

Smart CITY Patterns

Creating environmental stylesheets to template ‘inclusivity’ on Cardiff Bay Barrage.

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Abstract— From parks to shopping areas, smart technologies are being used throughout our cities to inform, guide and even persuade us into certain experiences. In terms of the technologies (and their usage), the emphasis is now very much on the mobile device and mobile applications that provide us with the digital media time to interact and share [1]. Moreover, what we are increasingly witnessing and experiencing, is how this mobile experience can fully absorb and disconnect us from the environment around us. The authors of this paper want to re-focus the actual role of the environment in the design of the smart city experiences. Integrating site-specific artworks with smart technologies, the goal of this research is to put the emphasis back into the environment as a place where everyone can engage and enjoy regardless of ability and/ or disability. This paper reports on the early conceptual stages of the Cardiff Bay Barrage project. It will highlight how the work (thinking and feeling) of artists, computer scientists, writers and engineers in alignment with the needs of industrial partners Cardiff Council and Philips Lighting Ltd. can bring ‘inclusivity’ to the experience of all/any visitors to Cardiff Bay Barrage. This paper presents the ‘pattern making’ process involved in the preparation for gathering and validating of initial requirements to support the overall design for this inclusive experience.

Keywords—*Inclusive design; aesthetic; smart technologies; internet of everything; patterns; stylesheets;*

I. INTRODUCTION

From parks to shopping areas, smart technologies are being introduced into the fabric of our urban environments to inform, guide and even persuade us into certain experiences. In terms of the technologies, emphasis is invariably placed on the mobile devices and applications enabling users to engage and interact with external stimuli and each other in the cityspace [1]. It is becoming increasingly plain at the same time how the mobile experience in fully absorbing can just as fully disconnect users from their real-world contexts. In 2005, [2] suggested re-thinking the mobile experience as a dynamic (rather than abstract) field of relationships, a mobile work environment creating elastic spatial and temporal relations. After him, our paper re-focusses the role of the experienced environment in smart city design. In *A Pattern Language* [3]

devised a guide for the design of coherent and whole environments, arguing: ‘when you build a thing you cannot merely build that thing in isolation, it must also repair the world around it, and within it, so that the larger world at that one place becomes more coherent, and more whole; and the thing which you make takes its place in the web of nature, as you make it’. Generating patterns from combinations of artworks, mobile technologies, beacons, sensors, RFID tags and Raspberry Pis, our research will identify and exploit ways of making the experiential environment fully available to any and everyone, whatever their age, cultural background, language community, physical, sensory or cognitive function.

Our project brings researchers at the University of South Wales (USW) together with partners Cardiff Council (CC), Cardiff Metropolitan University (CMET), University of the West of England (UWE) and Philips Lighting (UK Limited). The aim is to transform the Outer Harbour Arm of Cardiff Bay Barrage into a newly inclusive visitor attraction (see Fig. 1). The research examines how smart technologies can be embedded in and integrated with site-specific installation art to facilitate a uniquely individuated user-led multi-sensory journey through the fascinating aesthetic possibilities of a highly dynamic environment. A range of technological instruments (GPS/beacon and sensor/RFID) will be used to analyse user-behaviours in, interactions with, and responses to different on-site positions, environments, conditions and aesthetic stimuli. The data generated will help us refine a set of user-led design principles and methodologies to facilitate the building and furnishing of urban spaces and public installation artworks hospitable to and capable of engaging any kind of visitor, 24/7. This paper focusses on the initial stages involved in integrating a spatially networked system of smart technologies and site-specific artworks. The ‘pattern making’ process it presents will prepare for the gathering and validating of initial requirements to support the project’s user-led experiential design needs.

II. THE CARDIFF BAY BARRAGE PROJECT

Imagine a cityspace where difference and individuality are cherished, celebrated and valued; which asks you to teach it

how you want to experience it; which will respond by guiding you through the structures and possibilities (concrete and imagined, historical and cultural-political) that it makes available - and might condition your experiencing of it - in ways suited to your particular needs and/or interests. A space in which no architectural, cultural or organizational barrier is insurmountable, whatever your age, physical/cognitive capacity, or language.

This research brings together partners from academia, government and industry to explore how we can create public spaces that are available to and can engage all and any users that might be drawn to it; and to prove the power of art to direct technological progress down socially and culturally-aware avenues. We envisage deploying a newly nuanced set of user-led design principles and methods to facilitate an aesthetically Smart-er Cardiff; a 21st century capital city whose user-sensitized public spaces and art are more fully and hospitably inclusive than any other.

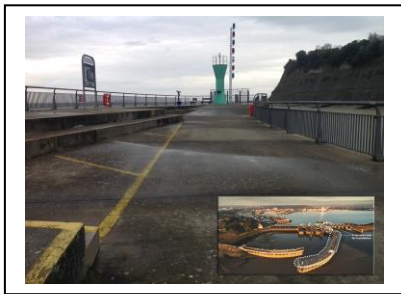


Fig. 1. Cardiff Bay Barrage

As [4] point out ‘the arts and design worlds opens the possibility of discovering new methodologies for and solutions to problems that, until now, have been beyond the reach of the computer science field to solve or perhaps even articulate’. The authors of this paper want to use smart technologies to understand and attempt to harness some of the numerous ways art can connect the embodied subject to the externally and internally conditioned and conditioning environment in which he or she is situated. For our team, this site is the exposed 1.1km isthmus of Cardiff Bay Barrage. The aim is to produce, through the fusing of art and technological knowledges, an enrichingly inclusive experience for all visitors regardless of ability and disabilities on a challenging coastal site.

III. IOE, SMART TECHNOLOGY AND AESTHETICS

The Internet of Everything (IoE) brings together ‘people, process, data, and things to make networked connections more relevant and valuable than ever before - turning information into actions that create new capabilities, richer experiences, and unprecedented economic opportunity for businesses, individuals, and countries’ [5]. ‘Smart’ IoE applications are leveraging ubiquitous connectivity, big data and analytics in cities all over the world. However, amid the storm of burgeoning information and proliferating connections, the challenge, increasingly, is to deliver experiences that are

meaningful to users of this strange new world. In the Smart-er urban spaces and structures our team envisages, this kind of information, fused/interfaces with the combined capabilities of beacons, sensors, RFID tags and raspberry Pis, can transform the experiential engagement of users with particular needs. Our project will explore the capacity of imaginatively user-sensitized technology to bring stimulatingly alive the external public environments, known and unfamiliar, on which so much quality of life and experience can depend.

Research has linked mindful interaction to embodied experience [6]. Embedded, transformingly, in site-specific art, traditional smart technologies can facilitate a more inclusive set of embodied, subjective interactions with any given site or (external) environment. In *Where the Action is – the Foundations of Embodied Interaction*, [7] centralizes the process of interaction: i.e. not just what is being done but also how it is being done. For [7], ‘embodiment’ constitutes ‘the way that physical and social phenomena unfold in real time and real space as a part of the world in which we are situated, right alongside and around us’. This paper contends that smart technologies reformed through artworks can not only transform environment/user engagement for certain types of visitor, but radically enhance our understanding of how best to realize that transformed experience.

[8] view aesthetics as ‘the way an object speaks to us, calls us, affords us, puts us into contact with others, is meaningful to us, shares its inner horizon with us’. Unsurprisingly perhaps, for [9] the design of products and systems should thus exceed any traditionally static aesthetic: ‘It requires a new language of form that incorporates the dynamics of behavior’. They argue that the aesthetics of interactive behavior can be a powerful design driver in connecting dynamic form, social and ethical aspects [9]. Harnessing the transformative powers of smart technology, our team conceives in the public art installation a catalyst for these interactions, capable of nurturing personal and wider social benefits through its capacity to make new and different experiences available to the users it engages. As creative artists, technologists and writers of today, we seek to recast ‘aesthetics into a unified theory that reflects the continuity, perceptual integration and engagement of our new encounters’ [10]. The specially designed, technologically enabled artworks we are installing along the length of the Barrage’s Outer Harbour Arm, will offer a uniquely enriched user-sensitized interactive and individualized site-experience, thanks to the fusing of artistic and scientific expertise and interests which underpin our research.

IV. INCLUSIVE AND EXPERIENCE DESIGN

Inclusive design ‘is comprehensive, integrated design which encompasses all aspects of a product used by consumers of diverse age and capability in a wide range of contexts’ [11]. At Microsoft, ‘inclusive’ technology is designed to increase access, reduce friction, and offer emotional context for the greatest number of people [12]. As [13] highlights, then, more than usability or a singular response (say satisfaction or attitude), technological experience constitutes the overall impression, feelings and interactions that a product or service produces in users. Like experience design [14], for us ‘inclusivity’ adumbrates all three spatial dimensions, time, the

five common senses and interactivity, alongside customer value and personal meaning. On Cardiff Barrage, we seek to create ‘inclusive’ experiences connecting visitors to each other in and through the site itself, beyond the edges of a particular artwork or the limits of a personal smart device.

Over the last twenty years, practitioners and researchers have sought to develop ‘broader conceptions of usability to encompass enjoyment, engagement, identity, trust and loyalty’ [15]. We will use new understandings of user diversity, assisted by the evolving technology, to think beyond obvious economic, logistic and cognitive/sensory limits, to anticipate and cater for a broad range of visitor expectations, needs, behaviours and responses. Technology’s increasingly ‘smart’ capacity to generate, register and potentially harness the ‘affect’ produced in a visitor (by any environment, context or experience) permits our team the chance to nurture ever-deeper, ever-richer site/user engagement.

V. PATTERNS FOR CONSTRUCTION

In many ways, the objectives of our smart city patterns resemble those of [16], using patterns to explore the essential features of real places. For [3], ‘each pattern describes a problem which occurs over and over again in our environment and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over without ever doing it the same way twice’. All his patterns are ordered and are related: they form replicable rules and building blocks in their solutions. For example, a pattern-set opening with the largest pattern (i.e. for a region or town), can work down through neighborhoods, buildings and rooms, to end with details of construction. Our research will start by examining how best integrate our different disciplinary knowledges, skills and experiences in meeting the challenge of bringing visitor-inclusivity to Cardiff Bay Barrage.

For us, artists, writers and technologists, patterns are attractive: they provide a way to identify the core design problem regardless of discipline. Using patterns as a basis, we can capture more specific information about people’s needs and desires in their experiential navigating of the Barrage environment. As [17] observes, ‘Installation art extends the trajectory incited by minimalism, body art, and conceptualism opens who we (think we) are’. Engaging many or all of the senses, installation art foregrounds experience and communication; definitively and specifically, it requires the active, embodied and psychic engagement of the participant user-viewer with the artwork it constitutes [18].



Fig. 2 Morse code path

The installation art experience centralized in this research will consist of an organic Morse code pathway running the length of the Barrage (see Fig.2); a wind-responsive whistling

weather vane (see Fig.3); an interactive cloud seat at the tip of the Barrage (see Fig 4), and a wind sock. All these elements will be designed to surprise and intrigue, and will be constructed in robust user- and technology-friendly materials.

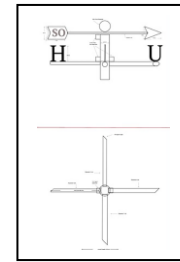


Fig.3. WeatherVane sketch

By technology-friendly, we mean that they will be tested to work with an enriching range of smart ‘push and pull’ technologies such as sensors, beacons, RFID tags and raspberry Pis. Encapsulated within an IoE framework, our ‘Smart’ artworks will be alerted to and be able to guide the visitor to the Barrage through the site to ensure his or her fully-engaged interaction with and participation in the dynamic environments of which it is composed. Our hope is that users will bring as much as to this reconceived visitor-experience as they might take from it.

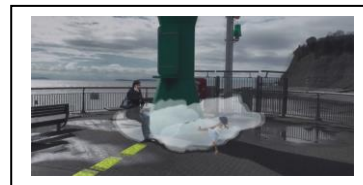


Fig.4 Cloud Seat

In detail, the visitor’s journey is envisaged as starting at the new café situated near the Outer Harbour Arm. At this location, visitors can download a mobile application enabling them to profile their needs. Alternatively, a generically profiled RFID tag sticker will be available for collection from the café (i.e. RFID tag programmed to ‘0’ will cater for the visitor with non-normative sight function; ‘1’ will cater for the wheelchair-user, etc.). Application and/or tag will alert the site-technology, especially the ‘Smart’ artworks to a particular visitor’s specific needs. Just as each element of our serial installation will encompass a silent dialogue between its materialities and the virtual technologies which it embeds, together they draw attention to the many kinds of distance between their concrete/plastic interventions on the site and the intangible nature of any imaginative or creative response they might stimulate in a visitor; and, further, between one experiencing subject and another. This core concept was inspired by a reflection in the 1927 novel *To The Lighthouse*: ‘So much depends ... upon distance’ [19]; the project was founded on and grew directly out of these words.

The visitor will first encounter the sparkling form of the larger-than-life weather vane, its cardinal structure (built of stainless steel pipes) designed – uniquely – to whistle on windy

days. Sensors embedded in the vane will harvest and transmit climactic and meteorological data to Raspberry Pis embedded elsewhere in the site to relay a real-time weather-specific experience. Thus the experience on a windy or rainy day will differ to the experience of a calm and/or sunny day. It is proposed that the second element, a Morse code path leading from the weather vane to the cloud seat and fabricated of a soft and malleable substance, will be embedded with hidden beacons and pressure sensors; on touch, the latter will turn the visitor's footprints to a color or sound or haptic imprint. Likewise integrated in the resin of the cloud seat, sensors, beacons and Raspberry Pis will enable visitor and seat to react to/interact with each other. We anticipate that such passive and active interactions, prompted by the artworks (aided by the mobile application, where it suits) will sharpen and heighten visitor-engagement with the site and its environments. To achieve this, all project partners apprehend both the nature of the challenge our research objectives pose, but the significance of integrating technology, plastic arts and user-led design knowledge in answer.

TABLE I. INCLUSIVE CARDIFF BAY BARRAGE PATTERN

A photograph	See Fig. 1
An introductory paragraph	'Equality making the 'difference for Cardiff': the 2016-2020 Strategic Equality Plan [20] envisages a city that enables people to fulfil their potential whatever their background or circumstances.
The Headline	Making an inclusive Cardiff Bay Barrage Experience
The Problem	A transformed visitor profile (i.e. including typically excluded groups), experience (ie 'inclusive') and radically increased footfall on Cardiff Barrage (Cardiff's newest park) 24/7.
The Solution	<i>Qualitative research</i> to better understand user-responses to, and potential socio-economic/cultural impact of, planned interactive art installations on Barrage; <i>Identification of functional and material requirements</i> for specified smart technologies and artworks; <i>Design specification</i> developed to answer principal art and technical questions concerning the (i) construction of separate elements and (ii) how they combine to meet visitor needs and achieve project objectives. <i>Iterative user-led testing programme</i> to (i) strengthen design, fabrication and integration of artworks and technology; (ii) examine visitor perceptions/approval of aesthetic and economic value / importance.
A diagram	See Fig.4
A closing paragraph	This pattern can be linked to the weather vane pattern (see Table 2), the cloud seat pattern, the morse code path pattern etc.

Using [3]'s pattern templates, the large problem (see Table 1) can be linked to smaller patterns such as the weather vane and cloud seat patterns; and smaller patterns again (the beacon technology and/ or the smooth resin material patterns). The range of patterns will refine the authors' understanding of different aspects of the desired experience; of the relationship between the project's art and technical aspects; and finally of the impact these will together have on the larger problem. For example, the problem section of the large pattern can provide an overall view of the issues with the environment whilst the solution section will involve the whole team in problem-

solving. The closing paragraph highlights the building blocks by linking the big pattern to other smaller related patterns.

VI. THE WEATHER VANE PATTERN

In our view, the success of the weather vane artefact depends how our combining of its unique aesthetic with appropriate smart technology to achieve an inclusive on-site experience. Devising the weather vane pattern involved several intense conversations on the form, look and functionality of the artefact. Importantly, the conversations centered on the relevance and impact of the weather on the visitor-experience of an exposed site. Although weather conditions can directly (and sometimes adversely) affect that experience, few visitors to the Barrage can access weather information.

As a multidisciplinary team, we were keen to ensure that our design exploit the artefact's harnessing of *physical* (its visible and audible signing of wind direction and strength) and *virtual* weather data (drawn down from local smart weather system and/or sensors) in an enhanced and inclusive on-site visitor experience. For this pattern, (see Table 2) our initial questions recognized the need to heighten the visitor's sense of presence on the Barrage. Would more precise understanding of the weather result in increased visitor-engagement? How deliver an *aesthetically* engaging experience? How best integrate virtual and physical data to ensure a more inclusive experience of the Barrage and its surroundings?

Discussions on sensors (such as temperature, humidity, pressure, wind speed, wind direction and rainfall) addressed questions about sensor-positioning, and the transference of data from these devices to a base station/ Raspberry Pi. What could the Raspberry Pi do with this data? Where could it be located in relation to the vane itself? How could it be powered? How protected from the outdoor elements? We also needed to work out what impact the data coming from the weather vane could have on the overall visitor-experience: i.e. how might wind direction and speed affect visitor-interactions with the path and cloud seat.

TABLE II. WEATHER VANE PATTERN

A photograph	See Fig. 3
An introductory paragraph	The Weather Vane aesthetically applies visuals, sound and data from local weather systems and/ or sensors to afford inclusive engagement with real time weather on-site.
The headline	The Weather Vane
The Problem	How to translate and combine its harnessing of physical (wind direction and strength) and virtual weather data (drawn from smart local weather system and/or sensors) in an enhanced and more inclusive on-site visitor experience. How will the data generated from this interaction inform the visitor's interactions with other elements of the installation (pathway and cloud seat)?
The solution	(i) exploration of the aesthetic / physical composition of vane (e.g. material, durability, finished appearance, opacity, texture and longevity ie resilience to maritime/weather and vandalism). (ii) identification of appropriate technologies for providing meaningful bi-directional communication between weather vane/visitor and other artworks (e.g. RFID visitor profiling; beacon-locating etc).

	(iii) feasibility of embedding electronic microcontroller in vane to monitor connected electronic sensors (e.g. pressure & temperature etc.) and trigger a response. (iv) Confirmation of functional and material requirements of associated supporting infrastructure (e.g. internet connectivity for obtaining local weather data and system updating). (v) evaluation of full scale interactive weather Vane to ensure more inclusive on-site visitor-experience.
A diagram	See Fig. 5
A closing paragraph	This pattern can be linked to the Barrage inclusive experience pattern, the cloud seat pattern, the Morse code path pattern etc.

After several iterations of the weather vane pattern, the team arrived at the idea of using a local smart weather system to seamlessly relay weather conditions that would not necessarily be experienced first-hand on the Cardiff Bay Barrage. In alignment with the visual and audible signals channeled by the vane itself, this smart weather data (channeled through a Raspberry Pi embedded in a weatherproof box in the environment) had the capacity to engage the visitor in a more fully inclusive site-experience. For example, the temperature on the Barrage could be visualized through LED lights embedded on the cloud seat (various shades of red depicting warmth etc.).

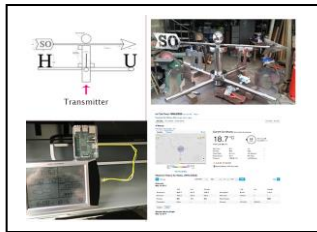


Fig.5 Weather Vane in construction

In terms of design, the pattern making process has afforded us the baseline from which to prepare for the requirements gathering phase of our research. To date, the construction of the weather vane has commenced on site (see fig.6); the weather vane pattern has allowed us to tease out important questions around the design of the weather vane and its potential not only to engage visitors aesthetically, but in doing so feed and nourish more inclusive on-site visitor-experience.



Fig.6 Weather Vane erected on site

The next stage is to observe target usergroups in the environment, in order to map and evaluate a range of interactions with the vane and the data it makes available.

VII. FOUNDATIONS FOR FUTURE WORK

Given the intention to anticipate and cater for different user needs, our next challenge is to test the possibility of defining different rules for different styles for the environment. For example, the environment could be styled differently for a person with non-normative sight function, or an autistic adult. Our approach will resemble that of Cascading Style Sheets (CSS); rules used to describe how HTML elements will display on screen, paper or in other media. This research proposes the idea of environmental stylesheets where new elements such as light, texture or sound build the infrastructure of the desired experiences (rather than the headers / footers / body etc. of the traditional webpage). Expanding the style sheet specifically developed to meet web-user needs, we propose a mechanism for the design of the environmental interface. We see environmental stylesheets as helping to describe how experiences are presented and/or created in the environment. We see it as a hands-on approach to implementing the solutions detailed in the patterns.

For example, the selector in the stylesheet points to a 'stylable' element in the environment, perhaps a LED light in the Morse code path. The declaration in the stylesheet consists of a property name and a value, say color with a value of red. As a wheelchair-user travels through the IoE framed Barrage environment, their RFID tag or application (programmed to their needs) will initiate an appropriate stylesheet. This stylesheet will activate/style all the elements in the environment to the desired experience (i.e. haptic, audio or visually driven etc.). It is important to note here that all visitors have the choice on whether they want their needs identified and tracked via RFID technologies. The aim is to design for inclusion and not intrusion. Excitingly, other real time elements such as the weather or a visitor's interaction with an artefact will also influence how the stylesheet is presented. A windy day would initiate a different experience for (any) user from a calm day. Experiences activated by the stylesheet will be enhanced and 'tailored' by the nature of a particular visitor's individual interaction and engagement in the environment. For example, the cloud seat might be styled with 'blue' tones on a cold day, until light, sound and/or pressure sensors – responding to visitor-interaction – turn it to a different colour or produce a different sound.

VIII. CONCLUSION

Cardiff City Council has estimated that some 80,000 of Cardiff's inhabitants (22%) are unable to navigate, interact and/or engage in other ways with the streets and landmarks of their home city [21]. In a world where the real and the digital are converging, technology should help visitors to traverse urban areas more easily. However, technology often creates its own barriers (i.e. distracting, not accessible, compatibility, not engaging etc.). To enhance and broaden the lives of all visitors, this research explores the role of the creative interface between the real and the digital. Through aesthetically engaging artworks, it aims to transform a challenging even hostile environment such as the Cardiff Bay Barrage into an engaging and inclusive experience for all visitors. As [22] point out 'Oddly in an era sometimes referred to as the "machine age,"

the research shows that human beings and the human imagination are fast emerging as the most vital economic commodity, the cutting edge of the economy'. In terms of Cardiff becoming the next smart city, the authors of this paper believe that the creative interface (the combined power of smart art and technology) has the potential and the capability to make people of all abilities and disabilities more included, to turn information into wisdom and make connections more accessible.

Like much multidisciplinary research, the challenge is to find common ground across our different languages, experiences and skills; to identify synergies between scientific and artistic knowledge and expertise, which can narrow the gaps between us. In this project, a pattern-making process has been adopted to make sense of the multidisciplinary journey from inspiration to execution. The process will enable us to capitalize on the enriching resources, which art and creativity can bring to technology and vice versa. The use of patterns has enabled the authors to identify and find unifying solutions to a central challenge to our core research objective: the transformation of Cardiff Bay Barrage into an inclusive visitor attraction. Guided by these patterns, the next phase will be to study how visitors currently experience our chosen site, while orchestrating and undertaking an intensive material and functional testing programme.

Our patterns have helped improve communication between the different members of a multi-disciplinary team, affording better understanding of how the art and technology can practically work together. They have also helped to capture the necessary expert knowledge needed to positively affect and have an impact on visitor's inclusion on the Cardiff Bay Barrage. As the research develops, we expect the patterns to crystallize into detailed stylesheets fully encapsulating sets of practical directions on how we might expand the use of stylesheets to encompass the design of a range of different environmental interfaces and experiences. On Cardiff Bay Barrage, it will allow for different experiences and in turn, greater inclusivity.

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