings, a fickle scenography of embroidered furnishings and sliding, transforming rooms, separating and creating halls and lounges with the turn of the seasons, in states of animation, reflecting the ceremonies of 'domestic' happenings… When importune, the furnishings truly disappear into the wall."[14] The "easily changeable rooms and furnishings" that Mollino describes are alive with possibilities for reconfiguring them. What fascinated this Turinese architect was not so much the physical movement afforded by the sliding partitions and furnishings (their mechanics), but mostly how these architectural elements, in their flexibility, reflected things external to them: the passing of the seasons, the unfolding rituals of domestic life, our own inner selves. In the rooms and furnishings of his own design, Mollino invited inhabitants to tune the mechanical features of these strange places to reflect the conditions of their interior lives—to reflect themselves in the environments in which they live, *to make themselves more at home*. In the number of interior domiciles he designed for himself, the frenetic Mollino sought a sense of restfulness for himself, but recognized, in states of torment and elation, the difficulty of capturing this peace, even for the duration of the shutter movement of his Leica camera.

Despite the best efforts of environmental design, its works are no more static than the lives living within them. When we enter a building, we bring with us the dimension of time. No inhabitant will ever have precisely the same experience here, nor will any other inhabitant have precisely the same experience here as someone else inhabiting the same space. The human experience, framed by the physical environment, is never precisely the same at two points in time. A work that is reconfigurable is one that, at least in conventional architectural terms, is *unfinished*: room is made in the very design of such a place for the inhabitants to, in a word, play. Architectural works, like all works of art, are "quite literally 'unfinished,'" Umberto Eco contended: "the author seems to hand them on to the performer more or less like the components of a construction kit."[15] For Eco, as might be said for F. T. Marinetti, "the comprehension and interpretation of a form can be achieved only … by repossessing the form in movement and not in static contemplation."[16] In the strange built environments described here, designers of IoT, IE, HRI and broadly CPS can discern compelling precedents for designing cyber-physical environments that actively grow and adapt with their users over time.

13 Alberti, L. (1988). On the art of building in ten books. Cambridge, Mass.: MIT Press, book VI, c.2, p.156.

14 Mollino, C. (1949). Utopia e Ambientazione. Domus (August 1949): 16 (author's translation).

15 Eco, U. (1989). The open work. Cambridge, Mass.: Harvard University Press. p.4.

16 Ibid., 163.

4 Drawing from literature

The means of computing (including robotics) can be integrated into the physical fabric of things to forge a more interactive, more intimate relationship between the built environment and us. Embedding digital technologies in selected aspects of the built environment, from small appliances to the metropolis, renders these a semblance of vitality: the capacity to move with and respond to things external to them, whether these things are living (people and pets), or inanimate (physical property), or phenomena far less tangible (data streaming over the Internet, the detection of weather). In this very active way—of engaging the world, drawing inferences, and responding in kind—cyber-physical artifacts are, to a degree, a reflection of us: our needs, our aspirations as vital beings that “change shape”.

As evidenced by its centrality in classical Greek mythology, “shape-shifting” has fascinated us for millennia. As Steven Levy asserts in *Artificial Life*, today’s human-made, life-like artifacts are founded not only in the contemporary imagination, but equally so in the many “ancient legends and tales” devoted to the theme of “inanimate objects” infused “with the breath of life.”[17]

Following Levy and recognizing physical reconfigurability as a pathway, today, to a more intimate correspondence between our physical environments and ourselves, it is not such a stretch to learn from the myth of Proteus, the Greek god who, more than other shape-shifters in Greek mythology, was capable of transforming himself into countless different forms. This captivating capacity of Proteus to shape-shift led to his ultimate “transformation”: into the familiar adjective, *protean*, which wonderfully captures a core behavior of the next horizons of HCI. Despite his advanced age and waning stamina, the Proteus of this poem of the eighth century B.C. has led an active and prolonged life under the same name but in different guises. Notably, Proteus is the name given to characters in Milton’s *Paradise Lost* and in Shakespeare’s *Henry VI* and *The Two Gentlemen of Verona*. Proteus is also the name given to historic warships (both USS *Proteus* and HMS *Proteus* of the Royal Navy), and to a novel, contemporary sailing vessel (the Proteus WAM-V, which features a reconfigurable hull that conforms to the surface geometry of water currents). Proteus is also the name given to, respectively, a medical syndrome popularly identified with “the Elephant Man,” a bacteria having a remarkable ability to evade the host’s immune system, and a family of flower having more than 1,400 varieties. Our fascination with shape-shifting is evidenced not only by this extended and variegated procession of forms under the name Proteus, but also by the contemporary usage of the word *protean*, defined by the *Oxford English Dictionary* as: *adopting or existing in various shapes, variable in form; able to do many different things;* and *versatile*. All of these definitions aptly describe the strivings of researchers engaged in developing the next horizons of HCI.

17 Levy, S. (1993). Artificial life: A Report from the Frontier Where Computers Meet Biology. New York: Vintage Books, p.18.

5 Drawing from psychology

There remains one more Proteus that will prove useful in uncovering the promise of the next horizons of human-computer interaction: the Proteus of psychology. Both the Proteus of Heinrich Khunrath, the sixteenth century German physician-alchemist, and the Proteus of Swiss psychologist Carl Jung in the twentieth century personified the elusive unconscious. But for our purposes, the more useful Proteus is the one that names a contemporary, psychological profile considered by psychiatrist Robert Jay Lifton. In *The Protean Self: Human Resilience in an Age of Fragmentation*, Lifton characterizes this modern-day Proteus as "fluid and many sided" and "evolving from a sense of self [that is] appropriate to the restlessness and flux of our time."[18] This Proteus, a "willful eclectic," draws strength from the variety, disorderliness, and general acceleration of historical change and upheaval. As Lifton writes, "One's loss of a sense of place or location, of home—psychological, ethical, and sometime geographical as well—can initiate searches for new 'places' in which to exist and function. The protean pattern becomes a quest for 'relocation.'"[19] According to Lifton, the protean self actively responds to life's challenges and opportunities—whether pedestrian (working life, family life) or grand-scaled (social, economic, political)—by seeking "new 'places'" best suited for improvement, advancement, or at least escape (figure 2). For the CHI community, we discover in the Protean Self a human personality that is amenable to and even drawn to flux and fluidity.

6 Drawing from evolutionary anthropology

The protean way—to be fluid, resilient, and on the move—is not only a tactical, cognitive response to living today, but is, according to anthropology researchers Antón, Potts, and Aiello, *the outstanding trait distinguishing the human species*. The protean way is defined as "adaptive flexibility," the cornerstone of this new paradigm for human evolution, as published by these three researchers in the journal, *Science*.[20] Antón, Potts, and Aiello find evidence for adaptive flexibility in all the "benchmarks" defining our species: "dietary, developmental, cognitive, and social."[21] Moreover, and critical to establishing the motivation for the next horizons of HCI, adaptive flexibility in the human species arose in response to "environmental instability" [2]. As argued by Antón, Potts, and Aiello, the human species did not evolve in "a stable or progressively arid savanna" as suggested in earlier paradigms of evolution, but rather "in the face of a dynamic and fluctuating environment" composed of "diverse temporal and spatial scales."[22] What distinguishes humans from other mammals is our adaptive flexibility, the capacity to "buffer and adjust to environmental dynamics."[23] The significance for our research community is clear: the human species is super-adaptive to "diverse spatial scales" and "environmental dynamics." This new paradigm for evolution, along with Lifton's concept of the Protean self, suggest that we are prepared for, and can in all probability make use of, controlled reconfigurations and adaptions of cyber-physical ecosystems under those life circumstances that warrant their application.

18 Lifton, R. (1994). The protean self: Human Resilience in an Age of Fragmentation. New York, NY: BasicBooks, p.1.

19 Ibid., 14–15.

20 Anton, S., Potts, R. and Aiello, L. (2014). Evolution of early Homo: An integrated biological perspective. Science, 345(6192):1236828, pp.7-8.

21 Ibid., 1236828, 8.

22 Ibid., 1236828, 9 and 1236828, 7.

23 Ibid., 1236828, 7.

7 Many and new places for adaptive beings

Cutting across the diverse perspectives briefly surveyed here, from art and art history, to environmental design, to Greek mythology, to psychology, and to human evolution, is a recognition of the vibrant exchange between the dynamic world in which we live and the intimate and social nature of our being. Central to what it means to be human is to be fluid, resilient, and on the move. The next horizons of human-computer interaction, borrowing Lifton's words, have the potential to cultivate "many and new places" for individuals and groups of individuals facing wide-ranging challenges and opportunities.

For the research community focused in adaptive environments, there are at least a number of ways to arrive at these new places: by selecting a new place among programmed places to match life needs and opportunities; by fine-tuning and then saving patterns of adaption and configuration to create new places; and by allowing the cyber-physical environment to anticipate needs and wants, reconfiguring itself a new place for us.

The new cyber-physical "places" promise to provide inhabitants the means for creating a careful balance between stability and flexibility in a given moment. At their best, these places will afford inhabitants the capacity, borrowing Lifton's words again, to "modify the self to include connections virtually anywhere while clinging to a measure of coherence."[24] What this chapter strives to offer is the recognition that we and the cyber-physical (eco)systems on the near horizon are well matched: diverse, dynamic, adaptive and sometimes blurred. Manifested as health-care facilities, classrooms, workspaces, assisted-care homes, and potentially as mass public transit and road systems (traversed by autonomous cars), the next horizons of HCI will collapse further the boundaries that distinguish us from our surroundings when the conditions suggest (we hope) the greatest benefit to the individuals and the groups inhabiting them.

Obviously the short space of a book chapter is woefully inadequate to elaborate, from six disciplinary perspectives, the motivations for the next horizons of HCI. The intent here, more so, is to offer the adaptive environments research community the impetus to reflect—to assume the "1000-mile view" that permits us *to see* (what we're doing), and to *recognize where we are*. From this vantage, Ivan Ilich saw in new technology "tools of conviviality" fostering "self-realization" and "play."[25] Buckminster Fuller saw a "spaceship earth" that lacked an operating manual that he could write, informed by "long-range, anticipatory, design science" characterized by "comprehensive," not only "specialized thinking."[26] This author sees, with *Superstudio* (figure 2) and John Cage as guides, "gardens of technology" where every "inanimate object has a spirit."[27] *What do you see?*

24 Lifton, R. (1994). The protean self: Human Resilience in an Age of Fragmentation. New York, NY: BasicBooks, p.230.

25 Illich, I. (2009). Tools for conviviality. London: Marion Boyars, p.24.

26 Fuller, R. (2014). Operating manual for spaceship earth. Baden, Switzerland: Lars Müller Publishers, pp.22 and 24.

27 Cage, J. (1980) Mesostic for Elfriede Fischinger. Center for Visual Music, Elfriede Fischinger Collection; and Cage, J. (1990) I-VI. The Charles Eliot Norton Lectures. Harvard University Press

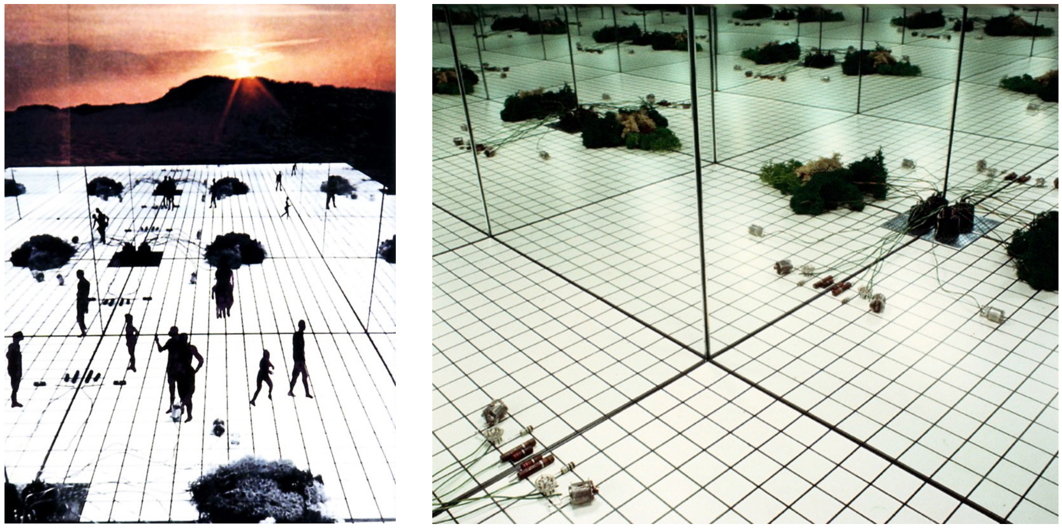

FIGURE 2 Photo collage by Superstudio from the "New Domestic Architecture" exhibition (MoMA, 1972)

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