Ada: Buildings as Organisms

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Abstract

Buildings are usually conceived as expressing a static functionality where users are required to adapt to its pre-defined properties. This view of architecture is outdated. Buildings can be conceived and constructed as perceiving, acting and adapting entities not unlike biological systems. Although several existing projects have aimed at developing "smart" rooms or buildings, in most of these attempts information technology is used in a strictly local way. "Ada: Intelligent space" goes beyond this utilitarian perspective and aims to develop a space that can dynamically change its overall functionality and quality through an active dialog with its visitors.

Named after Lady Ada Lovelace, one of the pioneers of computer science, Ada is conceived as an artificial organism that can interact and communicate with her visitors. She is based on current research in neuroinformatics. By means of her senses, i.e. vision, audition and touch, Ada will be able to locate and identify visitors. Her effectors, i.e. lights and sounds, will allow her to provide cues to visitors and express her internal states in an emotional language. Key functionalities of Ada are: to balance visitor density and flow; to identify, track and guide “interesting” visitors; to group selected visitors in space; and to play games with visitors. Ada has to achieve these behavioural goals by establishing active interactions with her visitors.

Ada is being constructed for the Swiss national exhibition Expo.02 (May 15-October 20, 2002) which is held once every 30 years. As an exhibition project, Ada aims to initiate a public debate of the application and implication of brain-based technology on our future society. This paper describes the concepts behind Ada, some of her key sensor and effector technologies, and how this collection of devices is integrated using a neuronal control system. Examples will be discussed from recent tests of this system during the Zürich festival of science and Zürifaescht.

Introduction

From the beginning of civilisation, humans have been installing infrastructure in their buildings. This infrastructure – physical, plumbing, electrical, environmental, communications – is designed to support the intended uses of that building. The users of the building serve as the regulatory intelligence that makes all of the subsystems work together to serve the users’ needs. Until the last years of the 20^{th} century, the structure and organisation of buildings was sufficiently simple and static that intermittent control by users provided more than enough computational power to maintain building integrity and operation.

However, this situation is changing. In many buildings, especially large multi-purpose buildings such as airports, shopping malls and skyscrapers, the number of dynamically modifiable components is increasing sharply. Both the structure and the operation of these buildings are becoming dynamically reconfigurable. Such reconfiguration is expected to occur under constraints of power, resources and the functional requirements of individual users. The growing demand for dynamic reconfiguration of building services is placing increasing demands upon the people controlling those services. To reduce the amount of active human intervention needed to keep things running smoothly, more of the necessary data processing is being delegated to automatic devices. Some of these devices form part of the building’s permanent infrastructure and some are objects (or organisms) that pass through the building with varying residence times. Modern industrialised societies are rapidly filling their buildings with interconnected devices, with an ever-increasing number of subtle interactions and side effects. But what happens when the components of a building reach a critical density in space and interconnectedness? Two things then occur:

1. Users begin to observe correlations between the actions of different subsystems of the building, which reach a certain level of coherence.
2. The overall operation of the building becomes opaque; non-experts are no longer able to control it. They can, however, perform actions on subsystems and observe the consequences, looking for correlations.

Under these conditions, the users of the building must engage in a dialogue with the building in order to achieve their goals, rather than simply controlling a few parameters. In the course of this dialogue, the users begin to treat the building as a single entity, and attribute purposeful cognition to the processing underlying the building's actions. From the viewpoint of the user, the building becomes more than the sum of its shell and subsystems; it appears to be alive. This change in our relationship with artefacts is not limited to buildings. In the future more of the objects we create will become more autonomous in completing more complex tasks.

The project "Ada: intelligent space" is an exploration in the creation of living architecture. It can be distinguished from existing "smart office" or "smart building" projects in four main ways. Firstly, the level of behavioural integration being attempted is far more extensive than in other projects. Secondly, the user interaction with the space is immersive rather than invisible – the building does not quietly serve its users' needs in the background, but becomes an active participant in their lives. Thirdly, the functionality of the space in its interactions with users is not fixed, but time-varying and adaptive. Finally, and most importantly, the space has its own goals which it actively tries to achieve by engaging its users.

Ada is the product of interdisciplinary research into the functioning of the brain at the Institute of Neuroinformatics (INI). The mission of the institute is to discover the underlying principles of brain function and to implement these principles in artificial systems that interact with the real world.

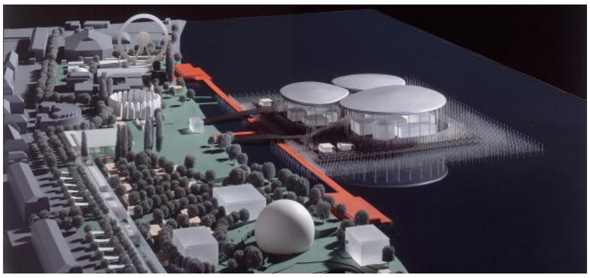

Figure 1: The Neuchatel exhibition area for Expo.02 in Switzerland. Ada will be located under the left-most oval roof structure (from Expo.02).

The Space and its Users

Ada is intended to stimulate public discussion of brain-like technologies and the social implications of their usage. "She" is being constructed as an exhibit at the Swiss Expo.02 in the town of Neuchatel, on a purpose-built platform over a lake bearing the same name as the town (Figure 1). She will function continuously for 10 hours a day over 6 months. The exhibit's components are shown in the table below.

Region	Area	Description
Conditioning tunnel (entry corridor)	65 m^2	Visitor waiting area, including a staged visitor introduction to the components of Ada and their basic functions
Interaction space	175 m^2	Octagonal room where all interaction with Ada occurs
Voyeur area	81 m^2	Corridor around interaction space so visitors can observe without interacting directly
Brainarium	45 m^2	Semi-technical display room showing internal processing states of Ada, using the observatory metaphor. Includes windows so that people can see back into the interaction space.
Explanatorium	45 m^2	Explanation and discussion of key technologies behind Ada
Lab area	73 m^2	Computer room, working area for operators

The overall goal of the exhibit is to entertain and inform each visitor during an average 10-15 minute visit. This is a difficult task, as Ada's visitors will have a wide variety of ages and educational/cultural backgrounds. What they do have in common is that they have paid to see Ada, and expect educational and entertainment value for money. Most will have little expertise in domains such as architecture and neuroinformatics, but many will have widely varying pre-conceived ideas and opinions about these topics, often based on public media hyperbole. Some of these opinions will be technically infeasible or considered irrelevant by "experts". It is of paramount importance that Ada does not disturb her visitors' preconceptions too much without giving them new food for thought. Ideally, each visitor will leave Ada with a positive impression, gained from her entertainment value and a sense of having something novel and challenging to think about regarding the future of brain-like technologies.

Sensors & Effectors

All organisms need some means for collecting information about the world. Ada will be equipped with sensors that mimic some of the capabilities of organisms: vision, hearing and touch. In the space the following sensors are applied:

- **Vision:** Ada has a *vision matrix* – a grid of cameras mounted above the floor pointed vertically downwards that can be used to watch visitors everywhere in the space. A number of pan-tilt cameras called *gazers* are also available for Ada to use for attentional, focused interactions with specific individual visitors.
- **Hearing:** There are clusters of three fixed microphones in the ceiling plane, with which Ada is able to identify and locate sound sources by triangulation. Directional microphones are also mounted on the gazers. Some forms of sound and word recognition will be available
- **Touch:** Ada has a "skin" of hexagonal pressure-sensitive floor tiles [1] that can detect the presence of visitors.

As well as sensing, Ada can also express herself and act upon her environment in the following ways:

- **Visual:** Ada uses a 360° ring of LCD projectors to express her internal states visually to visitors. There is also a ring of ambient lights for setting the overall visual emotional tone of the space. Local visual effects can be created using the RBG coloured neon lights in each floor tile in Ada's skin, rather like a chameleon.
- **Audio:** Ada is able to generate a wide range of sound effects. She expresses herself using sound and music composed in real-time on the basis of her internal states and sensory input. The composition is generated using a system called Roboser [2]. She is also able to perform a simple form of "baby talk" which imitates what she hears from her visitors.
- **Touch:** Ada has a number of pan-tilt movable *light fingers* for pointing at individual visitors or indicating different locations in the space. For reasons of safety and human psychology, we have chosen not to have Ada act on her environment using forceful actuators such as robot arms.

Behaviours & Interactions

Sensors and effectors alone are not enough for Ada to convince visitors that she shares properties of a natural organism. To achieve the feel of an organism, the operation of the space needs to be:

- Coherent
- Real-time
- Understandable to most visitors (the conditioning tunnel plays an important role here in providing initial visitor priming)
- Sufficiently rich in depth of possible interactions that visitors feel the presence of a kind of basic unitary intelligence

To provide for a natural progression in visitor interaction, Ada incorporates at least four basic behavioural functions. First, she will *track* individual visitors or groups of visitors, possibly (but not necessarily) giving them an indication that they are being tracked. At the same time, she will *identify* those visitors who are more "interesting" than others because of their responsiveness to simple cues that Ada uses to probe their reactions. These people are encouraged to form a *group* in part of the space through the use of various cues. When the conditions are appropriate, Ada can then *play* a number of group-based games with her visitors. All the time she evaluates the results of her actions and expresses emotional states accordingly, and tries to regulate the distribution and flow of visitors. Figure 2 depicts an artist's impression of what the interaction space could look like.

It is important to realise that the above scenario is not a static progression, but a set of interconnected, interdependent, simultaneously evolving internal processes. The underlying software is a mixture of simulated neural networks, agent-based systems and conventional procedural or object-oriented software.

Figure 2: Artist's impression of visitor interactions with Ada in the main space (from Vehovar & Jauslin Architektur).

Integration & Testing

Exploring unknown territory in organism-like architecture with a system as large as Ada could not occur without experience with smaller systems. As well as the continuously developing demo space at INI, since 1998 a number of increasingly large public system tests were run to evaluate the feasibility and scalability of the underlying architecture, gauge visitor impressions, and test different interaction scenarios.

One of these tests was at the Zurich Festival of Science (Zurich main station, May 2001, 100,000 visitors), where a system called Gulliver was run for three days in collaboration with the Remote Sensing Laboratories in the Department of Geography of the University of Zurich. Gulliver contained light fingers that could follow visitors, and a floor used as a large collective joystick to control a simulated flight over Switzerland (Figure 3). The main goal of this test was to gain experience in the technical and logistical aspects of running an exhibition.

Figure 3: Overview of activity at the Zurich Festival of Science. Visible are a light finger (top right) and its light patterns (bottom left), floor tile joystick (centre left) and the flight over Switzerland output (top left)

Züifaescht, the triennial Zurich city festival in July 2001, provided the setting for the following system test. This time a rather more Ada-like system called Gulliver II was deployed over three days, including an approximation of a raised “brainarium” area, from where spectators could observe the space and some displays showing the internal operations of Gulliver. Some basic Ada functionalities were tested, such as visitor tracking with floor tiles and light fingers, displaying visitor trajectories, sound localisation of handclap noises and a group football game (Figure 4).

Figure 4: Visitors playing a group football game at Zürifaescht. They are trying to trap the bouncing white tile in the corner of the floor.

Overall, the two tests proved to be very useful in affirming what the team was doing well, such as providing good system stability and adaptability to on-site conditions. The tests also indicated areas where improvements were needed. The two key issues that stood out from the results of the tests were a need for effective visitor flow control, and the importance of communicating Ada’s intentions clearly through the use of effective cues and visitor pre-conditioning sequences.

Outlook

In four months Ada will be operational when Expo.02 opens. But even then her development will not be complete. Apart from the usual tuning period that occurs with any public exhibit, Ada will be performance art and a living experiment. In the background, data collection related to fundamental research will occur using Ada as an experimental platform. The experiences and reactions of her visitors will lead to as-yet unknown changes to her behaviour, some introduced by Ada’s designers and some from Ada herself as she adapts to her visitors. Continuing system upgrades will incrementally increase Ada’s capabilities. So, over the course of Expo.02, Ada will interact with visitors, express herself and grow – just like the other organisms living and working at the exhibition.

Acknowledgments

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