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Architecture Aesthetics Evaluation Methodologies of Humans and Artificial Intelligence

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Abstract

Architecture is a discipline that contributes to science when it is related to the construction of buildings and art when it is related to the pleasure of the viewer and the user of these buildings. Aesthetics is the discipline that studies the pleasure of humans and how people approach the world through their senses. Human-computer interaction advances every day in our life. This paper discusses concepts behind architecture aesthetic evaluation methodologies by humans and Artificial Intelligence (AI). The first part of this paper identifies some philosophers with their theories about aesthetics that helps in understanding how people were concerned about art and how they relate it to their life. Also, the discussion about neuro-aesthetics helps in studying the biological basis of aesthetic experience. The second part discusses recent applications of AI in evaluating aesthetics and how people interact with AI and how to build a reliable AI system that people will enjoy interacting with it. The third part distinguishes AI methods that are used in architecture that help in storing and analyzing huge amounts of data that the human brain can`t interpret. Finally, the paper concludes with the main guidelines for establishing an integrated system for architectural aesthetics evaluation.

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1. Introduction

Aesthetics have been a subject of discussion over many centuries. The world now is being computerized whether in performing repetitive tasks or in performing creative tasks that were once limited to a small group of people like artists. The architecture was not far from this technology. Coupling architecture and artificial intelligence systems help in reaching more mature architecture products and retrieving principles that were lost by the speed of life. This integration is achieved by understanding the way both the human brain and AI work in the domain of aesthetics and architecture.

Architecture aesthetics come as a principle when designing buildings [1]. Its guidelines differ based on the features of the era. Nowadays, as everything in our life depend on the automation of tasks, studying how we can take advantage of this technology let our architecture contribute to the evolution of human everyday life.

This paper contributes to:

1. Identify some philosophers with their theories about aesthetics that helps in understanding how people in history were concerned about art and how they relate it to their life. “Neuro-aesthetics” is a new area of research that helps in studying the biological basis of aesthetic experience to build a reliable AI framework that can generate evaluations with a high degree of trust.
2. Distinguish AI concepts for mimicking human brains process and computational aesthetics and understanding how people reason about AI technologies.
3. Classify architecture and AI's recent integration techniques in designing buildings.

The remainder of this paper is organized as follows; section 2 introduces the evolution of the aesthetic experience of humans throughout history. The implementation of computational methods in the aesthetics field is discussed in section 3, the interaction between architecture and artificial intelligence is presented in section 4, and the guidelines for the integrated system are developed in section 5. Finally, section 6 concludes this paper.

2. Aesthetics and Architecture experience

2.1. Aesthetics History

In the 18th century, the word “aesthetics” was introduced in the German language by the philosopher Baumgarten and became a branch of philosophy [1]. The word "aesthetics" derives from the Greek "aisthetikos", meaning "sense of perception" [1]. Philosophers from the classical period tried to explore the world around them and how humans interact with it. As Plato (c.427–347 BC) was interested in ethics, metaphysics, and representational arts [2]. The English version of his writings about “Kalon” was related to the word beautiful [3]. Plato came up with the theory of form (a set of parameters to compare with knowledge) which represents his aesthetic evaluation criteria [4]. Aristotle’s (384–322 BC) writings relate aesthetics, as his fellows argued, with mimetics and that beauty is related to nature or represents patterns from nature [5]. Aristotle explains nature in a teleological model that is consciously free from psychological factors like desires, beliefs, and intentions [6]. Anthony

Ashley Cooper, the Third Earl of Shaftesbury (1671-1713) was an English philosopher, known also as Shaftesbury, who had the first spark of 18th-century thoughts, the aesthetic sense for him is like the moral sense, having universal standards of judgment [3]. Also, according to Immanuel Kant (1724–1804), a German philosopher from the 18th century, beauty is subjective and universal (i.e. certain things are beautiful to everyone) [7]. George D. Birkhoff (1884 – 1944) defines the aesthetic measure (M) that was published in 1933 with a function M =f (O/C) where O represents order, the pleasing or displeasing features that can be recognized in the object, and C is the complexity of the effort that the object demands of the perceiver [8]. Birkhoff was concerned in his function with two parameters (a) the perception of the viewer which represents the C in his function, and (b) the object itself which represents the O. These two parameters give the aesthetic measure M which rewards the perception and the understanding of the object [9].

In Summary, classical philosophers found that beauty is related to the object, whether they treat it as one object, or some parts related together in proportion and harmony. Modern philosophers see beauty in artworks related to nature or a reference that humans compare with their previous knowledge with the aid of their personalities and taste.

2.2. Architecture and Aesthetics

Vitruvius identifies the six principles composing the art and science of architecture: Order (the form of parts according to the whole picture), arrangement (like order but with the addition of the appropriate places for each part), symmetry (the harmony of parts among each other), Eurythmy (the use of numerical ratios), propriety (the usage of the building), and economy [10]. And then he reduces these principles to three, durability (Latin firmitas), convenience (Latin utilitas), and beauty (Latin venustas) [11]. This research work focuses on the last principle which is beauty. According to Vitruvius, the work of architecture is beautiful when it is pleasing and in good taste by applying proportion, order, and symmetry principles [11]. Leon Battista Alberti (1404–1472), an artist from the renaissance era, saw beauty as the appropriate fitting of every part of an object (Scruton, 2011). The Ciceronian notion of concinnitas or concinnity is Alberti`s concept of beauty in architecture [11]. Concinnity demonstrates three qualities number, outline, and position [12]. The number is related to the parts consisting of the building, the outline represents the scale of parts, and the position is related to their correct placement of them. By applying concinnity, Alberti conceived the fundamental rule of nature which is the ideal image as Plato argued in his theory of forms, that there is a Form that we compare the instance to it [11].

A recent study by Ghom and George concluded that aesthetics is no longer about visually appealing architecture instead, it is a combination of nine parameters which are Spatial organization, Functional efficiency, Social and psychological dimensions, Environmental aspects, Sustainability, Technology, Economic aspects, Legal frameworks and rating systems, and Durability and maintainability [13].

Table 1 summarizes some of the aesthetics and architecture directions throughout history.

Table 1 Aesthetics and Architecture Thinking (By authors)

	Notion
Plato	Universal & Proportion
Aristotle	Order, Symmetry/Proportion, definiteness, and Scale
Vitruvius	Order, Arrangement, Eurythmy, Symmetry, Propriety, and Economy
Alberti	Number of parts, Placement of parts, and concinnitas (Proportional relationship)
Shaftesbury	Individual perceiving with global comparison
Kant	Judgment of taste, disinterestedness, and universality.
Birkhoff	The aesthetic measure is order over complexity
Modern	Spatial and Sustainable function

So, Architecture was once related to the principles of art and beauty but nowadays, it turned into a scientific and sustainable endeavor where it doesn`t concern with the human soul. Architecture, as mentioned before, combines art and science and these two concepts can`t be separated, we must have sustainable, and well-functioning buildings, also we must design buildings that give viewers and users pleasure. And that will be obtained by redefining how we deal with aesthetic values and experience in the architecture domain.

2.3. Neuroaesthetics and the Aesthetic Experience

Neuroaesthetics is a discipline that studies the biological and neural bases of aesthetic experiences [14]. Gustav Theodor Fechner, known as the founder of experimental aesthetics, came up with three methods to be used, method of choice which humans select the most pleasing among several objects, method of production that humans can produce objects that were believed to be pleasing, and method of use that humans analyze objects concerning some of their characteristics [15]. V.S. Ramachandran and William Hirstein presented a theory about the aesthetic experience by introducing 8 laws of artistic experience, they are: the peak shift principle, isolating, grouping, contrast, symmetry, the generic viewpoint, perceptual problem solving, and art as a metaphor [16]. In 2003, and enhanced in 2014, Chatterjee came up with a model that was based on what he called an aesthetic triad (figure 1) that consists of three neural systems: Sensory-motor, Meaning–knowledge circuitry, and Emotion-valuation ([17] & [18]). In 2015, Redies propose a model of visual aesthetic experience that combines formalist and contextual aspects of aesthetics. His model was based on Chatterjee`s model. It is based on an external stimulus that triggers perceptual processing paralleled with cognitive processing that is related to the content information and context with the evoking of emotions to define the degree of an aesthetic experience [19].

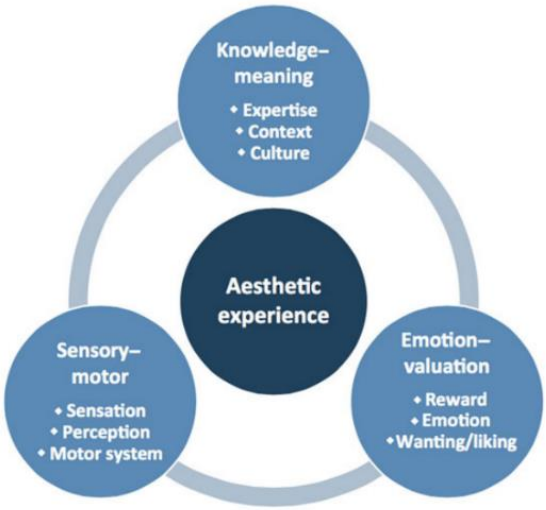

Fig. 1. The aesthetic triad [20]

In summary, aesthetic experience is divided into three main processes (as in Chatterjee`s model) perception, emotions, and cognition. Perception is where humans get to know what they see through their senses, emotions are released to define whether the individuals like or dislike what they see, and lastly, the cognitive process is where humans relate what they saw with their previous knowledge and experience.

2.4. How Humans Experience Architecture Aesthetics

Based on aesthetics and architecture theories that were discussed in the previous section, the notion of the human experience of aesthetics differs from the classical to the medieval to the present and will differ in the future. Now, the human experience of aesthetics could be demonstrated by the concept of Neuroaesthetics which is interpreted into three phases perception, emotion, and cognitive processes. As those three phases are related to the way we deal with the technology in our hands, such as products advertisement.

3. Machines and Aesthetics

The origin of Artificial Intelligence can be traced to the famous Turing Test by Turing in 1950, which explains the concept of Machine Learning [21]. The expression of Artificial Intelligence was developed in the workshop held on the campus of Dartmouth College in 1965 [22]. This marks the beginning of the age of AI. This paper discusses Cognitive Computing and Computational Aesthetics as two non-human technologies to understand what machines need to mimic human tasks in aesthetics evaluation. Then in sections 3.3 and 3.4., the paper formulates what humans need when they are dealing with an automated system in creative tasks.

3.1. Cognitive Computing

Cognitive computing is first defined by Valiant as “a discipline that links together neurobiology, cognitive psychology, and artificial intelligence” [23]. The goal of cognitive computing is to simulate human processes in a computerized model. The computer can mimic how the human brain works by using data mining, pattern recognition, and natural language processing. Cognitive computing is not a single technology, it uses artificial intelligence and machine learning techniques to predict, understand, and make sense of information. This system relies on the human-machine interaction that represents the basis [24]. Building a cognitive service is divided into three steps: ground truth data, build models, and finally train these models. The output of this service reaches the same “true” as the ground truth data [25].

3.2. Computational Aesthetics

Computational aesthetics, a subfield of computer vision, aims to evaluate visual objects automatically and aesthetically like humans [26].

Early studies on computational aesthetics mainly focused on hand-crafted features such as color, luminance, complexity, and symmetry, which were described as low-level image features. Classifiers were constructed by a training set that takes image features as inputs and manual image quality assessment results as output. So, predicting aesthetic evaluation results with trained classifiers is achieved by computational models [26].

3.3. People’s interaction with Artificial Intelligence

The research of Changhoon Oh was introduced to study the impact of how people reason about AI [27]. The results show that in creative or subjective fields, the need for an explanation about reasons why the AI system gives that score is a necessity so, there will be useful communication and interpretation between the two sides on the given scores. Also, experts in the field of study, photography, were the closest scores to AI, which gives some confidence that AI can help mimic the judgments of humans in a certain defined way. DuetDraw [28] is another AI interface that allows users to interact with technology but this time to draw pictures collaboratively with an AI. Users prefer to have the lead when collaborating with an AI agent and want detailed explanations when they want.

3.4. What people need from automated systems

People prefer to interact with a system that can automatically run but they lead it, they prefer to take the final decision, and they get frustrated when a system takes it instead of them or make an overall evaluation without interpretation of how it concludes the result. A reliable AI system should have two main features:

a. Let users lead the system, by choosing the way the system will help.
b. An interpretation of each decision made by it should be monitored.

These features will build a complex system, with a lot of data sets fed into it. So, the division of steps should be applied and then a calibrated technique to define the weight of each step to produce an overall rating system will simplify the system and reduce the time of running the system.

4. Architecture and Artificial Intelligence Interaction

Architecture shouldn`t be recognized as an artwork or a function-based work only, architecture serves humans and should be created in a way that helps users live a better life and get pleasure when they interact with the built environment. Using computational methods helps ease the process of designing not mechanization of the process and the product. The next 2 sections identify the recent technologies when dealing with architectural sketches and drawings.

4.1. From 2D sketch to 3D modeling

From Sketch to 2D images Using CycleGAN: The sketch-to-image translation system is a system that translates a sketch into a 2D image that contains image features that could lead to Sketch-based modeling [29]. Sketch-based modeling was introduced by judging 3D geometric shapes based on their contour.

Reconstruct 3D building from sequential images and Building Parsing: Agisoft Metashape is a standalone software that can be used for generating 3D spatial data based on RGB photographs [30]. It can reconstruct buildings based on images taken from the real environment. As an application for this software, the Digital Hybrid project produced one augmented living space from several real living spaces [31]. Building parsing is a related topic to computer vision that can be used in the 3D reconstruction of streets. It is a challenging problem due to not only the difference between building styles but also the vast variation of image features and the presence of non-building elements in images ([32], [33], and [34]).

4.2. Classification of Architectural Styles and Drawings recognition

Architectural styles classification: By using a deep convolutional neural network (DCNN), the system can identify and generalize style features from the dataset. Convolutional layers range in a hierarchy from simple features such as edges and shapes to complex ones like windows and roofs. The weight of each feature is compromised automatically through the learning process by a separated neural network to discover the optimal ones for the connection between layers. The learning process of this system consists of labeled images with the architect's name [35].

Architectural Drawings Recognition: generative adversarial network (GAN) is a powerful tool when it comes to recognizing and generating images based on the labeled dataset [36]. GAN has several models like PIX2pixHD for the recognition of architectural plans and the regeneration of new ones.

4.3. AI interaction with architecture

The way AI is integrated with architecture is mostly to measure tangible indicators. Concepts and abstract dimensions should be measured with them also. Expert opinions for measuring subjective indicators, diversity of data for building and features recognition, and their consistency for generative tasks form the bases of any AI system for architecture.

5. Guidelines for Integrated Architecture Aesthetics Evaluation system

Establishing an integrated system for architecture aesthetics evaluation helps in regaining the lost benefits of designing architecture through its basic concepts of utility, structure, and beauty by Vitruvius. Guidelines for achieving this is building a system with ground truth data that resembles the way humans experience aesthetics and architecture.

Firstly, the perception of the building can be interpreted by a quick classification of the building perceived, which is its style. This classification is based on the low-level features, materials, building outline, and opening style. This stage requires classified data based on architectural styles with definitions of their features which requires computer vision techniques. Secondly, an analysis of the high-level features, proportions, solid-to-void ratios, and complexity, occurs through the experience and knowledge of the perceiver about the style in which he relates the building. This stage is coupled with deep learning as those features will require complex analysis of building styles and its feature. Lastly, an overall rating based on a mature analysis of the building (objectivity), the relation to the context, and its function, combined with the emotions and preferences of the perceiver (Subjectivity) is produced. The last stage requires cognitive computing service as this service is based on the interaction between humans and machines.

6. Conclusion

This paper first introduced aesthetics and architecture theories with the aid of Neuroaesthetics for explaining humans' aesthetic experience, i.e., perception, emotion, and cognitive processes. Then, computational aesthetics techniques are proposed, and the way people interact with AI and what they need when interacting with it, i.e., that people lead the process and interpretation of AI decisions. Furthermore, the recent application of AI in perceiving and generating architecture was introduced to identify the next step in computing architecture. Finally, guidelines for establishing an integrated architecture aesthetics evaluation system between humans and AI were developed as first, architecture styles classification based on computer vision techniques, then deep learning models for high-level features analysis of the buildings, and in the end, cognitive computing service for the human-machine interaction.

This paper helps in assembling architect and AI methods for establishing an integrated system for architecture aesthetics evaluation from the architecture side. Further research into how to combine computer vision, deep learning, and cognitive computing and its interpretation is required for the realization of this system.

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