APPLICATION OF INVERSE SQUARE LAW IN PHOTOGRAPHY

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ABSTRACT

Photography is an aspect of the visual arts that falls within the gamut of Graphics. Even though photography is mostly viewed as an art form, there are numerous laws of physics evolved in producing an artistic expression. It is instructive to note here that Art is even more of science than the pure arts; reason is that all aspects of visual arts have some scientific inclinations be it drawing, painting, sculpture, ceramics, textiles or graphics. It is important for visual artists and photographers to understand the scientific bases of photography. These days almost everybody has become a photographer of some sort in the sense that even the smallest mobile phone comes with digital camera. Selfies (pictures taken personally) is now a daily happening in private and public spaces; we do this photography practices without recourse to the basic principles involved. It is against this backdrop that this paper takes a look at the scientific background of a very sensitive aspect of the visual arts which is photography. This paper showcases the application of the Inverse Square law in photography as propounded by Sir Isaac Newton.

Keywords: Photography, Physics, Law, Inverse, Square, Visual, Art.

Introduction

The whole world has become a global village courtesy of the digital revolution and information technology. This digital revolution revolves round everything that is happening in our society and this includes the art and science of photography. For thousands of years man attempted to capture and preserve what he saw with his eyes. This can be seen by the attempts of the cavemen to draw pictures of hunting expeditions on the walls of their caves. Until recently, paintings and drawings were the only means that man had of keeping visual records. For instance, the pictures of Jesus Christ we are now seeing everywhere were the contraption of the painters and draftsmen as camera was not in existence during the times of Jesus Christ. It was not until the mid-eighteenth century that the first process for producing permanent photographic images was developed; this was done by the French painter, Daguerre. Dennis and Jenkins [1] posited that an American, George Eastman (1854-1932) was the person who first made photography practical for everyone by producing roll film and standardizing camera sizes in which the film would fit. Since Eastman's developments in the late 1800s, rapid and important technological advances have taken place in photographic equipment, materials and processes.

Photography influences each day of our lives; the photographs in books, newspapers, magazines and other periodicals help us understand and feel more a part of the scene. Photographs in catalogs and advertisements permits us to see what we are buying. Photographs assist scientists with exploration of the unknown; help doctors treat patients; assist engineers with design and construction of buildings, roads and bridges; helps law enforcement officers track down criminals and solve crime-related problems and make it possible for people to remember past events, experiences and occurrences, helps the voting public to know who they are to vote and what he or she has contributed to their society.

These days nearly everyone owns a camera due to the proliferation and availability of mobile phones which comes in different shapes, sizes, camera mega-pixels and prices. Even the most modestly priced camera phone produce excellent photographs, if handled correctly.

Even at this, there is a considerable difference between the mobile phone camera and the professional digital camera prominent of which is that the mobile phone camera's sensor sizes are much smaller as compared to that of the professional camera; there might be a mobile phone with a 48 megapixel sensor and measuring less than 5mm which is 0.508cm meaning that even the 48 million pixels are just 0.8 microns; this is somehow too tiny as compared to a DSLR (Digital Single Lens Reflex) professional camera with a 48 megapixel sensor and a size which is probably larger and with a full frame sensor of 36mm (3.5814cm) wide which is larger and more responsive to light.

The development of highly automated processing equipment before the advent of colour technology made it possible for a person to have black-and-white film developed and photographs made very economically. This automated processing procedure permits a person to have film developed within twenty-four hours. Before the advent of the present day digital camera that is hundred percent automated both in focus, timing and shutter speed specifications, a photograph was produced by exposing film in a camera, developing the film to make a negative and making a positive print on a photo-sensitive paper from the negative.

In this paper, this writer will not want to dwell in detail as to the different types of camera but suffice it to state here that initially, there was the box camera, twin camera, miniature camera, single-lens reflex camera, press camera and the view camera. It is instructive to state here at this point that all the above-mentioned types of camera are now obsolete just as their inputs and materials. Today, due to advancement in digital technology, the professional digital camera has taken over, including the ones accompanying the various phones. Interestingly, the phones that we have these days and computer software enable us to tweak our photographs into various forms and shapes using various filters.

Photography: The Beginning

It is the art and science of capturing images using special gadget known as the camera. Photography could also be described as "drawing with light" because light is very essential when we take shots, even in the face of total darkness, we need a flash to illuminate the object of focus otherwise no image would be captured. Photography or "light drawing" as it is sometimes referred to is a combination of technique and visual observation.

Photography and graphic communications have been closely linked beginning with the first experiments to capture an image of nature with the camera. Joseph Niepce (1765-1833), a Frenchman first produced a photographic image and began his research by seeking an automated means of transferring drawings onto printing plates. As a lithographic printer of numerous religious images, Niepce searched for a way to make plates other than by drawing. In the year 1822, Meggs and Purvis [2] noted that he coated a pewter sheet with light-sensitive asphalt that hardens when exposed to light. He contact-printed a drawing which had

been oiled to make it transparent to the pewter with sunlight, he then washed the pewter with lavender oil to remove the parts not hardened by light, he etched it with acid to make an incised copy of the original. Niepce called his invention *heliogravure* (engraving with the sun). Fig. 1 is a Photoetching of an engraving of Cardinal George D'Ambroise by Joseph Niepce whereas Fig. 2 is the photograph of Niepce.

Fig. 1 Joseph Niepce. Photoetching of an engraving of Cardinal George D'Ambroise. (c.1826)
Source: Meggs and Purvis (2010)

Fig 2. Joseph Niepce (1765-1833)
Source: https://en.m.wikipedia.org

In 1826, according to Knobbler [3], Niepce went further in his discovery when he placed a pewter plate in the back of his *camera obscura* and pointing it out the window which would allow him make a picture directly from nature, the very earliest extant photograph was a pewter sheet that Niepce exposed throughout the day, as he removed the plate from the *camera obscura* and washed it with lavender oil, a hazy image of the buildings outside his studio was captured as shown in Fig. 3.

Fig. 3. Joseph Niepce First photograph from nature. (c.1827)
Source: Meggs and Purvis (2010)

In spite of the above discoveries, Niepce was not satisfied, his research exploration went further as he used light-sensitive silver-coated copper. At about this same time, Louise Jacques Daguerre (1799-1851) was also researching on the same subject, Niepce contacted Daguerre and they worked together until Niepce died of stroke in 1833.

Daguerre continued from where they stopped until 1839 when he perfected his study. This time, a clearer picture emerged as seen in Fig. 4.

Fig. 4. Louis Daguerre, Paris Boulevard. (1839)
Source: Meggs and Purvis (2010)

The latest discovery became known as *Daguerreotype* prints. William Henry Fox Talbot (1800-1877) continued from here and pioneered the process that formed the basis of both photography and photographic printing plates. He experimented with papers treated with silver compounds because he knew silver nitrate is sensitive to light and came up with a clearer and sharper image as seen in Fig. 5.

Fig. 5. William Henry Fox Talbot. Shadow picture of flowers (1839)
Source: Meggs and Purvis (2010)

The above illustrations are a brief description of the beginning of photography. Today, photography has become more scientific than the days of Daguerre. The inverse square law and the law of reflection now guide the way creative photography is done.

The Inverse Square Law and Photography

Interestingly, the inverse square law as propounded by Sir Isaac Newton and restated by Langford states that:

> "When a surface is illuminated by a point source of light, the intensity of illumination at the surface is inversely proportional to the square of its distance from the source of light." Pg. 24. [4]

Specifically, an inverse square law says that intensity equals the inverse of the square of the distance from the source of light. For example, the radiation exposure from a point source gets smaller the farther away it is; that is, if the source is twice as far away, it is one quarter as much exposure. In science, an inverse square law is any scientific law stating that a specified physical quantity is inversely proportional to the square of the distance from the source of that physical quantity. The fundamental cause for this can be understood as geometric dilution corresponding to point source radiation into three-dimensional space. There is a claim according to Sturken and Cartwright [5] that Robert Hooke discovered an inverse square relation of gravitating bodies prior to Sir Isaac Newton who later applied it more successfully in astronomy. Hooke apparently studied bodies on earth.

The inverse square law is basically about light and in summing up the nature of light, Vanden Berg and Katz [6] has the following to say:

(a). That light is a form of energy in transit, a comparatively narrow band of electro-magnetic radiation between ultra-violet and infra-red

(b). The speed of light varies with the density of the medium it is passing through

(c) Light waves travel on an overall straight line path with a waveform pattern of electro-magnetic force; the length of wave being measured in Angstrom units.

The view of Vanden Berg and Katz in their sum clearly lends credence to the workability of the inverse square law when analyzed side-by-side their views, for instance, the impression that the speed of light varies with the density of the medium it is passing through is clear when light passes through a mist to illuminate an object as compared to the same light passing through a clear atmospheric ambience. The photographs taken in clear weather condition will always come out sharper and clearer than the one taken in misty weather condition.

Fig. 5. Light far away from subject
Source: Hedgecoe (1996)

Moving the light further away from the subject makes the shadow transitions softer and less dense as shown in figure 5. If the light source is closer to the subject, the shadows become softer and have a less-defined edge but the shadows also become denser.

Definitely, the light modifier on the left image in Fig. 6 could be changed to something huge and far away and get soft edged shadows that are also less dense. Similarly, the light source on the right image could be changed to something small and very close and get sharp edged shadow that is also very dense. In figure 6, the image on the left shows that the light is intense on the subject hence the definite shadows observed on the nose and neck of the subject whereas the figure on the left shows that light source is far away from the subject hence the soft and undefined shadows on the nose and the neck as compared to the figure on the left. Arising from the above illustration there is a likely relationship between modifier size and the sharpness or softness of the shadow edge. In the example in Fig. 6, what it illustrates is contrast between the decrease in shadow and highlight as light is moved away from the subject and increase as the light source is moved closer to the subject.

The inverse square law is one of those principles of photography that most people find difficult to understand. It simply states that the intensity of an effect such as illumination or gravitational force changes in inverse proportion to the square of the distance from the source. To most people, this is somehow meaningless. Explaining further, Hedgecoe [7] noted that the inverse square law is the basis of good and perfect photography; but stressed that the problem with the inverse square law to Artists is that it is physics and it is mathematics which Artists, albeit Photographers don't always want to think about any time they go out on a photo shoot. If the inverse square law is mastered, a photographer does not need to go about with a calculator. Simply, it begins with light fall-off. Just how quickly (or slowly) the light gets darker the further away it gets from its source; the source being the flash. And because light travels in straight lines, rays from a point source spread farther and farther apart as their distance from the light source increases; in other words, they diverge. Due to this steady

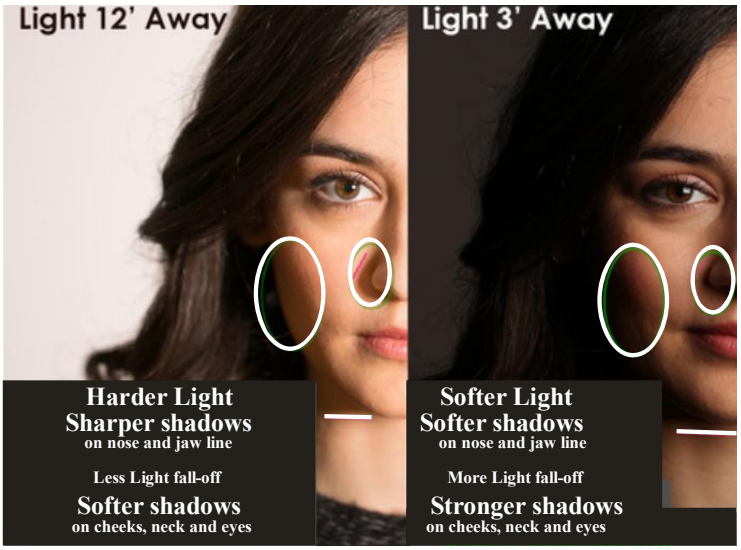

Fig. 6. Hedgecoe's experiment of light on a subject
Source: Hedgecoe (1996)

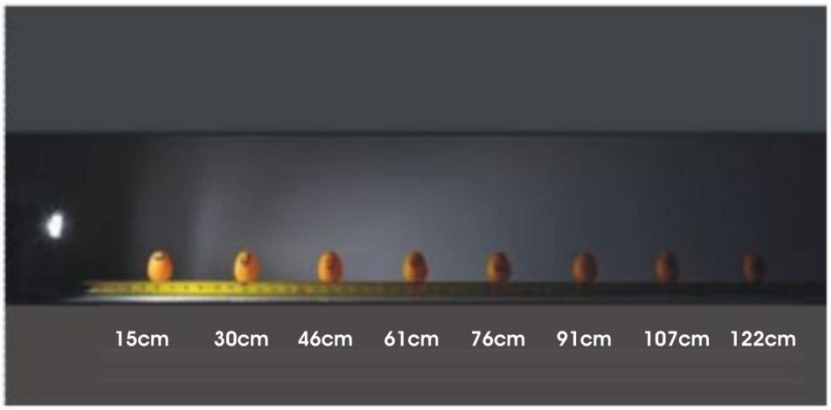

Fig. 6. Hedgecoe's experiment of light on arranged spaced subjects
Source: Hedgecoe (1996)

divergence, a small surface held near the light source will receive the same amount of light energy as a larger surface held farther away.

Another experiment to illustrate the inverse square law was carried out by Hedgecoe [8]. In Fig. 6, eggs were lined up 15cm apart; here we see a big difference in exposure between the nearest egg to the source of light and the last and the farthest from the source of light. Naturally, the nearest egg will receive more light than the last one even though they were arranged 15cm apart.

In the above experiment, there is a very little difference between the ones at 107cm and 122cm, which are also 15cm from each other.

The next step of this experiment clearly explains why people get confused by the Inverse square law; naturally, people assume that when you double the distance, you get half the light but this is not correct. When you double the distance, you only get a quarter of the light getting to the subject. On the experiment above, the photographer needed an aperture of f/22 to adequately expose for eggs at 15cm, f/11 and not f/16 exposes the egg at 30cm.

A more subtle and simpler example shows a portrait subject which was placed 91.44cm in front of a grey background. Here, the light is also 91.44cm in front of the subject. Shooting the subject at f/16, the subject was well exposed with a fairly dark grey background; when the light is moved a further 91.44cm from the subject, that is doubling the distance from 91.44cm to 182.88cm meant that the aperture must be opened up from f/16 to f/8 to get a good exposure again. Remember, when you double the distance, you lose two stops and the background becomes lighter. When the subject double in distance, going from 91.44cm to 182.88cm, the background only went from 182.88cm to 274.32cm it will only lose about a stop, when the aperture is adjusted to compensate for the subject, the background appears about a stop brighter. When the distance is doubled again, taking the light to subject distance from 182.88cm to 365.76cm,

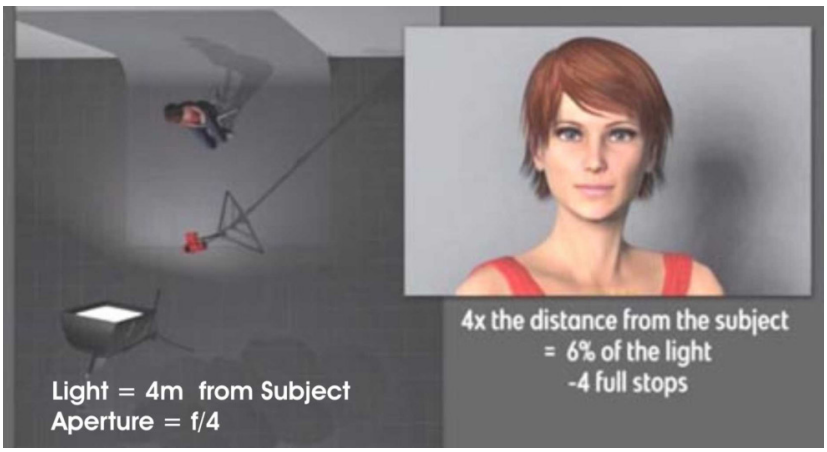

Fig. 7. Hedgecoe's experiment of light on background relative to subject.
Source: Hedgecoe (1996)

another two stops is lost, that is four stops below the original exposure. Eventually, at f/4, the background is even brighter relative to the subject as shown in Fig. 7

Langford [9], writing about the controllability or otherwise of the law of light wrote:

> "The law of light cannot be broken but they can be controlled; this is true because without light, there would be no such thing as photography but simply having light is not enough, cameras turn our three dimensional world into two dimensional flat image; light allows us to bring that third dimension back into our images and in order to do that, we need to know how to read it and how to control it"

For instance, working outside in bright sunlight, while we may not be able to move the light or have the patience to wait for it to move itself, we can move ourselves and often our subject for maximum effect. We can also diffuse it to make the light softer on our subject or better still, we can even change the direction of it using mirrors.

The mathematical connotation of the inverse square law is that as the distance from a light source increases, the intensity of light is equal to a value multiplied by $1/d^2$ [eq.A1] where d is the distance thus the closer a light source is, the brighter it is. This is evident from the fact that in the night when a car approaches us from a distance it looks dark but as it comes near the light the headlights make it brighter as the distance between the observer and the car has decreased. Similar concepts are also used in the gravitational law and the electric charge law of the Coulomb's law. The inverse square law intensity is applicable to not only the visible rays in the electromagnetic spectrum but also to all the other spectrums like the gamma rays, x-rays and UV rays. The intensity of visible light is measured in *candela* units while the intensity of other waves is measured in Watts per meter squared (w/m^2).[Eq.A2]

This writer do not intend to delve into the realm of further mathematics for this purpose but suffice it to state here that in any successful photography project, the application of the principles of inverse square law is a *sine qua non.*

A clear mastery of the inverse square law is a pathway to successful photography. The inverse square law actually determines two separate characteristics of the light; the fall-off in relation to the distance and the power in relation to the distance. When light is relatively close to a photographer and his model there is a big difference in exposure between the two because of the greater fall-off at the lower distance but when light is moved further away, the difference in exposure becomes smaller. This is especially important if one lights a large group of people because everyone has to be exposed properly.

The photography business in Nigeria has come a long way so much so that it has dovetailed into the new media technology. Nigeria photographers have advanced to the extent they no longer do photography for the sake of it. Photography is serious business in Nigeria and most professional photographers now showcase their works on internet; most of them have also graduated to the realm of the new media, including videography and animations. In the beginning, the average Nigerian photographer made use of the analog camera without recourse to most principles of good photography but the dawn of high-speed internet technology gave birth to a new approach that helps users to better utilize their time and attention to create rich, personalized social media environment. This is referred to as the new or innovative media. It is the amalgam of personalized media experience with global platform for involvement and it forms a unification of unlimited professional and user-created audio, video content with limited consumer time and attention; it recognizes that users increasingly have access to a two-way communication infrastructure. To realize the vision of modern media, two variables have to be in mind namely, new content distribution model that put users in control and more accurate and scalable data about

what they are watching, doing or creating. The combination of these two variables provides a unique media environment, a platform that connects media providers and media seekers. It also enables innovative media to flourish by allowing content owners, advertisers and users to discover, select, configure, distribute and exchange professionally-produced and user-generated content.

Since the production of cutting edge photographs is based on the theory of inverse square law, most Nigerian professional photographers have adopted this law in the shooting of their images both inside their studios and outdoors. In the studios, they have good lighting systems and computers, maybe sometimes to add extra value to their productions; this is evident as shown in Fig 8.

Amobi [10] sees new media as an interactive digital media, programmed or networked information and communication technologies such as the internet, as opposed to the traditional analog media. Lister et al [11] describes the new media technology as all environments that allow users search, share and research and then configure their media experiences so as to become valuable to users. Also, that these environments would become the primary means for users to navigate seamless professional, community-generated and user-generated content and services. In doing all these, these professionals take cognizance of the laws guiding good photographic production of which the inverse square law is part. In shooting cutting-edge photograph, the inverse square law is most important because without good photography, advertising of products and services would be defective and such advertisement may not meet the expectation of the target audience.

Crosbie [12] stressed that new media are uniquely industrialized and information can simultaneously be delivered or displayed to a potentially infinite number of people. Each of these people involved shares equal and mutual power over the content. Any media or content that is digital can be stored as the 1s and 0s of computer code including text, audio, photographs, and video. These digital materials can be delivered via various media such as CDs, DVDs, digital radio, or television broadcast signals. Over the past few decades, the growth of digital media, the rise of the internet, and the proliferation of mobile devices have combined to open the essence of mass media in several ways. Bolter and Grusin [13] aver that the change from analog to the digital platform was important whereby the internet is the interface space on which this digital content can be delivered to a wide range of devices, which include desktop computers, laptops, mobile phones, and other gadgets.

Manovich[14] sums up that all new media gadgets are composed of numerical

Fig. 8. A typical photo studio equipped with lighting fittings for good photography.
Source: www.pinterest.com

representations; new media refer to a wide range of changes in media production, distribution, and use which are more than technological changes; Akhagba [15] agrees that they are textual, convention and cultural and one of the most important features of the new media is that user control the message they consume and when they want to consume such message, they have to willingly participate. The Nigerian new media practitioners who were originally studio or freelance photographers are part and parcel of this new technological era.

Summary and Conclusion

Over time, professional photographers, graphic artists, and illustrators have come to realize the usefulness of good photography in advertising and other areas of human endeavors. Photography can be considered both an art and a science. It is a science because there are basic principles of physics that govern its practice and equally an art. After all, its beauty is subjective. Light is the essential ingredient of photos and one of the skills that separate photographers from snap shooters are the ability to solve lighting problems, and that is where a mastery of the inverse square law as applied in photography comes in handy and in this, there are two primary factors to consider as it relates to light; they are direction and color.

The direction the light comes from can make the image seem flat or three-dimensional. Front lighting is easy to photograph but such images are normally flat. Conversely, the top such as from the sun overhead also makes the image flat but shadows are short and dark whereas side lighting will generally emphasize texture and contours and create long shadows.

It is important to note that when taking photographs with the digital camera, the white balance setting of the camera will affect the color cast of the image; balancing the lighting of the subject therefore a good understanding of the inverse square law could solve such problems. Typical white balance settings of a camera include tungsten, fluorescent, shade, sunny, cloudy, flash, auto, and manual. To this end, filters can also be used to affect the color of light in the image.

It is also important to note that all digital cameras have various modes for shooting and whether one is using a digital camera, a smartphone, or an analog camera, the inverse square law remains constant. The bottom line is the lighting situation at a specific time and place. Finally, the inverse square law is the basis of good photography and all photographers should understand that without a mastery of the application of inverse square law, their end products might not meet the standard expected from their clients.

References

1. Dennis F, Jenkins H. Comprehensive Graphic Arts. Indianapolis: Bobbs-Merrill Educational Publishing; 1990.
2. Meggs PB, Purvis AW. History of Graphic Design. New Jersey: John Wiley & Sons; 2010.
3. Knobbler N. The Visual Dialogue. New York: Holt, Rinehart and Watson Inc; 1980.
4. Langford, M.J. Basic Photography: London: Focal Press; 1999 p24.
5. Sturken M, Cartwright L. Practices of Looking. New York: Oxford University Press; 2001.
6. Vanden Berg B.G., Katz H. Advertising Principles. Lincolnwood: NTC Business Books.
7. Hedgecoe J. New Introductory Photography. London: Focal Press; 1996. p27.
8. Hedgecoe J. New Introductory Photography. London: Focal Press; 1996. P46.
9. Langford, M.J. Advanced Photography: London: Focal Press; 2012
10. Amobi TI. Assessing global digital divide through computer ownership, literacy access and usage of new media by Nigerian youth. Unilag Communication Review. 2011 vol3 (4) p.14-20.
11. Lister MJ, Dovey J, Giddings IG, Kelly K. The new Media: A critical introduction. London: Routledge; 2009.

12. Crosbie V. Rebuilding Media: An Outlook. New York: Allworth; 2006.
13. Bolter J, Grusin R. The Media and Society. New York: McGraw Hill; 1999.
14. Manovich L. The New Media. Cambridge, MA: MIT Press; 2002.
15. Akhagba, M.O. New Media Technologies and Advertising Practice in Nigeria. 2014 Polonia Academy of Sciences, Polonia. Retrieved 24th May, 2021.

Appendices

1. Eq(A1) : Value x $1d^2$ (where d = distance
   As the distance from light source increases or decreases, the intensity of light is equal to the value x $1d^2$
2. Eq (A2): (w/m^2) The intensity of visible light is measured in candela units while the intensity of other waves are measured in watts per meter squared.