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Alternatives to artificial lighting: Varying patterns of bio-light in architecture

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Abstract

The notion of variability is identical to the phenomenon of light. The present paper examines characteristics that shape this variability, in all forms of light, both natural and artificial, as well as light that is experimentally produced in a laboratory environment, through genetic modification of plants, in line with current trend of architectural fluidity.
At a time when architecture is interacting with emerging technologies by creating parametrically changing shells and environments, that are evolving as biological models and organisms, lighting is becoming a tool for highlighting forms while ensuring the functionality of spaces.
It is up to the designer to manage these variables of light in an inspired way, in order to create an elegant, sustainable and environmentally friendly environment for all beings.

> *People are designed to seek for change and the visual system reacts primarily to contrast and changes. It is vital to vary the light*
> *(Karlsson, 2015).*

Keywords

bio-light; variability; parametric design; emerging technologies; bioluminescence

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Introduction

Every time a person opens his eyes, a new unique image of the environment emerges in front of him, which activates his visual perception of the world (Yot, 2010). The variety of this scenography is highlighted by the variability of light, depending on its attributes. Especially in an ever-changing natural and artificial lit environment, the designer looks like a magician holding a magic wand. By modifying the variables, he "shapes" the quality of the light, which, although not easily quantified is perceived through the created atmosphere by the forms of lighting, resulting to a sense of well-being.

The effects of depriving the environment of the variability of natural light

The widespread predominance of artificial lighting around the world has radically changed the picture of the periodic variability of light in the environment. The "dark" night image of the daylight cycle has completely changed, with the relative brightness of the starry night sky often disappearing, especially in the urban areas of the earth.

The resulting nocturnal pollution is associated with the genesis of many environmental impacts, the main ones being:

- the difficulty of performing astronomical observations and measurements (Hunter, 2017)
- the disturbance of the biological clock of all organisms, affecting their health and well-being (Atari, 1982), (Brenninkmeijer, 2008)
- the disorientation of migratory birds, which are attracted to artificial light sources and consequently disappear (Zielinska-Dabkowska, 2013)
- the inability of many nocturnal animals (terrestrial or marine) to find food, protect themselves from their enemies, or unite with their mate
- the disturbance of plant growth due to altered photosynthetic function (Biswas, 2013)
- the destructive for health of beings blue spectrum emitted by many light sources (Gudkov, 2017), (Gelder Van, 2004)
- the extensive disposal of destructive materials and substances for the environment, from light sources components (Ippolito, 2017)

Three versions of the variability of light in architecture

The self-evident importance of variability in human evolution is briefly demonstrated in Swami Vivekananda's excerpt from his lecture at Floral Home in Colombo, late 19th century: «Variation must exist; without variation life must cease» (Vivekananda, 1897).

As new trends in architecture and urban design are mainly based on the search for new dynamic and evolutionary forms, corresponding to the fluidity of modern urban life, lighting has become a dominant tool for highlighting and functioning these forms.

It is an indisputable fact that humans perceive the concept of variability of the natural environment through the alternations of light and darkness, which are determined due to natural phenomena. Then, after sunset, through the management of artificial lighting variables, variability is succeeded by producing a wide variety of lighting forms, both to expand daily activities and to increase the sense of security, while at the same time highlighting the structured environment.

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The variability of light, depending both on the functionality of the space and aesthetic requirements, dictates a different approach from the point of view of architectural design. The factors that shape the requirements for differentiating lighting in an architectural environment are:

- The environmental zone
- The specific climatic conditions
- The brightness of the adjacent environment
- The type of building
- The functional requirements of the spaces
- The lighting standards in accordance with applicable law

The characteristics that shape the variability of light, whether it comes from nature or is produced by man, as well as the variables that affect its form, are analyzed below:

I. Natural light

The variability of natural light follows the periodicity of the daily cycle, achieving the following:

- Helps living beings perceive the changes of the seasons and the daily periodicity
- Programs the circadian system (biological clock) of all beings, the main factor for maintaining their health and life
- Enhances the developmental functions of organisms
- Creates visual changes that outline the "scenography" of the environment and enriches it with unsurpassed aesthetic quality

The variability of daylight is determined by variables, most of which are imposed "from above", i.e. they are "unavoidable":

First variable is the source of origin. The main source is the sun, from which light is directly emitted. If the sky is covered by clouds, then the light penetrates through them and reaches the earth as diffused. But also, light is emitted reflected from all surfaces, on which sun ray's incident.

The second variable is the daily fluctuation of solar radiation, as has been recorded in scientific data (Muneer, 2004). The third variable is the range of the angle of incidence of the sun rays at the specific location, therefore depending on: a. the geographical location (essentially the geographical components, such as latitude and longitude) and b. the season and the time of day.

Finally, the variability of light is affected by the effects of scattering due to the medium through which it reaches a particular location.

Regarding the *variety* of forms of light, they could be divided into two main categories, depending on the source of origin, as well as on the type of surfaces. In the first case light is emitted either as direct, causing hard shadow patterns, or as indirect (diffused, by smoothing out shadows), while in the second, materials, textures and translucence of surfaces affect the color of reflected light.
In the case of natural light, the lighting designer should:

A. Keep in mind to take advantage of the properties of natural light to illuminate a building or space, while dealing with the potential problems that will arise, acting as follows:

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a. By selecting the appropriate orientation of the building openings (Baker, 2002),
b. By exploiting the advantages of natural light (creation of proper size and type openings, use of shelves of augmentation or reduction incoming light) (Littlefair, 1996) and
c. By "tackling" the potential problems caused by solar radiation, such as glare and overheating during warm seasons (use of shading systems and "devices" for deflecting incoming radiation).

B. Create varieties of lighting forms through effects and patterns, by using colored filters or glasses and specific constructions, to "play" with light and shadows, or just water surfaces to create varying reflectance (Niesewand, 2000).

II. Artificial light

During evening hours, artificial light allows people to extend their activities, with some of them taking place during the night and increase the sense of security and functionality. The variation of light is achieved through wide variety of light sources, each with different specifications (variables), that produce a variety of lighting forms, suitable for individual requirements. Current technology of lighting results in dynamic light sources, emitting light variating in intensity and color, activation ignition, dimming and shut off, to meet the different needs of users both on performing tasks and creating a nice atmosphere. In the case of artificial lighting, the desired variability of light is manageable through its variables, as follows:

1. The type of light source
2. The size of the light source
3. The luminous flux
4. The intensity of the light source (through dimmer settings)
5. The direction of the light beam (adjustment through "devices" and accessories of the luminaires)
6. The angle of the light beam
7. The type of luminaire that hosts the light source
8. The distance from the illuminated surface or object
9. The texture and color of the illuminated surface
10. Aesthetic requirements for a specific space or building
11. Function and quality standards for each activity
12. Time of ignition and shutdown (programming, sensors, controllers)

The forms of produced artificial light are varied, such as: a. monochromatic or multicolor, b. fixed or variable, c. warm or cool (corelated color temperature of radiation), d. directional (harsh shadows) or diffused, e. with high or poor color rendering, f. dramatic (strong contrast with shadows, sharp angles of incident rays on the surface or object) or "mild" (small contrasts) and g. creating effects (through projections, robots, special lens, filters and disks -Gobos).

Last variable, with the emergence of digital technology through state-of-the-art devices and software, introduced the innovation of interactive lighting in the urban space. Interaction contributed to the creation of changing forms of lighting, manageable by programming from consoles and computers. Through them, the interaction of humans with the environment and buildings is achieved as information, messages and artistic interventions.

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III. Bio-light

The concept of Genetic Architecture (Chu, 2011) emerges as a kind of "virtual DNA", (Gatti, 2010) which is inherited both on a scale and in projection in an innovative structured environment, both inside the buildings and in the surrounding outdoor space. It should be mentioned, that just as with organic DNA, the corresponding synthetic one resembles a constantly modified skin, which develops according to the laws of evolution (Armstrong, 2012). Through the simulation of biological systems and the emergence of adapted technologies (Hensel, 2013), among which bio-digital architecture dominates, the relationship between the functions of buildings and the anthropogenic environment becomes parametric, occasionally changing so that it responds to lifestyle and to the needs of users.

The phenomenon of light production by organisms in nature, is a challenge for the contemporary designer for possible utilization of this light in the design, so that: a) a structured space is created, more integrated in the natural environment, b) the space's operation is self-sufficient and c) some of the energy consumed to illuminate the building shells and the urban environment is saved.

In this case, the variability of light output is combined with the constant change of organisms, as they grow, being the sources of this light (Ardavani, 2019).

In the context of Genetic Architecture, the innovation of an "organic" or "living" light serves the main concept of creation of a transformative "skin" or cell, which will be adjusted to the special needs of human beings. Through genetic modification of plants with genes extracted from bioluminescent organisms, either fireflies, algae, or bacteria, they may perform as light sources. According to a recent experimental study, it was estimated that by using transgenic luminescent plants, low-traffic roads, sidewalks, dark parks, gardens, patios, etc. can be sufficiently illuminated according to International Illumination Standards (Ardavani, 2019). These light sources will grow close to human habitats, illuminating in an always variating way, depending on the following variables:

a. The plant's suitability to be genetically modified as luminescent (i.e. the availability of genetical protocol) (Fanourakis, 2005), *b.* the size, type and foliar area, as these data have proportional influence on the intensity of produced light (Ardavani, 2019), *c.* the orientation of the plant (James, 2000), *d.* the local climatic conditions, e. wind direction, e. the magnitude fields (Talà, 2010), *f.* solar radiation intensity, as according to researches, higher absorption of energy results to higher plant growth (Yan-Hong, 2009) and *g.* the maintenance of plants, as possible diseases and pathogens affect their health, resulting to lighting output reduction.

The *variety* of forms of emitted bio-light lies in the different color of monochromatic radiation (depending on the radiation wavelength).

In the case of bio-light, the designer, taking into account the above variables, may, with the appropriate selection of transgenic plants, acting as light sources, sculpt the bright environment, so that it meets the functional and aesthetic requirements for each illuminated space. It goes without saying that selected plants, in order to be genetically modified, must be capable of thriving in the local climatic conditions and the peculiarities of the geographical area.

In addition, the stage of growth of plants, but also the configuration of their foliage, is the most decisive parameter of their luminous performance as lighting fixtures. This parameter can be considered

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as an algorithm for estimating the amount of light emitted and it is the one that essentially affects the variability of light.

By simulating their measured light flux in a software, their minimum performance can be calculated, allowing the lighting designer to shape the backdrop of the bright environment. And it is particularly interesting that especially in the case of transgenic plants in the capacity of bio-luminescence, the variability of the emitted light is enhanced by the perpetual variability of light sources, not only in terms of their luminous efficiency, but also in terms of their shape (low shrubs, tall trees, all of them continuously evolving), resulting to patterns of light, that will always change unpredictably.

This variability, both in lighting and in the natural environment, integrated into the urban space and the structured web, creates a new perspective for the transformation of contemporary architecture according to the principles of biophilia. And perhaps this is an alternative to restoring the circadian rhythm of beings from the predominance of artificial lighting. Within future urban space, the varying bio-light is expected to create a vivid atmosphere and stimulate the senses, in line with architectural fluidity.

Conclusion

Natural, artificial and "bio" light are constantly being transformed and the wide variety of light forms produced, which depend on various variables, constitute the variability of light as a single whole. But it is crucial for lighting designers to vary light levels in the same way natural light varies. The development of the idea of utilizing bioluminescence in the urban space, is offered in this direction, while at the same time ensuring the enrichment of the urban environment with vegetation is an essential sustainable approach that improves the microclimate and the quality of life of the inhabitants. The ever-changing appearance of plants, which as living organisms grow and evolve influenced by the weather, the season and the conditions of their maintenance, results in the continuous and unpredictable differentiation of light produced.

In the context of light pollution, designers should expand the alternations of darkness and light instead of a plenty lit environment. This means, that modern man must be re-educated to live with less light and more darkness at night, in order to mitigate the destructive effects of light pollution on the environment and to restore the magic of the incomparable variability of light.

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References

Ardavani, O., Zerefos, S., Doulos, L., (2019, September 18). Redesigning the exterior lighting as part of the urban landscape: The role of transgenic bioluminescent plants in mediterranean urban and suburban lighting environments. Journal of Cleaner Production, V.242, Is. 2020, https://doi.org/10.1016/j.jclepro.2019.118477, p.p. 1-14.

Armstrong, R., (2012). Living Architecture: Biology Can Remake Our Cities and Reshape Our Lives?, ASIN: B0076QQJMY. London, UK: TED Books.

Atari, N., (1982, June 21). Piezoluminescence phenomenon, Licence no 4462970385711. Physics Letters A, Vol. 90, Issues 1-2, p.p. 93-96.

Baker, N., Steemers, K., (2002). Daylight Design of Buildings, ISBN: 1873936885. London, UK: James & James.

Biswas, K. D,. Xu, X., Li, G,Y., Ma, L.B., Jiang, M.G., (2013, February 01). Modification of photosynthesis and growth responses to elevated CO2 by ozone in two cultivars of winter wheat with different years of release, Doi: 10.1093/jxb/ert005. Journal of Experimental Botany, V.64, Is. 6, p.p. 1485-1496.

Brenninkmeijer, S. (2008, August-September). The attributes of light: and what remains in the office space. Professional Lighting Design Magasine, Issue 62, p.p. 48-51.

Chu, K. (2005). Metaphysics of Genetic Architecture and Computation. in T. J. Estevez A., Arquitecturas Geneticas [II], ISBN: 0-930829-59-X (pp. 158-180). Barcelona: Lumen, Inc./ Sites Books.

Chu, K. (2011, January 23). www.archimorph.com. Accessed in https://archimorph.com/2011/01/23/karl-chu-genetic-architecture/:

Cruz., C. N., Cruz, F., Da Silva, A.F., (2018, December). Variation of the speed of light and a minimum speed in the scenario of an inflationary universe with accelerated expansion, https://doi.org/10.1016/j.dark.2018.10.005. Physics of the Dark Universe, V.22, p.p. 127-136.

Estevez A., Truco J., Felipe, S., Perez, I.P., Eeinstock, M., Menges, A., Douglis, E., Chu, K., Roche, F. (2005). Arquitecturas Geneticas [II], ISBN: 0-930829-59-X. Barcelona: Lumen, Inc.

Fanourakis, K. (2005). Genetic Improovement of Plants: Basic Principles . Athens, Greece: ION.

Gatti, F., Lipari, F., Jyiott, A., Nie, S., (2010, January New York). Genetic Architecture:Housing, Project of participation to 2007 Housing Competition. Evolo Magazine.

Gelder Van, N. (2004, October 24). Blue light and the circadian clock, Doi: 101136/bjo.2004.042861/045120. British Journal of Ophtalmology, V.88, Is. 10, p. 1353.

Gudkov, V. A., Andreev, N.S., Barmina, V.E., Bunkin, F.N., Kartabaeva, B.B., Nesvat, P.A., Stepanov, V.E., Taranda, I.N., Khramov, N.R., Glinushkin, P.A., (2017, August 31). Effect of visible light on biological objects: Physiological and pathophysiological aspects, Doi: 103103/S1541308X17030074. Physics on Wave Phenomena, V.25, p.p. 207-213.

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Hensel, M. (2013). Emergent Technologies and Design: Towards a biological paradigm for architecture, ISBN 0415493447. Oxon, UK: Routledge.

Hunter, T. (2017, July 03). Go Founder's Message. International Dark Sky Association, V, 1.

Ippolito, M. I., Innocenzi, V., b, Michelis, I., Medici, G., Vegliò, F., (2017, June 01). Rare earth elements recovery from fluorescent lamps: A new thermal pretreatment to improve the efficiency of the hydrometallurgical process, https://doi.org/10.1016/j.jclepro.2017.03.195. Journal of Cleaner Production, V.153,, p.p. 287-298.

James, A. B. (2000, June 30). Leaf orientation, light interception and stomatal conductance of Eucalyptus globulus ssp. globulus leaves (PMID: 12651502). Tree Physiology, Vol.20, Issue 12, p.p. 815-823.

Karlsson, T. (2015). Evidence based design of light characters and automatic light variation, for a classroom in Malmö. Malmö: Human Centric School Lighting.

Kerschbaum, F. L., Lebzelter, T., Lazaro, C., (2001, June 08). Multi-colour light variation of AGB stars observed with ISO, DOI: 10.1051/0004-6361:20010889. Astronomy and Astrophysics, V. 375, p.p. 527-538.

Littlefair, J. P. (1996). Designing with Innovative daylighting, ISBN: 1860810462. London, UK: BRE Publications.

Muneer, T. (2004). Solar Radiation and Daylight Models, ISBN:0750659742. Burlington, UK: Elsevier.

Niesewand, N. (2000). Lighting, ISBN 1840000880. London, UK: Mitchel Beazley.

Talà, A. (2010, February 19). 2nd Workshop - Plasmi, Sorgenti, Biofisica ed Applicazioni, Salento, Italy: University of Salento, ISBN: 978-88-8305-087-9. Bioluminescence of marine vibrios is sensitive to magnetic field (p.p. 22-27)., p.p. 22-27.

Tregenza, P., Wilson, M., (2011). Daylighting: Architecture and Lighting Design, ISBN 9780419-25700-4. New York, USA: Routledge.

Vivekananda, S. (1897). Seventeen lectures: From Colombo to Almora. Madras: The Vyjayandi Press.

Yan-Hong, Z., Ying-Yun, Z., Xin, Z., Hai-Jing, Y., Kai, S., Jing-Quan, Y., (2009, January 24). Impact of Light Variation on Development of Photoprotection, Antioxidants, and Nutritional Value in Lactuca Sativa L, DOI: 10.1021/jf8040325. J Agric Food Chem, V.57, Is.12, p.p. 5494-500.

Yot, R. (2010). LIGHT for Visual Artists, ISBN: 978 1 85669 660 9. London: Laurence King Publishing.

Zielinska-Dabkowska, M. (2013, December). To light or not to light. Exterior illumination of tall buildings and bridges and its negative impact on the life of birds and fish – what professional lighting designers need to know. Professional Lighting Design Magazine, V.91, p.p. 39-43.

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Constantinos Miltiadis is a transdisciplinary architect whose research focuses on virtual spatiotemporal environments as a means of expanding the scope of architecture practice and aesthetics. He is currently an arts doctorate fellow at Aalto University, Helsinki. Constantinos has studied architecture at NTU-Athens, architectural computation and philosophy the Chair for CAAD ETH Zurich, and pursued studies in computer music at the Institute of Electronic Music of KU Graz. Between 2015 and 2019 he was assistant professor at the Institute of Architecture and Media of TU Graz where he founded the "Virtual Spaces Master Studio." Constantinos' work has been presented in exhibitions, seminars, published in academic conferences and by international press, and received awards in international competitions. In addition, he has taught creative programming and experimental computation in academic contexts, as well as in conferences and festivals. He was also founder and curator of the "IAM Open Lecture Series" as well as co-founder and co-curator of the experimental electronic music event series O.

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Interested in theorical knowledge as a key to develop the architectural practice, he has been involved in the academic research since graduated. He is currently completing his PhD program in UPV with a research focussed in concrete shells structures. Previously, he completed his M.Arch studies in the Universidade Federal do Rio de Janeiro, Brazil, in 2015. He has taught and being involved in several research and study programs of Universitat Politècnica de Valencia (Catedra Blanca Coordinator, EnBlanco Magazine Coordinator) and Istituto Europeo di Design - IED (MA. DE.IN - methodology), in Rio de Janeiro.

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