Scalable, Freeform Urban Lighting Displays

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CHI'13, April 27 – May 2, 2013, Paris, France.
ACM 978-1-XXXX-XXXX-X/XX/XX.

Abstract
Urban Lighting has many applications. This short paper outlines the case for classifying those applications on a single spectrum, and discusses the results and insights gained from a longitudinal field trial of a scalable technology designed to support these applications.

Author Keywords
Urban lighting displays; 3D lighting displays; Emergent displays; self-organizing particle displays; Firefly

ACM Classification Keywords
H.5.m. Information interfaces and presentation

Introduction
Urban lighting is broad concept. Many would consider lighting to be simply a commodity – a resource needed to enable their interaction with a city during hours of darkness. For others it provides a symbol of safety and security. Artists and architectural designers see it as a medium through which urban concepts and visions can be conveyed to the community. Revelers adorn their buildings with light at times of celebration such as Christmas and New Year. In recent years we have also seen an explosion in commercial and civic organizations making use of high lumen projection and embedded display technologies for digital signage and information services.

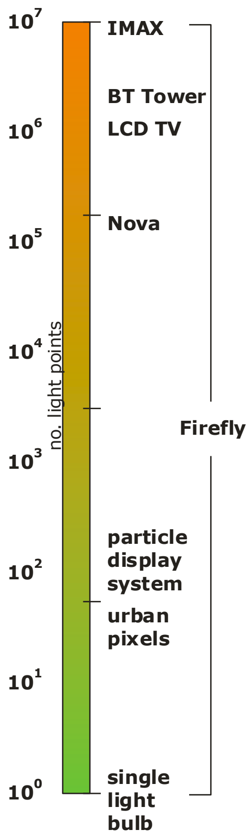

Figure 1: Lighting Display Spectrum [3][4][5][6]

Whilst the range of applications described above may at first appear distinct and independent, we believe they are in fact interrelated, and form classification points *within a single design space*. We argue this because, at a fundamental level, they all share three common fundamental characteristics:

1. *They rely upon the atomic concept of a controllable point of light*. From the most humble single bulb streetlight which is controlled on a daily cycle to the highest resolution public display containing millions of pixels updated 100 times per second, *they are all simply collections of controllable light points arranged strategically to achieve some visual goal*.

2. *They convey information*. From simple lights designed to raise awareness of hazards and promote security through ambient displays conveying simple messages in artistic fashions to high resolution digital signage and public displays - *they all send a message*. This may be as simple as 'watch out' or 'come in' or as complex as an urban digital signage system conveying community information.

3. *They form part of an artistic space*. Urban lighting is installed as part of a holistic design exercise, albeit sometimes badly. Architectural lighting illustrates to great effect how good design in highlighting buildings and monuments within a city greatly improves the overall feeling of the environment. *Every individual light installed within the city must consider both the people moving through the city, and the architecture surrounding it in order to enhance the environment as a whole.*

When considered in this way, we can place all urban lighting applications on a design spectrum, enumerated simply by the number of light points required to support that application. We illustrate this concept in Fig.1, indicating where common applications fall within this spectrum. Furthermore, we argue that all urban lighting systems, regardless of shape, size or purpose can be evaluated based on their ability to be effectively controlled, convey information and harmonize with the design of their surroundings.

The Firefly System

Readers familiar with the domain will appreciate that although the applications of urban lighting can arguably be classified together, the technologies currently employed to support them are far from unified, with many niche and/or proprietary systems used within each application domain. Over the past five years we have designed, developed, deployed and trialed a novel technology that aims to allow the deployment of light-point based architectural scale lighting displays *at any scale* that are highly controllable, convey information, and yet retain and artistic quality that can be designed to fit with the architecture it is installed in. We call this lighting display system *Firefly* [1][2].

Firefly provides a completely configurable lighting system through the use of a miniature intelligent pixel, known as a Lighting Element. Each Lighting Element (see Fig. 2) consists of a single LED, a low cost microcontroller and a few small components. At manufacture, these Lighting Elements (LEs) are identical and cost less than €1 to mass produce.

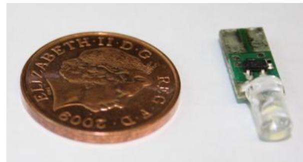

Figure 2: A Firefly Lighting Element

The Firefly lighting system enables individual control of these LEs. Up to 240 LEs can be chained together, and these chains can then be connected hierarchically to form highly scalable controllable lighting displays. Whilst other intelligent light point systems exist [3][4][5][6], what makes Firefly unique is its method of deployment. Firefly lighting elements can be deployed in any shape, size or density to suit their architectural environment – in 2D or 3D topologies. Once deployed, the system utilizes a highly parallelized computer vision algorithm to localize each of the light points in 3D space and build an accurate model of the installation. The localization of all the LEs is performed simultaneously using a standard digital camera. Information from multiple viewpoints is processed to create a 3D point cloud model of the display [2]. This enables us to deploy flexible, architectural displays tailored to the design of their environment at scales ranging from a single light point to millions. Once a model is created, the lighting display can be controlled directly through that model using a customized Renderer (Fig. 3). The Renderer enables the user to select *regions* of the display (either 3D or 2D) and schedule lighting effects to that region. As the model is a direct representation of the real, physical display, anything that can be rendered on the model can also be rendered on the Firefly display. Examples of content we support include wipes, fades, imagery, video, text, interactive applications and point cloud effects (Fig. 5).

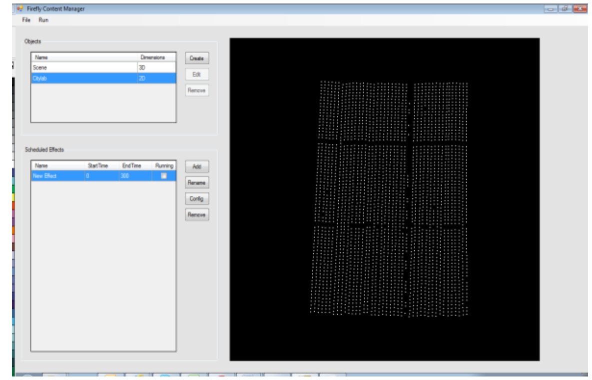

Figure 3: Firefly Renderer

Field Trial Evaluation: Lancaster, UK

Whist our in lab experiments validated controllability and scalability aspects of the system, we undertook a longitudinal, 5 year field trial of technology to determine its user acceptance, and its ability to harmonize architectural design with an ability to convey information. The trial took place in Lancaster's CityLab building - a traditional urban sandstone construction featuring an 8x5m smoked glass fascia which formed the basis for the ~3000 light point install (Fig. 4).

Figure 4: CityLab, Lancaster UK.

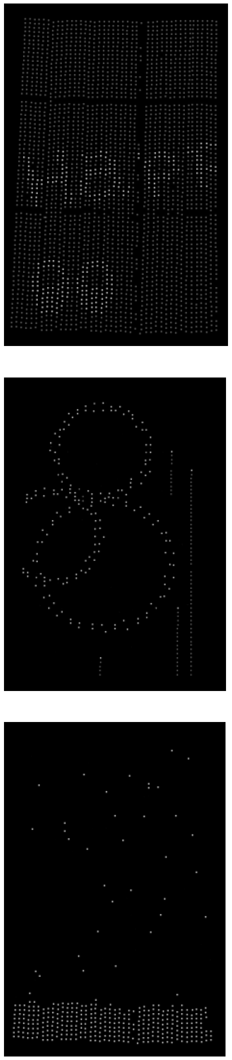

Figure 5: Bitmap and point cloud effects on Citylab

Situated in the heart of Lancaster, the CityLab installation is visible to a large volume of pedestrian and vehicular traffic and has operated in hours of darkness in the months of October-January between 2007 and 2013 (inclusive). During this time it has displayed a range of artistic effects pertaining to local events and or celebrations (such as Halloween, Christmas, New Year, etc.) and delivered local community information as scrolling text messages.

To ascertain the general public's acceptance of the technology we undertook a 100 user semi structured survey, conducted 2 months after Citylab was switched off in January, combined with interviews with local staff and residents. We inferred the following insights from our user studies:

- All of the building's 40-50 occupants recorded positive comments about the display.
- Passersby were overwhelmingly positive, providing quotes such as "it's a shame they don't seem to be on anymore", "a very attractive addition" and "very eye-catching". Some stopped to watch the display and several were recorded entering the building to comment positively to staff about it.
- A small percentage were concerned about the environmental impact of the display in terms of energy consumption (although it is <200W).
- 83% of frequent visitors to the area remembered seeing the display, with 54% for occasional (once a month or less) visitors.
- The survey comparison to a local digital signage system showed that only 71% of frequent visitors remembered the screens, with just 12% of occasional visitors. This is despite having roughly 30 LCD TVs in the digital signage system.

Conclusions and Future Work

Our field trial results have illustrated a large ($40m^2$) lighting display can simultaneously enhance an urban environment whilst conveying information. Moreover, our user studies have shown that city visitors and dwellers were overwhelmingly receptive to the display as a direct result of its artistic characteristics. This was in direct contrast to the higher resolution LCD TV system, where results suggest a degree of display blindness and a number of negative responses to their installation. For future works, we recommend further field trials of this technology in a range of scenarios and scales to investigate techniques and users acceptance of more interactive end-user applications.

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