

Implementation of Virtual Colored Overlays in Mobile Devices for People with Scotopic Sensitivity Syndrome

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Summary

In this paper, I implemented a mobile overlay application based on the Android operating system. To achieve this, I measured film overlay colors at transmit mode and reflect mode by using spectrum colorimeter and estimated and implemented color information to apply to virtual overlays. Chromaticity measured in reflect mode was heavier than the one measured in transmit mode. I found I needed to use chromaticity measured in reflect mode in order to keep the film's overlay effect in virtual colored overlay, which was applied to printed paper. The test results showed that it had the same effect as when existing film overlay was used on white paper, with the exception of color effect on the white screen of mobile devices.

Key words:

Scotopic Sensitivity Syndrome, virtual colored overlays, mobile environments, Android operating system, chromaticity in reflect mode

1. Introduction

In December 2010, the Korea Communication Commission legislated the Korean Web Accessibility Guidelines 2.0 [1] as a standard, and in September 2011, the Ministry of Public Administration and Security announced the Mobile Application Accessibility Guidelines [2] as a notification. These two regulations contained additional specifications on scotopic sensitivity seizure and introduced methods necessary for establishing web contents for those who had this symptom so that they could easily access information. These regulations were mandatory. However, test items were limited, not providing contents like flickering or blinking at 3-50 Hz frequency, and did not consider those who had light scotopic sensitivity syndrome such as visual stress and visual migraine. Symptoms of scotopic sensitivity syndrome are divided into visual discomfort such as blurring, floating, and zig-zag line crossing, and visual distortion such as dizziness and nausea. These can lead to reading disability, which in turn can develop as a learning disability. Another type of it is scotopic seizure, which can be more serious when a display device is smaller. For this reason, accessibility issues in mobile devices such as a smart phone or tablet PC, which are smaller display

devices, can be more serious. According to a recent "analysis on usage of mobile video" conducted among 1,023 Korean Internet consumers by Youtube, the highest usage category was communication (89.9 min) followed by music listening and watching TV broadcasting contents. The rate of e-Book reading time significantly increased at up to 50 min a day whereas only an average of 6.1min daily was used for reading on desktop PCs [3]. The usage of electrical textbook with the i-Pad or a similar type of tablet PC was replaced with paper textbook in CA, USA. This trend is expected to increase.

Olive Mears, a teacher in New Zealand reported that children's awareness with books and their reading disability were affected by the features of printed materials. Reading disability could be reduced when the size of books was reduced, colored paper was used, and contrast was reduced [4]. Effectiveness of colored overlays to mitigate this symptom was first reported by H. Irlen, US clinical psychologist, who first named this symptom as scotopic syndrome [5]. It was found that the syndrome occurred due to lack of magnocell in the brain. Those who have visual difficulties related with lack of magnocell tend to have low capability in determining and controlling visual direction which are linked to the functions of the cortex of the parietal bone. They also consequently tend to have low ocular movement and visual observational skills. The path of color information is strongly linked to the area where caution and ocular movement are involved and color stimuli greatly impact the magnocell, which is responsible for the visual information processes of the brain. In particular, those with scotopic syndrome are highly influenced when the magnocell in a corresponding area is abnormal. By applying this principle, Irlen first invented a film type of color overlay applied empirically to those with scotopic syndrome from 1980 and its effect was proven. Color stimuli vary among subjects and their effect is greatly demonstrated in specific color stimuli. Virtual colored overlay that can be used on PC was first introduced in the world as Virtual Reading Ruler [6] and it was first developed in 2008 in Korea too [7]. However, according to web search, no app for smart phones or tablet PCs has been announced in the world to improve information and communication access for those with scotopic syndrome. Therefore, it is an urgent requirement to develop auxiliary devices that improve accessibility to

electronic documents for those with scotopic sensitive seizure. This paper aims to provide systematic color stimuli, which are known to be effective for those with scotopic syndrome. It also purposes to implement virtual colored overlay as a color stimulating device working among smart phones or tablet PCs based on the Android operating system, with the subjects being able to choose effective colors for themselves.

2. Estimation of color information of virtual colored overlay

Designating colors is one of the most crucial matters in the design of virtual colored overlay. For colored overlay film types, Irlen Overlays were used from the early 1980s and then Intuitive Overlays were used since 1995. These two overlays were recognized for over a decade for their effectiveness, and color samples were empirically validated sufficiently. Irlen Overlays and Intuitive Overlays, two representative overlays, showed significant differences in chromaticity, but no correct chromaticity has been published. For Intuitive Overlays, Lightstone pointed out the differences of optimized color between overlays and lens in terms of usefulness of colors. This caused difficulty in the designation of chromaticity of virtual colored overlays. In his research paper about optimized chromaticity of the colored overlay film type and colored lens, He reported that these two methods could improve reading speed, but colored lens applied with the colored overlay film type did not improve reading speed as much as the optimized colored lens did. He also reported that colored overlay did not show reliable information empirically in the selection of optimized lens color. He used only abstract and obscure expression by commenting that overlays provided only surface colors whereas lens imitated the changes of colors under light source [8]. This paper attempted to identify the reasons by measuring the features of physical overlays, not by the empirical studies. For color samples in this paper, real product was measured by reference to Intuitive Overlays [9].

With a spectrophotometer, I measured color information and transmissivity of a single color, overlap of a single color, and overlap of a neighbor color of Intuitive Overlays with transmit mode. It was decided that this experiment was useful to analyze the features of film overlay itself. The spectrophotometer used for measurement was the CM-3600d Konica Minolta brand.

The measurement method used involved compensation of the device with the overlay film placed at the entrance of the receiver, lights penetrating the rougher side (visual side), and quantified overlay colors (CIE-L*u*v') and transmissivity. The chromaticities of measured overlays are presented in Figure 1 as CIE Lu'v' coordinate.

In order to measure the features of film overlay with reflect mode, CM-2600d, a spectrophotometer by Konica Minolta, and stick film overlay for white A4 copy paper were used while chromaticity and reflection rate were measured. Applied features were meant to be visual features, which were transferred to users when film overlay was used in white paper books. In general, Wilkins Reading Rate Test used film overlays, and Visual Stress Assessment Pack of Crossbow Education also applied film overlay to white and ivory colors, respectively, for experiment about selecting optimized colors. Since CM2600d adhered closely to the object vertically due to its mechanical structure for measurement, it had the advantages of blocking out surrounding illumination and reducing chromaticity error caused by changing the measuring angle. Measured colors are presented in Figure 2 as CIE Lu'v' coordinate.

I measured the chromaticity of film overlay by using the Galaxy Tab 10.0, a tablet PC on the Android mobile platform. For measuring chromaticity, I used CS-200 portable Chroma meter by Konica Minolta. CS-200 could measure brightness and chromaticity.. Since the focal length of CS200 was 296mm-limitless, I had limited distance to a Tablet PC screen at up to 60cm when measuring the chromaticity of screen. This experiment was conducted to identify whether the features of chromaticity were identical when a film overlay was applied to papers like books and IT devices like smart phones. Measured color overlay coordination is presented in Figure 3 as CIE Lu'v'. Coordination marked on the boundaries in Figures 1, 2, and 3 are the measurement result with overlays overlapping. Coordination marked on the inside of Figures 1, 2, and 3 is presented as a single overlay.

The geometric characteristic of measured color coordination of overlapped overlays was ellipse-shaped. In order to analyze the collective features of this coordination, I conducted the fitting of ellipses for coordination at MATLAB based on the direct least squares fitting of ellipses [10]. The information of ellipse resulting from ellipse fitting is presented in Table 1. In this table, you can see the big differences in the chromaticity of overlay colors when measured by transmit mode and by reflect mode with white paper background. The reason is in transmit mode, light penetrates an overlay one time, whereas in reflect mode, light reflects on the surface of the overlay and light reflects on white paper after penetrating overlays are combined.

It is expected that if a mobile device such as the Galaxy Tab 10.0 is applied with film colored overlay, it will be similar with the overlays measured at transmit mode when color distortion is removed. As seen in Table 1, the areas of two ellipses are similar. Reasons are that without surrounding illumination, light from mobile devices are measured by Chroma meter, which means light penetrates an overlay only one time.

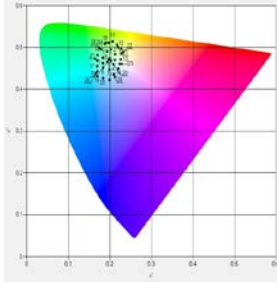


Fig. 1. Measurement results of u'v' chromaticity of Intuitive Overlays

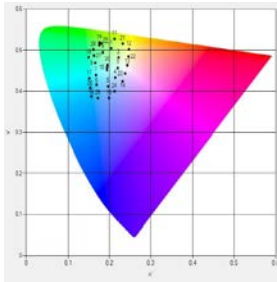


Fig. 2. Measurement results of u'v' chromaticity of Intuitive Overlays with background white paper

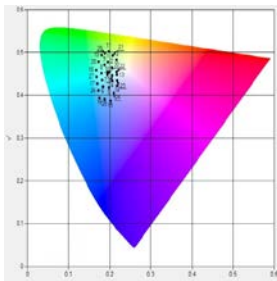


Fig. 3. Measurement results of u'v' chromaticity of Intuitive Overlays with white background of Galaxy Tab 10.1

If surrounding illumination is involved, it is expected that due to surrounding illumination, light is combined with the one from mobile device, and features of reflect mode will be presented as seen in the table depending on the brightness of two lights. u' and v' in CIE Lu'v' with the white background of Galaxy Tab 10.1 are 0.1943 and 0.4465, respectively, containing light purple. This is also the feature of a display device because it is made of OLED. Due to this feature, Figure 3 shows that the color of overlay is greatly distorted. As reported in Wilkins' paper, it is estimated that the differences of optimized color between the lens having different reading speeds in empirical studies and the overlays are caused by the fact that a lens presents transmitted color, whereas overlay presents the combination of transmitted color and reflected color. The virtual colored overlay implemented in this paper allows it to use optimized color that has been inspected with film overlay. In order to use a color sample

that has been verified empirically, it uses overlay color that has been measured at reflect mode.

Table 1. Features of ellipse composed of the u'v' chromaticities of the overlays

	center of ellipse	length of semi major axis	length of semi minor axis	area of ellipse	note
u'v' chromaticity of the overlays (transmit mode)	$x_0 = 0.1970$ $y_0 = 0.4688$	0.0469	0.0282	0.0042	
u'v' chromaticity of the overlays with background of white paper (reflect mode)	$x_0 = 0.1953$ $y_0 = 0.4572$	0.0766	0.0461	0.0111	expansion ratio s. minor axis : 1.6347 s. major axis: 1.6332
u'v' chromaticity of the overlays with background of Galaxy Tab 10.0 white screen	$x_0 = 0.1934$ $y_0 = 0.4446$	0.0583	0.0256	0.0047	expansion ratio s. minor axis : 0.9078 s. major axis : 1.24307

3. Design and implementation

The first operational requirement of virtual colored overlay in the Android operating system is the color of overlay selected in the early stage shall operate commonly in any screen. The second requirement is the virtual colored overlay shall not affect any screen working in a smart phone or tablet PC and applications that users interface with with the exception of visual effect. Third, the virtual colored overlay shall be able to change selected colors in different situations.

Unlike the Windows OS, the Android OS has only one foreground application, and the screen of a corresponding application takes full screen with the exception of a status line. When users run an application, it will run at foreground, and users can call for other applications or other screens within the same application [11]. These programs and screens are stored in an application stack by a system activity manager. Since virtual colored overlay must be displayed continuously even when other applications or screens are running, it cannot be implemented as an activity which must use foreground activity. Services are the activity that runs without direct interactions with users. Therefore, if virtual colored overlay is implemented as services, it can be activated without giving effect to screens or application that users interface with. Services can be implemented in both background and foreground. In the case where background service is used, when the memory capacity of an applicable smart phone or tablet PC is not sufficient for the requirements of an operating application, an operating

system forces the services to shut down. To prevent this, foreground service is required.

In foreground service, only a notification of “currently activating” is displayed (status bar at the top of the Android screen). Users can check if an applicable service is currently operating and they can shut down an operating system when necessary. The way to start a foreground service is to use startForeground, stopForeground, and internal method of service class.

This research used services in order to operate an application all the time, implementing virtual colored overlay at the top window that is used in a screen, and not to effect interaction among currently operating applications. The function of executing or stopping virtual colored overlay service is implemented as an activity. When this application is first used, select the color suitable for users before activating overlay services with the corresponding color. Android allows multiple windows. How the window is displayed on the screen in Android is presented in Figure 4.

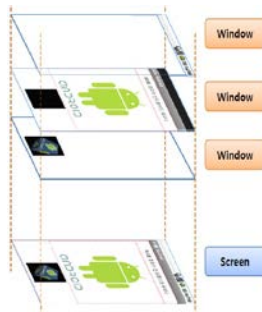


Fig. 4. Example of Android screen composed by multiple windows

As illustrated in the figure, when an overlay runs at the top window via background service, overlay is always on the screen regardless of which screen or app is used. In order to insert generated overlay at the top window, transfer users’ touch to a displayed screen via overlay, and to keep overlay transparent, you need to set a layout parameter of the window manager as seen in List 1 and register an overlay view in window via addview method. Addview method shall obtain permission from manifest and service at a later stage.

4. Test and result

In order to verify the chromaticity of implemented virtual colored overlay, I compared the measurement value of chromaticity by applying virtual colored overlay to the white background screen of a display unit with the color value obtained by penetrating film color overlay with spectrophotometer. For measuring chromaticity, I used CS-200 portable chroma meter by Konica Minolta and for

measuring transmitted light, I used CM-3600d by Konica Minolta.

For the tablet PC, I used Samsung Galaxy Tab 10.1. CS-200 could measure brightness and chromaticity. Brightness precision was $\pm 2\% \pm 1$ digit at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ temperature, and $150\text{cd}/\text{m}^2$ when maximum relative humidity was 65%. Brightness precision was $\pm 2\% \pm 1$, whereas digit chromaticity precision was ± 0.002 at L_v, x, y coordination. Since the focal length of CS200 was 296mm-limitless, I had limited distance to a tablet PC screen up to 60cm when measuring the chromaticity of LCD screen. During actual measurement, surrounding lightings were all shut down and all light sources were blocked. Measured color overlays coordination on Galaxy tablet 10.1 with chroma meter was presented in Figure 5 as CIE $Lu'v'$. Each number in the figure was the number of each overlay sample with 1-10 being single color, 11-20 being single overlapped color, and 21-29 being surrounding overlapped color numbers. Galaxy Tab 10.1 showed light purple with weak background, while the screen brightness against the white background was $394\text{cd}/\text{m}^2$.

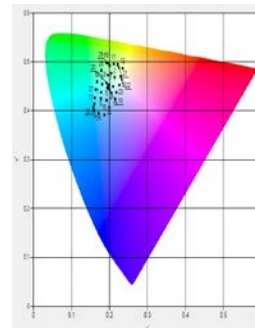


Fig. 5. Measurement results of $u'v'$ chromaticity of Virtual Overlays with white background in Galaxy Tab 10.1

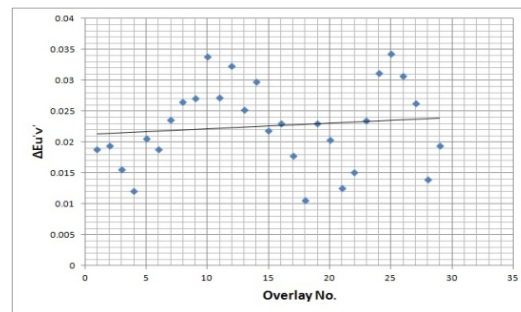


Fig. 6. Difference of chromaticity between Virtual Overlays and Intuitive Overlays in Galaxy Tab 10.1

The differences of chromaticity were the differences of CIE $Lu'v'$ coordination except the value of brightness and are presented as $\Delta u'$ and $\Delta v'$. This value is substituted to Formula 1 and its overall size is calculated ($\Delta Eu'v'$) with a different value. Calculated $\Delta Eu'v'$ value on 29 overlay samples are presented in Figure 6. Galaxy Tab showed big

differences in pink and purple overlay and mixture of two colors overlays. It was estimated that this result was related with the fact that the display of Galaxy Tab adapted OLED, in which white background was light purple. Average and standard deviation of color differences (ΔE_{uv}^*) between actual film overlay and virtual colored overlay were 0.022575 and 0.006654, respectively, which was not a big deviation to be distinguished visually. Reproducibility of chromaticity value of actual CM3600d was 0.02 on the basis of standard deviation ΔE^*_{ab} , and the precision of chromaticity of chroma meter CS-200 was ± 0.002 on L_v,xy coordination. Therefore, the measured differences were at a negligible level.

$$\Delta E_{uv}^* = \sqrt{\Delta u^*^2 + \Delta v^*^2} \tag{1}$$

Examples of application of implemented virtual colored overlay app to mobile phones are presented in Figure 7. Overlay operates as a service and works in a proper way without interfering with a currently operating app.



(a) : web browser sample
 (b) : text message sample
 (c) : graphic game sample

Fig. 1. Application samples of Virtual Overlays

5. Conclusion

This study implemented a virtual colored overlay app that can be used in a tablet PC operating on Android OS. This app had the effect of mitigating or removing scotopic sensitivity syndrome like scotopic seizure that was regulated in the Korean Web Accessibility Guidelines 2.0 and Mobile Application Accessibility Guidelines. Virtual colored overlay was implemented by determining the original chromaticity of virtual overlay though color conversion and nonlinear color designation. I found that if an optimized color selection test resulting in an existing

film overlay was to be used in virtual colored overlay and existing colors whose effects were verified with those with SSR empirically were to be implemented in virtual colored overlay, chromaticity measured in reflect mode with white paper background instead of transmit mode should be used. I measured the chromaticity of virtual overlay on the display of a tablet PC with chroma meter and found that it was almost identical with the case that film overlay was applied to printed books. I also verified that implemented virtual colored overlay operated well in a text message, message input window, web browser, and game with graphic objects.

Implemented overlay can be used in an application program such as a computer game, whose graphic object is operated by a mouse. The overlay is easy to use in the web browser application environment with a complex combination of list box selections and button controls, which can directly use colors selected from the WRRT result.

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