Three Robot-Rooms / The AWE Project

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Abstract

We describe innovative new work in the development of an "animated architecture." Specifically, we describe our early research aimed at the creation of intelligent, programmable, physical spaces supporting working life. Our research takes advantage of recent developments in HCI and continuum robotics to enable humans to exploit emerging technologies and adaptively alter both the ambience and functionality of their environments.

Keywords

Animated architecture, robotics

ACM Classification Keywords

J.4. Social and Behavioral Sciences, K.4.2 Social Issues, H.4.1. Office Automation.

Today's Workplaces and our Response

The four authors, representing architecture, robotics, human-factors and sociology, are together developing an "Animated Work Environment" [AWE] responsive to the demands of working life today.

Three contemporary conditions compel this reconsideration of the workplace: firstly, society is becoming increasingly digital; secondly, the working population is expanding in range to include, in increasing numbers, older people, immigrants, and those working flexible schedules; and thirdly, the place

figure 1: Brian Alexander's "Concept Work Station" – all design, no IT [1]

figure 2: UNC's "Office of the Future" – all IT, no design [9]

of work now extends well beyond the confines of the office to include the home, the café, the car and the internet. New organizational strategies and tools are clearly required to satisfy the demands of working life, defined today by fluid, decentralized relations across a wide spectrum of people, machines and environments. The efforts of the authors to design, prototype, demonstrate and evaluate a work environment for an increasingly digital society is inherently multi-disciplinary, spanning a number of areas of critical interest to CHI, including human-centered design and innovation, design research, and the social impact of technology.
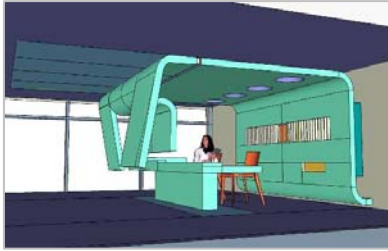
A key goal for the AWE project is to explore the potential for improving the quality of the work experience, both "at work" and "at home," by intelligently adapting the physical environment. We aim to bridge the divide between the work environments envisioned by Information Technology (IT) and those of Design (i.e. architectural, interior and furniture design) – the two fields most directly shaping today's workplace.

While even the most recognized, forward thinking Designers neglect to integrate IT into their work stations, IT investigators, meanwhile, neglect to consider the physical environment in developing IT applications to support work activities. This divide is epitomized by designer Brian Alexander's whimsical "Concept Work Station" (figure 1) from the Museum of Modern Art's *Workspheres* exhibition that treats IT as an appliance set upon, rather than integral to, the work station ensemble; and by an artist's rendering of University of North Carolina's "Office of the Future" (figure 2) epitomizing the general failure of IT

researchers to recognize the physical context as a means to intensify and expand the interaction of people and information technologies [9]. The most promising efforts to envision a work environment responsive to today's demands are IBM's "Blue Space" and IDEO's "Q" [4] both making important steps towards integrating IT and Design. "Blue Space," however, contains few and rather timid "smart" components and a narrow range of embedded IT peripherals, while "Q," better in these respects, only accommodates one user who must be seated, supports a limited range of work activities, and cannot be reconfigured.

In broad theoretical terms, the AWE team is inspired less by these precedents than by the convergence of IT and the built environment posited by William Mitchell; that "The building of the near future will function more and more like large computers" [7], and that "Our buildings will become…robots for living in" [7]. The AWE team also finds inspiration in the work of architect Kas Oosterhuis of the Technical University of Delft who is developing real-time configurability in programmable pavilions [8]. These two visions represent a surprisingly small faction of interest by architectural researchers in programmable, physical environments.

In our recent publication introducing AWE [2], the research team articulated the foundations for an articulated, programmable, physical environment embedded with integrated digital technologies. AWE is envisioned as an ensemble of continuous, morphing surfaces (e.g. walls, task surfaces) controlled by user-friendly interfaces that users adjust along a continuum, providing the sense of being more "at home" or more "at work," more leisurely or more productive, more

efficient or more innovative, while facilitating multiple activities.

Three Concepts for the Robot-Room of AWE

In this current, early phase of developing AWE, the two social scientists of the research team are examining, through surveys and usability studies, the environmental needs, wants and rituals of workers. The architect and robotics engineer are meanwhile exploring the formal possibilities of continuum robots – the expertise of the engineer – as employed in the built environment to create a programmable, "animated architecture" of user-controllable, morphing surfaces. This paper focuses on the first concepts of this "robot-room" – part of the larger, three-year effort by the four authors to create an Animated Work Environment [AWE].

The novel aspect of AWE is its ability to continuously "morph" to accommodate a wide range of user needs by way of its smooth, continuously deformable "smart" and user-controllable surfaces. These intelligent, morphing surfaces are the critical enabling aspect of AWE. The AWE team envisions three alternative concepts of the robot-room employing continuum robots: 1. a room comprised of bending, twisting and shape-shifting ribbons; 2. a room comprised of a continuous surface of triangulated, shape-shifting panels; and 3. a room comprised of shape-shifting ribs. All three concepts share a structure of continuum robots enveloped in a malleable skin.

Robot-Room / Concept-1
As elaborated in our published introduction to AWE [2], the first concept of the robot-room accepts the conventional room where AWE is to be installed as the

figure 3: AWE, Concept-1 [authors]

figure 4: Concept-1, extending the technology of the Continuum Robot to create three types of morphing surfaces: bending, twisting, and shape-shifting [authors].

envelope of the Animated Work Environment. An illustration drawn from that publication (figure 3) shows a typical room with AWE presented as an insertion of a series of shape-shifting, ribbon-like components: a storage wall that bends to become a ceiling that finally becomes four moving arms holding computer screens, and a morphing work surface. The action of these ribbon-like surfaces, bending, twisting and shape-shifting, is presented in figure 4.

Robot-Room / Concept-2
We arrived more recently at a second concept of the robot-room: one as a mostly seamless, three-dimensional envelope rather than the collection of components (e.g. the moving arms for computer screens and morphing work surface of the first concept). This second concept furthers a characteristic of the first concept, where the storage wall bends to create a roof and extendable arms. This continuous surface of the first concept lends AWE the sense of being an environment in-and-of itself, outside the limits of the conventional room. It is an environment, however, not closed but with two open ends created by its extended ribbon that folds along parallel axis (and potentially twists at the four arms carrying computer screens).

The second concept is an envelope, a closed form, with no open ends and what might be called a "blob." A blob, as defined by architect Greg Lynn, "connotes a thing which is neither singular nor multiple but an intelligence that behaves as if it were singular and networked, but in it form can become virtually infinitely multiplied and distributed" [6]. Lynn argues that a blob is an appropriate concept for architecture because the

life of architecture envelopes is dynamic, changing and subject to innumerable influences.

An entire area of architectural research and practice has developed virtual and real "blob" architecture. Given the purported promise of a "blob" in creating a new architecture, responsive to today's demands, it is curious that, "in the end, a form is chosen that is static – static like a sailing boat, which has a form that allows it to perform well in many different situations" [5]

There are numerous examples of blob architecture – *Blobmeister: DigitalReal* is an entire book devoted to them – that employ sophisticated 3-D NURBS software to create complex "blob" forms which are then, sometime, translated into physical, static buildings. The AWE team, however, is concerned in Concept-2 with a more radical research: an opportunity, by way of continuum robots, to realize the promise of blob architecture not as a malleable complex form framed on a computer screen that then becomes static as a physical entity in the built environment, but rather *as a dynamic, user-controllable, environment lifted from the confines of the computer screen and made physical –* an animated architecture response to human needs. This is more the vision of Mitchell and Oosterhuis, realized.

For Concept-2 of the AWE robot-room, the research team proposed to develop, effectively a hybrid of IDEO's Q (figure 5) and a blob not unlike that created on-screen by Greg Lynn (figure 6). Figure 7 provides a sense of this animated work environment that user's morph to accommodate their needs and whims.

figure 5: IDEO's Q [4]

figure 6: A Greg Lynn "Blob" [10]

As a physical, morphing blob architecture, Concept-2, works particularly well with the behavior and characteristics of continuum robots. The morphing of AWE's surfaces will be significantly more general than simple configuration-changing via traditional hinged or sliding joints. Our goal is to enable controllable and fluid movements of continuous sheets (e.g. walls, task surfaces) to suit the needs and whims of the user.
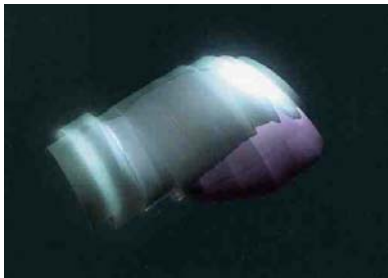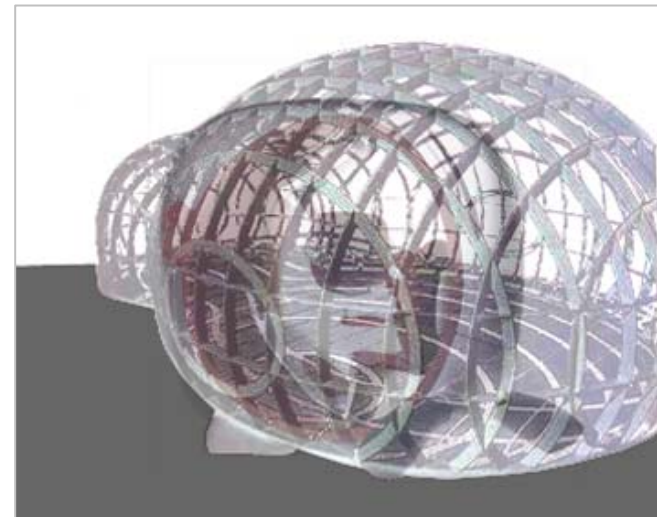

figure 7: Illustration of AWE, Concept-2 [collage byauthors].

Accordingly, we will adapt the emerging technology of continuum robots [11]. Continuum robots feature continuously evolving backbones with no rigid "links" as in traditional robots and architecturally engineered structures. More details of the technology and its possibilities are given in [11]. An example of a continuum robot that would provide the structure of the robot-room and enable its shape-shifting is shown in figure 8. This is an extrinsically actuated continuum
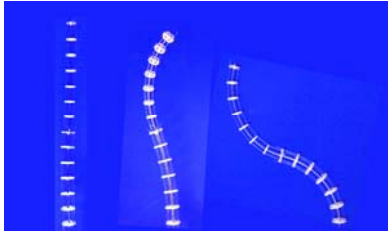
figure 8: Continuum robots in three configurations [authors].

figure 9: The Hyperbody Research Group's "Muscle Body" [3]

robot (external tendons determine the shape). We plan to adopt this technology in our initial designs due to its strength, inherent compliance and ease of shape control.

We propose to use continuum robots as boundary actuators for networks of flexible surfaces which make AWE. Sensors, displays, accessories, etc., will be embedded in the surfaces connected by the continuum robot actuators. Ultimately, we envision a "patchwork" of surfaces, as in figure 2. However, in our initial work, and for the purposes of discussion in this Work-in-Progress, we consider a smaller element of the more general structure, composed of several elements.

Concept-2 shares resemblance with the recent "Muscle Body" pavilion of Oosterhuis and his *Hyperbody Research Group* – a full-scale prototype of a blob architecture comprised of a continuous skin and 26 digitally controlled "muscles" manufactured by Festo, enabling it to shape-shift (figure 9). This prototype robot-room is set-up as a "game" accommodating half a dozen or so "players" whose movements are detected be pressure and proximity sensors imbedded in the skin. As the players move about, their movements are translated into changes of pressure in the muscle-bladders which alter the form of the enclosure.

The AWE team was delighted to discover this inspiring precedent which establishes, for us, a community of investigators exploring the prospects of blob-formed robot-rooms.

In the Muscle Body precedent, however, the functionality of the physical adaptability introduced is limited. The adaptability of the architecture is restricted

to producing compelling visual (but not functional) effects, and the movements are not predictably controllable and/or programmable [3]. These limitations are overcome in our Concept-2, where the more nimble, controllable continuum robot is employed to create an animated architecture responsive to the particular needs and whims of human beings engaged in the particularly intensive practices of working life. The AWE team also envisions that some parts of the blob may be fixed rather than shape-shifting, adding another level of complexity to our efforts. As well, the AWE full-scale working prototype that follows from the three three-year funding cycle of this investigation (briefly described here in the concluding section) will embody a range of "off-the-shelf" Information Technology components that, when suitably exploited, facilitate working life in an increasingly digital society.

Robot-Room / Concept-3
In our research, Concept-3 of the robot-room is simply an extension of the blob investigation of Concept-2 but substitutes a series of shape-shifting O-rings for the triangulated panels. The sense of Concept-3 as a series of shape-shifting ribs is shown in the digital model from the architectural office of Jacob and McFarlane in its design of the (static) café realized within the Pompidou Center (figure 10). Again, the AWE team reinterprets this static form as shape-shifting for Concept-3.

Towards a Total Concept of AWE
In our poster for CHI 2006, the AWE team aims to present virtual and physical models for all three robot-room concepts, and provide comparative evaluation of these. It is important to remember, however, that these formal efforts, principally of the architect and robotics engineer, to develop a programmable, physical

figure 10: Concept-3 as a series of ribs after Jacob McFarlane [10]

robot-room environment will, in the research phase undertaken following the Conference, be adjusted in response to the findings of the social scientists drawn from their surveys and usability studies.

The total concept of AWE is envisioned as a complex application that promises to: 1) integrate IT seamlessly into working life and leisure, home and office; 2) manage the "multi-tasking" demands of individual and groups of workers by facilitating and remembering varied projects requiring different configurations of digital and analog devices and information; 3) allow work environments to adjust for differences in physical and cognitive abilities across users, diminishing the barriers caused by disabilities, age and ageing, and enticing elders and those with special needs to participate in working life; and 4) promote a meaningful sense of connectedness to the place of work, to new technologies and to communities of working people – local and global.

Acknowledgements

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