An Application on Digitalization in Liquid Lens Glasses Design

Ahmet Reşit KAVSAOĞLU and Areej Mohammed BUQUNADAH
Biomedical Engineering
Karabuk University
Karabuk, Turkey
kavsaoglu@karabuk.edu.tr, 2014areeg2014@gmail.com

***Abstract*— Many eyeglass users have to change their lenses due to the continual decline in vision. Sometimes it can be uncomfortable for some people to use multiple eyeglasses of varying degrees to perform different activities. Therefore, researchers in the field of optics are developing solutions to solve this problem. This work aims to develop an adjustable eyeglass which are able to changes refraction degrees of their lenses. This type of eyeglasses helps patients with myopia and similar vision issues. In this study, a medical eyeglass was designed based on controlling the distance between two lenses by injecting a liquid silicone oil for changing the degree of the lenses. The amount of liquid between the lenses is controlled by an android application. Several tests and experiments have been performed to ensure the effectiveness and readiness of the eyeglass. The tests were performed with the help of a lensometer, and acceptable results are obtained as accurate. In the scientific literature, it is common to use a manual adjustment mechanism for the injection of a specified amount of a fluid. In this work, a different injection mechanism that automatically controlled by a mobile phone was used. By this way, the eyeglasses adjustment process became easier for individuals who wear eyeglasses. Personalized values in settings can be stored in the memory of the mobile application to make easy to change between different configurations.**

Keywords*— *Variable focal lenses; smart eyeglass; optics; adjustable eyeglasses; liquid injection mechanism.

I. Introduction

Vision problems are one of the most common health issues for human. With age, the natural lenses of the eye begin to deteriorate and cause conditions such as myopia, farsightedness, astigmatism and presbyopia [1]. The most common and oldest solution to correct vision is to use lenses and eyeglasses. The Romans developed small spherical pieces of glass that could help read small texts. The first wearable eyeglasses known in history appeared in Italy in the 13th century [2].

With the development of technology in recent years, manufacturers have developed eyeglasses types that include multiple lens types in a single frame, allowing to change the distance and alignment between lenses. This allows the degree of lens correction to be adjusted to suit the user.

In this study, medical glasses were designed based on adjusting the distance between two lenses by injecting liquid silicone oil and thus adjusting the degree of lenses. The amount of liquid injected between the lenses is controlled by an Android application connected to the control circuit. The application allows the user to adjust the lenses to a specific position and stores the parameters in its memory for future use.

The aim of this study is to produce eyeglasses with flexible lenses that expand when liquid is injected between the lenses. This simplifies the process of changing the refraction degree of the lens. Thus, instead of using multiple glasses of varying refraction degrees, the user can use a single pair of glasses and adjust them as needed. In addition, this study aims to produce eyeglasses solution that can be controlled by a smart phone. These eyeglasses are suitable for people who use eyeglasses of varying refraction degrees to perform their daily activities.

In this study, the system block diagram shown in Fig. 1 was realized. First, the frame of the adjustable eyeglasses was designed. And then a stepper motor-controlled liquid injection mechanism has been added to the eyeglasses. This injection mechanism is controlled with the designed smartphone application.

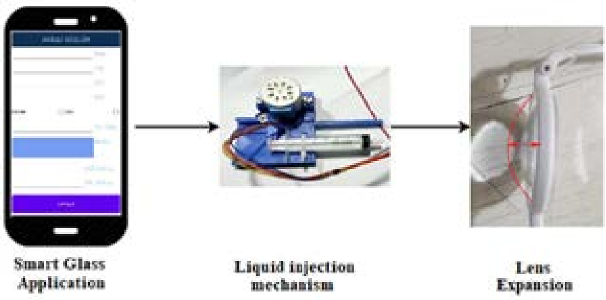

Fig. 1. Implemented system block diagram [3].

Some studies in the scientific literature:

In 2005, Ren, H. and Wu, S. T. proposed an adjustable liquid-filled lens. Their lens consists of an elastic membrane, an adjustable sealing ring and a solid plate, a constant volume of liquid is stored inside the lens. By adjusting the radius of the sealing ring, the liquid stored in the lens is redistributed. As shown in Fig. 2, when the sealing ring size is changed, the fluid

978-1-6654-3663-2/21/$31.00 ©2021 IEEE

is redistributed within the lens, causing the lens to expand and thus change its refraction degree [4].

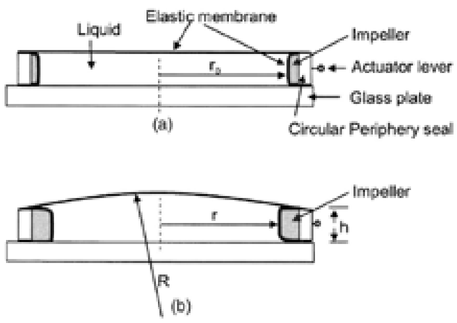

Fig. 2. Liquid lens proposed by Ren and Tson Wu [4].

In 2007, Ren, H. and Wu, S. T. proposed a varifocal liquid-filled lens based on pressure-induced fluid redistribution. The aperture size of the liquid-filled lens is determined by the hardness of the PDMS (Polydimethylsiloxane) film. The aperture size can vary from a few millimeters to centimeters. The focal length of the lens is controlled by an actuator which can be mechanical or piezoelectric as shown in Fig. 3 [5].

In 2011, Zapata, A., et al. have proposed adjustable eyeglass lenses depends on the Alvarez-Lohmann principle. These lenses can be used to provide low-cost glasses for subjective refractive errors correction and measurements. To enhance the advantages of this technology, a new mechanical framework has been designed. Their design includes a mechanism for matching the interpupillary distance to that of the centers of the lenses, as shown in Fig. 4 [6].

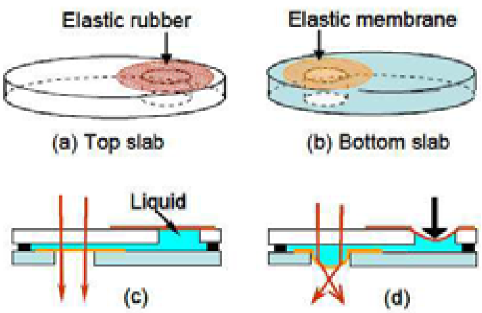

Fig. 3. The structure of a liquid-filled lens: a) the top plate, b) the bottom plate and side view of the lens c) defocusing and d) focusing states [5].

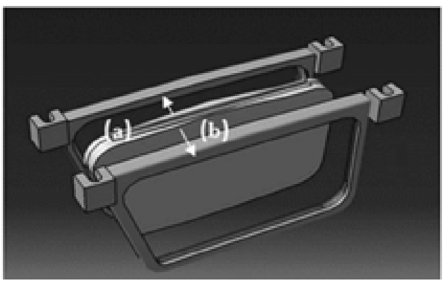

Fig. 4. Shape. 4. Alvarez–Lohmann lens, a) lens edge. b) Mounting direction of lenses in lens holders [6].

In 2011, Silver, J.D., et al. In their study, made a low-cost self-adjusting eyeglass to solve the problem of the lack of certain lens types in developing countries. These eyeglasses used liquid-filled lenses filled with silicone oil [7].

In 2014, Wang, L., et al. recommended a pair of diopter-adjusted glasses to correct presbyopia. The glasses provide an adjustable refraction degree over the entire surface of the lens cell. The user can control the refraction degree via a sliding stick on the bridge of the eyeglasses so that presbyopic vision can be effectively corrected [8].

In 2018, Padmanaban, N., et al. introduced a new presbyopia correction glasses called Autofocals. The glasses simulate the natural adaptation response by combining data from a depth sensor and eye trackers, and then adjust the focus-adjusted lenses automatically [9].

II. Materials and Methods

A. Mechanical Design

The spectacle frame was designed considering the common design of spectacle frames. It is important that the weight of the frame should not be more than 60 grams so that it does not cause issues on the skin around the eyes. The overall width of the spectacle frame is approximately 146 mm and the overall length is approximately 145 mm. As shown in Fig. 5, the radius of both lenses is 26 mm. The frame is designed using polyethylene terephthalate. A syringe is placed on either side of the frame and connected by a tube to deliver fluid to the area between the two lenses, as shown in Fig. 6.

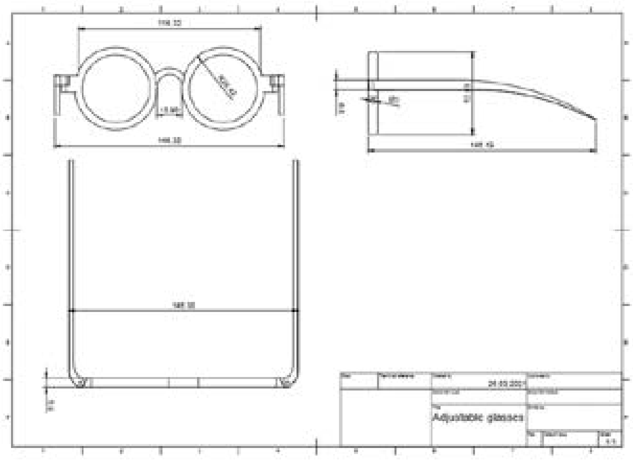

Fig. 5. Glasses design using an STL software [3].

The design of the liquid-filled lens is shown in Fig. 6. Lenses can be plano or curved so they meet medical eyeglasses standards. The designed lens consists of a four-layer lens. Two middle layers form the central double lens and provide refraction. Two outer layers surround the system and provide no correction (0 degrees). When liquid is injected between the lenses, the inner region expands, causing the curvature of the flexible lenses, thereby changing the refractive degree of the lens. The amount of liquid is precisely controlled by the liquid injection mechanism. Fig. 7 shows the liquid injection mechanism.

Fig. 6. Varifocal liquid-filled lens design [3].

Fig. 7. The design of liquid injection mechanism [3].

B. Electrical Circuit Design

A stepper motor is used in the liquid injection mechanism to control the amount of liquid inside the lenses. The PCB design shown in Fig. 8, is used to connect electrical parts together. A4988 Stepper motor driver and Arduino Nano are used in the circuit. Arduino Nano communicates with the mobile phone via the HC-05 Bluetooth Module with serial port standard and controls the liquid injection mechanism using the data recieved from mobile application.

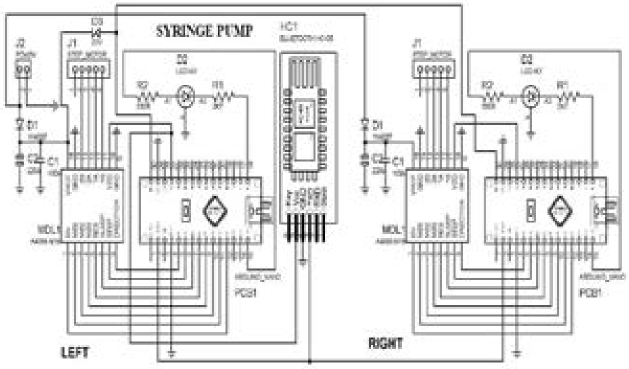

Fig. 8. The electrical circuit controlling the stepper motor in the injection mechanism [3].

C. Mobile Application Design

MIT App Inventor [10] is a development platform on the internet that anyone can use to solve some real-life problems. It provides a web-based "What you see is what you get" editor for creating smart phone applications for IOS and Android operating systems. It uses a block-based programming language built on Google Blockly and has been influenced by languages such as Scratch and StarLogo TNG, enabling anyone to create a mobile app to meet the need. Many people use MIT App Inventor to provide mobile app solutions for real problems in their own families, surrounding communities and the world [11].

The icon and interface of the smart eyeglass application are shown in Fig. 9. This application can be used by more than one person. For this reason, personal information such as name, gender, weight, height, age, address and telephone number are required before the glasses are used. It also stores the refraction degrees of the right and left eye in the memory.

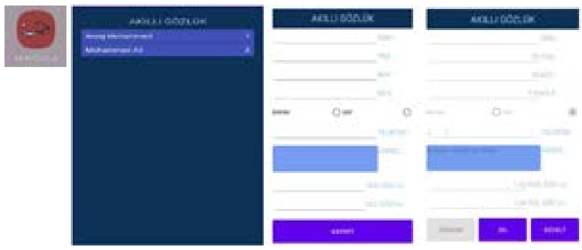

Fig. 9. Smart glasses mobile app icon and interface [3].

The lenses are attached to a small syringe placed on either side of the eyeglass frame. The user can adjust the amount of fluid injected into each lens using the Android application. When liquid is injected into the lens, the refraction degree of the lens increases (corrects hyperopia or farsightedness). Conversely, when the fluid is sucked out, the refraction degree of the lens is reduced, which corrects myopia. Changing the physical shape of the lens by injecting silicone oil inside or outside changes the degree of refraction. Fig. 10 shows the eyeglass frame design with syringes mounted on it.

Fig. 10. Glasses frame design with syringes mounted [3].

III. RESULTS AND DISCUSSION

After the glasses were prepared and all their parts were assembled, the lenses were filled with liquid. In this study, silicone oil with a viscosity of 5000 cst was used, this oil can be perfectly injected between the lenses. Silicone oils have good viscosity properties, making them an ideal choice for use in many optical fields. Fig. 11 shows the process of filling the lenses with the silicone oil.

Fig. 11. The process of filling lenses with liquid [3].

The lensometer device measures the refraction degrees of the lenses by directing the light beams to the lenses and measuring the refraction degree of the light passing through the lens [12]. In this study, tests were performed on the lenses by injecting different amounts of liquid into the lenses each time. Table I includes the measurement results obtained by lensometer using different amounts of liquid. The results were obtained using Essilor CLE070 brand lensmeter.

TABLE I. AMOUNT OF LIQUID AND RESULTED REFRACTION DEGREES [3].

Amount of liquid (ml)	*Refraction degree*
0.5 ml	+1.00
1.00 ml	+2.00
1.50 ml	+3.00
2.00 ml	+4.00
2.50 ml	+5.00
3.00 ml	+6.00
3.50 ml	+7.00
4.00 ml	+8.00
4.50 ml	+9.00
5.00ml	+10.00

Optical tests were performed on liquid-filled lenses at a distance of 40 cm and compared to a glass lens of the same grade at the same distance. Fig. 12 shows the comparison between the two lenses. Fig. 13 shows that the left and right lenses of the glasses can be adjusted separately with different lens degrees. Unlike other studies, this study offers adjustable glasses technology that can be controlled by a smart phone application.

Fig. 12. Comparison of liquid lens and glass lens at 40 cm distance [3].

Fig. 13. Liquid-filled lenses with different refraction degrees [3].

REFERENCES

[1] Wojciechowski, R., "Nature and nurture: The complex genetics of myopia and refractive error", *Clinical Genetics*, 79 (4): 301–320 (2011).

[2] Internet: All about eys, "See Into the Past: The Fascinating History of Eyeglasses",https://allaboutеyes.com/see-past-fascinating-history-eyeglasses/ (2021).

[3] Buqunadah A. M., "An application on digitalization in self- adjustable eyewear technology ", Master thesis, University of Karabuk Faculty of Engineering, Karabuk, (2021).

[4] Ren, H. and Wu, S. T., "Variable-focus liquid lens by changing aperture", *Applied Physics Letters*, 86 (21): 1–3 (2005).

[5] Ren, H. and Wu, S.-T., "Variable-focus liquid lens", *Optics Express*, Vol. 15, Issue 10, Pp. 5931-5936, 15 (10): 5931–5936 (2007).

[6] Zapata, A. and Barbero, S., "Mechanical design of a power-adjustable spectacle lens frame", *Journal Of Biomedical Optics*, 16 (5): 055001 (2011).

[7] He, M., Congdon, N., MacKenzie, G., Zeng, Y., Silver, J. D., and Ellwein, L., "The child self-refraction study: results from urban Chinese children in Guangzhou", *Ophthalmology*, 118 (6): 1162–1169 (2011)

[8] Wang, L., Cassinelli, A., Oku, H., and Ishikawa, M., "A pair of diopter-adjustable eyeglasses for presbyopia correction", *Novel Optical Systems Design And Optimization,* XVII, 9193: 91931G (2014).

[9] Padmanaban, N., Konrad, R., and Wetzstein, G., "Autofocals: gaze-contingent eyeglasses for presbyopes", *ACM SIGGRAPH 2018 Emerging Technologies*, 1–2 (2018).

[10] Internet: MIT App Inventor, "MIT App Inventor", https://appinventor.mit.edu/ (2021).

[11] Patton, E. W., Tissenbaum, M., and Harunani, F., "MIT app inventor: Objectives, design, and development", Computational Thinking Education, Springer, Singapore, 31–49 (2019).

[12] Bragg, T. L., "Mark E Wilkinson, OD Plus Cylinder Lensometry", (2015).