abstract
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IBN AL-HAYTHAM AND THE ORIGINS OF MODERN IMAGE ANALYSIS

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The noted science historian, David Lindberg, wrote that "Alhazen was undoubtedly the most significant figure in the history of optics between antiquity and the seventeenth century." Impressive and accurate as this characterization of Ibn al-Haytham (Latinized as Alhazen or Alhacen) is, it significantly understates the impact he had on areas as diverse as the theology, literature, art, and science of Europe. The work on computerized image analysis that I discuss elsewhere at this conference can be rightfully seen as the latest link in an unbroken chain that connects 21st century optical scientists with our intellectual progenitor, Ibn al-Haytham; a span of almost 1000 years.

Although records indicate al-Haytham wrote nearly one hundred works, many have not survived, and today he is primarily known for his writings on geometrical optics, astronomy, and mathematics. However, it is with his landmark seven-volume ***Kitāb al-Manāzir*** [***Book of Optics***], published sometime between 1028 [418 A.H.] and 1038 [429 A.H.] that he made his most important contribution to the culture as well as the science of Medieval and Renaissance Europe. In my estimation, his contribution to the development of Western thought of the period is comparable to that of those prototypical Renaissance figures Giotto, Brunelleschi, Michelangelo and Leonardo da Vinci.

Prior to al-Haytham, theories of vision could be classified into one of three categories: extramission, intromission, or a combination of the two. Extramission theories required some sort of illuminating particles be emitted by the eye. Euclid is one well-known scholar associated with this category of theory. Although there are obvious flaws with extramission theories, they do get the geometry right, with a one-to-one correspondence between points on the object and points on the eye. To elaborate one important connection between al-Haytham and western scholarship, Euclidian geometry, as influenced by al-Haytham's writings, is taught in every American and European school to this day.

Intromission theories of vision, with Aristotle as a prominent proponent, had objects continuously sloughing off replicas of themselves that then traveled to the eye of the observer. These theories avoided one obvious problem of extramission, that of near and far objects simultaneously being visible the moment the eye is opened, but at the expense of introducing other difficulties. Plato was a proponent of a combination of these theories, having light from a source like the sun, along with some sort of short-range emission from the eye, activate the air to let replicas travel to the viewer.

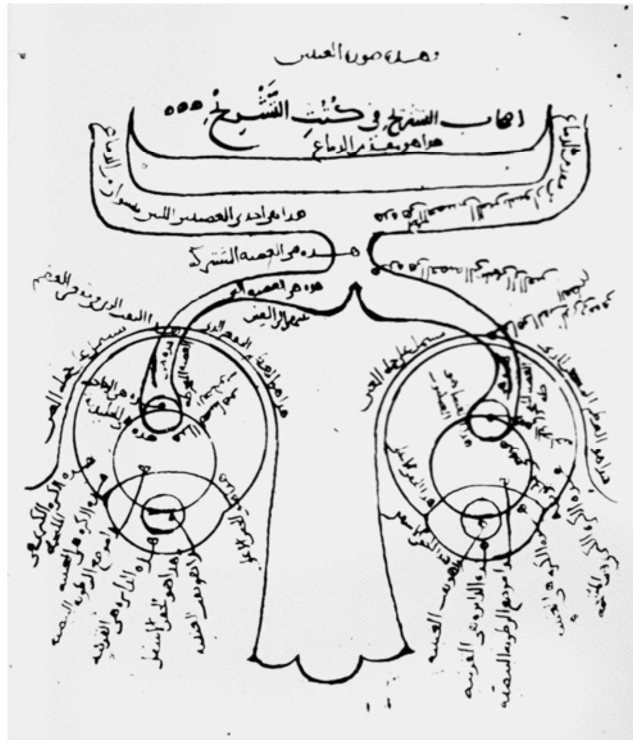

Figure 1 Ibn al-Haytham's description of the human visual system. From a 1083 [475 A.H.] copy of his ***Kitāb al-Manāzir*** in the Süleymaniye Library, Istanbul.

The genius of Ibn al-Haytham was not that he recognized there were problems with all existing theories of vision, since others before him had realized this as well. His genius lay in the fact that he found the solution that had eluded the best minds of antiquity. In addition, he recognized the crucial role of psychology (or how the mind interprets the world), and realized that to understand vision we must understand not only the geometrical optics of the eye, but also the psychological processes that interpret what the eye collects. Discussion of the psychology of vision occupies a significant part of his ***Kitāb al-Manāzir***, the first time this topic was addressed in a modern scientific fashion.

Al-Haytham did get one important aspect of vision wrong. The fact an image projected by a lens is upside down and flipped right-to-left apparently was more than he could accept in a theory of vision, even though it is contained within his optical formalism. However, Leonardo da Vinci also failed to accept this when he approached the problem much later. Five hundred years later, Kepler directly followed al-Haytham's formalism to its inevitable and logical conclusion in developing the theory of the retinal image. Al-Haytham's work was republished in Latin as ***Opticae thesaurus: Alhazeni Arabis…*** in 1572, after the advent of the printing press, and is explicitly referenced in the writings on optics by Descartes and Fermat as well as Kepler.

The ***Kitāb al-Manāzir*** was first translated into Latin as ***De aspectibus*** sometime prior to the 1230s, and the proposals contained within it are used in the optics manuscripts ***Perspectiva*** by Roger Bacon (c1265), ***Perspectiva*** by Witelo (c1275), and ***Perspectiva communis*** by John Pecham (c1280). Although today we think of these scholars as optical scientists, they approached their work as theologians. In each case their interest in optics was motivated by their interest in vision, which in turn was motivated by religious belief. In essence, they hoped that developing an understanding of physical vision would provide them with insights into spiritual vision. Hence, the developments in geometrical optics that came from their studies were actually incidental to their religious drive to understand spiritual vision.

The onset of the Protestant Reformation is typically dated to 1517, when the priest Martin Luther published his '95 Theses' criticizing the Christian 'Catholic' Church. Luther, however, built directly on the efforts of the 14thc priest, John Wycliffe, who is credited with being the intellectual progenitor of the Reformation. Like his fellow priests of the time, Wycliffe used optics in his theology. For example, he classified spiritual vision as direct, refracted, and reflected, and referred to al-Haytham in discussing the seven deadly sins in terms of the distortions in the seven types of mirrors analyzed in ***De aspectibus***.

Turning from religion to literature, one of the most widely read works in the French language for 300 years after its publication in c1275 was the poem ***Roman de la Rose*** [***Romance of the Rose***] by Guillaume de Lorris and Jean de Meun. Four pages in this poem describe the properties of mirrors, with the text exhibiting a surprisingly non-trivial understanding of optics. One short passage from these four pages makes its debt to al-Haytham (Alhazen) quite clear:

> *"Alhazen, the nephew of Hunain, was neither a fool nor a simpleton, and he wrote the book of 'Optics', which anyone who wants to know about the rainbow should know about. The student and observer of nature must know it and he must also know geometry, the mastery of which is necessary for the proofs in the book of 'Optics'."*

One hundred years later Geoffrey Chaucer produced his ***Canterbury Tales*** (written over the period 1387–1400), the first major piece of literature in the vernacular English language. Chaucer, too, was influenced by his understanding of the content of al-Haytham's works on vision and optics, as is clear from the following passage:

> *Then they referred to many a learned tome*
> *By Aristotle and by Alhazen*
> *And Witelo and other learned men*
> *Who when alive had written down directives*
> *For use of cunning mirrors and perspectives,*
> *As anyone can tell who has explored*
> *These authors.*

Al-Haytham not only had a direct influence on the development of European science, theology, and literature, but it also can be argued he had an indirect influence on art, as revealed by recent discoveries. The painter David Hockney in his book ***Secret Knowledge*** (Thames and Hudson, 2001) made fascinating observations about some of the best-known paintings of European art that affect long-held understandings of the emergence of realism at the dawn of the Renaissance. Building on these observations, Hockney and I developed the foundations of a new methodology for extracting information from complex, optics-based images. I report some of the applications of this work to computerized image analysis elsewhere at this conference. Briefly, we showed that certain features within very well-known paintings (e.g. the chandelier in 'The Arnolfini Marriage' by Jan van Eyck) are based on optical projections. In addition to van Eyck (c1430), we have found evidence of the use of optical projections within works by later artists, including Bermejo (c1475), Holbein (c1530), Caravaggio (c1600), de la Tour (c1650), Chardin (c1750) and Ingres (c1825). These examples demonstrate a continuum in the use of optics by artists from c1430, arguably initiated as a result of Ibn al-Haytham's influence, until today.

Ibn al-Haytham's intellectual contributions are intimately threaded throughout the core of post-Medieval Western culture. It is indeed unfortunate that each academic discipline today is largely unaware of the overall scope of his influence. To work toward rectifying this, I donated the initial funds necessary to establish "The Ibn al-Haytham Scholarship" in my College of Optical Sciences. The College is now seeking donations to endow this scholarship, which then will be used to attract the best and brightest graduate students from around the world to work on problems in the tradition of one of the most influential scientists of the past 1000 years. Please contact me if you would like to help.