Empathic Lighting

Fast responding personal Lighting based on Sensors and LEDs

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Abstract: Empathic lighting as project explores the usage of computers, sensors and actors to illuminate a scene. Starting from a modern colorful LED mounted on a tilt-swift bracket, which is controlled by a single micro-computer, a fast responding lighting system is developed to not only defy the impact of changing daylight conditions but to answer the environmental light intake on the fly and even anticipate a viewer's acting. Still at model scale the working system comprises two lighting units and a smart phone as both as camera input and user interface.

1. INTRODUCTION

The concept of flexible and dynamic lighting is not new at all. Personal lighting on demand has always been flexible and dynamic. Illuminating a place while carrying a torch is in fact one of the oldest use cases of lighting a scene at all.

Starting with electric lighting remote and unattended illuminations now have taken over. A scene, in architecture it is usually a room, is illuminated independent from its viewers, bystanders or, as room, occupants.

With computers and digital cameras at hand and the new possibilities of small sized micro-computers the old concept of personal lighting can be revived without the hassle of carrying personal items. This is what empathic lighting will stand for.

2. DIFFERENT CONCEPTS OF LIGHTING

In general there are three concepts of lighting, personal, scenic and ambient lighting. All of them are artificial, although ambient lighting as daylight can be natural. The knowledge of all three types are taken are taken from principles of the lighting of virtual models with CAD visualizing software.

2.1 Personal lighting

The concept of personal lighting is simply best described by the devices in use. These are headlights, flashlights or even torches, but also lights attached to vehicles and vessels. They are commonly not stationary and usually pointing into the same direction as their associated viewers.

2.2 Scenic lighting

Scenic lighting relates only to a scene, regardless whether or not observers are present. Several light sources are arranged in order to illuminate a designated space as scene.

These light sources are always point lights. Their light beams are radiating from a single point into all directions, even though they can be manipulated through reflection and refraction.

2.3 Ambient lighting

Ambient lighting does not always use dedicated light sources. Indirect lighting like soffit or close to wall lighting are intentionally hiding the light sources, while direct ambient lighting with bright illuminating surfaces like panels is an still evolving technology.

A special case of ambient lighting is simple daylight. Then there is no device at all.

3. DEVELOPING THE CONCEPT

The overall idea of arranging various light sources and to anticipate a desired illumniation is a known concept in lighting. Especially stage lighting with dozens or hundreds of orchestrated luminaries controlled manually or by automated applications reveals a wide range of possible use cases.

What is new is however the direct use of sensed and computed informations in an easy to reproduce lighting application.

3.1 General Idea

The main concepts evolved around the idea of implementing the effects of headlights without the headlights itself, meaning lights should be used similar to an illuminated stage and without carrying personal lightd.

In addition personal, scenic and ambient lighting should be integrated into one system.

3.2 Idea of the Prototype

The idea of the prototype integrates all three different concepts into one model of a user controlled illumination.

The system is based on the assumption that there would be an optimal state of lighting a designated scene for any user observing it. This illumination can be defined in relation to the user. By evaluating a current visual impression of the scene with the ideal state additional controllable light sources can be adjusted to match it.

This concept is introduced as empathic lighting: A user is observed and the surrounding scene is illuminated once the user enters the scene. The overall ambient light and, based on face detection, the viewing direction of the user is determined and the scene is illuminated according to the desired illumination and the detected values.

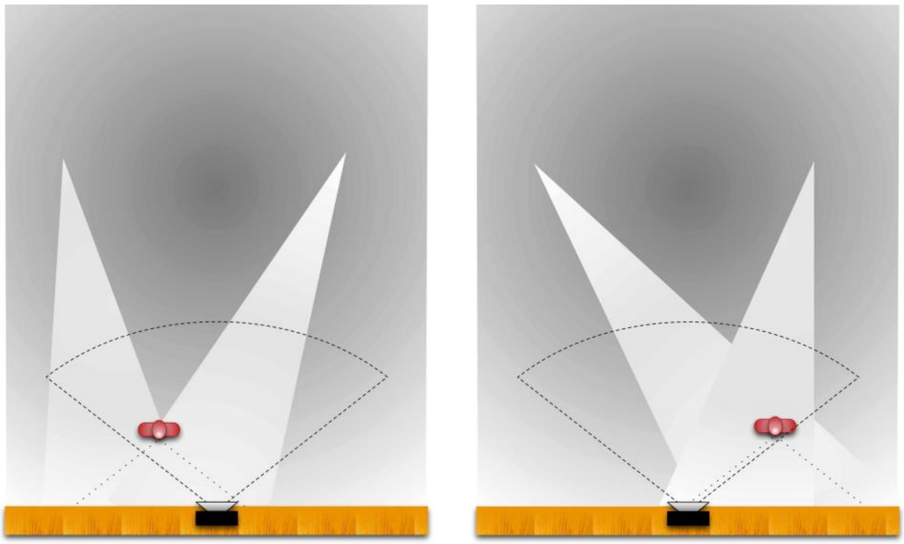

Figure 1. Concept: Two lights follow a user while moving.

3.3 Prototype

The prototype system itself is comprised of two specially designed lighting units. These are spot-lights with RGB-LEDs mounted on pan-tilt brackets. They are individually assessable: color, brightness and the direction can be changed on demand.

Each lighting unit deploys its own computational control component, an micro-controller on a board. The limiting factor here is the wiring, or better the number of pins that can be used. They have to not only provide digital values, like on and off, but analog values. Otherwise dimming the lights and controlling a motor would be unachievable.

The common technique is pulse-width modulation. The software of the micro-controller encapsulate this function. It can be simply controlled with one line of code.

To determine the present illumination a camera is used, which is for simplicity part of a mobile device. By means of image processing the immediate visual appearance is analyzed.

The first evaluation is the presence of observers at all. Otherwise all lamps are off and the system remains idle.

If a person is noticed, then the eye's position is determined to detect the viewing direction. Finally the lamps are directed accordingly.

Responding to the ever changing conditions introduced by an the observer and possible environmental effects the lighting color is corrected.

Any person in a scene provides both shading and color modifications even in an otherwise complete artificial illuminated setting.

With methods of image processing an overall color value is generated by summarizing all pixels and calculate a mean value thereof. This value is for correction, either as weighted value according to a designated field of interest inside the camera's view, or in relation to an overall referenced value taken before under controlled environmental conditions, or both. Then in an opponent color space the opposite color components of the lamps are raised. If, as example, a viewer in front of a painting is wearing green clothes and the detected overall value is more green than it should be then the emitted light of the luminary would be kind of reddish.

3.4 Maker culture

Making is yet another form of developing. Derived from the DIY (Do-it-yourself) culture it combines physical objects with the beneficial effects of programmable computers.

The makers' movement, like similar movements, is prudent when it comes to finalized definitions or even worse, the culture is subject to academic disputes. It has two consequences. By nature a theoretical discussion is almost impossible, and secondly, because of the avoidance of established rules some of their labels like 'experimental play' or 'basic democracy' compromise the movement and cast an unprofessional light on the results.

This is mentioned beforehand, because the project presented here is created with tools and techniques from the makers' scene. Otherwise it would not have been developed at all and the accompanying concepts could not have been established without them.

4. MAKING A LIGHTING UNIT

To give an insight, how to build such a project from scratch a more detailed than usual description of the process of making is given. Although working with electrical parts is not one of the main activities of architects, this project demonstrates that making an electronical design can be accomplished.

4.1 In the Making

The two lighting units deploy each a light source mounted on a servo operated position control and a controller. The light source itself is a colored LED with three color channels. It can deliver almost any color to the scene.

The pan-tilt mechanism is controlled by two servo-motors. Each can cover almost a complete semi-sphere.

4.2 Building the Lamp

Three essential elements are comprising the lamp, an RGB-LED as lighting source, a reflector, a diffusor and a small dowel pin made from plastic as enclosure.

Figure 2. RGB-LED, reflector and diffusor.

The LED is fixed onto the reflector and covered with the diffusor. The four pins on the backside are routed through the plastic pipe, which is fixed with some glue on the rear side of the reflector. Finally the wires are connected.

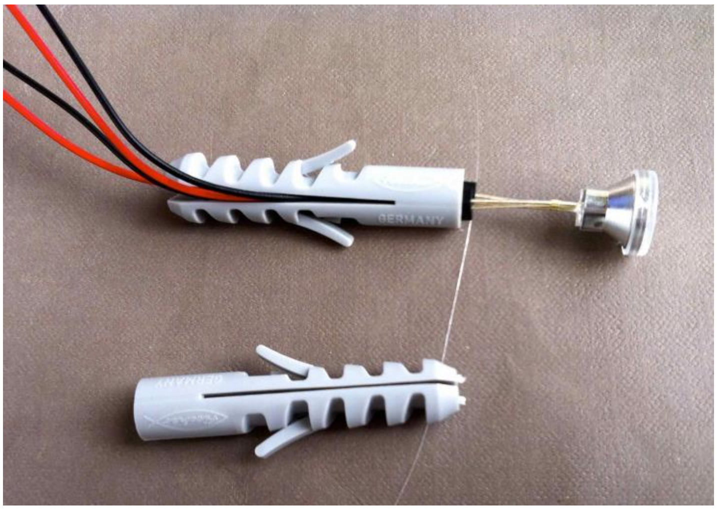

Figure 3. Assembled lamp with a second dowel pin

4.3 Making the Mount

To get a motorized pan-tilt bracket as mount several pieces of hardware needed to be assembled. Brackets and motors had to be assembled according to their accompanying instructions.

Figure 4. Two brackets and two servo motors, wheels, nuts and bolts

By putting the brackets together and installing the servos special care had been taken of controlling the brackets orientation. Not only had they point towards the right direction, they also have to be perfectly in synchronization for best results.

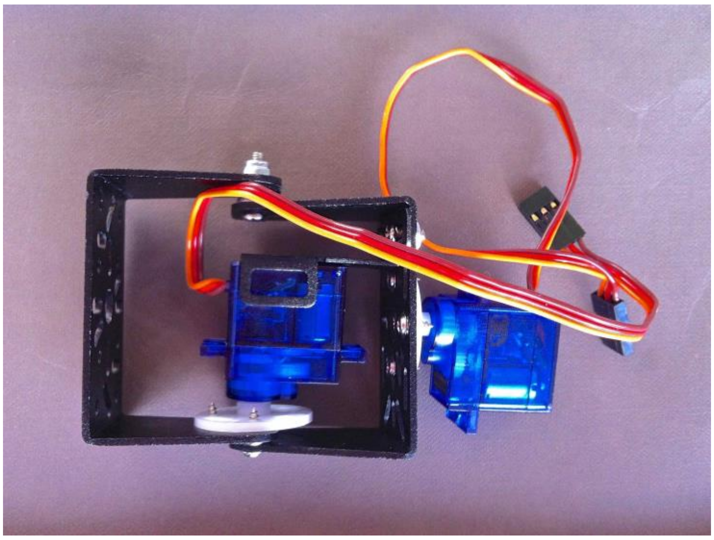

Figure 5. Motorized pan-tilt bracket.

4.4 Completion

Once the pan-tilt bracket and the lamp have been assembled a fixation was needed to mount the lamp onto the bracket. Luckily a simple cable tie could fulfill the task.

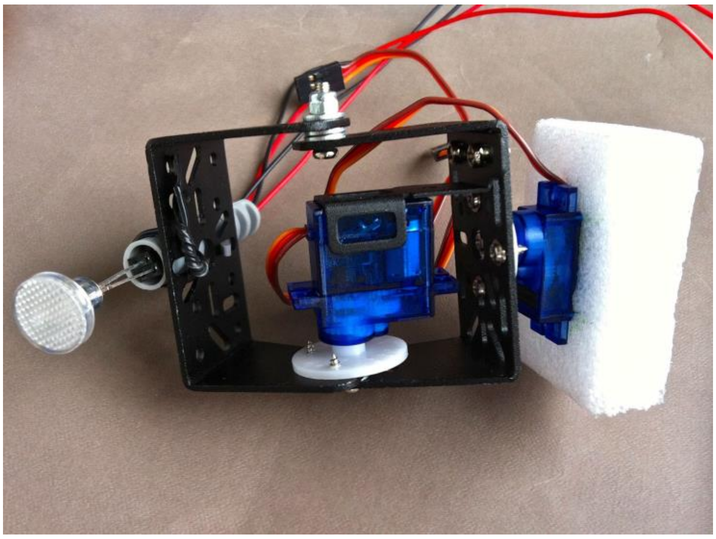

Figure 6. Completed lighting unit

Finally all wires, four from the lamp and 6, 3 for each servo, had to be routed to the breadboard.

4.5 Micro-Controller

The last component be assembled is the micro-controller. It is placed on a board which has only the bare functions as the pins to be connected and a programming interface implemented. During development the interface as USB-connector also did provide the power.

Enhancing the board is simple, other boards with dedicated functions for all purposes are available. They match the form factor and hence usually are pin-comaptible and can be stacked.

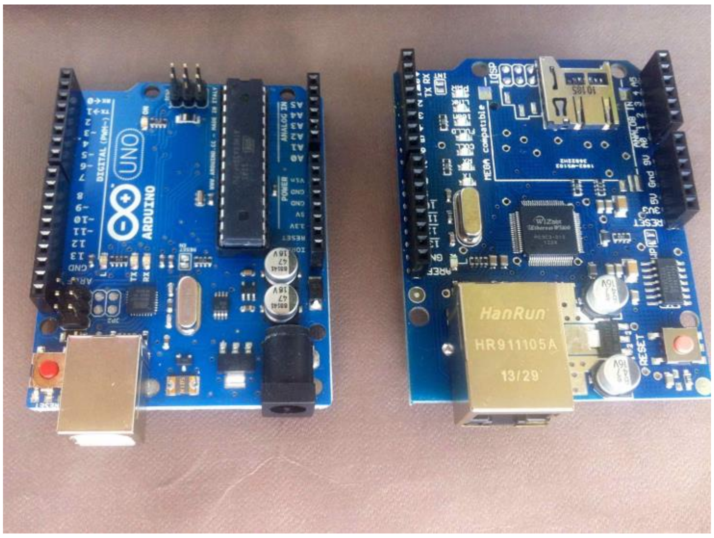

Figure 7. Micro-controller board and Ethernet shield

The prototype presented here got an Ethernet shield to the board of all lighting units attached to gain access to some network.

The outlets on both shields, power and USB on the micro-controller's board and above it the Ethernet connection provide the interfaces for a complete single luminary.

4.6 Connection

While all devices have contact to a network the last remaining task was to ensure that all units are connected to the same network established. Especially the wireless connection on the mobile device employing the camera need some extra care. Addressing itself is then simply managed by routing the IP-address of each unit.

4.7 Wiring

Finally all bits and pieces need some electrical connections. To avoid soldering and to enable reusability and refactoring, as it is a prototype, a common small breadboard is used to connect all wires.

In addition the resistors, one for each color channel of the LED, are placed on it. They are, as only elemental electrical parts in this project, necessary to protect the LED by limiting the current.

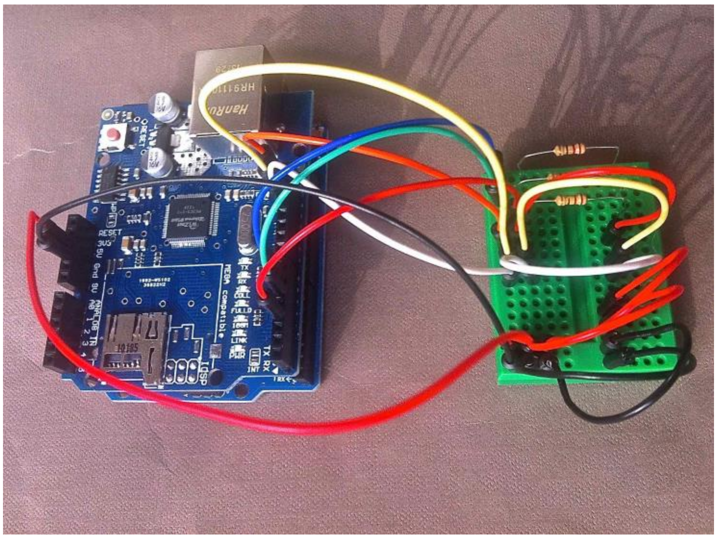

Figure 8. Stacked shields, small breadboard and wires

As the board itself provides enough power on all used outlets fortunately an external power supply for either the lamp or the motors is not necessary.

Other pins or outlets are not used. While it is contemplated, that locally attached sensors could render some useful results, like a photodiode to detach the overall intake of light, their usage was avoided.

The lighting unit is strictly regarded as an acting device following instructions without being influenced from other source. The restriction enables encapsulation, a technique known from object oriented programming. In other words, it will not talk back, which makes the progamming of the system much easier.

The key result of the assembling all parts is a functional lighting unit. It can cover the complete circle of colors in the color-hue model and it covers a semi-shere in space by rotating two brackets at 180 degrees with two servo-motors.

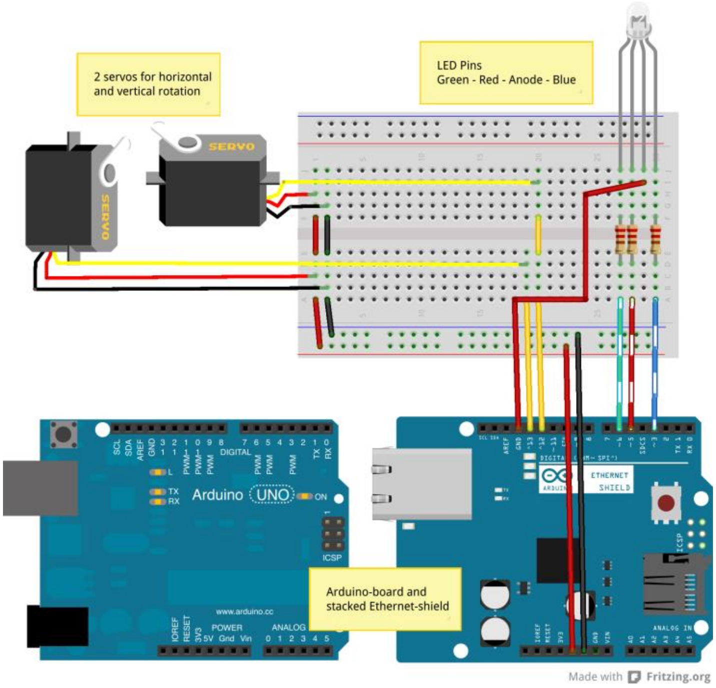

Figure 10. Schematic view of a single lighting unit.

Besides power, every unit needs instructions provided by an external source. A single unit is independent from other units, hence by design they can be arranged at any order and any count.

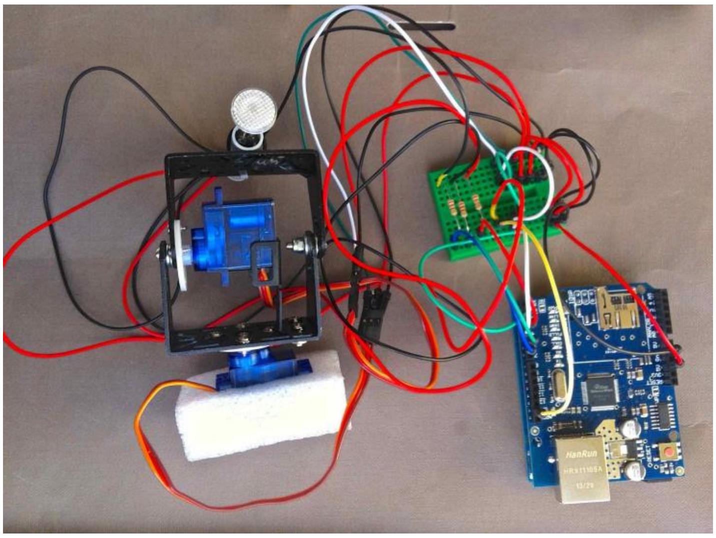

Figure 11. Finished lighting unit

5. SENSING UNIT

The sensing unit, as the name implies, provide the sensors in use like a camera or microphones. For simplicity this is a smart phone or similar with a camera and microphone attached.

5.1 Camera Input and Image Processing

The main camera is the main source of input. The incoming video stream is analyzed frame by frame in order to calculate both the color and the positional values for the lighting units.

Modern mobile devices are very capable of face detection and other personalized image processing tools. Hence they can perform a significant amount of computational workload, especially the sophisticated perception of users and their eyes' direction.

5.2 User Interface

While a mobile device was already in place for practical reasons it could also provide some user interface. Without the interference of sensed or perceived interactions it is a convenient tool for testing the lighting units and also for demonstrations.

It consists of two views. The camera shows the camera's view overlaid with some rectangles to indicate what values are about to be send. It is the view to watch while the system is under automatic controll.

The tool menu comprises two circular touch areas and some buttons.

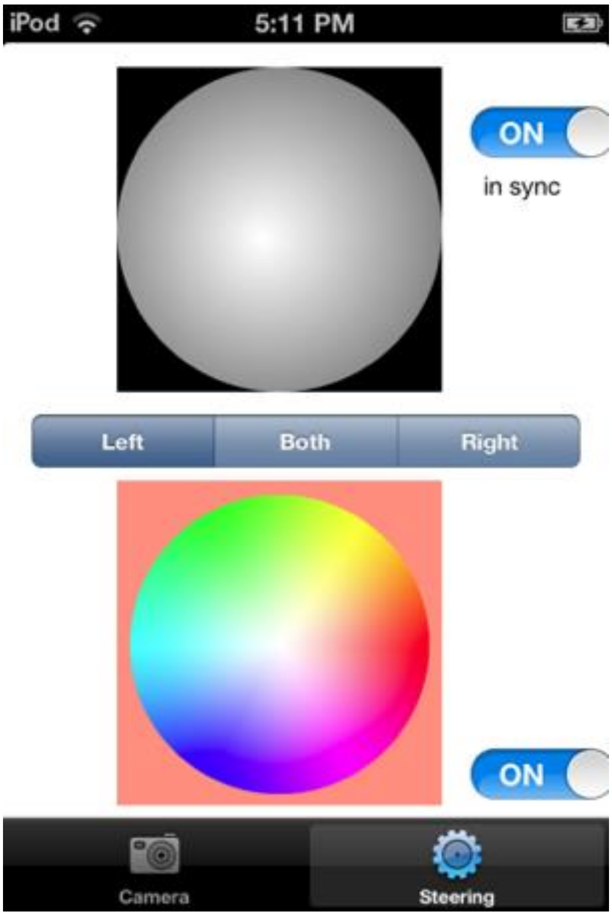

Figure 11. User-interface on a mobile device.

The upper circle controls the direction of the lumiary, the lower its respective color. These values are send as simple strings with numerical values, separated by commata. This little higher level of complication, the string needs to be parsed, allows for manual input through other interfaces.

6. RESULTS

As first prototype, while the working model is under continuous development, some options to enhance the system have become apparent, besides its overall outcome of two different kind of achievements.

6.1 Enhancements

The sensing part of the system, the camera with subsequent image processing, is aso under investigation because the embodying mobile device is already bloated with unused functionalities and more specialized cameras and optical sensors are entering the market.

The number of light sources can be increased, and the pattern of the light emitters, right now a single spot light, can be more flexible. Additionally ambient light source like an OLED panel can be added.

Most importantly the project could grow from its actual model scale to a real life scale.

6.2 Synchronization

One problem not anticipated is the synchronization of both the pure electrical and the motorized adjustments. While an LED itself can be controlled with the speed of light, changing their position with servo-motors take time and the delays have to be considered during calculations.

It is contemplated, that in a system on a larger scale the detected physical objects would move relatively slower than now on the model scale, while there are other options remaining, e.g. mirrors to direct the light.

6.3 Empathy

At first the direct goal of the project is fulfilled: A scene can be automatically illuminated. The system reacts to visual stimuli as if the lights are in a user's hand, at least a bit. This is an achievement.

6.4 Making

More important is the outcome, that the idea of Empathic Lighting has come into being with the tools and techniques of makers. In combination, but affordable controllers and other devices

In architecture, where there is still a focus on virtual models and how to bring them to reality, working with other than simple building materials is not yet regarded as an option. Electricity belongs to home automation, which then is better appliances and, as the name implies, not part of a building but applicated to it.

In this sense the creation of the system has proven that more than isolated applications can and should be mastered by architects. Buildings will no longer be static envelopes, they will become adaptive and responsive, to avoid the term ‘smart’.

The approach of architects to buildings has been always holistic. If they like to maintain it, they have to step in. Creating an empathic building will be as important as defining and creating the building’s shape.

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