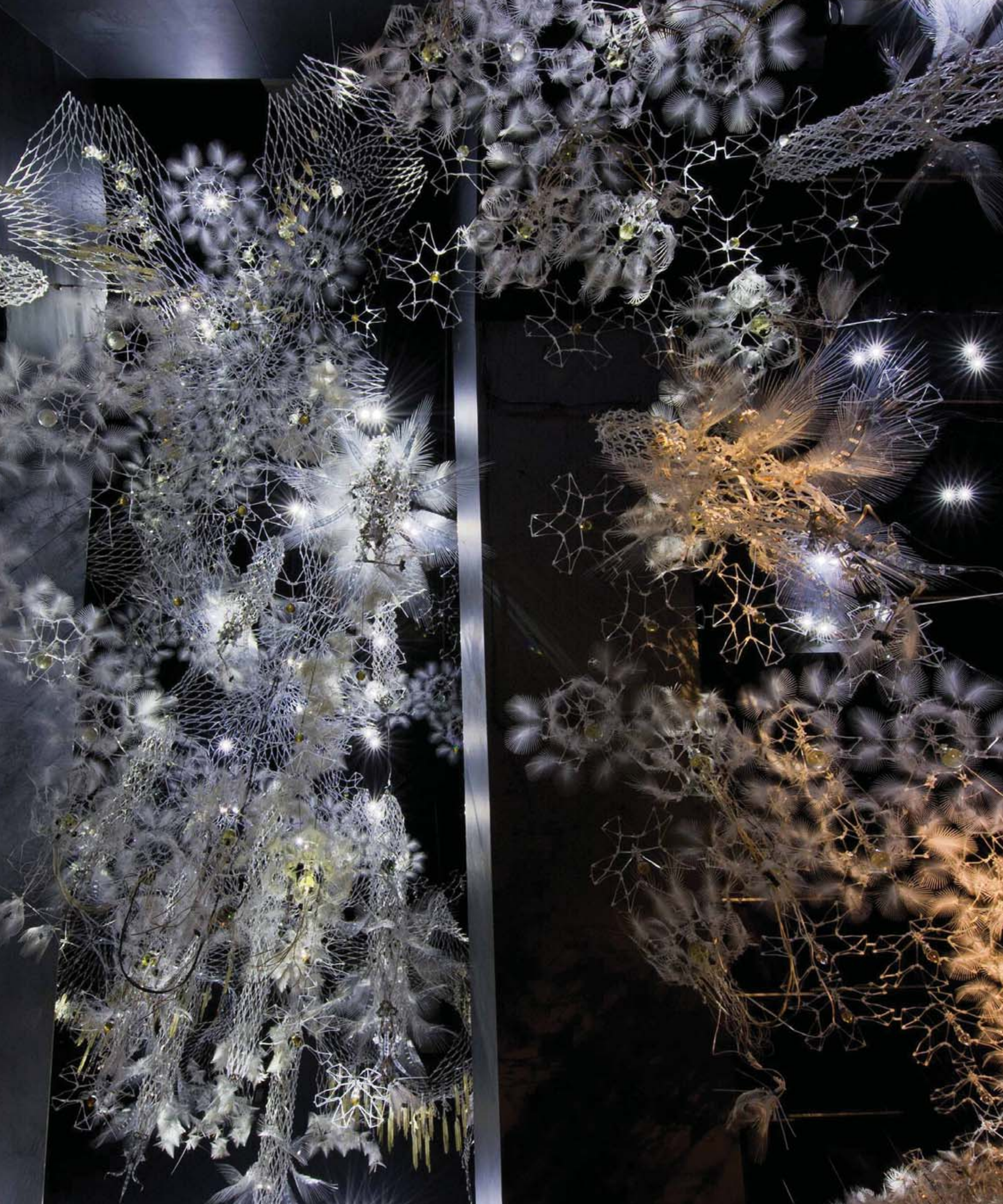


Anticipating Behaviours

Åsmund Izaki, Christian Derix & Lucy Helme

To design spaces for humans to thrive in, one must consider the principles of human behaviour and perception. At Aedas Computational Design & Research (CDR), we have conceptualised and applied new ideas of human-centric architecture through computational design practice over a decade, creating a *new organic architecture*[1]. With this in mind, we developed a parallel project, in collaboration with Philip Beesley Architect Inc., that would complement and interpret the *Hylozoic Series* with the purpose of communicating and predicting its spatial performance over time. The human-centric design approach had to be further expanded in order to address the embedded responsive mechanisms of *Hylozoic Veil* . Within the work, users interact with a near-living system, rather than a mute space, entering into a social relationship with their environment. New languages are needed that help articulate non-verbal interactions that consist of behavioural acts, such as movement in and through space. The social and adaptive relationships between entities can then become the primary material of design, no less physical and real than the pervasive parametric form generation found in digital design practices today.

1 Derix, Christian, and Åsmund Izaki. "Spatial Computing for the New Organic." *Architectural Design* 83.2 (2013): 42-47.

In the best case, spontaneous interactions emerge from bottom-up rules defined in a system. Examples from previous exhibitions show how psychologically complex situations arise from simple acts. For instance, when a particular visitor tried to trigger a response and felt ignored, he would turn around and give up. A delayed reaction then suddenly gave him the feeling *he* was the one being played with (rather than vice versa). In order to make these dialogues intellectually and perceptually stimulating it is important to understand how the behaviour of each agent, whether artificial or biological, is likely to play out spatially, over time. To map these relationships, we must simulate how spatial and behavioural systems mutually affect each other in the Hylozoic

facing page

2 Aerial view of Hylozoic Veil, Salt Lake City, 2011.

environments through a concept we call *co-relation*. This term is similar to the idea of correlation and dependence in statistics, that describes relationships between two sets of data, but rather than defining a causal relationship, the data sets co-exist and influence each other as fields. In fact, it bears closer relation to Hillier's conception of manifold or commutative square:

The architecture of architecture is equally based on such structures which include, for example, the mapping between human behaviour and its spatial containment, or between psycho-physiology and the environmental filter. In design the mapping structures are used as autonomic devices to solve problems. In research these mapping devices are studied in order to understand and improve them.[3]

3 Hillier, Bill, and Adrian Leaman. "How is design possible?" *Journal of Architectural and Planning Research* 3.1 (1974): 4-11.

In the Hylozoic environments the spatial organisation influences the probable movement patterns, but it is at the same time a product of way-finding principles and cognitive processes for decision-making. Similarly, the behaviour of the Hylozoic environment conditions visitors' behaviour: people learn how their actions affect the installation's response patterns, while in turn the response-rules are based on anticipating the actions of the visitors.

INTELLIGENCE IN THE STRUCTURE

According to Habraken[4], built environments are products of control distributions on different levels. In the Hylozoic system, each node controls its own behaviour at the local level, but the global result is also dependent on input from visitors and from other nodes. Even though there is a central system for coordination and communication, the Hylozoic system is cellular at the core. One way to describe it is to say that each node reads and writes space. It reads its environment through sensor values or activations from other nodes and it writes actuator outputs or activation signals to its neighbours. Sensing, actuation and communication combine into one medium. For each instance of the *Hylozoic Series*. the neighbourhood maps describing the network of communication between nodes are uniquely defined. These maps become part of the design and adaption of the system into a specific context, together with other behavioural rules that determine delay timings and recursion levels.

4 Habraken, N. John, and Jonathan Teicher, eds. *The structure of the ordinary: form and control in the built environment*. MIT press, 2000

In the work presented here we have focused on understanding global properties at the system level, in order to address fundamental architectural questions of space and occupation. Representation and visualisation of invisible qualities related to perception and affordance are used to understand the way one inhabits and relates to space, rather than literal simulations of people and their emotions. In *From Object to Field*,[5] Stan Allen suggests the "figure not as a demarcated object, but as an effect emerging from the field itself – as moments of intensity, as peaks or valleys within a continuous field". One of our visualisations developed for this project at the systemic level shows how spatial patterns of activation can form clusters, consisting of singular occurrences, or generate more continuous field conditions in line with the thoughts put forward by Allen. Responses can be generated to trigger people's curiosity to explore more secluded areas by drawing attention to these places. The Hylozoic system might be required to respond differently depending on the number of visitors in the space; a very densely crowded environment versus an almost empty space allows for different modes of interaction.

5 Allen, Stan. "From object to field: Field Conditions in Architecture and Urbanism." *Architectural Design* 127 (1997): 24-31.

The spatial layout itself - how the system is installed in a specific location - also invites a certain use-pattern. The modules can be configured in a forest-like typology where visitors primarily move through the installation on a single ground level. Alternatively, the elements can be mounted so that they are primarily observed from exterior points of views. This was the case with the *Hylozoic Veil* (2011) installation at The Leonardo in Salt Lake City, which was used as the primary case study and site for data collection. *Hylozoic Veil* was installed in a vertical atrium space, where the layout distribution suggested a vertical movement across floors, with escalators as observation. In a few places the visitors would also enter into the environment. Based on this set-up, we explored the possibility of the visitor experiencing the metabolism of the system by peeking into its internal mechanism and observing its responses to external stimuli.

EMERGENT PROPERTIES

Hillier[6] has shown that the topological structure of urban networks can determine local use patterns. A public square might only work if it is connected in a certain way to the rest of the urban fabric, or might become active through the rhythm of workplaces in adjacent neighbourhoods. These properties are emergent in the sense that local conditions in the system influence global states and other local conditions. Similarly, the Hylozoic environments' local activities propagate and affect other parts of the system.

6 Hillier, Bill. "Space is the machine: a configurational theory of architecture." (2007).

The prospect of designing with emergent systems has been an aspiration for computational design in architecture, especially in academia, for decades. In our view, bottom-up systems can be successfully applied to finding solutions and states that are otherwise difficult to create while they also have the capacity to address and meet external requirements. In philosophy, there are generally considered two types of *emergence: strong* and *weak*. In *weak emergence*, global states are reducible to lower-level rules, meaning that the resulting states and behaviours can be studied given the relevant rules and a computer, while properties of *strong emergence* are entirely irreducible and dependent on the actual relationships in the system. If one were to adopt this view, the designer would not be able to affect the system with intent since strongly emergent states could not be simulated or predicted. The designer would then be rendered incapable of any purposeful action, other than choosing an arbitrary set of simple rules with the resulting behaviours being foreign to the design process.

We believe there is much to be learnt from more systematic modelling and simulation in order to refine the spatial set up and behavioural programming based on rigorous explorations. That is the motivation behind developing a means to test and evaluate bottom-up processes according to the tacit knowledge of the designer or other stakeholders. Through simulation and modelling, some of the desirable qualities of the weak emergence of complex systems can be integrated with other strategies, such as agile development methods. The behavioural rules of the system can be refined through simulating the resultant changes. This strategy can be applied iteratively to converge to low-level rules that produce classes of systemic behaviour occurring in certain situations when visitors act according to a generic form. These are not linear static mappings of inputs at a certain time, but play out differently according to dynamic correlations between actors in the space.

PROTOTYPING SIMULATIONS

The Aedas Computational Design Research group (CDR) is responsible for developing three strands of simulations: operational diagrams, spatial field conditions and the geometric environment. This scope could only be addressed through an agile development strategy of smaller prototypes, rather than starting from a narrower problem description and required analysis. Each development worked as a sketch that could provide new information about the problem. The strand was refined through selection and evaluation of prototypes that guided the development. Through this method the prototypes would slowly converge towards useful solutions, while making sure that the simulation elements could be combined later on through user interfaces for control. Disparate concerns that first appeared to be unrelated would later on help to build up informed, layered understandings of the whole system.

From the start it was clear that a framework was needed that would allow different scenarios to be simulated, while keeping parameters open to change in real time. Initial aspects of the Hylozoic environments were encoded and modelled to prepare for simulations. The materials used as inputs were spatial descriptions, such as models and drawings, schematics of all the electronics, the Arduino code to control the sensor-actuator feedback in each microcontroller, and actual data logs of recorded events over four days at the Leonardo venue. CDR created an emulator in Java that mirrored the principles of the Arduino code to implement the same operations virtually, removing the need for reprogramming the modules to tweak the performance onsite. The virtual operations were connected to the spatial layout, specifying each type of module and its location, together with a topological diagram embedded in the neighbourhood maps.

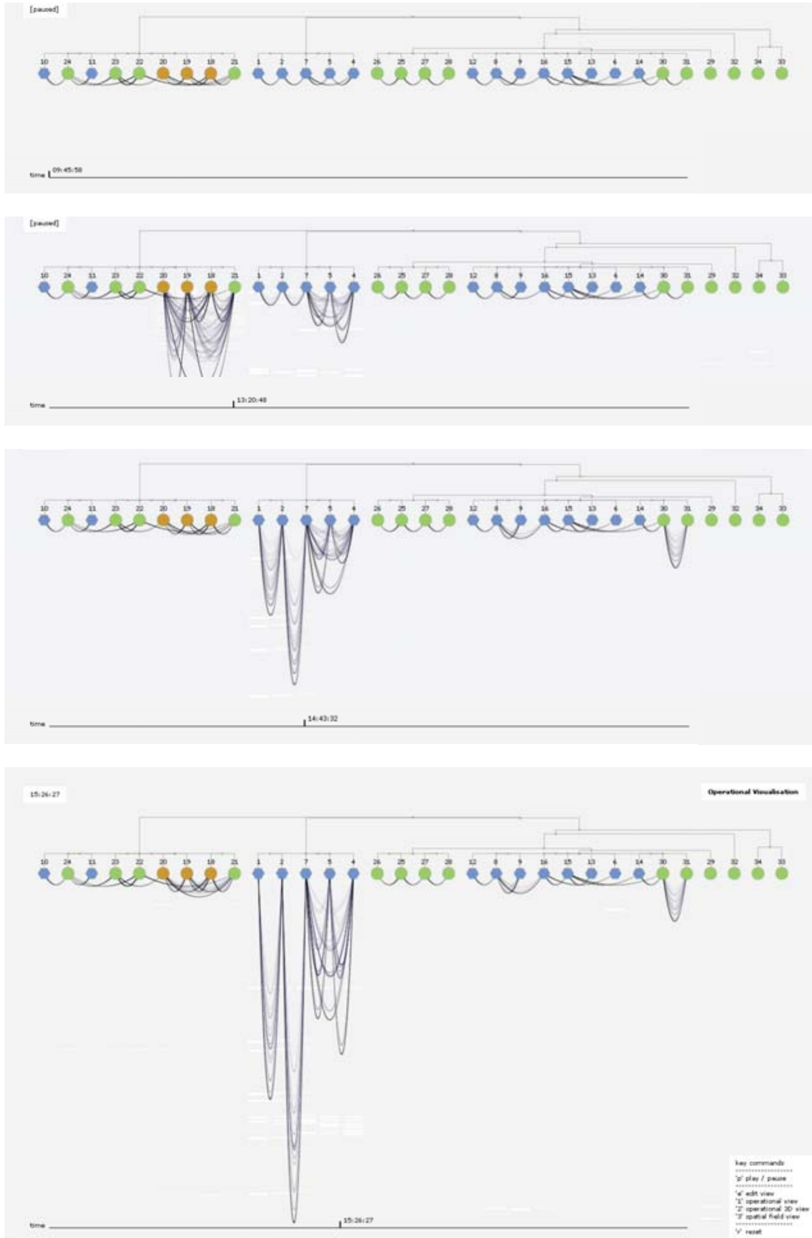
Statistical mappings helped reveal behaviour patterns of both the visitors and the Hylozoic system, through learning about historic operations and activations. Activation levels from the four day-long logs were visualised as statistical histograms to help find general trends in the occupants' behaviours, such as peak activity levels or the general distributions over time. An early operational mapping gave an impression of how behavioural dynamics played out to create temporal patterns that could be enacted visually through computational diagrams. In more refined versions, physics simulations and network models were used to find tactile expressions embodying aspects of the behaviour of the Hylozoic environments. Through other prototypes, CDR defined analogies to the coded behaviours of the Hylozoic system that could represent how it affected its environment. Methods such as vector fields and particle simulations were adapted for analysing these spatial fields.

CONVERGING MODEL

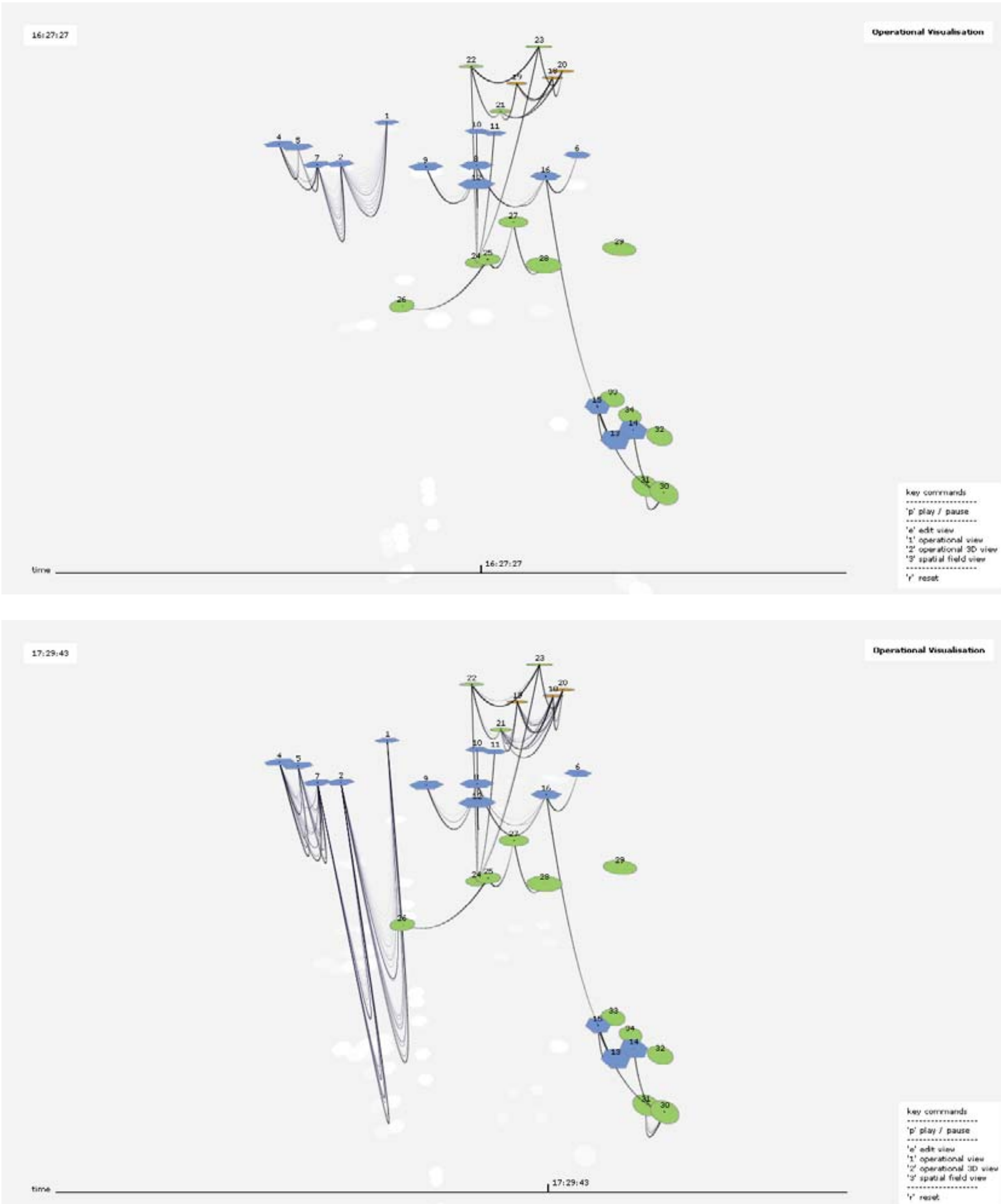
An integrated software application was built that could be used by the design team during planning of a new installation, or for tweaking an existing set-up. It was important to make it sufficiently open to accommodate changes during the design phases. The aim is that both spatial and behavioural design development can be informed by simulating the consequences of different decisions. The application consists of three parts: operational behaviour, spatial field conditions and the operational interface. In the interface, the user can tweak the topology of the neighbourhood maps and other behavioural parameters, with the different aspects synchronised and updated simultaneously. As we explain in the following sections, the operational and spatial behaviour of the system became tangible through dynamic visualisations emphasising different aspects of the system.

The operational visualisation shows how the internal patterns of communication build up differentiated networks over time. The components are first organised according to their topological relationships, so that connected parts are laid out next to each other spatially[7]. A dendrogram representation organises the topologically nearest pairs into trees, showing clusters of communicating nodes. Besides the organisational view, the user can also view the spatial configuration of the nodes as they are mounted in space[8]. In both views, links that are more frequently used increase their physical length to generate a hanging chain model. The resulting expression mirrors certain aspects of the physical structure, in that a catenary geometry is reminiscent of an elevation of a single layer in the Hylozoic installation.

The spatial visualisation treats the environment as a fluctuating field that is reinforced by the Hylozoic actuators[9]. The visualisation is built up as a 3D field that increases in strength for each actuation, but with a slow decay. The spatial intensities are visualised similar to a contour map for terrains; for each threshold value, a semi-transparent contour surface is drawn. This can help the designer plan how to set up neighbourhood maps and delay timings that determine how local sensor activations propagate and generate spatial affordances for the visitors. In visualising activity as a set of spatial intensities, we are trying to reveal the hidden patterns of activation and responses over time.



7 Operational diagram over time. The hanging chains embody the material language of the installation and give an impression of which links are used more often for communication.



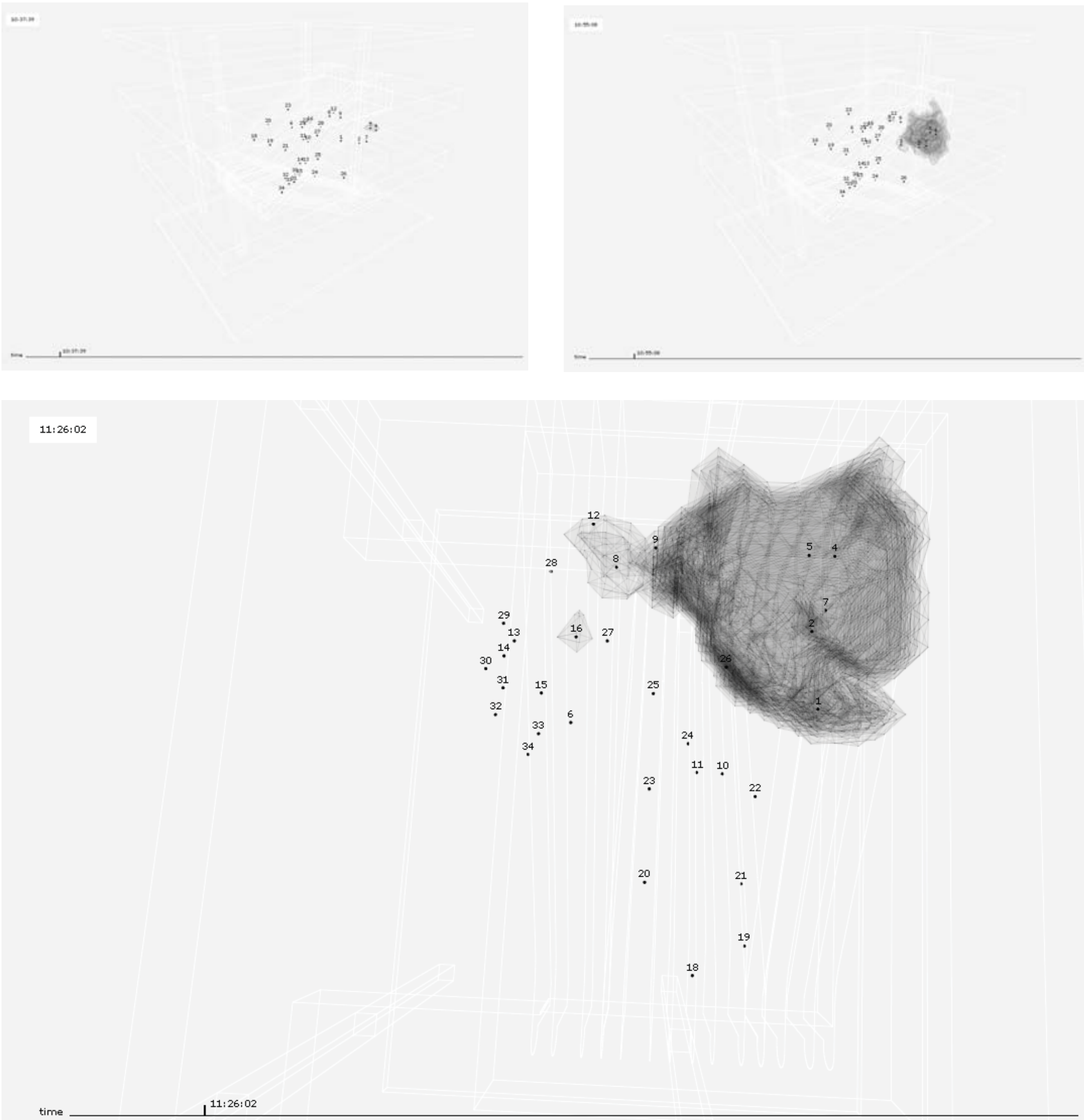
8 Operational diagram as a spatial model. Here the chains follow the spatial structure of the installation, which gives the advantage of being able to overlay the spatial and organisational levels.

The input data, in terms of deciding the scenario or log file that would be used as input, is determined at the time of execution by passing the filename as a parameter. CDR also developed a graphical user interface where some of the input parameters could be dynamically changed immediately during run time. For example, timing delays specify how the input activations trigger responses and communication with neighbour nodes, and can be changed through the manipulation of sliders. The most important interaction element is perhaps the live linking and un-linking of nodes in the neighbourhood maps. What would previously be specified as node IDs in a text file and checked against a diagram of the spatial layout can now be manipulated directly in the 3D configuration. Some data read-outs were also included to suggest quantitative measures of performance.

It is still not fully clear how the research and development described here will feed into the design thinking and development of the *Hylozoic Series*. The set of tools and capabilities offered by the system have still not been fully applied in the design of a particular exhibition, including the workflow for integrating and applying the findings in a systematic way. However we found out early on that in a workshop setting, immediate findings and strategies could be adapted through interactive re-linking, and checking the resulting spatial patterns visually. An important aspect to test, for example, might be how local the responses ought to be, either directing the curiosity of the visitor, or keeping the visitor interested in exploring their immediate neighbourhood.

FUTURE RESEARCH

We have shown here how we use the principle of anticipating behaviours of both visitors and the adaptive environment as a design material itself, and how the process of working with emergent systems can be combined with more traditional design practices, which demand a certain sense of control or predictability. Our aim is to create models where emergence and predictability are symbiotic. In other words, where a bottom-up and top-down model inform each other in real-time. It is important not to design a completely predictable, over-determined solution – what might be classified as overfitting in machine learning - nor a completely erratic system that is incapable of having design intention.



9 Spatial field diagram. The densities of the spatial field build up over time and show how the systems actuations are distributed in the exhibition space.

In further collaborative efforts there is an exciting prospect of embedding learning behaviours in the system itself. How can the *Hylozoic Series* learn from correlations that occurred, between visitors and its own spatial patterns, in order to engage in truly adaptive interchanges as in Gordon Pask's conversation theory?[10] By modifying one's behaviour a dialogue can take place that incorporates information learnt from the other cognitive system. Only then can one create systems that are truly open for deeper communication with humans.

10 Pask, Gordon. *Conversation theory*. New York: Elsevier, 1976.