An Implementation of Virtual Colored Overlay for Dyslexics

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Summary

A film colored overlay has been used as an assistive device for dyslexics, Recently, several virtual colored overlays which can be used in computer were developed. But existing virtual overlays have some drawbacks which have limited colors and limited control capability over overlapped window by the overlays. Limited colors may prevent optimum color selection and limited control capability can obstruct to transfer keyboard and mouse operation to the overlapped window.

In this paper, we implemented an overlay function which controls an overlapped window under the overlay window by using keyboard hooking and tray icon. We propose a method to determine the source color of a virtual overlays by estimating alpha value of alpha blending algorithm through measurement of the chromaticity and transmissivity of film overlays and implemented all colors which we can produce colors by using Intuitive Overlays. Test results of the developed virtual overlay show that all mentioned drawbacks of existing virtual overlays were eliminated and result of WRRT for 3 visual dyslexics using developed overlay shows that reading speed of 2 person are improved by 17.6%, 9.2% respectively, the speed of one person is not improved, but his reading durability is improved from 3 pages to 10 pages.

Key words: Dyslexia, Virtual colored overlay, Alpha value estimation, Control an overlapped window, WRRT
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1. Introduction

In the early 1980s, the US congress requested the National Institute of Health to research the cause of learning disabilities. In its findings, the NIH announced that dyslexia is the most common and prevalent symptom of learning disability. In 1994, it was reported that 1 of every 5 children were under the influence of such symptoms[1]. In 2003, the UK's Higher Education Statistics Agency announced that 31% of first-year students in the United Kingdom's higher educational institutions were dyslexic. In Korea, the National Institute for Special Education selected one elementary school from each of the 180 local Ministries of Education to study from May of 2001 for 1 year. In 10 areas and among 140,004 children aged 6-11, it was determined that 1.17% had a learning disability. An investigation by the Ministry of Education & Human Resources Development of Korea in 2005 on the actual condition of special education revealed that learning-disabled children account for 14.5% of all special education students, making them the second-largest group following mentally retarded students. Even though learning disabled students have a level of intelligence equivalent to that of normal children, they are slow in learning speed, and show disorders in reading and writing due to the abnormality of their brains' processing of information. The time required by learning-disabled children to read and write is almost 2-10 times that of normal students. Assistive devices can improve the studying faculty of such students. However, considering that such assistive devices are prescribed and imported only in very limited hospitals and by opticians in the form of contact lenses, many special education teachers do not even know of the existence of such assistive devices.

The cause of such learning disabilities was not specifically examined, but it was recently clarified that they can be attributed to a structural information processing disorder of the brain [2-4]. Learning-disabled children have either one or two factors of a learning disability. Bosse published the results of joint France/UK study, which revealed that the main factor of the dyslexia learning disability is visual information processing, showing a higher weight than the phonological factor [5]. Irlen syndrome, which is one the phenomena associated with dyslexia, causes a degradation of the learning faculty and occupational efficiency, such as reading and concentration problems, due to a nerve disorder that takes charge of visual information processing. It also designates phenomena that have a negative effect on various life activities such as sports, driving, and the use of a computer. Research by the Irlen research institute demonstrates that 10~12% of the US population suffer from Irlen syndrome. It is also presumed that 46% of those who experience dyslexia have this syndrome[6]. In the United Kingdom, it is reported that about 75% of those who suffer from dyslexia also have a visual impairment, such as unstable eye movement [7].

Optical instruments, such as colored overlay, colored glasses, and colored lenses, are commonly used as assistive devices to ease Irlen syndrome. The use of a colored overlay is reported to contribute to reducing the flash that appears in the eyes of those who have Irlen syndrome[6-9]. The state of California has regulations requiring that assistive devices, such as colored overlays,

be provided if requested for all types of public examination.

Some virtual colored overlays [10,11], which can be applied using information telecommunication devices such as computers, have been developed for persons with the learning disability of dyslexia. However, there are some drawbacks to such tools. First, the overlay window should not be overlapped when it is moved in order to control other windows that are liable to be overlapped under the overlay window. In the event that a user inputs text that is overlapped with an overlay, or selects a button or check box and controls the size, the virtual colored overlay should not be overlapped, or the control focus should be moved by using the keyboard's move key. However, it is viable to prevent the overlapping of two windows by the operation of a mouse only when information recognition becomes the premise. In this case, it can be used without the colored overlay. When controlling a graphic object by the operation of the mouse, as in a game, the move key of the keyboard cannot be used, and the graphic object cannot be selected by using the overlay with a mouse. Second, since the color expression of the overlay is limited, the selection of an optimum overlay color that is effective in relieving the symptoms is impossible. This inevitably reduces or eliminates the effect of overlay application. The problem of existing virtual overlay implementations is that alpha value is not open. Alpha blending technique[12,13] is used in the implementation of virtual colored overlays in order to achieve the transparent film effect. In this case, the establishment of the alpha value is very important.

In this paper, keyboard hooking and movement between windows through the tray icon were used rather than the keyboard for the focus control of windows that are overlapped with a virtual overlay window, in order to solve the problem of moving between windows. In order to solve the problem of implementation, the Intuitive overlays [14], which are a set of real film colored overlays that have been clinically verified for their effectiveness, was used. To solve the problem of implementation, the color information of a single color, the overlapped single color, and the overlapped neighbor color, and transmissivity were measured using the Spectrum colorimeter in the Intuitive overlays [14]. Measured value was used in estimating color and alpha value of the virtual colored overlay. To solve the problem of color limit, all colors used in WRRT (Wilkins Rate of Reading Test) were implemented in the virtual colored overlay. To avoid the complexity of color selection, color menus were classified into a single color, the overlapped single color, and the overlapped neighbor color. Even when performing WRRT on a computer using the virtual colored overlay, each step of the test was complied with. There was no implementing of neighbor colors in the case of existing virtual overlays. To test the function and performance of the overlay, it was

applied to Hangul text, an e-Book, a web browser, and game and VOD contents, including graphic objects. Since this virtual colored overlay helps in the reading of learning contents in the form of electronic documents, as well as in the writing of electronic documents, it can enhance the effectiveness of E-learning.

2. Effects of colored overlay and existing virtual overlay

2.1 Scotopic Sensitivity Syndrome and effects of colored overlay

In 1958, it was reported for the first time that children with dyslexia could read letters written on color cards. Olive Mears, a teacher in New Zealand, reported that children's recognition of text and reading disorders were influenced by the characteristics of publication, and that disability can be reduced if colored paper is used and contrast is reduced [15]. The person who first reported that colored overlays were effective in alleviating the symptoms of dyslexia is the US clinical psychologist H. Irlen, who coined the term 'Scotopic Sensitivity Syndrome'[16]. Since then, it has been also called Mears-Irlen Syndrome, taking the name of these two pioneers in the field.

The intuitive overlay, which was created by Wilkins, was applied to 426 students in a dozen UK schools. Wilkins reported that over 50% students showed reading improvement, and 5% showed an increase in their reading rate that was greater than 25%, despite the fact that his reading test was included in the fluency test of word recognition. However, the thing that Wilkins noticed was not the degree of fluency but the difference between before and after the use of the overlay. His research shows that a colored overlay is valuable to general students under visual stress, as well as to learning-disabled students with dyslexia [9].

Ludlow applied the colored overlay to the 19 autistic children and 19 normal children respectively. He found that the reading rate of fifteen autistic children (79% of the autistic group) improved, and this rate is significant compared to the result in the normal children group, in which only 16% showed an improvement of more than 5%. Accordingly, Ludlow reported that colored overlays were useful for children with autism. In his writings, Evans reported that the Intuitive Colorimeter and Intuitive Overlays were used as clinical tools as well as study tools [8]. The colored overlay is a cheap and transparent plastic film that covers the reading text. However, as the range of colors that can be tested is more limited than the Intuitive Colorimeter in the use of this overlay, perfect and accurate diagnosis cannot be conducted. Nonetheless, a well-designed colored overlay system can be systematically

equipped with a wide range of color samples. The color that can alleviate Irlen syndrome differs for each individual. The effect of a colored overlay can be conspicuous in some cases, but in others, it will have no effect.

2.2 The drawbacks of existing virtual overlays

Fig. 1 Application using graphic object and existing virtual overlay

Fig. 1 shows an existing virtual overlay applied to a card game, 'Solitaire,' which is provided by Microsoft. To play the game in this figure, an arbitrary card that is in the line with the 8 of clubs should be clicked with the mouse, and the target cards should be selected. Then, by dragging and dropping, the cards should be moved to the line with the 9 of diamonds. However, if you click a card that is in the line with the 8 of clubs, the card in the relevant line is not selected, but the mouse pointer appears on the overlay because the focus is now on the overlay. Accordingly, in this application, a conventional overlay cannot be applied. Generally, keyboard shortcuts can be used in applications. However, there is a problem that a keyboard shortcut cannot be used as a method of moving the window, because there is no function to move to the particular location of a specific arbitrary object. In the case of applications that are not mouse-exclusive, Alt +Tab is used to switch between applications currently being executed, Alt+F6 is used for the movement of multiple windows, and the Tab key is used in the same program. Movement of focus is possible using the Tab key, which can be used in the movement of objects in the same window. However, you need to be fully aware of the functions of several shortcut keys. If you must perform a keyboard operation several times for the selection of a creative and specific object over the window, it is inconvenient. The operation of the mouse or the keyboard should be delivered to a particular location, which is at the bottom of overlay in the case of a virtual overlay.

Smith et al. carried out the color selection test and reading rate test by using Intuitive Overlays and Eye level Reading on 48 students of two groups with visual stress [17]. The means of the visual stress symptom number of 2 groups were nearly the same, at 1.00 (SD 1.19) and 1.04 (SD 1.49), respectively. The test result was that the color that was selected in the 2 groups was different. The group of the Eye level Reading Rulers accurately read an average of 74.7 words per minute. Compared to the words reading

rate, 75.7 words, when the overlay was not used, there was no increase in the reading rate. Meanwhile, the group using Eye level Reading Rulers increased their average reading rate by reading an average of 80.5 words per minute. They maintained that the color of the Eye level Reading Rulers was limited to 5 colors, making the selection of an optimum color impossible, and there was no increase of reading rate because the condition was not optimum for color selection. Color selection should not be complex, and sufficient color should be provided in the virtual colored overlay.

The Virtual Reading Ruler, which is the virtual colored overlay of the Eye level Reading Rulers, used 5 colors when it was developed, and was recently increased to 10 colors. It allows the overlapping of the relevant color. The ComfortScreen, which is the virtual overlay recommended by the Irlen Center, offers 10 colors, and allows the adjustment of the brightness of the overlay. Accordingly, in these virtual overlays, the difficulty in making the optimal color selection due to the color limit is highlighted by Smith.

In terms of this color limit, the expression of color is a highly crucial matter. However, existing physical and virtual overlays do not enable accurate color coordination. Accordingly, the drawback of color setup can occur when a virtual overlay is newly implemented.

3. Design and Implementation

3.1 The Composition of Virtual Colored Overlay

The virtual colored overlay that is implemented in this paper was comprised of a dialogue-based program window, the overlay window, the menu bar, and the track bar of the program window. The overlay window is given a similar shape to plastic film by eliminating the title bar, the window boundary, and the status bar. The menus for the overlay control and status modification, such as the virtual color, overlay color, and track bar location control, were allocated in the menu bar. The track bar is the line to prevent confusion and enable the user find the location of a line in text reading. It is conducive to maintaining the focus of the eyes. The track bar is the line to prevent confusion and enable the user to find the location of line in text reading. The indication and location control of the track bar are feasible through the location control button of the track bar in the menu bar.

The virtual colored overlay provides convenience by enabling easy movement with a click of a mouse and a drag on the overlay window. The menu bar is seen only when the virtual colored overlay is in transparency reset state, and a mouse is located on the upper part of overlay in order to remove the rejection by maintaining a similar shape to plastic film.

The controls and functions of the menu bar are the same as in <Table 1>, and the compositional element of the virtual colored overlay are as shown in Fig. 2.

Table 1: Controls and their Functions of the overlay

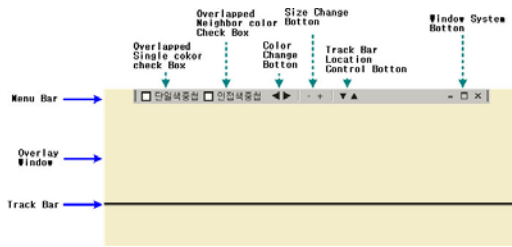| Control	Function
Color Change Button	The button used to select the overlay color desired by the user.
Overlapped Single Color Check Box	The check box for showing the effect of an overlapped single color.
Overlapped Neighbor Color Check Box	The check box for showing the effect of an overlapped neighbor color.
Size Change Button	The button to set the size of the overlay.
Track Bar Location Control Button	The location control button of the track bar for expressing the text reading location.
Window system button	The button to iconize, maximize, or hide the overlay.

Fig. 2 Elements of the Virtual Colored Overlay

3.2 Assignment of the Overlay Color

The virtual colored overlay of this paper is a dialogue-based application window that is operating in the Windows operating system. It implements a transparent overlay effect by using the alpha blending technique. The proper RGB color information was required in order to show the transparent overlay effect by using the alpha blending. The required RGB value was sought through the process below.

The single color, the overlapped single color, the overlapped neighbor color, and the transmissivity of the Intuitive Overlays of Wilkins were measured using the spectrum colorimeter. CM-3600d of Konica Minolta firm was used as the spectrum colorimeter. The measure wavelength range of CM-3600d is 360-740nm, in which all areas of the visible rays were measured. The measurement wavelength interval is 10nm, and reproducibility is within the standard deviation 0.1%. For the method of measurement, devices were calibrated, and overlay film was located in the entrance of the light-receiving part. Light was transmitted to a slightly bumpy side (visual side), and the color of an overlay and its transmissivity were measured. The measured color information is indicated with the CIE-L*ab value, and the measured values were as shown in Table 2.

Table 2: Wilkins 의 Intuitive Overlays Color Information, measured with the Spectrum Colorimeter

Color	L*(D65)	a(D65)	b(D65)	Transparency(D65)
Yellow	91.2	-4.81	20.82	78.92
Orange	88.91	6.11	12.27	73.98
Rose	89.01	10.05	1.71	74.19
Pink	86.4	11.3	-5.99	68.8
Purple	81.39	7.15	-14.15	59.18
Blue	83.13	-5.1	-13.1	62.4
Aqua	88.31	-9.49	-6.19	72.72
Lime	89.82	-10.1	15.86	75.91
Mint	89.85	-13.64	3.3	75.99
Grey	85.01	-0.48	1.36	66.03
...	...	...	...	...

The value of the measured color was converted to an RGB color value through the conversion process [18] of CIE-L*ab→XYZ→RGB. This RGB color is the RGB color of the Intuitive Overlays of the Wilkins, which is the color information that appears in the implementation of an overlay effect by implementing the alpha blending into the virtual colored overlay. The required RGB information is the source color information prior to the application of alpha blending. It was sought by the inverse transformation of the alpha blending algorithm.

$$O = α * S + (1 - α) * B \qquad (1)$$

Eq. 1 is the alpha blending algorithm. In this equation, S is the source color which is the foreground color, B shows the background color, and α represents the transparency. Transparency is expressed as a numerical value between 0.0 and 1.0. 0 represents total transparency, and 1 total opacity. As color gets closer to 0, it becomes more transparent; as it gets closer to 1, it becomes more opaque. O shows the Output (result color).

Eq. 2 is induced in Eq. 1 to seek the source color information.

$$S = (O - (1 - α) * B) / α \qquad (2)$$

By using (Formula 2), Sr, Sg and Sb of each original color RGB can be obtained as shown in Eq. 3.

$$S_r = (O_r - (1 - α) * B_r) / α$$
$$S_g = (O_g - (1 - α) * B_g) / α \qquad (3)$$
$$S_b = (O_b - (1 - α) * B_b) / α$$

In order to seek source color information S, 0xFF which represents background in the value of B was applied, and as a-value is close to 0, it represents the transparency. This has an inverse relation with transmissivity t by using the

spectrum colorimeter. The a-value that is applied to each color is estimated by using Eq. 4.

$$\alpha = (100 - t) / 100 \qquad (4)$$

As color cannot be expressed in the event that the result of the calculation of the source color is a negative number (-), it must be replaced with 0x00, and the remainder color divided by the absolute value of a negative number must be added to it. For example, in the event that Sr value is -74, and you seek the value of S_g and S_b, output is yielded by dividing the absolute value of 74 into 2, and adding it to each value. The reason why Sr value is as small as -74 is that the R component should be as small as 74. Since the minimum representative value of R component is 0, it cannot express the amount of smallness with 74. Accordingly, a similar effect appeared as other components, Sg and S_b value increased as much as 74/2. The values of source RGB, calculated through the process enumerated above are as shown in Table 3.

Table 3: Original RGB colors of virtual overlays obtained by inverse alpha blending transformation

Color	R	G	B
Yellow	OxC5	OxA8	Ox00
Orange	OxD9	Ox75	Ox2C
Rose	0xD4	0x6C	0x7B
Pink	0xB8	0x6F	0xA8
Purple	0x80	0x76	0xBF
Blue	0x40	0x8A	0xBF
Aqua	0x23	0x9C	0xAE
Lime	0x70	0x96	0x06
Mint	0x1A	0xA8	0x69
Grey	0x83	0x80	0x7B
...	...	...	...

The implemented virtual colored overlay became more similar to a colored film overlay in its optical features compared to existing virtual colored overlays. As shown in Fig. 4, by using 10 colors, 10 overlapped single colors, and 9 overlapped neighbor colors, a finer selection of overlay color is possible than in existing virtual overlays, which only use 10 single colors. In addition, the Virtual colored overlay satisfied all colors provided by the Intuitive Overlays of Wilkins

Table 4: Implemented overlay colors

Single Color	Overlapped single color	Overlapped neighbor color
Yellow	Double overlapped yellow	yellow-orange overlapped
Orange	Double overlapped orange	orange-rose overlapped
Rose	Double overlapped rose	pink-rose overlapped
Pink	Double overlapped pink	purple-pink overlapped
Purple	Double overlapped purple	blue-purple overlapped
Blue	Double overlapped blue	aqua-blue overlapped
Aqua	Double overlapped aqua	mint-aqua overlapped
Lime	Double overlapped lime	lime-mint overlapped
Mint	Double overlapped mint	yellow-lime overlapped
Grey	Double overlapped grey	

3.3 Object Control of Overlapped Window

The virtual colored overlay should recognize and supervise the state of the window that it is above. It should distinguish whether the event of a mouse operation and/or keyboard entry are for the operation of the virtual colored overlay or not. If such an event is for the operation of the overlapped window, the function to deliver the entered event to the overlapped window should be implemented. However, it is difficult for the virtual colored overlay to supervise the process state of the other window, distinguish the application object of the event, and implement the function of event delivery. There is also the problem that this feature will make the load and code size of the virtual colored overlay higher, due to the increased number of processes in addition to the original function of the colored overlay.

In this regard, this paper made a user select the window that is required for the event, such as the operation of the mouse and keyboard entry, without the implementation of complex functions described above, by making the focus movement of virtual colored overlay and overlapped window possible by inputting a special key value through keyboard hooking. The special key combination was designated as the Ctrl, Shift, and [,] keys in order to avoid the use of keyboard shortcuts that were already assigned to other programs. In addition, user convenience is provided by implementing the focus movement through a tray icon, so that the user is still able to perform the focus movement in the event that he or she is unaware of or forgets the keyboard shortcut. Fig. 3 shows the flow of the focus movement between windows through the keyboard hooking and the tray icon.

In Fig. 3, the term 'Transparent' is used to represent the state of window selection that is overlapped with the virtual colored overlay window. 'Transparent Off' is the state in which the window of the virtual colored overlay has the control focus. It can also be described as the dissolution of transparency. 'Transparent On' is the state in which another window has the selection focus, and it represents the setup of transparency. 'Transparent On,' as an instruction for the focus movement of windows, uses the key combination 'Ctrl+Shift + [', while Transparent Off uses 'Ctrl+Shift+]'.

Fig. 4 shows the tray icon and contextual menu for the movement of windows. You can select transparent menu

from the contextual menu for the focus movement of windows by using the tray icon. Toggle is completed in the Transparent On and Off whenever you select from the menu, and check mark is shown in the menu in the state of Transparent On.
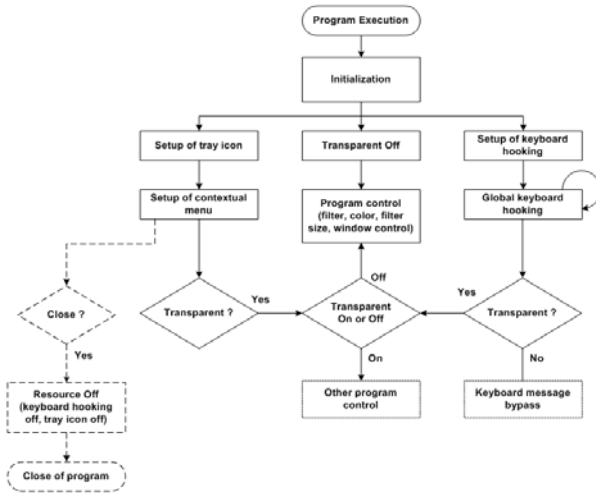

Fig. 3 The Flow of Focus Movement between Windows

Fig. 4 Tray Icon and Menu

4. Test and Result

A chromaticity comparison test was carried out through the application of a virtual colored overlay and the application of a film colored overlay to the white background screen of an LCD monitor, in order to validate the chromaticity of the implemented virtual colored overlay. To measure chromaticity, the 'CS-100A' Chroma meter of the Konica Minolta firm was used. LCD monitor was the SyncMaster CX701N by Samsung Electronics. The CS-100A can measure brightness to a precision level of $\pm2\%$, and color to a precision level of ±0.004. Since the focal distance of the CS 100A is 1,014mm~ infinity, the distance from the LCD screen was limited to 120cm in the measurement of screen chromaticity. As the absolute value in the measurement of chromaticity can be changed according to the gamma value and setup status of a monitor, it was measured using the relative difference. As the measured value was indicated as Δ Yxy, which is the difference in the CIE Yxy coordinate, the total size (ΔE) of a difference value was calculated by substituting this value for Formula 5. The average chromaticity difference of the measured 10 main colors was 0.013. This estimation was

relatively precise. Measurement was conducted after turning off all surrounding illuminations and blocking all lights.

$$\Delta E = \sqrt{\Delta Y^2 + \Delta x^2 + \Delta y^2} \qquad (5)$$

The color selection function of the implemented virtual colored overlay was tested. After practicing the virtual colored overlay, we clicked the color change button on the menu bar for the confirmation of color change. Like the overlapped single color check box (Fig. 5), we clicked the color change button in order to confirm the color change after selecting the overlapped neighbor colors, respectively. Once we select a check box, another one cannot be selected, because overlapped single color and overlapped neighbor color are options. 10 colors, including the gray, belong to general colors as in Table 4, while there are 10 overlapped single colors in which 2 pieces of general color are overlapped. Overlapped neighbor colors refers to the overlapping of general neighbor colors except for the gray. These represent 9 colors in total. As a test result, we could select 39 colors by the operation of the menu bar. Accordingly, the implemented virtual overlay can express 9 overlapped neighbor colors that were not included in previous virtual overlays. The selection of color, obtained as a result of WRRT, using the Intuitive Overlays, can be applied to this virtual overlay itself in the computer.
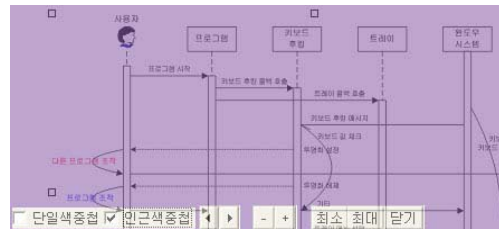

Fig. 5 Application example of virtual overlay that selects overlapped neighbor color

For this paper, we performed a test to control the object of the overlapped window with the mouse by implementing the virtual colored overlay developed in this paper. We inspected whether the operating sequence shown in Fig. 6 was maintained in the focus movement between overlay and overlapped window, and between overlays. The virtual overlay calls out the callback for setting up keyboard hooking and the tray icon, and Transparent is initialized with the state Transparent Off. Subsequently, the setup of Transparent-On for the control of the overlapped window with the overlay window and Transparent-Off for the control of the overlay window can be selected through the keyboard hooking and the menu selection of the tray icon.
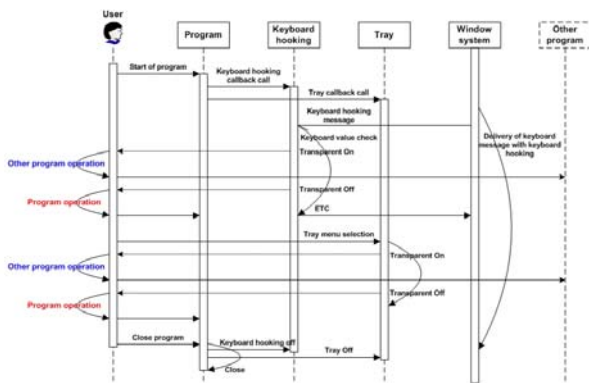
Fig. 6 Virtual Colored Overlay Movement Sequence

As in Table 5, the test objects are Hangul text, an e-Book, a web browser, a game, and VOD contents including a graphic object. The function and capacity of a virtual colored overlay were tested by the application of the objects.

Table 5: Contents and Application Tool in which Virtual Colored Overlay was applied

The Kinds of Contents	Application Tool
Hangul Text	Arae Hangul
	MS Word
e-Book	Epyrus
Web documents	Internet Explorer
Game	Windows card game
VOD	GOM player
	MS media player

In the test of the web browser, the address cannot be input in the address bar that is behind the overlay window in the existing virtual colored overlay. However, the developed overlay can input the address in the address window as shown in Fig. 7 by performing the instruction of Transparent On using the 'Ctrl+Shift+[' key combination. Like Fig. 7, which is a thickly-marked square, the overlay becomes Transparent On, and the operation of a keyword or mouse is delivered into the window of the NAVER homepage, which seems to be overlapped with the overlay.

In this overlay, mouse use is convenient compared to existing virtual overlays, and can be designated with several movements by using the move key of the executive program and the object move key, because the particular object of the overlapped window can be selected with one click. In particular, our approach is advantageous on web pages with multiple links. When using the object move key, the address window of NAVER cannot be selected. If you move to the search window, there are many

restrictions, such as the infeasibility of moving into another object like the linked address using the Tab key. As there are many limitations in use, it is expected that the use of existing virtual overlays is limited.

Fig. 7 Transparent On (Possible to enter text into the address bar

For static electronic documents, such as a Hangul file or an e-Book, there is no problem in seeing the file without the movement of focus. To control, move or change the size of the electronic document window, the focus between windows can be transferred with the Transparent On. Transparent Off is required for the selection of the overlay window in order to change overlay color and size again. Fig. 8 shows the screen that is liable to change the overlay color if we press the color change button of the overlay in the state of Transparent Off.
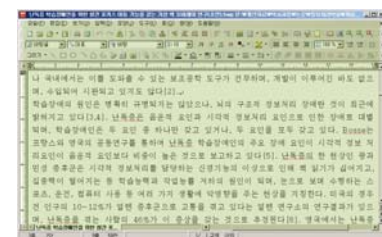

Fig. 8 Transparent Off (Overlay color change)

Since the game proceeds only by dragging the card that is the graphic object by using the mouse, focus movement to the card game is needed, and mouse drag is possible by the focus movement through the Transparent On. As existing virtual overlays cannot deliver the game program in the state of overlapped overlay through a mouse operation, they cannot be applied to this game. To move the focus to the overlay in order to change the size and color of the virtual colored overlay, while using the virtual colored overlay, we completed Transparent Off through the key combination of 'Ctrl+Shift+]' and changed the size and color. For VOD, there was a situation in which the image, which was overlapped with the virtual colored overlay, was not seen in the existing virtual colored overlay due to the output set-up of the VOD player, as in Fig. 9. This case was generated in the case of image outputting by using the overlay function of the graphic

card, like the Overlay Mixer. For using VMR (Video Mixing Renderer) that uses the function of Direct3D in the outputting image mode, the developed overlay can solve the matter of the outputting image as shown in Fig. 10.

Fig. 9 Outputting Image Mode: Application of Overlay Mixer and Overlay.

Fig. 10 Outputting image mode: application of VMR9 and overlay

4-1. Result of Clinical Experiment

As preceding research, a reading rate test was performed using a colored film overlay on seven elementary students with a learning disability and one normal student. In the test, the effect of the overlay was verified through an improvement in the reading rate [19]. This study administered the WRRT (Wilkins Reading Rate Test) using a developed application on 2 elementary students with a learning disability who had previously shown an improved reading rate by using an overlay, and 1 elementary student who had attended the general class. Among the students who participated in the test, 2 students selected yellow and 1 student selected the overlapped color of yellow and lime as the preferred color. In this experiment, we loaded the Arae Hangul document using the Sleep Mincho typeface at 9 points and used it on the computer display. The result of using the reading rate test of the overlay for 1 minute is as shown in Table 6. We compared the state before using the overlay with the state after using the overlay. 2 students showed an improvement in their reading rate of 17.6% and 9.2%, respectively. The remaining student did not show an improvement in the reading rate. However, the reading duration was increased from 3 pages to more than 10 pages. Accordingly, it was verified that the developed virtual colored overlay shows a similar effect to a colored film overlay.

Table 6 : WRRT results using the virtual overlay

Subject		Words, read correctly	Words, read incorrectly	Omitted words	Increase in reading rate %	Note
A	Before the application.	34	6	3	17.6	
	After the application.	40	3			
B	Before the application.	65	4	2	9.2	
	After the application.	71				
C	After the application.	55			-1.8	Reading durability increases from over 3 pages to over 10 pages
	After the application.	54				

5. Conclusion

This research implemented the convenient movement of windows and the detailed virtual colored overlay in color expression in order to solve the problem of existing virtual overlays. It verified the function and capacity of the virtual colored overlay through testing. After performing WRRT by applying the implemented overlay to 3 existing colored film overlay users, the reading rate of 2 students was significantly improved, and the reading duration of the remaining 1 student increased by more than 3 times. The keyboard hooking and tray icon were used for the security of the window movement. Single color, overlapped single color, and overlapped neighbor color using the existing film overlay were implemented. The color information and transmissivity of the Intuitive Overlays (the existing film overlays) were measured using a spectrum colorimeter in order to determine the precise source color and the alpha value of the virtual overlay. The alpha value, which would be applied to the virtual colored overlay, was estimated through the establishment of the relationship between transmissivity and alpha value. The source color of a virtual colored overlay was implemented by determining the source color of an overlay through color transformation and nonlinear color designation. The color of the virtual overlay on the LCD monitor was measured using colorimetry, and the result was nearly matched to the case of using the film overlay. This research applied the implemented virtual colored overlay into Hangul text, an e-Book, a web browser, game and VOD contents including graphic objects, and confirmed its proper operation. Only in the case of VOD, where outputting image mode was installed using the overlay function of the graphic card (i.e. Overlay Mixer), an image indication problem occurred. This problem could be solved by changing the setup of the image output mode.

The implemented overlay can be used in applications in which the graphic object is operated with a mouse, such as a computer game, which is not possible with existing virtual overlays. It is convenient to use in a web browser application environment such as electronic commerce, in which the text input and the list box selection and button controls are intricately combined. The direct use of color that is selected as the test result of WRRT is possible.

The Virtual colored overlay developed in this paper can be used to mitigate the visual information processing deficit of students with dyslexia. It is convenient to use in the e- learning environment. In the future, the implementation of automatic set-up of the outputting mode, making the application of virtual overlay possible, should be done by confirming the image output mode of the VOD player to enhance user convenience.

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