SIPHONOPHORE

A physical computing simulation of colonial intelligence organisms

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Abstract. This paper sets out to document the procedural design and implementation of “Siphonophore”; a multisensory digital ecology, mimicking colonial-ordered behaviour systems. The exploration of the notion of “self” in a complex system of highly integrated individuals with reference to the emergence of behaviours from the human-machine-context interaction, is engaged by this open system’s hierarchical articulation of electronics, Arduino boards, sensors and programming routines. User interaction and recorded statistics from the system’s core algorithm are assessed, in relation to the capacity of this prototype to provide an alternative methodology of describing collective intelligence, while presenting a non-standard perspective of body-space interaction and design as entertaining art. The overall impact is discussed in relation to the examined observations, towards a potential advancement to a system of superior contextual understanding.

Keywords. Colonial intelligence; multisensory installation; physical computing; spatial sensing; human-machine interaction.

1. Introduction

Great part of the interdisciplinary characteristics existing in contemporary architectural research has emerged due to the integration of embedded computation into design. Simulations, as a research resource have radically increased in quantity, as well as in the plurality of the concepts explored. Biomimetic-based simulations can operate as design initiatives, but also as analytical tools, such as in the case of agent based simulations, where the ecosystem of agents, integrated and mimicked, may vary from human populations, to flock of birds, swarms or even ant colonies. The main interest however lies, specifically in the simulations of ecologies with self-organizing characteristics, a great fraction of which is conducted in digital environments, populated by agent-members in a binary form, while contextual...
parameters are programmed manually, or via an automatic recreation, such as 3D scanning.

Physical computing is progressing into becoming the medium of programming behaviours into physical objects. Therefore, the transfer of knowledge from physical systems or individual organisms into the artificial designed ecosystems is assessed by a more consistent to nature methodology, which takes into account the object’s physical properties. Open-source platforms, such as the Arduino, have established a straightforwardly accessible connection between the designer and the world of electronics. Fox and Kemp (2009) argue that, designers are diverging from the figural humanoid robots to transformable systems made up of a number of smaller bots, while implementing self-assembly and multi-responsive routines into them. These new systems are accessible for architects to reconfigure them to open systems studying or inventing space.

“Siphonophore” utilizes physical computing via a biomimetic approach, towards the development of an interactive self-organizing artificial system with an inherent capacity to engage human interaction (Figure 1).

In this respect, this paper sets out to document and evaluate the design process and implementation of a multisensory digital ecology in the form of an interactive installation, mimicking colonial-ordered behaviours. “Siphonophore” is a floating system drawing inspiration, both in formal and functional terms, from the homonymous aquatic colonial organism; specifically from the Portuguese Man o’ War (Iosilevskii and Weihs, 2008). It is assembled by untethered transparent helium balloon-like entities that can exist independently or connected to each

Figure 1. Siphonophore floating in an interior space.
other, forming open clusters of collective behaviours from a series of autonomous modular “organisms” that are operating together, within a hierarchy of symbiosis.

User interaction as recorded observations of a communicative experience and the retrieved statistics, such as the quantity of interactions and the detection of physical-human boundaries, are assessed in relation to the capacity of this prototype to provide an alternative methodology of describing colonial ecologies. Thus, to signify a non-standard perspective of body-space interaction and design as entertaining art, with the potential of introducing a new virtually physical, interactive spatial biotope.

2. Background

2.1. PHYSICAL COMPUTING SIMULATIONS AS RESEARCH

While focusing on a relatively new field of research, there are preceding investigations that can relate to “Siphonophore”. A more elaborate comparison with previous work is out of the scope of this paper; however the following examples were crucial in assessing the accomplishment an alternative perspective to physical computing simulations.

The “Flockwall” installation, which is directly related in terms of inspiration and objectives with the presented system, is a physical simulation paradigm of collective behaviour, where an artificial flock of birds-bots is interacting with the visitors, sensing their presence in a predefined configuration outputting different light patterns as reactions to the users (Fox, 2009). “Siphonophore” differs greatly from that approach on the aspect of mobility. The modules in this case are free to “decide” their own route, thus the opposition of live design to static systems is imminent.

Two additional projects have also provided inspiration and practical knowledge. Those formal and technical systems are opposed to the dynamic emergent situations of the examined ecology and the intention of the designers to create not only a straightforwardly reacting system, but a complexity of interactions. The first one is ALAVs: Autonomous Light Air Vessels which consists of a networked objects population that communicates the concept of connectivity among people and the environment (Berk, 2007). In addition, in Festo’s “AirPenguin”, a group of three autonomously flying, “penguins” hovers freely through a predefined air space that is monitored by ultrasounds. The penguins are at liberty to move within this space and explore it (Festo, 2009), with the absence however of direct human interaction.

2.2. THE COLONIAL INTELLIGENCE PARADIGM

Siphonophore is a colonial (Mackie, 1986) aquatic invertebrate comprised of a number of highly specialized individual organisms-zooids that are very similar to
organisms that exist independently in the ocean, but regarding this case are physiologically integrated and specialized in one function which makes them dependable from the other zooids as part of the colony. As Casey Dunn (2009) indicates “Being a Siphonophore is as if you were to bud thousands of conjoined twins throughout your life, some with only legs to move everybody, others with only mouths to ingest food, others with enlarged hearts to circulate the shared blood, and others fully dedicated to the sexual production of new offspring colonies.”

A specific type of the 175 known species of Siphonophores is chosen, both for its morphological attributes, but also for the hierarchical structuring of its functions. This genus is the Portuguese Man o’ War or Physalia Physalis (Figure 2).

3. Siphonophore: A Digital Ecology

3.1. COLONIAL INTELLIGENCE ELEMENTS

The system operates as a tree at the root of which lies the main “brain” of the colony. The rest of the members operate on equal terms, following their inherent “intuition” sensing spatial qualities, reporting back to the “brain”, which coordinates their decisions. All the members can exist independently within the environment, in opposition to their symbiotic character.

The “scout” members of the colony are balloon-like structures, possessing a certain amount of intelligence; flying around feeling people’s presence, while reacting to boundaries and physical obstacles. The locomotion of the entity is achieved by two embedded motors, while sensing is addressed through capacitance sensors and the “feelers”. When stimulated by any kind of incentive, they modify their behaviour, by changing their direction and by altering the blinking patterns of the integrated on the
structure, LED lights. The “scouts” communicate with the “brain” transferring light signals in a vice versa mode. The “brain” can also move in a vertical mode by switching the spinning direction of his central fan, while calculating its distance from the ground by a proximity sensor, and at the same time outputting values of flotation while co-defining along with the LEDs outputs, its behavioural patterns. In the final installation, two “scout” entities were connected with the main “brain” (Figure 3).

3.2. DESIGN THROUGH MAKING

The flotation attribute has sculpted most of the ecology’s geometrical and morphological properties. Each entity had the capacity of bearing the load of an Arduino board, fans, motors and circuits, but also as a result of each member’s independency, a personal power source had to be embedded onto its structure. The
entities could also suffer a process similar to physical death, when the power run out or if destroyed during the implementation. This notion engages the actual delicate nature of Physalia Physalis, combined with the necessity for transparency and reflectivity. Something that made extremely complex to address a material system, which is lightweight and at the same time capable of withstanding the load of the system’s robotics without tearing.

Instead of being a top-down design process, “Siphonophore” is portrayed by the authors as a “design through making” procedure. The final result was the outcome of multiple testing in morphological configurations, overall sizes, materials, types of electronics and hardware, with a total of over forty developed prototypes.

3.3. PHYSICAL COMPUTING MODULES

Programming the behaviour and kinetic attributes, engaged coding in the Java based environment of the Arduino platform. The code is moderately simple as the analogue inputs, such as light sensing, capacitance and proximity are flowing in constant loop from digital commands back to analogue outputs of blinking patterns. Whereas, while coding for performance, the Processing language was utilized to manage and organize the great amount of simultaneous signals into a digital list that would be accessible by the algorithm of the decision making “brain” of the colony. Processing was also employed to code the data collection algorithm, which would map, the position of the colony entities at regular time intervals, enumerate the interactions, as well as the duration this interaction was in effect.

The hardware elements of “Siphonophore” can be comprised to the following. Two 9V motors with fans that placed in each entity, with the exception of the “brain” where only one motor is used. Lightweight cables within each member to utilize light and capacitance sensors, LEDs and the “feelers”; long metallic medium stiffness cables that bend while hitting a boundary, sending analogue signals on the input pins, altering the direction of the “scout” (Figure 4). The “brain” is also connected to a computer, through a USB port in order to record the data from the algorithm.

3.4. ASSEMBLY

Thin transparent polyester film which partially reflects the light signals produced by the LEDs was used in the final assembly. Those films were cut and heat glued together through ironing. In addition, the electronics bearing frames are created by stiff 1.5 mm frosted polymer plastic, capable of bending. The toroid morphology of the “brain” intends to differentiate it from the rest of the entities (Figure 5).

The necessity of cavity development for the robotic elements embodiment into the structure has lead to an organic configuration for the scouts. The arc shaped
polymer component (Figure 6) fits into the lower part of the balloon, while the fans are placed in a symmetrical manner to its two edges, attaining maximum freedom in rotational movements. A valve is also attached to each one of the modules in order to extend the entity into a re-usable helium assembly.
3.5. PROGRAMMING BEHAVIOUR

Mimicking colonial intelligence via a materialized approach is not meant to reduce interaction into the contextual framework but advance it to the human-machine interface. To this respect, the interaction focuses on an anthropocentric—user friendly approach, and can be summarized into a form of linked behaviours. The context and the human user stimulate the inputs of the system, while the ecology processes the data and outputs certain behavioural patterns (Figure 7).

The “brain” adopts certain moods by the processing of the data coming from its relevant position to the ground and the light signals from the “scouts”, returning at the same time light signals to the “scouts” affecting their trajectories.

“Siphonophore” implements a reactive character which is somehow ambiguous compared to the original organism. The collective output of the system appears as aggregated emergence between individual actions rather than being influenced by particular cases of interaction, deduced to its complex symbiotic nature. The recorded data of both human and environmental interaction act as a form of digital psychogeography, a mind-map for the colony’s journey.

![Figure 7. Behavioural diagram of the digital ecology.](image)

3.6. DATA AND OBSERVATIONS

Recorded observations from the installation can be either still images or videos illustrating in a more coherent understanding of “Siphonophore’s” behaviour. Interaction and the user’s reactions, blinking patterns and routes (Figure 8), become more apparent through the analysis of the recorded data, leading to repeating and emerging patterns.
The algorithm of the integrated recording routine, tracks the position of every member of the colony at regular time intervals into a local metric reference system, assisted by a ceiling to floor facing recording camera. By this method, the routes of the “Siphonophore” elements can be exported in a text document, along with the number of interactions, both human and spatial, collisions, as well as the duration of each interaction. Data can then be interpreted into graphical representations, illustrating the complex performance-based mapping of the existing space (Figure 9).

4. Conclusions

In “Siphonophore” the integration of physical characteristics into the illustration of the built-human context, has presented a solidified eco-system of “affordances” and interactions; while the aggregated emergence of collective actions rather than certain stimuli-based reactions, is reinforcing the notion of symbiosis diverging from any preceding approaches existing in the field. As Michael Weinstock (2010) argues “organisms and the ecological systems within which they exist have evolved from the interactions of elements that combine into a variety of ‘assemblies’. Some
‘assemblies’ survive and go on to become integrated into more complex ‘wholes’
that evolve through natural selection.” In the case of “Siphonophore” this evolution
is replicated within the relationship of space and social activity. However any ref-
ences to actual architecture are limited, as this system can be primarily
interpreted as an ephemeral installation.

The hypothesis of a physically digital mimesis can be expanded to notions like
spatial mapping, exceeding the designer’s initial expectations. Possible imple-
mentations in an unambiguous architectural research context would be motivating
and valuable in terms of spatial sensing due to the system’s proved capability to
map through its own perspective of programmed behaviours. That leads not only
to a passive random mapping but in a dynamically defined one, affecting the
mapped, as its playful character attracts human interaction and curiosity. In future
development, “Siphonophore’s” capacity can be upgraded through the implemen-
tation of a learning process algorithm. The use of an Artificial Neural Network
will organize the emerging behaviours of the system and coordinate its perform-
ance. Knowledge is gathered through previous encounters of the systems entities
with spatial boundaries, allowing memory based association of activity, providing
a unique emergent behaviour in the form of an alternative optimization methodol-
ogy for the particular system.

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