DANCE of the BULRUSHES

Building Conversations between Social Creatures

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I, Scott Tucker, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

ABSTRACT

The interactive installation is in vogue. Interaction design and physical installations are accepted fixtures of modern life, and with these technology-driven installations beginning to exert influence on modes of mass communication and general expectations for user experiences, it seems appropriate to explore the variety of interactions that exist. This paper surveys a number of successful projects with a critical eye toward assessing the type of communication and/or conversation generated between interactive installations and human participants. Moreover, this exploration seeks to identify whether specific tactics and/or technologies are particularly suited to engendering layers of dialogue or 'conversations' within interactive physical computing installations. It is asserted that thoughtful designs incorporating self-organizational abilities can foster rich dialogues in which participants and the installation collaboratively generate value in the interaction. To test this hypothesis an interactive installation was designed and deployed in locations in and around London. Details of the physical objects and employed technologies are discussed, and results of the installation sessions are shown to corroborate the key tenets of this argument in addition to highlighting other concerns that are specifically relevant to the broad topic of interactive design.

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ILLUSTRATIONS

Unless otherwise noted above, all photos are by the author.

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To my family:

Simply and unendingly, thank you.

INTRODUCTION

The increased popularity and presence of interactive installations – whether due to the pervasiveness of computing technologies, a groundswell of urban arts and information initiatives, corporate marketing efforts, social virtualization, or a mix of the above and more – is not disputable. From key advertising spaces to corporate headquarters, from academic entryways to museum rotundas, a proliferation of installations bristling with the latest technologies and the flashiest effects vie for public attention, critical canonization, and cash.

In a society glutted with computing, data, and gadgetry, the cross pollination of art, media and technology that has coalesced under the broad heading of "interactive design" was, it seems, inevitable. As such, some are dismissive of interactive design, or resentful of its rise to popularity, but if we view potential as perhaps even more than the sum of its parts, interactive design is rich with possibility. Adroitly employed, technology has the capacity to sense, gather and relate physical and metadata. Digital and informational layers of reality that are not readily visible, known or representable via other media, can be monitored, interpreted and exposed within the frame of augmented reality (Meas 2009). There is a novelty in this facility, especially when combined with the alluring and captivating visual elements common to interactive art.

Some of the sound and the fury of this reality is apparent in the burgeoning popular predilection for art and installations that can be ascribed the designation of "interactive" (Bullivant 2007a). Within this tumult there also, unfortunately, exists a profound risk of mediocrity and insignificance. Much of the current mediascape is dominated by fast-forward programs plying the latest goods and demanding little but purchases and passivity from audiences. If designers, in a rush to respond to the overwhelming demand for novel installations, allow interactive design to be subsumed by mass media's archetypical profit machine, it would seem inevitable that the field will fail to achieve its ideal stature and impact.

However, it is important to recognize that this is still a nascent form with some ways to go before achieving either maturity or redundancy. Moreover, there is, in circles, a keen awareness of the opportunities of interactivity, and a guiding philosophical and research framework has been built over better than half a century by cyberneticians like Gordon Pask and contemporary technologists and artists. Massimo Banzi, co-founder of the Arduino project, stated that, "Interaction Design is concerned with the creation of meaningful experiences between us (humans) and objects. It is a good way to explore the creation of beautiful – and maybe even controversial – experiences between us and technology" (Banzi 2009).

Implicit in this statement is an important opportunity – arguably a mandate – for designers to imbue their efforts with thoughtful consideration and intelligence in order to expand the form and function of interactive exchange. "Between" is the key preposition in that it suggests a reciprocity among humans and technology; it alludes to the difference in communication and conversation as set out by Pask:

> *Communication and conversation are distinct, and they do not always go hand in hand. Suppose that communication is liberally construed as the transmission and transformation of signals. If so, conversation requires at least some communication. But, enigmatically perhaps, very bad communication may admit very good conversation and the existence of a perfect channel is no guarantee that any conversation will take place…Conversation is "Concept sharing."* (Pask 1980)

This distinction between communication and conversation can be leveraged as a roadmap for successful interactive design. Pask was philosophically concerned with the richness and depth of narrative and the exchange of ideas generated through designed interactions and systems, and how systems can empower users to create value in their environment (Haque 2007b). Using his idea of concept sharing as a metric for assessing interactive installations leads to such questions as: What types of dialogue are generated by an installation? How can the installation learn or change from the user interaction? Is a system performing only scripted behavior, or is emergent behavior possible? Likewise, can audience participation inform the nature of the installed system or change the outcome of the interaction?

These types of questions are applied within this paper to assess the success of a number of recent and ongoing projects by Jason Bruges Studios and Daan Roosegaarde and an early project by Usman Haque. The resulting awareness is used to inform the design and implementation of a new interactive piece that seeks a balanced model of design, in which the installation and its visitors are accorded parity and mutual responsibility for creating value in the exchange.

Through creation of this installation, this project specifically seeks to identify specific tactics and/or technologies that may be particularly suited to engendering layers of dialogue or 'conversations' within interactive physical computing installations. It is proposed that by employing truly interactive – not merely responsive – behaviors, a physical installation, even one comprised of relatively simple objects, can generate rich, emergent behaviors.

This thesis project will explore types of communication dynamics observed in the installation, and strives to show that dialogue between objects within an installation is an additional level of discourse that contributes to the exchange built between an installation and its participant audience. It is recognized that the physical objects within an installation initially serve as catalysts or qualifiers for the interaction – for certainly the form of the installation will guide the nature of the discussion – but proceeding from the point of initialization, this exploration maintains that the nature and response of the installation should be determined by the contributions of the audience. Similarly, this project asserts that as an installation grows, it's actions and overtures to the audience should encourage new involvement and consideration from the visitors. In this way, people and objects collaboratively build a mutually enriching dialogue, a Paskian interactive exchange of ideas and actions that creates value for the audience, the installation and the synergistic whole.

BACKGROUND REVIEW OF 'INTERACTIVE' PROJECTS

It seems appropriate and important to analyze a number of actual physical works that have been accepted as interactive architectural or performance installations by the architectural and popular media. Each of the following three projects places physical objects into a space and endeavors to generate an interaction between the installation and its audience/participants.

While this fundamental goal is common to each of the projects, the mechanisms leveraged by the respective works are different, and each succeeds and fails on different counts. By examining and comparing the types of exchanges typical to each of the projects, it is possible to determine a path for forward study and a jumping off point for the physical installation described later in this thesis.

Beyond the three primary projects, a brief description of two physical projects created by the author during the course of the MSc AAC program is presented in order to illustrate the logical progression toward this thesis work.

DOTTY DUVEEN
Jason Bruges Studio
Tate Britain, 2005

The London-based interactive art and architectural installation design firm Jason Bruges Studios was commissioned to create a tactile installation for Tate Britain that encouraged a playful interaction within the museum's gallery space (Bullivant 2007b, Tate Online 2007, and Bruges 2005). The resulting design was comprised of an array of flexible 2 meter high rods placed on a 1.5 meter grid throughout the Octagon in the Duveen Galleries of the Tate for a single day exhibition. Each of the rods was topped by a small sphere that would illuminate in response to the movement in the rod. Due to the sensitivity of the space, the rods were non-destructively mounted to the floor by way of high strength suction pads.

Visitors to the space could touch, push, or bend the rods and the motion was captured by tilt sensors and accelerometers and used to trigger illumination of the rod's sphere. As long as the rod remained in motion, the sphere continued to glow. As such, visitors could move through the installation and activate numerous rods, creating an illuminated trail through the field of objects in the space.

The patterns of movement and interaction were also captured via a "live painting" video system that was installed above the gallery space (Bruges 2005). This aerial view footage was displayed via monitor in the gallery, and showed the real-time motion paths of visitors and the rods in the installation, as well as providing a historical reference of the installation activity.

Viewed as a physical whole, the Dotty Duveen installation exhibits an attractive visual simplicity that is evocative of nature. The forms are plant-like, and the motions in response to visitors' touches are rhythmic and engaging. Additionally, the quantity of objects creates an immersive space for visitors to inhabit, explore and touch.

In fact, according to Frances Williams, curator of the installation, the work was designed to "come alive with contact" (Bullivant 2007b). In analysis of the installation as a tactile art piece, it seems that the goal was met; video footage of the installation shows visitors engaged with the installation, learning how it functioned. Children in particular moved through the space, touching the rods, and creating patterns of light and motion based on tactile engagement with the installation. The Dotty Duveen installation certainly elicited involvement from visitors, but if the evaluation metric is shifted to assessing whether the installation actually facilitated or engendered "conversations" in Pask's sense as discussed above, the installation is not as inspiring.

There was no explicit logical or programmatic relationship between individual wands. Each rod responded only to touch, with no knowledge of, or interaction with any other object in the installation. While this installation managed to engage its audience, at least for short periods, it demanded that the visitors create their own value for the installation. The rods did not vary in response based on the interaction with a single visitor, or the group of visitors as a whole. The installation had no mechanism by which to update or change its behavior. Regardless of the type of interaction initiated by a visitor, the installation was built to return an identical response, and that response was the same for the first visitor of the day and the last.

Jason Bruges Studios created a successful art piece that fostered involvement from visitors, but the prevailing dialogue is more communicative than conversational. The binary nature of the rods' behaviors was easily predictable and interpretable. The physical construction and behavior of the independent objects in this installation is quite compelling, however the simplicity and static behavior of the overall installation is less satisfying. It encourages a line of questioning that the bulrushes project attempts to answer: does a simple, self-organizing intelligence model enable an interactive installation to build real conversations, in which both the visitors and the installation progressively contribute to a bilaterally responsive dialogue?

DUNE LANDSCAPE
Daan Roosegaarde
Multi-Location, 2006-Present

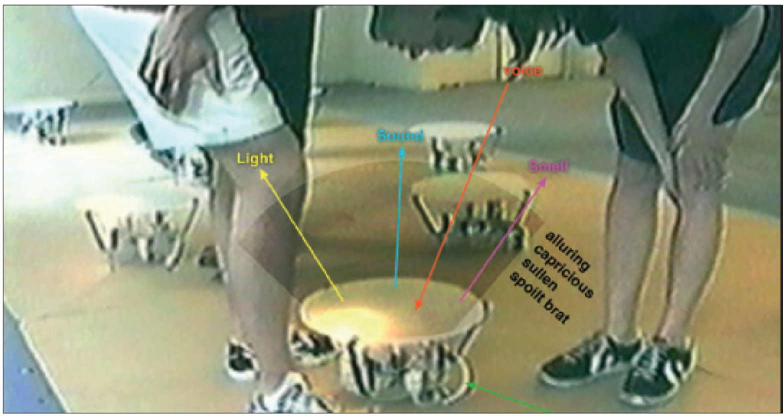
Another installation that builds on a naturalistic theme with the aim of creating an interactive space is the series of Dune "landscapes" by interactive artist Daan Roosegaarde. The Dune installations feature a dense mass of reed-like wands that respond to ambient sound and the motions of visitors within the installation environment by illuminating in locally oriented or installation-wide patterns (Bullivant 2007a).

Different portable configurations of the Dune landscape have been exhibited internationally, and a large scale (60 meter) permanent installation commissioned by the city of Rotterdam debuts in a public space by the Maas river in October 2009 (http://www.studioroosegaarde.net). The principle physical components are arrays of fibres with short, illuminating tips. Hundreds or thousands of these individual fibres are grouped together into bushy rows that are placed along the edges of a hallway or traffic path. As intentional visitors or commuters – depending on the location of the installation, the user demographic differs – move through the installation path, the fibres light up in programmed response patterns. In early versions of the landscape, groups of the fibres functioned as large units, rather than as independent objects. Electronic updates in later versions of the landscapes enabled addressing and scripting the fibres on an individual level. This increased the resolution and aesthetic appeal of the installation, but does not appear to have extended the general mode of communication offered.

In discussing the goals for his projects, Roosegaarde has commented, "I realized for me that the dynamics of the making, I wanted to integrate this more in the identity of the work, [so] that there would be some more relationship between what the visitor was doing and the way the object would appear" (Tate Online 2007). He mentions the Dune landscapes specifically as embodying the notion of sensing visitors' actions and movements within the space, and then acting in response to the visitors. This is presented as an interactive and responsive system.

The Dune projects have achieved broad critical commendation; but actually they offer a fairly flat and limited communication with the public. Current iterations of the landscapes seem to anticipate and respond to a narrow range of inputs with a top-down set of scripted behaviors. The installations do have functionality that enables, for instance, identifying a constant environmental noise and locking down response to that input; however, rather than constituting a conversation, in which the installation exchanges concepts with its visitors, this type of filtering functionality serves to regularize input rather than letting actual environmental conditions impact the system.

Instead of building a dialogue with the public, Roosegaarde's Dune series delivers a one-sided narrative. That narrative has several different threads that can be delivered responsively according to certain inputs, and this variability is forwarded as substantive interactivity, but in reality, the storylines are pre-determined and immutable. Although at a glance the Dune installations seem more intelligent and interactive than the Dotty Duveen exhibit, a closer inspection reveals a rigid and didactic presentation that is delivered to visitors, who have no opportunity to effect any real change in the installation or add value to the exchange.



MOODY MUSHROOM FLOOR
Usman Haque
The Bartlett, UCL, 1996

A third effort that bears consideration was produced by Usman Haque as his final year project for architecture studies at the Bartlett School of Architecture. The physicality and the system design of this project is substantially different from the preceding projects. Haque states that his Moody Mushroom Floor was interactive, which he intends in a Paskian sense, and that it "determined its outputs in relation to fluctuating goals and perceived responses – no behaviour was preprogrammed" (Haque 2007b).

It is without doubt that the physical objects created by Haque are thoughtfully constructed and that they employ a far more advanced and autonomous set of behaviors in pursuit of creating a conversation with visitors in the environment. Each of the eight mushrooms in this installation carried onboard sensor and output mechanisms. The mushrooms arbitrarily used light, sound, or olfactory output in order to attract or repel visitors. The goal of the output was not predetermined, but the mushrooms did gauge the effectiveness of the action based on the movement of visitors around the object. These observations were fed into a series of concurrently running genetic algorithms, and the mushrooms evolved varying response mechanisms determined by the success or failure of the original output as well as the input from other mushrooms regarding successful tactics. Alternately, the objects again employed arbitrary new efforts (Bullivant 2007a and http://www.haque.co.uk).

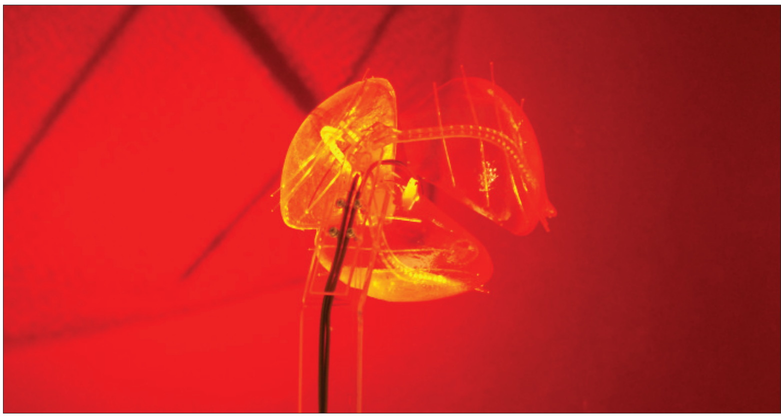
The prevailing goal was for each mushroom to assess the effectiveness of a set of actions, then parlay that assessment to generate an idealized target behavior for itself. The objects' goals tended to reflect their previously successful strategies; mushrooms that successfully attracted visitors adopted a personality geared toward attracting visitors. In this way the various mushrooms personalities emerged.

Within Haque's project, the mushrooms clearly are the more important members of the installation/audience interaction. One can envision that with slightly different mechanics, perhaps an added set of wheels, or a minimal change in performance assessment metrics, the mushrooms would not even need an audience of visitors. They could build behaviors without any input from people.

It is exactly this primacy of the built object that illustrates the shortcoming of this effort when viewed through the lens of creating balanced conversations. Haque's mushrooms generate emergent behaviors from a set of simple rules – and in doing so escape the issues that problematize Roosegaarde's Dune installations – but, these "auto-agents" do not derive any real value from visitors, and do not surrender value back to the audience. The mushrooms fall short of truly sharing a reciprocal role in creation of value, because the objects themselves are too self-determinate. They fail to create an aesthetically potent environment (Pask 1968) because the mushrooms do not derive any substantial value from exchanges with people.

Despite this criticism, Haque's moody mushrooms offer an interesting and informative example of emergence within a physical computing installation. The use of tactics based on unscripted input is quite satisfying, and points to the challenge of building an installation that more completely involves the audience participants in determining the growth and form of the environment. Indeed, it points to a challenge that Haque himself distilled in his comments about Pask's relevance to modern architecture: "It is about designing tools that people themselves may use to construct – in the widest sense of the word – their environments and as a result build their own sense of agency" (Haque 2007b).

It also is deemed fruitful to briefly review two projects built by the author earlier in the MSc Adaptive Architecture and Computation program. These pieces provided an intellectual introduction to the final thesis project, and each represents a foundation stone upon which this final project builds.



BASHFUL FLOWER
Author
The Bartlett, UCL, 2009

This rapid prototype object was built to represent the character "Bashful" from the *Snow White and the Seven Dwarves* tale. The flower moved and opened and closed its petals in response to people that it "met". Visitors could greet the plant by swiping an RFID card over a reader that was attached to the flower. True to its name, the Bashful Flower was reticent to engage with new visitors, it closed its petals, quickly turned away, and glowed a bashful red color. If a visitor persevered, eventually the flower – which stored a record of the "visits" from each unique RFID card – would become friendly, turn toward the visitor and open into a bright blue bloom. Friendship only lasted so long though, as the flower's memory was intentionally short, thereby creating a new set of circumstances as old friends tried to regain the plant's favor.

In form and function, the Bashful Flower was emotionally evocative and psychologically intriguing. From only six programmed behaviors, a wide range of interactions were generated. The Bashful Flower carried on a rich dialogue with visitors, and even exhibited limited learning abilities. That said, the flower had no mechanism by which visitors could substantially contribute to the object's form. Visitors could change the plant's human community, but the plant, as a single object had no machine community that could be impacted by visitors directly or by way of other members of an object network.

DIGITAL WISTERIA
Author
The Bartlett, UCL, 2009

Built as part of a digital ecology in which the occupant objects created light-based conversations, this interactive Wisteria exhibited the natural phototropic quality of plants; it was attracted to light sources within the environment and would move its leaf stems in the direction of the greatest illumination. The plant also contributed light to the ecology by blooming in ideal conditions. Each of the petals in the bloom stem contained fibre optic strands that distributed light from an onboard superbright LED.

Since the primary intended audience for this piece was comprised of the other objects within the ecology, less attention was paid to having the Wisteria develop psychologically rich behaviors aimed at human visitors. However, an explicit design goal was to incorporate sufficient physical complexity and realism into the built model that it provided a compelling piece and inspired interest from the human audience.

Beyond audience engagement though, the Wisteria was designed to function as an organism comprised of independent parts. Whereas the Bashful Flower was a single, complete entity, each of the Wisteria's individual stems exhibited autonomous local phototropism, but the quality of the light received by each stem was then intended to be communicated to the other stems in order to enable the organism as a whole to optimize its light gathering performance. In this way, the wisteria would update and modify the nature and behavior of the whole organism based on simple physical rules and local conditions experienced by the parts.

METHODOLOGY

A growing sense of this researcher leading into this project – one that has been corroborated by this research effort – is that many interactive and physical computing installations place demands and return value in either overbalanced user-centric or object-centric orientations. Within the Dotty Duveen project , the physical objects catalyzed the activity in the installation, but beyond contributing an initial novelty, the rods provided little value. The task of generating value fell squarely on the exhibit visitors, who were required to continually fuel the exchange.

By comparison, the Moody Mushrooms could easily evolve into solipsistic objects that need no contribution for the outside. Their behaviors, albeit unregulated and emergent, are so self-contained as to limit true interactivity between the installation and its visitors. Moreover, the value created by the mushrooms also is self-contained. It is not shared with or surrendered to any members of the environment.

The experiment detailed below attempts to respond to a challenge that seems manifest: to build an installation that takes on its form based on the contributions of its visitors and then communicates novelty and value to the visitor/contributors. In doing so, the installation opens the door to a balanced conversational exchange.

More rigidly defined, the goal of this project is to build an interactive installation comprised of visually interesting objects that operate independently and are governed by simple rules. These objects gain an awareness of the other objects in the installation by way of user interactions, and by again employing simple rules, the individual objects leverage user input to build a distributed awareness within the installation as a whole. As the network of objects continuously organizes (and reorganizes) itself based on user interactions, it is able to offer a richer user experience that simultaneously can provide a network-wide status snapshot for visitors, as well as suggesting different motivations for future interactions.

To achieve the goals of this study, eight independent physical objects – bulrushes – were crafted to form an outdoor deployable interactive installation. The bulrushes were designed to be attractive, emotionally evocative objects governed by very minimal rules of behavior: each bulrush would illuminate in response to being touched by a visitor. As visitors move through the installation touching other bulrushes, the plants illuminate in turn and wirelessly announce that they have had a visitor. Through this series of touches, human visitors build associations between the bulrushes in the installation.

A key component of this strategy is that each bulrush requires the intercession of a visitor to build community ties. As visitors create network patterns, the plants begin to respond to any individual contacts as a continually updating group. The plant network begins to return more expansive and diverse replies to visitor interactions.

It is important to note that the bulrushes have no specified goals that govern possible interactions. They are not motivated to attract visitors or to reward certain behaviors. An explicit design parameter of this experiment was to minimize and simplify rules and behaviors wherever possible, with the desired benefit being an increased observability of any emergent behavior patterns within the installation. To this end, the bulrush behaviors are modeled on the physiological rules that govern physical neural networks.

The sections below detail the physical design and construction, technologies employed, behavioral rules implemented in the bulrushes installation, and a list of performance evaluation metrics.

Project: Design and Construction

The lithe natural beauty and winsome movements of bulrushes (genus *Typha*) swaying in a breeze inspired the form of the objects for this installation. Continuing the naturalistic theme of the Bashful Flower and the Digital Wisteria projects was aesthetically, as well as intellectually, appealing. It is this researcher's opinion that objects taking their design cues from nature can provide a ready point of affinity for viewers/participants, and can increase the accessibility of digital installations.

Initial concepts for the bulrushes were physically and materially elaborate in an attempt to very closely replicate the natural objects. Each bulrush was built on a medium height plinth that would be used to house the mechanical actuators and electronic components. The objects were to incorporate ultrasonic proximity sensors to "see" visitors within the installation. Behaviors of this early concept were never fully developed, but involved having the plants engage in various spinning and undulating motions intended to attract visitors and then engage them in an unchoreographed dance. After some review, however, the initial design concept was set aside in favor of objects that offered a more tactile engagement with visitors, and subscribed more fully to the design goal of having simple objects governed by simple rules.

The proximity sensors were eliminated in favor of a motion sensor that indicated when the bulrush was touched – and consequently moved off axis – by a visitor. Since physical touch is a readily interpretable mode of engagement, this design transition was intended to eliminate abstraction and learning requirements. Visitors could easily understand the relationship between touching a plant and having the plant illuminate in response. The Dotty Duveen installation had already proven the success of this type of interaction, so there was little perceived risk in adopting it as the main input type for the bulrushes.

Having accepted touch as the input type, the physical form of the bulrushes migrated toward that of Bruges' objects for the Tate installation. An illuminating cylindrical flower element was carried over from the initial bulrush design concept, but in lieu of a manufactured plinth, the bulrush was reconceived to use a simple, flexible main shaft that would attach securely to the ground via a spike of some sort and extend to a height that positioned the bulrush flower roughly at eye level for an adult visitor.

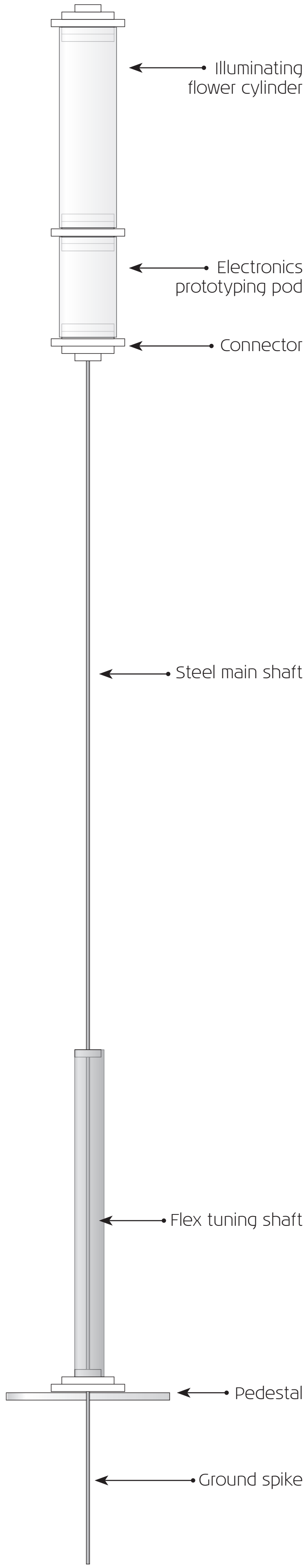
Identifying the correct material for the main shaft was paramount for achieving the desired quality of motion from the bulrushes. The aesthetically ideal movement would be damp, like an inverted, flexible pendulum, but with sufficient elastic memory to a return the bulrush to perfect upright center within 10–20 seconds depending on the force of input. Initial material selection focused on different gauges of PVC tubing, however tests of 1.5 and 2 meter lengths of PVC quickly showed that the material was too rigid and would not be able to provide the desired flexibility and quality of motion for the bulrushes. Elastic knuckle joints and flexible mechanical hinges also were considered, but after several unsatisfactory designs, this concept was discarded in favor of a simple 6mm stainless steel spring rod. Again, applying the mandate of simplicity proved to be of great value to this project.

Migrating to stainless steel rod provided a quality of motion and elasticity that was more appropriate for the bulrushes, and eliminated the need for a separate ground stake. The rod was cut to 1.5 meters; which provided 130cm of length for the main shaft and an extra 20cm that extended below a small round pedestal foot and served as an integrated ground spike to keep the bulrushes from toppling over. The final flex of the rod was tuned by attaching a short PVC tube sheath from the footer pedestal and the stainless rod. This provided better return to center performance for the plant once the flower unit was attached.

Perched atop the stainless rod, the translucent frosted acrylic "flower" is the focal point and interactivity center of the bulrushes. The flower houses all of the electronic components of the object and illuminates in response to a visitor's touch via an embedded RGB LED. It was important for the aesthetics of the installation that the illuminated flower produce an attractive, soft glowing light. In order to attain the desired quality of light, clear cast acrylic tubes were sandblasted to a frosted finish that nicely diffuses the light produced by the LED unit.

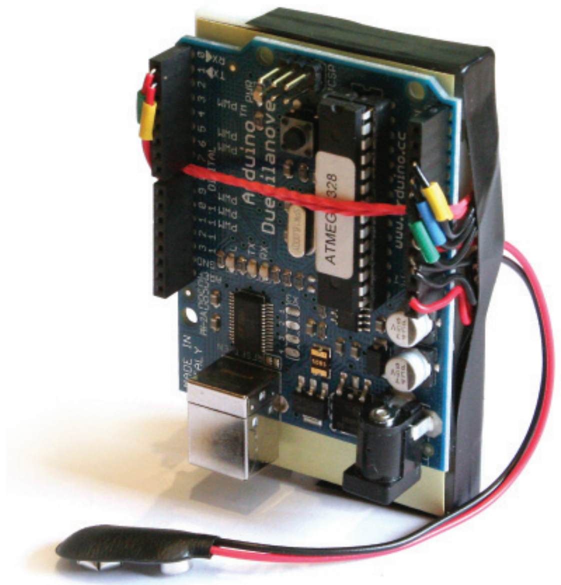
Although the flower is intended to comprise only a single cylindrical section, for ease of prototyping this phase of the bulrushes, a second separate modular "pod" is attached below the main flower unit and carries the electronics for the plants. Subsequent iterations of these objects are intended to use different electronic components (as described below) that will make the prototyping pod unnecessary.

Connector sections and the footer pedestals for the bulrushes were fabricated by laminating laser cut MDF material into functionally and aesthetically determined parts. These components are shown in the design illustration to the right.



Project: Materials List

- 1 2400 × 1200mm Sheet of 9mm MDF
- 30 Meters 32mm PVC tube
- 2 Meters 74mm Cast Acrylic Hollow Rod
- 16 Meters 6mm A304 Stainless Steel Rod
- 16 Stainless Steel Shaft Collars



Project: Technologies

Following is a discussion of the technology components used in the bulrushes to facilitate the interactivity of the objects.

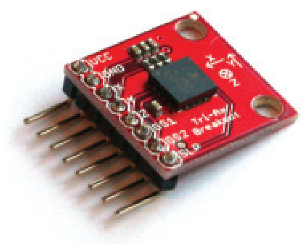
Illumination :: RGB LED

Illuminating the main cylinder of the bulrush creates life and responsiveness in the objects and provides visual clues to visitors about individual interactions as well as the developing state of the network of objects. Light is the primary communicative mode of the bulrushes, and as such, the importance of the LEDs is substantial and was given careful consideration.

Since the bulrushes were intended to be displayed in low-light conditions out of doors, the decision was made to use a single superbright RGB LED bulb in each physical unit. Testing showed that the bulb created a subtle, aesthetically pleasing and engaging quality of illumination. The LED drew power from the Arduino control board, and the intensity of the red, green and blue channels was independently addressable.

The quality of the lighting delivered by the single LED was deemed appropriate for the intended installation conditions, however for the bulrushes to be effectively deployed in daylight or bright indoor environments, the lighting intensity will need to increase. Possible upgrade options include using multiple LEDs, or shifting to a more advanced intelligent scriptable LED unit such as the I2C controlled BlinkM or BlinkM MaxM units.

Motion Sensing :: 3-Axis Accelerometer

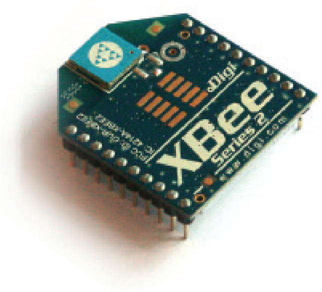


In order to detect when the bulrushes were being touched by installation participants, a compact digital 3-axis accelerometer was sourced from SparkFun Electronics. The unit utilizes the MMA7260Q accelerometer chip from Freescale Semiconductor to provide selectable resolution output of motion sensing in X, Y and Z axes.

The accelerometer functions by measuring the static and dynamic gravitational acceleration of the chip in space and returns that acceleration data as a variable voltage. In the case of the MMA7260Q units, a measurement of zero acceleration (indicating no movement in a given direction) returns a value of 1.65V, exactly half of the 3.3V supply voltage. Acceleration from the neutral position in a given axis is measured positively or negatively from the 1.65V value dependent on the direction of motion, and can return voltages ranging from 0–3.3V (Igoe 2007 and MMA7260Q Datasheet 2005).

Three voltages are output by the accelerometer (one value for each measured axis) and sent to discreet analog pins on the Arduino board. By calling the analogRead() function within the Arduino software, the voltage values undergo analog to digital conversion (ADC) and are returned as a integer between 0 and 1023. For the purposes of this project, the accelerometer was configured to read ±1.5g of acceleration and baseline self-assessment and damping values were scripted via the Arduino program in order constrain the sensor data to useful levels.

Wireless Communication :: XBee Series 2.5 Transceiver Modules

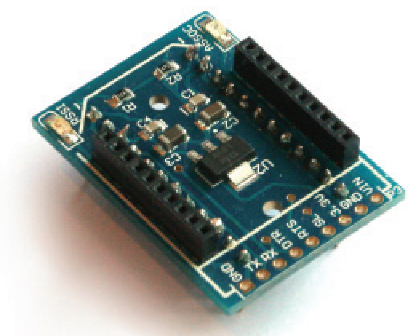


In order to create true autonomy of the objects within the installation, each of the bulrushes needed to physically and functionally discreet, but also capable of wireless issuing wireless communication as well as receive notification when the other bulrushes were interacting with people. A short-list of Bluetooth, WiFi and other RF modules were considered using the primary metrics of cost, performance, and ease of implementation as deciding factors.

Eventually, Series 2.5 XBee wireless RF units from Digi International were selected for the bulrushes. These 2.4GhZ transceivers are available in a variety of configurations featuring different output power specifications and antenna types, and the units are widely used in physical computing installations. Notable resources configuration and deployment information include the manufacturer's datasheets and online knowledge base, as well as the Arduino website (http://arduino.cc) and Tom Igoe's excellent text Making Things Talk (2007).

In keeping with the goal of autonomy and a true peer to peer relationship of the individual bulrushes, the initial parameters for this project were aimed toward an unmediated, unsupervised communication network. Digi's Series 2.5 modules, however, use a new chipset and instruction set that require a "coordinator" device to initiate the network and associate the other end unit XBee devices on the network. Although this was less desirable because it introduced an element of top-down control in the system, the overall impact on the project implementation was not significant. Once the coordinator device was in place, the bulrushes could dynamically join the network, thereby retaining the key elements of object autonomy (albeit autonomy with a helping hand from the coordinator).

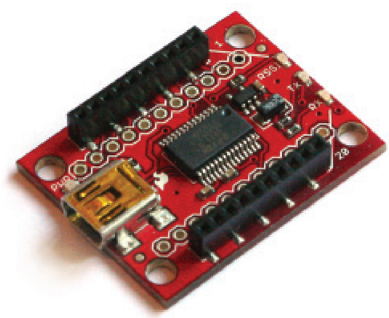
Communication :: XBee Simple Adapter Board



The XBee module output pins are a non-standard narrow 2mm pitch, so a breakout board from Droids SAS was used to enable attaching the transceiver/breakout board combination directly to a development breadboard. Additionally, the adapter board features a high power voltage regulator that delivers the correct operating voltage (3.3V) to the XBee modules.

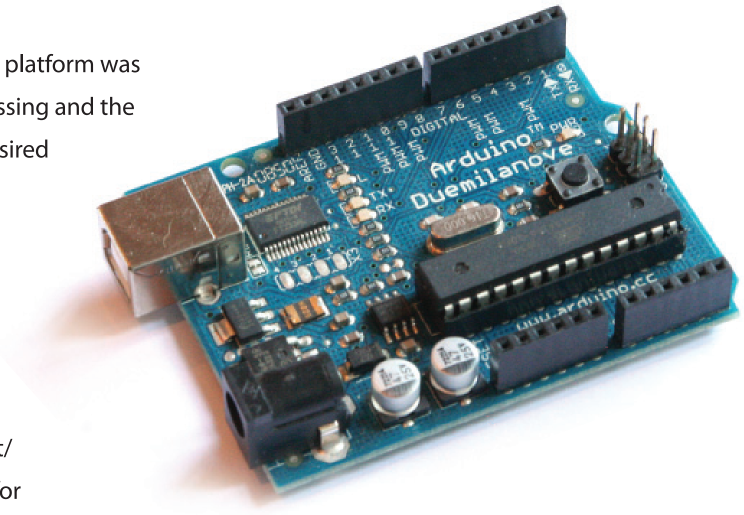
Communication & Control :: XBee Explorer USB Serial Interface board

The controller module for the network of bulrushes was comprised of an XBee module installed on the Explorer USB Serial Interface board from SparkFun Electronics. This unit enabled an XBee module to connect directly to a computer via a USB cable. At that point the module could be controlled via the XBee configuration software X-CTU from Digi, which was used for initial configuration of each of the eight XBee modules used in the bulrushes, as well as the external coordinator module. After initial setup, the Explorer board served as a connection to the coordinator module, and passed serial data between the bulrushes and the coordinator application.



Control :: Arduino Duemilanove

For development of the bulrushes, the Arduino platform was selected due to its close integration with Processing and the other components required for building the desired object functionality. The open source Arduino platform is comprised of a programming IDE and a variety of hardware boards that offer differing form factors and input/output 'pins'. For this phase of the bulrushes project, the Arduino Duemilanove board was used. This model provides a full complement of input/output pins, as well on-board USB connection for ease of communication and program upload.



For future iterations of the bulrush objects, the smaller Arduino Pro Mini module could be used. The Pro Mini dispenses with on-board USB and certain connections in favor of a substantially smaller size; its footprint is approximately one-sixth of the Duemilanove. As such, the Pro Mini would be ideal for use in bulrushes and would facilitate removal of the prototyping electronics pod that was used in the physical objects for this experiment. This would be more in keeping with the aesthetic goals for the physical objects; however, for this phase of study, the ease of prototyping offered by the larger Duemilanove board was a deciding factor.

Behavioral Rules

The rules that govern the behavior of the bulrushes initially were devised solely to deliver a compelling, playful experience for visitors. This experience was intended to visually illustrate how participants' exchanges with individual plants initialized and defined associations between different bulrushes in the installation.

To that end, a general pattern of behaviors was developed. When a visitor touched any individual plant (Plant A), it would light up in response to being moved. The visitor (or a different visitor) would then touch a different plant (Plant B) which would in turn illuminate. This second touch would also serve another key function: when Plant B is touched, it sends a wireless broadcast indicating that it has been touched. Plant A, having registered the immediately preceding touch , strengthens its association to Plant B.

This very simple rule would play out over many touch cycles in the creation of a detailed association network between the individual plants. It was recognized and desired that the mechanism be prone to errors (or at least substantial deviations) in any individual visit cycle – for example, Visitor A may move in a path from **Plant A** > **Plant B** > **Plant C**, but the prevailing network association path could register as **Plant A** > **Plant G** > **Plant F** > **Plant B** > **Plant E** > **Plant C,** if a second individual, Visitor B, happened to be interacting with Plants G, F and E concurrently to Visitor A's interaction with Plant A, B, and C.

The opportunity to observe whether, in practice, the association network begins to converge on an accurate representation of the actual patterns of movement of visitors through the installation was considered to be a very exciting facet of this experiment.

In order to implement this project, the general behaviors described above were refined using the model of a physical neural network in which individual cells communicate via electronic pulses passed along the cell axon to make a synaptic connection with other receiving cells. Depending on various factors, the receiving cell may or may not issue a resulting pulse. It is not within the scope of this paper to explore all of the physiological mechanisms at work in real neural networks; however the chart below indicates the neural network components and behaviors that have been applied to the bulrushes installation.

Specific code used for the individual bulrushes as well as the communication coordinator is included in the Appendix.

Neural Network	**Bulrush Installation**
Cell	Individual Bulrush
Axon	Wireless network
Environmental Stimulus	Visitor Contact
Cell Pulse (Firing)	Flower Illumination
Synapse	Wireless communication
Synaptic Weighting	Increase in association between plant A and the next plant touched
Synaptic Inhibition	Decrease in association between plant A and the plants that are not touched next
Threshold	Association strength required for flower illumination not based on direct visitor contact
Refractory Period	Short time delay following illumination in which a bulrush cannot fire again
Time Varying Threshold	Following the refractory period, the flower slowly regains its ability to illuminate again
Fatigue	Resistance to firing increases if the individual flower is illuminating above an 'average' rate

Evaluation Metrics

In order to assess the overall performance of the bulrushes installation and gauge the relative success of the object and network behaviors, sets of two discreet, back-to-back evaluation sessions were planned. Each assessment set was intended to include one "control" period and one "test" period.

In order to generate a baseline for evaluation, the initial installation "control" period was to be conducted with the objects running in a limited performance mode – the bulrushes would illuminate when touched by visitors, but no network associations would be recorded. Essentially, the bulrushes would be functioning as an array of totally independent objects. They would illuminate in a purely linear, responsive mode. This configuration mirrors the performance parameters of the rods in the Dotty Duveen installation discussed above.

For the "test" period, the neural network behavior program was invoked. The bulrushes again would respond to being touched and moved. In this period, visitors' input would generate associative relationships between the individual bulrushes according to the neural cell model.

During both periods, the installations were to be monitored and data collected regarding the following metrics:

1. Number of visitors
2. Typical duration of visitor stay
3. Types of passerby and visitor responses to the installation

4. Visitor behaviors while engaged with the installation
5. Observed emergent behaviors from the bulrushes or visitors
6. Network convergence

The two final performance areas were expected to provide the most fruitful comparisons between the control and test configurations, and would form the crux of the success or failure of this experiment's hypothesis.

INSTALLATION RESULTS & OBSERVATIONS

This section provides observation logs of each installation session.

SESSION #1 | Gadebridge Park, Hemel Hempstead | Time: 18:30-20:30 | Visitor Tally: 20-25

Responses:

- "Have fun playing with your UFOs."
- "Are those fireworks?"
- "Have they got computers in them?"
- "Those are really cool."

Key Observations:

- People very hesitant to interact as the sun set and light waned.
- Trepidation about physically engaging with the objects.
- People wanted to interact with the researcher first, rather than immediately engaging with the bulrushes.
- Many comments were in relation to the artistic nature of the objects and the overall attractiveness of the display, but a sense of uncertainty regarding how to interact with the objects was common.

Installation Performance & Notes:

- It was very difficult to install quickly in the field, because the accelerometer boot cycle commenced as soon as power was attached.
- Bulrushes hit 'epileptic' mode quickly based on interaction. Once the network began uncontrolled firing, the coordinator program commands didn't register predictably with the individual plants. The egocentric model employed so that the plants prioritized on direct contact versus secondary firing locked out radio contact and precluded breaking out of the epileptic loop.

The initial bulrush installation was deployed in a busy suburban park environment. This location's public sports fields and extensive skate/bike park facilities, as well as walking paths and riparian setting draw a large number of users from residential communities within walking distance as well as commuting visitors. Weekend and weekday use is frequently quite heavy and visitors comprise a broad demographic range of individual, family and other groups.

A key motivator for selecting this site was the opportunity to observe the general responses and attitudes of a suburban population in regard to a interactive digital installation, which more typically might be presented to a metro-center audience. It was assumed that the suburban group might evince a particular hesitancy to engage with the bulrushes compared to an urban audience, and at the conclusion of this first observation period, it seemed that this hypothesis was borne out in practice. More site-to-site comparisons follows.

SESSION 1 | Gadebridge Park

For the Hemel Hempstead observation session, the bulrushes were placed in two parallel rows of four plants forming a 3×12 meter grid in a green space by the primary entryway to the park. This site was selected because it flanked the main pedestrian path between the park grounds and the car park. The site also was well situated just across a stream from the skate/bike ramp area. The proximity to the skate ramps meant that the installation was set up in full view and easy earshot of the youth who were using the park. The developing installation generated a substantial amount of interest and frequent comments and queries from the skaters and bikers, who wanted to know what the objects were and whether they might possibly explode or launch.

SESSIONS 2 & 3 | Regent's Park

Beyond the amusing distance interaction with skaters in the park, other visitors ranging from single, elderly walkers to families came in closer to the installation to ask questions. Many more people were interested in the installation but skirted the actual objects. The first installation session attracted fewer individuals than was hoped, but did provide valuable insights regarding the physical functionality of the bulrushes as well as revealing high level considerations about the logistics and implementation of the experiment that will be addressed below.

SESSION #2 | Regent's Park, London | Time: 15:30-17:30 | Visitor Tally: Appx. 50

Responses:

- “It is really interesting to combine artificial intelligence with natural intelligence.”
- “Are they solar lights?”
- “Is this a new permanent installation in the park? It should be.”
- “How do you know so much about them?”
- “What wireless protocol are they using? Is it an ad hoc or coordinated network?”

Key Observations:

- Again, people are somewhat hesitant to physically engaging with the objects.
- The physical display aesthetically integrates with the Regent’s Park floral gardens; many visitors seem to accept the installation as something intrinsic to the park.
- International visitors seem more willing to explore the installation and engage with the objects.
- Visitors are much more interested in the neural network mode of operation.

Installation Performance Notes:

- The revised set-up program and break-in functions that could be run from the coordinator program facilitated maintenance of the installation.
- Bulrushes’ illumination, as suspected, was insufficient for daylight placements.
- Engagement needs to be more active. The bulrushes’ passive attraction mechanism is not sufficient to compel people into initiating interactions.
- The physical objects performed robustly with the exception of the laminated MDF bases, several of which sheared at the point where the flex tuning rod contacted the base. This was transparent to visitors, but does inform material requirements for future iterations of the bulrushes.

The second installation session was conducted in Regent’s Park in London. The space was open and attractive, with more pedestrian traffic than the Hemel Hempstead location. Use was split between individuals who moved through the area quickly and a substantial number of visitors who stayed in the park for extended periods to relax, visit or picnic.

The same 3×12 meter physical grid was set up adjacent to a main intersection of paths in the inner park, and it immediately became a focal point of attention and conversation. Many individuals who observed the installation chose to not engage with it. This session also had the only instances of completely oblivious participants, that is, people who seemingly unknowingly walked right through the display without interacting or responding at all. Most importantly however, the afternoon session hosted the longest, richest and most varied interactions of the project.

A broad cross-section of individuals interacted with the bulrushes. From university students to a baby riding in a backpack, to joggers and a elderly, soft-spoken woman, people seemed most willing to initiate interaction with the display during this session, in spite of the bright afternoon light, which substantially diminished the visibility of the bulrushes illuminated mode.

What daylight took away in terms of visual impressiveness, it returned in duration of interaction. Several of the visits lasted for more than ten minutes, as people wandered through the display touching every bulrush, and shielding their eyes from the sun so that they could track the firing of other bulrushes, looking for progressively different responses based on their fundamentally similar actions. These types of behaviors were exciting to observe, because they confirm this paper's hypothesis that simple mechanisms and tactics can be used in conjunction with simple objects to generate rich interactions. The bulrush objects, working from a simple set of rules, shaped visitors' own input to construct a delightful output that is "continually surprising and new" (Gage 2008). The quality of interactions was extremely satisfying from an artistic perspective as well as a research position.

SESSION #3 | Regent's Park, London | Time: 18:30-20:30 | Visitor Tally: Appx. 35

Responses:

- "Will these be here after the show? I'd like to see these when it's truly dark. I think they'd be lovely."
- "I've been watching these and I want to see what makes them work."
- "This is far nicer than the installation that the council just spent our tax increase on."
- "Look, that other one just lit up!"

Key Observations:

- - People were content to view the bulrushes from afar, especially since they are brighter and more visible in the darker conditions.
- - Of the individuals who engaged with the bulrushes, many did so for short time periods.
- - Visitors seemed to accept the installation as a part of the park.

Installation Performance & Notes:

- - The visual attraction method is more successful in the evening's lower light.
- - Two batteries finally failed, after more than six hours of continuous use. This is encouraging for future miniaturized versions of the bulrush electronics.

The final session at the Regent's Park location, like the Hemel Hempstead study, was conducted from dusk until dark, and the bulrushes created an attractive spectacle that even drew the attention of the wedding party that was finishing a ceremony nearby. With the darker ambient conditions, people noticed the installation and were interested in coming in closer to view the objects, but didn't necessarily physically engage with the bulrushes.

Interaction durations for this session were shorter than the earlier Regent's Park session. This is thought to have been influenced by the nature of traffic at that time. Many of the people moving through the area were attending a production of the musical *Hello Dolly* at the park's open air stage. Consequently, the bulrushes captured an arts-minded group, but they were also intent on a time-sensitive engagement. A few visitors moved quickly through portions of the bulrush installation and were intrigued by the concept and function of the neural network mode. Three separate groups asked whether the installation would be available during intermission or after the production. This short interaction period is consistent with the first nighttime session and may indicate a precedent for shorter interactions after dark.

DISCUSSION

In Situ Performance

The performance of the bulrushes was largely satisfactory, and the primary physical and communicative goals were met when the installation was field deployed. The bulrushes were very attractive, garnering repeated laudatory comments through each of the installation sessions. The electronic components worked exceedingly well and the coded behaviors of the plants functioned predictably on site, especially after the accelerometer calibration and refractory delay functions were refined in response to the first installation session. These updates contributed to the stability and overall installation performance at the Regent's Park sessions.

Although the general functionality of the installation was excellent, it is worth revisiting bias toward optimal performance in low-light conditions. The observed hesitancy of people to engage with the bulrushes "in the wild" was exacerbated as soon as optimal ambient lighting conditions were reached. That is, as soon as it was dark enough for the bulrushes to really shine, people were increasingly adverse to engaging with unknown objects. In conceiving and developing the installation's basic mechanisms, it was thought that glowing objects in a night-time setting would be aesthetically compelling and would provide a ready avenue of accessibility for visitors. Indeed, a response from an elderly gentleman who visited the installation in Regent's Park at dusk (approximately 19:20 in the evening) corroborates this overall sense. While interacting with two of the bulrushes, the man commented that they "would be great fun in a garden in the dark." However, his ready response and willingness to initiate interaction based purely on observing the objects was more progressive than typical.

Terms of Engagement

Once on-site, it became obvious that although the objects were intended to be passive attractors and the experiments were meant to be hands-off and observation-based, an intervention model would need to be adopted in order to have a meaningful installation. The development model for the bulrushes explicitly eschewed the use of behavioral mechanisms for attracting visitors, relying rather on passive engagement. The observed hesitancy to interact was initially thought to represent a characteristic of the suburban audience; however, the sessions in Regent's Park elevated this to a general concern. Simply put, waiting for audience interaction was not a successful tactic. The bulrushes needed to actively engage with visitors, to drive the interactions, because a handful of elderly gentlemen, foreign families, and inquisitive students notwithstanding, most visitors were unsure about how to engage or whether they were permitted to do so.

In light of this observation, it was deemed important to intervene on behalf of the installation by approaching individuals who appeared to be interested, but not willing to engage. These people were invited to interact with the bulrushes, and everyone who was approached did proceed to engage with the objects. It would be extremely interesting outgrowth of this project to study the psychology of human interaction with objects in the public space vis à vis issues of permission, boundaries and social mores.

In the short term, this decision provided the opportunity to build person-to-person conversations as well as facilitating the person-to-installation conversations that were the initial goal of the project. This added a layer of richness to the experiment because visitors provided real-time comments about the bulrushes. It is worth noting that same action reduced the neutrality of comparison between the control and neural network modes of function in the installation. Once a person-to-person conversation began, none of the visitors was interested in the control mode. In fact, two visitors explicitly asked if the networked mode could be launched.

Moving forward, the need for a more direct and effective engagement mechanism is clear. An alternate implementation or functionality is necessary if later versions of the bulrushes are to successfully stand alone without observer intervention.

Audience Intentionality

It seems plausible that some of the engagement issues that existed with this installation, but did not appear as plainly in review of the other projects above, stem from the decision to install the bulrushes out of doors. Beyond obvious physical considerations such as weather, general exposure, and location or logistical concerns including power and communications, the decision to install the bulrushes in outdoor settings brought with it a meta-issue of audience intentionality that warrants careful reflection in specific relation to this and other digital installations.

The projects surveyed earlier in this paper were primarily indoor installations. The only exception is the upcoming outdoor iteration of the Dune landscape, and its success – however appropriate to this discussion – cannot yet be judged. The Maas riverfront Dune exhibition excluded, Roosegaarde's other landscapes, as well as the Dotty Duveen and Haque installations all aimed to engage with captive or intentional audiences. Whether these groups were inside the Tate Gallery or passing through a commuter hallway, the audience being addressed was either in a captive position without alternative path (barring outright avoidance) or had willfully sought out at least the environment if not the specific installation in question. In these cases audiences are predisposed to a certain types of interactions. They have invested themselves in the experience and it is only natural that they will seek to validate that investment with a readiness to interact.

In contrast, an outdoor exhibit that is simply found, not sought out, must generate an impetus toward engagement that is powerful enough to motivate deviation from intent in its audience. The bulrushes needed to impose themselves on the consciousness of the potential audience and provide a significant motivation for individuals to seek out interaction.

This kind of motivation or intentionality was present in the visitors of the Dune, Dotty Duveen and Moody Mushroom installations, as well as in those who chose to attend the Bashful Flower and Digital Wisteria exhibits. Those audiences were seeking out a specific type of exploration and experience. The visitors who came upon the bulrush installation were not so explicitly motivated, and as such the bulrush installation needed to provide an additional attraction to capture a large audience. Recognizing this dynamic is an extremely fortuitous result of the experiment since it enables more accurate planning so that future installations can adequately address not just creating valuable and intriguing interactions, but also delivering ample motivation and fostering intention for potential audiences.

CONCLUSION

At its best, interactive design and physical installations can open a dialogue between art, information and people. It is an assertion of this paper that digital installations should endeavor to deliver value to individual visitors by employing a Paskian model of interactivity, in which the object and the audience both generate value and derive value from the experience. As such, the central aim of this research effort was to explore the digital interactive medium as a tool to build not simply communication, but real conversations between the built artifact and its audience.

This study set out to explore the types of dialogue that can be generated by an installation, and how an installation might learn, update, or change based on interactions with visitors. The bulrushes, even in this initial form which can profit from refinement, succeeded in showing that the application of thoughtful design and a self-organizing mechanism can combine to encourage conversations of depth, richness and fluency – exchanges in which visitors responded to the installation, created definition and value in the physical object network, and derived a satisfying and intriguing experience from the exchange.

In some cases this dialogue was tentative or cautious. An important outgrowth of these observations is the recognition that much attention must be devoted to understanding the psychological and social predispositions of visitors that can inform and impact involvement with a given installation. In order to attain greater relevancy to non-intentional or non-captive audiences – that is, audiences that have not actively sought out interaction with an installation, are not somehow constrained to involvement, or those who are not generally predisposed toward similar types of interactive experiences – digital installations need to actively create initial engagement so as to overcome natural or societally encoded reservations. In the case of the bulrushes, this immediate engagement mechanism was missing, or at least underdeveloped. The initial design decision to create a tactile set of objects overvalued aesthetics and curiosity as motivators or impetuses for building interaction and failed to accurately identify the threshold requirements of audience engagement. As was seen in numerous instances during the test installations, visitors initially expressed reluctance to touch the bulrushes because they didn't want to interfere with an art exhibit, or risk damaging the objects. For everyone who overcame this trepidation and sought engagement with the installation, more walked by, interested, examining, and obviously inquisitive, but unwilling to initiate an interaction, or even unaware that an interaction was possible.

A more careful selection of technologies would go far toward ameliorating this issue. If, for instance, proximity sensors were used, the bulrushes could generate more effective attraction ploys that actively addressed and engaged potential visitors rather than relying on a passive attraction mechanism. Based on the overwhelming levels of interest in passersby that failed to convert into actual interactions, it seems certain that providing the bulrushes with a greater capacity to initiate conversation would radically augment the installation's success rate.

Above and beyond the tentative interactions, there was a set of real conversations that took place during the bulrush observation sessions. These interactions definitively confirmed this study's hypothesis that tactics and methods exist that can engender powerful, mutually defined, and worthwhile interactions between people and digital art. Each of these higher value conversations took place while the bulrush installation was functioning in its neural network mode. The addition of a logic model to the objects – compared to the simple reactivity of the bulrushes' control mode – increased the quality, depth and impact of the interactions. In one notable instance, a family of four chased each other through the installation. The mother with a toddler daughter and young son ran through the plants trying to activate all of the bulrushes at once, while the husband followed, tracking down the bulrushes that the other members had touched and other plants that were firing based on the network connections that his family members were actively building. At another point a man attentively walked among the plants in different paths, engaging different plants and observing the network response.

Conversations blossomed as the visitors and the bulrushes contributed to an increasingly articulate engagement. The built and the engaged each played an impromptu part as people and technology collaboratively enriched a unique shared experience. The dialogue was sublime, and the bulrushes – as well as some of the visitors – indeed, danced.

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Online Resources

http://www.arduino.cc | Primary online resource for Arduino hardware platform

http://www.clearplasticsupplies.co.uk | Supplier of extruded acrylic tube, rod and profile material

http://www.coolcomponents.co.uk | Supplier of electronic hardware for physical computing

http://www.digitalexperience.dk | Interaction and experience design blog

http://www.digi.net | Producer of XBee and ZigBee modules and X-CTU configuration software

http://www.faludi.com | Personal and project website of Rob Faludi, physical computing specialist

http://www.haque.co.uk | Research and project site of Haque Design + Research Ltd.

http://www.interactivearchitecture.org | Site surveying state of the art interactive installations and architecture

http://www.maplin.com | Supplier of electronic parts

http://www.metals4u.co.uk | Supplier of metal stock and plastics

http://www.processing.org | Primary online resource for Processing software application

http://www.shiffman.net | Website of Daniel Shiffman, physical computing lecturer and author of *Learning Processing: A Beginner's Guide to Programming Images, Animation, and Interaction*

http://www.sparkfun.com | US-based supplier of an extensive range of electronic products for physical computing; SparkFun also designs and produces several Arduino board models

http://www.studioroosegaarde.net | Website of Daan Roosegaarde, creator, 'Dune' series installations

http://www.tigoe.net | Personal and project website of Tom Igoe, Arduino team member and physical computing lecturer and author

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XBee Explorer USB (USB to Serial Board) Schematic | Sparkfun.com | http://www.sparkfun.com/datasheets/Wireless/Zigbee/XBee-Explorer.pdf

XBee Simple Board 990.001 Technical Specifications | Droids SAS | http://www.droids.it/data_sheets/990.001%20datasheet.pdf

XBee®/XBee-PRO® ZB RF Modules User Manual. Rev. 90000976_C (2009) | Digi International, Inc. | http://ftp1.digi.com/support/documentation/90000866_C.pdf

APPENDIX

Arduino Code for Bulrushes

```
/*
DANCE OF THE BULRUSHES // ARDUINO CODE
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Set baseline values for accelerometer data then look for
deviations from the baseline in order to determine movement.
When movement is sensed, fire the Bulrushes.

Props to David Mellis & Tom Igoe for the sensor example code:
http://www.arduino.cc/en/Tutorial/ADXL3xx
*/


//-----------------LED & Accelerometer Setup-----------------//


// Set pins for R, G, B legs of LED
const int ledR = 11;
const int ledG = 10;
const int ledB = 9;

// Define input pins for X, Y, Z axes of accelerometer
const int xPin = 3;
const int yPin = 2;
const int zPin = 1;

// Number of accelerometer input cycles used to set Baselines
int numEvalCycles = 20;

// Baseline values for X, Y, Z axes of accelerometer, determined by evaluations
in setup()
int xPinBaseline = 0;
int yPinBaseline = 0;
int zPinBaseline = 0;

// Accelerometer damping values, the +/-value from the Baseline before movement
is registered
int xDamp = 35;
int yDamp = 25;
int zDamp = 35;

// A single cycle of pin read from the accelerometer (used for Baselines then to
register motion)
int readX = 0;
int readY = 0;
int readZ = 0;


//----------------- NEURAL NETWORK MODE -----------------//


// Modes of behavior: false = Independent Bulrushes, true = Neural Net mode
boolean NNmode = false;
```

```
// Value >= threshold and the Bulrush fires, < threshold and Bulrush does not fire
float threshold = .95;

// Initial weight of this Bulrush object, will change over time & with
associations
float weight = 0.25;

// Incoming weight based on network associations with other Bulrushes
float inWeight = .10;

// Weight of received input signal from coordinator
float pulseInput = 0.25;

// Absolute Refactory Period time delay after firing in which Bulrush cannot fire
again
int ARP = 2000;

// Cell recovery rate...lack of recent firing increases sensitivity
float recoverRate = 0.001;

// Control epileptic behavior caused by over-firing
int cellFatigue = 0;

// Cell fatigue rate...lots of firing reduces sensitivity
float fatigueRate = 0.00001;

// Variable to receive incoming serial data from Coordinator
//char incomingData[0];
int incomingData = 0;

// Node ID of XBee radio attached to this bulrush
//char* XBeeName = ("SWT04"); //For long names
int XBeeName = 6; // For single character Radio names


//----------------- VOID SETUP -----------------//


void setup() {
// Initialize serial communication
Serial.begin(9600);

// Evaluate a sample set of accelerometer input data to establish baseline
readings
evaluate();

// Set LED into initial non-firing attract mode
attract();
}


//----------------- VOID LOOP -----------------//


void loop() {
// Listen for serial communication & act according to commands
listen();
```

```
// Read X, Y, Z values from the accelerometer
int readX = analogRead(xPin);
int readY = analogRead(yPin);
int readZ = analogRead(zPin);

// Comparison of current accel readings to baselines +/- damping values to
determine movement
if (readX < (xPinBaseline-xDamp) ||
  readX > (xPinBaseline+xDamp) ||
  readY < (yPinBaseline-yDamp) ||
  readY > (yPinBaseline+yDamp) ||
  readZ < (zPinBaseline-zDamp) ||
  readZ > (zPinBaseline+zDamp) )
  {
  fire();
  }
else
  {
  attract();
  }
}

//----------------- BULRUSH FUNCTIONS -----------------//

void fire() {
if (NNmode == false)   // Control Mode
{
analogWrite(ledR, 0);
analogWrite(ledG, 0);
analogWrite(ledB, 255);
}
else if (NNmode == true) // Neural Network Mode
{
//weight -= fatigueRate; // NC version
analogWrite(ledR, 0);
analogWrite(ledG, 0);
analogWrite(ledB, 255);
Serial.print(XBeeName);  // s/b print not printLn
delay (2*ARP);
analogWrite(ledR, 0);
analogWrite(ledG, 0);
analogWrite(ledB, 0);
delay (ARP);
increaseWeight();
}
}

void sympatheticFire() {
analogWrite(ledR, 0);
analogWrite(ledG, 0);
analogWrite(ledB, 255);
delay (2*ARP);
analogWrite(ledR, 0);
analogWrite(ledG, 0);
analogWrite(ledB, 0);
delay (ARP);
cellFatigue += 1;
if (cellFatigue == 10) {
 resetCell();
```

```
}
else {
associate();
}
}

void attract() {
analogWrite(ledR, 0);
analogWrite(ledG, 0);
analogWrite(ledB, 20);
decayWeights();
}

void listen() {
if (Serial.available()> 0){
  incomingData = Serial.read();
  //Serial.print(incomingData);
 }

//if (incomingData == (XBeeName)){
// increaseWeight();
// }

switch (incomingData) {
 case 'a':
  attract();
  break;
 case 'b':
  MoreDamp();
  break;
 case 'c':
  LessDamp();
  break;
 case 'd':
  increaseWeight();
  break;
 case 'e':
  evaluate();
  break;
 case 'f':
  fireAll();
  break;
 case 'g':
  ARPup();
  break;
 case 'h':
  ARPdown();
  break;
 case 'm':
  setControlmode();
  break;
 case 'n':
  setNNmode();
  break;
 case 'o':
  PIup();
  break;
 case 'p':
  PIdown();
```

```
  break;
 case 'r':
  reset();
  break;
 case 's':
  superFunkadelic();
  break;
 case 'u':
  updateBulrush();
  break;
 case 'z':
  zeroFatigue();
  break;
 //default:
  //updateBulrush();
}
}

// Update bulrush weight and initiate firing if appropriate
void updateBulrush() {
if ((weight + pulseInput) >= threshold){
 sympatheticFire();
}
else {
 decayWeights();
}
}

// Add the association strength to the cell weight
void increaseWeight() {
weight += inWeight;
weight = constrain(weight, -.50, .9);
}

// This function builds in cell recovery...lack of recent firing increases
sensitivity
void associate() {
weight += recoverRate;
weight = constrain(weight, -.50, .90);
}

// This decays cell weights over time
void decayWeights() {
weight -= fatigueRate;
weight = constrain(weight, -.50, .90);
}

// Evaluate a sample set of accelerometer input data to establish baseline
readings
void evaluate(){
for (int i = 0; i < numEvalCycles; i++) {
 readX += analogRead(xPin);
 readY += analogRead(yPin);
 readZ += analogRead(zPin);
}

// Set accelerometer baseline values
xPinBaseline = readX / numEvalCycles;
yPinBaseline = readY / numEvalCycles;
```

```
zPinBaseline = readZ / numEvalCycles;

}


//----------------- OPTIONAL UPDATE FUNCTIONS -----------------//


// Flash key Bulrush settings to initial values
void reset() {
NNmode = false;
weight = .35;
inWeight = .15;
pulseInput = .5;
fatigueRate = 0.00001;
ARP = 2000;
xDamp = 35;
yDamp = 25;
zDamp = 35;
attract();
}

// Stop epileptic behavior with protracted ARP & weight reset
void resetCell() {
delay (ARP*10);
weight = .35;
attract();
}

// Set to Neural Network mode
void setNNmode() {
NNmode = true;
}

// Set to Control mode
void setControlmode() {
NNmode = false;
}

// Increase pulseInput
void PIup() {
pulseInput += .05;
}

// Decrease pulseInput
void PIdown() {
pulseInput -= .05;
}

// Increase cell ARP
void ARPup() {
ARP += 500;
}

// Decrease cell ARP
void ARPdown() {
ARP += 500;
}
```

```
// Take Fatigue Rate to zero
void zeroFatigue() {
fatigueRate = 0;
}

// Increase Accelerometer Damping values on the fly
void MoreDamp() {
xDamp += 10;
yDamp += 10;
zDamp += 10;
}

// Decrease Accelerometer Damping values on the fly
void LessDamp() {
xDamp -= 10;
yDamp -= 10;
zDamp -= 10;
}

// Intervention/Attraction Mode
void superFunkadelic() {
for (int i=0; i<5; i++) {
 analogWrite(ledR, 0);
 analogWrite(ledG, 0);
 analogWrite(ledB, 255);
 delay(200);
 analogWrite(ledR, 0);
 analogWrite(ledG, 0);
 analogWrite(ledB, 51);
 delay(200);
}
}

// Hmmm...fireAll...what could that be? Yeah, fire all, but without the en mass
serial.write()
void fireAll() {
analogWrite(ledR, 0);
analogWrite(ledG, 0);
analogWrite(ledB, 255);
delay (2*ARP);
analogWrite(ledR, 0);
analogWrite(ledG, 0);
analogWrite(ledB, 0);
delay (ARP);
attract();
}
```

Processing Code for Bulrush Coordinator Node

```
import processing.serial.*;

PFont headerFont;
PFont graphFont;
PImage bulrush;

int leading = 15;
int graphX = 30;
int graphY = 210;

Serial Coordinator; // The serial port

String signalRadio = "";


//----------------- VOID SETUP -----------------//


void setup() {
// List available serial ports
println(Serial.list());

// Identify Coordinator port and set baud rate
Coordinator = new Serial(this, "COM21", 9600);

// Set fonts
headerFont = loadFont("MyriadWebPro-Bold-24.vlw");
graphFont = loadFont("EurostileBold-14.vlw");

// Set background image
bulrush = loadImage("data/bulrush.jpg");

// Build UI
size (500,500);
image(bulrush, 0, 0);
noStroke();
smooth();
fill(#A8A8A8);
textFont(graphFont);
text("a = attract",graphX, graphY);
text("b = more damp",graphX,graphY+leading);
text("c = less damp",graphX,graphY+(2*leading));
text("d = increase weight",graphX, (graphY+(3*leading)));
text("e = evaluate accelerometers",graphX, (graphY+(4*leading)));
text("f = fire all",graphX, (graphY+(5*leading)));
text("g = arp up",graphX, (graphY+(6*leading)));
text("h = arp down",graphX, (graphY+(7*leading)));
text("m = set control mode",graphX, (graphY+(8*leading)));
text("n = set nn mode",graphX, (graphY+(9*leading)));
text("o = decrease pulse in",graphX, (graphY+(10*leading)));
text("p = increase pulse in",graphX, (graphY+(11*leading)));
text("r = reset",graphX, (graphY+(12*leading)));
text("s = super funkadelic",graphX, (graphY+(13*leading)));
text("u = update bulrush",graphX, (graphY+(14*leading)));
text("z = zero fatigue",graphX, (graphY+(15*leading)));
}
```

```
//----------------- VOID DRAW -----------------//


void draw() {

while (Coordinator.available() > 0) {
 String inBuffer = Coordinator.readString();
 if (inBuffer != null) {
  inBuffer = trim(inBuffer);
  signalRadio = inBuffer;
  //serialInput.add(signalRadio);
  //println(serialInput.get(0));
  println(inBuffer);
  Coordinator.write('u');
 }
}
Coordinator.clear();
}


//----------------- COMMANDS -----------------//


void keyPressed() {
switch(key){
 case 'a':
  Coordinator.write('a');
  break;
 case 'b':
  Coordinator.write('b');
  break;
 case 'c':
  Coordinator.write('c');
  break;
 case 'd':
  Coordinator.write('d');
  break;
 case '3':
  Coordinator.write('e');
  break;
 case 'f':
  Coordinator.write('f');
  break;
 case 'g':
  Coordinator.write('g');
  break;
 case 'h':
  Coordinator.write('h');
  break;
 case 'm':
  Coordinator.write('m');
  break;
 case 'n':
  Coordinator.write('n');
  break;
 case 'o':
  Coordinator.write('o');
```

```
  break;
 case 'p':
  Coordinator.write('p');
  break;
 case 'r':
  Coordinator.write('r');
  break;
 case 's':
  Coordinator.write('s');
  break;
 case 'u':
  Coordinator.write('u');
  break;
 case 'z':
  Coordinator.write('z');
  break;
}
}
```