1st International Conference
on
Lighting, Interactivity, heritaGe, Health, Technology and Sustainability.

LigHTS 2020

BOOK of ABSTRACTS

ONLINE
OCTOBER 10th, 2020

HELLENIC OPEN UNIVERSITY

ECOSLIGHT

Co-funded by the Erasmus+ Programme of the European Union

ΜΑΡΙΟΛΟΠΟΥΛΕΙΟ - ΚΑΝΑΓΚΙΝΕΙΟ ΙΔΡΥΜΑ ΕΠΙΣΤΗΜΩΝ ΠΕΡΙΒΑΛΛΟΝΤΟΣ

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Book of Abstracts

of the

1st International Conference

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2020

Online Participation

October 10th, 2020

Editor:

Stelios Zerefos, Professor H.O.U.

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FOREWORD

One word that characterizes the situation in the lighting industry during the recent years is “transition”. This transition to a new era is caused by changes in the symbiotic relationship between technological development, lighting design and, of course, sustainability principles. Lighting digitization together with the widespread use of LED lamps has led to increased device connectivity and interactivity offering a wide range of possibilities. LiFi, Internet of Things, Power over Ethernet and wireless sensors have transformed the traditional luminaires into smart devices capable to connect in a network transmitting information. As light is now enriched with information, it is possible to increase energy savings through smart controls and also to include additional functions, such as dynamic operation according to the users’ expectations and needs. The aforementioned developments allow not only the manipulation of a luminaire’s emitted luminous flux but also the color temperature of the light source. This is the core concept of the Human Centric Lighting which affects health, well-being and productivity, providing proper lighting when and where is needed. Fortunately, it seems that in this new era the focus of lighting design has just moved from spatial aspects to human aspects.

Furthermore, the use of artificial lighting in the built environment during nighttime can affect not only the visual performance and the wellbeing of humans, but also the environment. As architectural lighting is focusing into highlighting building facades and exterior areas, new formed legislations are trying to minimize the negative effects of the irrational use of artificial lighting. The lack of lighting design and energy consumption restrictions for exterior areas such as building facades, sports and recreation areas, have increased the use of lighting installations. Nowadays with the advent of energy efficient luminaires (LED) and state of the art lighting controls, the need for a better living environment should be promoted along with environmentally friendly lighting design techniques.

It is therefore of urgent importance that the new and often contradictory lighting trends are thoroughly examined and this is exactly the scope of this International Conference. LIGHTS2020 will try to highlight the role of lighting in the built environment, including the corresponding positive and negative issues that have recently emerged and document the current trends of lighting design for interior and exterior places. Case studies of highly remarkable lighting practices and exceptional lighting projects are also welcome.

Overall, the emerging developments on Lighting, Interactivity, Heritage, Health, Technology and Sustainability create specific skills and competences requirements for the human capital that works or would like to work in these areas. These topics are at the core of the ECOSLIGHT- Environmentally Conscious Smart Lighting EU-funded project (612658-EPP-1-2019-1-EL-EPPKA2-SSA). Therefore, one of the objectives of the conference is to contribute to the identification of those needs.

The Conference has accepted 24 papers after a reviewing process by the Scientific Committee. These papers are organized into six categories, namely Daylighting, Lighting Technology and Metrics, Human Factors in Lighting, Lighting and Art, Lighting and Environment, Lighting and Heritage. This categorization really shows the multidisciplinary character of both LIGHTS2020, as well as the subject of lighting.

Furthermore, the Conference is supported by three internationally renowned keynote speakers that address important issues in lighting and providing the state-of-the-art.

Konstantinos (Kosta) Papamichael is a Professor Emeritus in the Department of Design and served as the Co-Director of the California Lighting Technology Center at the University of California, Davis from 2004 to 2019. He holds an Architectural Engineering degree from the Aristotelian University of Thessaloniki, Greece, a Masters in Architecture from Iowa State University, and a Ph.D. in Architecture from the University of California at Berkeley.

Kosta has been working on the development of energy efficiency strategies and technologies for buildings for over 35 years, focusing on strategies, technologies and design tools for fenestration systems, daylighting, and the integration of fenestration, electric lighting and HVAC controls. He holds seven patents and is author/co-author of more than 100 publications. He is the author of the Daylight Chapter of the Advanced Lighting Guidelines, the Chair of the IES Daylighting Committee, and the recipient of the 2013 IES Presidential Award for leading the development of the new version of the IES Recommended Practice for Daylighting Buildings. Kosta is also serving in the Executive Committee and is the Communications VP of the US National Committee of the International Commission on Illumination.

His keynote presentation in his words is focused on *"lighting, fenestration and HVAC controls, with emphasis on adaptive systems, i.e., systems that automatically adjust their state based on context, as well as occupant controls and their harmonization. The presentation includes results on potential energy savings from simulations, assuming different control strategies in different geographic locations. It also includes identification of key control parameters, along with environmental conditions considered for their automated operation, along with high-level control strategies and their implementation in a laboratory environment, using off-the-shelf* *controls and communications components. The presentation also includes challenges and main issues of the laboratory implementation, along with the plans for a field demonstration in a building at the University of California campus at Davis, California."*

Anna Sbokou is founder of ASlight, an award winning independent lighting design studio based in London and Athens, working on local and international projects for over 10 years. She specializes in high-end, human-centric lighting design. Completed works includes high profile exhibitions, leisure, hospitality, commercial, cultural, exterior and residential projects, as well as theatre productions, temporary artistic installations and daylight analysis world-wide.

In 2016 she was also on the 40underfourty list of up-and-coming lighting designers at the International Lighting Design Awards. Anna also served on the Board of Directors of the International Association of Lighting Designers for 6 years and is currently a member of the IALD European Steering Committee.

Her presentation titled "From Life to Light and Back" focuses on current issues of lighting design merged with contemporary living conditions.

Georges Zissis is a full Professor and Vice-Rector at Toulouse 3 University (France), SMIEE, President IEEE Industrial Application Society. Born in Athens in 1964, he has graduated in 1986 from Physics department of University of Crete in general physics. He got his MSc and PhD in Plasma Science in 1987 and 1990 from Toulouse 3 University (France).

His primary area of work is in the field of Light Sources Science and Technology. He is especially interested in the physics of electrical discharges used as light sources; system and metrology issues for solid-state lighting systems; normalization and quality issues for light sources; impact of lighting to energy, environment, quality of life, health and security; interaction between light source and associated power supply; illumination and lighting.

His keynote speech titled “Frontiers in Lighting Systems Technology: Toward the human-centered intelligent lighting era” focuses on artificial lighting technology, SSl systems and the emergence of digital lighting. In his own words: *“Since the human race emerged it has been known that fire and heated objects emit light that can be used for lighting purposes; artificial lighting has been discovered. Since of 19th-century end, artificial lighting has been the subject of a continuous and fascinating evolution; 20th century scientists and development engineers worldwide created such a wide range of lighting solutions for every lighting application. Today, the importance and application of these “legacy” lighting technologies is decreasing. In fact, as International Energy Agency underlines, today, the momentum created by the ongoing phaseout of incandescent and halogen lamps as well as declining shares of fluorescent technologies is raising lighting efficiency globally.*

Artificial light production absorbs around 2900 TWh corresponding 16,5% of the world’s electricity annual production. Even if this quantity is still very high, it should be noticed that till beginning of 2010’s electrical light sources were considered as responsible for an energy consumption of around 2651 TWh, which represented roughly 19% of world's total electricity consumption. This tendency suggests the beginning of a harnessing of consumption which can be explained by the increase of light system efficiency when keeping service level stable (measured in quantity of light).

During the last decade, SSLs-Solid-State Lighting based on components like LEDs, OLEDs and LDs, challenges conventional technologies. In particular, LED has turned *into a game changer beating the conventional technologies in all aspects. It is therefore anticipated that in short term, all of electric lighting will be based on SSLs. Today, SSLs proceed to the projected conclusion: replacing all legacy technologies, this is a major change in the lighting market that is considered as a revolution. The only massive adoption of SSLs during the next years can contribute to harness electricity use for lighting, up to 4% by 2030. But "rebound effect" can seriously blur this prediction. One potential solution to avoid that negative effect consists on switching to smart human-centric lighting driven by both "application efficiency" and quality of light. This just means that next gen lighting systems should provide the "Right Light" with the best efficiency and quality, when and where it is needed.*

Historically speaking, past century's research and development focused on single energy efficacy enhancement. As SSL technology matures, maximizing the energy savings from connected SSL systems will become increasingly dependent on successful integration into the built environment. Furthermore, we are witnessing a transition from the conventional "analogue" lighting technologies to "digital" lighting. Intelligent lighting will become the backbone for smart homes and smart cities. This way, lighting will become the heart of the "Internet of Things". Consequently, we knowingly were not serving society as effectively as we could. Industry has coined a new term "human-centric lighting" (HCL) to draw renewed attention to its primary effort to be successful in meeting society's needs."

I would personally like to extend my thanks to all speakers, to the honor given to us by the participation of the three keynote speakers as well as to the co-organizers of this Conference the Mariolopoulos-Kanagkinis Foundation of Environmental Sciences. My sincere thanks to Anna Vafeiadou and Trevor Davis for partnering with us in these difficult COVID-19 times and acquiring the auspices of the Municipality of

Athens. Furthermore, I would like to thank the Scientific Committee for their help in reviewing the submitted papers, as well as chairing the Conference Sessions, and the Organizing Committee for helping with the organization. Most of all I would like to personally thank Thanos Balafoutis for developing the Conference graphics and this volume, Dorina Moullou for organizing the easychair platform, Ioannis Messalas for developing the Conference website, Gerasimos Vonitsanos and Iasonas Forlidas for organizing the YouTube channel live streaming, and Spiros Borotis and Leana Giannopoulou for their overall help.

Looking forward to LIGHTS2021!

Professor Stelios Zerefos

School of Applied Arts, Hellenic Open University

LIGHTS2020 Conference Programme

VIRTUAL ROOM A		
09:15-10:00	Test connections-links	
Opening Session		**Chair: Stelios Zerefos**
Time	***Title***	***Speaker***
10:00-10:10	Welcome to LIGHTS2020	Stelios Zerefos
10:10-10:20	Hellenic Open University	Odysseus Ioannis Zoras
10:20-10:30	Nordic Urban Lab	Trevor Davies
10:30-10:45	The ECOSLIGHT project	Spiros Borotis
10:45-10:50	BREAK	
Keynote Speech		**Chair: Aris Tsangrasoulis**
Time	***Title***	***Keynote Speaker***
10:50-11:15	Integrated Lighting, Daylighting & HVAC Controls for Comfort & Energy Efficiency	**Kostas Papamichael**
Session A1	**Theme: Daylighting**	**Chair: Aris Tsangrasoulis**
Time	***Title***	***Speaker***
11:15-11:30	Kinetic Facades for the exploitation of daylighting	Antonios Tamkatzoglou, Ioanna Symeonidou
11:30-11:45	Impacts of a prototype active sunlight redirection system on daylighting and energy balance of office spaces	Antonis Kontadakis, Lambros Doulos and Aris Tsangrasoulis
11:45-12:00	Design of Skylights ofr the transfer of natural light in underground spaces	Aggelos Tzortzis, Aris Tsangrasoulis, Theodora Antonakaki

12:00-12:10	Questions/interaction	ALL
12:10-12:25	BREAK	
Session A2	**Theme: Human factors in Lighting**	**Chair: Sophia Sotiropoulou**
Time	***Title***	***Speaker***
12:25-12:40	Light as a design tool for children with Autism Spectrum Disorders in educational spaces	Eleni Georgiadou and Christina Skandali
12:40-12:55	Lighting Design for the visually impaired`	Eleni Patroni
12:55-13:10	Lighting Design in Preschool Center versus Lighting Design in Retirement Home	Maria Brasinika and Katerina Skalkou
13:10-13:20	Questions/interaction	ALL
13:20-13:45	BREAK	
Keynote Speech		**Chair: Frangiskos V. Topalis**
Time	***Title***	***Keynote Speaker***
13:40-14:05	Frontiers in Lighting Systems Technology: Toward the human-centric intelligent lighting era.	**Georges Zissis**
Session A3	**Theme: Lighting Technology and Metrics**	**Chair: Frangiskos V. Topalis**
Time	***Title***	***Speaker***
14:05-14:20	Light flicker health issues and metrics: a critical review	Athanasios Kotsenos and Anastasios Dimitrakis
14:20-14:35	Multi-angle lighting measurements of outdoor installations using unmanned aerial systems	Constantinos A. Bouroussis and Frangiskos V. Topalis

14:35-14:50	The Evolution of Color Rendering	Anastasios Dimitrakis and Athanasios Kotsenos
14:50-15:05	Algorithm for specifying the influence of geometrical and other parameters to the light reflected on surfaces	Asterios Tolidis
15:05-15:20	Chaotic phenomena in LED driver circuits	Elias Tsirbas, Evangelos Skoubris and Frangiskos V. Topalis
15:20-15:30	Questions/interaction	ALL
15:30-15:40	BREAK	

VIRTUAL ROOM B		
Session B1	**Theme: Lighting and Heritage**	**Chair: Dorina Moullou**
Time	***Title***	***Speaker***
10:50-11:05	Exterior lighting and collective memory: the case of coastal areas.	Hara Sigala and Gourgioti Aggeliki
11:05-11:20	Light qualities of Ancient Greece: a contemporary approach for the lighting design of archaeological & cultural heritage	Athena Sivi and Nikos Trivyzadakis
11:20-11:35	Emerging from oblivion. Accent Lighting for the Castle of Levadia.	Loukas Angelis, Dorina Moullou and Hara Sigala
11:35-11:45	Questions/interaction	ALL
Keynote Speech		**Chair: Stelios Zerefos**
Time	***Title***	***Keynote Speaker***
11:45-12:10	From Light to Life and Back	**Anna Sbokou**
12:10-12:25	BREAK	
Session B2	**Theme: Lighting and Environment**	**Chair: Stelios Zerefos**

Time	*Title*	*Speaker*
12:25-12:40	«Facade lighting of historic buildings concerning the consequences on light pollution»	Militsa Tomasovits, Lambros Doulos, Stelios Zerefos and Thanos Balafoutis
12:40-12:55	Planning an International Dark-Sky Place in Aenos National Park: The first steps	Andreas Papalambrou, Lambros Doulos, Georgios Drakatos, Michail Xanthakis, Panagiotis Minetos and Anastasia-Eleni Magoula
12:55-13:10	Lighting Design as a sustainable parameter in International Building Green Certificates	Ioannis Panagiotopoulos
13:10-13:25	Sustainable Light Design. A Greek School Building as a Case Study	Chrysoula Fragkouli, Katerina Skalkos and Theodora Antonakaki
13:25-13:40	The effect of artificial lighting on plant growth	Konstantinos Christodoulou, Lambros Doulos, Sophia Sotiropoulou
13:40-13:50	Questions/interaction	ALL
13:50-14:05	BREAK	
Session B3	**Theme: Lighting and Art**	**Chair: Veroniki Korakidou**
Time	*Title*	*Speaker*
14:05-14:20	Electronic art in the 20th century. The case of Frank J. Malina A STEAM methodology educational program for primary school children	Kiriaki Genitsaridou
14:20-14:35	Bioluminescence in contemporary art and lighting design:advantages and limitations	Veroniki Korakidou
14:35-14:50	REFLECTIONS A reference on the work of Nicolas Schöffer through contemporary trends and applications in Light Art	Eftychia Gianniou

14:50-15:05	Lighting and procedures for creating a suitcase theater performance. The theater out of its conventional space - street theater	Panagiotis Nikolidakis, Thanos Balafoutis, Ioannis Skopeteas
15:05-15:20	Theorising and evaluating film lighting	Ioannis Skopeteas
15:20-15:30	Questions/interaction	ALL
15:30-15:40	BREAK	

Closing Remarks		**Chair: Stelios Zerefos**
Time	***Title***	***Speaker***
15:45-16:15	Reflections on the Conference and closing remarks	Stelios Zerefos

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KINETIC FACADES FOR THE EXPLOITATION OF DAYLIGHTING

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*Corresponding author

Keywords: Kinetic Architecture, Digital Design, Daylighting Exploitation, Parametric Design

Abstract

The paper examines diverse metholodologies for the exploitation of daylighting with the use of architectural elements installed on the facade of a building. More specifically, it will discuss the use of kinetic facades, which consists of moving elements that respond to daylighting in order to create optimal living conditions, visual and thermal comfort, based on the inhabitants needs. The research is based on examples drawn from the international bibliography and from built examples, with the aim to create a taxonomy of the main morphological features in, the use of materials and automation. The research methodology is enhanced by empirical data and experimentation where several different typologies of kinetic facades act as parameter data for building a functional parametric model that responds to daylight, leading to energy saving, uniformity in lighting and the improvement of visual comfort and living conditions. Various tests are carried out with specialized software in order to reach the optimal solution. The thesis concludes on how much the digital environment can produce solutions that meet the challenges of the built environment in the present and near future.

Introduction

One of the key aspects of human survival is the use and exploitation of the environment. However Industrial Revolution and the end of Second World War, showed the impact of human activity globally. Earth, water, sea pollution, desertification and the creation of extreme climate events are some of the catastrophic effects that humanity experiences even more frequently than ever before. The creation of sustainable conditions of environmental preservation, preventing further pollution is necessary.

Architecture has always reflected societal trends. The needs and desires of human, the trends and developments in Art and Technology are depicted in the form, decoration and construction of the built environment. The creation of dynamically changing buildings represents modern society. The need for built environment that responds to climate, seasonal changes is apparent. Studies on Health Science, such as that on circadian rhythm show that quality living conditions with lighting comfort and daylighting are essential. The use of friendly forms of energy and the conversion of solar power to electrical is the gateway to environmental sustainability.

The use of dynamic elements isn’t new, considering that inhabitants always adjusted buildings, in relation to current season and daytime. A prime example is the use of shades that are adjusted according to weather conditions and daylight. The first attempt for the creation of a full dynamically changing building was made by Cedric Price. The Fun Palace was a radical idea that introduced the concept of continuous change and the interaction between user and space (Mathews 2005, 79). Modern Architects influenced by such theories like Tristan d'Estrée Sterk and based on theories of Nicholas Negroponte about intelligent design systems, propose the use of adaptive envelopes in climatic conditions (Sterk 2005, 226). The use of automation and the evolution of technology produced examples as early as of 1980’s. Jean Nouvel’s Institut du Monde Arabe and the facade of Al Bahar tower, propose a new paradigm of using envelopes not only for aesthetics but also for the utilization of daylighting according to user needs (Meagher 2015, 2019). The ability to install

sensors, servomotors, and the advancements in fast prototyping, are essential tools in the hands of the modern Architect.
In recent years kinetic facades are built throughout the world gather the attention of researchers and designers. The European Cooperation in Science and Technology established Action TU 1403, a framework that promotes networking opportunities in Europe for early career investigators and investors, connecting scientific communities throughout Europe enabling the diffuse of knowledge concerning adaptive facades (Luible et al. 2018, 20). Kinetic facades offer not only functional use by improving daylighting but also contribute to the aesthetic improvement of the built environment, providing a dynamic spectacle that changes constantly.
Kinetic facades require interdisciplinary research, advanced design and knowledge. The use and development of digital and computational tools enables designers to rapidly create prototypes, test daylighting conditions and change the design according to intent and design goals. Computational design enables the use of motion and environmental data such as the sun position act that act as parameters influencing the produced form. The designer has an array of tools that enable informed decision making.

Materials and Methods

The paper examines what are the qualitative and quantitative characteristics that optimize the performance of a building, and to transfer them as variables in the digital environment. The purpose is the production of new forms with the best possible performance utilizing daylight. Using parametric design software such as Rhino Grasshopper, new forms are created that are influenced by daylighting and the designer's ideas. With the use of plugins such as DIVA, Honeybee, Ladybug, etc a series of performance tests are carried out in order to examine the characteristics of each form, and thus create a feedback loop between design and performance for optimal design.

Results and Discussion

The results produced are a series of designed forms, and diagrams with performance values depicted as pseudocolours. The optimal forms are selected in accordance to characteristics underlined, such as uniformity in lighting, daylight factor, energy saving.

Conclusion

The materials and methods of the aforementioned methodology not only create tangible results such as new forms, but also enrich the architectural discourse by contributing with findings about the process itself, examining how the digital environment can help push forward the discipline of Architecture, reaching results that not only minimize production costs and act as a great alternative to physical scaled models, but they also prove to be time efficient and a source of inspiration for environmentally conscious yet iconic design of contemporary buildings.

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IMPACTS OF A PROTOTYPE ACTIVE SUNLIGHT REDIRECTION SYSTEM ON DAYLIGHTING AND ENERGY BALANCE OF OFFICE SPACES

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Keywords: daylight redirection, sunlight redirection, core daylighting, solar tracking, heliostats, innovative daylighting systems

Introduction

The aim of this work is to present key findings derived from the assessment, both in terms of daylight efficiency and energy savings, of an innovative daylighting system that utilizes a heliostatic configuration for sunlight redirection in a deep South oriented office space (Kontadakis et al. 2017, Kontadakis and Tsangrassoulis 2017, Kontadakis et al. 2019). It comprises a light shelf, mounted at about mid-window height, that captures sunlight using a heliostat configuration that actively tracks and collects sunlight, with the use of an array of mirrors, referred to as active sunlight redirection system (ASRS). The ASRS can be attached to the building façade, on the window system and redirect solar beam radiation deeper into the room to specific locations on the ceiling plane, in order to provide higher work-plane illuminance levels deeper into the room, away from the perimeter zone and thus offset the lighting energy requirements over a larger floor area.

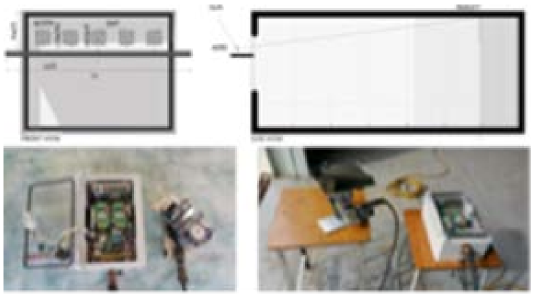

Figure 1 Main configuration of the Active Sunlight Redirection System (ASRS) and a photograph of the prototype heliostat unit (MAKv1) that was build.

1. Methodology

Extended Simulations were performed using Radiance (Ward and Shakespeare 1998) and EnergyPlus (Energyplus 2016) for two (2) different climate zones respectively, Athens, (Lat. 37.900, Lon. 23.700) and Thessaloniki (Lat. 40.520, Lon. 22.970), located in Greece. To facilitate the simulation procedure a solar-tracking computer algorithm was implemented to create the data needed as inputs to the simulation engines. Daylight simulations were conducted to hourly calculate: a) the annual illuminance distribution on the working surface (0.8 m from the floor), b) the lighting energy savings for both perimeter (daylight) and non-daylight zones of the space equipped with an ideal dimming system, c) the internal heat gains due to the reflected sun-patches on the ceiling. The information obtained from previous steps were used to create schedule files that were fed into the energy model resulting in estimating the annual energy performance. The effect of the reflected sunpatches on the building energy balance was calculated using EnergyPlus' SurfaceProperty:SolarIncidentInside object. Using this method, the normal EnergyPlus calculation is replaced by a schedule of solar incidence values that are calculated with the help of the solar-tracking computer algorithm. The workflow of the process is presented in Figure 2. For the evaluation of the proposed ASRS, a South oriented, deep office space was used as a reference case. The room was illuminated by an unshaded and unobstructed (no surrounding buildings or landscape details) vertical window with an opening of Window to Floor Ratio (WFR) of 10% (including the window frame). The dimensions of the space were: 4 m width; 7 m length; and 3 m height, with surface reflectances for the interior floor, walls and, ceiling of 20%, 60%, and 80% respectively. The window-sill was set at 1 m height and had the following dimensions: 1.5 m height and 1.6 m width, with a window frame of 0.05×0.05 m. The window system comprises a clear doubleglazing Low-E pane, with a visible transmittance of 74.4%, Solar Heat Gain Coefficient (SHGC) 56.8% and U-Factor 1.912 W/m2 K.

To illustrate how the prototype ASRS, performs in terms of daylight and energy the output variables were compared against other cases. The South office space was simulated for three (3) alternative fenestration system configurations, as presented in Table 1 below.

Table 1 Description of the cases examined.

BASE CASE	with a conventional fenestration system, that is unshaded and unobstructed coupled with the daylight responsive system, which represent the reference case
LIGHTSHELF CASE	which is the reference case equipped with an external lightshelf Width 0.5 m and Length 1.6 m, equal to the length of the window. The light shelf was perfectly diffuse (80%) and the mirrors were assumed to have a specular reflectance of 98%.
SUNLIGHT CASE	which is the reference case equipped with the proposed active sunlight redirection system (ASRS) with an array of five (5) mirrors with dimensions 0.2×0.2 m each. The mirror array was set to redirect the incoming sun rays towards the back end of the room, beyond the perimeter zone and the target of the reflected sun-rays was set at the ceiling plane 3 m from the floor and 6 m inside the space (measured from the interior wall).

For the energy simulations, the reference office room was modelled to be part of an office building with only one facade exposed to the external environment. The office room was constructed to meet the minimum requirements of the national law N.3661/2017: Regulation on the Energy Performance of BuildingsKENAK (N.3661 2017) which describes the calculation methodology according to the European standards for the two (2) climate zones, from 08:00 to 18:00 (10 hrs) without counting Weekends. Lighting energy savings were calculated by using two (2) calculation points inside the room: one (1) in the center of the perimeter (daylight) area as this was calculated by the EN15193:1 (EN 15193:1 2017) at 2.125 m, and the other at the center of the secondary (non-daylight) area, at the back end of the room (at 5.625 m). The design illuminance was set at 500 lx for both sensors.

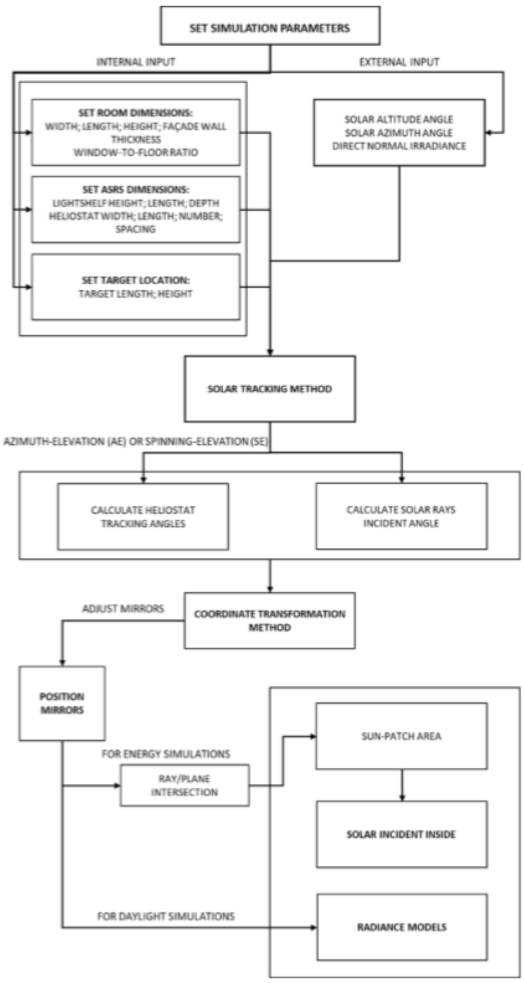

Figure 2 Flowchart of the of the simulation process to determine the position of the mirrors, sun-patch area, and solar incident of the ASRS to evaluate the performance in terms of daylight and energy.

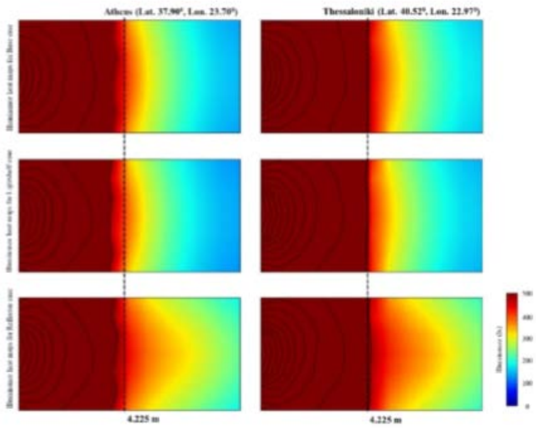

Figure 3 Annual average illuminance heat maps across the floor area of the simulated cases.

Figure 3 illustrates the average annual illuminance distribution across the floor area of the simulated cased. Results showed that the SUNLIGHT CASE performs significantly better, compared to the other cases, with an increase in the illuminance values through the operation of the movable mirrors, especially in the non-daylight zone of the space (> 4.25 m) for both climate zones. Compared with the BASE CASE; the office room equipped with the ASRS manages to increase illuminance levels in the secondary area (non-daylit zone) from 48% for Athens to over 64% for Thessaloniki. High illuminance values near the opening and lower at the back create a non-uniform lighting environment with high contrasts. The implementation of the ASRS, manages to balance the illuminance distribution of the space where the external lightshelf diminishes the extreme variations between the front and back, providing a more balanced distribution. The LIGHTSHELF CASE manages to enhance uniformity by 17% compared with the BASE CASE for Athens and by 16% for Thessaloniki, whereas the SUNLIGHT CASE by 56% and 54% compared with the BASE CASE for Athens and Thessaloniki, respectively.

2. Results

Table 2 Annual energy performance for the simulated cases in terms of energy demand.

ENERGY DEMAND (kWh/m²)			
ATHENS	Cooling	Heating	Elec. Lights
BASE CASE	*37*	*8*	*12*
LIGHTSHELF CASE	*33*	*9*	*13*
SUNLIGHT CASE	*46*	*7*	*9*
THESS/NIKI	Cooling	Heating	Elec. Lights
BASE CASE	*29*	*20*	*11*
LIGHTSHELF CASE	*25*	*22*	*12*
SUNLIGHT CASE	*36*	*19*	*8*

The simulation results of the energy performance of the space in terms of energy demand, under the various fenestration system configurations, were quite interesting. Table 2 presents the simulated results for Athens and Thessaloniki, respectively. The effect of reflected sun-patches on the building energy balance were as follows: Comparing the BASE CASE with the SUNLIGHT CASE, the reduction in electricity use for artificial lighting was estimated at 23% for Athens and at 25% for Thessaloniki. The reduction increases when compared against the LIGHTSHELF CASE by approximately 26% and 29% the two (2) climate zones, respectively. The internal heat gains may be useful when the space requires heating (during winter) but is counterproductive when the building requires cooling during summertime. In terms of cooling consumption there is an apparent increase, which is estimated at approx. 24% when compared with the BASE CASE and 38% when compared with the LIGHTSHELF CASE for Athens. The increase in cooling for Thessaloniki is estimated at 26% and 47% compared with the BASE CASE and LIGHTSHELF CASE, respectively. The reverse phenomenon occurs with the heating loads, where the addition of heat gains from the operation of the proposed system help reduce the heating requirements of the space. For Athens compared with the base case the reduction is approx. 15% and 2% for the LIGHTSHELF CASE, whereas for Thessaloniki is 12% and 2.5%, respectively.

3. Conclusions

The In general cooling systems must compensate for the heat generated by the lighting system, plus the addition of other internal loads such as equipment, people, etc. For the case equipped with the "ASRS" , heat gains are added to the space from the mirror arrays and depend on their initial size and the intensity of solar radiation, more specifically the direct component. The sun patches created on the ceiling depend on the size, shape, and reflection characteristics of the mirrors. Specular reflection creates a sharply defined rhomboidal bright spot, and although the target point is fixed, the overall spot area changes over time due to the change in the relative sun-mirror position. Over the years there have been several developments in daylighting, and it seems that there is a tendency to move away from static towards more dynamic approaches. Advanced daylighting systems by effectively controlling how natural light is admitted and distributed inside a building space help improve the users' productivity and well-being while reducing the electric lighting power if coupled with a daylight responsive lighting control system. The focus was primarily to investigate the impact of sunlight redirection for illuminating under-lit office areas through the utilization of this innovative daylighting concept system for side-lighting in different climates. The results indicate that: • The use of sunlight redirection indicates the potential to significantly improve the daylight levels of non-daylit areas. • A reduction in electricity use for artificial lighting can be achieved for both climate zones. • Energy demand for cooling is increased for both climate zones. The additional heat from direct solar radiation has a negative impact on the building's energy balance. The electricity used for cooling increases significantly, which in turn diminishes the savings gained by turning off or

supplementing the electric lights. The reverse phenomenon occurs with the heating loads, where the addition of heat gains from the operation of the proposed system help reduce the heating requirements of the space.
Controlling direct sunlight is always a tricky thing. Uncontrolled direct sunlight is substantially brighter than conventional artificial light sources and carries much more infrared energy thus contributing significant heat to any surface it hits, which in turn is accompanied by an increase in primary energy cooling consumption. It seems that a slight decrease in lighting consumption is always accompanied by an increase in cooling consumption. Uncontrolled direct sunlight and poorly insulated glazing, especially when South orientation, can have a profound impact on heat gains and loads, making the maintenance of occupant thermal comfort difficult.

Acknowledgements
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DESIGN OF SKYLIGHTS FOR THE TRANSFER OF NATURAL LIGHT IN UNDERGROUND SPACES

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Keywords: Natural lighting, skylights, subterranean / underground spaces, Metro station

Introduction

The need to transfer natural light to areas with problematic access to it becomes more often nowadays. For subterranean areas (e.g. metro stations) vertical transportation is obvious. The purpose of this study is to develop a methodology for rapid assessment of the performance of skylights based on parametric analysis. The latter takes into account the shape of the skylight, the coating material of the upper and lower part of the skylight, the cost and the estimation of energy efficiency. Parametric analysis results in the most efficient daylight system for installation at Victoria Metro Station in Athens, in combination with some initial choices dictated by the geometric characteristics of the building, its historical value, the frequency of its use, the cost of the proposed structures, the ease of installation, operation and maintenance etc. This paper is a summary of the dissertation entitled “design of skylights for the transfer of natural light in underground spaces” for the postgraduate program Lighting Design of the Hellenic Open University.

1. The importance of daylighting

Less than a third of the sun's radiation reaching the earth returns to space. The rest of this radiation is absorbed and heats the air, the surface of the land and the sea (Tregenza & Wilson 2011). Depending on the sunshine, the light is distinguished into direct and diffuse light. Natural lighting affects the mood of human beings in a positive way, as it gives a sense of dynamic change in contrast to artificial lighting that is usually "stable" over time (Tsangrassoulis 2016). Natural light has a continuous spectrum, on the contrary of the artificial light which has a maximum value for certain wavelengths, thus helping the human visual system to perceive colors and space.

According to Tregenza and Wilson, "circadian rhythms are clocks in the bodies of mammals and other living organisms that regulate functions such as body temperature, wakefulness and sleep" resulting in the human body's function being coordinated with the rhythmic alternation of day and night and making the management of natural light in buildings important (Tregenza & Wilson 2011). Natural light is also related to parameters such as the performance of students in schools (Heshong Mahone Group 1999) and the performance in workplaces where it is reported that lack of natural light and external view intensifies work stress (Mohirta 2012).

The indications that accompany underground spaces are those of dark, empty and unhealthy places. Attempts have often been made to mitigate them even by introducing neologisms such as "geotecture" or "terratecture" in order to replace the term "architecture of underground spaces" (Mohirta 2012). Staying in an underground subway station is usually short, it nevertheless has an effect on human psychophysiology. This negative effect is intensified in urban environments with low sunshine during the year.

2. Methodology

Four different design cases (1A, 1B, 2A and 2B) are analyzed for a room of 6m.* 6m., with the same height as the station (h = 3.2m.), with a single skylight in the center, black color on all surfaces, depth of concrete slab = 1.2m.

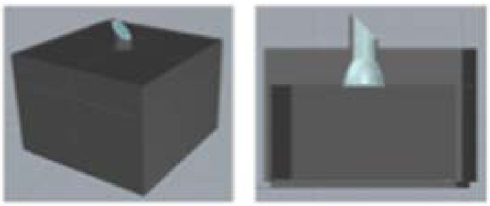

Figure 1 Construction of a room of 6 x 6 m. Four alternative scenarios for the daylight system are examined

Lighting autonomy, that is the percentage of time during which the target price can be ensured, and it is the indicator that is first extracted. This target is estimated at 150 lx, on the floor, which determines the adequacy of the natural lighting. The lighting autonomy is obtained for the whole year, based on the climate file for Athens [International Weather for Energy Calculations (IWEC) of ASHRAE], as an average value for each point of the grid defined on the floor of the room and with distances of 0.6 m between the nodes. The values presented in the four cases are taken for opening hours 8 am - 6pm.

Then, values are calculated (the absolute lighting values in lx at the floor level) for specific days and hours (30/12: 9.00 am, 12 pm, 15.00 pm and 15/06: 9.00 am, 12 pm, 15.00 pm). The appropriate distance between the identical successive skylights along the station platform is also taken into consideration. It is also worth mentioning that achieving uniformity is not unequivocally the goal for introducing natural light in underground spaces (Bouchet & Fontoynont 1996).

The next step is the selection of the appropriate daylight system and its placement in the threedimensional model of the station. An area between two consecutive skylights will then have to be identified in order to recalculate the lighting autonomy throughout the year. Also, the calculation of the glare at noon, for two days of the year (30/12 and 15/6) and the estimation of glare on an annual basis (annual glare), will document the installation of skylights. Finally, the potential of energy savings in the operation of the electric lighting system is calculated.

3. Four different design cases - lighting simulations

The options for the skylight 1A are: Horizontal circular opening at the top, diameter of the upper part δ = 0.6m., glass at the top with transparency t = 0.85, opening at the bottom D = 1.2m., horizontal glass at the level of the cylinder section and parabola with transparency t = 0.90, aluminum cladding with reflectivity R = 0.92, cladding thickness = 1 mm, depth of the daylight system = 1.6m., level of placement of the external opening = 0.4m. The variation of the skylight 2B is the extension of the upper part in such a way as to operate in a 45° inclination and therefore it has an elliptical opening.

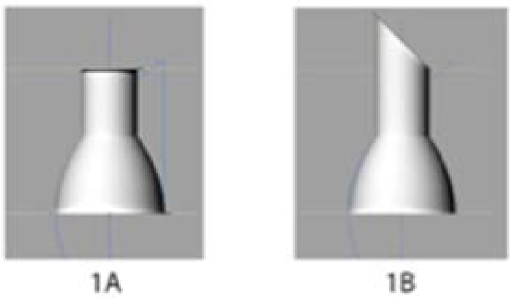

Figure 2 Cases 1A and 1B

In a similar manner, the initial choices are made for the skylight 2A with a larger perimeter and widening of the opening at the bottom: Horizontal circular opening, diameter of the upper part δ = 1m., glass at the top with transparency t = 0.85, opening at the bottom Δ = 1.4m., highly reflective white plastic cladding R = 0.80, horizontal glass in the joint of cylinder and cone with transparency t = 0.90, cladding thickness = 1 mm, depth of the daylight system = 1.6m. and opening level from square floor = 0.4m. The variation of the skylight 2B is the extension of the upper part in such a way as to operate also in a 45 ° inclination.

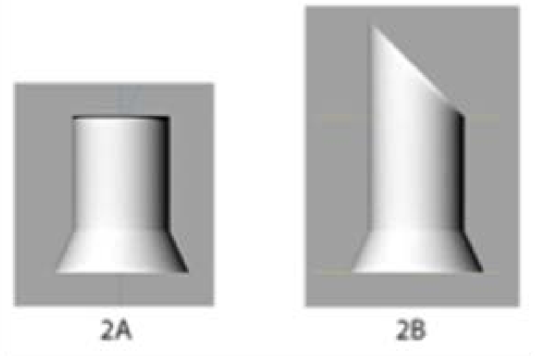

Figure 3 Cases 2A and 2B

The solutions that achieve the best lighting levels throughout the year are 2A and 2B, as they show higher values of lighting autonomy than 1A and 1B. The average value for lighting autonomy is about 7% for 1A and 1B, while for 2A and 2B this value is about 36%, thus proving the importance of the diameter of the skylight for the incoming luminus flux.

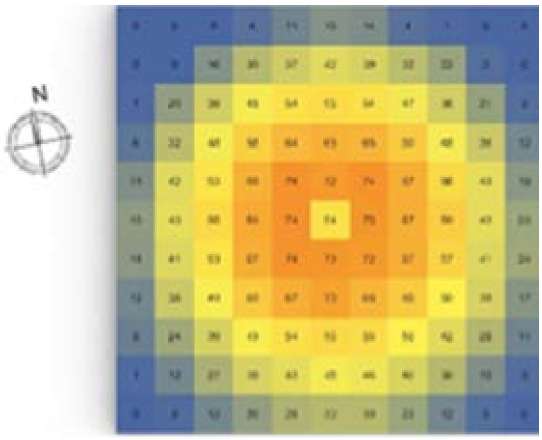

Figure 4 Simulations for lighting autonomy for case 2B.

As the estimation of efficiency through autonomy and lighting levels shows small differences between 2A & 2B, solution 2B will be chosen since it has a larger incoming light flux, due to the larger aperture area (ellipse versus the circular horizontal aperture of solution 1A) and it can shape an interesting object for the city space. At the same time it shows higher values in the lighting levels.

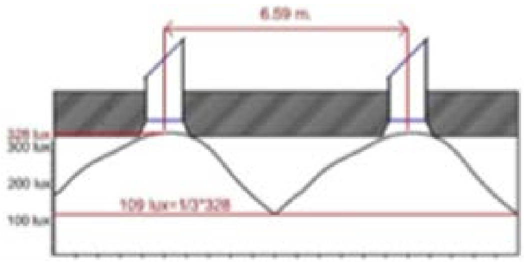

Figure 5 Determination of distances between skylights (Case 2B). The values of the lighting levels of the central axis (axis of installation of the skylights) for the date 15/06 and time 12.00 pm are taken into consideration. The skylights are placed at such a distance from each other, in order to ensure that in the middle of their distance lighting intensity is greater than one third of the maximum value, thus ensuring a minimum percentage of uniformity. Ideally this value should exceed 150 lx.

4. Lighting simulations in the model of the station

A shading mask is created, in order to provide a detailed picture of the duration of sunshine throughout the year.

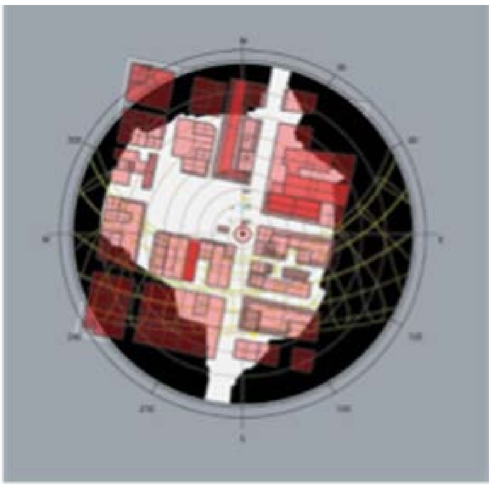

Figure 6 Shading mask. The shading of the center of the opening from the surrounding buildings

takes place between the early morning hours and late afternoon in summer. In winter, the aperture receives direct sunlight only at noon.

The installation of the skylights is taking place at two groups of three items each, every 6 meters (less than 6.59 m.), while the height of the metro station is 3.2 m. as aforementioned.

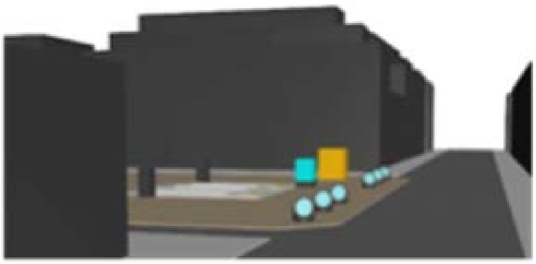

Figure 7 External view of the skylights

Figure 8 Internal view of the skylights

The recalculation of lighting autonomy shows that on average, at 41.39% of the operating time the target value of 150 lx can be reached. Regarding the glare, for three cameras that correspond to some of the most common angles that any visitor of the site will have, these values are small (1%, 0% and 1%) on 30/12 and show a slight increase on 15/06 (3%, 1% and 4%).

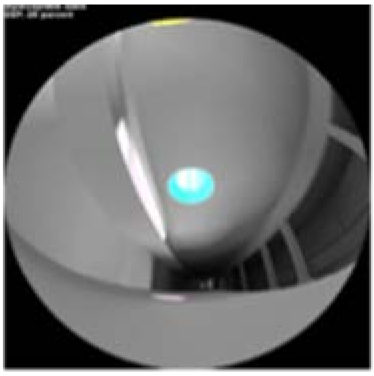

Figure 9 Fisheye view, glare estimation - 15/06, 12.00. The value of the DGP (Daylight Glare Probability) index, which expresses the percentage of people who are bothered by glare, is increased only when observers are looking at the skylight (27% on 12/30 and 26% on 15/06).

5. Energy efficiency

For the calculation of the potential energy savings, a spreadsheet is produced in which the lighting values are entered per hour and every day of the year at each point of the defined grid. These values are derived from the simulation of lighting autonomy on the model of the metro station. Depending on the target value of 150 lx, and with the use of appropriate indicators and mathematical formulas, the potential for energy savings arises. This was calculated at 26% for 24 hour operation and 46% for 5.00 am. until 12.00 am, which is the actual opening hours of the Victoria station.

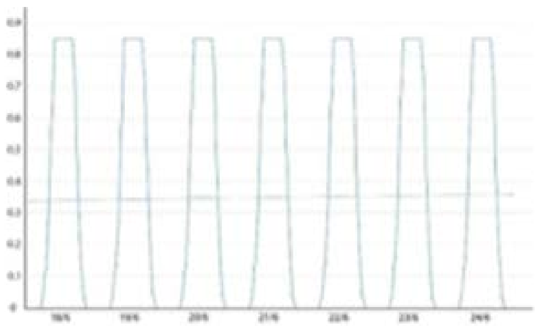

Figure 10 The energy efficiency is also shown in diagrams: Energy savings rate chart from 18 to 24 June. The maximum savings values reach 85%

while the average price is close to 35% (the diagram concerns 24 - hour operation).

4. Conclusions

Through the parametric analysis of four alternative design scenarios, the appropriate daylight system was determined. Lighting simulations were performed on the model of Victoria station using DIVA for Rhino and DIVA for Grasshopper software. The necessity of the integration of natural lighting in Architecture was documented through this work and a possible next step is the implementation of similar daylight systems in buildings, especially in metro stations.

The evaluation of energy efficiency is carried out with the help of a system for regulating the luminous flux of luminaires with a daylight sensor that is mounted on the ceiling. The calculation of energy savings is an important part of the study, as it was documented the fact that vertical devices for the import of natural light in buildings can contribute significantly to reducing the energy consumption of the artificial lighting system.

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LIGHT AS A DESIGN TOOL FOR CHILDREN WITH AUTISM SPECTRUM DISORDERS IN EDUCATIONAL SPACES

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Keywords: adaptive restorative lighting environments, educational spaces, human centric lighting, spectrum autism disorders

Introduction

Autism Spectrum Disorders (ASD) are a congenital neurodevelopmental disease of cognitive nature (Παπαγεωργίου 2005), which is associated with multiple Sensory Modulation Disorders (SMD) (Miller et al. 2007) and a number of comorbidities (Βέρβερη 2014, 54). People with autism show a reduced disposition towards socializing, with a characteristic introversion (Miller et al. 2007) which is combined, in many cases, with a lack of development of a series of cognitive, behavioural and communicational skills (Wing and Gould 1979). The heterogeneous symptomatology, the multiple coexisting sensory disorders, and the differences in the way exogenous stimuli are identified and processed, describe a highly complex clinical condition whose etiopathogenetic identity has not been fully decoded (Βέρβερη 2014, 1). The geometric increase of the percentages of people that are diagnosed on the spectrum, the reduced number of "suitable" facilities and specialized studies focusing on the essential integration of light by targeting the sensory completion of the subject, substantiate to a significant degree the importance of the present study. All the above-mentioned render a highly complex theoretical background that diminishes the potential of a universal approach which aims to make full use of the inherent properties of any lighting installation as a coherent way of addressing the current problematic.

Objectives

The most important question that naturally emerges at this point and directly guides the present study is,· to what extent could, potentially, light function as an intervention tool and to what extent could it contribute to the facilitation of the daily routine of children suffering from autism. In this context, the present study attempts an in depth understanding of ASD under the prism of any impending light, sensory issues, focusing on the dynamic presence of light in educational spaces, as a virtual tool in balancing these sensory dysfunctions. In this sense, the current study is based on a series of information that derive from the existing literature which acknowledges light as a spatial parameter, that through its inherent properties could contribute to the psychosomatic well-being of the individual. The initial hypothesis supports the adoption of sensory-sensitive spatial strategies in regard to the use of the properties of light, as such an approach could potentially produce a vast set of optimized lighting solutions that could help the child to develop a range of cognitive, communicational and behavioural skills, not as a means of therapy, but as a tool for restoring, to some extent, the subject's "optimal" sensory regulation. In the case of children with ASD, light can act as a sensory suppressor of unwanted visual stimuli, in order to mobilize voluntary attention in the context of any educational intervention. Therefore, the provision of a series of controlled light stimuli could positively affect the child's sensory and behavioural predisposition, promoting its sensory engagement for effective learning. In this context, the current project aims to identify the individual photometric criteria, which stem from the actual needs of the children, under the scope of a Human Centric Lighting approach (HCL), which will lead to the organization of a series of parameterized specifications, that could potentially guide the design of similar lighting installations in educational premises that host children that are diagnosed on the spectrum.

Research methodology

The connection of both natural and artificial light and the reductive correlation of its beneficial properties in combination with the sensory processing of visuaospatial stimuli, require the collection of various information, resulting from a wider interdisciplinary referential framework. The adopted research methodology focuses on the identification and the analysis of the basic sensory processing mechanisms of visual stimuli in cases of children with autism and accordingly, on the study and clarification of the "therapeutic" properties of light in relation to the sensory balancing of the subject, aiming, ultimately, at composing a solid methodological matrix that could function as a kind of a lighting, design-sensory tool. The current methodological approach unfolds gradually in a linear progression, starting from the recording of a series of theoretical and experimental research information and towards the drafting of a flexible, methodological model for the design of lighting installations in educational spaces for children with ASD. In addition to all the above and in order to determine, the degree of correlation between the related bibliographic findings and the corresponding data in educational facilities in Greece, further research was conducted using questionnaires addressed to specialized educators/therapists and guardians of children with ASD. The resulting lighting design matrix sets a system of design principles and a series of general instructions followed by a set of lighting specifications that address the typological and morphological, spatial structuring of a typical classroom, thus giving emphasis to the potential usage of any materials, colors, textures and to the necessary functioning and sensory zoning of the space that is dictated by the respective educational interventions.

Findings

The study of all the above leads to the general conclusion that the design decisions concerning the individual characteristics of any lighting installation could virtually function as tools for designing sensory sensitive environments, which bring focus on the actual needs of the children within a broader Human Centric Lighting (HCL) design approach. Despite the continuous increase in the prevalence of ASD and consequently the proliferation of relevant studies (Βέρβερη 2014, 1) there are, yet, no clear guidelines for the sensory organization of specialized educational facilities. In the above context, the dynamic presence of light, as a sub-spatial parameter, has not been sufficiently documented. People with autism are extremely sensitive to increased, illuminance levels that lack uniformity. Such lighting conditions seem to negatively affect the emotional and sensory predisposition of the child, causing extreme behavioural responses. It has been found that the absence of appropriate light levels can cause some relative, inability to capture the child’s attention (Winterbottom and Wilkins 2009) which is unable to engage to “positive learning” interventions. Furthermore, the presence of glare due to direct eye contact (disability glare) with the installed light sources or due to intense reflections (discomfort glare), could lead to increased stress levels that contribute to the sensory deregulation of the subject which tends to exhibit idiosyncratic behavioural patterns (Ornitz et al. 1970). Self-stimulatory behaviours seem to deteriorate in the presence of fluorescent lamps with magnetic ballasts due to the perceivable light flicker (low-frequency) (Colman et al. 1976). Regarding the use of natural light, the available research demonstrates its beneficial nature

for the user’s psychosomatic well-being, but nonetheless emphasizes on individual cases of children who show limited tolerance to its presence (Bogdashina 2003, 63). More specifically, the incoming, direct light in educational spaces can cause serious disturbances which lead to undesirable behavioural patterns (stereotypical or selfstimulatory behaviours) due to its high intensity and its lack of spatial uniformity (Winterbottom and Wilkins 2009).

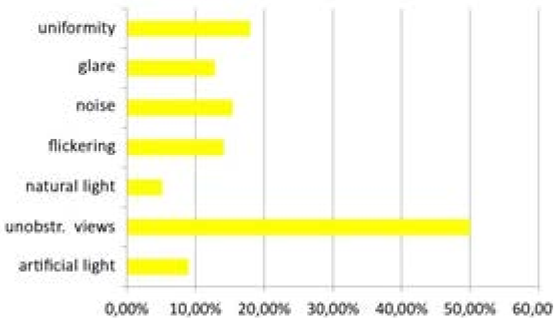

Diagram 1 Sensitivity frequency (%) under the presence of seven different lighting parameters: uniformity, glare, noise, flickering, natural light, unobstructed external views, artificial light (Γεωργιάδου 2020, 127)

The inductive statistical analysis of the collected data supports further the existing bibliographic findings. It appears that individuals suffering from ASD are easily disoriented in the event of intense light fluctuations (Luminance and CCT) with a particularly high incidence of severe sensitivities due to unobstructed outdoor views, but mild or severe sensitivities to artificial light (Γεωργιάδου 2020, 126). Moreover, people with low-functioning autism are more prone to the presence of “unbalanced” lighting sources and particularly under the presence of any impending glare incidents and intense light contrasts. More specifically seven parameters were examined (level of sensitivity 1 to 5 Likhert Scale) natural light, outdoor views, artificial light, light flickering and produced noise, glare and light uniformity. In relation to natural light only 9% of the sample showed serious disturbances but more than 48% of the available cases presented severe disorientation with a characteristic distraction due to unobstructed external views. Accordingly, sensitivities due to the presence of artificial lights appear to have been particularly low in frequency (5.1% presented severe disturbances) with more than 30% of the participants to demonstrate extreme annoyance, in at least one of the four abovementioned parameters. The preliminary statistical review of the available data (78 total participants) demonstrates mild and in some cases severe light sensitivities, but statistical significant in relation to their degree and intensity (Γεωργιάδου 2020, 119-139).

Conclusion and further studies Taking into account the technological capabilities and the wide range of the available lighting options, the implementation of the properties of natural light to the artificial one could affect the physical wellbeing of the subject by facilitating the processing of multiple, competing, spatial stimuli. The biodynamic nature of artificial light and the ability of the user to interact with the applied quantitative and qualitative characteristics of any potential lighting installation can activate a series of "therapeutic experiences" aiming at reducing stressful visual stimuli. The synergy between natural and artificial light, based on light’s inherent properties, could contribute in engaging the voluntary attention of children diagnosed with ASD and respectively restore, to some extent, their sensory predisposition under the general concept of sensory completion. However, at this point, it should be mentioned that in order to achieve the optimal lighting conditions in a classroom, there is a need to adapt lighting systems to the different requirements of children, which in many cases can be contradictory. In the above context, the term Adaptive Restorative Lighting Environments (ARLEs) is adopted in order to describe the essential nature of the above-mentioned lighting installations that ultimately aim at the cooperation of all the involved “infrastructures” through a dynamic iterative, interaction of their parts and the occupants’ preferences. The potential application of such complex systems requires further investigation that should be able to determine the photometric validity of the proposed methodology by evaluating each lighting parameter in regard to the children’s particular preferences taking into account the sensory profile of each user. In achieving such a composite venture it is necessary to estimate the dynamics of control systems by using appropriate protocols and algorithmic models (machine learning) for the iterative re-adaptation of the predefined lighting settings. The idea of machine learning for the optimization of lighting conditions in educational spaces hosting autistic children with diverse sensory profiles could detect and implement multiple lighting solutions based on indirect occupant feedback via the identification of emerging behavioural and sensory patterns that could not be recognized using conventional mapping methods.

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LIGHTING DESIGN FOR THE VISUALLY IMPAIRED

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Keywords: Visual impairment, lighting design, architectural design

Introduction
This is a study on the mechanism of vision and visual perception, how these are disturbed in case of visual impairment and the way in which architectural and lighting design can and should support the visually impaired and improve their quality of life, especially in their residence.

1. Visual impairment – World Data
Visual impairment is the condition which affects an individual who has lost his vision, to varying degrees, causing a variety of symptoms such as blurriness, loss of visual acuity, loss of contrast sensitivity, loss of peripheral vision, the occurrence of blind spots or a combination of the above, and cannot be corrected, with means such as glasses or surgery. (Wikipedia n.d.) (World Health Organization 2015) According to the World Health Organization, about 285 million people are estimated to be visually impaired worldwide: 39 million are blind and 246 have low vision. (World Health Organization 2014)

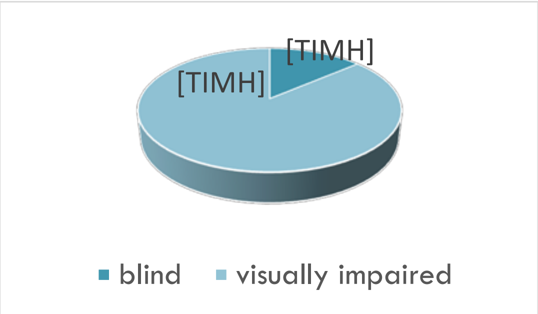

Figure 1 World data for visual impairment and blindness (World Health Organization 2010)

Most common causes worldwide are uncorrected refractive errors, cataract, glaucoma, age-related macular degeneration, corneal opacification, diabetic retinopathy and trachoma. (World Health Organization 2012)

Figure 2 Normal vision (http://www.bairamoglou.gr/, 2018)

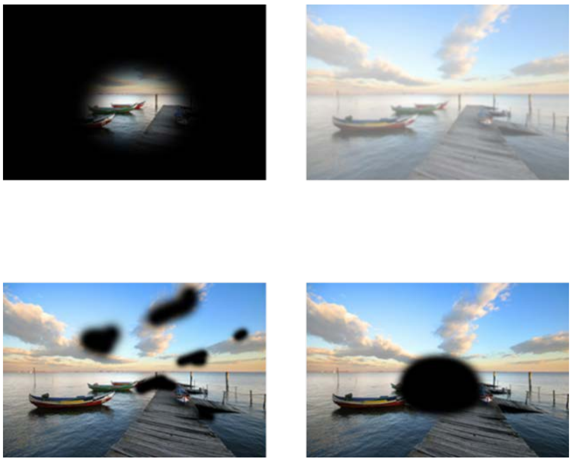

Figure 3 The same image as seen by a person with glaucoma, cataract, diabetic retinopathy and age related macular degeneration (http://www.bairamoglou.gr/, 2018)

People mainly affected are women and inhabitants of developing countries, where many cases can be prevented or treated. It's more likely to be affected by some degree of vision loss while growing older. (Crosker Houde 2007) Worldwide, 82% of people living with blindness and 65% of the visually impaired are over 50 years old. (World Health Organization 2014) This happens because, while growing old, a lot of changes occur to the human eye, since the muscles controlling the iris become weaker (Boyce 2003), the refractive elements of the eye get blurry (Plainis and Palikaris 2006), the sensitivity to colors is reduced (Tregenza and Wilson 2011) and diseases that cause visual impairment are more common. For these reasons a lot of older people suffer from vision loss, without a specific eye condition.

People with visual impairment face a variety of practical and psychological difficulties in their everyday life. They have difficulty in movement and orientation in public (Barker, Barrick and Wilson 1995) which sometimes gets more intense, because of increased glare. (Lewis 2015) There is difficulty in finding work or proper education (Athanasiadis 2018) and it is common that they face racism and discriminations. (Crosker Houde 2007) This leads to disturbing feelings such as anxiety, depression, feeling of loss, insecurity and fear about their future. (Hanson, et al. 2002) In many cases blindness is treated as a social stigma, characterized by a feeling of shame. This leads to creating stereotypes which in turn strengthen the stigma of vision loss. For a lot of people with visual impairment, their house becomes the main area that they live into (Barker, Barrick and Wilson 1995) and it is usual to create a mental map of their house in their mind in order to be more autonomous. (Hanson, et al. 2002) If their everyday environment was better designed, these people would be more independent and functional and their way of living would improve. (Torrington and Lewis 2011)

2. Guidelines

The current guidelines about lighting design for a the visually impaired and the elderly are the Low Vision published in 1997 by the International Commission on Illumination, the Lighting and the Visual Environment for Senior Living published in 1998 by the Illuminating Engineering Society of North America and the most recent CIE - 227 lighting for older people and people with visual impairment in buildings. The older guidelines include suggestions about illuminance in certain rooms of the house and mention that glare should be avoided. (Akizuki, et al. 2017) For working areas is proposed to follow the needs and preferences of the user. No photometric quantity is defined, based on the reason of visual impairment. Old lighting fixtures are used and there is no mention of latest technologies, such as LEDs. The CIE – 227 guideline, while setting an understanding the aging population worldwide, is suggesting higher illumination levels and lower UGR measurements, to prevent discomfort from glare for older or visually impaired people, in correlation with the desired levels for young adults. Non-visual effects of lighting in maintaining the circles of wake and sleep are mentioned and suggestions are made on how sleep disorders usually coexisting with visual impairment can be improved with the right use of light. Guidelines still need to incorporate the new technologies of the past 20 years and to make connections between the reason for visual impairment and the best possible design. (Shikder, Price and Mourshed 2010)

The Greek legislation is lacking any code about design for the visually impaired and there are only some random mentions that these people should be taken under consideration, without any specifications about architectural design or the quality or quantity of light needed.

Some entities give consulting and recommendations about architectural and lighting design, but these initiatives are limited and, in many cases, people are not informed about them and they cannot profit from them. (Torrington and Lewis 2011)

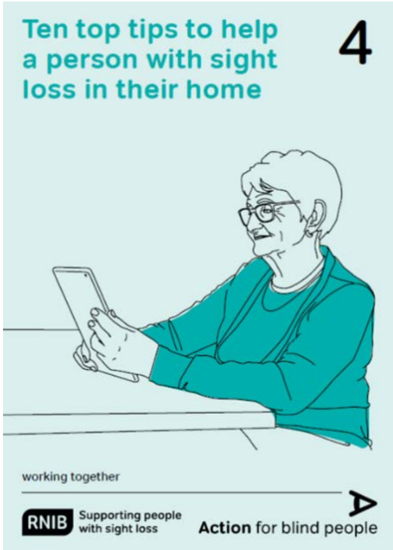

Figure 4 Tips to help a person with sight loss by the Scottish government (2016 Action for Blind People Reg charity)

- increasing the intensity of lighting. (Sinoo 2016) People with visual impairment and older people with vision loss tend to prefer higher levels of illuminance and feel insecure or have difficulty in performing certain tasks with decreased light (Evans, et al. 2010). Regarding activities, such as cooking or reading, they need two times the light needed by a person with normal vision, on their working area. (Evans, et al. 2010) (Smith 2014)

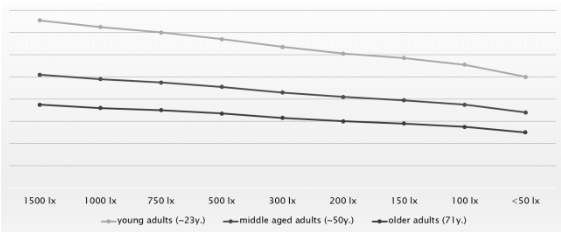

Figure 5 Visual acuity dependent upon illuminance on the task area (CIE-2017)

3. Architectural design

All changes proposed for an existing settlement or the decisions taken when designing a new living space should ensure that all safety regulations are taken into consideration, increasing the levels of safety and functionality of it and make it more friendly and easy to use by the resident. (Barker, Barrick and Wilson 1995)

When designing a space for visually impaired people, there are two points of view: the individual approach and the notion that 'one size fits all'. The individual approach is based on understanding the reason for the user's visual impairment, how his vision is affected and the user's preferences. (Evans, et al. 2010) This means a lot of experimenting in order to find the best solution in architectural and lighting design.

The opposite approach suggests that one solution is ideal for every case, and there should be rules based which should be followed when design takes place, based on general lighting design practices. (Brodrick and Barrett 2008)

The best practice is somewhere in between. (Boyce 2003) According to the patient's condition, needs and preferences, a personalized approach is needed, but there are some rules that work positively in the majority of cases.

4. Lighting design

Regarding lighting design, the basic tools are:

- increasing the uniformity of light. High uniformity prevents the formation of spots of light and darkness, which disorientate people with visual impairment and increase the risk of accidents. (Akizuki, et al. 2017) Ceilings and walls are advised to be painted with light colours, to reflect as much as possible light and create a consistent result (Akizuki, et al. 2017). The usual suggestion for the ratio of light between the task area, the surrounding area and the background area is 10-3-1, but for visually impaired people it is suggested to be 5-3-1. (Akizuki, et al. 2017) This ensures good visual performance, so that people are able to perform their visual tasks speedily, safely and accurately for prolonged periods.
- reducing glare (Akizuki, et al. 2017). The majority of visually impaired people are very sensitive to glare (Littlefair 2010), so it's best to avoid it as much as possible. Surfaces should have a matte, non-reflective finish (Barker, Barrick and Wilson 1995).

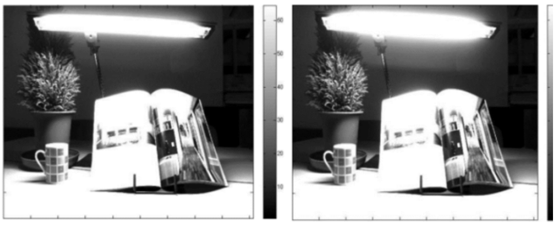

Figure 6 The same image as viewed by a young adult and an older person with vision problems(CIE-2017)

When it comes to photometric quantities visually impaired and older people need higher levels of illuminance and uniformity and reduced glare compared to young adults (Akizuki, et al. 2017). These needs increase if there is a demanding task or if there are other co-existing health issues such as dementia.

• increasing the colour or tone contrast between different elements or surfaces. (Akizuki, et al. 2017) Increasing contrast intensifies objects (Barker, Barrick and Wilson 1995) so that movement and orientation within the space and activities are done more easily. Colour contrast is advised between floors and walls (Smith 2014), where there is a change of level (Barker, Barrick and Wilson 1995) and to mark accessories such as switches, door knobs and bathroom equipment (Barker, Barrick and Wilson 1995).

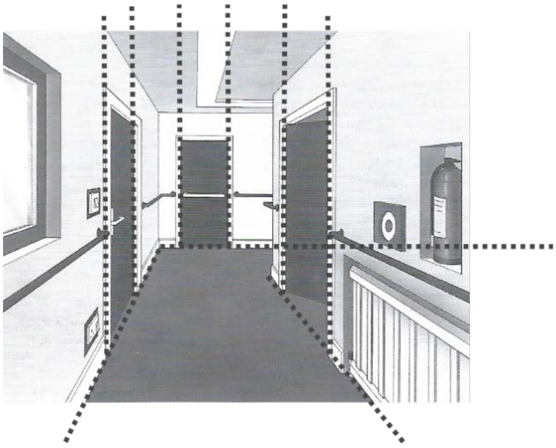

Figure 7 A corridor with strong colour contrast (Source: building sight, 1995)

• lighting installations should be easy to control, adjust to the resident's needs every single time and allow him to create light scenarios (Improving the lighting in your home 2009). This can be done using dimmer switches (Lewis 2015).

• The lighting fixtures used should have high lighting efficiency, longevity, high colour render index, be dimmable, of low cost, non-flickering since it is annoying for people with visual impairment (Sotiropoulou 2014) and not emit heat, because it increases the risk of an accident. (Improving the lighting in your home 2009) The best solution that combines most of the above are LED fixtures and bulbs. (Improving the lighting in your home 2009)
Concerning the colour temperature warm to natural white (3000- 4000 K) are preferred by people with visual impairments or elderly people (Sinoo 2016).

• All rooms of the house should have natural light (Lewis 2015), since natural light usually has high illuminance and uniformity (Littlefair 2010) helps coordinating the circadian rhythm (Wikipedia n.d.), gives non-visual stimuli to the resident, makes it easier for him to orientate and has an excellent colour render index. (Tregenza and Wilson 2011) The main disadvantage of natural light is glare (Littlefair 2010), but it can be controlled with shadings at the windows facing East, West and South. (Barker, Barrick and Wilson 1995) (Lewis 2015)

5. Conclusion

In conclusion, the right lighting design can aid effectively people with visual impairment in their everyday life and improve their lives on a practical, emotional and psychological level.

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LIGHTING DESIGN IN PRESCHOOL CENTER VERSUS LIGHTING DESIGN IN RETIREMENT HOME

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Keywords: preschool center, retirement home, human centric lighting design, circadian rhythm, intergenerational spaces

Introduction

Recently, the scientific interest in issues related to the well-being of preschool age children and elderly adults is increasing. The statistics of aged population and the need to eliminate ageism lead to intergenerational space design for different agegroups integration. Lighting is one environmental element that influences the design of space and is considered as a factor of well-being. Therefore it is a challenge to find the impacts of proper lighting design on visual, physical, cognitive and psychosocial level on each age group and how it can be used in intergenerational spaces promoting the well-ness of human beings (Craig & Baucum, 2007; McAlister et al 2019; Andreopouli et al, 2009; Akpek & Smith, 2013; Jarrot, 2007; Freedman, 2019; StJoseph's home, 2020; Dellmann-Jenkins, 1997; Bressler et al 2005; Basto Camargo, 2017; Tong & Shushan, 2018; Norouzi, 2012).

1. Subject

This research focuses on two age groups: preschool children (2-6years old) and elderly adults (65+). The first group represents the beginning of rapid changes in physical, cognitive and psycho-social development, forming the basis of human evolution, while the second represents the period of gradual degeneration of those acquired in the past. The main subject of this research is a comparative approach between lighting design in preschool centers and in retirement homes. The main research question is the impact of natural and artificial lighting on well-being of preschoolers and elderly in preschool and senior care facilities. The examination of other research sub-questions such as the role of lighting designer, the role of user and the possible success story of intergenerational spaces strengthens the main research question.

1.1 Goals

The scope of this research is to clarify and compare the appropriate guidelines of lighting design in preschool centers and retirement homes and to propose general lighting principles for short-term interaction in intergenerational spaces for the wellbeing of users.

1.2 Methodology

The followed research method includes a thorough literature review which approaches the characteristics of the main users, the lighting conditions in kindergartens and retirement homes, the existing lighting requirements for senior care homes and nursery schools and the current aspects in designing educational and senior care facilities (Craig & Baucum, 2007; Akpek & Smith, 2013; WHO, 2002; Sismani et al, 2011; Boyce P. R., 2014; Cameron et al 2002; Ehrlich et al. 2009, Evans et al. 2002; Derungs, n.d; Sotiropoulou, 2014; Kurtz, 2006). The secondary research investigates the effects of lighting on biological functions, on human perception, on emotional and on visual requirements of users and approaches subjects related to intergenerational spaces (Licht.wissen07, n.d.; Licht.wissen19, n.d; Licht.wissen21, n.d.; Boyce P. R., 2014;

McNamara, 2019; Zerefos, 2014; Lovell et al, 1995; Yacan, 2014).

This research project assesses and compares the optimal lighting design conditions in preschool centers and retirement homes through the presentation of selected lighting design examples such as Kyobashi Child Center in Tokyo and Humana Retirement Home in Glave in Sweden (Gielen, 2010; Shimz design, n.d.; Fujita et al, 2017; IALD, 2015; Davis et al, 2016; Jonson, 2016; Humana, n.d.; Nordisk Lyspris, 2018; Ljusrum, n.d.).

Based on the results of the secondary research, semistructured interviews have been conducted in order to collect qualitative data from people related to childhood and old age. The main results of this overall research are used in order to draw conclusions for lighting design as a factor of prosperity and to propose lighting design guidelines for intergenerational environments (Licht.wissen 02, n.d.; Gaitanidis, 2010; Loe et al 1999; Bourousis, Doulos, 2013; Hopper, 2017; Morrow & Kanakri, 2018; Hartstein et al 2018; Zumtobel, 2020; Figueiro M., 2008; Roberts, 2013; Kunduraci, 2015; Zumtobel, n.d.; Licht.wissen21, n.d.; Licht.wissen19, n.d; Atilgan, 2018; White Paper, 2017).

2. Main results

Lighting has a significant impact on biological, psychological and social level affecting the wellbeing of the two age groups. The maximum of positive effects is achieved when the needs of each age-group are taken into consideration. A key factor for successful lighting design is the collaboration between lighting designers and architects in order to maximize the benefits of natural and artificial lighting on human beings, achieving synchronization of circadian rhythm by means of human centric lighting design. Interaction and feedback between users and designers are also crucial factors in design process.

This research concluded that the requirements proposed by Regulations do not meet the users' needs. In preschool centers the static functional lighting creates dull, inadequate learning environment while illuminance proposed for retirement homes meets the adults' needs, not the needs of elderly people.

Similarities and differences of proper lighting impacts on preschoolers and elderly adults are presented in the following Table 1.

According to this research the use of dynamic lighting in preschool centres and retirement homes hasn't been yet a common practice. The main reasons are: the high cost of installation, the lack of information about lighting effects and the lack of training in the use of new lighting systems without showing concern for the qualitative characteristics of space.

Comparing the main spaces of these facilities (activity classroom- recreational area, restaurant, residents' room, rest room, corridors) through a qualitative approach, the similarities in lighting design in preschool and elderly facilities are:

> The holistic design, taking into account many factors, including the users' needs, the sustainability, the architectural design and financing.

> The use of natural lighting, as a primary free light resource in combination with artificial lighting. It is an ideal choice because users benefit from the positive effects of daylight and the imitation of its changes during the day containing the daylight spectrum.

> The application of dynamic lighting. Artificial light offers the adjustment of light color and illuminance according to light scenarios and scenes, easy to select. This simulates the effects of natural lighting and creates the appropriate conditions for a short or long-term prosperity.

> The view of external environment. The visual contact, through windows, satisfies the need of "biophilia" and improves the social skills of human beings. It provides contact with the natural lighting, the season changes and synchronizes the internal clock.

> The training necessity. Staff and users should know how to use the lighting system in order to maximize the positive lighting impacts.

The differences of lighting design in preschool and nursing facilities according to this research can be summarized as in the following Table 2.

> Illuminance in nursing homes may need to be three times higher compared to that of preschool centers in order to aid visual acuity and perception.

> Reduced mobility of elderly creates the necessity of effective glare management through uniform lighting. On the other hand,

preschoolers have greater tolerance to bright contrasts due to their agile nature until they feel visual fatigue.

> Diminished number of ganglion cells and reduced mobility of elderly create the necessity of planar ceiling lighting in order to light a larger part of the retina maintaining the regularity of biological rhythm. On the contrary, the mobility and curiosity of young children as well as the larger number of ganglion cells, allow light to penetrate the retina from different angles.

> In nursing homes, the dynamic light scenes are based on the changes of natural daylight in order to synchronize the function of circadian rhythm, which in long term affects the well-being. In preschool centers, the lighting scenes depend on the activity and the learning process, influencing the behavior, the concentration, the need for relaxation and the visual needs of preschoolers.

> Bright contrasts and sharp shadows affect more the perceptual ability of elderly people increasing the risk of accident, causing confusion and inability of self-care. On the other hand bright contrast could be stimulus for preschoolers' mental development.

> In nursing homes, the use of individual led luminaires for various activities is necessary for independency. On the contrary, this practice is hazardous in kindergartens, where individual led luminaires can be used only for learning purpose.

The successful implementation of intergenerational programs in indoor spaces is feasible under certain conditions such as: i) the appropriate preparation of hosting area for safer accommodation, ii) the type of activities should meet the users' needs iii) the duration and v) the schedule of the programs.

In intergenerational spaces, natural daylight is an ideal lighting choice. This practice explains the fact that many intergenerational activities take place outdoors. In indoor activities, artificial lighting is proposed as supplement. The space should have diffused lighting that provides uniformity, so that both pre-schoolers and elderly people may have a good visual perception of facial features, gestures and expressions, improving their social skills and their integration. The general lighting should be evenly distributed without strong-sharp shadows, avoiding visual fatigue or risk of accidents.

Intergenerational spaces should meet the needs of the age-group that is more vulnerable to inadequate and improper lighting design as long as the interaction is brief. This age-group is the elderly. Lighting design shouldn't cause visual disturbance or incapacity to perform activities. Lighting should be functional and at the same time should have a positive impact on human organism, emotions and behaviors, diminishing the risk of accidents. Under this approach, such a space can have more positive impacts for both participants.

3. Conclusion and Further consideration

To sum up, proper and adequate lighting can promote the quality of life for preschoolers and elderly people in preschool and retirement facilities by applying the principles of human centric lighting design. As a result of the overall research, a new issue arises: *Lighting design for spaces that will host long-term intergenerational programs daily, taking into account the employees, as a different target group, representing adults.*

The purpose of this future study is to create a background for expanding the lighting design research to spaces that hosts full-time intergenerational activities. This fact will be inevitable in the future mainly due to the statistics on aging and to the increasing need for human contact among different age groups, following the development of educational and geriatric science.

Table 1 An overview: impacts of proper lighting on preschoolers and elderly.

	Preschooler	Elderly
Vision and perception	➢ Development of optical system-vision ➢ Screening of visual problems and eye diseases ➢ Visual stimulus enhancement ➢ Minimizing visual fatigue ➢ Forming visual cognition of 3d space and objects ➢ Recognition of facial characteristics, behavioural patterns, gestures and motions ➢ Enforcement of colour perception and education ➢ Assisting education/memory ➢ Assisting development of skills	➢ Assists the quality of vision depending on the vision impairments ➢ The increase of illuminance offers better visual acuity, recognition of details-colors and objects. ➢ Enforce color perception ➢ Lighting uniformity prevents false perception of space due to bright contrasts/reflections minimizing visual fatigue. ➢ Assists the recognition of facial characteristic and details. ➢ Assists visual perception to maximize self-sufficient and accident - free living. ➢ Assists vision during an activity providing self-confidence but doesn't restore vision of youth
Biological level	Stimulates the function of circadian rhythm, affects brain function, body temperature, the sleeping quality and affects the long-term or short-term health improvement, promotes mobility and independence.	
Psychological – social level	The appropriate lighting effects:	
	➢ Mood changes ➢ Sense of alertness and relaxation ➢ psychology ➢ behavior ➢ stress management ➢ recognition of faces ➢ sense of security ➢ well-being – productivity and social skills Dynamic lighting is connected with positive feelings while static lighting increases the possibility of depression.	
	➢ Improves concentration ➢ Reduces hyper-activity ➢ Reduces fatigue and improve mental/ emotional energy and willingness for participation (Kiteo, 2019)	➢ Stimulates mind ➢ Sleeping quality ➢ Improves memory (Kiteo, 2019)

Table 2 Qualitative Lighting Differences between Preschool Centres and Retirement homes.

	Preschool center	Retirement home
Illuminance	300lx-500lx-750lx according to the activities	three times higher 300lx-500lx-1500lx
Glare	Higher tolerance due to agile nature	High necessity for glare management due to reduced mobility
Direction - distribution	The mobility and the large number of ganglions cells of the retina offers different approaches of lighting	Effective circadian light needs to enter the eye from the front and from above (ceiling planar lighting, indirect ceiling lighting like sky)
Lighting system control	Dynamic led lighting system with lighting scenes depending on the activity, on the users' needs and the educational approach. Supplementary to daylight	Automatic Dynamic led lighting system strictly synchronized with the day/night rhythm. Supplementary to daylight during the day.
Changes of illuminance and color temperature	Dynamic lighting scenes adjusted according to activities and learning practices. color temperature : 6500K - 2700K	Need to be adjusted dynamically imitating the dynamic changes of daylight - 6500K early in the morning illuminance: 300lx -500lx - 6500K-4500K until noon illuminance: 1500lx - 3000K- 2700K after noon - midnight 300lx-500lx
Bright contrasts – sharp shadows - uniformity	Stimulus for mental development – intriguing innate curiosity	Affect visual perception- higher uniformity increases the risk of falls, causes confusion and inability for self-care.
Individual led luminaires	Hazardous- only for learning purpose- usage under supervision	Necessary for various activities improving visual acuity.

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LIGHT FLICKER HEALTH ISSUES AND METRICS: A CRITICAL REVIEW

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Introduction

Theoretically all the electric light sources which operate with AC power (alter-current supply) produce regular fluctuations in the amount of light emitted. Changes in the supply power phase produce a correspondingly fast, periodic change of the emitted optical radiation and resultant lighting intensity or luminance. (IESNA 2000) These fluctuations can be caused by various reasons such as mains or power supplies, drivers and dimmers and differs for each type of light source and type of power supplies.

The flickering of the luminaries was a major concern since HID bulbs and electromagnetic ballasts of the fluorescent bulbs were culminating before the mid1990s (Wilkins et. al. 1989; Veitch and McColl 1995). When high-frequency electronic ballasts appeared on the market for better energy efficiency, reports of flickering were greatly reduced (Veitch and McColl 1995).

With the introduction of the solid state light sources, flicker reappeared as a problem. Despite the undoubted advantages of the Light Emitting Diode (LED), one of its main advantages, the rapid response to power changes, contributes among other reasons for the creation of flicker. Semi-conductors react at approx. 300 microseconds. This high-speed reaction of the LED used with pulse width modulation (PWM) then becomes its downfall with regard to the desired flicker-free operation. Flicker, stroboscopic effects and phantom array effect are the major types of the temporary light artifacts (TLAs) which is the general term for visual effects caused by a rapidly fluctuating light source that causes an undesirable effect to the observer (Bierman 2017; CIE 2016).

The International Commission on Illumination's (CIE) technical note (CIE 2016) and the Illuminating Engineering Society (IES) (IES 2018) define flicker as the perception of visual instability prompted by a light stimulus whose luminance or spectral distribution oscillates with time for a stationary observer in a stationary environment. The stroboscopic effect is described as the change in motion perception induced by a light stimulus, the luminance or spectral distribution of which fluctuates with time, for a static observer in a non-static environment. The phantom array effect (ghosting) describes the change in perceived shape or spatial positions of objects. Induced by a light stimulus, the luminance or spectral distribution of which fluctuates with time, for a non-static observer in a static environment.

1. Flicker consequences

The irregularity of light modulation can cause visual fatigue, headaches, migraine episodes and even epileptic seizures (Wirrell and Hernandez 2019; IEEE 2015; 4E 2014). The TLAs can also cause problems that are not directly health-related such as reduced visual task performance, apparent slowing or stopping of motion (stroboscopic effect), distraction, unstable light output for video purposes (SCHEER 2018). Lighting flicker can cause misjudgment of the position, shape or speed of an object can lead to accidents and injury. Poor lighting conditions can affect the quality of work, particularly in a situation where precision is required, and overall productivity (Roth 2012).

2. Standards/directions

International and national directions from industry bodies provide advice to lighting professional and manufacturers on how to define measures and limit the effect of the disturbing artifacts.

Initially, the Illuminating Engineering Society of North America (IESNA) adopted the flicker index (Eastman and Campbell 1952) and the percent flicker metrics. The flicker index describes the ratio of the areas above the luminous flux average of the emitted light to the total emitted luminous flux in an observation interval and actually measures the cyclic variation in output of the light source considering the waveform of the lighting output. It can vary between 0 and 1, and it is recommended (IESNA 2000) that for good lighting quality it should remain below 0.1. The percent flicker is the ratio between the difference and the sum of the maximum and minimum light signal amplitudes and is a relative measure of the cyclic variation in output of a light source (percent modulation) (IESNA 2000; IES 2018).

New improved and more sophisticated indexes were introduced since then. If the input modulation is not a periodic signal, the frequency-based methods cannot easily be applied and a time domain based analysis is recommended. The International Electrotechnical Commission (IEC) in the EMC standard IEC 610003-3 adopts the short term flicker severity Pst which quantifies the perceived light flicker. The method yields a short-term flicker indication, Pst, over a 10min period and its associated limit Pst = 1 defines the threshold of irritability. In short-term flicker, a distinction is made between flicker caused by the power supply voltage PstV and flicker caused by the light source in connection with the ballast PstLM (IEC 2013; IEC 2015; CIE 2016). The IEC has also described the functional and design specifications of a flickermeter (IEC 2010) which can be described by five sequential blocks: input voltage adaptor, squaring multiplier, weighting filters, squaring and smoothing and on-line statistical analysis.

The Alliance for Solid-State Illumination Systems and Technologies (ASSIST) presented a method for the assessment of the perception of flicker directly observed from light sources. It produces a single numerical result, the flicker perception metric Mp, using a relative light output waveform measurement (IEC 2013; ASSIST 2016).

The IEEE standards committee developed the IEEE PAR1789 which provides a recommended operating area for LEDs (IEEE 2015). Assuming that the power line condition is perfect, in order to restrict the biological effects and detection of flickering in general illumination, the Modulation (%) = 100 • (Lmax – Lmin)/(Lmax + Lmin), where Lmax and Lmin are the maximum and minimum luminance respectively, should be kept within specific limits, no effect or low risk areas, for various frequencies.

In case of stroboscopic effects, an effective index should consider the effects of moving and rotating objects when illuminated with light modulation. The stroboscopic visibility measure (SVM) value results after the application of Fast Fourier Transform Analysis and represents the average detection ability of an average human observer (IEC 2018; NEMA 2017; CIE 2016).

In proportion, European Union, acknowledged the lack of standardization, issued the regulation 2019/2015 and adopted – it will come into force on 1st September 2021 – as metric for light flicker the parameter PstLM where subscript st stands for short term and LM for light flickermeter method. The critical value of PstLM is 1 which depicts that the average observer has 50% probability to detect

flicker. The functional requirement for LED is set to PstLM ≤ 1 at full -load. Regarding stroboscopic effects European Union adopted SVM with required value ≤ 0.4 at full-load with some exceptions mainly for outdoor applications (EC 2019).

3. Discussion

Despite the fact that flicker index and percent flicker are easy to calculate and understand, they are now considered outdated since they do not quantify correctly and objectively TLA effects.

They use the analysis of one cycle of the periodic waveform without taking into account any frequency component and the wave shape of the light output. The human perception nevertheless has strong frequency and wave-shape dependence (NEMA 2017). They are also not selective since they do not distinguish flicker from stroboscopic effect (Perz et. al. 2017; Miller and Lehman 2015).

Even the new indexes are not perfect. IEC 61000-3-3 is quite complex and it is limited to up to 80Hz. The ASSIST flicker perception metric Mp covers frequencies from 5Hz to 80Hz. The SVM assumes an unrealistic fixed gaze from the viewer and does not predict the visibility of the phantom array effect (Miller 2018). Although IEEE 1789 considers the main frequency, the proposed limits may avoid any chances of harmful effects but they are quite strict for many applications and usually give false alarms. It also does not distinguish the wave form of the light (Wright 2015; NEMA 2015; NEMA 2017). The PstLM index was initially created as a measure of the power quality since it is a weighted percentile formula based on voltage variations creating perceptible flicker from a 60W incandescent lamp (Perz 2019). It takes into account the waveform of the light output as well as the human perception but it turns out to be very complicated.

The ideal TLA metric should account numerous parameters such as the frequency, the shape of the waveform, the mean luminance, the position in the visual field, the movement of the source/viewer, the visible and the non-visible flicker and simultaneously be adaptable for different applications and exposure factors, easy to measure/calculate/understand in order to be widely adopted and become a worldwiderecognized standard (Lehman and Wilkins 2014). Also, the associated electronics of a light source, mostly drivers and dimmers, introduce undesirable flicker. It becomes even more complicated when one would try to embed factors such as the exposure time period, the individual’s age or the level of tiredness that can affect how acutely the flicker is perceived by a person. Existing flicker measurement standards are inconsistent to fulfill all the above (EERE 2020).

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MULTI-ANGLE LIGHTING MEASURMENTS OF OUTDOOR INSTALLATIONS USING UNMANNED AERIAL SYSTEMS

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Introduction

The major aim of outdoor lighting installations is to assist users to recognize hazards, orientate themselves and to increase the feeling of safety. The illumination of roads, parks and other outdoor places was always an indication of economic growth that was combined with the illumination of building facades, monuments, and other architectural structures. The increase of outdoor artificial light was also a result of rapid urbanism.

The transition from conventional light sources to LED technology led to the decrease of the corresponding energy consumption. However, the continuous drop of LED technology created a rebound effect of over-illumination, even in areas where outdoor lighting was not present before (Kyba et al. 2017) (Kinzey Richland et al. 2017). Highly illuminated outdoor areas create the phenomenon of obtrusive light while the concentrated over-illumination in urban areas increases the skyglow at night in much higher levels compared to the natural night sky. Although obtrusive light can be generally considered and controlled during the lighting design phase, various limitations on software and design techniques prevents it. This is also strengthened by the unknown reflectance of the relevant surfaces and the geometric characteristics of the surroundings

On the other hand, the new technology on lighting controls and smart luminaires assist towards the direction of adaptive lighting. There is a great potential for the outdoor adaptive systems to mitigate the effects of obtrusive light and skyglow (Janiga et al. 2015) (Nikoalou at al. 2017).

According to CIE 150:2017 (CIE 2017), obtrusive light is mainly produced by the following installations:

- Street lighting on cities, motorways, interchanges, toll stations etc.
- Squares, parks, parking areas and of the outdoor recreational areas
- Sports facilities
- Airports, seaports, train stations, etc.
- Façade lighting and monument lighting
- Self-illuminated or externally illuminated signs and static or dynamic billboards and advertisement media.
- Illuminated monuments and cultural heritage structures

The assessment of the above outdoor lighting installations is currently covered by relevant standards, guides, and regulations like the EN13201-4 (CEN 2014a), EN 12464-2 (CEN 2014b), CIE 194 (CIE 2011), CIE 150 and other. In all these cases, the defined methods refer to ground-based measurements or measurements that are limited to a fixed position (typical observers) and the luminous quantities (e.g. illuminance and luminance) are measured towards the ground or the relevant task area. The excess or spill light that is unavoidably reflected or directly emitted towards the upper hemisphere, is generally difficult or not possible to be measured given the current techniques (Hänel at al. 2017). The limited amount or the absence of field lighting measurements at the commissioning stage or during installation's lifetime, increases the chances of over-illumination. In addition, practical issues may arise during the field measurement like the difficulty to set the measurement grid, the

timeconsuming measurement procedure, the expensive equipment, and other factors.
There are, therefore, certain limitations related to measurement geometries and assessment methods for obtrusive light and light pollution. Since the typical measurement geometries are defined at ground locations and standard observers are defined to look towards the ground or around the installations, there is a noticeable limitation on the measurement from additional directions.

The drone-gonio-photometer

To address the above-mentioned issues, the Lighting Laboratory of NTUA introduced the concept of the drone-gonio-photometer, DGPM (Bouroussis and Topalis 2020). The term DGPM is a combination of the Drone and the goniophotometer which is a well-known term in lighting engineering and reveals the combined character of the measurement system that takes advantage from the benefits of both technologies. It is equipped with an imaging sensor that is calibrated against luminance standard for the estimation of luminance distribution of areas under inspection.
The DGPM is proposed for the assessment of lighting installation against the relevant standards but also against their contribution to light pollution and obtrusive light. It is able to execute controllable flights anywhere on the 3D space around the lighting installations and to measure the corresponding luminous quantities.
The benefits of using such device are the following.
• Flexible multi-angle measurements. The main benefit of the DGPM is that it offers the capability to carry virtually any kind of lighting or radiance sensor on any position in the 3D space towards any direction at any time.
• Programmable paths. Due to its nature, can execute measurements for a simple of complex set of locations on the 3D space. This is similar to the goniophotometers which performs a programmed combination of measurements and angular movements.
• Stop and go or scanning. In case where one or more measurements require long exposure time or static measurement of a modulated light source, the DGPM can operate in a steady mode (hovering). On the other hand, in case of a need for speedy measurements, a dynamic and scanning way of measurements is also possible with such aerial platform.
• High repeatability. In situations where hight repeatability is needed, the DGPM offers location accuracy via GPS sensors. The GPS accuracy of UAS varies between 3-6m when using common GPS modules down to few centimetres in case of a Real Time Kinematics (RTK) GPS hardware. However, the uncertainty of the positioning of a UAS depends on both the GPS accuracy and the distance of measurements, thus, in certain cases, a common GPS accuracy may offer acceptable angular accuracy.
• Acceptable accuracy. The DGPM can offer high accuracy levels when combined with high accuracy sensor and an accurate measurement path.
• Low altitude and higher image resolution. In the case of image-based measurements, the relatively low flight altitude offers hight measurement resolution compared other aerial methods like airplanes, satellites, and balloons that flight in much higher altitudes. This is essential for obtrusive light investigation in the near field.
• Short measurement times. DGPM offers the shortest preparation and operational time of all other aerial measurement platforms. It takes only few minutes to prepare the flight path and execute the measurement procedure. In addition, DGPM can give the ability to the user to cancel and reprogram the flight mission without any additional complications.
• Low cost of ownership and operation. Compared to airplanes, satellites and balloons, the DGPM required significantly less investment for acquiring or development and is low cost in operation. The benefits of the DGPM and its limitations as well as the comparison to the other technologies used for light pollution assessment will be presented and discussed thoroughly. In addition, the corresponding calibration procedures of the DGPM will be also presented.

Measurement methods and geometries

In order to gain the benefits of the new proposed technology for lighting assessment, a set of standardized measurement geometries were developed and proposed. The ability to perform flexible measurement patterns is one of the key added values of the DGPM. Therefore, the measurement geometries can be applied for the assessment of typical lighting installations.

Three measurement geometries are proposed, Type 1, 2 and 3 and briefly described below.

Type 1 – Planar: This geometry is imitating a line or poly-line path above an installation (similar to an airplane). The flight path comprises of distinctive or continuous measurement points across it. The observation angle can be either nadiral or oblique depending on the installation under measurement. The Planar geometry can be used to assess the upward lighting from the lighting installation and the emitted / reflected light is various angles close to the vertical

Type 2 – Arched: This geometry comprises a variable flight path over a virtual arch or generally a path that starts and ends on or close to the ground level while the maximum heigh depends on the specific needs. In this case the angle of observation is variable towards the subject under investigation. This results to a luminous profile of the installation on the corresponding virtual plane. The density of the observation points and a precise data processing can reveal significant details for the contribution of the installation to light pollution.

Type 3 – Spiral: This geometry is proposed for cases where a holistic threedimensional assessment of outdoor lighting installations. Although this is the most complicated geometry it can offer the complete lighting distribution of the installation. The observation angle in this case is also variable, aiming towards the area of interest.

These generic measurement geometries can be applied to any kind of outdoor lighting installation while can be slightly modified in order to be adapted to specific needs.

Independently of the selected standard geometry, the DGPM multi-dimensional measurement data. These are the X, Y, Z coordinates of the observation point (3D space), the direction of observation, the 2D data of the captured image, the derived luminance and/or the colour data, the time of the measurement and the associated measurement uncertainties.

Preliminary results and future work

The drone-gonio-photometer has executed various test measurement in order to define the specific settings, methods, angles and to validate the proposed measurement geometries. These measurements include motorway interchanges, city streets, sections of highways, parking lots and other. The preliminary results revealed that this technology and the corresponding techniques are very promising towards the effort to standardize the measurement of obtrusive light.

The future research work will be focused mainly on the measurement techniques and the validation of the measurement system. In addition, specific measurement methods are going to be prepared and proposed for typical cases of outdoor installations.

Several test cases will be presented discussed.

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THE EVOLUTION OF COLOR RENDERING

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Keywords: Color rendering, Color Rendering Index (CRI), IES TM-30, reference illuminant, color preference

Introduction

The lighting industry operated under the color rendering index (commonly called CRI) for the last 55 years and its limitations have become more prominent (Davis and Ohno 2010; Houser et. al. 2016; Ohno 2005; Royer et. al. 2016; Smet et. al. 2015; Xu et. al. 2016) with the advent of new technologies and applications. A shift in how we operate about color rendering will be required. High color fidelity is an assumption of high color quality however a higher fidelity is not always preferred (Hashimoto and others 2007; Judd 1967; Davis and Ohno 2010; Smet et. al. 2011; Thornton 1974; Wei et. al. 2014).

A key to better color rendition is to understand that any single average metric is unable to capture all dimensions of color rendition. Sources with the same value for fidelity index may in fact desaturate, saturate or have a shift effect on colors of an object. The addition of the average level of saturation, visual descriptions of hue, saturation changes and many others values provides a better indication of the suitability of a source for a specific application.

A possible change of color rendition measure method can be easily and quickly implemented because all of the calculations are founded on the source's spectral power distribution (SPD) which was already measured to determine the known CIE CRI. The challenge is to be adapted with the knowledge to engineer, specify and classify sources through the new evaluation color rendition methods.

Comparison of prior tools

Color rendering is defined as the "effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant" (CIE 2011). There are some alternatives of reference sources such as Planckian radiator, CIE D Series Illuminants, as shown in Figure 1, off-Planckian reference illuminants and custom reference illuminants.

Research has showed that the differences by using all Planckian radiation or all CIE D Series Illuminants were less than a few points and they were slightly related to the differences in gamut shape. Using a fixed reference has resulted lower values because of the different CCT and using off-Planckian reference illuminants is resulted desaturated sources with lower fidelity (Royer et. al. 2016). Reference is the foundation for communicating but no possible reference is inherently superior. The use of Planckian radiation, daylight or combination of those two has been established as reference sources because people are familiar with those two non-electric light sources. They do not necessarily provide the ideal color rendering in every application but an improved framework, for understanding how a test source is different than the reference source, is a possibly solution.

Is the difference between the prior and new tools important? Research community focused on comparing the IES TM-30 Fidelity Index (IES Rf) to the CIE General Color Rendering Index (Ra) (CIE 1995) and CIE Rf. Other measures of color fidelity such as Color Quality (CQS) Qf (Davis and Ohno

2010), CRI2012 (Smet et. al. 2013) and Ra1-14 (Khanh, Vinh and Bodrogi 2016) are not examined because they are not formalized by a national or international lighting authority. Many past comparisons with small sets of commercial SPDs do not present a complete result of this difference because the commercial sources have a limited diversity of gamut shapes (Rea and Freyssinier 2015; Smet et. al. 2015). CIE Ra is calculated only with eight color samples and there are wavelength regions with increased sensitivity and other with little or no sensitivity in contract with IES TM-30 which is calculated with 99 color samples with wavelength uniformity and they cover the area of consumer goods and natural objects. Researches with big sets of SPDs with variety of gamut shapes showed that the differences are significant and systematic (Royer 2017). A possibly replacement does not mean a more proper evaluation of color rendition but it is necessary because this will require consideration of other important aspects such as gamut shape and gamut area.

Gamut area measures are presented as complements to fidelity indexes. There have been proposed at least twelve gamut measures, the most important of them are documented in Table 1. An extended comparison of gamut area measures showed that methods with few color samples sets or samples that are not spaced in the results may compress the gamut area even for sources with increased gamut area (Royer 2019).

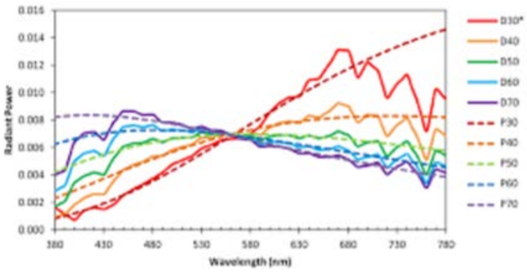

Figure 1 Comparison of Planckian (P) and CIE D Series illuminants (D) at five CCTs. Each source is normalized for equal luminous flux. The filtering of light by Earth's atmosphere is the difference between Planckian radiation and a CIE D Series illuminant of the CCT

Gamut area is a formula of chroma changes but they are not well correlated because it is also influenced by hue shifts. Multi-measure models of gamut area are more useful such as IES Rg because they provided more independent information.

Beyond the prior tools and conclusions

Is a two average measure system capable to provide information about the rendition of objects with specific hues? Sources with equal IES hue angles appeared results with significant differences. In case of high chroma color samples Rf and IES Rg may be perceived differently because they distort different hues in different

Table 1 Previously documented measures related to gamut area, gamut volume or chroma shift

Year	Measure and abbrevation	Color Samples	Color Space / Chromaticity Diagram	Reference Illuminant
2015, 2018	Gamut Index (Rg)	99/16 CES (IES TM-30-18)	CAM02-UCS	Relative Planckian/ mixed/CIE D Series
2016	Relative Gamut Area Index (RGAI)	8 TCS (CIE 13.3-1995)	CAM02-UCS	Relative Planckian/ CIE D Series
2016	Relative Gamut Area Index (Ga)	8 TCS (CIE 13.3-1995)	CIE 1964 U*V*W*	Relative Planckian/ CIE D Series
2010	Gamut Area Scale (Qg)	15 VS	CIE LAB	Relative Planckian/ CIE D Series
2009	Color Saturation Index (CSI)	1269 Munsell	None/MacAdam	Relative Planckian/ CIE D Series
2008	Gamut Area Index (GAI)	8 TCS (CIE 13.3-1995)	CIE 1976 UCS	Fixed CIE Illuminant E
1993, 2007	Feelings of Contrast Index (FCI)	4	CIE LAB or CIE CAM02	Fixed CIE D65
1997	Cone surface area (CSA)	8 TCS (CIE 13.3-1995), w'	CIE 1976 UCS	None
1984, 1993	Color rendering capacity (CRC)	Theoretical all colors	CIE LUV	None
1972	Color Discrimination Index (CDI)	8 TCS (CIE 13.3-1995)	CIE 1960 UCS	Fixed CIE Illuminant C

ways (Royer et. al. 2016). ANSI/IES TM-30-18 includes key components that go beyond the two high-level average values. The Color Vector Graphic (CVG) in a modern and uniform color space such as CAM02-UCS (uniform color space), allows visual understanding of color rendition characteristics for lighting sources with different hues. A gross comparison of light sources is possible, however small differences are not always visible. Numerical specification for these differences is urgent. Local Chroma Shift values and Local Hue Shift values address this limitation. They can be more informative than a possible corresponding fidelity value because the same fidelity value may result from saturated, desaturated or chroma changes.

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ALGORITHM FOR SPECIFYING THE INFLUENCE OF GEOMETRICAL AND OTHER PARAMETERS TO THE LIGHT REFLECTED ON SURFACES

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Keywords: Lighting Design, Parametric Design, Algorithms.

Introduction

Light is what makes objects visible and thus one able to perceive the environment. Depending on the properties of itself as well as of the surfaces it is reflected on, it stimulates human vision and creates an image of the surrounding world. Consequently, the study of these properties and their influence on the creation of an image of space is very important. Research is being conducted [Tolidis 2019] relevant to the construction of a parametric model that would provide a lighting design solution for achieving a certain visual result. The parametric model involves parameters for both the visual result and the lighting design solution in terms of measurable properties of light and its aim is to interrelate these parameters in order to lead to an output of an optimum lighting design solution for a specific input of a desired visual result. One of the initial steps of the construction of such a model is the creation of an algorithm that would calculate parametrically the illuminance on a certain point of view that comes from one point light source located at another point in space by reflection on every point of a surface. Such an algorithm doesn't seem to be much different than a common rendering algorithm. A significant difference for this case's algorithm is that it should keep the parameters accessible and handy so as to be able to change their values independently and see the effect of these changes to the final result. For example, it would be very useful to be able to change parameters like the distance of the light source or the point of view from the surface, or the orientation of the normal vector on each little part of the surface and find out the influence on the illuminance. It is also very important to determine the interrelations between the parameters of the algorithm and the way they influence each other and to keep these interrelations as clear and obvious as possible. It would be very useful to obtain the mathematical relations describing the change of some parameter values according to the change of some others.

The development of an algorithm such as the aforementioned is included in the study that this paper refers to.

Methods

The Bidirectional Reflectance Distribution Function (BRDF), a common tool in rendering, is the basic relation that is used for the calculations. It associates the outgoing luminance Lr in direction (θr,ϕr) of a light ray reflected on a surface to the illuminance Ei from the incident direction (θi,ϕi) [Theoharis et al. 2015, 363], where θr,ϕr are the spherical coordinates of the luminance direction vector and θr,ϕr are the spherical coordinates of the illuminance direction vector:

$$BRDF = Lr/E \quad (1)$$

The BRDF has been chosen as the main function for the calculations, first because in many of its common definitions it includes quality attributes of the surface as parameters along with the geometrical parameters of light and surface and second because there is the flexibility to use empirically specified types of the function in the whole calculation procedure and not be restricted to use a simulation rendering model for the final result. There are studies [Renhorn and Boreman 2018], [Bonnefoy et al. 2000], that deal with experimentally determined or tested BRDFs by measurements in a physical model i.e. a piece of the material and these functions are very useful because they can cover some special cases of surfaces.

Findings and Argument

In this specific study, the algorithm has been developed for a particular example of space. It calculates parametrically, for a certain cylindrical space under a semispherical dome, the illuminance on a certain point of the floor of the cylindrical space that comes from one point source located at another point of the floor by reflection on every point of the surface of the dome. The idea is for the algorithm to be used in a case of a dome with a tessellated surface. It is of great interest to study the way that parameters like the size, position, orientation, color, or the existence of glaze of the tiles of the mosaic influence the way that light is reflected on them and produces a certain visual effect. There are pieces of evidence mentioned in relevant literature [De Luca 1989] that middle age mosaic artists in Ravenna, Italy were putting deliberately the little pieces of their mosaics in a wellstudied manner regarding the position and orientation to reflect light in a certain way and produce specific effects. The algorithm at this moment is still quite simple. Only the contribution of the dome is considered, the light source is single and the interreflections between points of the dome surface are not considered. In future steps, the algorithm will be expanded to take into account more light sources, to consider the interreflections and to resolve more geometries than a single dome. It is always kept in mind that the main aim is to come up with an algorithm that is fully parametrical. Thus, the algorithm is being built in small steps and during each of them the proper parameters are extracted, and their interrelations are studied. Moreover, in each step the algorithm is to be tested for whether the visual effect suggested by the algorithm and obtained by a proper rendering procedure matches the real one being observed (or measured in the case of illuminance) in situ. For that purpose, several churches that have dome and potentially drum with windows are to be used in the near future. Three churches in Thessaloniki: The "Panagia Dexia" church, the church of Saint Panteleimon and the "Hagia Sofia" church of Thessaloniki are initially to be observed in order for the efforts to be experimentally tested, with the intention for more to be added on the list. Up to now, the testing of the algorithm has been limited to the check upon its functionality, i.e. to see if it is working and giving acceptable results. In this context, the output of the algorithm includes acceptable values of illuminance and between reasonable limits. It would make sense first to expand the algorithm so as to describe a more realistic case of illuminated space and then to test it by comparing its results with in situ visual effects.

Conclusions

An algorithm that could offer a better apprehension of the lighting parameters and the way that they affect the visual result is obtainable and by this study the first step towards its construction was made. The algorithm with its expansions will give the ability to describe the influence of the lighting parameters by means of mathematical expressions and thus to reveal their interrelations and this is very important to the lighting design procedure. Algorithms such as this will contribute significantly to the creation of models and the establishment of methodologies for an optimized lighting design of space.

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CHAOTIC PHENOMENA IN LED DRIVERS THAT IMPAIRS ILLUMINANCE PERFORMANCE

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Keywords: LED boost converter, chaos, nonlinear dynamics, lighting circuits

Abstract

Under specific conditions LED driver circuits are prone to unpredictable chaotic behaviour, which can significantly reduce their performance. A notable relationship between the switching frequency of the LED driver transistor and the circuit's inherent nonlinear properties is shown. A theoretical method has been devised to predict the unstable frequency regions based on certain dependence equations. This work proves that particular nonlinear parameters may influence the circuit's behaviour, such as the reverse-recovery time of the boost diode, as well as the collective effect of the inductance and the diode's junction capacitance. The proposed dependence equations demonstrate a correlation between these inherent nonlinearities and the switching frequency of the boost transistor. Period doublings and transitions to chaos occur for several regions of the examined switching frequency range. The theoretical method used for the numerical analysis is based on the periodicity of certain voltage waveform peaks, probed at key points on the converter. The LED boost driver displays a wealth of nonlinear phenomena and detrimental effects on its brightness levels throughout the nonlinear frequency regions.

Introduction

Unpredictable phenomena have been found in the operation of DC-DC boost power converter circuits [Giaouris, et al. 2012] or in Power Factor Correction (PFC) power supplies, which can degrade the power factor significantly [Dai, et al. 2007]. The linearization approach that is still commonly used in the industry, can provide inaccurate solutions to designers, since nonlinear instabilities that can affect a power converter's response, cannot be easily detected without a certain type of nonlinear analysis. Such an analysis can offer an insight of the behaviour of these power electronic circuits that appear in the form of subharmonics [Mandal, et al. 2013] as well as other chaotic phenomena in such power converter circuits [Banerjee, 2001]. Initially, a diode resonator circuit made an introduction to electronics chaos [Caroll, 1995]. The inductor and the diode of this simple circuit have proven to be highly nonlinear circuit elements, as it has been shown in [Chua, 1998] and [Collantes, 2000]. In certain circumstances, the nonlinear capacitance of the diode's equivalent circuit can be combined with a nonlinear resistor, and then a peculiar behaviour may appear, which is appropriately called chaos [Matsumoto, 1987]. At the course of this phenomenon, a signal waveform's period loses its stability as a control parameter of the circuit is varied, until the corresponding time-series finally becomes chaotic and the signal's period becomes undetectable. The circuit diverges from its designated operation, as in rectifier circuits that employ slow-response diodes [Karadzinov, 1998].

Since LED driver circuits are essentially modified DC-DC power converters [ON Semiconductors, 2014] for lighting applications, it is important to explore the conditions that could cause chaos in such a system. In most published papers though, chaos appears mainly due to controller instabilities of the feedback loop in such power converters [Basak, 2010] or as a result of slope disturbances [Wu, et al. 2012]. In this paper, the possibility of chaos is examined without the feedback loop, in order to prove that chaos can be possible only due to the combined inherent nonlinear properties of the boost diode and the inductor.

1. Circuit description and theoretical method

The LED boost driver circuit, is essentially a modified version of a DC-DC boost converter. Its main operation is described as follows. A DC input voltage supplies the converter, while energy is stored in both the inductor and its output capacitor. At the same time, a MOSFET transistor switch (Q1) controls this energy transfer by switching on and off rapidly, while magnetic field is stored in the inductor when Q1 is on. During this energy transfer, voltage is also stored in the output capacitor when Q1 is off. When the transistor is off (Q1-open), the LED is supplied with this combined capacitor and inductor voltage, before this switching cycle repeats itself. This transistor switching operation is carried out by a signal generator labelled as Vsw in Figure 1. The combined output voltage is higher than the input voltage and it supplies the proper current for LED operation.

The MOSFET duty cycle is controlled and set at D=0.5 (50% pulse on-50% pulse off) which increases the input supply voltage. This results in an LED output current between 4-12 mA for particular experiments. The calculated LED forward voltage along with the corresponding LED operating current provide a stable response. Two main DC-DC boost converter circuits form the basis of the experiments. One open-loop boost converter with a resistive load, and one LED boost driver. The circuit in Figure 1 shows the experimental configuration of the LED boost driver.

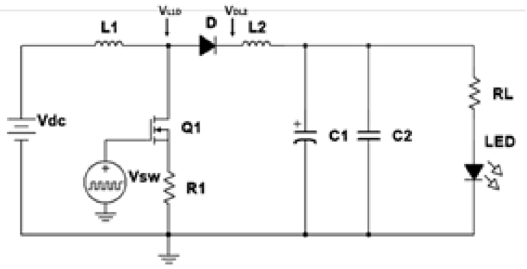

Figure 1 LED boost driver experimental circuit schematic.

There are certain nonlinear characteristics which influence the diode's operation within the LED driver circuit. The resonant frequency which relates the diode's reverse-recovery time, and the resonant frequency which relates the parasitic capacitance and the inductance of the circuit. As a result, two inherent resonant frequencies emerge from these nonlinear characteristics, $f_{\tau RR}$ and f_{LD}. When these resonant frequencies are synchronised with the switching frequency of the Q1 transistor, chaos occurs at multiples and sub-multiples of these resonant frequencies. Our research method examines specific voltages on the LED driver and observes the dynamics of their waveforms. This theoretical analysis follows an iteration sample procedure which detects the periodicity of the waveform peaks. If the peaks repeat at the same amplitude and shape periodically, then the system is in a stable and linear state. If the peaks show period doubling, the waveform peaks appear twice, before the waveforms' period starts again. If the peaks do not show a regular periodic pattern, chaos is observed in the system. Two voltage variables have been selected, the MOSFET drain voltage VL1D and the diode voltage VDL2. The suggested peak analysis method involves an iteration algorithm for the two voltages as shown below

$V_{L1D,(n+1)T} = f(V_{L1D,nT})$ (1)
$V_{DL2,(n+1)T} = f(V_{DL2,nT})$ (2)

where T is the switching period and n is the iteration number (n =1, 2, … k), which is an independent variable.

It is from this peak analysis that the dynamics and the periodicity of each waveform can be further processed, in order to observe the periodic and the non-periodic regions of the circuit.

2. Illuminance Results

The main experiment of this paper involves the variation of the switching frequency of the LED driver's transistor in order to explore the circuit's dynamics. The resistive boost converter was utilised as the initial experimental circuit, in order to perform this switching frequency variation procedure. Subsequently, the same experiments were applied in the LED boost driver circuit in order to explore the inherent dynamics. Table 1 shows the circuit configuration for the LED boost driver.

Table 1 LED boost driver circuit configuration.

Resistors	$R_L = 10\ \Omega$ (2W) (Load) $R_1 = 1.2\ \Omega$ (Q1-MOSFET source)
Inductors	$L_1 = 4.48$ mH, $L_2 = 470\ \mu$H
Boost diodes Circuit - 1 (diode D_5) Circuit - 2 (diode D_2)	D_5 = type 1N4007 ($C_j = 10$ pF, $\tau_{RR} = 5\ \mu$s) D_2 = type BYG20J ($C_j = 25$ pF, $\tau_{RR} = 75$ ns)
Output capacitor	$C = 10\ \mu$F (C_1//C_2)
DC Voltage source amplitude	$V_{dc} = 1.7$ V
Frequency of pulsed voltage source	$f_{sw} = 1$ kHz to 1 MHz

Circuit - 1: Boost diode-1N4007 (slow-response): A stable periodic behaviour at 50 kHz was recorded, along with relatively high brightness levels (230 lx, Figures. 2-3). At much lower switching frequencies the LED illuminance peaks at 460 lx. With the same diode, a chaotic response has been observed at 80 and 200 kHz (Figures. 4-5). The illuminance levels drop considerably at these frequencies, due to the high nonlinearity of the system.


Figure 2 (Left) LED Driver period-1 response,50 kHz, Time-domain waveform

Figure 3 (Right) LED Driver period-1 response,50 kHz, Phase space plot

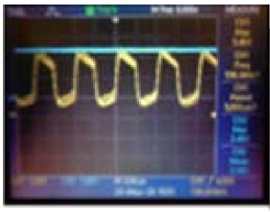


Figure 4 (Left) LED Driver chaotic response,200 kHz, Time-domain waveform

Figure 5 (Right) LED Driver chaotic response,200 kHz, Phase space plot

The illuminance data has been collected and further processed in order to plot it against the switching frequency. The illuminance graph for the 1N4007 diode is shown in Figure 6.

Circuit - 2: Boost diode-BYG20J (fast-response): With the ultra-fast diode, larger areas of linear behaviour have been observed, as this diode's reverse recovery time is considerably faster than the 1N4007 diode. A very high illuminance was recorded in the periodic regions reaching a maximum of 1353 lx, whilst the illuminance falls to just 17 lx in the chaotic attractor regions (Figure 7). The proposed research method predicts these nonlinear resonant frequencies where chaos dominates the system.

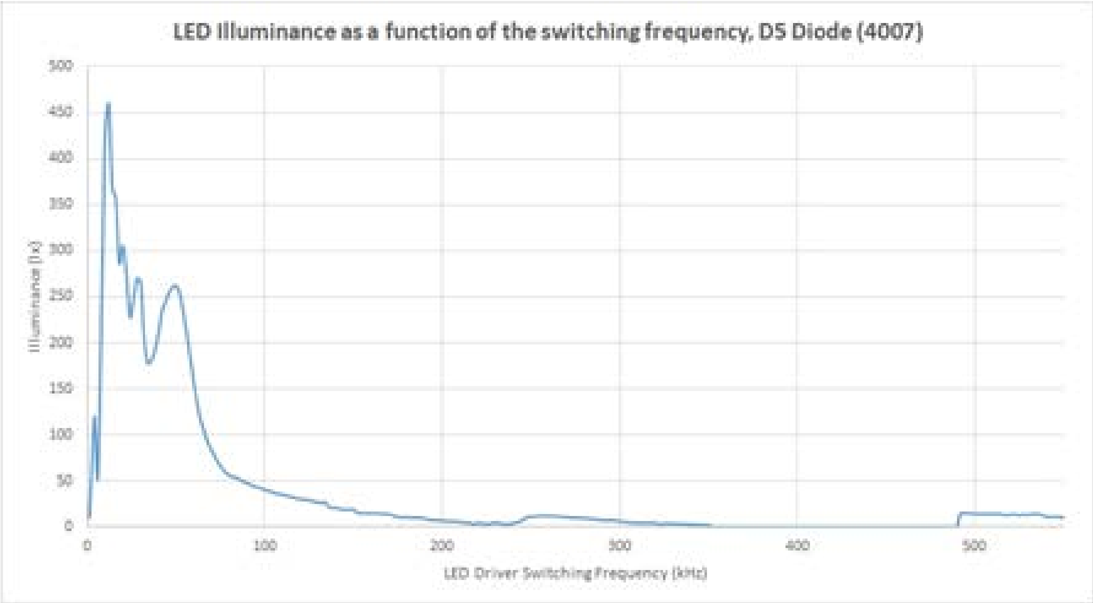

Figure 6 LED Driver chaotic response,200 kHz, Phase space plot

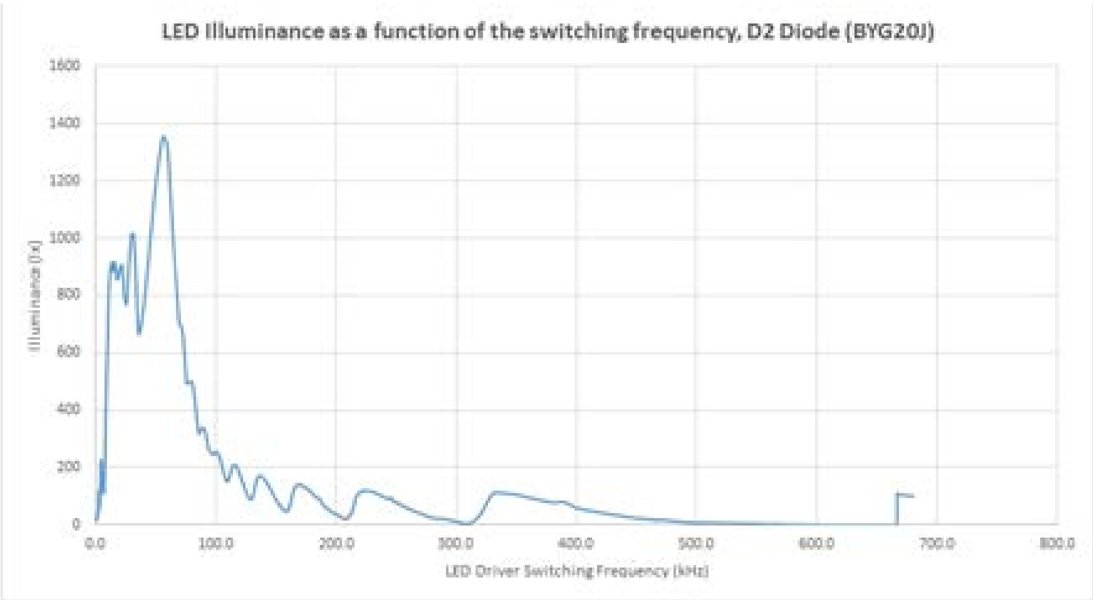

Figure 7 Illuminance as a function of the frequency (fast-response diode) MOSFET switching.

The fast diode exhibits more illuminance peaks at higher frequencies, where the slow diode was going through a very unstable region. Still, chaos has been observed at certain frequencies at the lower peaks of the graph, e.g. at 80, 130 or 200 kHz.

Conclusion

Two nonlinear resonant frequencies of an LED driver circuit have been detected, which influence harmfully its performance. This behaviour manifests itself only in the power section of the boost driver, and unlike previous literature, chaos occurs without a feedback loop. The synchronisation of these resonant frequencies with the transistor switching frequency, steers the LED converter towards chaos. Negative effects include a significant degradation in illuminance performance, especially at the chaotic regions. The suggested nonlinear analysis includes a bifurcation peak-to-peak method, in order to guide the interested researcher to avoid such unstable regions. A number of research suggestions for further steps of this work can be considered. In this context, the resonant response of even faster diodes can be investigated. The interested reader can also explore the low-frequency chaos that has been found in such fast diodes. Finally, some abrupt transitions to chaos that have been recorded at specific frequencies, could be investigated as forms of interior crisis within this nonlinear system.

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EXTERIOR LIGHTING AND COLLECTIVE MEMORY: THE CASE OF COASTAL AREAS

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Keywords: exterior public lighting, collective memory, sea-side lighting, highlighting city's boundary, lighting concept, local history

Introduction

This research studies the relation between the exterior lighting and collective memory in the coastal areas of a city. Coastal areas are considered one of the most historical places in a waterfront city that carry on the traditions and the local myths over the centuries. At the same time, they consist the border of the city where land meets the water and for this reason the design of the landscape is highly important. Lighting is one of the most significant factors on the final exterior image during nighttime and often the lighting concept is linked with the local history that forms the collective memory of the people.

The purpose of this study is to investigate possible lighting techniques for seaside areas that highlight the collective memory of the people.

Methodology

The theory of the research is based on the analysis of the collective memory as an integral part of the urban architecture. Especially in the coastal historic parts of the city, the design concept can derive from local myths and tradition. Also, we studied the special characteristics and specifications of the lighting design in a marine environment taking into account the maintenance, the light pollution and the requirements for the lighting levels.

The research of sea-side lighting was approached by studying different case studies all over the world, analyzing the concept and the lighting techniques according to the landscape, the design priorities and the contribution of the local collective memory. After creating a data base which includes lighting techniques that one meets in coastal landscapes, we propose a specific lighting intervention based on the local collective memory in an interesting sea-side area in the city of Volos, Greece.

Collective memory and design

Collective memory refers to how a social group remembers the past, sharing the same pool of memories, knowledge and information that is associated with its identity. Its role is to preserve the history but also has a constantly changing and updated meaning so as to provide an interpretive reapproach of an event that took place in a specific area (Halbwachs[1], 1925). Historical elements that contribute to the reconstruction of the memory are its urban myths, its informal stories and its monuments. According to Aldo Rossi who considered the city as the "locus" of the collective memory, we could say that collective memory becomes an integral factor of urban design when it comes to old parts of the city such as the coastal areas (Rossi,1978)[2]. Historical, geographical, social and cultural factors shape the collective memory and the

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[1] Maurice Halbwachs, "On collective memory" , Chicago, The University of Chicago Press, 1992 και Les cadres sociaux de la mémoire (Paris PUF, 1925). Accessed March 20, 2020
https://en.wikipedia.org/wiki/Collective_memory
https://www.scientificamerican.com/article/the-power-of-collective-memory/

[2] Aldo Rossi, " L' architettura della citta ", Milano, May 1978, Accessed on April 10, 2020
https://www.academia.edu/RegisterToDownload#BulkDownload

identity of a place and form the aesthetical approach of the local society (Nora, 1989)[3]. This fact often inspires designers to create a successful atmosphere in popular landmarks such as gathering places, historical routes and monumental places. Collective memory can become a design tool that gives a familiar character to a location, recalling experiences, memories and pleasant feelings.

Sea side lighting

The seaside places of a waterfront city bring together activities like entertainment, recreation and relaxation since they are open-air areas with a nice sea view. The landscape design is always interesting including long promenades, ramps and benches designed in different levels and along the coastline. This fact gives lighting an important role not only to create a pleasant and safe environment but also to highlight the architectural elements upgrading the image of the area during the night. Compliance with the Lighting Standards for exterior spaces ensures the necessary lighting levels in the ground, the vertical hemi-spherical illumination and the uniformity establishing the feeling of security, a good orientation and easy way finding. The marine environment requires high standards for the specifications of the lighting equipment for maintenance reasons. The protection of the biodiversity of this area is in high priority and is achieved by avoiding the direct lighting in the vegetation and the water, using warm lighting temperature and installing a control system that sets the minimum lighting levels during the night. Taking into account all the above restrictions and guidelines, we have collected all the possible lighting techniques that could be applied in a waterfront project. The various lighting methods have been categorized according to the type of application such as routes, seating areas, stairs, vertical surfaces. The aesthetical result of each technique was analyzed and linked with possible meanings and feelings deriving from the processing of the collective memory.

[3] Pier Nora, " Les Lieux de Mémoire ", The University of California Press, Spring 1989, Accessed on April 12, 2020, https://forward.com/culture/138461/building-a-collective-consciousness-on-a-national

Case studies

A strong concept was developed for the lighting scheme of the Pier in the city of Bournemouth by Michael Grubb Studio. The concept derives from the story of a Princess who visited the city back in the 19th century and used to place candles making a lit route through the gardens towards the sea. The result of the project was to achieve an all-encompassing lit experience that provides a range of lighting scenes. The collective memory plays a major part in this lighting project since a local myth becomes the concept of this waterfront area.

Experimental case Study

Based on the methodology described above, a lighting concept was proposed for the coastal area of Anavros, in the city of Volos, Greece. The story dates back to 1955 when a big earthquake that took place in the area changed the seaside landscape influencing the local collective memory. In accordance with the results of a possible "lighting earthquake", the proposal illuminates emerging landscape symbolizing elements of the past. The lighting techniques used on the path, the various seating areas, the exterior statues, the vegetation and the water are linked with different parts of the local history and tradition. The visitors have the opportunity to recall memories or be informed through a theatrical experience enjoying at the same time the sea view in an interesting lit environment.

Conclusions

The collective memory is formed not only through the official recording of history but also through the everyday images of the city. The lighting design plays a major role in the collective memory of a city, since it can contribute to the protection of the cultural heritage. This study relates the value of the collective memory in the urban design through the lighting intervention in a seaside area. Using specific techniques lighting becomes a design tool that highlights the tradition and also transforms an important part of the waterfront city into an attractive area.

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LIGHT QUALITIES OF ANCIENT GREECE: A CONTEMPORARY APPROACH FOR THE LIGHTING DESIGN OF ARCHAEOLOGICAL & CULTURAL HERITAGE

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Keywords: light qualities, contemporary systems, antiquity, cultural heritage, Ancient Greece

Introduction

While science and technology have equipped humans with various lighting systems, countless applications and capabilities, the role and substance of light have been altered in human perception. The notion of light is intertwined with artificial light, which is one of the most supportive, to contemporary lifestyle, technological achievements and an inextricable component of human living, well-being and culture. Light is functional, an architectural tool, an implement for artistic creation and always outcome of human work. Man, not only has conquered artificial light in quality variety and power, but has developed low energy LED technology, upgrading lighting industry to eco-friendly and viable. Man, as long as light is concerned, is considered a “little god”, with all these magic, low cost and energy saving lamps in his hands, and has the “power” to change the scenery following his mood, the trends, spreading light all over or blocking up the sun. Designing lighting for archaeological and heritage environments “seems “to be an easy task, often by brightening every dark corner of the area or by integrating to former lighting frames available recent technologies to achieve innovative solutions. Sometimes, current lighting projects aim only to gain a leading role next to the antiquities that they are supposed to promote. This leads to the unfortunate conclusion that new technologies and techniques cannot ensure a successful lighting result. In the case of archaeological and cultural heritage applications, lighting design approaches and plans must be set from a different view. Archaeological sites and monuments were constructed thousand years ago by societies where light was granted with different values of aesthetical and ideological features. Could the light qualities of their time help us find a more thorough approach for heritage applications? Could a journey in time, back to ancient years, enlighten us as to which features are fundamental and may have been lost in the passing of time and maybe should be rediscovered. A study of the qualities that were given to light at ancient times, with a focus on the geographical region
of Ancient Greece, as a quest of how these qualities can form a new design approach to enrich contemporary lighting approaches in archaeological and heritage environments, will be followed. To practically demonstrate the above theory, a new lighting system proposal for the Macedonian Tomb III, at Agios Athanasios of Thessaloniki, based on this design approach, will be attempted and presented.

1. Methods

The study begins from modern times, outlining the qualities of light, mostly as an outcome of human science and technology achievements and spotting contemporary artificial lighting application weaknesses in archaeological and heritage environments. The study of light in ancient years, will follow, outlining its divine origin and various qualities. The qualities of light of both times will be compared. Identifying ancient light qualities and comparing them to the light qualities of contemporary era can result in a creative blend of design aspirations that can be fulfilled by a more thorough lighting design process. “Grafting” ancient qualities into modern lighting practices could confine the defects and at the same time enrich and improve the design process. A theoretical design procedure that could be followed in lighting applications of archaeological interest, as well as in all lighting applications, will be suggested. Methodologies supported by recent technologies that should be used systematically for lighting up archaeological and heritages spaces and buildings will be indicated.

2. Findings & Argument

Broad knowledge in optics and light science sets the photometric principles for effective lighting systems. Great progress in lighting technology offers the means for the implementation of complicated and more sophisticated lighting design projects. Artificial light is available, accessible and affordable. Multiple technologies offer a variety of choice, regarding white color temperature, different colors, light distribution, and the capability of combining all these attributes via lighting management systems.

On the other hand, design practices that aim simply to space illumination, as a mean of “extinguishing” the darkness and making everything visible to human eye, or practices that focus on aesthetic aspects of the lighting installation, can only lead to poor and unbalanced solutions, especially in the case of cultural heritage applications, where essence and symbolisms should be revealed through light. Technologies by themselves cannot ensure a successful lighting result. Well balanced practices can set the guidelines for effective lighting solutions. And a substantial feature for a complete design process is the spiritual and ideological premises of the lighting solution. Other weaknesses detected in contemporary lighting systems, resulting from excessive use, are: biological impacts on humans and living beings, ecological effects on the surrounding area and energy waste. In ancient Greek culture, light was connected to rituals, mystery, symbolisms, as well as to natural world. It was considered God-inspired and at the same time it derived from nature. Sun, fire and light were closely connected to mythology, worship and symbolisms. Hesiod’s "Theogony" (Genealogy of Erebus, Nyx, Aether and Hemera), the myth of Prometheus (the theft of fire from the gods), the "Allegory of the Cave" in Plato’s work "Republic" (darkness and light symbolisms), the fire as a symbol in rituals of Ancient Greek mysticism (in Cabeiri mysteries flame symbolizes the purification of human soul), the orientation of Greek temple (in accordance to sun path in divinity’s celebration day), are only a few examples of the important essence of light, radiated by sun rays or flame illumination, to all cultural aspects of ancient Greek civilization. Light was coming from Gods, through elements of nature, bringing to people life, warmth, safety, knowledge, enlightenment, purity. As a result, ancient Greek qualities of light can be summed up as follows: (i) Divine origin, (ii) interpreter of spiritual essence and symbolisms, (iii) interplay state to darkness as its opposite element in the world, (iv) natural character as an element of nature. Modern lighting practices for archaeological and heritage environments could include Ancient Greek light qualities in a systematic design process by integrating into technical and morphological characteristics, as structure, material, pattern, shape, diffusion, color or operating profile, correlations to the "Divine" and to “natural world”. The divine and symbolic character of ancient light is related to human emotions and spiritual awareness. In contemporary applications this is interpreted as the given ambience, hidden symbolisms and meanings that refer to the illuminated area or object, that will be inspired by its history and use in time and are expressed by the lighting installation. This quality revealed and expressed by the lighting solution is related to human emotions and spiritual awareness of the visitor.

The antithetic connection of light and darkness can be deployed throughout the design process of setting light sources, choosing distribution flows and creating shadows. “Drawing” with light, color, shadow and darkness can result to more balanced, sharp and intriguing solutions.

Finally, the natural features of ancient light, coming out from fire and sun, can give to contemporary lighting systems a more naturalistic and a humancentric character, harmonized to nature and human circadian rhythm. Practices in this orientation include: (i) Management systems with variable photometric features (intensity and color temperature, e.g. tunable white tech.) according to time and geographical area, in an attempt to simulate sun's oddity to make non perceivable quality changes, (ii) Geometries inspired by natural elements and use of natural materials in construction, (iii) Incorporation of available natural light. Blending qualities from both time periods, a thorough practice can be proposed, serving lighting needs of vision and human spirit. Suggested steps of the design process could be: (1) Setting optical needs (photometry), (2) Deciding on the ambience, the symbolisms and the spiritual essence of the installation (based on history and use), (3) Giving natural features to the lighting system, (4) Designing the previously set requirements of visual comfort and ambient character with an interplay of light and darkness, adding color and shadow effects, (5) Choosing lighting equipment (luminaires, lamps, management). Contemporary lighting design for archaeological sites & monuments should be diachronic. Not formed by contemporary trends of lighting technology, or the architectural last decade aesthetics. Of course, latest lighting technology can support indeed sophisticated projects with: various white color temperature, effective light diffusion, UV-IR free radiation apparatus, low energy consumption installations.

3. Case study: Macedonian Tomb at Agios Athanasios

Tomb III at Agios Athanasios in Thessaloniki Greece was the grave of a prominent military of Ancient Greek Macedonia (~320BC). The lighting solution was "constructed" on visual comfort standards and inspired by spiritual essence and symbolisms of monument's history and use, as the utterly dark last residence of a man. The artificial light sources are adjusted on the steel and concrete structures of the outer protective building of the monument, mostly hidden from the visitor's sight, with their emerging flux in warm white CCTs. Linear luminaires for the outer area of the tomb with a light imitating flame and a mystical otherworldly light, and projectors featuring the exquisite frieze and painting on the tomb's façade.

4. Conclusions

The notion of light and the qualities given to light by human-beings throughout the centuries are related to its nature. At ancient times light, coming strictly from the sun and fire, obtained the attributes of magnificence and preciousness, the role of an important balancing factor in people's lives and morals. By making a comparison in light qualities of antiquity and modern times, we can identify the qualities that are missing from contemporary lighting systems or are partly present. There lies the real substance of light for living creatures. We tend to forget light's vital impact on our health and well-being, its fundamental participation in human vision, its many essences, its ability to bring magic, its alternating sequence with darkness which reveals its glory (emphasized by its absence). In other words, light was something greater than electric lamps for the ancient man, it was a gift given to mankind by god, by the universe, by the laws of Physics. Ancient qualities as: spiritual essence (as the basic component of the solution expressed by atmosphere and symbolisms), natural characteristics (harmonizing artificial light with human biology and environment), and a light – darkness interplay (bringing sharpness and intrigue to the scene) could become the trailhead and path for a holistic, well-balanced design process, that can lead to more creative and expressive solutions for archaeological & heritage applications. Applying our conclusions on the case study of Macedonian Tomb III, we hopefully accomplished a complete and intriguing lighting proposal, which serves both human senses and emotions and communicates symbolisms of human soul and consciousness.

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EMERGING FROM OBLIVION
ACCENT LIGHTING FOR THE CASTLE OF LEVADIA

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Keywords: Castle of Levadia city, accent lighting, urban landscape, oblivion, memory.

Introduction

Cities with historical monuments inherit a significant part of their historical value. Monuments add characteristics of great importance to the urban environment and influence people's daily lives and collective memory. Perceiving them as part of the city brings them to life, even if they are not used for their original purpose. Nevertheless, their presence is not sufficient in itself to make them stand out as much as they deserve. In many cases, their existence is undermined by abandonment and decay, by the intense presence of the city environment around them, and by their unsuitable use and presentation. As a consequence, the monuments are separated from the urban landscape around them and their cultural meaning is obscure. This disturbance causes temporal and spatial disorientation. The relationship between the citizens and the history of their city is disrupted, creating a sense of uncertainty and apprehension about the future. This also leaves the cultural diversity of the city and even historical events open to misinterpretation and undermining. The "loss" of monuments leads to unbalanced development and a "loss" of proper foundations. Avoidance of the above phenomenon can be achieved by redefining the urban landscape composition, including the monuments as active parts of it. Contemporary city life has extended urban activities until long after sunset; therefore, the night image of the city has a great impact on the citizen's perception of the urban landscape. The relationship between the monuments, the city and the citizens can be linked with a tool activated during night time: artificial lighting. Illuminating the monuments at night can play this binding role provided that it is not considered an isolated project, but instead, an integral part the city. Artificial lighting can enhance the values of monuments and at the same time it completely modifies the way the urban landscape is perceived. With light, elements of the forgotten past of the city can be restored and the collective oblivion can be reversed.

Aim and methodology

The main aim of this study is to explore the significance of perceiving monuments as part of the city to which they belong. This is achieved through qualitative and quantitative research methods, bibliographic documentation as well as collecting and documenting general opinions, assessments and perceptions. A further objective is to consider the possibilities offered by artificial architectural lighting in order to enhance monuments properly. In this case, the research method is mixed, applying in-depth observation and case study analysis in order to ensure that the information is correctly understood and to define the necessary parameters. The case study allows us to document the decisive role played by the artificial accent lighting of an urban monument.

Implementation - Case study

The Castle of Levadia, an exceptional fortification work of 35.000 acres, is the main subject of this case study. Levadia is a city located in a fertile plane at the foot of the mountain "Helicon" in central Greece: a strategic point for controlling a large part of the country's interior. The castle is situated in the most historical part of the city. The surrounding terrain, the springs of Lethe and Mnemosyne (oblivion and memory), feed the lifebringing river and the influence of this work on the historical-urban development of the city. They are the principal features inextricably linking the monument to the history and shape of the urban landscape. It is the largest and most significant monument in the greater region. Although it is a monument of impressive size and great historical significance, due to its abandonment it is currently invisible to both citizens and visitors of the modern city. Over the last century the castle has been left to decay, leading to a significant depreciation of its role. Nowadays, it is barely noticeable during the daytime due to the dense vegetation surrounding it, nor at night due to inadequate lighting (Figs.1-2). The local inhabitants underrate its importance, while visitors cannot perceive its presence and so do not visit it. The castle has been consigned to oblivion and its relationship to the city has been disrupted.

Figure 1 The Castle of Levadia in 1909. After y Liuch 1991.

Figure 2 Photo of Levadias Castle today (Angelis 2020).

This study is an attempt to analyse the value of this monument as an integral part of the city and to highlight it by using artificial lighting. A developed modern city has a duty to confront oblivion with the collective memory of its historic and cultural heritage. To that end, the relationship between the historical castle and the city must be re-established. The intention of this initiative is not to separate the monument from the city, but, on the contrary, to reintegrate it and lay the basis for a new form of relationship in which monuments such as the Castle of Levadia interact with the urban landscape. The main objectives are to highlight the architecture of the monument and the surrounding terrain with specific, careful interventions, with low-cost energy solutions, which will protect the monument and the urban landscape. In light of the above evidence, an accent lighting implementation study has been undertaken based on the in-depth analysis of the artificial lighting parameters and the data and historical information on the monument and its city. Experimental models have been used to achieve the objectives of this project. (Figs.3,4,5). The monument has been surveyed using in situ observations and measurements as well as the results of previous studies. For each section of the project, photometric calculations were performed. A series of plans for the location of the lighting media was prepared, as well as tables that summarize their characteristics, taking into account the individual particularities were created.

Figure 3 Drawing of a part of the monuments showing the intended lighting (Angelis 2020).

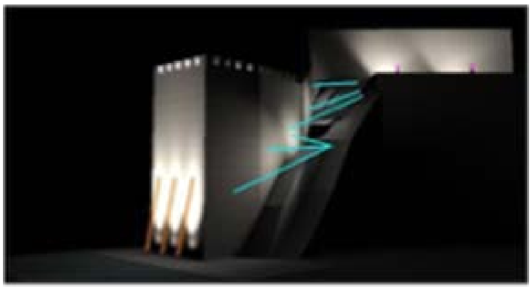

Figure 4 Experimental model of the application of the accent lighting in the section of the North east part of the monument (Angelis 2020).

Figure 5 Drawing of the North view of the castle after the implementation of the proposal (Angelis 2020).

The study was organized on the basis of a strategic plan with clear choices. Among them are the protection of the natural and urban environment, the distinctness of the architectural units of the monument along with conveying the monument's significance, as well as the potential access, the avoidance of glare and light pollution.

The above characterize almost all the proposals for monument lighting. What makes this proposal different, however, lies in the effort undertaken to illuminate the monument as a live, integral part of the city. In order to achieve the purpose of reconstructing the urban landscape, the monument was not intended to be lit as a solitary protagonist of a theatrical "scenery" but as a functional part of the city.

As such, it had to be viewed from the central parts of the city and from selected neighbourhoods.

Discussion of the Results

As a result, processed images of the intended urban landscape, from main points of view were created. The images include the monument in its urban context in order to highlight the significant change on the landscape with the application of lighting. The results of this study demonstrate that the urban landscape can be restored. The images and plans included in this study highlight the fact that artificial lighting is capable of restoring the memory that is the monument's due while transforming the visual perception of the city. The castle can now be present at night among the other activities of the city: an inseparable part of citizens' lives. With the proper lighting, it can be converted into an important landmark and reference point, making it not only a visual enhancement but also a contemporary landmark for orientation. Highlighting its presence at night means that people can feel safer and become increasingly familiar with the urban space and cultural heritage around them. The severed relationship between the city and the forgotten monument can be restored by lighting the castle properly (Figs.6,7,8).

Conclusion

Artificial lighting has a great deal to offer as evidenced by the study and consideration of the accent lighting of an historical monument. It is a vital tool for highlighting and enhancing the monument, rendering it visible to visitors and allowing the inhabitants to preserve the visual sense of the city even by night. Furthermore, artificial lighting is demonstrated to be a "force" capable of regenerating collective memory. Light can not only illuminate in the darkness but also shed light on forgotten elements of the past. The observer of the lit monument can gain knowledge and absorb cultural elements of the past, fitting in the missing pieces of the puzzle. At the same time, this study proves the point that an intervention using artificial accent lighting can add to the city's dynamism. It can be integrated into the wider urban environment without altering the quality of everyday life. It also respects the natural environment and shows that major engineering works with a light environmental footprint are possible. Finally, the study of the artificial lighting possibilities of a major urban monument stressed the imperative need for an efficient and integrated planning proposal for the night-time view, in order to ensure the preservation of urban landscape values. The attempt to highlight this important part of the city raises the issue of an integrated proposal using lighting development master plans.

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Figure 6&7 Photographs of the current view of the city. Day and night. (Angelis 2020).

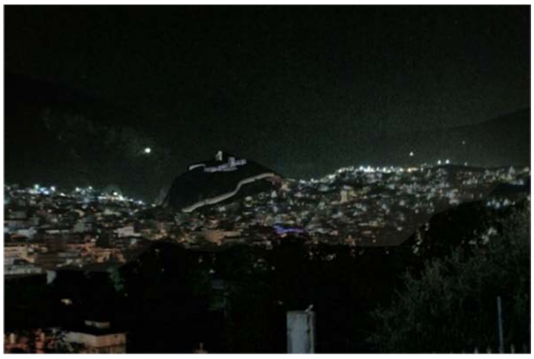

Figure 8 Edited image with the expected results, after the implementation of the accent lighting (Angelis 2020).

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LIGHTS 2020

FACADE LIGHTING OF HISTORIC BUILDINGS CONCERNING THE CONSEQUENCES ON LIGHT POLLUTION

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Keywords: Exterior lighting, façade lighting, historic buildings, light pollution

Introduction

The phenomenon of light pollution causes various effects and changes to natural environment and people (Falchi & Cinzano & Elvidge & Keith & Haim, 2011) (Gaston & Duffy & Gaston & Bennie & Davies, 2014). The increasing interest in light pollution requires methods of calculating its levels and consequences (Lyytimäki, 2015), as long as with an institutional framework related to ways of facing it (Zielinska-Dablowska, Xavia, 2019). The objective of this presentation is the study of lighting the facades of historic buildings having as an orientation the reduction of dire effects on environment and people (Rumanova & Okuliarova & Zeman, 2020) (Gallaway & Olsen & Mitchell, 2019) (European Commission, 2019). The aim of this research is to: a) investigate appropriate lighting techniques of historic buildings' facades by studying and estimating the possible levels of light loss to areas such as the atmosphere, b) draw conclusions regarding how the levels of light pollution depend on the application of different lighting techniques and the use of different types of lighting fixtures. Lighting is an important way of underlining characteristics (such as beauty and identity) of historic buildings which are part of our cultural heritage (Tural & Yener, 2015). Scientists have outlined the effects of light pollution on the environment and people (Schroer & Hölker, 2016), and therefore the lighting designer has to apply efficient lighting design proposals that are environmentally and human friendly according to building's architecture.

Methodology

The methodology comprises the following steps:
Step 1: The first step is related to the study of relevant examples of architectural lighting of historic buildings. Photographs of preserved buildings illuminated at night in Belgrade were taken and other illuminated historic buildings have been considered as well. Then, indicative examples are selected and lighting techniques of the considered type of buildings have been analyzed. Based on these examples, conclusions are drawn regarding the most common ways of lighting preserved buildings.

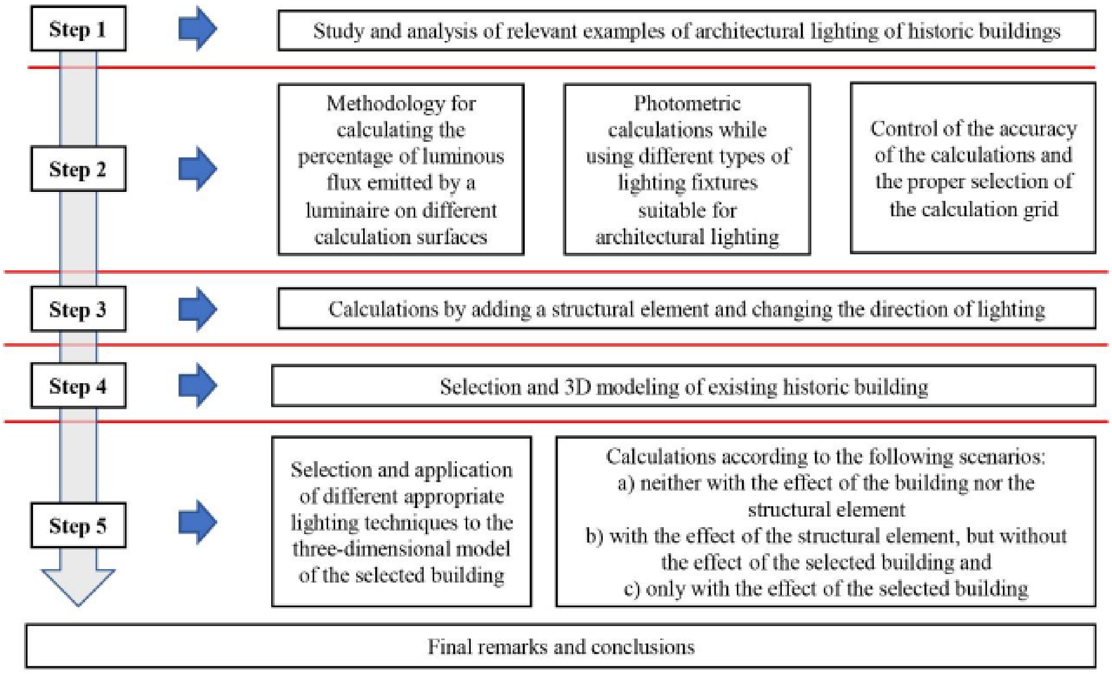

Figure 1 Methodology diagram

Step 2: In order to proceed with analysis and calculations, a cube which consists of calculation surfaces has been developed in Relux software. Photometric calculations are performed by using different types of lighting fixtures suitable for architectural lighting of facades which have been placed in the cube. A methodology for calculating the percentage of luminous flux emitted by each luminaire on each surface is proposed. The accuracy of the calculations is checked by calculating the percentage error. Each calculation surface consists of a number of points that form a grid. Calculations have been performed while changing the density of the grid. The appropriate grid density of the calculation surfaces is then selected in order to achieve higher accuracy of the calculation results.

Step 3: Further calculations have been performed by using a structural element and changing the direction of the luminaires.

Step 4: A specific existing preserved building is selected and different lighting methods have been considered in order to be applied on its three-dimensional model which was developed. Moreover, its morphology and its special characteristics have been assessed.

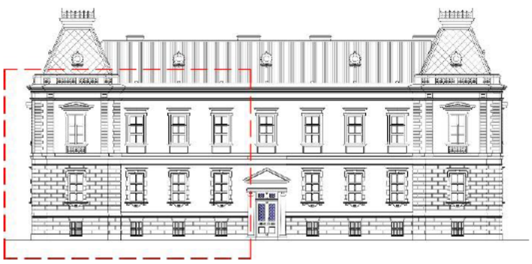

Figure 2 Selection of part of historic building's façade for the application of different lighting scenarios

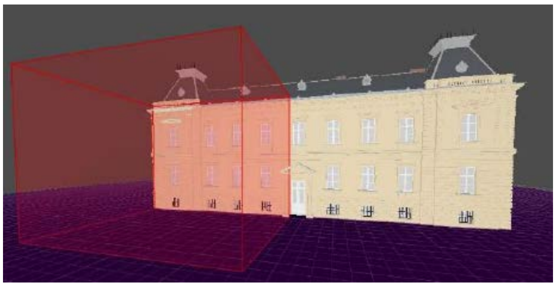

Figure 3 Adjustment of the cube (which consists of calculation surfaces) to the selected part of the building's façade

Step 5: Different appropriate lighting techniques have been selected and applied to the three-dimensional model for the selected building. For each lighting proposal photometric calculations are demonstrated according to the following scenarios: a) neither with the effect of the building nor the structural element, b) with the effect of the structural element, but without the effect of the selected building and c) only with the effect of the selected building. The aim is to calculate the light pollution levels in each case and to compare the different proposals based on the obtained results. Finally, remarks are noted and the conclusions are developed.

Findings and Conclusions

Based on the implementation of scenarios with different lighting techniques in a three-dimensional model created for an existing building, the percentages of light emitted in areas outside the building have been calculated. These results contributed to calculating the percentages of light pollution. It can be observed that by using different types of luminaires, it is necessary to use a dense grid of calculation points in order to accomplish better accuracy of the calculations. The relation between the density of the grid and the accuracy of the results has been evident. It can be concluded that the density and the deviations are disproportionate. Furthermore, it has been also found that the narrower the beam of the luminaire is, the greater the deviation of the photometric calculations are.

Factors such as the type of luminaire, the luminaire's beam angle and distribution, direction, their placement and their targeting significantly affect the final percentage of light pollution. The different calculations show the effect of reflections on light pollution rates and how the combination of proper placement and targeting can lead to lower light pollution levels, by considering the architectural structure of the building facade and the way in which the emitted light is reflected. It can be observed that the luminaires with asymmetric beam targeted on the facade and the wall washer type of luminaires cause lower levels of light pollution than the luminaires with symmetrical and wide lighting beam.

Through this research it can be noticed that the use of modern tools such as photometric calculation programs before the implementation of a lighting design proposal is of great importance. These tools do not limit the design of a lighting proposal but it is necessary to pay close attention to the specifications of the used luminaires. Nowadays, with the help of technology lighting methods can be selected in a way to offer an aesthetic result which at the same time does not have negative effects such as the phenomenon of light pollution and high energy consumption.

In addition, in order to achieve proper lighting design of historic buildings, the importance of

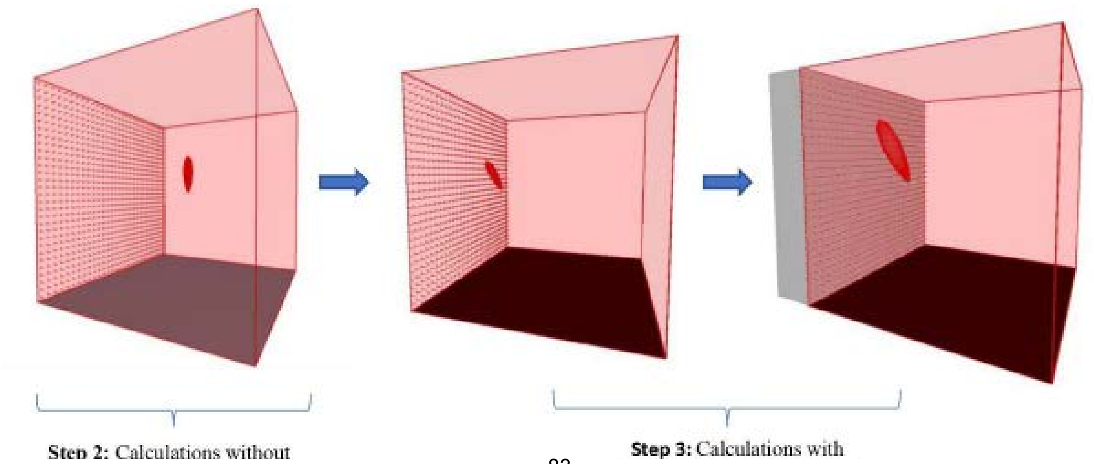

Figure 4 Testing of the proposed method by changing the direction of lighting and adding a structural element

the relevant regulations and specifications is emphasized (CIE 150, 2017) (EN12464-2, 2014) (ANSI/ASHRAE/IES Standard 90.1.2019), which offer guidance regarding the lighting limits of the facades in order to avoid negative impacts on environment and people. Additional attention has been given to the sector of street lighting in terms of reducing light pollution. However, it is necessary to take measures in order to limit the phenomenon in terms of lighting the facades. This part of lighting can be further researched by scientists and lighting designers. It is important to provide information and raise awareness not only to professionals and but also to the general public about light pollution (Hänel & Doulos & Schroer & Gălăţanu & Topalis, 2016) (Balafoutis & Zerefos, 2015) and the adoption and implementation of relevant measures and regulations.

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PLANNING AN INTERNATIONAL DARK-SKY PLACE IN AENOS NATIONAL PARK: THE FIRST STEPS

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Keywords: exterior lighting, dark sky parks, dark sky, light pollution

Introduction

The use of artificial lighting in the built environment can affect not only the visual perception and wellbeing of humans but also the environment. Light pollution is a type of pollution that climaxes in the cities, but occurs increasingly away from them, due to the increase of artificial lighting but also due to malpractices and improper lighting design. Lighting malpractices may involve inappropriate selection of luminaires, aiming or placement, excessive illumination levels but also unwanted spectral characteristics of the emitted light. Furthermore, the lack of lighting design and energy consumption restrictions for areas in the exterior of buildings, such as building façades, and sports and recreation areas has led to an increase in the use of lighting installations. Increasingly, light pollution also affects the countryside due to local lighting but also distant lighting propagating from urban areas. This has significant impact to ecosystems and astronomical observing sites which is a relatively unknown fact to most people. In order to protect sites of significant ecosystems, natural beauty or astronomical interest, it is important that light pollution reduction is included in the top priorities of national parks, protected ecosystem areas and astronomical observatories as well as public policy and ordinances. This work studies a) the first steps of methods, parameters and special requirements for the planning of a light pollution protected area in the form of an International Dark-Sky Park in Aenos National Park at the island of Kefalonia and b) the early results from identifying the luminaire types of the adjusted villages.

1. About the National Park

The National Park of Mt. Aenos consist of an area of 2,862 ha, which expands at the mountain Aenos and at the adjacent mountain Roudi (Fig. 1). Its main feature is its Cephalonian Fir forest (Abies cephalonica), which is unique in the Ionian islands and constitutes the reason for the foundation of the National Park in 1962. Mt. Aenos with alt. of 1,628 m is the highest mountain in the Ionian Islands, whereas Mt. Roudi reaches an alt. of 1,125 m. In recognition of its significance at the European level, the National Park it has been designated as a European Biogenetic Reserve, belongs to the "Natura 2000" European Ecological Network of Protected Areas (GR2220002) and is a Special

Protected Area for the protection of avifauna (GR2220006) It has also been declared as a Wildlife Reserve. The Management Body was established in 2002. Its purpose is to manage, protect and promote Mt. Aenos National Park. From the area of National Park there have been recorded more than 400 plant species. The largest part is dominated by the forest of Abies cephalonica (Cephalonian Fir), which is Greek endemic species. More than 100 bird species have been recorded in the national Park. A herd of semi-wild horses lives freely in the northerneast part of the mountain.

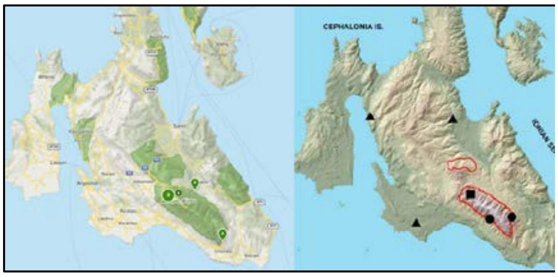


Figure 1 Kefalonia island and the main core of National Park of Mt. Aenos.

2. International Dark-Sky Parks

The most prominent international effort to counteract light pollution is the one conducted by the International Dark-Sky Association. Since its establishment in 1988, IDA has led the effort around the world to promote light pollution awareness, lighting ordinances and specific area protection. IDA has a number of chapters around the world, including a Greek chapter. One of the most prominent efforts of IDA has been the international Dark-Sky Places program. This program recognizes protected areas as Dark-Sky Places based on criteria such as their importance for astronomy or the ecosystems, their outreach programs and activities. The international Dark-Sky Places program was founded in 2001 and as of September 2020 there are over 130 certified places globally. In order to be designated as an International Dark Sky Place of any type, a strict application process is required. In this process, applicants need to demonstrate strong support by the community and also provide all necessary documents that prove that the candidate area fulfils the program requirements. Also, in particular for an area to be declared as an International Dark Sky Park, an existing protection designation must already exist, for example natural protected site, cultural protected site or astronomical protected site.

3. Methods

Figure 2 presents the basic steps of the methodology that can be followed in order to plan the International Dark-Sky Place in Aenos National Park, namely:

- Lighting inventory survey
- Intensity and Spectrum characteristics
- Light pollution assessment

Sky brightness measurements assist in recording the intensity of skyglow in an area. This is important to assess the importance of the area as a site, its risk as well as monitor skyglow progress either increasing or decreasing. There are many methods to record sky brightness including visual, photographic and instrumental. While visual methods, such as the Naked Eye Limiting Magnitude measurement, can be very accurate if executed correctly, they tend to vary widely depending on observer experience, age and effort. The de facto standard device for measuring sky brightness is the Sky Quality Meter (SQM) developed by Unihedron and endorsed by the International Dark Sky association.

Creating a lighting inventory consists of surveying existing outdoor light fixtures in the nearby area. This includes outdoor fixture location, design, light source type, intensity and spectrum.

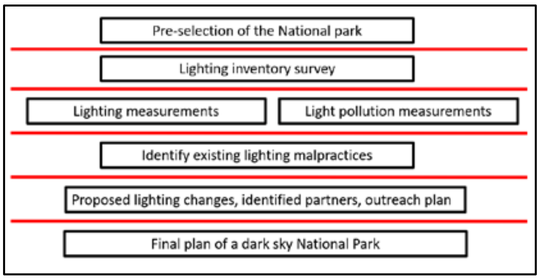


Figure 2 Basic steps for planning the International Dark-Sky Place in Aenos National Park.

4. Early Results

In order for SQM measurements to be taken, the instrument was fixed to a tripod containing a bubble level, so it can point to zenith when fixed perpendicularly. Each time three successive measurements of the same area were averaged and rounded to nearest 0.05. The zenithal measurement of the astronomical site in Aenos National Park averaged at 21.35 visual magnitudes per square arc second, peaking at 21.45 under favorable conditions with lowest readings of 21.25 under busier summer periods. This makes all measurements better than the required minimum of 21.20.

Lighting inventory in the nearby area consists mainly of old, unshielded or semi-shielded luminaires either in their original form using older technology lamps (High Pressure Mercury, HPM lamps) or retro-fitted with LED or Compact Fluorescent Lamps (CFL) light lamps. In the main area of the City of Argostoli, and more specific in the main plaza of the city, new LED luminaires were installed (Table 1).

Several malpractices were identified (Figs. 3 and 4):

- Luminaire installation with large inclinations, even in the streets with the newly installed LED luminaires.
- Oversized and over illuminated areas (Main plaza in Argostoli with LED luminaires, Main plaza in Poros with illuminance values ranging from 45lx to 411lx, while the proper lighting levels must not excide 20lx)
- Over illuminating facades at the main buildings of the Argostoli (Alpha Bank).
- Reach in blue content of the luminous sources of most of the 50% of the existing luminaires (Table 2)

Table 1. Some of the existing types of luminaires in the adjusted areas from the Aenos National Park.

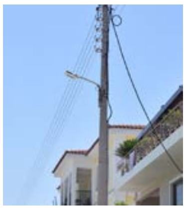
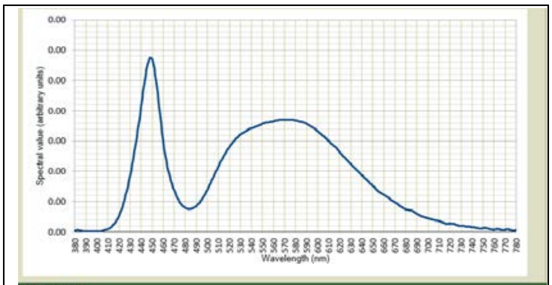
Type of luminaire	Photo of luminaire	Area located
High Pressure Mercury		City of Argostoli, Nearby large villages
Compact Fluorescent Lamp		City of Argostoli, Nearby small villages
New LED luminaires		City of Argostoli

Figure 3 Self-Limitation (black painted luminaires) of the obtrusive light from the users of the building.

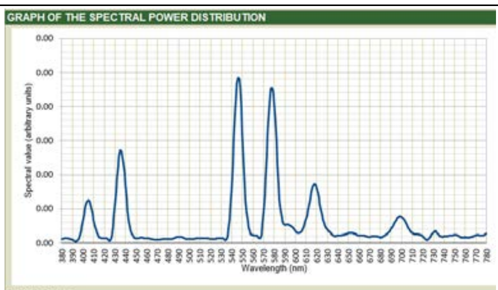
Figure 4 Awareness of the proper selection of the emitted spectrum of the light source. Three different type of lamps used in the main plaza of Poros.

Table 2. Spectrums of the typical luminaires that were identified in the adjusted areas.



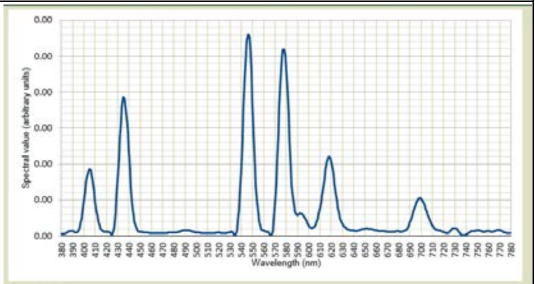
INPUT DATA			
Spectral range (nm)	Wavelength interval covered by the input data	380	780
Spectrum	Number of input data points	401	
Step (nm)	Wavelength difference among consecutive input data	1	
ORIENTATIVE CHARACTERIZATION OF THE SPECTRUM			
G	Estimated spectral index G	0.6	
Q	% (L500,V), blue radiance (below 500 nm) divided	58.00%	
Δλ	Spectrum equivalent width	120.97	
λ_{eff}	Effective wavelength of the input spectrum	549.59	

LED luminaire, 5101K



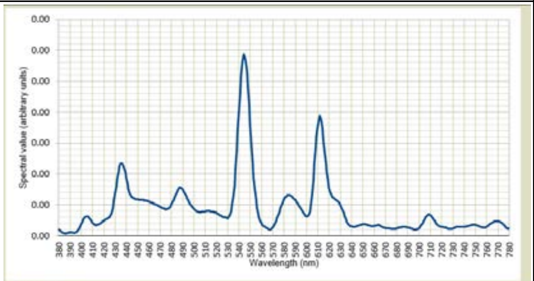
INPUT DATA			
Spectral range (nm)	Wavelength interval covered by the input data	380	780
Spectrum	Number of input data points	401	
Step (nm)	Wavelength difference among consecutive input data	1	
ORIENTATIVE CHARACTERIZATION OF THE SPECTRUM			
G	Estimated spectral index G	0.88	
Q	% (L500,V), blue radiance (below 500 nm) divided	44.00%	
Δλ	Spectrum equivalent width	47.96	
λ_{eff}	Effective wavelength of the input spectrum	562.71	

HPM luminaire, 4134K



INPUT DATA			
Spectral range (nm)	Wavelength interval covered by the input data	380	780
Spectrum	Number of input data points	401	
Step (nm)	Wavelength difference among consecutive input data	1	
ORIENTATIVE CHARACTERIZATION OF THE SPECTRUM			
G	Estimated spectral index G	0.69	
Q	% (L500,V), blue radiance (below 500 nm) divided	53.00%	
Δλ	Spectrum equivalent width	46.31	
λ_{eff}	Effective wavelength of the input spectrum	551.08	

HPM luminaire, 4208K



INPUT DATA			
Spectral range (nm)	Wavelength interval covered by the input data	380	780
Spectrum	Number of input data points	401	
Step (nm)	Wavelength difference among consecutive input data	1	
ORIENTATIVE CHARACTERIZATION OF THE SPECTRUM			
G	Estimated spectral index G	0.38	
Q	% (L500,V), blue radiance (below 500 nm) divided	70.00%	
Δλ	Spectrum equivalent width	60.27	
λ_{eff}	Effective wavelength of the input spectrum	552.55	

CFL luminaire, 5490K

5. Conclusions

The awareness of the negative effects of lighting pollution is affecting the lighting design of streets and small cities near national parks and protective areas. Today, with the advent of energy-efficient luminaires (LED) and state-of-the-art lighting control, the need for a better living environment should be placed along with environmentally friendly lighting design techniques. The first steps before an area of a city enters to LED era, is to a) recognize the existing malpractices and avoid them in the new light masterplan, b) set the proper guidelines (not only in lighting design but also in luminaires), c) identify if it is adjusted with

protected areas or national parks (to set extra promotions).
This paper presents a) the first steps for identifying a protected area (National Park of Aenos) proper for a dark sky nomination and b) the early results from identifying the luminaire types of the adjusted area of the National Park.
Various malpractices were identified, mainly in the areas with the new installations of LED luminaires. This is evident of how important is the early plan of the lighting design and the selection of the proper luminaires, especially in the areas that affect the National Park.
The main problem of the area is enlarged with the blue rich radiation that was measured from the existed luminaires. While the HPM luminaires were around 4000K, the blue radiance content Q was varied from 44% to 53%. Furthermore, Cool CCT Compact Fluorescent lamps (5400K) were installed resulting in the enormous amount of 70% blue radiation. However, the most important issue that should alert the decision makers of the street lighting design is the awareness of the technical characteristics that were chosen for the newly installed LED luminaires that blue light reached 58%

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LIGHTING DESIGN AS A SUSTAINABLE PARAMETER IN INTERNATIONAL GREEN BUILDING CERTIFICATES

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Keywords: sustainability, lighting design, green building, natural light.

Introduction

Modern world, especially developed countries have completed a transition from living in natural environment to urban environment for most of their population. However, this artificial structure that forms modern cities cannot replace the role of natural environment and modern people still have the need to feel connected with nature.

However, there is a controversial relationship among nature and human progress like constructions since the last have been proved as causes of deterioration of nature. Buildings that consist the main human constructions in cities are considered responsible for 17% of potable water consumption, 25% of timber usage, 33% of CO_2 emissions and 40% of materials and energy exploitation (World Green Building Council, 2013). The answer to the problem, is the green building.

A sustainable (green) building is a building with lower consumption of energy and accordingly lower CO_2 emissions. A sustainable building should provide a healthy, pleasant, comfortable and friendly environment for its users enhancing their productivity. A smart building is sustainable and advanced technologically on the same time.

A critical characteristic of a smart building is its flexibility to be renovated in accordance with future developments in construction. Smart buildings assist their users to be more productive and creative and enhance the feeling of safety and warmth. They should be of high aesthetics both internally and externally. Smart buildings operate as platforms where modern technologies and advancements are applied signaling the technological level and the spirit of their era and this consists an important inheritance for next generations (Panagiotopoulos, 2018).

There are plenty of certificates for the assessment of green buildings. These certificates assess the environmental impact of buildings and additionally their impact to their tenants and local societies. Most of the parameters that make up such a system are common. Elements like the geographical position, the use of water, energy management, recycling, transportations, lighting design (LD) and others, are detected in most of these certificates (Panagiotopoulos, 2018). Lighting design (LD) consists a process for the integration of the element of light in building total architecture. A successful LD is based on sustainability. It should use available energy to provide light where is needed and on the same time to limit light where it is not necessary or desirable. Sustainable LD demands control of light, glare and energy consumption, in order to be in line with the principles of ecology. Moreover, lighting designers should realize the direct impact of natural and artificial lighting in biological functions and behavior of humans (Gordon, 2014).

Research Question and Method

What is the position of lighting design inside the most important green buildings rating systems? The present research is based on a qualitative and comparative content analysis in the field of rating systems for the assessment of the environmental impact of buildings (Babbie, 2011). The most well-known and used rating systems have been evaluated with special focus on the parameter of LD. The needed information is retrieved through research in specialized business and engineering journals, specialized websites and scientific articles and books.

Goals and Importance of Research

The aim of this study it the promotion of LD value for sustainable development in modern buildings through its exploitation in green buildings rating systems. The assessment of green buildings rating systems with focus on LD could be useful for their foreseen amended versions. The underestimated sustainable factor of LD could be reconsidered by specialists since these certificates affects construction industry. An upgraded role for LD inside these rating systems could contribute to a better understanding of its multidimensional role in human life and to buildings with better lighting conditions and more pleased users.

Findings

Several rating systems for the assessment of environmental impact of buildings were presented during the period 1995- 2010 (Table 1). The plurality of them were created in Europe, Asia and North America despite Africa and Middle East where their spread is limited. There were at least 382 software tools for the energy assessment of buildings, the use of alternative energy sources and sustainable building management up to 2010. However, only a few of them are recognized internationally and in use from the majority of construction industry professionals (Bernardi et al., 2017; Binh K Nguyen and Altan, 2011).

A serious side effect of green building certificates was the focus of professionals on getting them rather on really applying sustainable principles. This trend for obtaining green building certificates by using superficially environmentally friendly design and technologies was made for profit maximization since green building are commercially more attractive than conventional buildings. Developers of green certificates had focused mainly on the phases of initial design and construction of buildings (Strong and Burrows 2017). Focus was on first cost alone for the building and its systems that affects the phases up to commissioning of them and not on a life cycle cost that includes everyday operation and maintenance of their whole commercial life. So, the first buildings which obtained such certificates used to fulfill the environmental standards established at that time but their environmental impact due to their operation and maintenance was similar with conventional constructions. We notice that in general the most promoted internationally rating systems have common sustainable principles and similar criteria for building assessment. Analyzing these criteria we could recognize as main axes of them the below cornerstones (Candace Say and Wood, 2008):

Table 1 The most popular green building rating systems internationally

Rating System	Origin	First year
BREEAM (Building Research Establishments Environmental Assessment Method)	UK	1990
HK- BEAM (Hong Kong Green Building Council Limited (HKGBC) Organization	Hong Kong	1996
CASBEE ("Comprehensive Assessment System for Built Environment Efficiency (CASBEE)," n.d.)	Japan	2001
LEED (Leadership in Energy and Environmental Design)	USA	1998
Green Star	Australia	2003
Green Globes	USA & Canada	2000
DNBG (Deutche Gesellschaft fur Nachhaltiges Bauen)	Germany	2009
HQETM (Haute Qualite Environmental)	France	1994
Green Mark	Singapore	2005

• Selection of geographical location

- Water management
- Energy management
- Transportations
- Recycling
- Ventilation
- Selection of sustainable materials
- Materials of low gases emission
- Lighting and indoor temperature
- View of external environment
- Glaring control

Table 2 The three axes of modern LD Environment- Humanity- Economy

AXES	Strategic Goals	Tactical Goals	Actions/ Technologies/ Innovations
ENVIRONMENT	Natural Resources Protection	Exploitation of Natural Light	1. Proper orientation of the building 2. Openings in the building 3. Light Diffusion & Redirection Systems 4. Light Transmission Systems 5. Automatic Light Control System
		Exploitation of Green Energy	1. Photovoltaics
		Thermal Protection	1. Shading Systems 2. High Efficiency Lamps
	Environmental Impact Reduction	Reduction of Pollutant Emissions	1. Exploitation of Natural Light 2. Shading Systems 3. Building Automatic Control Systems 4. Exploitation of Green Energy
		Reduction of Solid & Dangerous Waste	1. Recycling of Lamps 2. Use of High- Tech, Long- Lived & Environmentally Friendly Lamp
		Light Pollution	1. Lighting Automatic Control Systems
HUMANITY	Health, Safety & Quality of Life in, out & around the Building	Adequacy of Lighting	1. Compliance with Lighting Regulations
		Quality of Lighting	1. Exploitation of Natural Light
		Optical Comfort	1. Glare Control
		Thermal Comfort	1. Shading Systems 2. Building Automatic Control Systems
		View of Exterior Environment	1. Openings in the Building 2. Glare Control
		Light Pollution	1. Light Automatic Control Systems
ECONOMY	Money Saving	Reduction of Electricity Consumption	1. Exploitation of Natural Light 2. Photovoltaics 3. Shading Systems 4. Building Automatic Control Systems 5. High Efficiency Lamps
	Productivity (Health, Safety & Quality of Life in Building)	Adequacy of Lighting Quality of Lighting Optical Comfort Thermal Comfort View of Exterior Environment	1. Compliance with Lighting Regulations 2. Exploitation of Natural Light

- Noise control

Conclusions

Suggestions LD is a sustainable factor that concerns mainly the commercial life of a building and affects its everyday cost of operation and maintenance. However, LD should start with the architectural design of the building since parameters like the orientation of the building, openings for glazing, the existence of overhangs and canopies, clerestories, etc. cannot added afterwards without a significant cost increase. LD should not be treated as a single parameter for rating systems. LD is involved in several sustainable parameters and affects them with a determinant way. A proper LD should consider: (i) the preservation of natural environment, (ii) the protection of human health, safety and quality of living and working and (iii) its impact on the economic situation of the building either through money savings or money earned (Table 2).

The fact that building certification systems have omitted to develop the fledged dynamic of LD in areas like the physical and psychological health of users, its impact in productivity, etc. have resulted into the development of a new category of building standards that focus on users' health and quality of life like WELL building standard, etc. The transition from just green buildings to sustainable buildings has as prerequisite the holistic consideration of LD and the ensuing incorporation of its multidimensional role in building certificates.

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SUSTAINABLE LIGHT DESIGN – A GREEK SCHOOL BUILDING AS A CASE STUDY

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Keywords: Sustainability, lighting design, low energy consumption, daylight, human centric lighting

Introduction

The present project attempts to identify the methods that can be used for sustainable lighting design and the best techniques that can be applied to an existing building or a new installation in order to minimize its energy footprint due to lighting, maximize the utilization of natural light and simultaneously create a bright, functional environment with positive impact to the mood, productivity, wellness and even health of the users.

1. Sustainability

The term "Sustainability" and "Sustainable Development" has been around since the 1980s, when it was most clearly defined as «Development that meets the needs of the present without compromising the ability of future generations to meet their own needs» (UN, Our Common Future, 1986). It is the common place of environmental, economic, social and lately cultural human needs (Commitee, 2010). It is not just about reducing energy consumption, using natural resources efficiently and protecting the environment, but it aims to improve the quality of life, to restore social inequalities and to support all people independently, without economic, geographical and social exclusion (Mousiopoulos, 2015) (Dempsey, Bramley, Power, & Brown, 2011).

1.1 Sustainable Development

Global action for sustainable development is taken with “Agenda 30”, which was launched by UN in 2015, with 17 goals to be achieved by the year 2030. The same time according to EU, greenhouse gas emissions should be reduced to 40% and the same time 32% of the energy consumed in the EU should be produced by renewable energy sources by the year 2030 (EU, 2018).

1.2 Sustainability in Lighting Design

Lighting can be the main cause of energy consumption in a building, as people spend a large percentage of their time indoors while their activities have been extended after sunset. According to (DOE, 2010) in the USA, 18% of the total energy buildings consumption is consumed for their lighting, the same also for Greece (Mousiopoulos, 2015), while in some uses such as libraries, schools, hospitals, it can reach up to 70%. So, a large amount of energy is consumed for lighting that leads in environmental burden and reckless use of available natural resources. Besides low energy consumption, sustainable light design deals with a quality lighting environment with visual comfort, usage of Human Centric Lighting (HCL) and especially in exterior lighting elimination of social discriminations and reduction of light pollution and its negative side effects in the environment, climate, wild life, night sky and even human health (IDA, 2020). Human centric lighting (HCL) considers not only visual but also biological and emotional human needs, and it is a basic constant of sustainable design. It creates a living/working environment that provides the required lighting according to user’s individual conditions (licht.wissen21, 2018), trying to simulate daylight and it’s changes in color temperature, intensity and distribution (ERCO, 2019).

1.3 Green Building Certification

Lighting design according to the principles of sustainability is a necessity nowadays. There are even developed lighting evaluation systems of buildings like LEED and BREEAM, which offer light designers a way to document their sustainable approach with a positive impact on all aspects of social, economic and cultural life (LEED, 2020), (BREEAM, 2020). Certified buildings apart from the reduced energy footprint, improve working culture and support corporate social responsibility.

1.4 Artificial Lighting

Artificial lighting is used widely, so energy efficient lighting fixtures and rational use are important for conserving available energy resources for future generations (Mousiopoulos, 2015). It is based on specific photometric characteristics such as luminous efficacy, power consumption, glare, color temperature, light output ratio etc. which values are defined by European (EN- 12464) (licht.wissen4, 2012), (licht.wissen2, 2012) and national (TOTEE) (TOTEE, 2017) regulations. The evaluation of the light bulbs through the years resulted to more efficient lighting systems. LEDs, which are commonly used, have much better photometric characteristics, longer expected lifetime, the potential of dynamic adjustability and recycle and the same time they provide a high quality lighting environment with low energy consumption (Bourousis, 2014). OLEDs from the other hand are flexible light sources with the minimum percentage of blue light, so they liken to daylight. Lately, in order to lit up small scale projects, designers use the bioluminescence from plants and some life forms (Glowee, 2017) (Livinglight, 2020), which is a state of the art method with future perspectives of evolution. Selection of the appropriate lighting fixtures based on their photometric characteristics, avoidance of glare and flickering, extended lifetime, sustainable life cycle, recycling and reduced number of luminaires are important in sustainable light design and have a direct correlation with the energy consumption of the installation. Meanwhile, task lighting in specific areas that meets user needs without energy waste, presence and movement sensors and photosensors, dimming of luminous flux, programmable light scenarios and light management systems in order to control and combine them all together (Doulos, 2013), are the most commonly used methods for further energy reduction, along with the correct handling from the end users.

1.5 Daylight

Daylight is another important aspect when we refer to sustainable light design. It can drastically affect circadian rhythm, concentration, mood, and productivity of humans while its utilization can cause significant reduction to power consumption and strain of the installation. Buildings and openings orientation and layout should be selected rationally, because they affect daylight factor and the daylight zone, the area that receive significant quantities of daylight during the day and daylight harvesting control systems can be installed (Tregenza, 2011). To maximize daylight penetration into the buildings light selves and light tubes can be used. The same time glare caused by direct sunlight and non-uniform light distribution should be taken into consideration and a convenient shading system like blinds, brise soleil, horizontal and vertical fins should be considered in order to avoid them (Lechner, 2015), (Tsangrasoulis, 2016). The installation of photosensors, in order to dim artificial lighting due to adequate daylight, can provide maximum daylight exploitation and reduce in energy consumption and a significant solution when we refer to sustainable light design (Doulos, 2007).

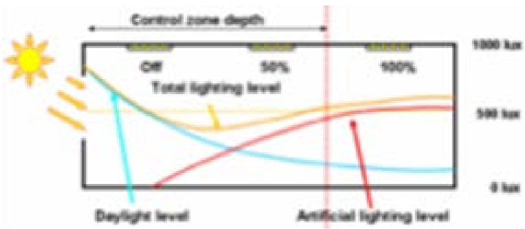

Figure 1 Photosensors between daylight and artificial light (Doulos, 2007)

2. Methodology

Some of the methods mentioned above will be implemented in an existing school building to redesign its lighting installation with a sustainable approach. The case study is selected because it is a building of everyday use and significant energy demand as its lighting should follow specific regulations, so a more efficient lighting installation can affect its energy footprint. Moreover, the end users, which are students, can take advantage of the positive consequences of HCL and improve learning performance with suitable lighting at the right time. Daylighting and maximum exposure to natural light is crucial to the successful design of an academic space, so it is considered too, along with an appropriate shading system to avoid glare.

2.1 Existing Installation

A classroom and the gym of the school, which is also used as a multipurpose room, both with NE orientation and NE oriented windows, are selected for the study. The existing light installation based on fluorescent lamps is not always adequate, there are large fluctuations in uniformity, high energy consumption (1.137 kWh/a for the classroom and 2.855 kWh/a for the gym) and glare (UGR>19) are observed. The color temperature is 6500K, that is not appropriate for a classroom. DF in the rooms is more than adequate but the absence of shading systems caused glare, as evolved from the observation of the two places.

2.2 Artificial Lighting

Concerning artificial lighting, the interventions aim to reduce energy consumption, create an optimized lighting environment, increase the ability to focus and concentrate during lessons and fulfill different needs throughout the day. In both rooms fluorescent luminaries were replaced with new LED technology of low energy consumption (< 8.4 W/m2) and high luminous efficiency (>60lm/W). Task lighting is not used, as a uniform result is necessary in the entire classroom area.

2.3 Artificial Lighting in the Classroom

In the classroom tunable white luminaries with LED light sources, that can be tuned from cool white to warm white light, for a relaxing environment that the same time reinforce concentration and performance, are selected for the general lighting. The blackboard is lit independently for a better optic result. The photometric characteristics of the luminaire are shown in the tables below.

Table 1 Photometric Characteristics of the general lighting luminaire in the classroom

General Lighting	
Luminous Efficacy	114 lm/W
CRI	90
Luminous Flux	3695 lm
Power Consumption	32.5W
DLOR	97%
Lifetime	50.000h
CCT	2700 ± 6500K
Dimmable	1%

Table 2 Photometric Characteristics of the blackboard luminaire in the classroom

Blackboard Lighting	
Luminous Efficacy	66 lm/W
CRI	92
Luminous Flux	1528 lm
Power Consumption	23W
Lifetime	50.000h
CCT	3500K

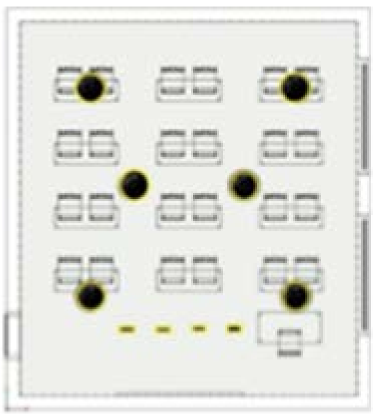

Figure 2 Lighting Fixtures in the classroom floor plan (Dialux)

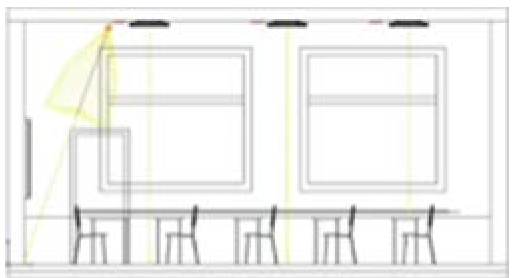

Figure 3 Lighting Fixtures in the classroom (Dialux)

Moreover, in the classroom there are placed presence sensors to switch off the lighting fixtures when there are not any users in the place. Pre- defined lighting scenarios are also created. The color temperature is set in 6500K for the first school class or during work that demands focus as it improves alertness. The rest of the day 3000-4000K ensure a better light environment without visual strain, while 2700K provides a relaxing ambience when needed.

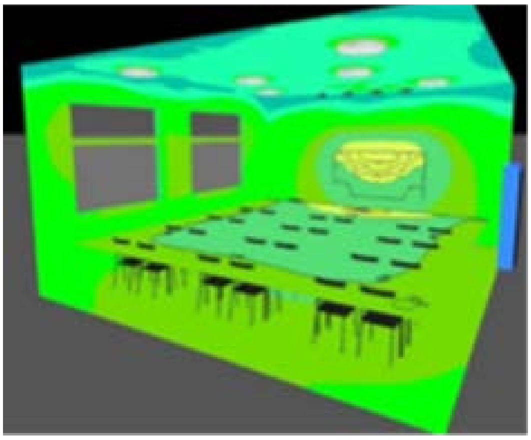

Figure 4 False colors in the classroom (Dialux)

Figure 5 3d visualization of the classroom (Dialux)

2.4 Artificial Lighting in the Gym

For the gym, the luminaire selected for the general lighting is suitable for sport venues. Additional lighting that is need in the stage of the room, is provided by a tunable white luminaire, as shown in table 4. Besides that, there are placed 4 RGBW spotlights, for architectural lighting of the stage, when needed.

Table 3 Photometric Characteristics of the general lighting luminaire in the gym

General Lighting	
Luminous Efficacy	121 lm/W
CRI	80
Luminous Flux	5022 lm
Power Consumption	42 W
DLOR	100%
Lifetime	50.000h
CCT	4000K
Dimmable	1%

Table 4 Photometric Characteristics of the stage luminaire in the gym

General Lighting of the scene	
Luminous Efficacy	100 lm/W
CRI	80
Luminous Flux	4000 lm
Power Consumption	50W
DLOR	97%
Lifetime	50.000h
CCT	2700 ± 6500K

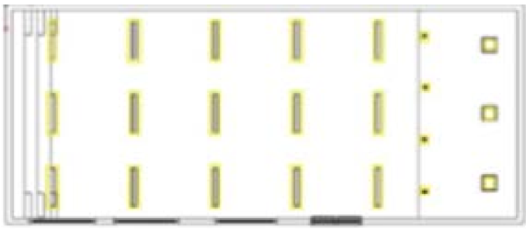

Figure 6 Gym floor plan (Dialux)

Presence sensors and pre- defined lighting scenarios are also created in that case, that can change the lighting depending on the activity that took place in the place (training, performance on the stage or parents meeting).

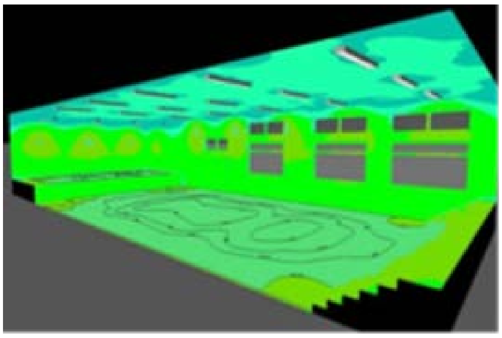

Figure 7 False colors in the gym (Dialux)

Figure 8 3d visualization of the gym (Dialux)

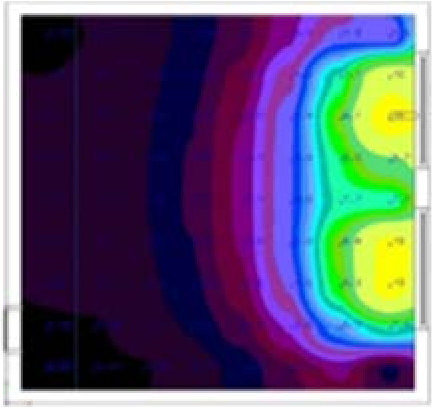

Figure 10 DF in the classroom (Dialux)

2.5 Daylight, Daylight Zone, DF

Maximize daylight exposure in the two rooms and the same time design a new shading system is another important issue. Daylight Zone Area = a*b, where a is the depth and b the width of the daylight area, in relation to the width and the height of the windows, as shown in figure

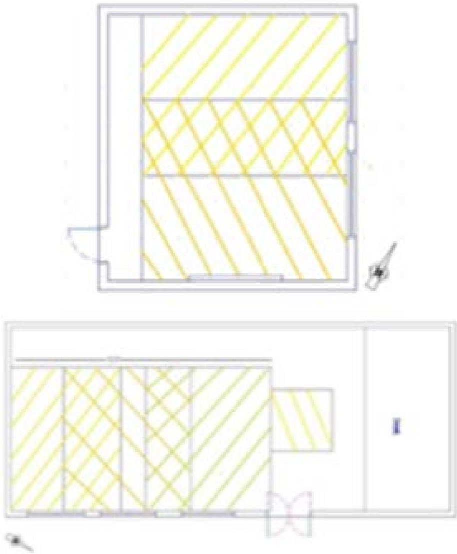

Figure 9 Daylight Zone Area in the classroom and the gym (Dialux)

The Daylight Factor is also calculated with Dialux as shown in figures 10 and 11. In the case of the classroom it is DF = 3,542 % while in the gym it is DF = 1.966 %.

Figure 11 DF in the gym (Dialux)

Both values indicate that the installation of photosensors, in the lighting fixtures inside the daylight zone, to control the lighting in the rooms, can reduce energy consumption That modification shown in figures 12 and 13 leads to an additional reduction to the energy consumption. The final energy consumption is 320 kWh/for the classroom and 1400 kWh/for the gym.

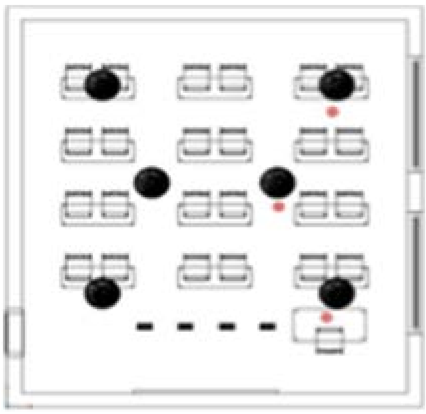

Figure 12 Photosensors in the classroom (Dialux)

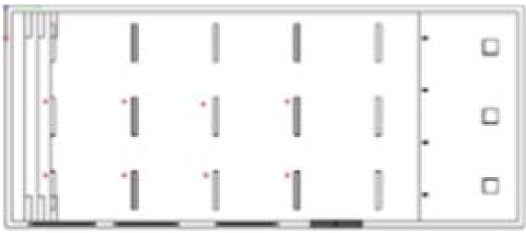

Figure 13 Photosensors in the gym (Dialux)

2.6 Shading

Solar shelves and blinds are selected to be placed in the external openings. The use of blinds reduces the glare caused by direct sunlight for both areas, whereas solar shelves increase daylight penetration, DF and uniformity.

Figure 14 3d visualization of the shading system in the classroom (Dialux)

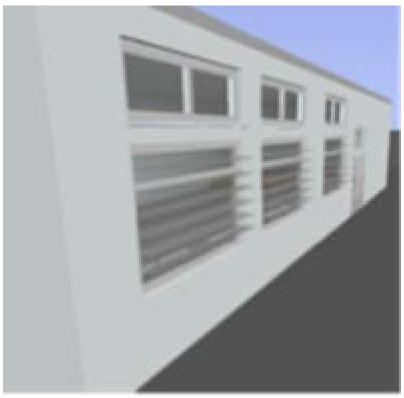

Figure 15 3d visualization of the shading system in the gym (Dialux)

3. Results

The focal point of the lighting design in that case study were the students and a better lighting environment that helps students to concentrate and provide visual euphoria. From the results derived from the study, that goal is achieved.

3.1 Classroom

That modification in artificial lighting results in a lighting environment without glare, satisfying illuminance levels and uniformity according to regulations as shown in the table below, while the total energy consumption is 503 kWh/a. The lighting design took into account the concept of cylindrical illuminance Ez, which value is 150 lux.

Table 5 Artificial Lighting Results in the classroom (Dialux)

	Classroom	Gym
Em	358 lux	513 lux
UGR	19	14,3
Uo	0.69	0,71
Power	6,3 W/m^2	

3.2 Gym

The same result is obtained in the gym as shown in table 6, while the total energy consumption 1796 kWh/a.

Table 6 Artificial Lighting Results in the gym (Dialux)

	Gym
Em	354 lux
GR	20,2
Uo	0.73
Power	5,08 W/m^2

3.3 Energy Consumption

The annual power consumption in the classroom is reduced by 55.7% with LEDs and by 71.85% in total with daylight utilization. In the gym the percentage is 37% in the first case and 50.9% in the second one, achieving significant energy savings.

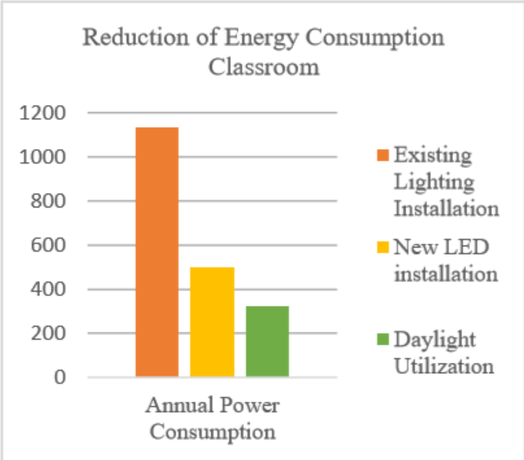

Figure 16 Annual Reduction in Energy Consumption in the classroom

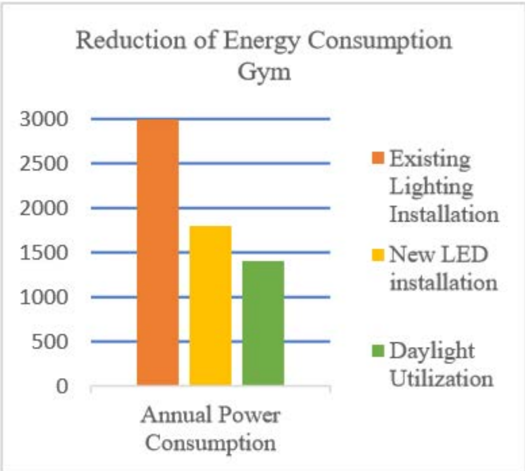

Figure 17 Annual Reduction in Energy Consumption in the gym

3.4 Quality Comparison of the Shading System

The following figures of the classroom and gym show their interior before and after light selves and blinds are installed. The comparison between the two conditions indicates the better lighting conditions after the installation. The comparison is relied on quality factors.

Figure 18 3d visualization of the classroom before light selves and blinds installation (Dialux)

Figure 19 3d visualization of the classroom after light selves and blinds installation (Dialux)

Figure 20 3d visualization of the gym before light selves and blinds installation (Dialux)

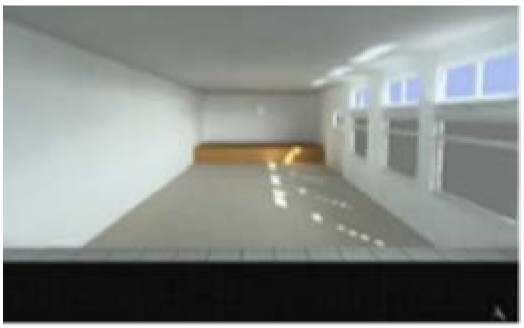

Figure 21 3d visualization of the gym after light selves and blinds installation (Dialux)

4. Conclusions

To conclude, it is understood that sustainable lighting design is a multidimensional concept that can have multiple benefits for humans. Its implementation requires specific steps in the design of a space, which will have multiple benefits for users at all levels, promoting a culture of respect for the environment and society but primarily to the users of the space themselves. It cares about people's physical and psychological well-being and the same time reduce the cost of lighting installations, prevent light pollution, spare natural sources, and reduce energy consumption. In that case study the reduction in energy consumption reach 70%, while it placed the users in the center of the design. The limitations that derive from the fact that the case study concern an existing building, are the restrictions regarding daylight harvesting and alteration in building and windows structure.

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THE EFFECT OF ARTIFICIAL LIGHTING ON PLANT GROWTH

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Keywords: Special applications, artificial lighting, grow lighting, controlled plant growth, photoperiodism, spinach growth, indoor farming, vertical farming, absence of natural light

Introduction

The sunlight is the primary source of energy for earth's climate system and the only source of natural light. It radiates light and heat, which makes it possible for life to exist on Earth. Plants need sunlight to grow. Animals, including humans, need plants for food and the oxygen they produce. So, the Sun is one of the most important reasons of life on earth. The need of human to extend the useful hours during the night, forced him to create light sources that use energy (mostly electrical), in order to create optical radiation, mainly in visual spectrum called lighting.

Artificial lighting is a form of radiative energy that is emitted in significant quantities indoors and outdoors. Nowadays, society displays a plethora of further developments in light technology where energy aspects as well as ergonomic and other considerations have their place. It is well established that humans and other biological entities are sensitive to light to various degrees, and that normal physiological processes can be, and are, influenced by light from natural or artificial sources. Similarly, to human needs for light, plants use light to produce ingredients that helps the grow, through a process called photosynthesis. During photosynthesis, plants use the green chlorophyll, a pigment, to help convert carbon dioxide, water, and light into carbohydrates and oxygen. When they do this, they create the materials that they need to grow.,

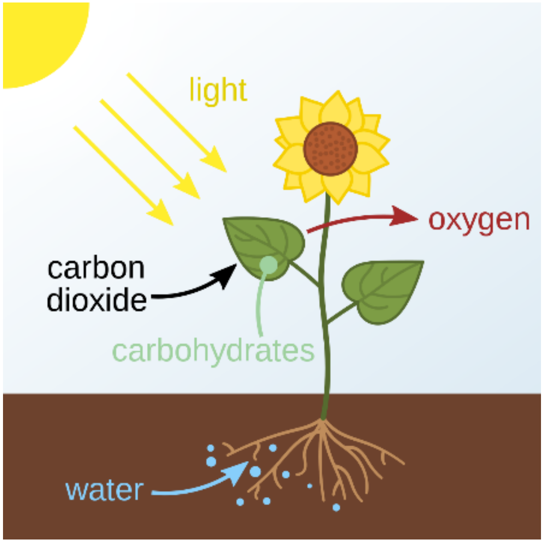

Figure 1 The light is the primary source of energy in plant growth

1. How lighting affects plant growth

Urban environments include significantly larger quantities of artificial light sources which increase the exposure of human and plants to this spectrum of radiation during the night. This phenomenon is mainly due to the operation of wrongly designed street lighting, advertising, illumination of sports stadiums, construction, security, façade lighting etc. However, this status comes at a price and negatively impacts on the environment. One such negative phenomenon is Light Pollution - a term used to describe excessive nighttime artificial lighting, present especially in large urban areas.

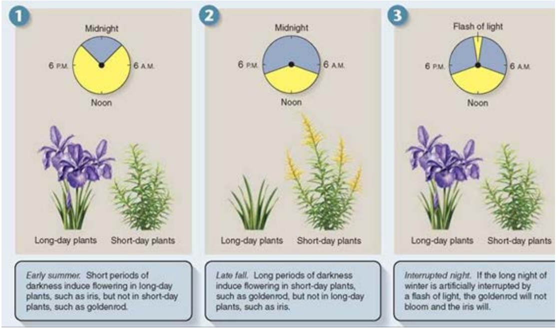

Figure 2 The effect of photoperiodism on flowering

Through artificial lighting, big quantities of energy are emitted into the environment and in this way plant growth and development are influenced by light spectral quality, quantity and duration. The plant photoreceptors – phytochromes, cryptochromes and phytotropins mediate physiological and developmental responses in plants. The phytochrome is blue-green plant pigment which regulates plant development, seed germination, flowering and leaf expansion. The phytochrome system allows plants to grow towards light. Sometimes photoreceptors act independently, sometimes redundantly, sometimes cooperatively, sometimes antagonistically, sometimes at the same stage of development, and sometimes at different stages of development. Moreover, some of these responses are incredibly sensitive. Some plants and tree species also react to strong light sources and to changes in the day/night length. Approximately 80% of flowering plants are sensitive to photo-periodism, the physiological reaction of organisms to the length of night or a dark period.

2. Increased needs of productivity worldwide

At the same time, new technologies of artificial lighting, as well as the needs that arise in modern societies, have led to the development of new special applications of artificial light, for growing plants in areas with complete absence of daylight. By 2050, the human population is expected to reach 9.7 billion people with almost 70% living in cities[1]. Not only does this increase in population place tremendous pressure on the fundamental infrastructure that is necessary for contemporary society to function, but the rise of urbanization makes accessing the vital nutrients human needs to live challenging.

Figure 3 Vertical farming uses 95% less water and requires less than 1% of the land needed for outdoor farms

Farming and agriculture are two systems with mounting pressure to accelerate outputs in the next three decades and are currently facing mass disruption with innovators in this space looking beyond traditional methods to accommodate to increasing consumer needs. Vertical and indoor farming are new ways of farming located in fully controlled environments, used to produce green food. They use artificial light and are commonly founded on soil-free growing systems. The benefits are far reaching. Not only does vertical farming have the potential to facilitate urban food production, fewer food miles, seasonal independence of crop production, and price stabilization, but also allows for product consistency. These methods also reduce water consumption[2] as water evaporated from the

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[1] Centre, J. I. (2020, July 15). Vertical Farming Could Help Agriculture Meet Food Supply Needs. Ανάκτηση από www.technologynetworks.com: https://www.technologynetworks.com/applied-sciences/news/vertical-farming-could-help-agriculture-meet-food-supply-needs-337416

[2] UrbanKisaan. (2020, March 11). UrbanKisaan — Vertical farming company in India. Retrieved from medium.com:

plants is captured and reused. As an additional result of new technologies, vertical gardens are becoming a trend in modern architecture, by creating indoor gardens i.e. on walls, in areas with total absence of natural lighting.

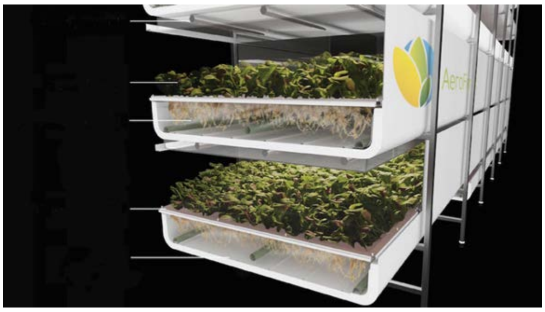

Figure 4 Soil-free plant growth under the effect of artificial lighting

3. Aim and method of the research

The aim of this research was to investigate the influence of the artificial lighting sources, used for interior places against daylight and plant growth lamps, on the growth and development of a plant. For this reason, an experimental process was designed and implemented through which the growth of a plant was controlled, under the influence of different spectrums of artificial light sources.

In more detail, thirteen different cases were installed and tested. One case was designated to examine the growth of plants under the influence of sunlight and used as the reference scenario. Six case studies designated to examine the growth under the influence both of sunlight and artificial lighting and the other six the growth in total absence of natural light.

	Artificial lighting	Natural lighting	Short period	Long period	Cool Light 6500K	Warm Light 2700K	Grow Light
Case 1:	x			x			x
Case 2:	x		x				x
Case 3:	x			x		x	
Case 4:	x		x			x	
Case 5:	x			x	x		
Case 6:	x		x		x		
Case 7:	x	x	x		x		
Case 8:	x	x	x			x	
Case 9:	x	x	x				x
Case 10:	x	x		x	x		
Case 11:	x	x		x		x	
Case 12:	x	x		x			x
Case 13:		x	N/A	N/A	N/A	N/A	N/A

Figure 5 Index of different cases tested

Both main groups of indoor and outdoor cases (cases 1 to 12), were tested under the influence of different artificial light sources. The sources selected were typical LEDs for interior rooms (Hotels, residentials, etc) with different Correlated Color Temperature, such as a warm light source in 2700K together with a cool light source in 6500K and a special light source of a grow lighting type, emitting a more specific spectrum to help plant growth (in blue and red visual spectrum only). Finally, as already mentioned, photo-periodism is important for plant growth and development, so half of the cases were exposed in artificial light fewer hours during the day, and half more hours. For the results of this process, the dry mass of the plants was measured and compared.

In more detail, the duration of the total process was almost four months from which three months needed for the growth and one month for the drying. All plants were planted and grown in similar environmental conditions in order to keep all other parameters that affect plant growth, almost the same (such as soil, watering, temperature etc.). For ensuring that the results exported from the process were reliable, a quantity of 24 spinach plants per case were used, so 312 spinach plants in total. Finally, for exporting the results, each plant was removed carefully from the soil, by keeping the root and were all dried. The results exported are based on the weighting of the dried complete plants.

Metering

During the whole process there was a detailed metering of various parameters, such as indoor and outdoor temperature, illuminance during different type of days (sunny, cloudy, rainy etc.) and different hours through the day, as also plant growth, through capturing.

Since the aim was not to achieve the best possible production, but to export results by comparing similar installations with specifically different characteristic, a range of three different type of artificial light sources with almost similar output and different color temperature were used. The parameter of these three different light sources in combination with a different duration during the day and the effect or not of natural lighting during the plant growth process, returned 13 different cases to check and compare.

https://medium.com/@urbankisaanfarms/urbankisaan-a-vertical-farming-company-in-india-a231ee5a0edb

	Artificial lighting	Natural lighting	Short period	Long period	Cool Light 6500K	Warm Light 2700K	Grow Light	Remarks	Weighing after pruning [gr]	Weighing [gr]	Summarise weighing [gr]
Case 0:		x	N/A	N/A				Testing			
Case 1:	x			x			x		9	11	20
Case 2:	x		x				x		7	8	15
Case 3:	x			x		x			5	2	7
Case 4:	x		x			x			6	2	8
Case 5:	x			x	x				7	3	10
Case 6:	x		x		x				5	8	13
Case 7:	x	x	x		x				10	11	21
Case 8:	x	x	x			x			8	12	20
Case 9:	x	x	x				x		9	8	17
Case 10:	x	x		x	x				12	10	22
Case 11:	x	x		x		x			10	9	19
Case 12:	x	x		x			x		11	14	25
Case 13:		x	N/A	N/A	N/A	N/A	N/A	No artificial light	11	14	25

Figure 6 Results exported - total plant production per case

Regarding the illuminance metering, the numbers were stable during the whole process, as there were no external factors to change the results. So, for the indoor cases the illuminance for grow lighting technology was around 350lx, for warm lighting was almost 500lx and for cool lighting was 900lx. On the other hand, regarding the cases grown under the sunlight, the illuminance range was from 15.000lx to 54.000lx, during noon referring to the sunny days while in partly sunny days the maximum illuminance achieved 46000lx.

Results

As was expected, the plant growth of the plants under the natural light, was more instant and more natural. On the other side, in the six scenarios with the absent of daylight, the energy emitted by the artificial light sources was enough to help plants grow and stay alive during the whole experimental process. Comparing the different light sources results, plants grown under the 'grow lighting' sources, forced the growth further than all other typical LED light sources. Finally, comparing the different duration of exposing the plants under the artificial light sources, no special difference occurred.

On the other hand, based on the optical observation of the plant growth during the experimental process, the leaves produced by the plants under the sunlight were significantly bigger than the ones produced by the plants indoors, with the total absence of the natural light. Also, referring to the watering process, the plants growing under the sunlight in combination with the 'grow lighting' artificial light source, had higher needs of water, compared to all other cases. Finally, it is important to be mentioned that, during the experimental process, the local temperature turned very high compared to the normal temperature expected for the season, so, the result of this fact was that the plants growing outdoors turned into yellow and were dying day after day, while the plants growing indoors, were growing normally as the environmental conditions were more stable and the indoor temperature didn't achieve the outdoor levels.

A plant growth is a dynamic process, as each plant is an alive organism and has its own characteristics. There is a wide range of research and applications worldwide nowadays that are trying to find the best combination concerning all different parameters that affect plant growth.

Figure 7 Different cases tested during experimental process

Figure 8 312 pieces of spinach plants were used during experimental process

Figure 9 This is the indoor installation using vertical dividers

Figure 10 This is the indoor installation showing the different color temperatures from different light sources

Figure 11 This is the outdoor installation using separators between cases and a cover in order to control quantity of water from rain

Figure 12 Outdoor installation covered in order to avoid extra watering from the rain

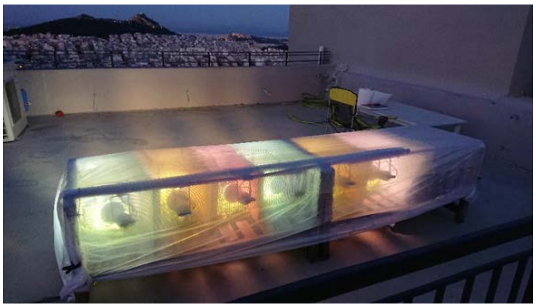

Figure 13 This is the outdoor installation during the night, showing the different color temperatures from different light sources

Figure 14 Outdoor illuminance measuring

Figure 15 Indoor illuminance measuring

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LigHTS 2020

ELECTRONIC ART IN THE 20TH CENTURY. THE CASE OF FRANK J. MALINA A STEAM METHODOLOGY EDUCATIONAL PROGRAM FOR PRIMARY SCHOOL CHILDREN

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Keywords: Lumino kinetic art, Frank Malina, Play of Brilliants, STEAM

Introduction

This paper examines the work of Frank J. Malina in parallel with artistic and technological developments that took place in the 20th century. First the research is considering the pioneers of early kinetic and Lumino-kinetic art who integrated computer science and lighting technology in their artworks. Then comes the main focus to the work of pioneer artist and scientist Frank J. Malina, exploring his multitalented personality and influence not only on his contemporaries but also his descendants, seeking to find connections with today's practice. The outcome of this theoretical research using bibliography resources and visual examples is the design and implementation of an art-science educational program for primary school children, combining contemporary digital programming tools with basic principles of light design and visual perception thus allowing primary school children to get more familiar with Lumino- kinetic art.

1. Lumino Kinetic art

Kinetic art officially emerged as an artistic movement in the 1950s. But the artist's need to express himself through movement pre-existed. From antiquity until today, the depiction of movement has been timeless in the search for artists. Lumino-kinetic art came a little later in the early 60's as a subset of kinetic art. Photo-kinetic artists took advantage of light as a medium and used it to express themselves. Developments in technology and sociopolitical changes in the 1950s and 1960s also had an impact on art. Artists of the time explored the possibilities of motion and light as means of expression using mechanical and electronic elements as well as electricity. Around 1955 the American artist and scientist Frank J. Malina suggested a renewal in the art of moving light.

1.1 Frank J.Malina

From the beginning of his career as an artist, Frank J. Malina was looking for an exploration of the third dimension. In all his experiments and art works he used electrical light and colour patterns in motion. He discovered that light transparency could be used as a form of expression. He invented an electromechanical system that he called 'Lumidyne' in which he used fixed sources of light, moving parts (rotors), stable parts (stator) and a translucent screen. In Lumidyne system light's transmission occurs from an object directly to the eye or on to a translucent screen or on an external projection on to an object.

1.2 Play of Briliants

Play of Brilliants is the result of light which refers to the various lighting effects that can be created by the play of light on objects or spaces. It arouses the eye and curiosity, it can distract or entertain.

2. STEAM

The purpose of the educational program is to familiarize children with the effects of light and in particular the Play of brilliants through the work of Frank J. Malina. This educational program is based on STEAM (Science, Technology, Engineering, Arts & Mathematics) methodology offering a crossdisciplinary, holistic and innovative approach to the school learning process. The STEAM methodology is an augmented evolution of the STEM (Science, Technology, Mathematics) teaching approach with the addition of 'A' representing 'Art'. It is a didactic approach in which the individual subjects are coordinated and support each other under an educational structure such as Technology, Science, Mathematics and Art are actually related to each other. The purpose of the educational program is for students to understand the effect of light (play of brilliants) and to distinguish it in the work of Frank J. Malina The educational program is aimed at primary school children of 6th Grade who have basic programming knowledge with blocks. At first a presentation was shown to students regarding Frank Malina, Lumino-kinetic art, light and its effects especially the play of brilliants. Then students had a class about how to build a virtual application in Tinkercad platform using a virtual Arduino and virtual LEDs. They also watched videos or Frank J. Malina's work 'Sink and source' and 'Mitosis'. The experiment was implemented also with a real Arduino and LEDs in classroom in a dark environment so the effects of light would be shown more intense.

The goals of the program for the students were:

• To get familiarized with the effects of light (play of brilliants). • To get familiar with kinetic art and Frank J. Malina through his work.

• To learn to connect the microcontroller to the programming environment.

• To learn to use a virtual Arduino, create an algorithm in Tinkercad and simulate circuit in Tinkercad platform.

• To develop a communicative and team spirit of cooperation

3. Findings

In this lesson, the children generally knew what light was, but did not associate the concept of light with information. They did not know the effects of light, nor had they ever heard of kinetic art or Frank Malina. The whole experience for them was unprecedented. Working on Tinkercad was not surprising, as they were familiar with the Scratch language environment. All students remembered concepts and names, especially Frank Malina's. They were impressed that so many years ago someone was working with space, rockets, UNESCO and art and all that successfully. After seeing the videos "sink and source" and "mitosis" they were asked which effect of light was recognized in them. All students answered "Play of Brilliants". In this teaching scenario students did not have any knowledge of the subject, but the knowledge that was acquired was retained. For days later they talked about Frank J. Malina and the play of brilliants.

Conclusions

Art was and is a special form of expression. With the discovery of electricity and the electric generator, many artists were able to capture aspects of the human environment that relate to light, motion, the Sun, space, color and its changes, using them to create kinetic art. Lumino-kinetic art is a subset of it. Art historian Frank Popper saw it as a sign of "aesthetic concerns associated with technological progress" 1(Nechvatal, Joseph, and Frank Popper, 2004) and a starting point for high-tech art. Movement, dynamism, duration, color and interaction are some of the elements through which artists of photo-kinetic art express themselves. The educational program that was designed and implemented was effective in enhancing creative thinking, student participation and cognitive goals. The students completed all the activities successfully, understood the term kinetic art, 'met' Frank Malina and became familiar with his work. They fully understood the term Play of Brilliants and were able to recognize it in Malina's work. They learned how to connect the Arduino to the programming environment, create a circuit with virtual Arduino in Tinkercad, and simulate circuit in the platform. The combination of ICT, art and science brought strong positive educational and student-learning impressions and created the appropriate background for the repetition of the script in different groups of students.

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1st International Conference on Lighting, Interactivity, heritaGe, Health, Technology and Sustainability

BIOLUMINESCENCE IN CONTEMPORARY ART AND LIGHTING DESIGN ADVANTAGES AND LIMITATIONS

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Keywords: (photo)luminescence, bioluminescence, light art, sustainability, environmental design

Introduction

Sustainability and environmental consciousness are becoming a central concept in both contemporary art and lighting design. Addressing such issues as low energy consumption and the creation of environmentally friendly light installations, as well as other lighting design applications, has been the topic of relevant research with regards to the use of bioluminescence in contemporary art and lighting design.

1. Statement and research questions

This paper examines a number of both artistic and lighting design projects focusing on the possible advantages of the use of bioluminescence in art and lighting design, as well as certain limitations that may arise from its use. Main research questions addressed in this paper are:

a) How can the use of bioluminescence contribute to a sustainable environment though environmentally friendly applications? b) How do contemporary artists and lighting designers engage with the use of bioluminescence in art and design? What are the best practices? c) What are the limitations towards a wide scale application of the use of bioluminescence in lighting design? Are there any recommendations to tackle those limitations, if any?

2. Research argument and findings

Bioluminescence is broadly defined as luminescence created by living organisms (Harvey, 1952). Photoluminescence is the emission of light from a source or a substance that has not been heated, therefore researchers refer to this phenomenon as "cold light" (Valeur and Berberan-Santos, 2011). Examples of "cold light" are fluorescence and phosphorescence. Bioluminescence is a form of chemiluminescence. Such cold light emissions originating from living organisms are more often observed in the ocean (Widder, 2001). The most common organisms to emit bioluminescence, apart from sea creatures, are insects (i.e. fireflies or fireworms), fungi and bioluminescent bacteria (Kirkland, 2007: 85). Some of these organisms emit bioluminescence as a result of symbiotic relationships with bioluminescent bacteria, while others are able to emit bioluminescence themselves (Olatunji, O., 2020: 350). Before we start examining best practices of bioluminescence in art projects and lighting installations, we need, first, to overview the science causing this phenomenon and the historical background of relevant research.

3. Background research

In 1884 Raphael Dubois started studying the bioluminescence of a specific tropical firefly called Pyrophorus. Earlier than this research was the scientific discovery of Robert Boyle, that a prerequisite of bioluminescence is the existence of oxygen (Boyle, 1672). Dubois proved that this process is associated with the oxidation of an enzyme of a biochemical compound, which he named luciferin. He introduced the luciferinluciferase system to the beatle Pyrophorus and the mollusk Pholas dactylus, overturning earlier theories linking bioluminescence to fluorescence or phosphorescence (Dubois, 1900). Current biotechnology research has used luciferase systems in the process of genetic modification. Firefly genes as well as bioluminescent bacteria have also been used in biomedical research. In 1986 firefly luciferase genes were used to genetically modify tobacco plants (Ow et al., 1986).

4. Transgenic art and bioluminescent light installations

4.1. Transgenic art

Alba was the "luminous" rabbit of artist and founder of transgenic art Eduardo Kac. This rabbit had the ability to emit green luminescence when exposed to blue light. The rabbit lived for about 2 years and created a stir in the field of art and science (Clüver C., 2010).

4.2. Art and bioluminescence

Hunter Cole is a New Orleans-based artist and geneticist who creates what she calls “Living Drawings” with bioluminescent bacteria (Vartan, 2018). At Montana State University-Bozeman, a team of researchers and artists created the BIOGLYPHS project, which involved "some microbiology training, imagination, and a lot of petri dishes", according to Betsey Pitts, a director of the project and research scientist at the Center for Biofilm Engineering (Norris, 2017).

Another example comes from Dr. Siouxsie Wiles, a microbiologist from the University of Auckland, who conceived and curated an exhibition named “Biolumination”, where she invited artists to paint bioluminescent images on agar plates (Dean, 2016). Among other contemporary artists or groups working with bioluminescence are Nicola Burggraf with Luminale installation (2010), Robin Meier και Andre Gwerder with Synchronicity (2015), Andreas Greiner with Multitudes (2015) and Andrew Quitmeyer with Living Lightning performance.

4.3. Bioluminescence in lighting design

Bioluminescence has inspired not only artists, but also designers, such as the Dutch designer Teresa van Dongen who designed “Spark of life”, a pendant LED bulb powered by electrochemically active bacteria. Such living organisms require regular feeding and this is one of the implications of the sustainability and wider commercial applications of such projects. Bacteria that are cultivated in petri dishes using agar are expected to live no more than three days.

University of Wisconsin–Madison researchers used genetically engineered bioluminescent E. coli bacteria, for creating an electricity-free light bulb (Mosher, 2013). Other projects utilising similar technology are E. glowli by Cambridge iGEM students and Glowee (2016) by designer and entrepreneur Sandra Rey. Other similar attempts are also Biobulb, launched by research students from the University of Wisconsin (Spoon, 2013), as well as Philips Bio-light (Doiron) or industrial pieces inspired by the marine snail Hinea brasiliana, for lighting future cars at the Scripps Institute of Oceanography (Blanc and Benish, 2017: 137).

In 2011, Philips launched a microbial system to create ambient lighting for domestic use. This system was presented during the Dutch Design Week 2011, where Philips Design in Eindhoven “presented a conceptual self-sufficient home that converts sewage and rubbish into power” (Etherington, 2011). Such applications offer new opportunities for lighting design that reduce the environmental footprint and production of carbon dioxide of lighting by reducing energy consumption, whilst offering user friendly lighting design that stimulates a healthy lifestyle thus adding towards a better quality of life. Other experimental design or commercial applications include Sophia Sobers’ wearable piece

“Heartbeats & Bioluminescence”, “Dino Pet”, a design object powered by dinoflagellates (Yonder Biology) and commercial applications such as “Glow in the dark ice cream” (Afzal, 2013).

4.4. Street lighting and bioluminescence

In April 2013, three biohackers from California's DoIt-Yourself biology lab, BioCurious, launched a Kickstarter campaign to raise money for the implementation of their biotechnology plan to create a glowing plant. They also created “Light Fountain”, a prototype lamp powered by dinoflagellates. MIT engineers were able to stimulate plants to emit a faint light for about four hours. With further optimization, such plants will at some point be bright enough to illuminate entire workplaces (Trafton). In January 2014, Bioglow company introduced the

"Starlight Avatar", the first "autonomously bright" plant in the world (Drotleff, 2013). An idea, which started by Dutch Daan Roosegaarde, was to replace street lighting with similar plants (Studio Roosegaarde). A wide scale application of bioluminescence in street lighting could significantly reduce the environmental footprint of street lighting, considering that "cold light" created from living organisms does not consume energy but waste and its products are 100% organic. In addition, "cold light" does not contribute to light pollution and is soft for the human eye sight. It can adjust to almost any use of light and can take any form or shape required for human needs. However, these forms of lighting design are still experimental and require significant amounts of research funding to become commercially sustainable. The problems that need to be tackled are mostly the fact that living organisms need to be constantly fed and are unpredictable, they have a short life period and may cause overpopulation when this is not desired. Such issues need to be studied on an experimental basis, in order to create sustainable lighting applications that can be maintained and repaired if needed.

Conclusions

The use of bioluminescence in lighting design can be an effective tool to reduce energy consumption and lighting pollution by reducing the environmental footprint of lighting. Applications such as lighting bulbs, lighting design for domestic or professional uses, as well as light installations and street lighting, may contribute towards the improvement of the quality of human life, because the "cold light" emitted by living organisms is compatible with the human eyesight and does not cause light pollution. Cold light does not consume energy but it is produced by living organisms, such as plants, or bacteria that feed on organic waste, and, subsequently, does not produce any carbon dioxide.

The opportunities for creative applications of bioluminescence in lighting design are still to be further explored, as well as a wide scale commercial application of bioluminescence in lighting design. As a natural, organic material, "living light" or "cold light" can take any form and shape, however it may be difficult to maintain and further study is needed.

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REFLECTIONS
A REFERENCE ON THE WORK OF NICOLAS SCHÖFFER THROUGH CONTEMPORARY TRENDS AND APPLICATIONS IN LIGHT ART

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Keywords: Kinetic art, motion in art, Nicolas Schöffer, light art, cybernetic art, light installation

Abstract

This study refers to Kinetic art, a major art movement of the 20th century, focusing on the work of pioneer artist Nicolas Schöffer. In the beginning of the 20th century, quite a few artists experimented with movement, as it was a common quest to add movement (kinesis) in static images or sculptural works.

Even in Painting, which is confined in, only, two dimensional surfaces, there are numerous works of this early period in modern art, in which artists managed to add the concept of movement in the displayed scenes. In Sculpture, artists such as Marcel Duchamp, created impressive works of art, which not only implied movement, but also added a component of actual movement in the sculptural work, be it manually or mechanically produced (Gombrich, 2011).

This study consists of two parts: in the first one there is a historical reference to the artists of earlier movements, before Kinetic Art, where efforts had been attempted to integrate the concept of motion in art. In the beginning, this mostly applied in paintings, and later on, in sculptures as well. For example, Impressionist painter Degas was one of the first artists to show interest in rendering the element of movement in his works. And also Paul Klee, under the cubist influence, managed to manifest movement in his painting called Sailboat (Honour & Fleming, 1998). Within this early phase, the main focus of this research paper is on the work of the most important artist and kinetic art pioneer, Nicolas Schöffer, who introduced such artistic concepts as spatiodynamics, luminodynamics, chronodynamics and cybernetic art by using all the possibilities of the technology of that time.

In the second part, there is an attempt to document and analyze certain works of artists who are still active in the late 20th and early 21st centuries and are mainly concerned with the creation of structures that combine the use of lighting effects and movement. These artists such as ART + COM studio and George Rickey create installations that combine stunning light art techniques with some of Kinetic art. Although they employ digital technology and current artistic new trends in their works, they have many similarities with those aesthetic elements, as introduced by Nicolas Schöffer.

Finally, within this scope, an artistic installation is proposed, based on the work of Schöffer and his techniques. At this point, a more thorough analysis of the characteristics of his main works is made, upon which the design of the installation is based. The aim of this installation is to create an experiential space, within which the public will be able to interact with the installation, by manually affecting the movement of the sculptural part and the light effects, thus creating a unique visitor's experience (Schöffer, 2018).

Introduction

The fast pace of modern everyday life, emotional alienation in urban environments and rapid industrialization, as the tendencies to overcome the old and discover the new, were the key-aspects of the shift that took place in modern art in the beginning of the 20th century to depart from representation towards abstraction. Artists were intrigued by technological and scientific

advances, exiting from a previous century that was dominated by romantic ideas and occultism. This shift gave a strong incentive to pioneer artists at that time to experiment with the notion of movement in their artworks (Gombrich, 2011).
Motion is perceived by light, so these two concepts are inextricably linked. From the 1850s onwards,
artists often tried to include the element of movement in their works, but few were able to succeed. Especially in Painting, where only depictions of still life are possible to capture, 19th century artists found it hard to represent temporal changes in their works (Honour & Fleming, 1998).
Our historical reference starts with the efforts of 19th century artists who wished to include elements of motion in their artworks. More specifically, in the late 1800s, Impressionist artists Manet and Degas made remarkable efforts to attribute movement into their paintings. Furthermore, in the beginning of the 20th century, under the influence of cubism, Paul Klee's painting "Sailboat" is an excellent example where movement is evident. Under the same influences, Marcel Duchamp created mobiles, sculptures that were able to move.
Following these first steps, the transition to the paradigm of kinetic art was only one step away. Kinetic art is a modern art movement that appeared in the 1920s and ever since changed the perception of movement in art. Artists who devoted themselves to the research towards movement in art, created sculptures that could be moved, either manually or mechanically. Naum Gabo in 1920, made one of the first mobile sculptures using magnets to create oscillations. Vladimir Tatlin, also designed a mobile tower that was, however, never materialized (Foster et al., 2018).
More steps towards reaching a kinetic art were taken by pioneer artist Nicolas Schöffer. By aiming to add the elements of space, light and time to his constructions, Schöffer divided his work into three categories: 1 | spatiodynamism, 2 | luminodynamism and 3 | chronodynamism. At the same time, he came up with a new concept, Cybernetic Art. Movement in art could now be automated, either by using electricity or electronic means, (i.e. computers), or other input from the environment, such as weather conditions. Our study's topic focuses on the artist's main means of expression, namely forms, colors, materials, as well as lighting and sound techniques (Schöffer, 2018).
We also analyze selected works by contemporary light artists who created constructions that incorporate the concept of movement, as well as many techniques drawing from early kinetic art, more specifically in terms of the use of form or lighting effects. There are five works by these artistic groups in which common elements with some of Schöffer's most famous works (Spatiodynamique 29, Microtemps and Lux10) can be traced.
Finally, the design of an installation of a kinetic, interactive installation is proposed, which aims to create an experiential environment, in which each visitor will come in contact with a combination of elements drawing from Schöffer's works. More specifically, two identical constructions are proposed to be placed on the ceiling of an exhibition space. These two sculptural parts will be able to be rotated manually by visitors. At the base of each construction there will be four LED spotlights that will illuminate them. With each manual rotation from the visitors, all parts of the sculpture will be set in motion, resulting in a complex variety of reflections in the room. Two lighting scenarios are described. In the first one, only one sculpture is set in motion, while in the second scenario both sculptures move at the same time, creating a spectacle of different reflections and colors that become entangled, giving the audience the feeling that the boundaries between the physical space and the visitors are being lost, as they are being immersed within a moving kaleidoscope.

Conclusions

When rapid changes in social norms, science and technology affect everyday life, thus disturbing previous balance, they also give rise to artistic experimentation. Artists are gifted with highly sensitive social antennas, therefore, are, usually, the first among others, to grasp the opportunity and challenge of such changes, in order to present innovative works that manifest the spirit of their times. Combining scientific knowledge and new technologies with their art techniques, pioneer artists created works that are important milestones in the history of art, because these works reflect on respective social change and technological advances. The concept of movement has always been a great field of investigation, and as mentioned above, when combined with other elements, such as lighting and sound effects, can together create dazzling sets of unprecedented experiences. Since the beginning of the 20th century and onwards, painters such as Degas, Duchamp, Klee, and many others, made significant efforts to highlight this element through their works.

Nicolas Schöffer was an innovative artist who transformed static modern sculpture by the elements of space, light and time in his constructions. At the same time, he elaborated on new concepts, introducing new terms, such as cybernetic art and automation. He also collaborated with a number of engineers, musicians, as well as dancers, and achieved what for many seemed impossible, to combine altogether the elements of movement, sound and lighting effects in his works.

Schöffer could also be described as a forerunner of Light Art and Installation Art, as he designed constructions that created unprecedented experiences for the public with lighting effects. By placing them mostly in urban environments, where they would beeasily accessible to all, his work is still today an inspiration for artists, who wish to create large scale installations in public spaces.

Finally, contemporary digital trends add to the previous aesthetics of Schöffer's works and are evolving into new art forms. Interactive Art and Light Art are both artistic leaps influenced by new digital techniques and promising new art experiences. Light artists are in constant search of new techniques that visually stimulate the audience's imagination and spark their experience.

There are many artists who took up on elements from Schöffer's work, especially in the field of Cybernetics, combining them with contemporary digital trends and developing them further. The three basic concepts (spatiodynamism, luminodynamism and chronodynamism) used by Nicolas Schöffer in his works can be found in contemporary sculptural and installation works, but also light installations, not only in galleries but also in public spaces.

The possibilities offered by the combination of light and movement conclude to the design of this proposed installation, which combines concepts from all three basic principles, as analyzed by Nicolas Schöffer, namely luminodynamism, spatiodynamism and chronodynamism.

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LIGHTING AND PROCEDURES FOR CREATING A SUITCASE THEATER PERFORMANCE. THE THEATER OUT OF ITS CONVENTIONAL SPACE - STREET THEATER

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Introduction

Theatrical productions are organized in places that have been built for this purpose. However, there are alternative production approaches taking into account the traditional separation of actors and audiences, using mobile elements (suitcase theater), commonly known as Street Theater. Crossing the boundaries between audiences and actors, out-of-the-way action installations are set up in abandoned buildings, public spaces to be recovered, and even in degraded neighborhoods. The selected areas are temporarily transformed into themes without any similarity to a traditional scene. The spectators are invited and encouraged to explore the space and interact with the actors in an environment that is unrealistically real. The particularity is based on the fact that is about open spaces changing while the movement and conversion of the scene presupposes different actions and lighting scenario. The more the spectator is willing to participate and interact with the plot the more realistic the experience and boundaries between reality and fiction will become (Oddey A, 2006).

Goals and importance of the research

Lighting design is an organic element of the performance that the main issue, is to be in harmony with other means of expression. For this reason, the use of lighting, its purpose and role as well as its connection with the desired result is studied. Then the methodology for outdoor performances with the characteristics studied is compiled. The methodology that is used is based on bibliographic research and the analysis of specific examples from the theater. Finally, an (In situ) investigation is carried out in the city of Chania, where the results will be applied to a small theatrical production. It is studied how light can render a scene in uncontrolled conditions, how interacts with the built environment, how the actors communicate with the audience by exchanging roles, how the motion becomes part of the stage and how everyday life is projected in places where memory bursts and regenerates under the light. In other words, it touches on urban planning and the investigation is attempted in the light of the recovery and use of public spaces (Gregory, 2009).

Public space in transition

Public space is perceived as a living and evolving space where the user is called to interact with it. In memory, visiting the space it seems to be shaped not only by its image, but also by our experience in it. Memory is also of great importance in theatre. In Greek cities, the fulfilment of the collective interest seems to be violently provoked, due to both individualistic and egocentric attitudes (Oddey A., White C., 2006). A public space, outdoor or not, is not governed by the same rules of drama, but this depends on its use. A dramatic space requires intense shadows and colour contrasts, a certain scale, usually larger than the human dimension, repetition of elements and much more. It is understood that the space itself, does not have theatricality elements. There must be active action, an intervention beyond time, according to Pearson, will be able to transform space into a space with identity, called a space-place (Casey, E S., 1998).

These spaces can be anywhere, including shopping malls, parking lots, squares, streets, and generally any open space to use or not. Is required the dramatization of social and political issues, which usually occur outside conventional spaces and deal with controversial social and political issues that usually take place outdoors. In this approach, the audience is invited to intervene and reproduce a particular scene, encouraging them to think of a contextual social issue to facilitate dialogue between actors and spectators. (Singhal, 2004).

Light manipulation

While uncontrolled conditions are an inhibitory factor outdoors, the formation of a spatial experience through manipulation of light, must be seen as a reaction to specific places and spaces, (Bohme Jernot, 2014).

Interaction is the two-way form of this relationship of influence between individuals that differentiates it from the conventional form of action: cause-and-effect. It focuses on the spatial, sensory and harmonic properties of light and is related to image or movement. The person, after determining the qualitative and quantitative characteristics of light, understands the way that is formed in space and creates an atmosphere, through the differences in colour and direction of light, the manipulations of the visual media. By constantly changing the colour and intensity of light from different directions, settle the right conditions to achieve interactivity (Bohme Jernot, 2014).

An Example of In situ

In the example that follows the Vivid Street Theater "The Western Walls", takes place in ten parts of the old city of Chania. The main idea of this production is to create an experience where the audience walks in a live "scene" during various events take place in houses and alleys of the Venetian port, transforming the urban environment into a theatrical stage. The areas of action mark the three (3) dominant elements that determined the urban space of the Old Town of Chania. It is about the Hebrew, the Turkish and the Greek element coexisting under the strictly shaped public space of the Venetian period (Andrianakis Michalis, 1997).

In a performance that takes place in an open public space, all of the above should be taken into account when designing lighting, regarding the existing lighting, and affect the performance, the expression, the structure of the work and the communication with the public.

Figure 1 Scene 1 (Kokotsaki, Nikolidakis, 2020)

The actors in a dramatic approach place their emotional feelings (Figure 1). Without a specific plot or verbal meanings they are inspired by the dreams and the power of the subconscious. Through physical action, (Shelley, 2013) intense sound intervention and the selection of texts concerning the use and gaps of Public space, interaction is a privilege of the spectators - recipients redefining free expression in Public space.

The stage seems to be washed in blue light by led floor lamps placed in the two front corners of the stage facing the actors but with inclination and torsion constantly changing in relation to the position of the actors. Although there are motion control systems, due to the high cost, the move of the light beam is done manually. Extra lighting fixtures give warm light to the actors from positions on the rear sides and upper. The different lighting colour of the actors from the urban environment helps to separate the different qualities and roles. The blue light that

upwards illuminates defines better the geometry of the scene. This technique tries to expand the limits of human potential and its transcendence, the limits of the known and absolute freedom. By creating a dreamy environment with unreal elements, the emotion is enhancing, the experiential experience is attempted with familiar tools, on a path to the impossible.
The front lighting is avoided in most dramatic scenes, in order to give a different atmosphere. When the background lighting enhances the three-dimensional form of the actors, the use of coloured light is followed in both actors and stage lighting, with blue being the most common colour. In terms of light intensity, you choose to be brighter in happier scenes than the rest.
The fragmentary character of the scenes is visualized through the arrangement of words and phrases without order, giving the impression that they are floating in space. The simulation and verification of this scene is presented in the following figures. The first presents the positions of the luminaires and their targeting.

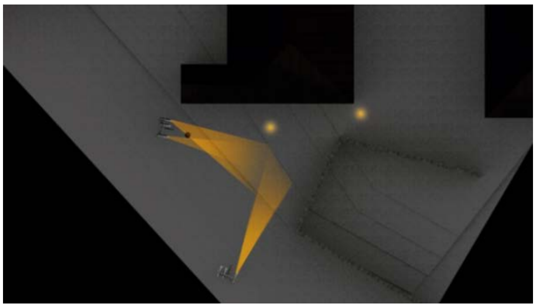
Figure 2 Position and targeting of luminaires (Nikolidakis, 2020)


Figure 3 Photorealism scene 1a (Nikolidakis, 2020)

The lighting here fulfills its functional purpose as the movements of the actors are effortlessly visible. With the use of warm and cool light a special atmosphere is created while with the alternation of warm and cool light horizontal zones of light are created parallel to the stage image, which increase the sense of depth.


Figure 4 Photorealism scene 1b (Nikolidakis Panagiotis, 2020)

The use of blue in combination with the urban lighting and the existing structure of the space, create confusion through an unconventional atmosphere, which is not recognized as familiar but challenges you to explore it. The shadows are not intense, reducing the already great drama of the show.

Conclusion
Public spaces have their own lighting, influencing the experiential as much as the lighting experience. Sometimes they are dimmed or dark and sometimes illuminated with great intensity using a different treatment. To this equation should be added private spaces (shops, houses, etc.) that have their own lighting and affect the scene. As such, the lighting of a street theater performance takes into account, all the parameters and participates during design process, since the choice of stops or movements depends directly on the general lighting. For example, the actors could avoid lighting in a position, and then allow the light to highlight their next dynamic movement with greater intensity (Narboni, Roger, 2004).
By choosing bright or dark areas, with the ideal incentive proportions create a complete sensory experience that highlights the meaning of the performance. Also carves through the following corridors or postures, a guide for lighting design. In such a lighting situation, the actors participate in the design of their lighting, as they knowing the positions of lighting fixtures (fixed) and they take full advantage by improvisation use.

The impression of a color and the message it conveys is important for creating the psychological mood or atmosphere that supports space operation. In physical terms, the basic colors are blue, red and green. Although blue is cool and distant, the eye's response in changes to the blue edge of the visible spectrum. This shows that in cool light sources we can see more easily (Robert Bean, 2004). Particularly important for the blue color selection, is the overstimulation it causes. Overstimulation, in turn, causes changes in breathing rate, increased pulse rate and blood pressure, increased muscle tension. The main signs of an overstimulated environment are the intense color intensity (saturated), the color harmonies that are too complex or incompatible (Frank H. Mahnke, 2012). The sense of color experienced by the observer therefore depends on the color insight as well other colors influence in the field of view that affect the color adaptation. Thus blue is always in contrast to ochre (usual masonry color, yellow-orange), which is used to denote internal and external conflicts. Despite the conflicting nature of these colors, in color theory, they are referred as complementary. The contrast of different colors, makes the faces of the actors look intense and bright (Moyer, 2005).

In conclusion, prevailing emotions and moods such as eroticism, nostalgia, disgust, anger, joy, sadness, masculinity, femininity, relief, trust, betrayal, retreat and surrender seek expression under the limits and restrictions of public space. In the suitcase theater, the absence of scenes (the setting is the urban environment and the participants) highlights the light, making it in combination with the movement, the attitude and the speech dominant in transmitting of meanings. However, the lighting can be an element of space, movement and mean of transmitting, depend on the purpose of the performance.

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THEORISING AND EVALUATING FILM LIGHTING

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Film lighting in film production is a significant output of the cinematography discipline, that is, the part of the film image production that concerns the process of recording what is in front of the camera lens on data-sensitive material. In short, cinematography is a photographic practice that concerns lighting and frame composition during the recording of moving images. However, while international, and Greek film theory is quite huge considering film narration, context, direction, genres and themes, it remains quite obscure when it refers to cinematography and film lighting, as it neither considers them as a distinct field of aesthetic research nor classifies them into modes and trends.

1. Aim and methodology

Several attempts to provide a straight classification of cinematographic elements have always concentrated on some of them and never as a whole i.e. as a special type of photographic art (for example Henderson 1999, Henderson 1976, Durgnat 1990, Mac Dougall 1992, Baxter 1976, Eisenstein 1943, Dreyer 1997, Jonson 1970, Durgnat, 1983, Winston 1996, Neale 1992. Therefore, an important theoretical question remains unanswered: How can we evaluate cinematography and, more specifically, film lighting design and methods in a film? What aspects in the film image should a researcher take into consideration in order to classify and comment on film lighting modes and trends? The aim of this paper is to clarify the evaluation criteria and propose a process within which film and lighting researchers, critics an practitioners may comment an evaluate the lighting in a film or other audiovisual work.

The methodology adopted is a pure bibliographical one concerning the approaches used so far by film critics and theorists.

2. Definitions

In the Greek Labour Legislation, there is a formal indirect definition of this practice (Presidential Decree 160/1980), the Director of Photography (DoP) is defined as the person who

"following the instructions of the director, is responsible for photographic technique and the artistic quality of the recorded images in the shooting process on interior or exterior locations. In particular, the director of photography is responsible for the lighting of the setting, the framing and composition of the shots ..." In the Greek practice, according to all major cinematographers, both young and old, "the film belongs to the director who decides everything. The cinematographer's role is to serve the vision of the director by carrying out his projects" (Rammou 1998, 14)

Before, during and after shooting, the Director of Photography, the director, the cameraman and their assistants are fully or partly responsible for technical issues such as the appropriate film stock in terms of frame proportion, speed and image quality, the types of cameras and supportive equipment used, the lenses and their focal length, quality, definition, diffusion and sharpness, the type of filters used, the aperture used, the speed of recording and the focusing distance, the development and the printing of the film according to the initial planning as well as

- the quantity of lighting and supportive equipment selected
- the intensity of lighting equipment
- the position of the lighting equipment
- the means of lighting diffusion
- the colour temperature provided by the lighting equipment

These technical decisions, as taken by the filmmakers, are the very first level of cinematographic practice. The same decisions, in the context of the film image as a whole, constitute "lighting style"- in short, its aesthetics.

A plethora of texts have been written about these elements. As Lindgren put it as early as 1948, the three basic factors that govern the image of a film frame are "the form or the movement of the object itself, the position of the camera in relation to the object, and the way in which the object is lit".

3. Lighting issues

Therefore, following the major theoretical handbooks (such as Alton 1995, Braveman 2014, Brown 2012, Brown 1996, Frost 2009, Lyver & Swainson 1999, Malkiewicz 1986, the lighting issues governed by the cinematographer/lighting designer are:

Lighting quality: either 'hard' (directional, shading) lighting or 'soft' (diffused, shadowless) lighting.

Lighting mood: either 'warm' or 'cool', depending on the colour temperature of the lights.

Lighting contrast: This term refers to the relationship of the key and the fill light; it is either 'high', 'low' or 'mid' (medium) contrast. In general, if the relationship between the key and the fill light is 1:1, there is 'low' contrast. If it is 2:1 or (arguably) 3:1, there is 'mid' contrast; if it is 4:1 or more, there is 'high' contrast.

Lighting tonality : either 'high key' (generally bright with high tones everywhere and very few shadows) or 'low key' (dark tones dominate and there are very few high tone points) or of a 'graduated' tonality.

Effect in colour: The impact of lighting on the saturation and the hue of the colour in clothes , scenery etc. The basic distinction refers to 'strong' (saturated) colours and 'muted' (de-saturated) ones. The issue of b/w cinematography and the aspects of of film stock (e.g. grain) are discussed at this point as well.

All the above occur in lighting/ cinematography regardless of the film's genre, mode, length, etc. The multiple and variable uses of these factors have, de facto, proved their expressive potential. Therefore, they have been called elements (Cormack 1994, 16), conventions (Sklovsky 1991, 133), codes (Metz, 1974, 28) or techniques of a patterned and significant use (Bordwell, D.-Thompson, K, 1997, 168). Any research on lighting (and cinematography) has to count, interpret and analyse these elements. The next question is "how".

4. Conclusion: a four-step theoretical analysis

Considering the facts mentioned above, this paper may propose the following four steps for evaluating and theorising lighting in audiovisual works – the steps will thoroughly analysed in the oral presentation of the conference:

Step a: determining the style where the majority of the shots belong to, via a statistical style analysis i.e the registration and counting of the cinematographic elements of lighting per se as well as the frequency with which they are used in the film image. This provides a quantitative and structural analysis based on the methods firstly introduced in film theory by Barry Salt (1976) and Mike Cormack (1994).

Step b: determining the overall style and visual arts tradition (expressionism, realism etc) where these shots belong to

Step c: proposing functions for this kind of lighting within the context of the narrative of the major scenes and the whole film. As said above and mentioned by the Greek law, lighting (and cinematography) in any film does not have an autonomous role but functions as a "servant" of the narrative and the overall meaning of the film.

Step d: defining a thesis about the links of this lighting style with the tradition, the makers background and the cultural context of the film i,e. define the relationship of lighting to the conditions under which it was designed: from the photographic context to the filmic context and, then, the production context, i.e. the cultural, economic and political factors which influence film aesthetics.

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