GLASSES GIVING SIGHT TO THE VISUALLY IMPAIRED

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ABSTRACT

This study will present the significance of, and the expected future impact of glasses that give sight to the visually impaired. This product is known as the eSight 3 glasses which was researched and developed by the eSight corporation. The significance of this product is that it enhances the gift of sight for those who are visually impaired, legally blind or not, but not for those without light perception. This product became a discovery transitioned into practice because Conrad Lewis, current CEO of eSight, wanted to give his two sisters their sight back after being diagnosed with Stargardt disease. This product can be expected to personally impact the visually impaired community, and financially impact other commercial products that augment reality with a head mounted device. This product can be expected to impact regulations in the areas of society that the visually impaired can participate in, and it can impact the demand for assistive care services and eye surgeries. This study will also provide information on the method and apparatus that is patented for the eSight glasses to show the novelty and significance of their technical accomplishment.

1. INTRODUCTION

The leader for the development of the eSight glasses is Conrad Lewis, who is an electrical engineer. When Conrad discovered the unfortunate condition of his sisters' vision, he said *If I can assemble teams of engineers who can build incredible products for the commercial market, why not assemble an engineering team that can build electronic glasses that would let my sisters see?* [1] This shows an interesting example of a product coming into existence for family, as opposed to the push-for or the pull-from the masses in the commercial market. In the development of these glasses it became clear that this product would have to satisfy a variety of conditions to truly be useful for someone who is visually impaired. These are the following criteria that the technology would have to meet:

- Be a hands-free device
- Be comfortable to wear
- Auto-focus between short, mid, & long-range vision without perceptible lag
- Replace all single-task assistive devices that don't provide actual sight
- Provide true mobility
- Enable those legally blind to independently do all Activities of Daily Living [1]

The importance of meeting the above criteria can be exemplified by the challenges that visually impaired people face on a regular basis, some of which are shown below in Table 1. Example issues related to independent physical mobility include: not being able to walk to the bathroom, go shopping, and getting up to go cook without help. Limited participation in social events refers to not seeing what someone points out, not seeing the outfit that someone was complemented for wearing, not seeing the live-action plays at a sporting event, and more. Isolation refers to how the visually impaired tend to stay within a

small radius of their home, or rarely go outside, because that's the area they feel comfortable navigating. Healthcare inequality refers to the lack of accessible information as a patient, such as not being able to read their own test results or confirm their own appointments because the text was not given in a format that can be read (ie. large text, braille). Children struggle with the desire to be independent like all children, but those who are visually impaired must find closure in not being able to play on a playground by themselves, dress themselves, and walk alone without their hand being held. Students who have low vision, which means their sight is impaired but not to the point of legal blindness, may feel their condition is not being taken seriously because they're still able to do activities such as catching a frisbee of a specific color, but not other activities such as reading the lecture information being presented in class.

Table 1: Challenges for the Visually Impaired

Demographic	**Challenge**	**Source**
Any	Independent physical mobility	[9]
Any	Limited participation in social events	[9]
Any	Using common technology	[9]
Adults	Limited employment opportunities	[9] [10]
Adults	Isolation	[10]
Adults	Healthcare Inequality	[10]
Children	"I want to do it on my own"	[11]
Students	Adequate access to the lecture information	[12]
Students	Not being taken seriously	[12]

The definition of visual impairment is outlined in Figures 1 – 4. In Figure 1, the visual acuity of someone with normal vision on the left is compared with that of legal blindness on the right. This figure shows that someone can become visually impaired due to severe aberration of the light they perceive. In Figure 2, the visual field of someone with normal vision on the left is compared with that of legal blindness on the right. This figure shows that someone can become visually impaired due to a severe restriction of their visual field. In Figure 3, another form of a visual impairment is presented in which the center of the visual field is indistinguishable, and the peripheral vision is aberrated. This figure shows the visual impairment of Conrad Lewis' sisters, Stargardt disease. In Figure 4, the two conditions for legal blindness in the USA are presented. The image to the left in this figure is meant to show that if an individual can only read line 1 (E) from 20 feet away, then they are legally blind. If an individual could only read line 3 (TOZ) from 20 feet away, then they have low vision. The image to the right in this figure is meant to show that if an individual has a visual field of 20 degrees or less, then they are legally blind.

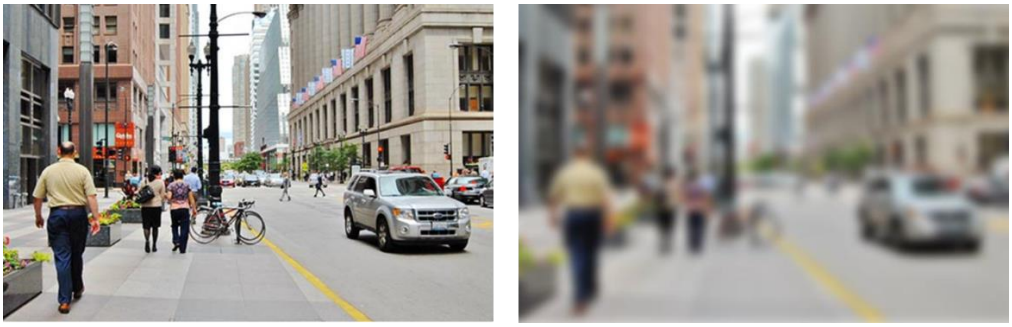

Figure 1: Visual Acuity [7]

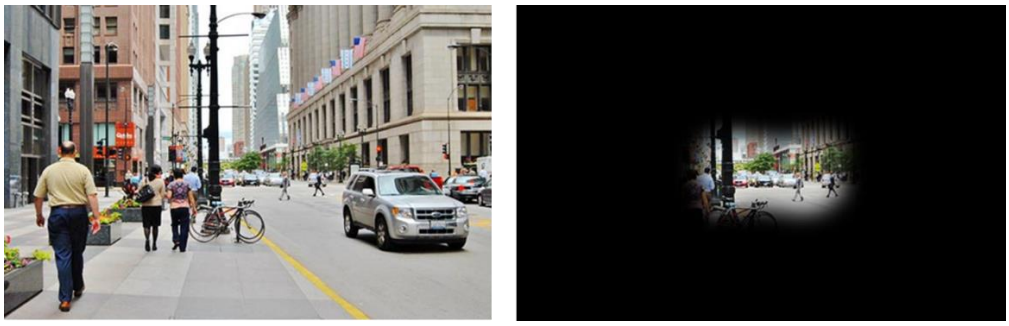

Figure 2: Visual Field [7]

Figure 3: Stargardt Disease

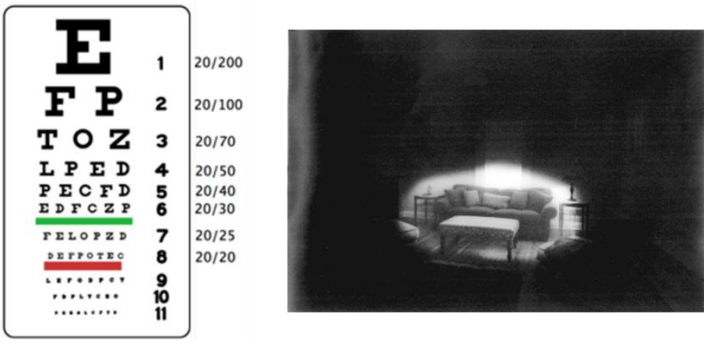

Figure 4: Legal Blindness [8]

The timeline of events that lead to the development of the eSight glasses is outlined in Figure 5 below. This series of events show years of fund raising from 2009 up until 2017 when the eSight 3 glasses have been brought to market.

Recent News & Activity

Date	Activity
Dec 26, 2017	eSight: New York Times - Deals — Some Things About Tech Were Good in 2017. No, Really.
Apr 27, 2017	eSight: Nanalyze — 6 Vision Enhancement Devices You Need to See
Apr 20, 2017	eSight: CBC News — With these glasses, a legally blind teen can see — and shoot 3s with the Harlem Globetrotters
Feb 15, 2017	eSight: Mobile Syrup — eSight launches new smart glasses promising 20/20 vision for the legally blind
Feb 15, 2017	eSight: The Verge — The eSight 3 is an augmented reality headset designed to help the legally blind see
Nov 11, 2015	eSight raised an undisclosed amount / Series Unknown from iGan Partners
May 3, 2015	eSight raised $562,631 / Series Unknown
Feb 18, 2014	eSight raised CA$4,200,000 / Series Unknown from iGan Partners
Mar 24, 2013	eSight: Tech Vibes — Government Invests Total of $3.7 Million in Six Canadian Tech Startups
Jul 12, 2012	eSight raised $1,829,440 / Series Unknown from Fort Point Angels and Oleg Uritsky
Jan 5, 2010	eSight raised $750,000 / Series Unknown
Apr 29, 2009	eSight raised an undisclosed amount / Seed from MaRS Investment Accelerator Fund

Figure 5: eSight Timeline [13]

2. THE DEVICE

The eSight glasses are shown below in Figure 6. This figure shows what it looks like if the user were to put on the glasses. There is a camera aparatus in front of the lenses which captures a video feed of what the user is looking at. The feed is then sent into the CPU where the images are enchanced using proprietary algorithms according to the feature settings chosen by the user. These features include brightness, focus, constrast, and zoom as shown in this figure. The feed is then sent back to the glasses where they are projected in color on the two near-to-eye OLED screens without any perceptible latency.

Figure 6: eSight Glasses [1]

The physical and functional decomposition of the eSight glasses are shown below in Figure 7. In each step of the process from 1510 to 1580, the top section refers to the physical hardware, followed by the quality of the video feed, then the expected time spent, and finally the bottom section refers to the functions being performed. The algorithms that are run at each step are proprietary, so the exact method is not perfectly clear, but the expected behavior of some of these functions will be demonstrated in the upcoming figures. In this figure it shows that the camera takes in 120 frames per second, and frames are being dropped throughout the process of image enhancement to achieve the desired computing speed, and finally outputs at 60 frames per second for the user to see. A reference point that highlights this technology's achievement of imperceptible latency is television, which outputs at 25 – 30 frames per second currently.

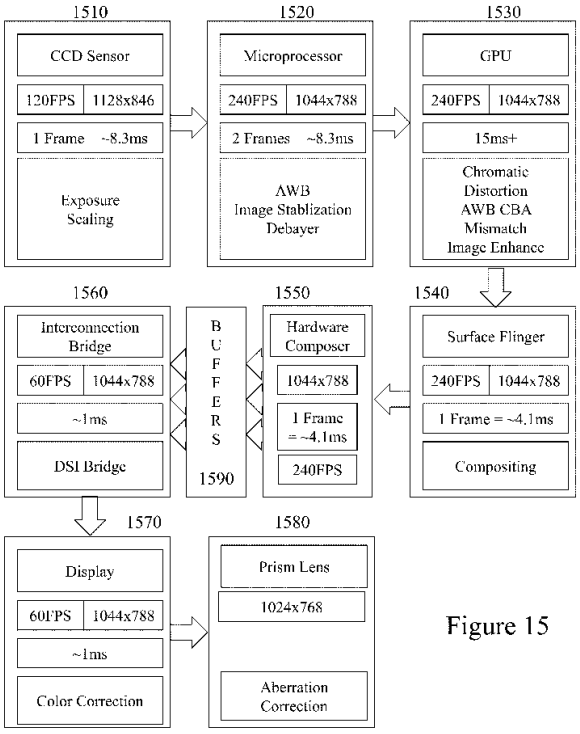

Figure 7: Figure 15 from eSight Patent – Devices and Methods for Optical Aberration Correction [3]

The function of automatic white balancing (AWB) is shown below in Figure 8. This figure shows a picture of mars and how objects within the image are more distinguishable by assuming something in the figure is white. By assuming something in the picture is white, this will adjust the lighting conditions in the image, hence why the picture on the most right looks the least murky.

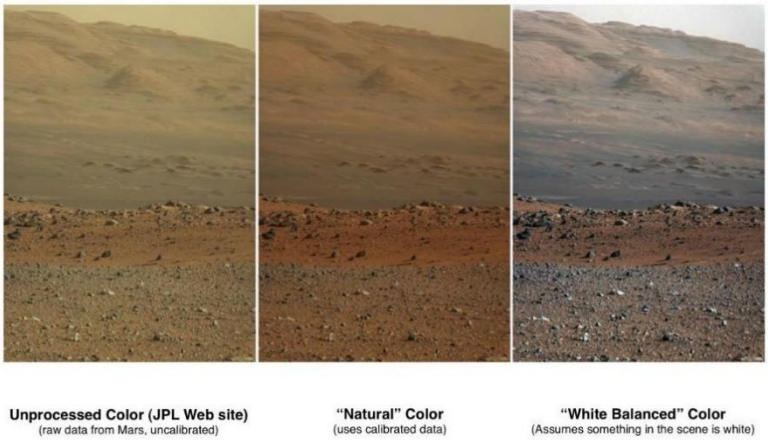

Figure 8: Automatic White Balance (AWB)

The function of image stabilization is shown below in Figure 9. This figure shows how a camera is unstable when capturing a picture because a human is not perfectly steady with their motions. This results in the camera capturing the motion, where the optical path that the light travels is not converging onto a distinct point on the camera lens, hence the blurred picture in the top of this figure. Image stabilization adjusts for this blur by varying the optical path to the camera's lens so there is a consistent point of convergence, which will handle common human motions such as tilt and rotation.

Figure 9: Image Stabilization

The function of chromatic aberration correction is shown below in Figure 10. This figure shows how light of different wavelengths enters the lens (the human eyes in our case) at the same point, but after passing through the lens the light doesn't converge onto a consistent point for the brain to interpret, hence the chromatic aberration which looks like multiple offset pictures of differing color. The correction is caught by another set of lenses (the near-to-eye OLED screens in our case) which adjusts the optical path so there is a consistent point of convergence as shown in the bottom most diagram of this figure.

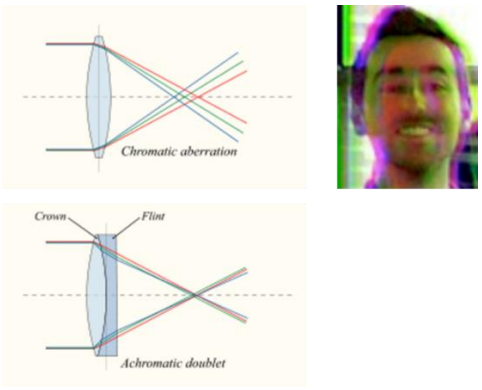

Figure 10: Chromatic Aberration

The zoom feature that the user controls can go up to 24X which is the picture on the right in Figure 11 below, and the most left picture represents what the user is seeing without any zoom (eg. 1X). This is useful for the visually impaired who are near sighted, and those who rely on magnifying text so that can read.

Figure 11: Zoom Feature

The contrast feature allows objects in the visual field to become more distinguishable by adjusting their size, shape, shade, color, and/or proximity as define below in Figure 12. Adjusting color is useful to allow light that is imperceptible for someone with a reduced visual field, to become visible by changing hue, saturation, and brightness levels.

Figure 12: Contrast Feature

The characteristics of color are outlined below in Figure 13. An example of the relationship between hue, saturation, and brightness can be found in a classroom. Think of hue as the Expo marker one picks up from the whiteboard, it's either blue, red, green, etc. Think of saturation as the amount of ink left in the Expo marker, where a marker with more ink will result in a deeper color and a marker with less ink will result in a fading color. Think of brightness as the light setting in the room; a room with bright lights will create a glare that makes the color look whiter and a dimly lit room will darken one's perception of the

color. The interaction of these characteristics produces the color one sees when the Expo marker is applied to the whiteboard.

Figure 13: Color Feature

Another interesting feature of this device is it can record videos/pictures to then upload to a computer via an HDMI. This is interesting because people today in their daily life are not able to capture natural moments in real-time, because there is always a set up period to prepare a camera or video device. These glasses however allow for such moments to be captured as they happen without any set up time required.

3. SOCIETAL IMPACT

The societal impact of this device can be decomposed into three areas of interest: business, regulation, and personal. The area of business refers to the competitive impact that this device can have on businesses. The area of regulation refers to the impact on systems where fairness and honesty is of upmost importance. The personal area refers to the impact this technology can have on individuals in terms of their relationships and life style. These three areas are shown below in Figure 14 where the colors green, gray, and orange classify the areas of business, regulations, and personal respectively.

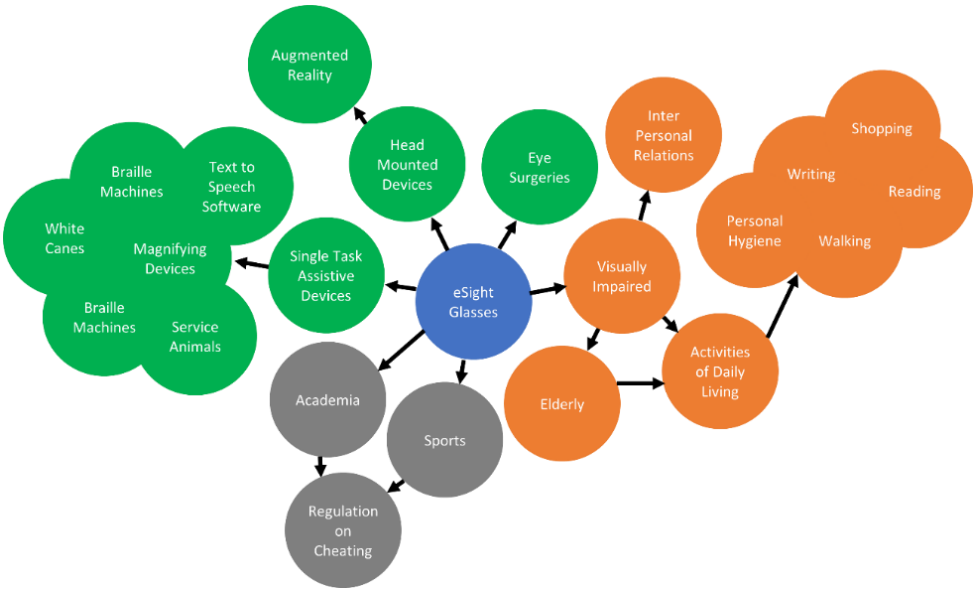

Figure 14: Societal Impact Diagram

Businesses that develop and supply single-task assistive devices may lose market share. This is because the eSight glasses can substitute products and services that the visually impaired have relied on such as white canes, magnifying devices, service animals, braille machines, closed-circuit television scanners (eg. video magnifiers), and text-to-speech software. The demand for eye surgeries may reduce given that 85% of USA LASIK surgeons in 2017 have been charging anywhere from $1,501 to $2,500 per eye [14] without being a permanent solution because as the eyes continue to age, there may be a need to purchase glasses or contact lens [15]. In comparison, the eSight 3 glasses have dropped in price from $15,000 to $9,999 [1] and represents a permanent solution because the device adapts to the user's current eye condition. This device is augmenting reality to allow people to see a reality, that they haven't seen, as it is, whereas augmented reality gaming devices add features to reality that don't exist. As eSight develops and patents their methods and devices, this may place a restriction on the functionality of other augmented reality devices and methods, and vis versa.

Regulations may develop in sports, now that someone who is naturally visually impaired from a young age can train their skills in sports. This regulation is likely to focus on the zoom feature of the device where the wearer of these glasses could have an advantage in terms of accessing the other team's information with the zoom feature to possibly read lips or read the play books. Recall in 2007, the New England Patriots incident known as Spygate where the Patriots were videotaping the New York Jets' coaching signals from an unauthorized location during a September game. These glasses would allow the wearer to videotape many things from many locations which could easily raise similar issues as in this 2007 incident. Regulation may focus on to what extent of visual impairment warrants the use of these glasses, for instance if contact lenses are sufficient to fix moderate near or far sightedness, then the use of these glasses would be an unnecessary solution for such an individual. The challenges surrounding the integration of individuals with these expensive head mounted devices into current sporting leagues may push for additional leagues for those wearing vision enhancement devices. Regulation may have to be further developed in academia to deal with the zoom feature as well. Currently, visually impaired students may use magnifying devices to allow them to read the text on their tests easier, where they are restricted to reading their own test in front of them because it would be obvious if they were to physically move to apply their magnifying device to another person's test. Students wearing these glasses while taking a test could zoom in on anyone else's test without any clear indication that it's happening because it requires just the slight tilt or rotation their head to achieve a desired angle. These challenges surrounding academic dishonesty may require the video feed to be saved and recorded on these glasses, and then uploaded to a computer from which the teacher can verify honest test taking occurred.

The personal impact that these glasses are expected to have on individuals is tremendous, as this is the primary purpose of the technology. Those who are visually impaired due to eye conditions since a young age, as well as the elderly whose eye sight is worsened due to aging, are expected to have the greatest to gain from these glasses. These individuals will gain a sense of independence that they have never experienced or have been longing to have back. The ability to perform activities of daily living is common for most people as approximately just 3.3% of people in the world today have moderate to severe visually impairment [6]. Now because of this technology, over 80% of the visually impaired [6] can now shop, walk, read, write, satisfy one's personal hygiene, etc. as seamless and independently as 96.7% of the world. A setback for some who are visually impaired may be maintaining their sense of identity and relationships with others who are visually impaired. This is because the visually impaired community is a sub-culture in its own respect, where only members within the community can truly

sympathize and relate to one another. By using these glasses, one would be differentiating themselves from the community they identify with to then attempt integrating into another community who doesn't require such a device. This may leave individuals to feel more isolated than before when they are first adopting such a device that is expected to be life changing.

4. INTELLECTUAL PROPERTY

The eSight patent for Devices and Methods for Optical Aberration Correction is summarized below. The functionality and hardware included in this patent has been covered in detail throughout section 2 of this study. This is a grant patent filed on April 22, 2016 and assigned to eSight on December 5, 2017. There have not been any legal issues surrounding this patent in the current history.

Patent: Devices and Methods for Optical Aberration Correction

In accordance with an embodiment of the invention there is provided a method comprising:

1. receiving image data for presentation to a user on a near-to-eye (N2I) display wherein an optical train is disposed between the user's eye and the N2I display;
2. processing the received image data in dependence upon a static vertex buffer with an image processing pipeline;
3. storing the processed output from the image processing pipeline within a frame buffer; and
4. displaying the processed output to the user on the N2I display.
   [2]

The eSight patent for a Dynamic "Region of Interest" is summarized below. The functionality and hardware in this patent refers to the devices ability to track the individual's eyes to determine the region of interest that the user wants to look at. This allows for the image quality to be enhanced for a specific region which in turn sacrifices the overall quality outside the region of interest. This is a grant patent filed on May 25, 2016 and assigned to eSight on August 1, 2017. There have not been any legal issues surrounding this patent in the current history.

Patent: Devices and Methods for a Dynamic "Region of Interest"

- The concept of performing image enhancements on a reduced area of the displayed image corresponding to the wearer's "Region of Interest" (ROI)
- A modified image can be superimposed on an unmodified image, in order to maintain the original peripheral information while enhancing the ROI
  [4]

The eSight patent for a Bioptic Real Time Video System is summarized below. The hardware and functionality in this patent refers to the ability to tilt up the camera apparatus to sacrifice image quality but still allows the enhanced image to be imposed on top of the user's original vision. This allows the user to see a more enhanced image without losing their sense of self in proximity to the physical world. This biopic tilt is what allows the user to walk safely. This is a grant patent filed on December 5, 2014 and

assigned to eSight on June 21, 2016. There have not been any legal issues surrounding this patent in the current history.

Patent: Devices and Methods for a Bioptic Real Time Video System

- The wearer can choose, through simple adjustments of their neck and eye angles, to either look at the displayed video image or their natural environment.
- The use of motion and position sensors incorporated into the head-worn device to automatically adjust the vertical angle of either the camera or the electronic display or both, by sensing the vertical angular position of the user's head.
  [5]

4. CONCLUSION

This device in action is heart-warming, there are teachers who can now see the hallways they've been walking through for decades. There are children who can finally describe things in terms that their parents and friends can understand. There are a multitude of instances where thousands of people are coming together to make these glasses affordable for just one person. People can recreate their wedding, so they can see it for the first time themselves. Another example is holidays, holidays anywhere have always been a visual feat, to see what a holiday looks like is very much what it means to experience the holiday itself. There are people who get diagnosed as legally blind by the doctor and may receive an official note stating that they are *legally blind, and no treatment will help*, which is incorrect. In turn, the way some people find out that this treatment exists is on social media platforms as opposed to the clinician. The eSight glasses are a true innovation brought to the market by family will, to give back the gift of sight to those who've lost it. It's clear that this product will continue to make an impact as the information becomes widely available that this is the first sustainable life-long solution for anyone who desires to see clearly.

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