Paper Title – Author Name - Affiliation(s)

Visualizing Living Architecture: Augmented Reality Visualizations of Sensors, Actuators, and Signal Flows

Authors

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Abstract (150 words maximum)

This paper demonstrates how augmented reality visualizations of data collected via Living Architectures can help introduce the Internet of Things (IoT) to general audiences. The ultimate goal is to empower non-expert users in understanding intelligent systems.

3. Paper Content (1500-2000 words).

As the built environment becomes increasingly more complex and integrated with new technologies—including the emerging Internet of Things (IoT)—there is an urgent need to understand how embedded technologies affect the experience of individuals that inhabit these spaces and how these technologies can be most appropriately used to improve occupant experience, comfort, and well-being. In addition, the IoT provides an opportunity as well as a challenge when it comes to helping users understand how these intelligent systems gather and process information such as sensor data and internal feedback loops.

The Visualizing Living Architecture project aims to help system architects, designers, and general audiences understand the inner workings of tightly coupled sensor-actuator systems that interlink machine and human intelligence. It aims to empower many to master basic concepts related to the operation and design of complex dynamical systems and the IoT. Specifically, it uses architectural blue prints of living architecture installations together with real-time data streams to visualize the operation of Living Architecture installations, see

Figure 1. Created by the Living Architecture Systems Group at the University of Waterloo (Canada), these installations can move, respond, and learn; they grow themselves and are adaptive and empathic toward their inhabitants. Börner's team at Indiana University (USA) adds dynamic visualizations to the installations to help visitors, academics, and designers understand the many sensors and actuators used in the design of complex architectural systems, along with artificial intelligence processes rapidly being integrated into next generation architecture.

The visualizations detail how sensory system input (collected via movement, light, and sound sensors but also cameras) is processed by artificial intelligence control circuits and used to control an array of actuators (sound, light, movement) within the living architecture.

In the initial phase of the project, a Cyclops testbed was setup (see Figure 2) comprising one light sensor (the Cyclops' eye), three actuators, as well as hardware and software required to position and drive the sensors/actuators.

Figure 2: Cyclops testbed

The game engine Unity 3D is used to create augmented reality Visualizing Living Architecture applications (VLA app). The VLA app reads the three-dimensional CAD drawing of a Living Architecture installation, e.g., the Cyclops, together with real-time data streams recorded for this installation. The VLA app can be installed and run on laptops, smartphones, and other mobile devices. It geo-registers the Living Architecture by means of a predefined key image or three-dimensional shape then goes into a data visualization mode which visualizes sensor/actuator positions together with signal flows (Figure 3).

Figure 3: Augmented reality visualization of Cyclops sensor and actuator positions.

Initially, we are interested to answer the following questions: What visual metaphors work best for communicating different sensor and actuator types, positions, and activations? How

can signal flows (type and speed) and processing (local and remote) best be communicated? Does speeding up and slowing down time help gaining a more holistic understanding of human-machine intelligence interaction patterns? What visualizations are helpful for experts aiming to optimize Living Architectures? What extensions, if any, are needed to the Visualization Framework (Börner & Polley, 2014, Börner, 2015) to cover these visualizations?

Future work will also aim to answer: What meaningful and qualitative human-machine interactions can be understood from data? How can we design informative and playful augmented-reality environments to engage untrained users with living architectures? How can we enhance data visualization literacy by exposing users to an intelligent system with the comfort and help of our app?

The research will provide a means to analyze and visualize the underlying dynamics within existing interactive architectures, to understand dynamics between space and people, and its larger social impact. The development of novel interfaces will in turn enable individuals, designers, and architects to modify architectural behaviour for greater agency and more meaningful interaction.

Hi-res images/illustrations (figures) saved as TIFF, JPG or PNG (file size of individual images should not exceed 10MB & Maximum of 8 images in total)
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Figure 1. Details of LASG installation Epiphyte Grove as exhibited Trondheim, Norway (2012)
Figure 2: Unity – a game engine we use to create augmented-reality environments
Figure 3: "Cyclops" – a "miniature" living sculpture with one sensor and three actuators

References/Citations - MLA Style

Börner, Katy. *Atlas of knowledge: Anyone can map*. MIT Press, 2015.

Börner, Katy, and David E. Polley. *Visual insights: A practical guide to making sense of data*. MIT Press, 2014.

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1. **Author's Bio – a) short bio (one sentence) b) Long bio (150-200 words)**

SHORT:

Katy Börner is the Victor H. Yngve Distinguished Professor of Information Science in the School of Informatics and Computing at Indiana University.

Andreas Bueckle is a PhD student in Information Science at Indiana University.

LONG:

Katy Börner is the Victor H. Yngve Distinguished Professor of Information Science in the Department of Information and Library Science, School of Informatics and Computing, Adjunct Professor at the Department of Statistics in the College of Arts and Sciences, Core Faculty of Cognitive Science, Member of the Advanced Visualization Laboratory, Founding Director of the Cyberinfrastructure for Network Science Center at Indiana University, Bloomington, IN, Visiting Professor at the Royal Netherlands Academy of Arts and Sciences (KNAW) in The Netherlands, and Visiting Professor and Mercator Fellow, Department of Computer Science and Applied Cognitive Science, University of Duisburg-Essen, Germany. She is a curator of the international Places & Spaces: Mapping Science exhibit and the author of the *Atlas of Knowledge* and *Atlas of Science* (MIT Press). She holds a MS in Electrical Engineering from the University of Technology in Leipzig, 1991 and a Ph.D. in Computer Science from the University of Kaiserslautern, 1997. She became an American Association for the Advancement of Science (AAAS) Fellow in 2012.

Andreas Bueckle is a PhD student with deep interests in developing theoretical frameworks and creating (immersive) data visualization tools that encourage smart decision making. In his research, he focuses on how data visualization literacy and computational literacy can be improved by engaging students and general audiences in well designed in-vivo studies that aim to improve our understanding of human perception and processing but also learning of data visualizations and computational thinking skills. Being a visual thinker and tool maker by nature, he has collected extensive experience as a video journalist and photographer prior to entering academia.

2. **Author's Portrait**

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