Eye-Tracking Applications in Architecture and Design

Subjects: Computer Science, Hardware & Architecture

Contributor: Alexandros A. Lavdas

Eye-tracking is a biometrics technique that has started to find applications in research related to our interaction with the built environment. Depending on the focus of a given study, the collection of valence and arousal measurements can also be conducted to acquire emotional, cognitive, and behavioral insights and correlate them with eye-tracking data. These measurements can give architects and designers a basis for data-driven decision-making throughout the design process. In instances involving existing structures, biometric data can also be utilized for post-occupancy analysis. This entry will discuss eye-tracking and eye-tracking simulation in the context of our current understanding of the importance of our interaction with the built environment for both physical and mental well-being.

biometrics eye-tracking architecture design virtual reality neuroaesthetics neuroarchitecture

History of Eye Tracking

The first documented systematic interest in eye movements can be found in Aristotle [1], with the first experimental setup attributed to Prolemy, who had devised a board for examining the range of binocular single and double vision [2]. This topic was later examined in detail by Alhazen [3] and approached systematically in the modern era first by Wells [4]. During the 19th century, interest in the systematic study of eye movements increased [5][6], and in 1879 the French ophthalmologist Louis Émile Javal noticed that readers' eyes do not scan a text with a constant speed while reading but make quick movements interrupted by short pauses instead—making the first description of the motion known as saccades [7]. In 1901, Dodge and Cline introduced a non-invasive eye tracking technique using light reflected from the cornea, recording eye position onto a photographic plate [8]. However, it only recorded eye positions on the horizontal plane and required the participant's head to be motionless.

A few years later, motion picture photography was first used to record eye movements in two dimensions [9], utilizing a small speck of white material that had been placed on the participants' eyes. A more intrusive approach was that of Edmund Huey in 1908, utilizing an apparatus that could be used to track eye movement during reading. Subjects had to wear a type of contact lens that had a small opening in front of the pupil and was connected to a pointer that changed its position in response to the movements of the eye [10].

The first dedicated eye-tracking laboratory was founded in 1929 by Edmund T. Rolls at the University of Cambridge, marking the recognition of eye tracking as a field of study. A number of additional advances in eye tracking systems were made during the first half of the twentieth century by combining corneal reflection and motion picture techniques (see [11] for a review). In one of them, in the late 1940s, motion picture cameras were used to study the movements of pilots' eyes as they used cockpit controls and instruments to land an airplane, in what was the earliest application of eye tracking to usability engineering, i.e., the systematic study of users interacting with products, aimed at improving product design [12]. In the early 1950s, the development of the electrooculogram (EOG) marked a new chapter in the field of eye tracking, providing a more accurate method for tracking eye movements than earlier techniques. The EOG measures the cornea-positive standing potential relative to the back of the eye. It uses skin electrodes attached outside the eye near the lateral and medial canthus, allowing the potential to be measured when participants move their eyes a set distance in the horizontal plane [13]. In the 1950s and 1960s, Alfred Lukyanovich Yarbus pioneered the study of saccades when viewing complex images by recording the eye movements performed by observers presented with natural objects and scenes [14]. An important finding was that gaze fixations can be influenced by the instructions given to an observer, demonstrating that low-level, stimulus-driven guidance of attention can be overridden by high-level factors [15].

The pupil center corneal reflection technique (PCCR) was developed in the 1970s and became a standard method for tracking eye movements because of its accuracy and ease of application [6]. It involves using specialized glasses that shine near-infrared light directed at the pupil, creating reflections that can be detected in both the pupil and the cornea. An infrared camera incorporated in the glasses tracks the vector between the cornea and pupil, determining gaze direction. This technology allows researchers to observe the participants' natural gaze and attention in various environments. Other, less frequently used methods have also been developed [5].

The first eye-tracking study of images, including images of architecture, was performed as early as 1935 [16], with the first study dedicated to architecture appearing in the 1970s, followed by a handful of studies in the following years (see [17]). The use of eye tracking as a tool for investigating our interactions with the built environment has grown very rapidly in recent years, and the following paragraphs discuss some of the relevant studies, especially in the context of evidence-based design for promoting psychosomatic health.

References

1. Ross, W.D. The Works of Aristotle; Clarendon: Oxford, UK, 1927; Volume 7.
2. Lejeune, A. L'Optique de Claude Ptolémée dans la Version Latine d'après l'Arabe de l´Émir Eugène de Sicile; Université de Louvain: Louvain, Belgium, 1956.
3. Sabra, A.I. The Optics of Ibn Al-Haytham; TheWarburg Institute: London, UK, 1989.
4. Wells, W.C. An Essay upon Single Vision with Two Eyes: Together with Experiments and Observations on Several Other Subjects in Optics; Cadell: London, UK, 1792.

5. Wade, N.J. Pioneers of eye movement research. Iperception 2010, 1, 33–68.
6. Jacob, R.J.K.; Karn, K.S. Eye tracking in Human-Computer Interaction and Usability Research: Ready to Deliver the Promises. In The Mind's Eye: Cognitive and Applied Aspects of Eye Movement Research; Hyönä, J., Radach, R., Deubel, H., Eds.; Elsevier Science: Amsterdam, The Netherlands, 2003; Volume 2, pp. 573–605.
7. Javal, E. Essai sur la physiologie de la lecture. Ann. D'oculi-Stique 1878, 80, 97–117.
8. Dodge, R.; Cline, T.S. The angle velocity of eye movements. Psychol. Rev. 1901, 8, 145–157.
9. Judd, C.H.; McAllister, C.N.; Steel, W.M. General introduction to a series of studies of eye movements by means of kinetoscopic photographs. In Psychological Review, Monograph Supplements; Baldwin, J.M., Warren, H.C., Judd, C.H., Eds.; The Review Publishing Company: Baltimore, MD, USA, 1905; Volume 7, pp. 1–16.
10. Huey, E.B. The Psychology and Pedagogy of Reading, with a Review of the History of Reading and Writing and of Methods, Texts, and Hygiene in Reading; Macmillan: New York, NY, USA, 1908; p. xvi+469.
11. Mackworth, J.F.; Mackworth, N.H. Eye fixations recorded on changing visual scenes by the television eye-marker. J. Opt. Soc. Am. 1958, 48, 439–445.
12. Fitts, P.M.; Jones, R.E.; Milton, J.L. Eye movements of aircraft pilots during instrument-landing approaches. Aeronaut. Eng. Rev. 1950, 9, 56.
13. Creel, D.J. The electrooculogram. In Handbook of Clinical Neurology; Levin, K.H., Chauvel, P., Eds.; Elsevier: Amsterdam, The Netherlands, 2019; Volume 160, pp. 495–499.
14. Yarbus, A.L. Eye Movements and Vision; Haigh, B., Translator; Plenum Press: New York, NY, USA, 1967.
15. Tatler, B.W.; Wade, N.J.; Kwan, H.; Findlay, J.M.; Velichkovsky, B.M. Yarbus, eye movements, and vision. Iperception 2010, 1, 7–27.
16. Buswell, G.T. How People Look at Pictures: A Study of the Psychology and Perception in Art; University Chicago Press: Chicago, IL, USA, 1935.
17. AAlto, P.; Steinert, M. Emergence of eye-tracking in architectural research: A review of studies 1976–2021. Archit. Sci. Rev. 2024, 1, 1–11.

Retrieved from https://encyclopedia.pub/entry/history/show/128355