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Net Work: Lessons from collaboratively designing an interactive artwork

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Abstract

For the last 18 months we have been involved in designing and building the software and hardware for a prototype floating interactive artwork, Net Work, that is constructed from autonomous light-emitting buoys that respond to their physical environment and the state of neighbouring buoys. The completed artwork will be installed at a London location (such as the dockside basin adjacent to Wapping Art) and in further venues across the UK (potentially next to the pier in Herne Bay).
The design process has involved the collaboration of artists, designers, programmers and engineers. Although

Jane Prophet had an artistic vision of the project, initially there were no clearly defined collective goals or individual roles. Consequently, the project has not employed a traditional engineering problem-solving methodology. The project's goals, and the means of achieving them, have developed through an open-ended process that has benefited from the contributions of different collaborators. In this paper we describe some lessons we have learnt from using an interdisciplinary, collaborative approach to build the prototype of Net Work. It is our belief that this approach could be productively applied a large class of design problems where there is no clear, well-defined goal.

1. What is Net Work?

Net Work will be a large scale interactive art installation constructed from 100 autonomous light emitting buoys placed at 1 meter intervals to form a 10×10 grid. The buoys display colours that correspond to their behavioural state, which depends on both the environment (wave motion and light levels) and the state of neighbouring buoys. The artwork will be installed at a London location (such as the dockside basin adjacent to Wapping Art) and in further venues across the UK (potentially next to the pier in Herne Bay – Figure 1).

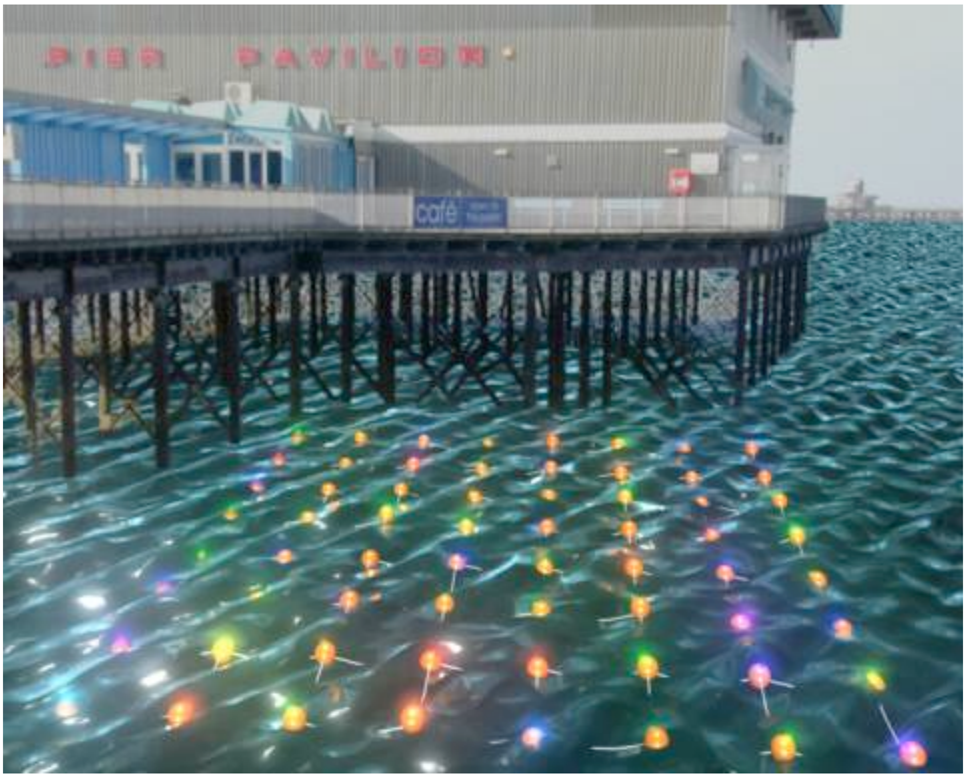

Figure 1: a visualization of Net Work adjacent to Herne Bay pier, UK

Net Work will respond to two types of user interaction: one where the audience is physically proximate; and the second, where a remote audience can affect the installation over the Internet. The local audience can shine torchlight on the buoys, activating their light sensors and thereby changing their state and corresponding colour. For the online audience we will provide software for participants to design their own buoy interaction rules, run them in simulation and see a visualization of the behaviour of the installation. We will save these online designs so they can be downloaded onto Net Work and drive the physical artwork.

2. Building an interactive artwork as a case study for interdisciplinary collaboration

There are two key reasons why building an interactive artwork is a good case study for interdisciplinary collaboration. First, the skills required are often beyond the expertise of one person. There are many pragmatic and aesthetic challenges involved in building an interactive artwork that can only be solved with a wide range of specialist knowledge. The Net Work project has benefited from experts in the fields of: art; design; engineering; software development; and biological sciences. Second, designing and building a large scale outdoor interactive artwork is not a well-defined problem.

There are many unknowns involved in building physical artefacts that need to respond to the environment. In our case the artwork will be situated in a particularly challenging physical environment where it has to float, be autonomous with respect to energy and to keep its structural integrity while coping with all kinds of weather and waves. Just how long the buoys can survive in water is currently an open issue. As Net Work is a public artwork we also have to consider maintenance issues such as how to cope with vandalism.

Furthermore, it may be that an open-ended approach is the only viable option when trying to design systems with even minimal agency; that is, where system components autonomously interact with and respond to the environment in which they are situated. This is because it is often not possible to define in advance all the significant parameters of interactive systems and the environments in which they are operating. Consequently it is hard to predict the behaviour that will result from system-environment interactions. Penny [1, p.416] describes the advantages of an artistic training for building autonomous, interactive systems where the focus is on what he calls 'interactive esthetics' rather than implementing an "externally specified task for the system"; that is, the type of problem that requires an open-ended approach. He argues that an artist is "able to experiment without the constraint of total reliability or a pragmatic work-oriented goal" and consequently they can "open up a wide field of possibilities, some of [which] may ultimately have application or relevance in pragmatic applications" (pp.420-421).

3. How have we designed Net Work?

In 2005, d'Inverno and Prophet set up an Interdisciplinary Research Cluster (IRC) funded by the EPSRC and AHRC entitled: 'Designing physical artefacts from computational simulations and building computational simulations of physical systems' (www.interdisciplinary.co.uk). The major aim of this project was to form a new research community centred on simulation and digital art and design. Specifically, the IRC explores how interdisciplinary collaboration can lead to new forms of design suitable for the challenges of the 21st century.

3.1 IRC methodology

Even though there was some notion of the kinds of issues we wanted to explore in the IRC, we had no strict plans or schedules that specified how we should go about our activity. Initially, after setting up a newsgroup and website, and putting out various calls to join our community, there was very little online discussion. We organised several meetings of a very mixed set of people (including artists, designers, computer scientists and engineers) and decided that in order to explore the issues of collaboration in design it would be best to actually build a physical artefact that had computational and generative elements. Ten projects were proposed and investigated over a two-day workshop. Towards the end of the workshop a vote was taken and the group decided to make a prototype of Net Work, Jane Prophet's proposed interactive installation. Because members of our group felt a sense of ownership, not only of the goal to collectively build a physical artefact, but also of the design process, the traffic on the newsgroup increased significantly. Many members of the cluster gave their time freely to debate the best way to build the Net Work prototype. The advantage of having a large number of collaborators, with a broad range of artistic, computing and engineering skills, was evidenced by the large number of potential solutions offered to software and engineering problems, the subsequent high level debate, and the speed at which the research cluster solved many of the challenges associated with building Net Work. The collaborative process led Prophet to further develop and clarify her core idea and the project evolved as collaborators introduced and argued for new elements.


Figure 2: the 3 x 3 buoy Net Work prototype

3.2 The next phase

Having built a 3x3 buoy prototype (Figure 2), there are still several engineering challenges to be solved before the artwork can be displayed for long periods of time. We expect the hardware design will evolve further through collaboration and experimentation.

In the next phase of the project we are also focusing on two other outstanding challenges. First, how we can get a local and remote audience (via the internet) to engage with the artwork? Second, how can the artwork provide the public with insights into self-organizing systems? Specifically, how can Net Work demonstrate to the public that the interaction of simple elements can lead to more complex global behaviour. The generative software in Net

Work is inspired by team members' research into modelling biological systems, particularly stem cell behaviour [2][3]. A key goal is to make the 'invisible' behaviour of stem cells visible for the public. In the next section we describe our initial approach to these challenges.

4. Giving the public insights into self-organizing systems

One of the general aims of the IRC was to investigate the relationship between the physical and computational worlds. We plan to use questionnaires and explore other feedback methods to evaluate how audiences engage with Net Work. We would like to investigate the following questions: How do we perceive and relate to computational processes embedded in the physical world? Are there clear differences between the way that artists, scientists and the public engage with interactive systems such as Net Work? Can we make the invisible interactions of cells in the human body visible in an artwork? How can we best demonstrate to audiences that simple rules can lead to complex behaviour?

Models of stem cell behaviour published in the literature (including our own) are often based on very simple rules specifying cell-cell interaction and how cells react to environmental changes [4]. Descriptions of these simple rules were posted on the cluster's web site and Jon Bird, one of the cluster's original members, proposed using a very simple homeostat model to drive the activity of the autonomous buoys. The paper gives an overview of this model in the next section, but for full technical details please refer to [5].

5. Ashby's Homeostat Model

Ashby defined an ultrastable system as one that is able to reconfigure plastically in response to any of its essential variables going outside their stable bounds and thereby return the variable to an acceptable level. A biological example is the way that animals keep their body temperatures relatively constant. Ashby argued that in order for ultrastable mechanisms to adapt in this way they necessarily consist of both a primary feedback between the sensorimotor system and the environment and a secondary, intermittent feedback between the essential variables and the sensorimotor system. The secondary feedback reconfigures the primary feedback connections when the systems essential variables go outside of given limits.

Ashby built the homeostat in order to empirically demonstrate his theoretical arguments about ultrastable mechanisms. The homeostat (Figure 3) is comprised of four units, each of which consists of a magnet, electronic circuitry and other physical components. The magnetic field drives the position of a needle on top of the unit that is free to move in an approximately 180 degree arc. The needles' positions represent the essential variables of the system that are to be kept within bounds, which are defined as 45 degrees either side of a central point at the front of each unit. All four units are connected to each other electrically and the torque on each magnet is proportional to the sum of the three input currents from the neighbouring units and a single recurrent connection. The current that a unit sends to its neighbours, and feeds back to itself, is proportional to the deviation of its needle from the central position. No current is passed if the needle is positioned within the stable region and larger currents are passed as the deviation from this region increases.


Figure 3: Ashby's four unit homeostat.

Each of the units can be arbitrarily conceptualised as representing the environment or sensorimotor system of an ultrastable mechanism and the electrical interactions between the units therefore model the primary feedback. When a needle deviates outside of its stable bounds, a secondary feedback mechanism is triggered that randomly changes a number of parameters that affect the movement of the magnet. The magnet in each unit is driven by the activity of four coils, each of which is dependent on the settings of an associated commutator and potentiometer. Three of the coils are connected to one of the input connections from a neighbouring unit and the other coil is connected to the recurrent connection. The polarity of each input, including the self-connection, is determined by the state of the commutator and the proportion of each input signal reaching its associated coil is determined by the state of the potentiometer. The secondary feedback is implemented by connecting a uniselector to each unit. This device has 25 discrete states, each of which consists of a triple of random values, derived from a standard statistical table. This can be thought of as a look up table with 25 rows and 3 columns which provides random numbers to reconfigure the system; in contemporary digital systems a pseudo-random number generator plays a similar functional role. Each of these random values controls the operation of one of the commutator/potentiometer pairs and thereby determines the weighting and polarity of an input connection from a neighbouring unit. There are 25^4 (390,625) different combinations of uniselector parameter values that a four unit homeostat can randomly explore in order to find a combination that leads to all of the units displaying stable behaviour. When each potentiometer/commutator pair is assigned a new random parameter value, the polarity and amplitude of the associated input current are changed. This affects the movement of a unit's needle and in turn, through its electrical connections, the movement of the needles in the other units of the homeostat. Through this simple, random mechanism the homeostat behaves as though it were seeking to keep its needles in central positions in a goal oriented fashion.

Ashby tested the homeostat by first allowing it to stabilise and then taking control of one of the units and reversing the commutator by hand, thereby causing an instability. He then observed how the system adapted its configuration until it found a stable state once more. He argued that the homeostat displayed, "in elementary form, the power of self-organisation" that was analogous to the action of the nervous system: "first the established reaction, then an alteration made in the environment by the experimenter, and finally a reorganisation within the nervous system, compensating for the experimental alteration" [6, p.107].

Recently, there has been a renewed interest in the homeostat and there have been several different applications of ultrastable architectures by Artificial Life researchers. Eldridge [7] implemented neural network simulations of the homeostat and used them as a component in number of generative music systems[1].

5.1 The Homeostat Model in Net Work

The homeostat simulation used to drive the Net Work prototype was based on Eldridge's [7] neural network C code, although different parameter values were used. It was re-implemented in Java in the Processing environment (http://processing.org). The user interface was built using John Beech's MyGUI library. The source code and interactive demonstrations of the homeostat model used in Net Work project are online at: www.cogs.susx.ac.uk/users/jonba/homeostat/instructions.htm.

5.2 Visualizing the Homeostat Activation Dynamics

In the homeostat simulation of Net Work each buoy is represented by a neural network unit. In order to visualize the dynamics of the network the activation of each unit is mapped to a hue value (using the HSB colour model). The hue representing the stable activity was empirically determined so that changes in the activation could be clearly visualized. For example, shifting the stable hue to either the green or red regions of the HSB colour space makes it more difficult to visualize small changes in activity. Currently only the hue of the units is used to visualize changes in activation and saturation and brightness stay constant at 0.

Each unit is connected to its four nearest neighbours (positioned N, E, S and W). The number of connections was restricted in order to minimise the time it takes the network to stabilize. The sign of the weights (range [-1.0, 1.0]) represents the action of the commutator and the strength the action of the potentiometer in Ashby's original homeostat. If a unit's activity goes outside of its stable bounds (defined as [-0.1,0.1]), then the sign and strength of its four connections to its nearest neighbours (but not its recurrent connection) are randomly changed by setting each connection to a different random value in the range [-1.0, 1.0]. The maximum change in activity of a unit in a single time step is initially set to +/- 0.01, but this value can be changed by a user. Each time the homeostatic network is updated a small noise value is added to the activation of each of the units. Initially, the activation of each of the units is set to a random value in the range [-0.03, 0.03].

In the next phase of Net Work the simulation will be developed in a number of ways: the environment model, in particular wave dynamics, will enhanced; we will explore how saturation and brightness can enhance the visualization; and other algorithms, based on cellular automata, will be implemented in order to explore the best way of providing the public insights into self-organization.

6. Lessons learnt

Many challenges facing the 21st century clearly need experts from very different disciplines to work together. However, building and sustaining teams is difficult because these disciplines and their underlying cultures are so different: we lack a shared language and common methodology for interdisciplinary, collaborative research. Furthermore, tangible outcomes are seldom guaranteed when trying to solve open-ended problems. In order to achieve our second phase goals, we have applied for a research grant. This application process required us to describe how the project will be managed using a standard hierarchical structure where there is a clear allocation of responsibilities. This management framework does not facilitate the type of open-ended collaboration that we argue is crucial to the success of the project. In future there will need to be funding streams that allow for much more process-based investigation where the goals

and outcomes develop during the project.
Designing the prototype of Net Work has shown us the benefits of interdisciplinary collaboration. We have learnt two lessons on how art, design, science and technology can collaborate so that innovation emerges. First, there has to be an element of trust and empathy between people working together as interdisciplinary, collaborative teams. Second, a sense of ownership of the process and the product for all contributors is essential: without this the relationship between contributors changes from collaboration to employment.
We need mechanisms for testing and evaluating methods for building interdisciplinary teams. We think it would be useful to have a trained observer, such as a social anthropologist, as part of a collaborative team in order to observe how the process of interaction actually takes place. This paper is a first step in documenting collaborative, interdisciplinary activity and we aim to develope a framework for conducting this sort of research. We would like to hear from others who are engaged in similar projects.

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[1] An excerpt from one of her musical compositions, *Fond Punctions*, can be downloaded from: http://www.ecila.or