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AWE: A Robotic Wall and Reconfigurable Desk Supporting Working Life in a Digital Society

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Abstract—**"AWE" is a programmable "Animated Work Environment" supporting everyday human activities, at home, work and school, in an increasingly digital society. AWE features a novel robotic "wall," three horizontal, reconfigurable work surfaces, and embedded information technologies. The video shows AWE as a digital simulation moving through six standard wall-desk configurations, interspersed with still photos and video clips of people interacting with the physical, full-scale, working prototype. The video also shows AWE beginning to behave intelligently as well as users fine-tuning AWE's configurations by gesturing proximity sensors mounted at the hinges between wall panels. Usability testing suggests that AWE clearly adapts to variations in complex activities involving users working or playing in a single physical space with both physical and digital tools and artifacts.**

I. Outline of the Work Presented in the Video

WORKING life is more varied and complex in an increasingly digital society. The Animated Work Environment, or "AWE," employs robotics to modify the physical, everyday "static" workspace, making it more responsive to the demands and desires of workers working today. AWE affords two particular aspects of working life not normally accommodated by other workspaces: first, AWE accommodates multiple users working intimately together on complex computer tasks in a shared physical space; and two, AWE accommodates work activities involving a more seamless and simultaneous engagement with both digital and physical artifacts.

The video begins with various still images of different users, of different ages, employing AWE in collaborative group activities. These activities fall along a continuum of activities defined on one end as "work" and on the other end as "leisure."

From here, the video presents an overall view of the Animated Work Environment showing AWE's key components: a robotic wall and three mobile desk units. The robotic wall supports multiple computer displays which can be mechanically repositioned by the users. The three mobile desk units are set on casters to allow users to separate them, rotate them, and recombine them to effectively "program" three typologies of horizontal work surfaces: a U-shaped form conducive to intensive work accommodating, at once, four workers; a desk for two workers as well as a small meeting table accommodating four people; and a larger conference table which can accommodates up to eight people.

The video continues with a presentation of the moving robotic wall as both a virtual simulation and as a demonstration of the full-scale, working prototype. The AWE wall is a foldable surface comprised of multiple hinged panels. The hinges are actuated by electric motors geared down via harmonic drives. Motion planning of the AWE wall is biologically inspired by the forms and behaviors of such livings things as the cobra and the trunk of an elephant to reflect the "organic" nature of the wall. With eight degrees of freedom, the wall is a novel, kinematically redundant surface.

Much of the video is dedicated to presenting the six standard configurations the AWE wall assumes. Each of these configurations defines a particular physical space, defined by both the morphing wall and the mobile desks, which is most conducive to a particular set of work activities. The number and nature of the configurations were defined following Task Analysis of workers (accountants, school teachers, and architects) working in their familiar physical settings as well as Usability Testing of the developing physical prototype.

Configuration-1 is suited to collaborating, composing and viewing.

Configuration-2 is suited to composing, gaming and viewing.

Configuration-3 is suited to composing, playing and viewing.

Configuration-4 is suited to presenting, lounging and playing.

Configuration-5 is suited to conferencing, presenting and viewing.

And Configuration-6 is suited to lounging, playing, viewing.

The video concludes by demonstrating how AWE's six configurations are fine-tuned by users and how AWE begins to exhibit intelligence. Fine-tuning of the AWE wall is activated by IR sensors mounted to the hinges between panels. From a user's perspective facing AWE's computer displays, the IR sensors on the right activate movement of the panels away from the user, while the IR sensors on the left activate movement of the panels toward the user. It is envisioned that this fine-tuning of AWE's configurations can be saved and later recalled by users. Towards the close of the video, footage of our developing prototype reveals the structural frames of the panels and base of AWE and

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demonstrates how AWE, again activated by IR sensors, intelligently pulls upwards and away from a user who suddenly moves from a seated position to a standing position. As discernable in the video, the sound of the motors are quiet – not particularly distracting to thought or conversation – and the movements of the overall system can be characterized as elegant, graceful and occurring at non-imposing speeds.

Intelligent, reconfigurable, and user friendly, AWE accommodates a wide range of tasks as defined by an Information World.

II. Related Work

AWE takes advantage of advances in IT to anticipate, within a programmable physical environment, the integration of multiple technologies such as flexible screens, input devices, and proximity sensors. AWE is also viewed as part of a growing tendency within IT research concerned with various crosscutting issues related to working life, including the use of multiple displays [1][2], managing mixed-media [3], managing healthcare records [4]; and, more broadly, practices frequently defined as *Computer-Supported Collaborative Work* [CSCW] [5]. In particular, AWE builds on prior research in intelligent environments such as the *Interactive Workspaces Project* and *Roomware* [both 6]. However, unlike these precedents which focus their concerns on the manipulation of information on computer screens, digital tablets and digital white boards of various kinds, AWE sits technologically at the interface between computer technology, architectural design and robotics, where the physical environment (including display surfaces for paper) is also subject to manipulation.

The aforementioned body of research focuses not on robotics but mostly on collections of computer displays, whiteboards and novel peripherals to create electronic meeting rooms; however, AWE pointedly aims to improve the quality of work, both "at work" and "at home," by intelligently adapting – *physically* – to work and leisure activities which employ digital and analog tools and documents. The AWE concept is inspired in part by William Mitchell's vision offered in "e-topia" [7]. Mitchell believes that "the building of the near future will function more and more like large computers" and that "our buildings will become…robots for living in" [7]. An elaboration of the motivations for and ambitions of the AWE Project was previously articulated by the authors [8].

The robotic dimension of the AWE project is enabled, in part, by recent progress in the exploration of continuum "links" to create active spaces [9]. This has been explored by the group of Kas Oosterhuis at the Technical University of Delft, which has constructed programmable flexible spaces framed by continuum structures as a play space [10]. The physical AWE prototype presented here is partly a novel, hyper-redundant robotic system which is instead responsive to urgent human needs associated with an increasingly digital society.

III. Conclusions and Link to AWE Publications

AWE is the result of an iterative design process involving surveys, task analyses, virtual and physical prototyping, and usability testing accomplished by a transdisciplinary team of architects, computer engineers, sociologists and human factors psychologists. Future work involves studying various combinations of sensors to further explore intelligence in this system. The efficacy of AWE has been iteratively evaluated by human factors investigators who have submitted AWE to usability testing. The outcome of these tests suggest that AWE significantly enhances computer-oriented working life in ways that do not exist in other computer platforms by virtue of its novel mix of IT, robotics, and architectural design which intelligently shapes, at once, the computing and physical environments for individuals and for groups. Access to published papers, images, and earlier videos on the AWE project are found at www.AWEproject.org.

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