“Ethics and the Smart Exoskeleton”

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Introduction

A key to the modern standard's rationale is interoperability — among diverse systems, among products from different manufacturers, with future technologies. Standards — complex agreements — provide a framework for productive competition and integratable invention.

When technologies are combined, the implications, good and bad, can be greater than the sum of the parts. With computers and communications playing a role in almost all new innovations, every new technology is in effect a compound technology with compound repercussions. Advances in constituent technologies — microprocessor design, for example — can have a widespread ripple effect.

Buildings, especially large structures, have long served as a nexus of technologies. Today's large buildings are increasingly a collection of independent electronic systems interoperating across a network.

But the future suggests a new approach to architecture, an approach encouraged by the evolving needs of both building owners and society as a whole. Today's architectural islands of automation are giving way to tomorrow's integrated environment, and energy concerns are adding a new, potentially game-changing layer of technology to the mix.

As the modern building evolves into a combination of shelter and complex tool, an interdisciplinary mix of standards offers a way for the constituent technologies to evolve in a constructive, mutually supportive fashion. This standards framework encompasses topics as diverse as building codes, construction methods, electronics and data-processing infrastructure, adaptive software techniques, and electric power.

In addition, as large structures develop more "intelligence" in terms of their ability to control conditions without human intervention, the utopian kernel of technology, the hope of positive transformation through human ingeniousness, threatens to devolve into invasive, dystopian scenarios unless agreements — standards, codes, practices — assure that future structures be designed and integrated with respect to society's most enlightened values regarding privacy, security, and data integrity. With powerful technologies, which can imply an entire world view, come powerful ethical questions.

The Building as Integrated System

For decades now, the various systems that constitute a building, especially a larger, complex structure, have already undergone a major convergence, driven from all quarters. Building users and owners have been requiring that buildings use existing IT infrastructure for new capabilities. They want to manage diverse systems from any location, and they need to manage energy consumption and reduce operating costs and maintenance. A workable environment dictates a common, platform-independent interface for all systems, usually a web interface. And all parties need supplier independence for an increasingly multivendor environment.

A large structure's Building Management System is a computerized control system that monitors and controls various building systems (primarily air conditioning, but also lighting, fire, security, electric power, etc.). Such systems have long been migrating away from proprietary protocols and toward Internet protocols, XML, and other open standards. For example, BACnet (ISO 16484-5:2007, maintained by the ASHRAE SSPC 135), an established protocol for building automation, is an international standard, and the LON protocol (ANSI CEA 709.1) is in the process of internationalization.

This is an example of how standards beget standards. It is the open networking standards, notably the IEEE Std 802 family of standards, that led directly to the explosion of the connectivity enjoyed today and the integration of the Internet into the basic infrastructure of large buildings. Furthermore, this open backbone has led manufacturers in many cases to abandon proprietary protocols and interfaces and redesign for a building increasingly based on open standards.

The Building as Inhabitable Computer

But this embrace of open standards and reliance on a generic IT backbone for the range of services a modern structure is expected to provide are just the beginning. This standards-based foundation is already serving as the launching pad for a range of new, intelligent enhancements to the interior environment.

These enhanced capabilities are increasingly referred to as *smart environments*, in which a collection of linked computer systems coordinate an environment of embedded sensors, controls, displays, and actuators, all aware of each other and responsive to a variety of factors. This is an approach to environmental design that derives from the concept of *ubiquitous* (or *pervasive*) *computing*, which places humans within such a "wired" environment. In a sense, this wholly integrated approach to computing means the eventual end of the computer per se; furniture, everyday objects, light switches, clothing – basically, all objects with which humans interact in a building – can be imbued with intelligence and connectivity, opening the door to a distributed computing environment that detects, learns patterns, offers customized choices to the user, and adjusts parameters automatically. Ironically, the most advanced, futuristic computing environment is one in which the computer effectively disappears as an object in itself, replaced by traditional objects imbued with intelligence. It is helpful to recall that not so long ago the idea of a refrigerator or small appliance with on-board computing power would have generated more laughs than sales.

The concept of ubiquitous computing has evolved separately and partly as a reaction to some of the limitations of virtual reality, but both concepts are in a sense different interface strategies for achieving many of the same goals. VR creates an illusion of an environment with which the user interacts, while ubiquitous computing imbues actual physical objects with intelligence. The pervasive model is location-specific, in that it is physically tied to objects and a space, while the VR model moves with the user. They are both valuable and can work in a complementary fashion.

In effect, an intelligent building can achieve the VR interface's goal of being able to walk through a manipulable smart space. The ubiquitous-computing model has the additional advantage of incorporating sensors that can monitor everything from blood pressure to dew point and adjust physical conditions accordingly. Ultimately, this collection of advanced technologies can serve to customize the building on the fly for different users with different needs, invoking a range of automated agents as needed, depending on circumstances that change continuously.

There have been many projects along these lines, including the House_n endeavor at the MIT Department of Architecture,[1] one element of which is the sensor-laden PlaceLab, a residence "designed to be a highly flexible and multi-disciplinary observational research facility for the scientific study of people and their interaction patterns with new technologies and home environments." [2] IBM Research's Everywhere Displays Project turns a surface into a touchscreen. [3] The MavHome project explored prediction algorithms with the goal of creating "a home that acts as a rational agent." [4] There are many others.

Multiple standards are essential in such a heterogeneous environment, which incorporates device remote control and communication, data acquisition from sensors, and some kinds of decision-making capability based on observation and prediction. Many technologies have to interoperate seamlessly in order for this kind of environment

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[1] http://architecture.mit.edu/house_n/
[2] http://architecture.mit.edu/house_n/placelab.html
[3] http://www.research.ibm.com/ed/
[4] Sajal K. Das, Diane J. Cook, Amiya Bhattacharya, Edwin O. Heierman III, Tze-Yun Lin, "The role of prediction algorithms in the MavHome smart home architecture," *IEEE Wireless Communications*, vol. 9, no. 6, December 2002 pp. 77-84

to work properly, including communications, speech and image recognition, biometrics, various sensors, and networking.

The implications of these complex, interwoven technologies are far-reaching, and, as is too often the case, the line between utopia and dystopia can be crossed without warning. For example, wall-to-wall security in a building can provide safety (or the illusion of safety) for its owners and inhabitants, but it is only a matter of degree before such an environment becomes oppressive and counter to the values of a free society. Islands of control in a sea of freedom will inevitably be good for neither, and the illusion of complete security can easily serve as “the safe bet,” the default position, while the freedoms of the larger society become regarded as luxuries rather than the glue that actually holds society together. When the politics of the buildings we inhabit run at cross purposes to the values of society, the disharmony should serve as a warning. At a certain point, the technologies become powerful enough to transcend the technical and become questions of public policy. No matter how convenient and cost-saving, a “Big Brother” building would be cause for concern. A building can indeed be too intelligent (or not intelligent enough, depending on one’s perspective).

In effect, an intelligent building becomes more micro-society than mere dwelling, and the systems that control the building become more government than mere automation. Perhaps it is the responsibility of the international standards community to address this issue directly and formally harmonize architectural principles with the larger values of society. Standards provide not only the framework with which to create such complex systems but also the opportunity to make them systemically consonant with the values of society. After all, intelligence – real or artificial – can be destructive without an ethical basis.

The Building as Quasi-Organism

A major step in this architectural evolution will be local, decentralized production of electricity. Energy management has long been a central concern of building automation, but new technologies and global realities are poised to alter radically the relationship between a building and the power grid.

Slowly but surely, buildings are incorporating renewable-energy technologies, including advanced photovoltaic arrays and wind turbines. Developments on the horizon suggest a near future in which some buildings generate enough power to satisfy their electrical needs. As the relevant technologies improve, one can foresee the day when some buildings commonly produce a surplus of electricity.

The power grid will probably remain in place indefinitely, but net metering makes it a two-way street. As renewable technologies gain power and efficiency, any structure could become an energy source, and excess generation could be sold to the grid according to market value.

The situation is somewhat analogous to the revolution that occurred when central mainframe computers and terminals gave way to intelligent microcomputers and networks – a revolution embracing resource decentralization and peer relationships among nodes. As we have seen in the computer world, this architectural shift has had massive repercussions throughout society; one might reasonably expect a similar transformation in the area of electricity. Although power systems have long been computerized, this will mark the first time that the actual modern computing/networking model is applied in the world of power generation and distribution.

In this scenario, one would expect a totally computerized energy environment in which a building's systems constantly monitor energy use, energy generation, daily market cost of electricity, and a variety of other factors that would determine — presumably without human intervention — how the building should provide power to its inhabitants in the most cost-effective and environmentally positive fashion. Photovoltaic capability is already being engineered into some building materials, and it's not that far-fetched to imagine at least many of a building's exterior surfaces generating electricity from the sun. Wind turbines can be designed into suitable structures, even undetectably. As battery and other energy-storage technologies improve, a building could decide whether to store surplus electricity or sell it on the open market by using a decision-making process, a process that starts to look like judgment, a continuous cost-benefit analysis in real time.

Such a building-wide system would automatically adjust blinds and curtains, all HVAC parameters, window opacity and reflectivity, and other building elements according to a matrix of considerations, from occupant comfort to angle of the sun to the cost of energy at that moment. Parts of the building might rotate to follow the location of the sun. Structural use of "smart fluids," whose properties change when exposed to electrical (electro-rheological) or magnetic (magneto-rheological) fields, could radically alter a high-rise building's response to an earthquake when it senses seismic activity.

In this scenario, what is now the Building Management System turns into a much more complicated affair. Open design, defined interfaces, and a focus on standards-based interoperability are the cleanest way — maybe the only way — to integrate such a diverse collection of systems in a seamless and reliable way.

One cannot be blamed for seeing such an organic megasystem as somehow alive, a man-made creature using a process functionally similar to photosynthesis to generate necessary energy. The live-in computer becomes the live-in organism.

The Building as Intelligent Exoskeleton

Integrating all the constituent technologies so they behave as a coherent whole, seamlessly and automatically, will come with responsibilities beyond the strictly technical. In fact, this kind of integration, in which the overall system is responsible for a range of functions including creating its own electricity, requires algorithms that could be seen as a primitive form of self — a need for self-preservation almost has to be written into the building's code. The building has to want to survive in some sense, and that survival depends on generating sufficient energy from the environment — creating a bridge between the cybernetic and the biological.

The issues surrounding the politics inherent in an intelligent structure become even more urgent when the building's very survival hinges on its decisions. Naturally, nobody wants a building with its own agenda — the famous HAL 9000 computer made that argument effectively.[5] Only when interoperating systems become independent of human intervention do the truly visionary capabilities become possible, yet when crucial decisions are delegated to machines, one shouldn't be surprised when the machines make unpredictable and maybe undesirable decisions. Again, the space between utopia and dystopia shimmers like a mirage.

This is the final step in a building's evolution from shelter to de facto government, and the global standards community is in the unique position to respond. In such an environment, where all building operations are controlled by complex software, some of which is programmed with elements that at least implicitly define a system's self-interest, closed and proprietary systems become more than a nuisance for systems integrators — they become potentially dangerous black boxes in which important decisions are made without human oversight. Again, the technical becomes political and ethical, and this reality will no doubt become a growing challenge for standards developers and technologists. This confluence of transformative technologies promises that future structures, although superficially resembling those of today, will conceal an entirely different deep structure.

Tomorrow's intelligent building becomes more than an inhabitable computer, more than a man-made organism. It becomes, in effect, a customized intelligent exoskeleton for each of its inhabitants. The optimistic

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[5] Clarke, Arthur C., 1968. *2001: A Space Odyssey*. London: Arrow.

vision might imagine a building that, although more self-sufficient than today's structures, is at the same time less insular and more a part of the community than ever before.

Conclusions

How does the international standards community respond to these challenges? There is no single or simple answer. The inhabitable structure seems destined to become a super-hub to which all infrastructures attach, which is an effective model only if there is transparent interoperability all down the line.

Perhaps there might evolve hybrid standards that address issues now considered discrete and unrelated, standards that address the overall implications of the combination of technologies involved in a massive, complex project.

Perhaps standards might begin addressing issues beyond the strictly technical, including the social and ethical implications of technologies, before implementation.

Naturally, unintended consequences are by definition surprising, and it might seem beyond the standardization bailiwick to confront non-quantifiable issues such as the politics of inhabitable space, but establishing a standards framework for addressing the political and ethical questions raised by interoperating megasystems to which we entrust the human habitat might be necessary if the technologies are to live up to their utopian promise, if the building of the future is to augment rather than thwart human potential. The risks are significant, the opportunities as well.

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