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Constructing a Simulation Testbed of Age-related Cataract

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Abstract

Nowadays, the population of aging people increases rapidly, therefore, how to design products for elderly has become a hot issue. Due to the age gap; young designers cannot truly experience the physical problems that happen to elderly. This might causes low quality of aging product design. This study focuses on a common degenerating feature of aging vision - age-related cataract/senile cataract and constructs a product testbed for simulating elder's vision. It can help industrial designers to have a guide when processing product detailed design. This study applies cataract knowledge of ophthalmology as basis, and utilizes image processing technique of Visual Basic to simulate the sight of cataract. In the research, it constructs a digital eye chart and confirms its accuracy with standard eye chart of outpatient services by an experiment. The experiment objects are 15 age-related cataract patients (28 target eyes). Furthermore, this study makes an Age-related Cataract Image Blurring Program which can blur the digital eye chart for the second experiment - "blurry image recognition experiment". The purpose of the second experiment is to decrease the visual acuity of young healthy eyes (vision with correction, 1.0) and to gather statistics for recognition critical point. These statistics represent different blurry degree of visual degeneration and are used to construct the simulation function of testbed. The whole program is a product design testbed. The purpose of it is to provide industrial designers a tool to import the image of product model and to evaluate the suitability of product for elders with age-related cataract. In the case verification, it applies a digital hanging clock as an example. The research result shows that when an age-related cataract patient's visual acuity decreases to 0.4 and 0.3, the appropriate word heights of digital clock are 140*mm* and 190*mm*.

Keywords: age-related cataract, elder's vision, image blurring, age-related cataract vision simulation testbed.

1. Introduction

Nowadays, many developing and developed countries have become aging society or aged society. However, the industrial designers in design industries are mostly with younger ages. They do not personally experienced aging physiology status. It might cause difficulties when considering suitable usability of aging products.

In the cognitive functions of human beings, the sense of sight is a main function to identify the status of surrounding objects and to learn experiences. Cataract is a most common visual degeneration symptom that happens to senile people. Also, it is the top one illness to cause blind. A cataract patient can change their lens to improve visual acuity by operation; however, the process of degeneration before operation is a long path.

In the visual degeneration simulation related studies, the description on how to match the degree of visual degeneration with mock up figures was not thorough. How to apply a standard to make the real vision and mock up figures have corresponding result is the main issue in this study.

This study applies cataract visual degeneration information as basis, and tries to find out the different vision level of age-related cataract through two experiments. Furthermore, it tries to construct a simulation testbed of age-related cataract to simulate how the blurry vision sees the product. Users can import product image into the testbed and get the image processing result to know if the product is suitable to certain senior people or not.

About the literature review of age-related vision degeneration simulation, this study explores two main aspects. Firstly, it focuses on the application of aging vision simulation. For example, cases that applying devices, 2D graphics, or webbed display function to describe the visual degeneration status. Secondly, it focuses on academic studies that apply study methods and experiments to gain the data for simulating aging vision.

In 2D simulation, about.com (2008) showed the image processing result to describe the cataract symptom. It applied animation software to display different degree of age-related illnesses. It utilized medical data to make the simulation. The website also solved the problem of text size that often bothers aging people by adding the function of adjusting text size by users. To write a computer program, former study has developed a similar platform. The platform was called aging vision simulator tool (Aging Vision Simulator, 2009). The purpose of it was to apply ergonomics knowledge to simulate aging vision and to educate people about what does aging people encounter. This tool concisely displayed the vision degeneration of 60 and 75 years old. It compared 20 years old vision with 60 and 75 years old vision by processing image. In the sample image, the vision has become darken and yellowed after processing.

In the preceding description, most of the application of age-related vision degenerating simulation focused on informing people about aging vision. Aging vision simulation could be displayed by devices, website display, and image processing software. Some of these works were developed based on medical studies. However, these applications did not reveal the detail study process.

There were many published age-related macular degeneration (AMD) simulation researches, and the purpose was to educate people about the symptom of the illness. AMD happens to the macula lutea that located at center part of retina. The sight of patient becomes dark and has distortion that causes reading difficulties. Some of the patient sees the periphery shape of a clock, but cannot see the time. The VRMedLab developed a Tele-Immersive medical education environment. To simulate the AMD symptoms, it created two masks. First mask was for simulating scotoma. The mask opacity could be changed into different levels to simulate the blurring center vision. Another mask showed the wavy effect of AMD (Jin, 1995).

Toufaili (2004) indicated that vision loss of 65 years old people were mostly irreversible cases. In the aspect of vision degeneration simulation, this study applied Head Mounted Device (HMD) to develop a simulator to inform people the progress of vision degenerating problem. This simulator could process digital image to change it gradually. It used an Eye Tracker to continuously define the fixation point of a user. In the experiment, 27 aging subjects were tested to find out the levels of degeneration. In addition, 9 subjects with center vision 20/20, average age 28 were tested with mask images to know the decreasing level of visual acuity. Another experiment was done by 18 subjects who had only one ill eye. It tried to figure out if the image processing was match to the reality. This study finally created a virtual environment to simulate cataract and AMD.

Ishihara (2001) indicated that in an aging society, the visual ability of age-related decline was an important issue. In order to identify the daily living problems caused by age-related visual degeneration and to propose aging design suggestion for design activity, this research studied elder's yellowed lens. This study executed a color judgment experiment, and found out that people older than 75 years old had the problem of yellowed lens. The experiment applied computer graphics to simulate senile people's color sensation. Young subject were assigned to view the experiment objects. The experiment results found out some problems. The color discrimination experiment supported the hypothesis that some elderly people fail to discriminate between some combinations of colors, such as yellow/white, blue/green, dark blue/black, and purple/dark red. In the interviews, the elderly mentioned difficulties in their daily life resulting from their misjudgment of colors. That might result from the age-related yellowing of vision. Aging vision would have color change, for example, red was recognized as pink; pink became orange; yellow was like white; and blue became dark green or dark blue. Some combination of color was hard to be determined in aging vision. For instance, yellow/white; dark green/blue or black; purple/black were hard to be recognized. This study finally simulated how aging eye sees a city map, and tried to improve the design of public signs for case verification.

With reference to color sensation change, there was a study applied films to process a color simulation experiment. Yoshida and Sakuraba (1996) investigated 303 elders, age 65~95 years old to conclude 7 levels of yellowed vision. The research found out that the dense of yellow degree was highly related to the rate of vision loss. This study picked up yellow films from the chromatics point of view. It defined two Y Intensity which equals to 53% and 89% as pure yellow. These two yellow films were used to simulate elders' yellowed vision. The research results were used for design issues. It could help architect to design city environment or building.

Elder's vision degeneration could have negative effect upon reading speed. The investigate result of Fine and Rubin (1999) showed the reading speed of people who has vision degeneration was slower than normal vision people. In the study, there were two kinds of vision degeneration symptom included in the experiment. One of them was central vision loss plus cataract, the other was scotoma plus cataract. The subjects read sentences with simulated vision loss status. The sentences included five kinds of word sizes. The experiment result showed that central vision loss plus cataract need larger word size than normal vision. Scotoma plus cataract need the largest word size in the study.

To summarize the research above, vision simulation research can be done by confirming elder's vision status and design experiment for young subject to see object in simulated vision. The data gained from experiment result can be used in the simulation program. However, most of the research experiment does not reveal the complete process. In addition, the way of defining degeneration is done with percentage but not done through a standard visual acuity check. Therefore, how to design experiment and analyze the data for different degree of vision degeneration is a key point to study. In the following content, the experiment process and simulation program will be described.

2. Methods

This study applies cataract data of ophthalmology as basis, and designs the experiments process by interview result. The first experiment objects are age-related cataract patients. The experiment purpose is to compare a digital eye chart which is constructed by this study with standard eye chart of outpatient services. The digital eye chart is applied to process second experiment. The second experiment objects are young healthy eyes. The main purpose of the experiment is to know the degradation relationship between image processing and visual acuity by testing object through digital eye chart. The experiment result will be utilized to construct a simulation testbed of age-related cataract. The following content will describe more details about the construction of digital eye chart, details of two experiments, and the construction of a simulation testbed.

2.1 The Construction of Digital Eye Chart

This study uses formula to construct a digital eye chart. The basic idea of Visual Acuity (V.A.) is to test if a person can recognize the detail part of a word or a sign. It also means to recognize the Minimal Separable Visual Angle (MSVA). Table 1 shows different visual angle of MSVA and compare it with visual acuity.

Table 1 Visual angle of MSVA and visual acuity

MSVA	Visual Acuity		
	Fraction (Imperial System	Decimal	Fraction (Metric system)
1' of arc	20/20	1.0	6/6
1.5' of arc	20/30	0.66	6/9
2' of arc	20/40	0.5	6/12
2.5' of arc	20/50	0.4	6/15
5' of arc	20/100	0.2	6/30
10' of arc	20/200	0.1	6/60

In the formula, a visual target height of V.A. 20/20 is $2h$. The distance of checking V.A. is d. $2h$=5' of arc. MSVA equals to 1' of arc. The formula and a explanation diagram

(Fig. 1) is show in the following content. For

$$2.5' \text{ of } arc \div 60 = 0.04167° \quad \text{......(1)}$$

$$\tan(0.04167°) = 0.0007272 = \frac{h}{d} = \frac{h}{20\,feet} = \frac{h}{6{,}096mm} \quad \text{......(2)}$$

$\therefore h = 4.433\, mm$

Then, $2h$ (total height of a 20/20 letter at 20 $feet$) = 8.866 mm.

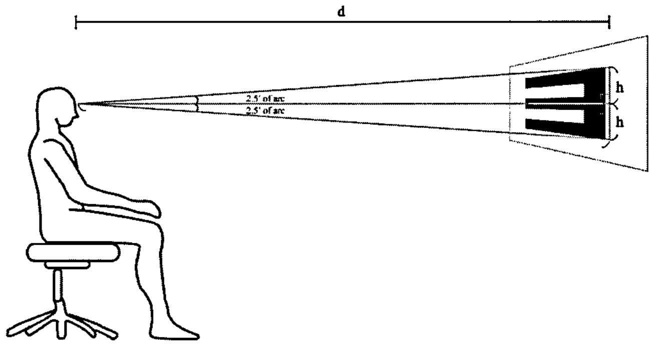

Fig. 1 Image of E visual target and formula sign

Finally, this study illustrators a digital eye chart for the experiment (Fig. 2).

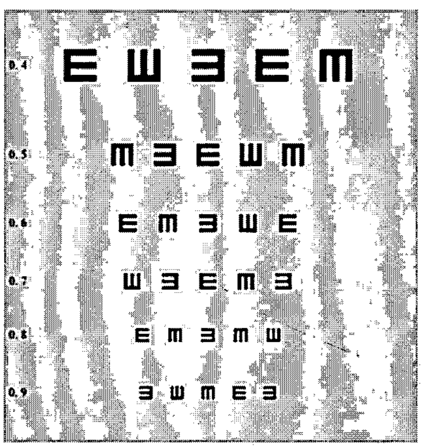

Fig. 2 Sample of digital eye chart

2.2 The Experiment for Testing the Accuracy of Digital Eye Chart

In Taiwan, the operation basis of cataract is to test visual acuity by Snellen eye chart. If one's visual acuity is decreased to 0.3~0.4, it reaches the standard to do the lens operation. This study draws a digital distance visual acuity eye chart, and compares it with standard eye chart of outpatient services. In addition, it applies statistical method to confirm the p value between two groups of V.A. checking data. If the p values shows that the two charts have variations, the adjusting parameter should be find out. The object of this experiment is age-related patient who are older than 40 years old. The outpatient services doctor should describe the degree of cataract eyes. The subjects' eye must fit to the following conditions.

- Without AMD.
- Without Glaucoma.
- Without Eye operation experience.
- With age-related cataract.
- Wear the correct glasses during experiment process.

In the first section, the experiment is done in Chung Shan Medical University in Taiwan. There are 15 objects fit to the limitation. There are totally 28 objects' eyes to be put into statistical calculation. Each testing result is transferred into certain percentages for counting. The data is transferred according to the basic idea of visual acuity judgment.

This study uses pared t-test to calculate the variation between two eye charts. The hypothesis is Two Tailed Test (Two Side Test) and is as following statement.

$$H_0 : \theta = \theta_0 \quad \text{......(3)}$$

$$H_1 : \theta \neq \theta_0 \quad \text{......(4)}$$

The result of statistical counting by the software, SPSS, shows the p value is 0.663. It is larger than 0.05. In other word, there is no evidence to show that the digital eye chart is different from the outpatient service eye chart.

2.3 Recognition Experiment of Cataract Blurring Image

In this phase, there are 31 objects, age 18~35 years old join the test. The objects cannot have eye related illness and the corrected visual acuity must reach 1.0. The Age-related Cataract Image Blurring Program is used to process the image of visual targets in digital eye chart. There are different blurry degrees visual target images created for the recognition experiment. The degradation of visual acuity of objects will be recorded and apply into the testbed. **Fig. 3** and **Fig. 4** are the sample images that processed by the age-related cataract image blurring program.

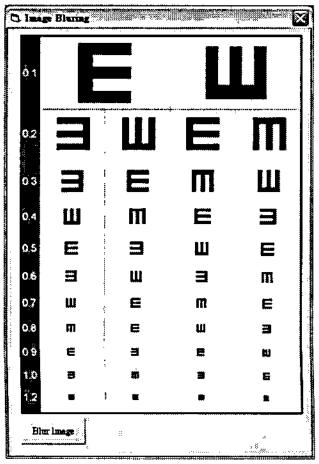

Fig.3 Sample Image of Image Blurring Program (Normal)

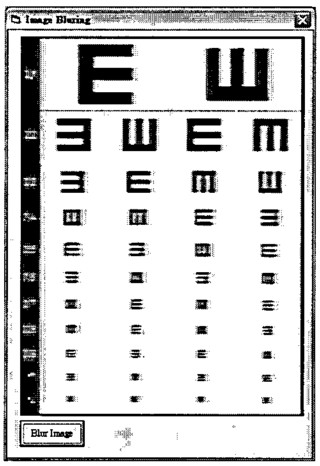

Fig. 4 Sample Image of Image Blurring Program (Blurry)

The age-related cataract image blurring program is written by Visual Basic 6.0. The basic idea of its algorithm is to decrease the MSVA. It calculates the group of pixels to have average color. Therefore, the nearby pixels have similar color gradually till it is not recognizable. In the program, every 4 pixels are assigned to one group. As Fig. 5 shows, the pixel no. 1, 2, 13, 14 are assigned in one group, and 5, 6, 17, 18 are assigned in the same group. After that, two pixel groups are processed into average color, and the MSVA is decreased in this way.

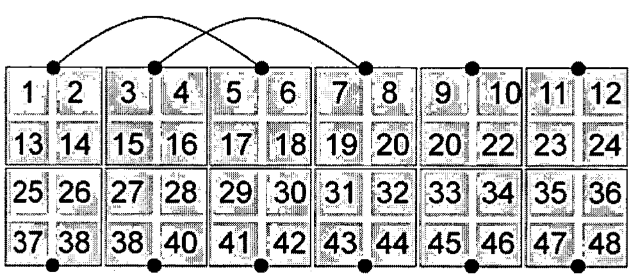

Fig. 5 Chart of Pixel Group

As Fig. 6 and Fig. 7 presents, the visual targets of 1.0 have been process 3 times and 6 times by blurring program. After processing 3 times the picture is clear than 6 times. Fig. 8 shows the visual target 0.7 processed 6 times. The detailed part of the sign is clear than Fig. 7.

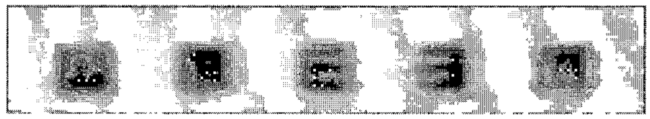

Fig. 6 Visual target 1.0 process 3 times by blurring program

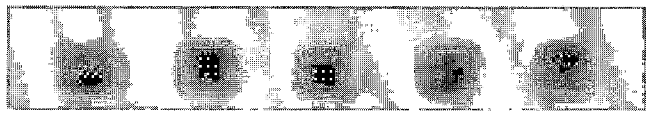

Fig. 7 Visual target 1.0 process 6 times by blurring program

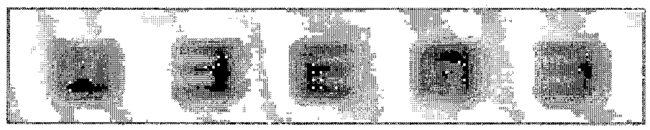

Fig. 8 Visual target 0.7 process 6 times by blurring program

In this second experiment, there are 8 blurry images picked up for every group of visual targets. There are totally 11 groups of visual target and 88 images for experiment (Table 2). The larger visual target groups contain higher degree of blurry images. In other words, different visual targets with different level of blurry degree are in the experiment image database. Furthermore, every visual target groups are added one low blurry image for decrease the pressure of objects. In order to prevent visual tiredness of the objects, the 88 images are arranged randomly. The experiment result will figure out the relationship between processing times and visual degradation degree.

Table 2 Visual Target Groups and Processing Times

Visual Target Group	Low Blurry Images	Blurry Images	No. of Images
0.1	95 times	98~104 times	8
0.15	94 times	97~103 times	8
0.2	75 times	78~84 times	8
0.3	71 times	74~80 times	8
0.4	54 times	57~63 times	8
0.5	36 times	39~45 times	8
0.6	34 times	37~43 times	8
0.7	11 times	14~20 times	8
0.8	5 times	8~14 times	8
0.9	3 times	6~12 times	8
1.0	1 times	2~8 times	8
Total			88

※The "times" in the table means the processing times.

There are totally 31 target eyes finished the experiment. As standard eye chart testing rule, every data should answer 3 correct visual targets out of 5 targets in each line. The average data is regarded as the recognition threshold (Table 3) to recognize the different groups of visual targets and is used to construct the visual simulation testbed.

Table 3 Visual Target Groups and Threshold

Visual Target Group	Recognition Threshold
0.1	104 times
0.15	102 times
0.2	81 times
0.3	75 times
0.4	58 times
0.5	42 times
0.6	39 times
0.7	16 times
0.8	10 times
0.9	8 times
1.0	4 times

※The "times" in the Table means the processing times.

2.4 Construction of Age-related Cataract Visual Simulation Testbed

The testbed (Fig. 9) is separated into two sections. The first section (Fig. 10) simulates 3 kinds of age-related cataract that are often seen cases. This section is only constructed to display the situation that a patient sees, not for research purpose. The 3 kinds of symptom are Coronary type, Cuneiform type, and Morgagnian type (Fig. 11, Fig. 12, and Fig. 13).

Fig. 9 The Initial Page of Tesbed

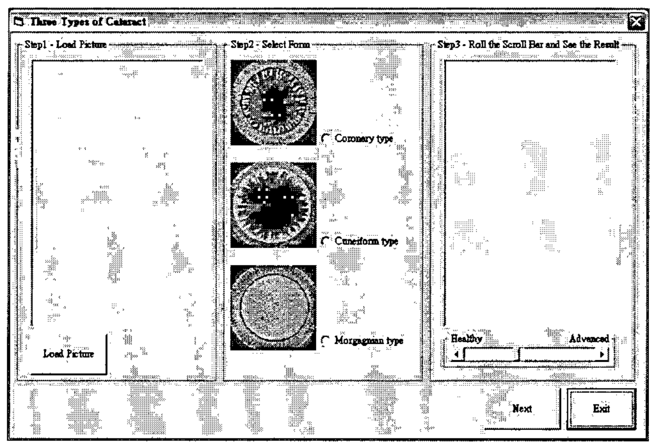

Fig. 10 3 Kinds of age-related cataract simulation.

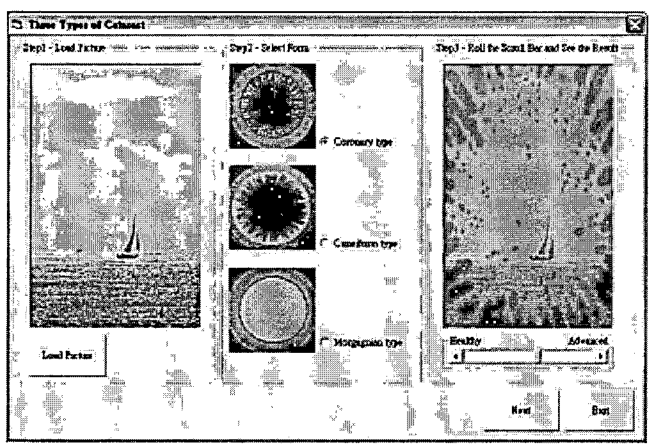

Fig. 11 Simulation of coronary type

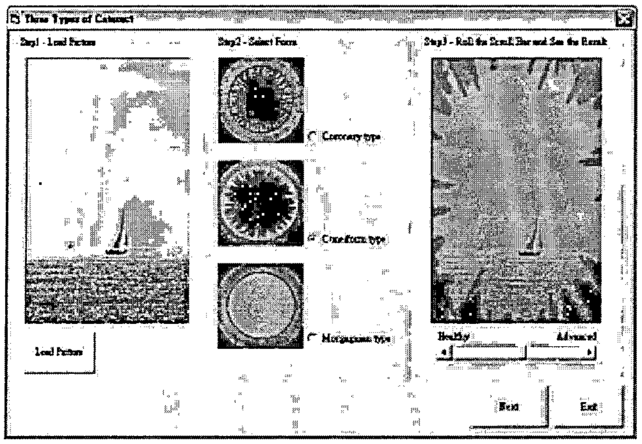

Fig. 12 Simulation of cuneiform Type

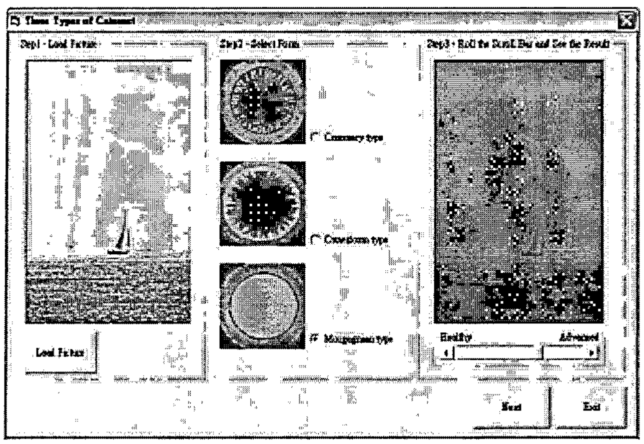

Fig. 13 Simulation of morgagnian type

The second section of the testbed applies the data obtained by second experiment result of this study. The main function of it is to select the visual degeneration degree, and it is adjusted to become coordinate with the experiment result. The imported images can be processed by the testbed. Fig. 14 shows the burring function of the testbed.

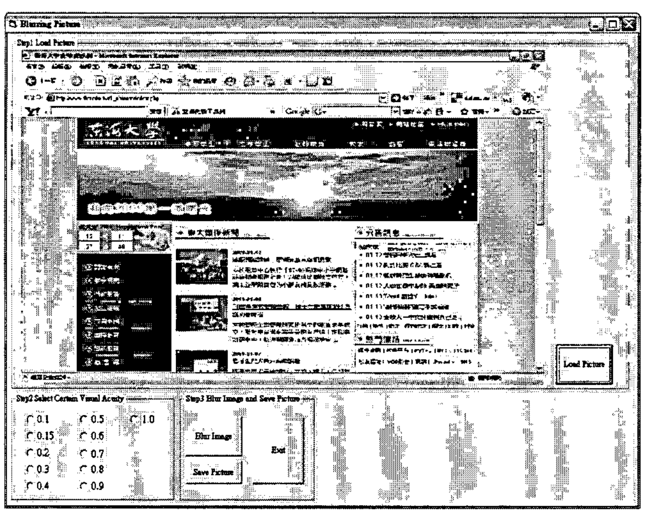

Fig. 14 Blurring function of the testbed

About the operating steps, a user can import images that are going to process blurring function into the testbed. At the bottom left part of the program page, the user can chooses different degree of visual acuity. After finishing image process function, the user can save pictures as the form of .bmp or .jpg.

3. Results

Because of electrical development trend, there will be many different kind of electronic equipment and monitor systems with digital screen at home in the future. Previous researches often focus on the short distance product interface. However, many visual disability people have difficulties on recognizing the object at the distance of more than 3 meters. In the age-related cataract, the degeneration of long distance visual acuity is the main confuse to daily life activities. Therefore, this study picks up digital hanging clock (Fig. 15) that will be used in long distance in the living space as case verification. It applies the function of visual simulation testbed to test the word height of digital hanging clock. The main purpose of the verification is to find out the need of word height in the vision of 0.3~0.4 which are suitable for cataract operation.

The font of screen number is "Digital 7". The screen chose for testing is transparent grey screen (Fig. 16).

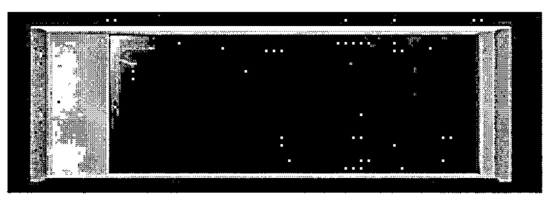

Fig. 15 Digital hanging clock

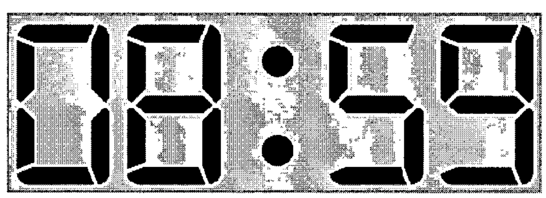

Fig. 16 Tested numbers and background color

In order to match the need of visual disability people who have difficulties on recognizing the object at the distance of more than 3 meters. In the product test phase, the digital screen is observed further than 3 meters. In addition, the outpatient service test chart is at the distance of 3.5 meters; therefore, this study observes the image processing result at the distance of 3.5

meters. The processing level is settled at simulation V.A. degeneration 0.3 and 0.4.

This study test many level of word height and every 10 *mm* is defined as one level. It tests 100 *mm* ~ 190 *mm* word height and totally tests 10 screen panel boards. The result shows when an observer is at the distance of 3.5 meters, the simulation V.A. 0.4 should use at least word height 140 *mm*. Simulation V.A. 0.3 should use at least word height 190 *mm*. Fig. 17 shows the processing result of word height 140 *mm* and Fig. 18 shows the result of word height 190 *mm*.

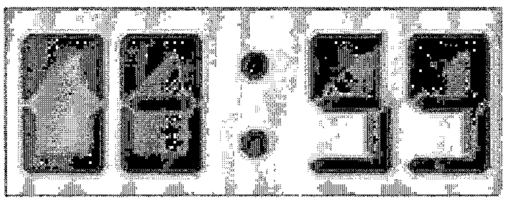

Fig. 17 Processing result of word height 140 *mm*

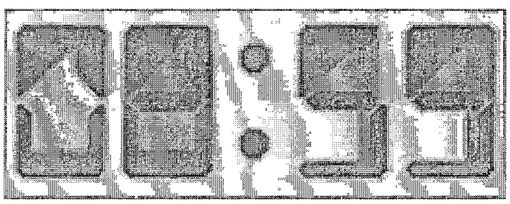

Fig. 18 Processing result of word height 190 *mm*

4. Conclusion

This study applies age-related cataract knowledge of ophthalmology as basis to construct a simulating age-related cataract visual product testbed for industrial designers. It utilized digital hanging clock as case verification. The works have been done are as following description:

- To construct a digital eye chart and confirm the accuracy by experiment.
- To process an age-related blurring image recognition experiment and gain the data for constructing visual degeneration simulation.
- To construct a testbed for simulating age-related cataract which can choose different level of simulated V.A. and put product images for evaluating the product suitability.
- To apply a digital hanging clock as case verification and propose in the distance of 3.5 meter, simulated V.A. 0.4 & 0.3 should use at least 140 *mm* height & 190 *mm* digital numbers.
- To simulate 3 different kinds of age-related cataract and apply standard eye checking system to transfer data into simulation data for product evaluation needs.

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