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論文題目
AR Paper Document Zoom Glasses System for Presbyopic People
(老視者のための実際の紙ドキュメントが拡大されたように見えるAR拡大眼鏡システム)

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Chapter 1

Introduction

The human eyes have an adjustment ability that allows them to focus on how far or near they need to see. This adjustment is done primarily by changing the thickness of the lens. However, the lens loses elasticity and hardens as human ages, making it difficult to change its thickness. The loss of accommodation due to lens hardening is called presbyopia. Presbyopia is a physiological phenomenon that, like refractive errors such as myopia and hyperopia, can happen to anyone. On average, in middle age (like 40 years old), the near focus point (the closest position can focus) start moving away, making people more difficult to see things that are close to their eyes. And as ages, the near focus point becomes much farther. For example, even in a person with normal vision, the near focus point is about 20 cm from the eye in the 40 years old, but in the 50 or 60 years old, the near focus point can be about 40 cm [1]. Thus, when a presbyopic person tries to read a book written in small text and holds the book close to his face, the characters appear large but are not recognized due to defocus. However, when the book is moved away from the person's face, there appeared another problem that the book could be focused but the characters are too small to be read.

According to the research of NCBI [2], 80% of people older than 45 years have presbyopia (Fig. 1.1) in North America. Also, as of 2020, there will already be more than 1.8 billion people over the age of 40 years old that account for 36.81% of the world's population (Fig. 1.2). Furthermore, data from the visual capitalist shows that as the medical care improves, the human lifespan increases, and the declining of birth rates, older people will become more prevalent in the human age structure [3]. This means that, in the meanwhile, there will be more and more presbyopic sufferers.

Based on the research of Statista [4], I know that there are only 35% of e-book readers older than 49 years old (Fig. 1.3) in North America. Even E-books are easy to be zoom-in, but older people are more inclined to read printed books and are prone to presbyopia. Although reading glasses are often used when people suffering from presbyopia to read paper documents or books, it is necessary to repeatedly remove and put on the glasses, when they are for example taking notes and trying to do other operations on a desk. It is difficult to cope with such complex situations even if using multifocal glasses. In addition, as time goes on, the symptoms of presbyopia get worse. This makes them have to change their glasses to fit with the increasing degrees.

By the way, Huiyi Fang and Prof. Kenji Funahashi have proposed the automatic display zoom system of a smartphone and tablet for presbyopic people [5]. The area a subject wants to see more detail is specified by touching on a screen. The center of a screen is zoomed in partially and the surroundings are zoomed out from the original screen when a user touches the center. Because this study can only be used on a smartphone or tablet and is limited by the size of the screen. At the same time, presbyopia is also more inclined to read paper books. Thus in this paper, I propose an AR paper document zoom system using see-through HMD glasses (Fig. 1.4). Presbyopic people can read enlarged paper documents easily by the glasses system. Whether the user is holding a paper document or placing it on the desktop for reading, the system based on the HMD glasses should automatically identify the position of the paper document in the user's field of view from the screen information acquired by the camera on the glasses, crops the image of the document from the background, and then overlays it in the user's field of view in real-time

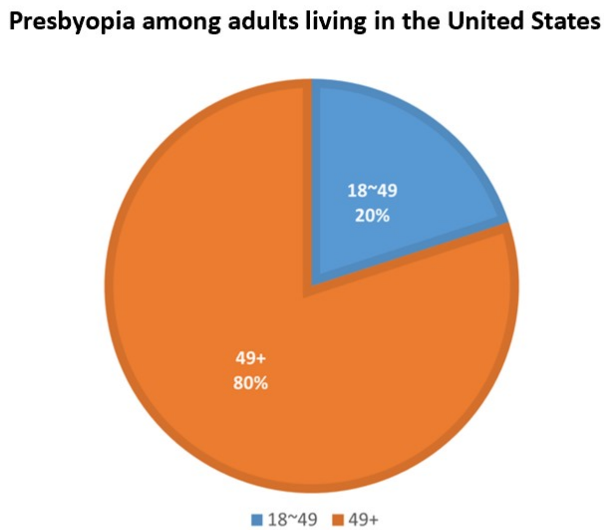


Figure 1.1: Presbyopia among adults living in the United States.

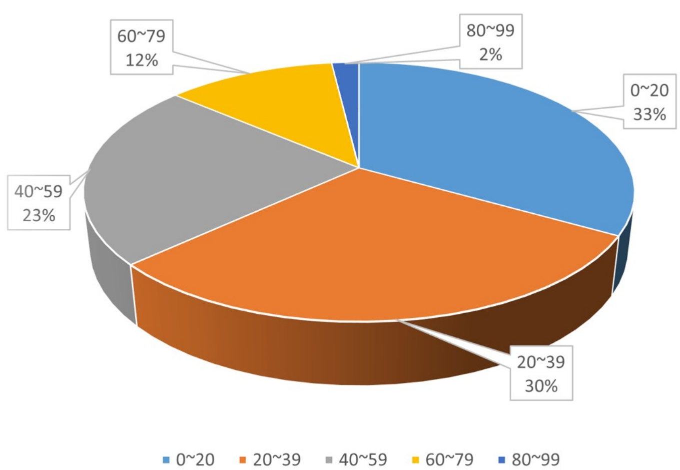


Figure 1.2: Age structure of the world population.

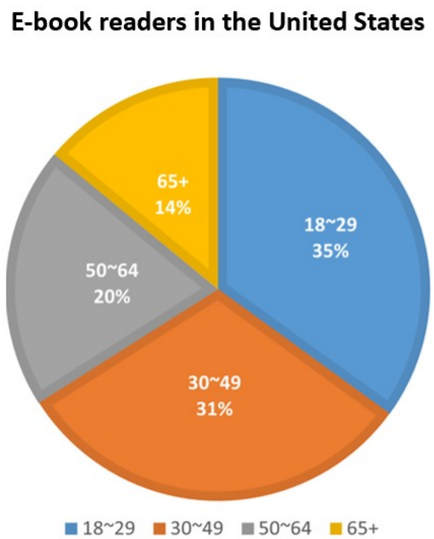


Figure 1.3: E-book readers in the United States in 2018, by age.

Figure 1.4: HMD device (EPSON-BT300).

through the display screen of the HMD glasses. The user interacts with the system through the touch controller of the HMD glasses to determine when magnification is required and how much magnification of the paper document they need.

In order to realize AR paper document zoom-in, a camera is of course needed to shoot at the paper document (Fig. 1.5). The image information in the reader's field of view is needed to be shot in real-time first. The camera is mounted on HMD glasses. Then the paper document area is extracted from the camera image to prepare for only document area zoom-in. Once a user faces the paper document and starts the system (Fig.1.6), he will see the enlarged document and background at the same time (Fig.1.7). It is not a simple task to extract the document area from the general scene image. A paper may bend, and the edges of it may not become smooth straight lines. The paper material is able to be a similar color to the background. The background situation will also become complex, and sometimes there may be a frame image like a paper document. In addition, I also consider two application scenarios, where the user places the paper document on the desktop for reading and the user holds the paper document for reading. The difference between the two application scenarios is that in the former scenario the four vertices of the paper document are intact; while in the latter scenario, depending on how the reader holds the document, one or more of the four vertices of the paper document may be missing. Finally, the clipped document area is overlaid in the user's field of view through the AR glasses, and a user-adjustable magnification is provided. Furthermore, the clipped document area is overlaid in the user's field of view and the display of the HMD glasses has transparency, which means the background will cause a huge influence on the image that the users want to see. Especially when there is a lot of small text on the book, the text of the original image and clipped document area will become staggered together, which makes reading extremely difficult. I solve this problem by enhancing the contrast of the clipped document area image.

In summary, the prototype HMD glasses system has three basic modules: target

Figure 1.5: HMD glasses' camera

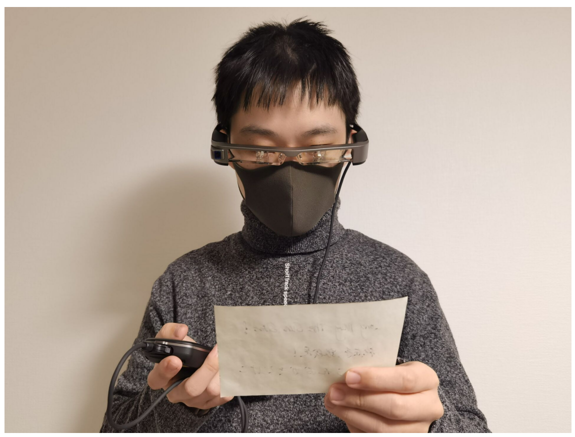


Figure 1.6: Appearance of application scenario.

Figure 1.7: Zoomed-in view illustrative composite image through glasses

area automatic recognition module, adjustable magnification module, image enhancement module. Based on the overview of the prototype HMD glasses system, chapter 2 will describe the method for extracting the target area based on two different application scenarios. And chapter 3 will show how to achieve the automatic zoom-in operation of the target area. And chapter 4, I will illustrate how to solve the problem caused by the transparency of HMD glasses. Chapter 5 will show the experiments of the HMD glasses system. And chapter 6 will show the conclusion and future work.

Chapter 2

Target area automatic recognition module

In chapter 1, I assume two different application scenarios, placing the paper document on the desktop for reading and holding the paper document for reading. The difference between the two application scenarios is whether the vertices of the paper document are missing or not. For these two cases, I design two different extraction methods. The basic principle of both methods is similar. They both scan the color value of each pixel of the image data within the user's field of view to determine whether the pixel is included in the target area (paper document). In this approach, the RGB value of the document and background will seriously affect the positioning results of the target area. And in fact, The paper material can be a similar color to the background. The background situation will also become complex, and sometimes there may be a frame image just like another paper document. So now times, it is hard to handle a wide variety of colors and shapes of documents and background combinations. In order to validate my idea of the AR zoom glasses system, it is assumed for a prototype system that the paper document is a clear white quadrilateral in the dark color background that is not white to reduce the effect of color. Also, the paper document's edges do not bend, but the vertices of the paper document could have one or more missed. However, the paper document can be rotated in 3D space. In the other words, this system should be robust to the rotation and missing vertices of paper documents. The coordinates of these vertices will be used to determine the location of the target area and prepare for the zoom-in operation.

2.1 Desktop mode

2.1.1 The design of desktop mode

As mentioned above, when the reader places the paper document on a flat desktop, the four vertices of the paper document should be intact without missing, in the meanwhile the edges of the document are distinct and not bent. In the prototype system, I already assume that the RGB value of the target area (paper document) has an obvious difference from the background area. So by comparing the RGB value of the two-pixel, the prototype system will identify the pixel belonging to the target area or background area.

In this circumstance, first of all, a camera is set on the HMD to obtain the user's field of view image data. In order to obtain the four vertices of the target area, every frames' image data will be scanned several times in different directions and check every pair pixel's RGB value. Once a frame of data enters the system, the system will scan the frame multiple times in parallel from top to bottom and bottom to top until it hits the highest and lowest vertices of the target area. The highest and lowest vertices of the target area will be stored. Then, according to the coordinates of the two vertices, the system will calculate the slope of the line through the two points (Fig. 2.1). Based on the equation of this line through the highest and lowest vertices of the target area, the system scans the frame image multiple times again. By changing the intercept of the line equation, every scan is parallels to this line. In this way, the system will determine the remaining two vertices from side edges to center (Fig. 2.2).

2.1.2 The confirm of desktop mode

As I said, the target area (paper document) should be a white quadrilateral in the desktop mode. Its edges could not be bent. And its four vertices should be clear

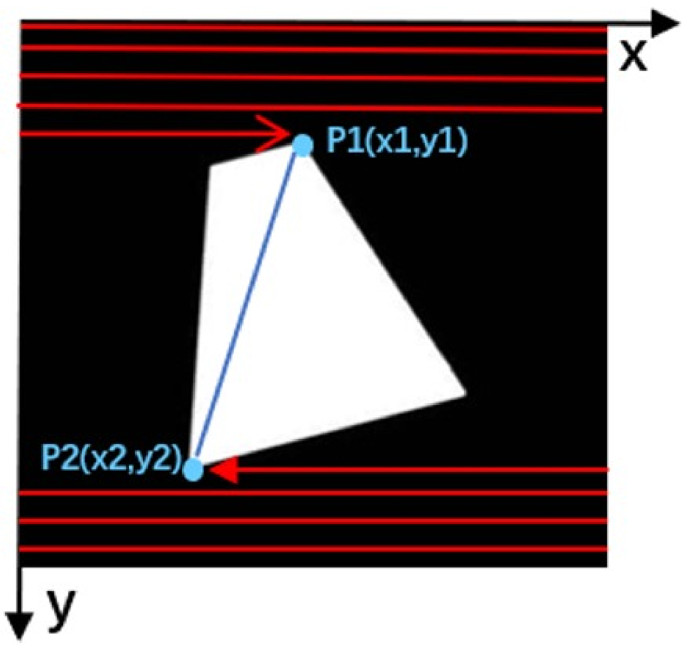


Figure 2.1: Determine the highest and lowest points of target area.

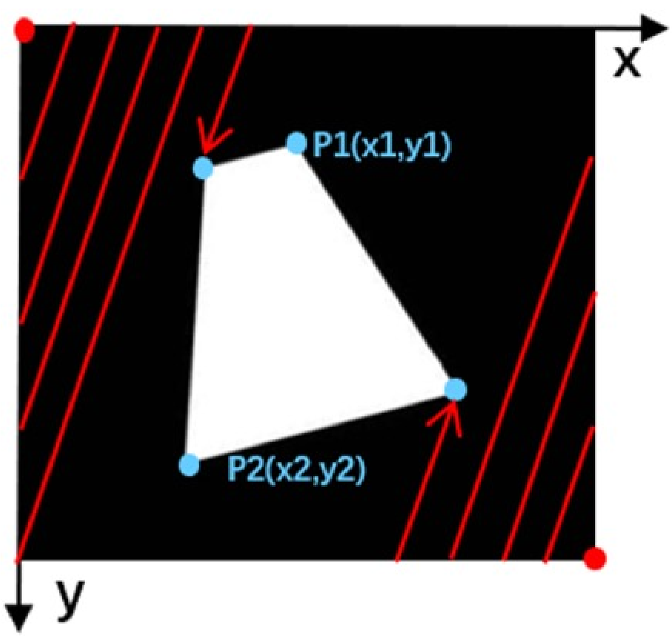


Figure 2.2: Determine remaining two vertices.

and complete, in other words, not missing. But the target area (paper document) can rotate in 3D space, no matter what kind of quadrilateral it is. So I use a series of different shaped quadrilaterals in different rotations to verify the accuracy of the prototype system. The test result (Fig. 2.3) shows that under the above conditions, the prototype system can quickly identify the four vertices of any quadrilateral. And the effectiveness and robustness of the prototype system were confirmed.

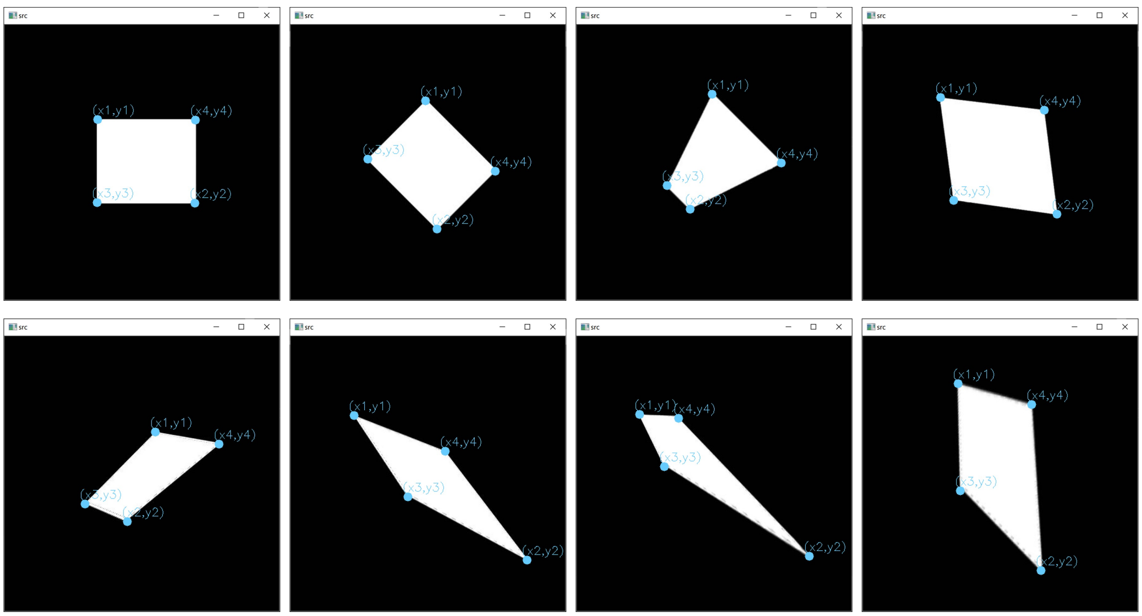


Figure 2.3: Test result of destop mode.

2.2 Hand-hold mode

2.2.1 The design of hand-hold mode

For readers, reading is not only on the desktop but also by holding a book or a paper document. Especially for presbyopic people, they always need using hands to hold the paper document to adjust the distance between the eyes and paper which could make them see the text of the document clearly. When a reader holds a document, the user's hand may cover the target document area, in which case occlusion occurs in the area. In particular, when the hand covers the vertices of the target document area (Fig. 2.4), the accuracy of determining the target area will be reduced. Also, when the reader uses two hands to hold the book or paper document, there is a high probability that their fingers will cover one more vertex of the paper document. In this circumstance, the prototype system definitely needs to have the ability to deal with the situation of missing vertices. Even if readers' fingers cover the vertices of paper cause the vertices missing, the prototype system should still work effectively. Based on the scanning strategy of desktop mode, I design a new way to identify vertices and complete missing vertices. By the way, in this mode, the assumption of paper documents that no edge bent, color difference, and rotation will stay the same.

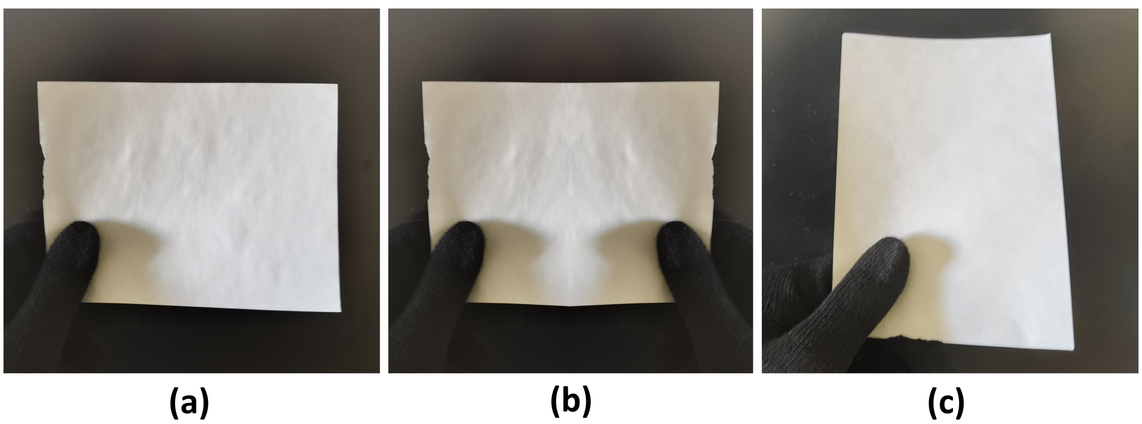


Figure 2.4: A example of hand-hold. (a) One vertex missing, (b) More than one vertex missing, (c) One vertex missing with paper document rotated.

To solve this kind of vertices missing problem, first of all, the prototype system will do the same thing: scan multiple times in parallel from top to bottom and bottom to top until it hits the highest and lowest vertices of the target area (Fig. 2.5 (a)). This step will tell the system the height range of the target area that will help the system to reduce the time cost of the next step. Next, the target area will be scanned multiple times in four parallel directions: up, down, left, and right which is within the height range of the target area. In this step, the system will obtain the coordinates of the boundary points of the target area. Based on these coordinates, the system will calculate a series of slop of the target area's edge line and pick up the correct one to construct a linear equation (Fig. 2.5 (b)). The intersection points of each line are calculated by the equation to obtain the coordinates of the vertices of the target area (Fig. 2.5 (c)).

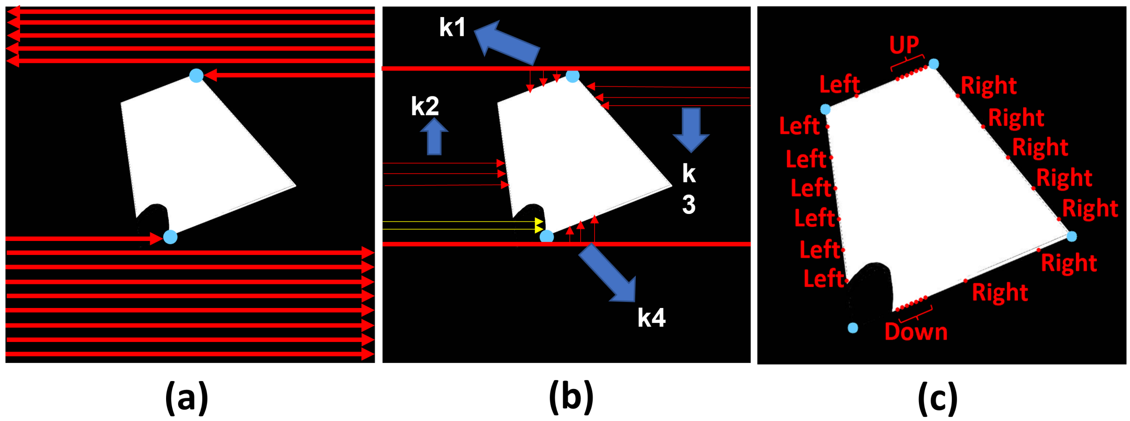


Figure 2.5: The strategy hand-hold mode. (a) Determination height range of target area, (b) Scan multiple times in four parallel directions and calculate the edge line's slop, (c) Complete the missing vertex

2.2.2 The confirm of hand-hold mode

In the process of confirmation of hand-hold mode, I used different locations, numbers, and degrees of vertex missing images to verify the validity and accuracy of the handheld mode. The result shows that no matter how the area is rotated or how many vertices are missing, these covered vertices can be correctly identified (Fig. 2.6). At the same time, as the last picture of Fig. 2.6 shows slight variations of lighting do not affect the results.

2.3 Scanning speed optimization

As described above, when the system tries to determine the position of the target area, it will scan the picture of the user's view field multiple times in different directions. Since the target area only occupies a part of the entire screen, most of the scans are meaningless. Too much scanning will slow down the system's operating

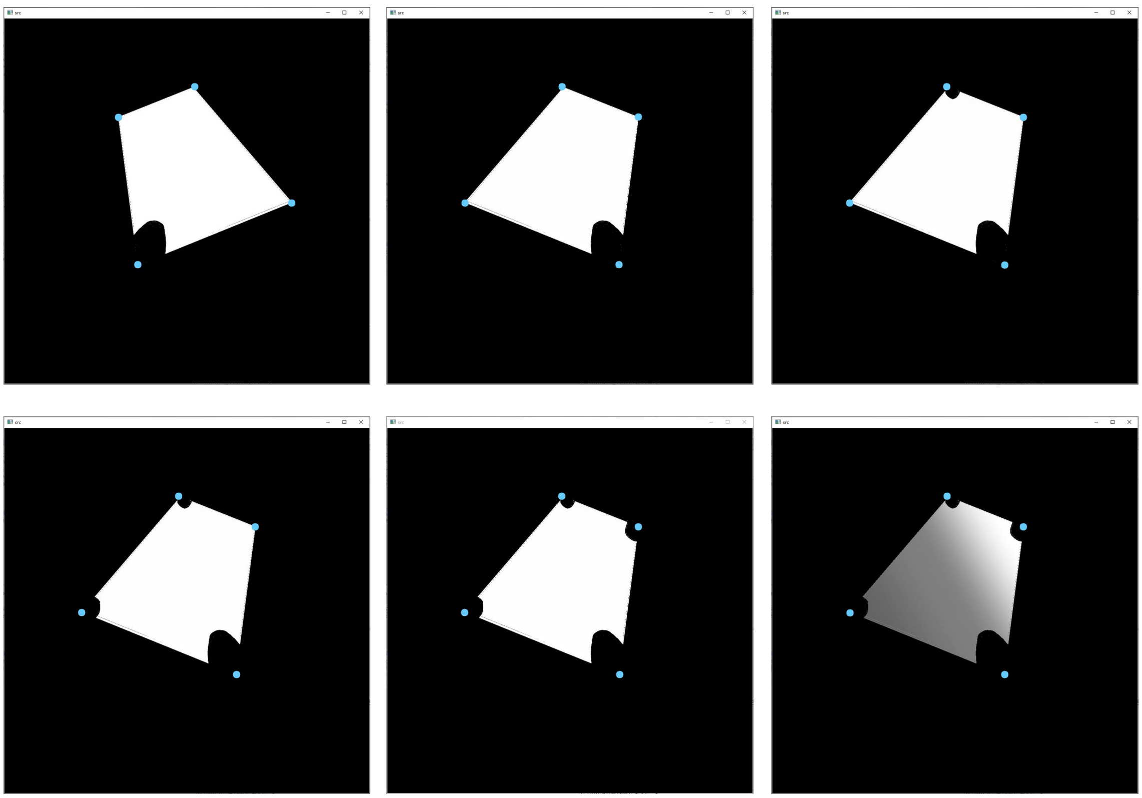


Figure 2.6: Test result of hand-hold mode.

efficiency and cost lots of RAM. So in the process to find the highest and lowest coordinates or determining the coordinates of each boundary point of the target area, the system uses a binary heuristic search algorithm [6] [7]. Take finding the lowest point as an example, the system will first try to execute a horizontal scan at half the height of the entire screen and then scan again at a quarter of the height if it hits the target area. Like the example image shows, one quarter misses the target area. Then, the system starts with one-half as the starting point and moves down one-eighth of the distance to scan again. I set one-eighth as the shortest step size, and from here I will scan line by line to a quarter until I hit the lowest point (Fig. 2.7 (a)). I use the same idea to deal with the process of determining the boundary coordinates of the target area. The difference is that all scanning takes place on a column of pixels (Fig. 2.7 (b)).

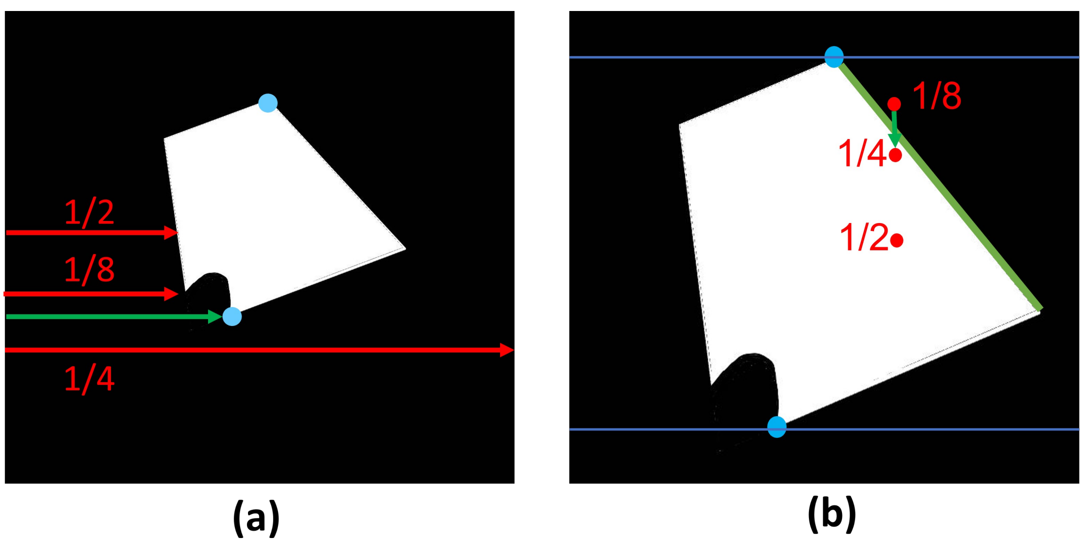


Figure 2.7: Two speed optimization of system. (a) Find the highest and lowest coordinates of the target area, (b) Determine the coordinates of each boundary point of the target area.

Chapter 3

Adjustable magnification module

3.1 The design of adjustable magnification module

The system needs to crop the target area from the view field of the user, then enlarge this part and overlay the display on the HMD glasses' screen. But without an eyeball tracking device, the system can not really know where the user is reading right now. Sometimes, even if the user equips HMD glasses, their eyes will not keep staring at the center of the glasses. They will look around within the paper document area (Fig. 3.1(a)). Under this circumstance, I deal with this problem with the assumption that the users slight keep staring at the glasses' center (Fig. 3.1(b)). So the prototype system should keep the center of the original image is same as the enlarged image. Although the user sees the dark color background and white paper that are originally included in the field of view (Fig. 3.2(a)), they also see the enlarged part of the paper extracted from the camera image (Fig. 3.2(b)). The user will see AR overlaid view like the illustrative composite image as the field of view (Fig. 3.2(c)). In this approach, users will know where they are reading now and can easily adjust the magnification whatever they need to fit their degree of presbyopic eyes.

As mentioned in section 2, the system already got every vertex coordinate of the target area. So in the prototype system, the target area is determined. In order to keep the center of the original image the same as an enlarged image, the system needs to maintain the center of the original image constant. So the strategy of

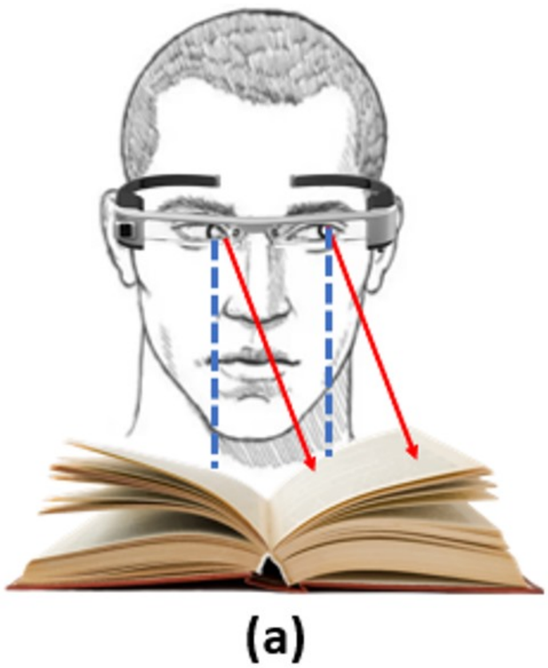


Figure 3.1: User's sight. (a) Normal sight, (b) Assuming sight.

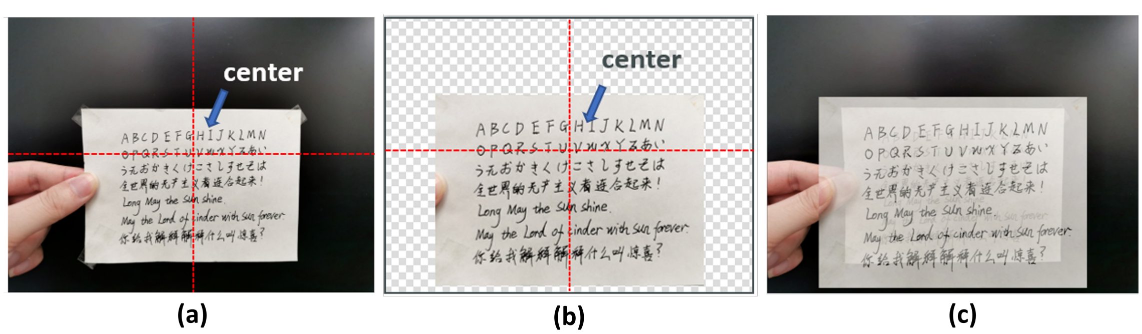


Figure 3.2: Enlarged display. (a) Field of view from camera, (b) Enlarged image for display, (c) User view.

the prototype system is that take the center coordinate of the original image as the coordinate origin point to rebuild a coordinate system from camera coordinate (Fig. 3.3(a)) system to a new one (Fig. 3.3(b)). By rebuilding the coordinate system, the center coordinate will stay (0,0) no matter how the user moves their head or HMD glasses. Once, a new coordinate system was built, the prototype system will recalculate the coordinates of the original vertices of the target area in the new coordinate system and crop the target area from the original image. Then, the system will use an adjustable magnification to transform the new vertices' coordinate linearly to enlarge the target area (Fig. 3.3(c)) and overlay display on the HMD glasses' screen just like Fig. 3.2(c).

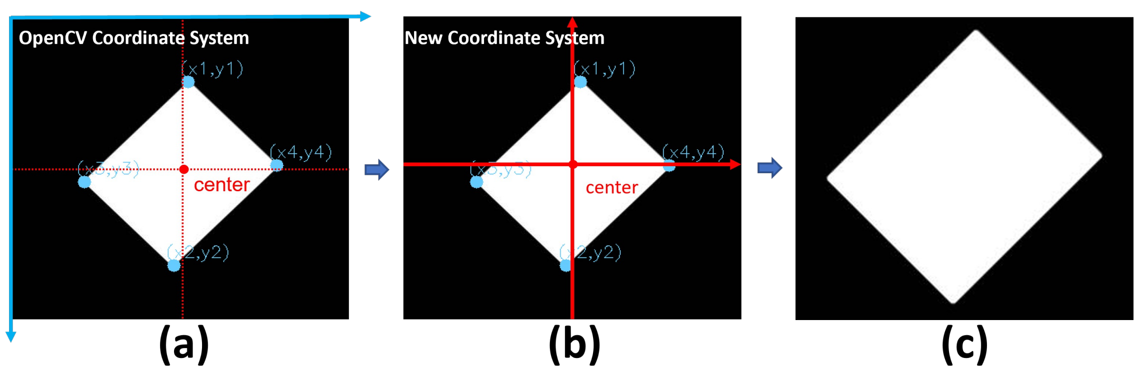


Figure 3.3: The field of view center maintenance process. (a) Originally image's coordinate system, (b) Enlarged image's coordinate system, (c) cropped enlarged image for display.

3.2 The confirm of adjustable magnification module

In order to confirm the target area zoom-in module, I mark the target area with the number and divide it into nine parts to check whether the center position is the same before and after enlargement (Fig. 3.4(a)(b)). As the result shows no matter how the target area is rotated the center of the original image is the same as the enlarged image. And based on the new coordinate system, the target area was enlarged correctly (Fig. 3.4(c)(d)).

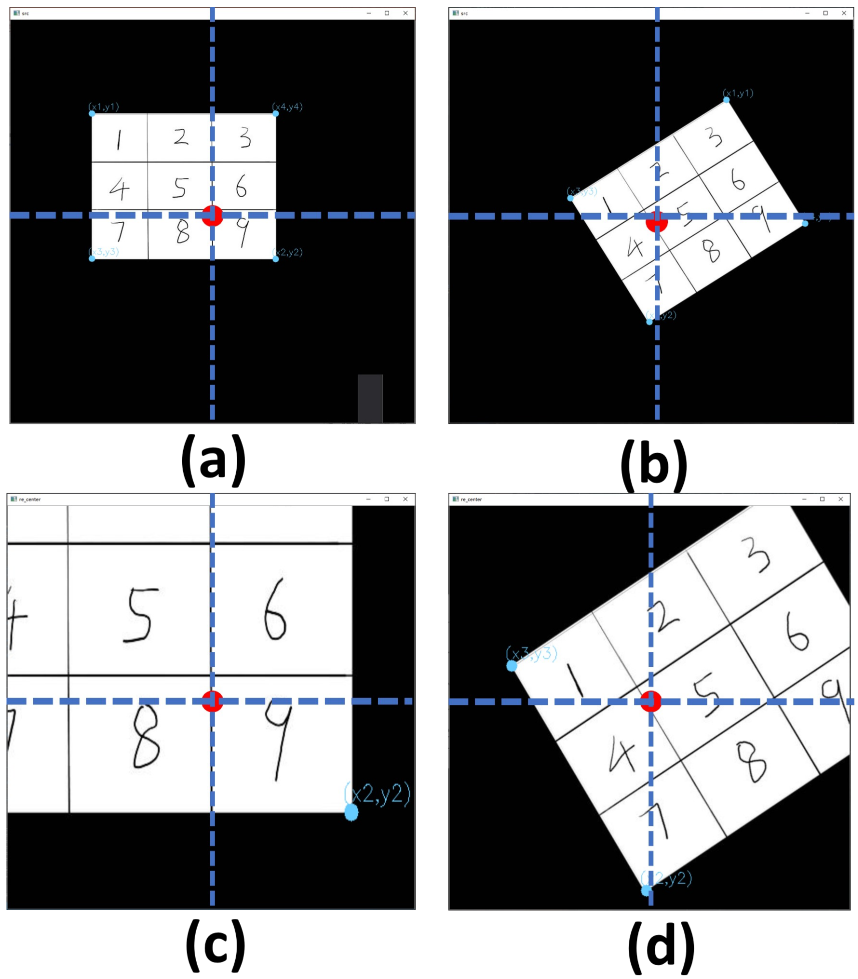


Figure 3.4: The test result of adjustable magnification module. (a) Originally image, (b) Originally image rotated, (c) Enlarged image, (d) Enlarge of rotated image.

Chapter 4

Image enhancement module

4.1 The design of image enhancement module

As I mentioned above, the HMD glasses have are transparent feature (Fig. 4.1(a)), and the enlarged target area is overlaid display on the user's field of view (Fig. 4.1(b)). Users will see the dark color background and white paper that are originally included in the field of view, they also see the enlarged part of the paper extracted from the camera image. It means that the text in the background will have an influence on the text of the enlarged target area, especially when the text of the paper document is very dense, and this influence will make the text of the target area become too difficult to read. Under this circumstance, the system should avoid this phenomenon and make sure the image of the enlarged part is much clearer. The system will enhance the cropped target area image's contrast to reduce the influence of the background image.

Contrast enhancement algorithms for images have important applications in many situations. Especially in medical images, because visual inspection of medical images is necessary for the diagnosis of many diseases. The contrast of medical images is very low due to the limitations of the images themselves and the imaging conditions. Therefore, a lot of research has been carried out in this area. Such enhancement algorithms generally follow certain visual principles. It is known that the human eye is more sensitive to high-frequency signals (at edges, etc.). Although detailed information is often a high-frequency signal, they are often embedded in a large

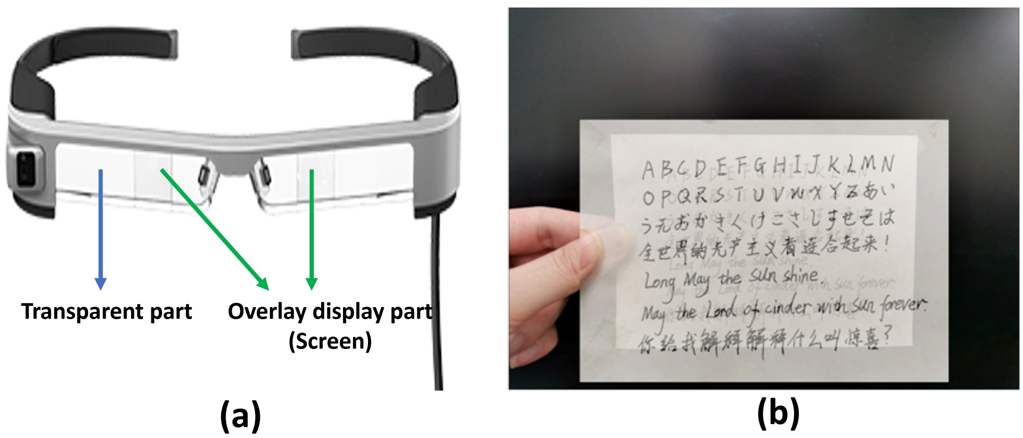


Figure 4.1: (a) HMD glasses feature, (b) User view.

amount of low-frequency background signals, which makes them less visually visible. Therefore, an appropriate increase of the high-frequency part can improve the visual effect and facilitate the diagnosis.

The traditional linear contrast boosting and histogram equalization is the most widely used global image enhancement methods. Contrast boosting linearly adjusts the dynamic range of the image, while histogram equalization uses the cumulative histogram distribution probabilities to remap the image data. Although these methods are simple, they do not take into account local information. Moreover, global histogram equalization (GHE) also produces some noise over-enhancement [8].

So I used the ACE (Adaptive Contrast Enhancement) algorithm based on the research of Patrenahalli M. Narendra and Robert C. Fitch [9]. The ACE algorithm uses the unsharp mask technique, and the process is as follows: first, the image is divided into two parts. One is the low-frequency unsharp mask component, which can be obtained by low-pass filtering (smoothing, blurring technique) of the image. The second is the high-frequency component, which can be obtained by subtracting the inverse sharpening mask from the original image. Then the high-frequency component is amplified and added to the unsharp mask. Finally, the enhanced image will be rebuilt. Not only is contrast-enhanced, but I also transform the original image into the HSI color space and enhance the I brightness channel to make the enlarged part much brighter.

4.2 The confirmation of image enhancement module

In order to confirm the imager enhancement module, firstly I test some basic images to confirm the image contrast enhancement module is working normally and efficiently. As mentioned above, a contrast enhancement algorithm is often used on medical images, so firstly I test some cell scan images (Fig. 4.2(a)). The result (Fig. 4.2(b)) shows that cells' edges and holes have become clearer, and the brightness has been significantly improved. Then, I take a picture of a white paper fixed on the black board and test it in the same way (Fig. 4.2(c)). Similarly, the text in the picture becomes clearer (black and white contrast), and the entire paper document is more obvious on the dark color background board (Fig. 4.2(d)).

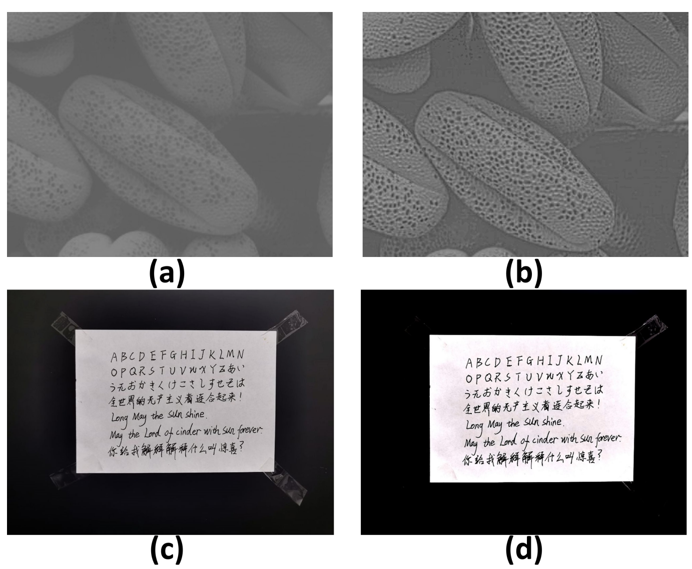


Figure 4.2: The test result of enhancement. (a) Original cells image, (b) Enhanced cells image, (c) Original document image, (d) Enhanced doucument image.

Chapter 5

Experiments

The prototype system has been developed based on three basic modules: target area automatic recognition module, adjustable magnification module, image enhancement module. Once the system is started, the camera on the HMD glasses will capture the image data in the user's field of view and transmit it to the three modules of the system for processing. Whether the paper document is placed on the desktop or held in the hand, the system will automatically determine the location of the target area and provide an adjustable zoom function. At the same time, the image contrast of the target area will be automatically enhanced to solve the problem of overlapping text caused by the transparency of HMD glasses. So I build the system on an HMD glasses device: EPSON BT-300 to test the three modules following the process, to confirm the effectiveness and accuracy of the prototype system (Fig 5.1). Because the performance of this HMD glasses is too low to process one frame. In order to better verify the effectiveness and accuracy of the modules and algorithms, I also used the tablet computer to conduct experiments (Fig 5.2).

5.1 The experiment of target area automatic recognition module

When the system tries to determine the location of the target area, it will face two different application scenarios: hand-hold the paper document or placed it on the desktop. For the two application scenarios, I conducted experiments separately to

Figure 5.1: Appearance of an experiment (on glasses).

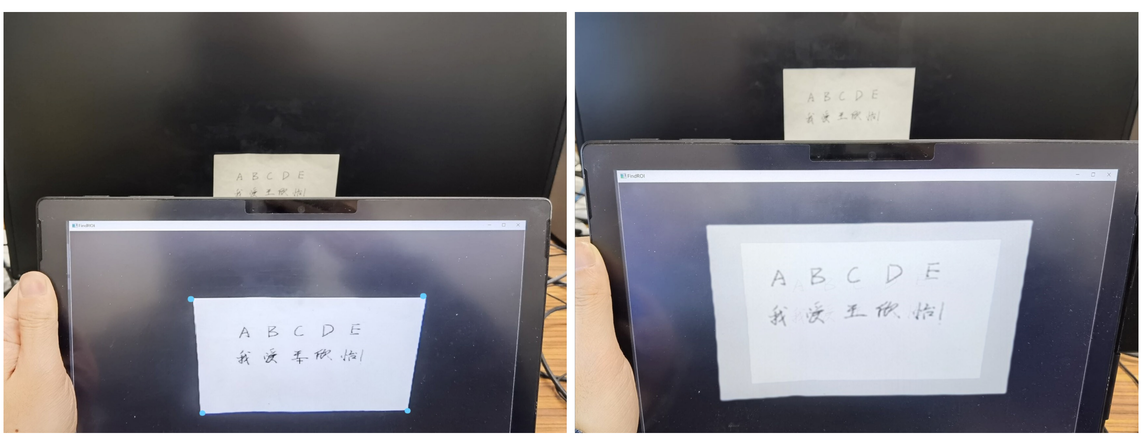


Figure 5.2: Appearance of an experiment (on tablet computer).

confirm that the module works properly. As mentioned in section 2, the system needs the color of the paper document to have a significant difference from the color of the background. Also, the paper document's edges do not bend, but the vertices of the paper document could have one or more missed. However, the paper document can be rotated in 3D space.

Because of putting the document on the desktop, there is no finger influence or 3D rotation in the desktop mode. When the user uses HMD glasses and places the paper document on the desktop, the camera on the HMD glasses is often not kept perpendicular to the paper document, and the projection of the paper document on the plane which is perpendicular to the camera will be another quadrilateral (Fig. 5.3). That means I still have to consider other shapes quadrilateral in desktop mode.

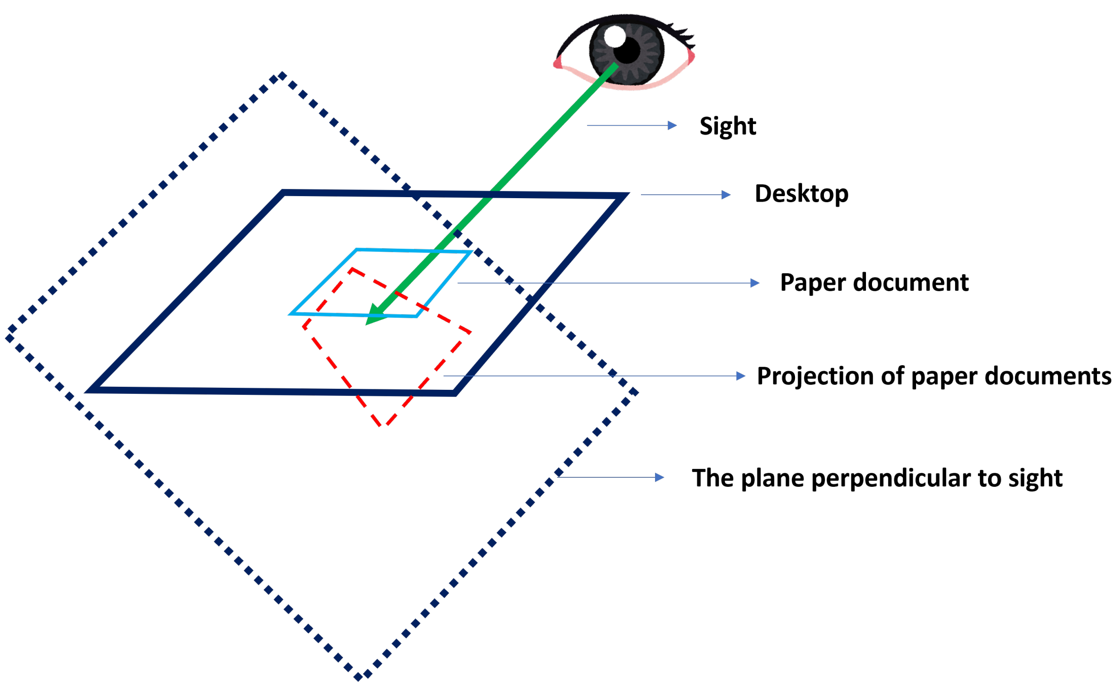


Figure 5.3: An example of paper document projection.

So in the experiment of the desktop mode, I fixed various shapes of white quadrilateral paper documents on a dark color board and set the paper document to lots of different rotations. Different shapes and different angles of rotation of the quadrilateral paper documents create various combinations. I hand them over to the system to verify the accuracy and effectiveness of the target area automatic recognition module.

I tested several common shapes of quadrilaterals and rotated them at various angles. As the result shows, this module of the system can identify quadrilaterals with various angles and shapes and automatically mark their vertex positions (Fig. 5.4, 5.5). These marked vertex positions will be transmitted to the next module: the adjustable magnification module for readers to customize their appropriate magnification.

As I've said, hand-hold mode requires more consideration than desktop mode. In addition to the projection of paper documents, there may be more situations. The biggest influence is that when the reader holds the paper document, the fingers will cover the document, resulting in one or more vertices of the paper document missing. This made the scanning method in the desktop mode no longer applicable, so I redesigned the scanning strategy based on this to complete the missing vertices.

In the experiment of hand-hold mode, the experimenter will wear a pair of black gloves to reduce the effect of hand color on paper documents. Then the experimenter will hold the paper document with one hand or both hands and rotate the paper document at different angles. The experiment focuses on whether the system can autocomplete missing vertex (one or more) in hand-hold mode and still recognize all vertices in the target area under different rotation angles. Experiment result shows that no matter how the paper document rotated, the missing vertex still could be identified and more vertices missing do not affect the result (Fig. 5.6).

5.2 The experiment of adjustable magnification module

As mentioned above, without an eyeball tracking device, the system can not figure out where the user is reading right now. Under this circumstance, the system's strategy is to keep the center of the original image is same as enlarged image. In

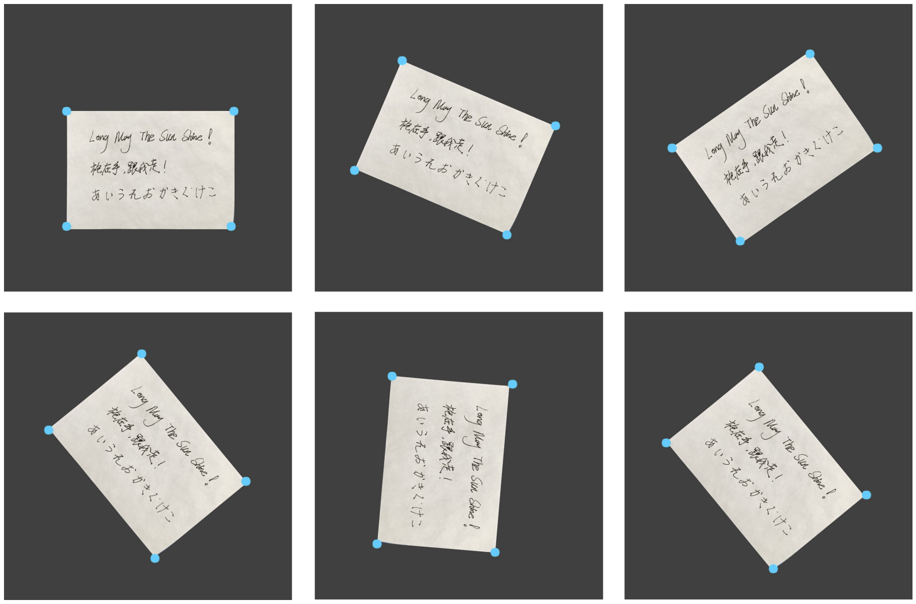


Figure 5.4: Recognition results of rectangular paper documents under various rotation conditions.

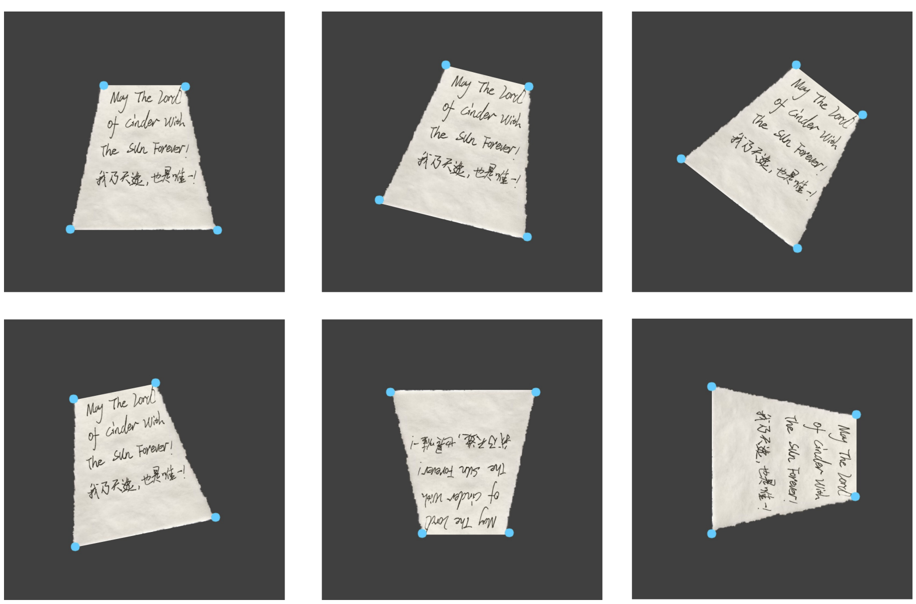


Figure 5.5: Recognition results of trapezoidal paper documents under various rotation conditions.

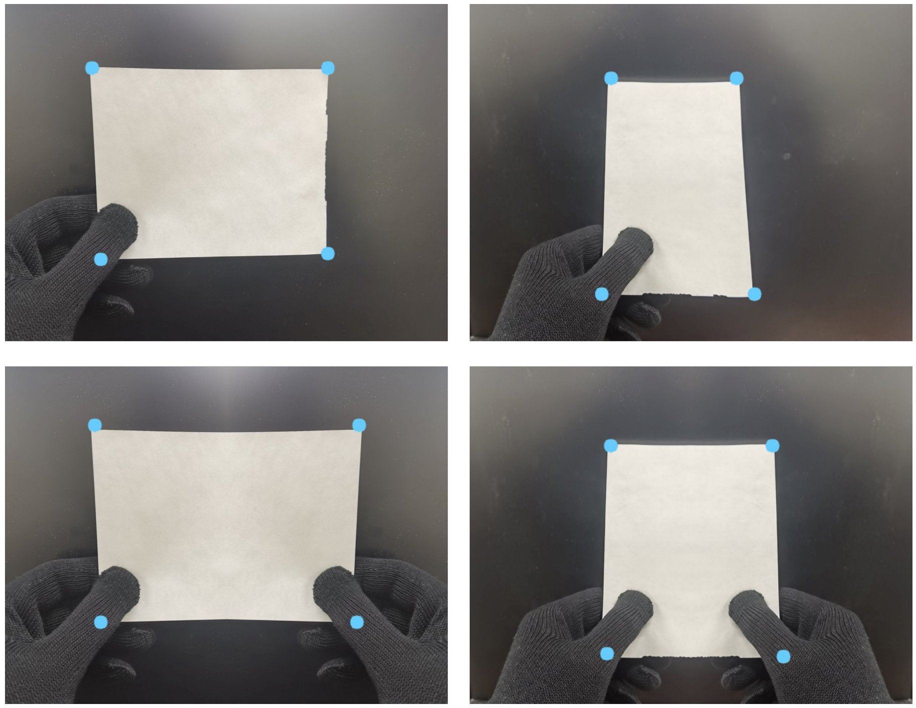


Figure 5.6: Recognition results of hand-hold mod under various rotation and vertices missing.

this way, users will know where they are reading now and can easily adjust the magnification whatever they need to fit to their degree of presbyopic eyes.

In experiments on the system's adjustable magnification module, two important things must be confirmed: whether the module can provide an adjustable magnification and whether the center of the enlarged image is the same as the original image. If the target area automatic recognition module works properly, the adjustable magnification module will work properly too. Because the operating results of this module depend on mathematical relationships, if the results of the previous module are accurate, there must be no problem with this module. So I made some of the simplest comparison tests to make sure the module was working properly. I fixed the paper document on the dark color plate. And I simply move and rotate the paper document to generate different experimental use cases, zoom in on the use cases to different magnification degrees and observe whether the enlarged image and originally image's centers are consistent. As the experimental results show, no matter how the experimenter moved or rotated the paper document. This module always maintains the image center position before and after magnification and provides an adjustable magnification (Fig. 5.7).

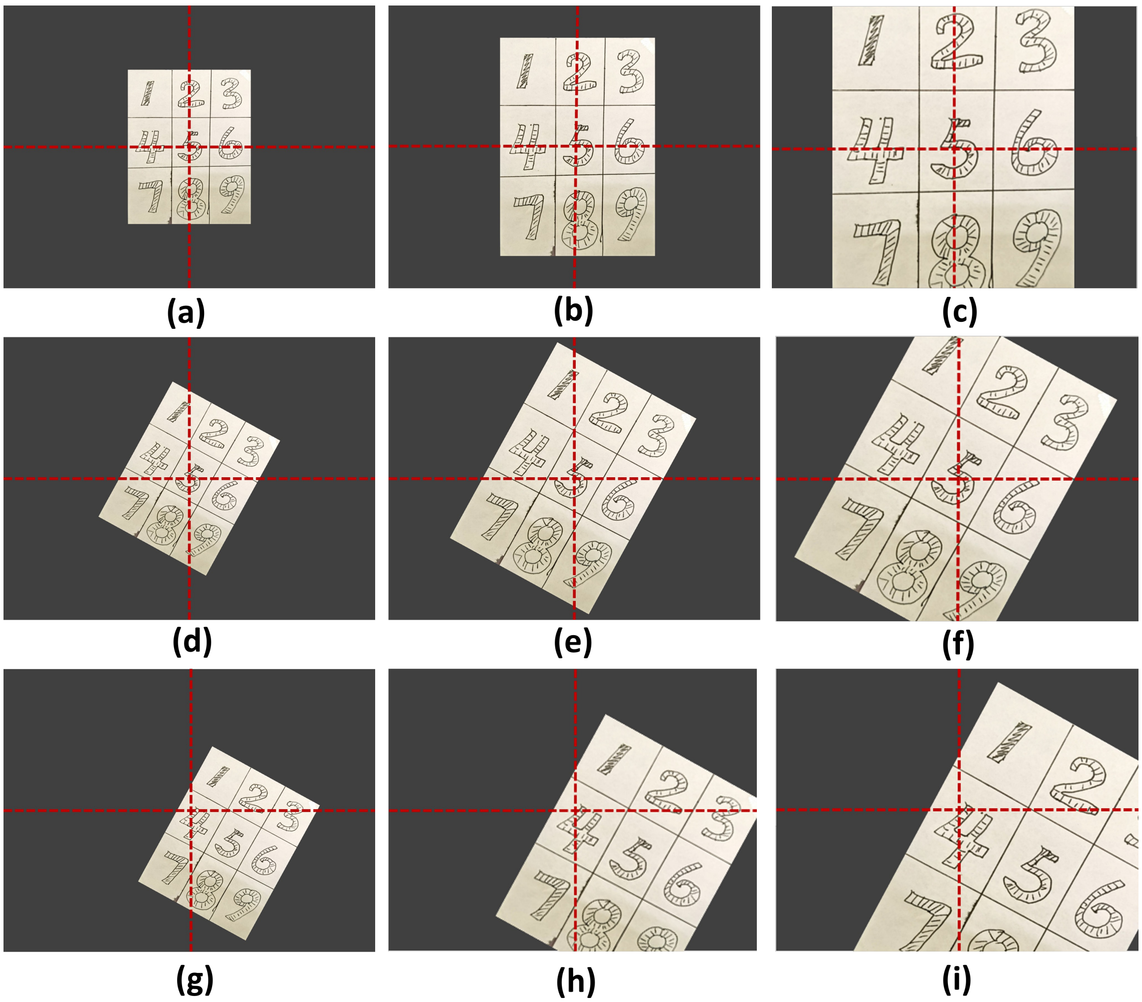
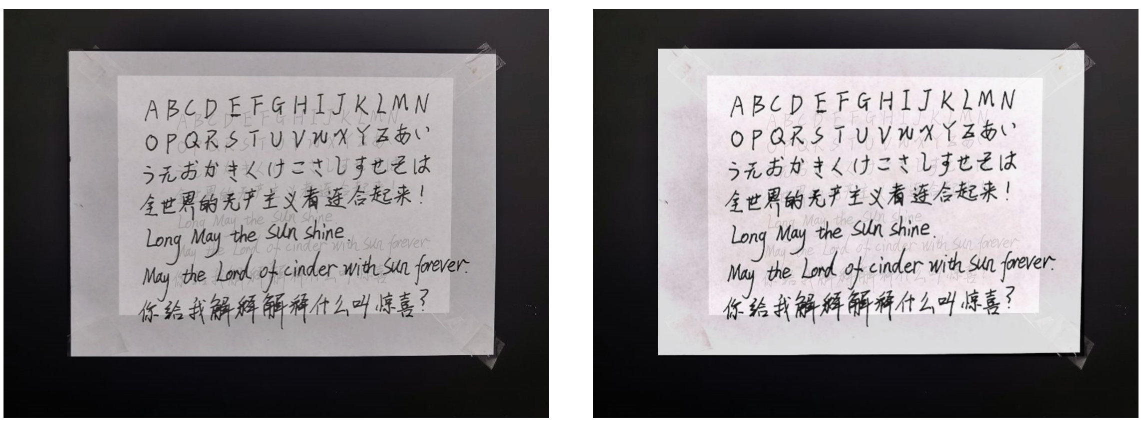


Figure 5.7: The result of the experiment of adjustable magnification module. (a) Original image, (b) Original image enlarged by 1.5 times, (c) Original image enlarged by 2 times, (d) Rotated original image, (e) Rotated original image enlarged by 1.5 times, (f) Rotated original image enlarged by 2 times, (g) Rotated and moved original image, (h) Rotated and moved original image enlarged by 1.5 times, (i) Rotated and moved original image enlarged by 2 times.

5.3 The experiment of image enhancement module

In order to solve the reading influence of the translucency of the overlaid display of HMD devices, the system will adjust the contrast of the enlarged part (target area) to make it more clear. In experiments on the system's image enhancement module, I still use a white paper document fixed on a dark color plate. After the processing of the target area automatic recognition module and adjustable magnification module, then enhance the cropped target area. As the result shows that the original image's background has an influence on the enlarged part (Fig. 5.8 (a)), but with the enhancement, the enlarger part becomes clearer and brighter (Fig. 5.8 (b)) and the influence from the background been reduced.



(a) (b)

Figure 5.8: The result of the experiment of image enhancement module. (a) The original image, (b)The enhanced image.

5.4 The experiment of system and evaluation

In order to verify the effectiveness of the system for user assistance, firstly subjects try to read the document without my proposal system. They need to face a black plate with a white document. Then they read the text on the white document, and take some notes about it in the meantime (Fig. 5.9 (a)). Next, subjects will wear the HMD glasses, and perform the same work again (Fig. 5.9 (b)). When a subject clicks the zoom button of the system, it starts scanning the camera image. The paper area is automatically recognized, and the enlarged area is overlaid on the HMD. It is difficult to take an AR seen photo through an HMD, an illustrative composite image shows the user's field of view (Fig. 5.9 (c)). Subjects can change the magnification of zoom manually. After all these, a questionnaire is used to obtain the reading experience and feelings of all the experimental subjects on whether they were equipped with HMD or not. Subjects indicated that it is easier to operate than adjusting the glasses and moving the head or the document to focus and to find the appropriate magnification using the touchpad. They also mentioned that this system can make it more convenient to take notes or other hand's tasks.

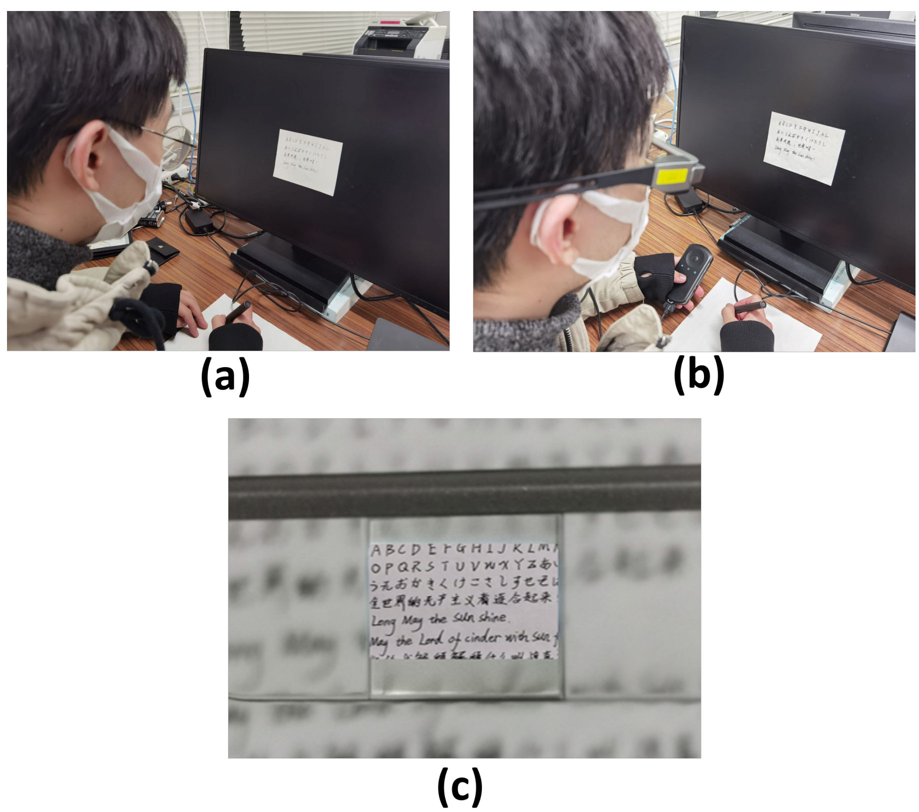


Figure 5.9: The experiment of the system. (a) Read document and take notes without HMD glasses, (b) Equip the HMD glasses to read doucment and take notes, (c) Illustrative composite image as field of view.

Chapter 6

Conclusion and future work

6.1 Conclusion

Presbyopia is hard to adjust their eyes' lens and they prefer to read printed books. When they move the book to a distance their eyes would not out of focus, but the text becomes too small to read; when they move the book to a close distance, the text becomes larger but still difficult to read because of being out of focus. On the other hand, although reading glasses are often used when people suffering from presbyopia to read the paper document, it is necessary to repeatedly remove and put on the glasses, when they are for example taking notes and other operations on a desk. It is difficult to cope with such complex situations even if using multifocal glasses. As people's age grows, no matter the severity of presbyopia or physical coordination will get worse and worse. From this, I have proposed an HMD glasses system that can automatically identify the book area and provide an adjustable magnification, in addition to enhancing the image of the book section. The system is easy to operate and can effectively help presbyopia to read.

6.2 Future work

In the future, target area recognition should be generalized for, i.e. any background or any document, by applying CV technology. I will keep the focus on further improving the reading influence of the translucency of the overlaid display of HMD devices by adjusting the contrast. And for the experiment, it is important how the technique compares to bifocal or progressive lenses. I also would like to detect the distance between the eyes and the paper document and determine whether enlarge operation is needed automatically [10].

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