Designing the Infrastructure of Human Building Interaction

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DOI string

Abstract
UPDATED—19 January 2016.

As a global leader in architectural design, Foster + Partners targets the design of memorable experiences for inhabitants while seamlessly integrating the systems required for elegant, efficient operation. Prioritizing this level of integration has required a strong knowledge of the infrastructure required to support a building, a consideration of occupants' desires, and ingenuity to find new ways to combine the two. Developments in sensing, control, and actuation technology, and growing concerns about privacy and data security, opens up new possibilities and challenges for the architectural community to provide enriching experiences and more comfortable, functional spaces. This paper outlines a series of provocations and possibilities through the lenses of interface, control, response, safety and security, and function to help direct research around providing occupant-centric interactive experiences and to prompt discussion in the architecture community about new possibilities for design across scales.

Author Keywords
Occupant-centric design; distributed sensing; responsive environments; architectural design; building infrastructure

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; See http://acm.org/about/class/1998 for the full list of ACM classifiers. This section is required.

Introduction
Foster + Partners has built a reputation on its strength for integrating the complex demands of building operation into designs that prioritize affective occupant experiences while also functioning beautifully. When constructed well, an inhabitant's experience with the built environment should be intuitive and delightful, with infrastructural elements providing comfort, services, and security seamlessly. Designing spaces to provide these experiences has historically relied on making assumptions about the desires of the occupants and constructing static or limited systems to fulfill these assumptions. Once a project is constructed, the wants and well-being of actual occupants can have little influence on the nature of the experience. However, as certain technologies within sensing, distributed computing, and data collection and analysis become more widely available and less expensive, the opportunities to enrich the relationship between humans and their environment increase. Current regimes of habitation have the possibility of moving from simple response to genuine interaction. This paper outlines a vision for how occupants could have a more direct influence on their experience by examining the issue of interaction through a range relevant components: interface, control, response, provision of safety, and function of space. To facilitate the examination, a specific use case – a large commercial office space – is used as a means to outline examples of each component.

Interface
When occupants want to enact a change in buildings, they are accustomed to a common set of techniques, such as thermostats for temperature control, switches for lights and fans, or door or window handles. Buildings in the last few decades have incorporated additional methods focused on automation, such as switches tied to occupancy and proximity sensors, and even more recently through remote access by connecting appliances with mobile applications. Between buildings and humans there is a highly entrenched grammar of interaction.

Distributed sensing increases ways for a building to know about the occupant, as well as ways for the occupant to relay desires to the environment. Embedding sensors and computation systems within building elements could expand the grammar of interface, so that an occupant's desire for state change might be more direct or intuitive. Considering an office space with automated movable partitions, embedding capacitive sensors into walls might permit a simple swipe action to reconfigure a room from a large to a small conference room.

As wearable devices bring environmental sensing closer to an individual level, occupants might no longer need to register discomfort through shifting a thermostat. Collecting ambient air and skin temperature, and possibly other vital statistics, on an occupant-centric basis would indicate that building systems need to adjust to meet thermal comfort demands. Increasing the type of information that can be collected within buildings, and expanding the source of information about building conditions and the actions of occupants could open up the means of human-building interface beyond proximity and active state change. Data could be gathered that would allow a space to best fit current occupants and ensure individual comfort, and more natural grammars of interaction could be developed.

Beyond buildings simply adapting to inhabitants, distributed sensing can also generate a more fine-grained image of the conditions of an environment. Communicating this information in a way that is integral to ones' experience of the space then also generates the possibility for human adaptation to the building. Considering an office space model with flexible workstations that allows hot-desking, employees might select where to work based on the temperature, humidity, solar radiation, and sound level of a space. As opposed to expending energy to provide an absolutely consistent office environment for every employee, control of different spaces could vary, accommodating a range of preferences by occupants self-selecting. Focusing more on the actual range of environments that people prefer could lead to building strategies and control regimes that not only provide a higher level of occupant satisfaction, but could also provide further energy savings from current high performance building practices.

Control

Newer buildings are already operating as cyber-physical systems, with building management systems that use collected sensor data to determine control of physical building elements, including elements that control thermal comfort, lighting, and security. The control regimes for many of these devices are based on static assumptions about occupant satisfaction, schedule, and activity. Changes to the controls of such systems are mostly manually programmed by the building occupant or operator, in response to observed performance.

Emerging building products have begun to introduce control devices that learn behaviours, often based on schedule of manually inputted preferences. The Nest thermostat, for example, records the schedule of occupants preferred thermostat settings and automatically adjusts according to the time of day. Similarly, researchers at the Architecture and Building Systems lab at Eidgenössische Technische Hochschule in Zürich are developing lighting control regimes that adapt to the schedules of individual occupants. Both of these approaches represent a positive development for environments growing more adaptive, but both are addressing single-input, single-output problems, and providing comfortable, engaging occupant experiences typically involves understanding and managing many inter-related conditions.

To create buildings that learn and adapt to human occupants, the principles of learning need to be based on the right questions, and consider the complexity of information that influence human decisions. Many research institutions that target Human-Building Interaction tend to focus on increased energy efficiency while fulfilling focused bands of human comfort. The interconnection between these two principles is extremely valuable, however establishing the goal state of human comfort rarely considers variation in demand based on population. Given an open office condition with desk space for 45 individuals, a standard control regime would be to provide a uniform temperature and ventilation rate across the entire space assuming that all 45 spaces are occupied during working hour. If systems' controls could be more closely coupled with actual occupant data, services could be adjusted to reflect conditions where possibly only 20 desks are occupied and the average preference among the individuals present is for a slightly higher temperature. Such a system could still effectively provide for optimum occupant comfort while reducing resource consumption.

Building occupants may be satisfied for many building services to operate relatively autonomously, but in some cases the desire for input into the system will remain. Collecting information and balancing preferences between multiple individuals within a space will be a critical issue in determining appropriate building response and managing occupant expectations.

Response

Increasing the type and resolution of data available about a building creates a more accurate picture of the building's state, but to actually interact with occupants, some mechanisms are required to generate change in the building. Current building services range both in rate and scale of response, from lighting, which is highly cellular and can change state quickly, to enclosure, which very rarely changes state and can affect multiple people. Building systems are designed to respond to current input devices and control regimes. With more opportunities for collecting information about the building's state and its occupants and control strategies that attempt to balance the concerns of many individual preferences, the physical mechanisms that provide building services require reconsideration to operate at pace that provides a sense of interaction between humans and their environment. Reconsidering basic strategies for how elements of the built environment are provided, such as connectivity, comfort, and enclosure, would open up new possibilities for how spaces can adapt to the range of human needs.

In addition to the physical conditioning needed to make a space enjoyable, advancements in virtual and augmented reality, as well as screen and projection technology, provide new avenues for interactive experiences. As opposed to over-riding or replacing the physical environment, digitally augmenting technologies might be used to enhance the environmental quality of previously less comfortable spaces. In an office where programmatic or spatial demands require a room to be underground, artificial skylights and windows could still provide a sense of connection to the natural environment and might help reinforce healthy circadian cycles. Additionally, augmented reality systems and connected devices might open up new possibilities for the relay of information. Targeting multiple senses for feedback and response by using intuitive aural, haptic, and visual triggers could enhance the interactive experience of occupants.

Safety, Security and Accessibility

The increasing integration of technology into quotidian activities brings additional opportunities but also new concerns. The architecture, engineering and construction industry is one in which the failure or misuse of systems and data could have direct impacts on physical safety and wellbeing – and conversely, in which thoughtful integration of technology could provide substantial benefits. As buildings gain greater agency it is critical that they be designed as benevolent agents and that both the physical and informational infrastructure underpinning them is maintained for the benefit of their inhabitants.

The car industry has recently received significant publicity that underlines the dependency of automobiles on computer systems, from the manipulation of emissions testing through programming, to security flaws in critical computer-controlled safety systems. Building management systems and other contemporary manifestations of building informatics may not have had such a spate of bad publicity but the potential for accidents to create a 'bricked' (unusable) building or for malevolent actors to hack a building for their own purposes are certainly possible.

As computing becomes increasingly ubiquitous, notions of security in the physical and digital worlds must be considered together. Most cities have clear distinctions between public and private space, often codified in law. These distinct spaces in the physical world are accruing virtual counterparts – geo-tagged photos, real-time traffic routing, RFID-based building access records, to name a few. The accelerating rate at which such data is recorded and inter-related is sometimes outstripping clear judgment and precedent about whether these virtual artefacts have the same right to privacy or obligation to publicity as do the sites and agents from which they originated.

Technology can create new opportunities for the use and enjoyment of buildings for those with physical and mental conditions that make access challenging. But it can also increase a sense of inequality if benefits to the able-bodied outpace those to the whole population. Building designers – and particularly those designing public buildings and spaces – will do well to consider the notions of *graceful degradation* and *progressive enhancement* which have been critical to deployment of new technologies in the worldwide web. Both of these modes of design serve the goal of supporting as many users as possible while maintaining graded levels of functionality.

Function of Space

Well into the networked society, the built environment is expected to reflect the spatial and temporal flexibility of every-day life. For example, new media and interaction technologies allow for office spaces to support the new networked mode of businesses spread around the world and operating 24-7. Multi-touch walls and tables coupled with 3d audio technologies based on two-dimensional speaker arrays can provide immersive real-time experiences of collaboration with partners on the other side of the world. Furthermore, such technologies allow for a different type of flexibility dominant in our times; that of multi-use spaces, able to accommodate the most diverse uses. The vision of a programmatically playful architecture can now be realized since a break room can be transformed into a high-tech conference room by noon and host a social event by evening seamlessly. Innovation and creativity in the 21st century lies in the transgression of previously hard boundaries between different disciplines. Smart spaces and ambient intelligence can be used to enhance this communication between different fields via the creation of event-spaces[i]. The emergence of the in-between spaces, hosts to the new and the unexpected, becomes more possible than ever before in an interactive, inter-connected building. True events are only possible when the active subjects, which engage in an interaction, are open to be altered by this interaction and become part of completely new experiences and conditions. Such an 'eventful' interaction can take place between a smart self-regulating space and an active subject such as the human. This would happen through a process of multiple feedback loops between the space and its occupant, where the first would adapt its operating cycles to the demands of the second, and the second would alter and expand his/her actions based on the affordances of the first. The incorporation of such transformative interactions in the building's life cycle has an important impact on the design process as well. The architect is now expected to conceive domains which describe a continuum of alterations instead of static, programmatic and morphological, solutions. He is creating the conditions of change and not the change itself.

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