Tools for Interaction and User Participation in Urban Lighting

LightStories case

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Abstract. *This proposed paper presents the results of a real world demo of adaptive urban lighting in a pedestrian oriented street in the core centre of a northern city of 65°01' latitude, Oulu, Finland. The case project – LightStories (Valotarina) – explores the methods to enable city dwellers to participate in the design of public urban lighting, as well as interaction and communication through urban lighting. It applies a web-based design tool which offers city dwellers the possibility to design one hour long light animations to be displayed along a pedestrian oriented street. In addition to describing the design and development process of the lighting system and the participatory design tools used in this case, the paper presents general discussion about the process and tools, and also about the role of algorithm aided methods in enabling the user participation in lighting design with the tool.*
Keywords. *Adaptive urban lighting; user participation; design tool; algorithm aided; real world demo.*

INTRODUCTION

Challenges of interactive and participatory lighting

Lighting design for urban environments is gradually changing from static lighting towards dynamic and adaptive lighting. With the help of sensors and transmitters, lighting can adapt to prevailing environmental conditions and react to different stimulus and signals, such as presence, movement, noise, trace data and SMS-messages. Intelligently controlled lighting system can also analyse the received data, learn and adapt its operation to respond to the needs of the city inhabitants. Visions and prototypes of intelligent lighting control systems, which are part of the ubiquitous intelligent infrastructure of the city, are currently being presented both on the level of a whole city (Volosencu et al, 2008) and on the level of smaller urban environments (Iannoni, 2011).

The inhabitants of urban environments can possess different levels of sense-of-control in regards to adaptive urban lighting. Lighting adaptation can occur independently of the users of urban space, or it can react to their presence and actions. Lighting adaptations can also occur as real time interactions between user and urban lighting, and thus involve bidirectional communication. This form of adaptive lighting can be called interactive. From this point of view, urban lighting design can be seen as interaction design. On a very high level of sense-of-control, users of urban space also understand how their actions and choices determine the outcome as lighting. In this way, inhabitants can participate in the lighting design of public urban spaces. New design tools, which enable user participation, are needed.

LightStories case and its research context

This paper presents the results of a case project – *LightStories* – which studies the methods to enable city dwellers to participate in the design of public urban lighting, as well as interaction and communication through urban lighting. The aims in this real world demo of adaptive urban lighting were threefold: 1) On the level of *Design Process* the aim was to gain understanding of a design process of a participatory and interactive lighting solution in urban environment, and of the methods and tools needed in the process. For that purpose a pilot version of a participatory design tool was developed and taken into real world test use. In addition, the target was to explore the ways to employ algorithm aided design methods in the process; 2) On the level of *User Experience* the aim was to research how both the participants and passers-by experienced the created participatory and interactive urban lighting setting. The target was also more specifically to get feedback from the users of the piloted design tool; 3) On the level of *Adaptive Lighting System* our challenge was to design and build an interactive and communicative lighting system, which allows city dwellers to participate in the design of public lighting, employing existing street lighting infrastructure.

LightStories case produced a wealth of research material, all of which is not in the scope of this article. This paper concentrates in the results of participatory lighting design process, tool development and piloting, and algorithm aided design point of view. The user experience is reflected from that perspective. Interviews included many questions about interviewees' attitudes towards adaptive urban lighting in general, and their ideas and wishes for further applications of adaptive lighting in regards to their daily environment. These very interesting subjects are discussed in other venues and articles. In addition, the focus of interest in the system level was not on creating any new technological solutions but on using the existing lighting control system in a novel way. Moreover, the process of designing and building the system was for us in the role of a research setting for studying the design and participation process, so the refinement of its technology beyond the level of sufficient operation was not the issue. The research questions which are answered in this article reflecting *LightStories* case project are:

- What phases and components does a design process of participatory lighting solution include from the perspectives of professional designer and layman participant?
- How users experienced the *LightStories* participatory design tool? How the tool was used as a lighting design tool? What further development needs and options can be drawn from the feedback and the recorded use data?
- How can algorithm aided design methods be used in enabling user participation?

LightStories case is part of a research project *Adaptive Urban Lighting – Algorithm Aided Lighting Design* (University of Oulu, Department of Architecture, 2011 – 2013). The project aims to research and develop algorithm aided design methods for designing adaptive urban lighting. The benefits of adaptive urban lighting are connected e.g. with energy savings, the pedestrians' feeling of security, and with the experiential value of an artificially lit environment. Real world demos are designed and built to test adaptive lighting and its design in real urban environments. The evaluation of the user experiences in the real world demos is carried out in collaboration with multidisciplinary *UBI Metrics – Multidisciplinary Framework for Evaluating Ubicomp Systems in Real-World Urban Settings* research project (University of Oulu, 2011-2014).

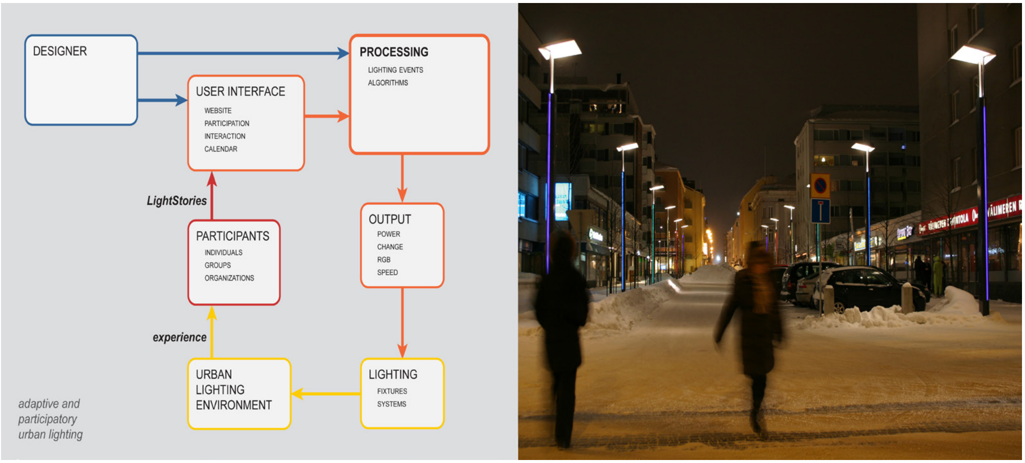

Figure 1
Diagram describing the process of adaptive and participatory urban lighting, with the view of one user-generated lightstory presented in the street.

METHODS

Our research problem – the participatory design process of public urban lighting – is situated in the context of design practice. Lighting design is approached as a transdisciplinary field of knowledge, which combines knowledge from various fields of science and practice. The problematics of participatory and interactive lighting summons expertise from fields that have not traditionally been so closely related to lighting design: algorithm aided design, participatory design, UI design, lighting control technology, and programming. The relevant way to approach this kind of multifaceted research problem is to carry out research in real world settings, in our case by building a demo in a real urban environment. (Gibbons et al, 1996) This same tendency is also seen in recent HCI research, which approaches ubiquitous computing in urban settings. (e.g. Paulos, Anderson and Townsend, 2004). Our approach is related to *research by design* and *action research* research traditions. Design process is applied to get a direct contact to the phenomenon under research, and to reach its multi-dimensionality. Multiple research methods are used, both quantitative and qualitative, to analyse the research material created in the process.

User participation in urban lighting through LightStories design tool

In the *LightStories* case project, we approach lighting as an experiential, interactive, social and communicative element of public urban space. The main concept of *LightStories* is to introduce a part of public street lighting as a forum for personal narratives, messages and greetings. Through this playful idea of a street lighting as a social media, people are invited to participate in the lighting design of a public street. For one hour at a time, anyone can have the power to decide what kind of atmosphere the lighting is creating there through RGB-LED stripes situated on the sides of street light poles. The stripes provide colouring and ambiance to the environment, but the more functional part of the street lighting, provided through indirect metal halide lamp luminaires, could not be controlled. This was due to limitations of the existing lighting system.

User participation in lighting design is enabled through an easy-to-use web interface which was designed and built in the project. Each participant using this interface, books a suitable time for their story and creates a lighting design by choosing different colours, effects and at which tempo they are displayed. Additionally, users write a story, a message or a greeting, which relates to their lighting design. These texts are viewable on the *LightStories* website and on the public UBI touchscreens in the city centre. Real-time video of the street is also displayed to illustrate the current story for the website users. The *LightStories* project was designed and realized during autumn and winter 2011-2012. The design tool was in use and the *LightStories* were presented during February 2012 along a pedestrian oriented street.

Research environment: LightStories – a participatory and adaptive lighting system

The realization of participatory and interactive urban lighting system included various components and design tasks, which are listed below:

Although *LightStories* is set up as a temporary lighting installation, it used existing lighting infrastructure and ubiquitous technology built in the city (luminaires and lighting control device, cable and wireless network, public touchscreens). The existing technology was already sufficient for the application of this demo and there was no need for additional devices. The control of the lighting fixtures' RGB-LED stripes is implemented using commercial Pharos LPC (Lighting Playback Controller) lighting control unit [1] that we connected to the city's communications' network. This communicational pathway between the research team and the control unit allowed for the real time testing and demoing of different lighting situations and effects. In aid was also

Designing citizens' web-based user interface to control street lighting
- → web page
- → design tool
- → lighting effect templates
- → database of user created lighting designs and narratives
- → *LightStories* application on UBI touchscreens

Programming of the lighting control device
- → designing the lighting effect templates
- → scripting the interactive lighting effect templates
- → defining and building the system functionalities for linking the web-based design tool and the lighting control unit
- → defining system functionalities for maintaining and running the LightStories service

Constructing the necessary communication links
- → connecting the lighting control unit to the city's communication network
- → direct VPN connection to the lighting control unit for the research team
- → web servers
- → server for the webcam

Employing existing infrastructure
- → lighting fixtures
- → lighting control unit
- → Ubi touchscreens
- → free Pan-Oulu wireless Wi-Fi network covering the city centre

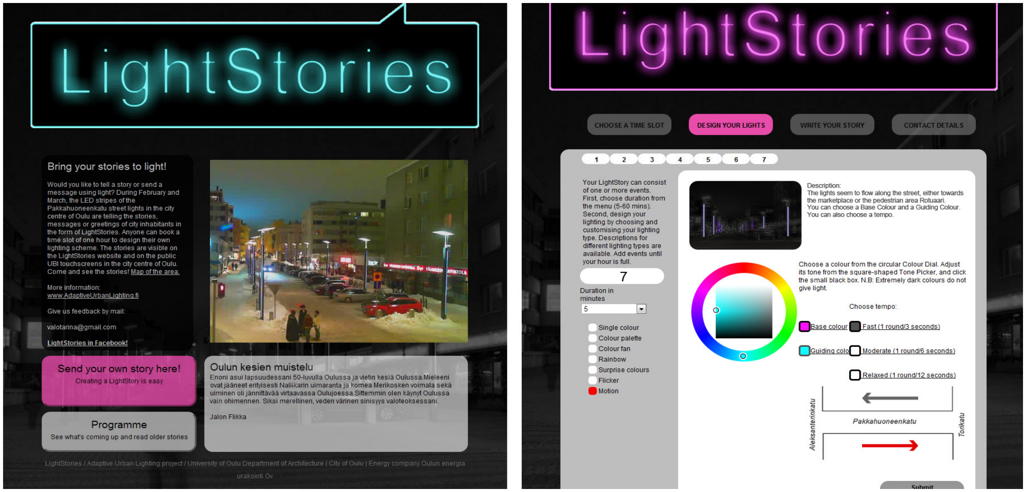

Figure 2
The LightStories website and lighting design tool.

the setup of live video feed, which fed video to the public LightStories website. This in-situ test phase was crucial in the design of the interactive and controllable effects, as the simulation view of the design software and how the lights actually appeared in real life differed greatly. Adjustments after testing were made especially in the speed parameters of the different effects.

LightStories lighting installation consists of two distinct set of systems; the web based design interface and the lighting control unit's internal program to display that design. New solutions were developed for building a working link between the web interface and the unit. The web user interface saves the finished user designs as textual CSV files, which consist of information about the effects, colours and other parameters in a predetermined and specific order. All CSV files for a night were combined and stored on to the lighting control unit's memory during the bright time of day over FTP. Because the file transfer resets the lighting control unit (a process, which takes about a minute after the connection is closed), it was done only once a day and not, for instance, hourly. This limitation led to the web design interface to lock the next night from entries at noon and thus defining the minimum delay between the design and the show. The shortening of this delay would require different communication methods between the web user interface and the lighting control unit, and possibly an additional device in between to act as a buffer.

Research material and methods

LightStories was in operation in February 2012, during a period of 25 days. Within that time, 105 user-generated dynamic lighting designs were displayed in the pedestrian-oriented street. The participants of *LightStories* were requested to fill a web-based questionnaire, which collects basic information about the users. They were asked to answer a short set of multiple choice and open questions relating to the experience of participating in lighting design. Voluntary participants were also invited for further theme interviews.

All in all, the research material developed in the *LightStories* case project included documentation of the design and realisation process; video documentations of the user created lighting designs, detailed data of the lighting designs and the associated narratives saved to the database; questionnaire results from 90 users; and videotaped interviews of 7 participants and 3 accompanying friends. Information about interviewees is presented in figure 3.

	Group interview 1		Group interview 2			Interview 1	Interview 2	Interview 3	Interview 4	Interview 5
Age	20-29	20-29	20-29	20-29	30-39	30-39	20-29	60-69	40-49	30-39
Sex	Female	Male	Female	Male	Female	Female	Male	Female	Male	Female
Occupation	Architecture (student)	Architecture (student)	Business economics	Electrical engineering	Geography	Publishing	Social instructor	Retired (health care)	Biology	UI designer
Had made a LightStory	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes

Figure 3
Information about interviewees.

To answer the research questions, following methods were used: reflection of case design process; statistical analyses of the participant's lighting designs, story texts and questionnaire data; and qualitative analyses of interview material and questionnaire answers. Results from different methods were reflected against each other.

RESULTS

Participatory lighting design process analysed

The flow chart presented in Figure 4 describes in parallel the design processes in the *LightStories* project from the perspectives of different actors of participatory design process – the professional designer and the layman participant. These processes are presented as actions in a simplified system context of *LightStories*.

The professional designer starts by framing the user's design task, in order to ease the process of the layman participant designing dynamic lighting within the streetscape. With the lighting controller's software, designer defines the participant's possibilities through devising, scripting and testing different effect templates to be used in the lighting designs. This framing is also done in parallel in the process of devising the functionalities and principles of web-based design tool, with which the participant approaches the design task.

A major part of the professional designer's task is related to designing the participatory and adap-

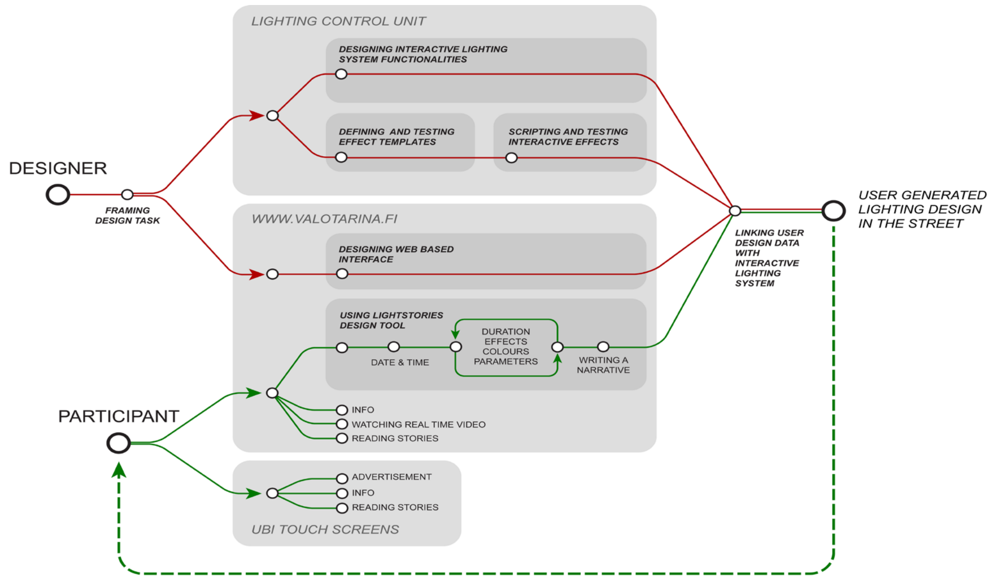

Figure 4
Flow chart describing the parallel design processes and paths.

tive lighting system, which brings the user generated designs into the streetscape. The designer devises the functionalities of the interactive lighting system; these make the lighting system operate according to choreography suitable for the requirements of the participatory project in question, and link user design data with the interactive lighting system.

The complicated system level is deliberately kept out of the participant's sight, as their contact point to the system is the easy-to-use web-based design tool. This design tool is used in the creation of the lighting designs, starting from time slot selection and the actual design task – carried out by combining and modifying effect templates – all the way to the writing of the narrative text. On the web site, people can also read stories and messages other users have written, watch real-time video of the street and receive information about the project. Public UBI screens are also part of the system as they provide a venue for reading the stories and advertising the participation possibility.

LightStories design tool evaluated

LightStories design tool has been evaluated and analysed from the perspective of participatory design by reflecting the tool design process, user feedback, and data from the user-generated LightStories. As the focus of our research is not on user interface design, but on development of design tools and methods, the analysis does not cover general UI design issues but concentrates on the usability and operation of the design tool.

The tool is analysed from the following viewpoints: 1) Freedom of design versus ease of use, 2) User path and instructions, 3) Feedback, 4) Entertainment and pleasure, and 5) Narrative. These viewpoints have emerged during the design process as relevant issues. In addition, many of the themes also appear in research about lighting control interface design and evaluation, which as a subject is closely related to ours (e.g. Dugar, Donn and Osterhaus, 2011; Dugar, Donn and Marshall 2012).

1. Freedom of design versus ease of use

One central problem in the tool design was how to strike a balance between the amount of design choices that were offered to users and how uncomplicated and simple the user experience should be. Making the tool as easy-to-use as possible has the risk of limiting the users' freedom of choice, thus discouraging also their design aspirations. A design tool which is too simple and restricting may well be boring and frustrating if the users' expectations and design tool possibilities do not meet. On the other hand, if there are too many design possibilities, the participant may be over-whelmed by the amount of choices and by the complicated process. A participatory design tool in our case was not meant for professionals but for everybody, including schoolchildren, and it should be attractive and encourage people to participate.

The creative options, that LightStories user could have, were carefully designed considering the tool designer's responsibility to prevent any possible harm to pedestrians and neighboring buildings caused by ill-devised lighting schemes. The choices of light colour and intensity rates were tested to be slow enough not to cause traffic or medical problems. However, the colour palette was kept whole not to limit any creativity, and to offer the possibility to dim the lights with darker colours.

The interviewees' answers indicate that the offered amount of effect choices was sufficient, it was even difficult to them to invent anything else they would have wanted to do. They felt that they really had possibility to design themselves, not just to select ready-made options. Also the data of user-generated designs tells that all the effect templates were needed, as they were all used (Figure 5). Those effects, which could be characterized as the most dynamic ones – "flicker" and "movement" – were the most commonly used ones. Of three tempo alternatives, the "quick" was very clearly used more than "moderate" and "slow". Of the different lengths of light events used the shorter lengths were more popular among the users than the longer lengths (Figure 5). In the user feedback, there appeared a wish to have also shorter light event lengths than the shortest one (5 minutes). One interviewee thought that there should also be options to make shorter lighting design than one hour – for example 15 minutes would be a more suitable length for the show to be watched as a whole. The starting times for a lightstory between mid-night and 6 in the morning were used only 0 to 2 times each (Figure 5), which could be interpreted that there is not a great need for this kind of service during the night.

Most of the interviewees thought that the design tool was easy to use. Only one interviewee, who was an elderly woman, was telling widely about the difficulties in using the web interface. Besides some technical problems with the web-site, the proceeding with design task had been difficult for her as she was missing logical cues how to continue forward in some spots. She did not have lots of previous experience with design programs. In the questionnaire, there was on open question how did the participants experience making a lightstory. From the users, 69% described it with positive adjectives (easy (30%), fun, nice, inspiring etc.), 17 % mentioned something positive, but commented something to be done better, 7 % were unable to form a clear opinion, and 7 % were negative or indicated as having experienced difficulties.

2. User path and instructions

The use of the design tool was considered mostly as logical, at least after reading the instructions. The amount of instructions was considered generally sufficient – not too little but not too much. One interviewee commented that the tool should guide the user more automatically: the phases should follow each other more automatically, so that the user would not have to read the instructions. Our online

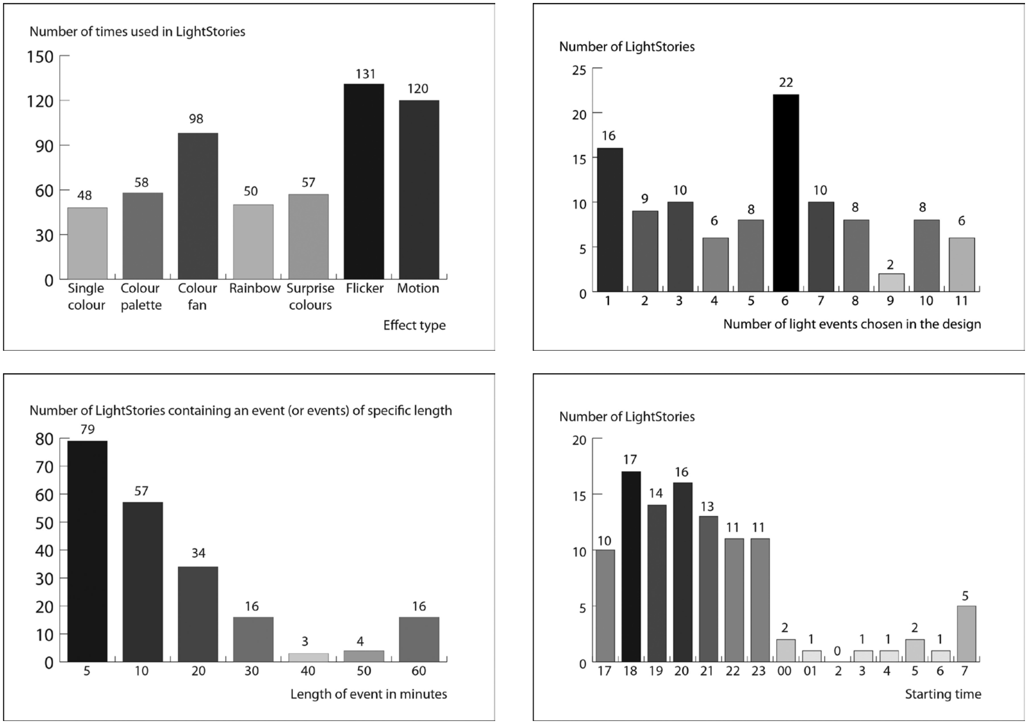

Figure 5
Statistics about the usage of the LightStories design tool.

participatory design tool was built around the concept of a timeline, which is used in many control device manufacturers' design programs. Users compile their lighting schemes of different kinds of partially pre-determined light events, both static and dynamic, which the users can modify to their own preferences. One shortcoming, which appeared in many answers, was the fact that it was not possible to return to the previous design steps while doing a lightstory. This was something that research group had also recognised, but had to keep the web interface structure fairly simple because of technical constrains of the pilot version.

3. Response and feedback

A successful design tool should give the user sufficient response to proceeding with the task, and also illustrate design options as well as simulate the results of design. Development of the lighting design piece by piece on the timeline was shown on top of the web page, in order to tell to the user how he/she proceeds and how much time he/she has left. This function was not presented clearly enough in the web-page design, and most of the interviewees had missed it. Users experienced that the gif-animations of effect templates choices helped them to understand the design possibilities. Their opinions varied about simulating the created design: Some thought that it would be nice to see a simulation of the finished lighting design, and even to get a kind of digital recording of its parameters to be sent from the service to user's e-mail address. On the other hand, some of the interviewees thought that seeing the simulation might decrease the pleasure and excitement of seeing the real world presentation, and perhaps it would make it hard for some users to stop refining the design. The real-time feedback and interaction with lighting was not possible in this demo since we used the booking system with fixed time slots. This was due to the transfer method of the user design data. It was also a way to solve multi-user aspects in interaction, as well as to provide means to censor written texts if necessary. Anyhow, the system could be developed technically further to allow real-time creation of lighting designs, and this was also wished in user feedback.

4. Entertainment and pleasure

Another challenge for creating interaction through participation is to make the process fun enough and certainly not overly tedious, in order to attract the visitor landing on the first page to continue until the end of the process, and perhaps to even participate again. In tool design, no special tricks were used to make the interface more game-like. We trusted that the subject itself is tempting enough, and a clearly designed tool which conveys the content in informative and elegant way is enough. From both the interview and questionnaire answers, we could indicate that the matter in this case was more or less like that: users were really fascinated by the possibility to design dynamic lighting in public environment themselves ("The street was mine!"), and they found it fun to play with light and colours and to test different possibilities. Most of the user feedback from the questionnaire was somehow announcing enthusiasm, pleasure and excitement to participate in LightStories.

5. Narrative

The utilisation of the narrative element was intended to help participants without previous design experience to start designing dynamic lighting. The 90 stories that were saved to the server (15 lighting designs were saved without the text part, supposedly because of a system error) varied from short greetings to longer narratives, describing, for example, a memorable situation in the writer's personal history, a current theme, or the writer's state of mind at the moment of creating the story. In interviews, attitudes towards the narrative part varied: some participants found it really inspiring and important part of the process. For example, one participant compared telling the story with light to making a narrative with music, which was familiar to him. Couple of interviewees suggested that writing should be done in parallel with making the lighting design, so that each light event composed could be linked with the associating part of the written story. This could also be transmitted to the presentation phase of the lighting design. For some of the interviewees, on the other hand, the play with light and colours was the primary part, and writing something that would be published on the website was seen as unimportant or as even an unpleasant necessity.

The role of algorithm aided design in enabling user participation

The Pharos LPC lighting control unit is used mainly for showing predetermined lighting animations and colour effects, which can be designed using Pharos's free design software (Pharos Designer) that is based on the sequential display of pre-determined effect and colour combinations. The design happens by adding various lighting effects on a timeline, which then can be started by different triggers, such as time or control devices. The design software is very versatile, even offering if-then conditional clauses to be used with the triggers, but as an essential perquisite for the demo, it does not readily offer the possibility to control lighting effects interactively. This problem can be solved by a skilled designer, as the software offers the possibility to extend its capabilities through scripting, using simple LUA scripting language. This allows for the creation of custom lighting algorithms and to add functionality to the device.

To add the ability to design lighting situations interactively with the Pharos LPC, we used LUA scripting in combination with the Pharos Designer triggers to exceed the build-in limitations and functionality of the device by constructing our own parallel interface and functions. This interface did not replace the software's interface, but was built upon it as an extension and a collection of custom script triggers. The lighting effect algorithms were reconstructed by using the existing Pharos effects as reference, and this allowed adding interactive controllability and functionality directly into the effects. Participants' choices of colours, effects or other parameters, such as speed or direction, could then be inserted into the control program.

DISCUSSION

LightStories has produced valuable knowledge about participatory lighting design process, user experience of a tested participatory design tool from which further development needs can be derived, and understanding how algorithm aided methods can be applied in the participatory lighting design process. For the professional designer, choreographing a participatory design project is a challenging task which includes many phases to be done in parallel and which demands expertise from various disciplines. In the process, an essential starting point is the framing of the design task for the user, which is carried out simultaneously in different design contexts for realizing different parts of the interactive lighting system: in the lighting control design and in the user interface design. On the other hand, the whole design process can be seen also as linking the parts of interactive lighting system together, which puts the professional designer's and layman participants inputs together, in order to create the realized lighting design devised by the participant.

The demo has shown us successfully that participants can be brought into the design process of lighting in public environments with a tool which gives the users the chance and ability to design themselves. Results have been promising as the design process was valued mostly to be a positive experience. Further challenges for the development of the tool include following aspects: 1) Making the design process more interactive by a adding the chance to design and present lightstories in realtime, without booking; 2) Making the composing of lighting designs more free with use of time so that the length of the whole lighting design as well as the length of a single light event can be varied more flexibly; 3) Allowing steps back and forth in the design process. 4) Refining and clarifying the feedback of the design process in timeline presentation and design simulation; 5) Making the written text part voluntary and adding to the user interface the possibility to write and design lighting simultaneously; and 6) Making the service available on multiple platforms.

The use of algorithm aided design methods was an essential part in enabling the possibility for user-generated designs to be inserted into the interactive lighting system. This could not have been possible by solely utilizing the existing graphical user interface of the design program. The lighting algorithms of the effect templates were kept relatively simple and straightforward, as it gave the user a very high sense of control and an accurate idea of what the results would look like. More complex algorithms, for example swarm algorithms, could be used in creating the effects. Also, environmental data could be added to the process as extra parameters controlling some aspects of the design. This added complexity would increase the unpredictability of the design result and additionally, it would emphasize more the design professional's part as a creative designer. On the other hand, it would lessen the sense of control of the participant.

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