論文

Colour Veil View: a unique feature for Sharp's smartphones

カラーベールビュー：シャープ製スマートフォン向けのオンリーワン機能

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Since 2008, Sharp smartphones for the Japanese market have featured the "Colour Veil View" switchable privacy technology. This is an image data processing function which allows users to switch the display to a private mode in which reconfigurable colour side images are produced, obscuring the main image content for off-axis viewers. The added functionality is implemented in the display control electronics, and requires no additional LC panel hardware or complexity, and results in no change to the display performance in the public mode. This paper will describe the method by which "Colour Veil View" operates and outline the implementation.

2008年より，カラーベールビューと呼ばれる切り替え可能なプライバシー保護機能がシャープ製スマートフォンに搭載され，特徴のひとつとなっている。これは，ユーザがディスプレイをプライベートモードに切り替えることができる画像データ処理機能であり，制御可能なカラー副画像を生成し，正面以外のユーザからは主画像が見えないようにするものである。この機能はディスプレイ制御回路に実装され，液晶パネルのハードウェア追加が不要で，複雑性も増大せず，パブリックモードにおけるディスプレイの性能劣化もない。本稿では，カラーベールビューの動作方法ならびに実装方法の概要について述べる。

1．Introduction

Since the development of high information content, wide viewing angle capability LCDs for portable devices such as mobile phones, tablets and notebook PCs, it has been desirable to provide a switchable privacy function to allow confidential information to be viewed in public places, without compromising the capability to display public information over a wide viewing angle when desired. Sharp has provided such a switchable privacy function on mobile phones since 2005 with the "Veil View" function, included for example on the FOMA Dolce for NTT DoCoMo.

This "Veil View" function required an additional LC cell placed in front of or behind the image panel image panel and an additional polariser film[1)]. This method provided a strong privacy effect, with a fixed privacy pattern obscuring the main image, in the horizontal viewing plane only, but the additional cost and thickness resulting from the secondary LC panel was undesirable. As a result, an image processing only privacy solution was released by Sharp on the DoCoMo Sh702is. This method strongly degraded the on-axis image contrast in the private mode in order to make the image unreadable off-axis[2)].

Also, other manufacturers have released LCDs with a privacy function, but these have used modified image panels with a portion of the display sub-pixels used to control the viewing angle, rather than contribute to the image detail and brightness[3−4)]. These methods incur both significant cost due to the additional or modified display hardware, and result in degraded display performance when the privacy feature is not in use, due to the reduction of resolution and aperture ratio required to include pixels which provide no image information on-axis, but are for view angle control only.

The "Colour Veil View" method, jointly developed at Sharp Laboratories of Europe (Oxford, UK) and Communications Systems Division (Hiroshima, Japan), uses only image data modifications to produce a fully controllable, animated side image in the private mode. It requires no modification to the LC panel hardware, and therefore allows the display to be operated in the public mode with no image quality degradation compared to a standard panel.

2．View Angle Dependence

Fig. 1 (a) shows the display luminance against data level,

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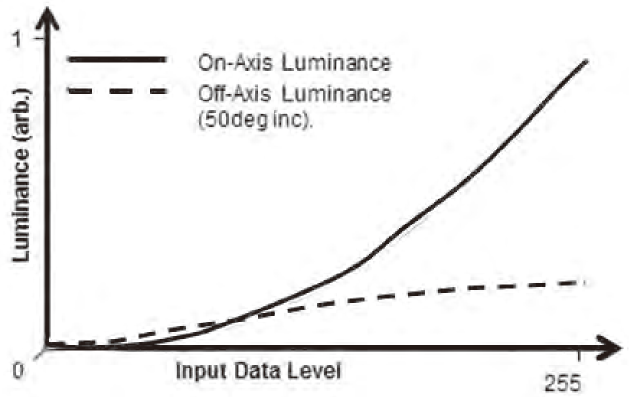

Fig. 1(a) On-axis and off-axis luminance as a function of input data level for a typical VAN mode LCD

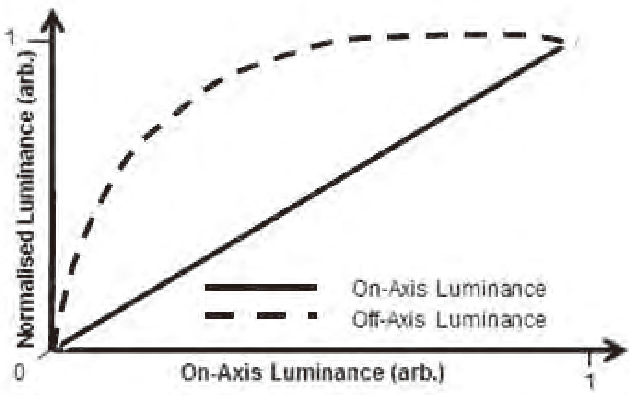

Fig. 1(b) On-axis and off-axis luminance as a function of on-axis luminance for a typical VAN mode LCD

i.e. “gamma curves”, for a multi-domain vertically aligned (VA mode) LCD[5−6], measured along the display normal (on-axis) and at a 50° inclination in the horizontal direction (off-axis). If the same data series are normalised to their respective maximum values, and the off-axis luminance is shown as a function of the on-axis luminance, for each input data level, as in **Fig. 1 (b)**, the relative shift in normalised luminance with viewing angle is shown. It can be seen that, although there is minimal contrast inversion, and the black-to-white contrast level off-axis remains high, the relative luminance for all mid-grey values off-axis is excessively high, and the effective gamma curve of the display is view-angle dependent.

This viewing angle dependency of the display gamma curve allows a means of varying the average off-axis luminance produced by a pair of pixels in combination, while maintaining the average on-axis luminance[7]. This effect is illustrated in **Fig. 2**, which shows the resulting average off-axis to on-axis luminance values for a range of combinations of two pixel data values. It can be seen from the figure that an average on-axis luminance of 0.5 can be produced by two pixels both having a luminance of 0.5, or with one pixel having zero luminance and one having maximum luminance, or indeed any other combination of luminance values with a total of 1 shared between the two pixels. While these combinations all result in the same average luminance on-axis, due to the gamma curve variation, they will produce differing average off-axis luminances.

For any average on-axis luminance value, multiple individual pixel luminance combinations exist (except for minimum and maximum luminance, for which both pixels must be at 0 and 1 respectively) each with a different off-axis luminance. It can be seen that generally, the closer the two individual pixel luminance values, the higher the average off-axis luminance, and the more different the two on-axis values, the lower the resulting off-axis luminance. For any given off-axis luminance, the highest off-axis luminance is produced by a pixel combination with both values the same (shown by the circles in **Fig. 2**), and the lowest off-axis luminance is produce when one pixel of the pair it at its minimum (0) or maximum (1) on-axis value (shown by diamonds in **Fig. 2**).

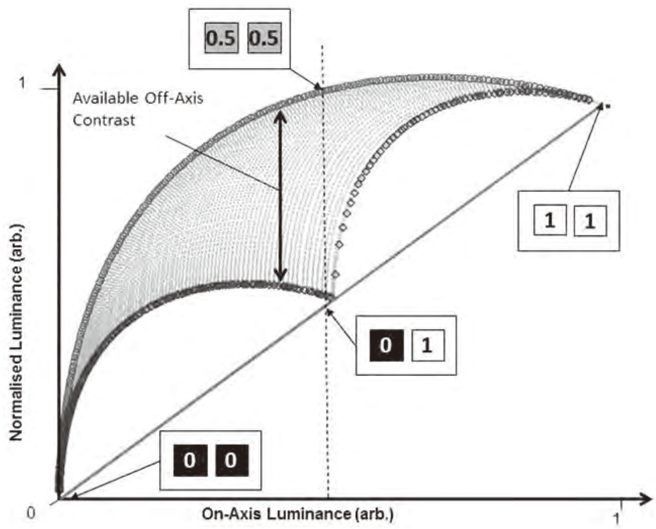

Fig. 2 Average off-axis luminance against average on-axis luminance of two pixels for all combinations of data values

3. The “Colour Veil View” Process

The on-axis and off-axis gamma curves of any given display may be measured and used to calculate the average on-axis and off-axis luminance produced by all combinations of data values applied to a pair of pixels.

A Look-up Table (LUT) may then be generated, storing pairs of pixel data combinations for each required average on-

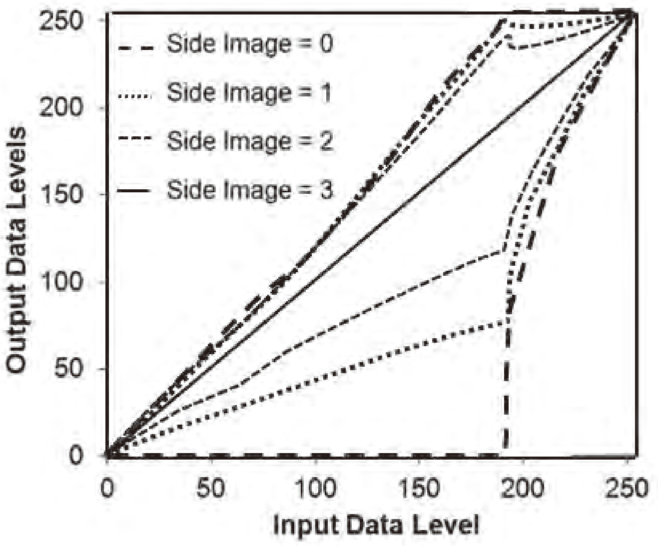

Fig. 3(a) LUT values for the two output data levels corresponding to each input main image data level and side image data level

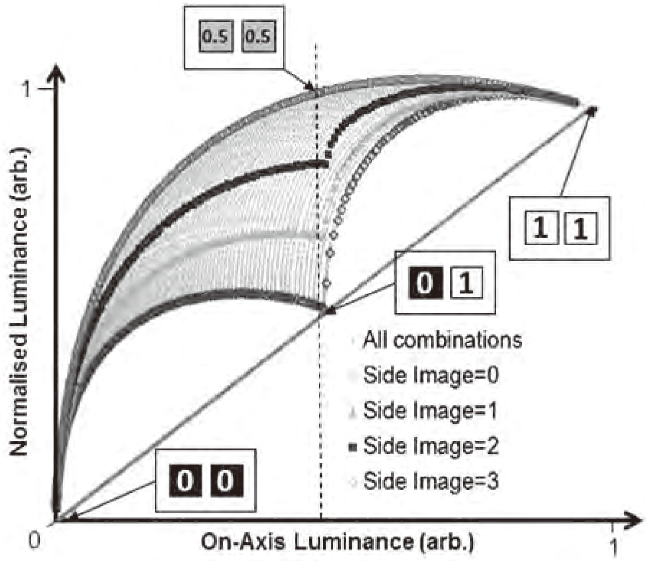

Fig. 3(b) The resulting off-axis to on-axis luminance produced by the LUT values of Figure 3a

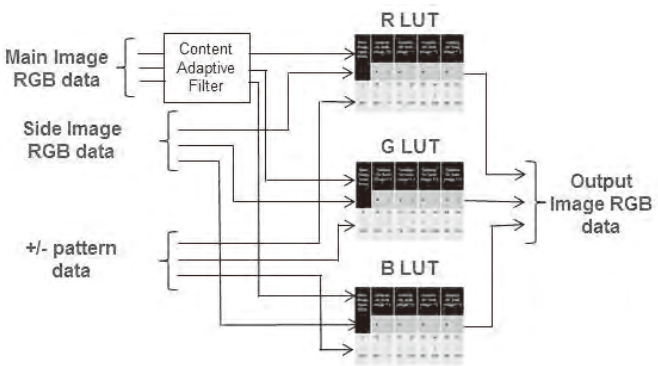

Fig. 4 The image data process flow of the Colour Veil View method

axis and off-axis luminance. A display requiring 8 bit/colour on-axis bit depth, and allowing 4 off-axis luminances for any given on-axis luminance therefore allows a 64 colour side image, and requires 256×*4×3(RGB)×2(data pairs in each combination)=6,120 bytes of memory. In order to reproduce the side image as clearly as possible to the off-axis viewer, the output data values stored were those that produced equally spaced off-axis luminances for each main image input data value. A plot of example LUT values for a 4 level side image is shown in Fig. 3(a), and the resultant off-axis to on-axis luminance values for each side image value are shown in Fig. 3(b).

The LUT is then used in the image data processing flow shown in Fig. 4 to produce a switchable privacy effect[8]. In the public mode, the main image data is sent to the LC panel in the normal manner with no alteration. In the private mode, the main image data and side image data are used to index the LUT, and retrieve a modified output data value which is then sent to the LC panel. The two data values provided by the LUT for each main image/side age data combination are assigned to pixels alternately, so that on average the intended on-axis and off-axis luminance is generated by each neighbouring pair of pixels.

4. Results

As the individual pixel data values required to produce the minimum off-axis luminance are as different as possible, regions of the resulting output image corresponding to dark regions of the input side image have a bright-dark pattern imposed on them. On the very high resolution displays used in mobile phones and other portable devices, this high spatial frequency variation and consequent resolution loss is not visible, and the on-axis viewer perceives the main image with little degradation. The microscopic appearance of the resulting image for a bright main image region and bright and dark side image regions is shown in Fig. 5, and the appearance of the resulting image from an on-axis and off-axis perspective, viewed at the usual distance is shown by the photographs of Fig. 6.

There is however the possibility of “killer patterns” in the main image content which clash with the imposed bright-dark pixel pattern of the output image and can create strongly coloured artefacts visible to the on-axis viewer. Also, as the “Colour Veil View” image data modification process operates on a single pixel at a time, but two pixels are required to produce the intended average on-axis luminance, single pixel

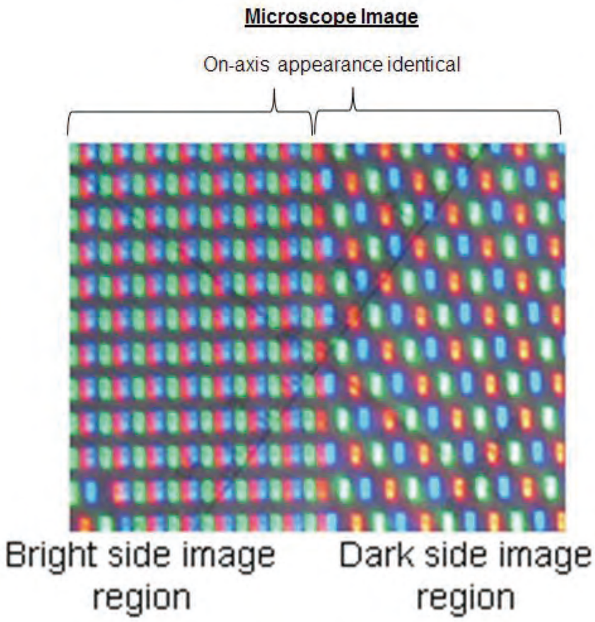

Fig. 5　A microscope image of a Colour Veil View processed image on a display, with dark and bright side image regions

Fig. 6　A photograph of the visual appearance of Colour Veil View on a mobile phone display

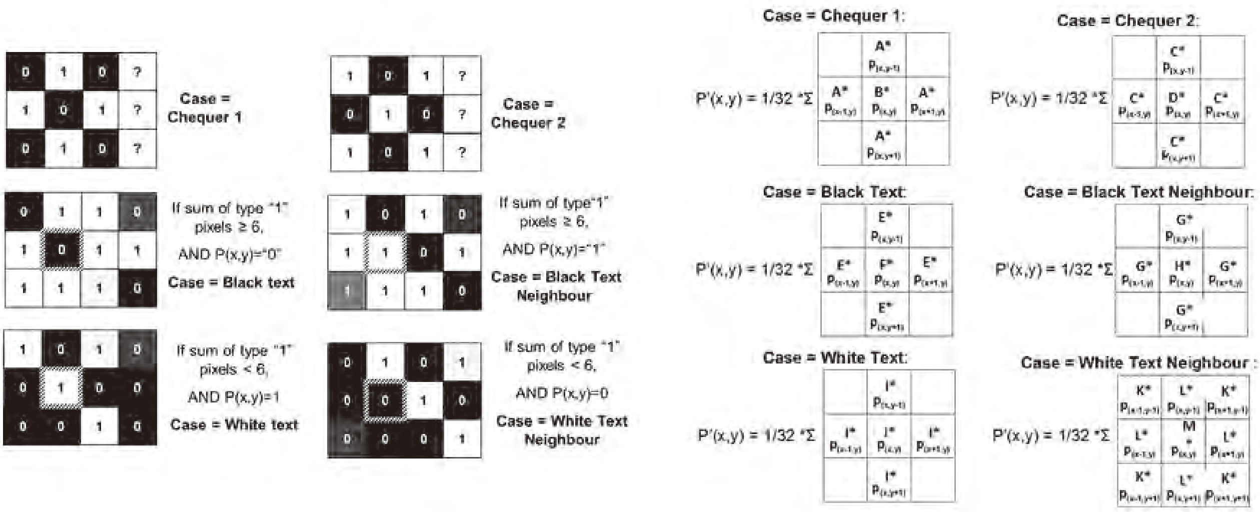

Fig. 7　Outline of the local case detection function and resulting blending filters applied to the input main image

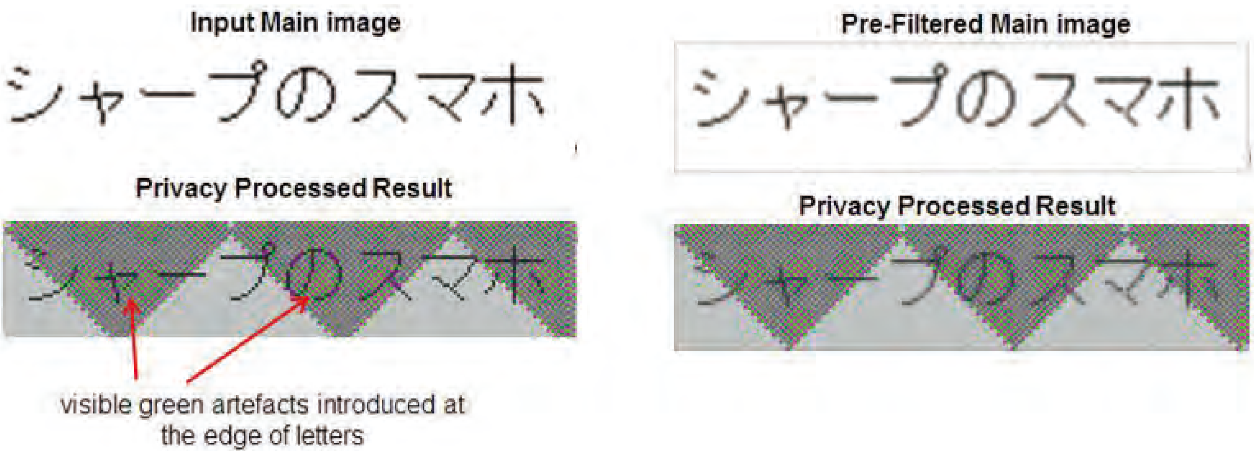

Fig. 8　Illustration of the result of the main image pre-filter applied to example text features, and the subsequent appearance of the Colour Veil View processed image

width features may be effectively erased by the process. To prevent these visible artefacts a content adaptive image filter was developed[9].

A 3×3 pixel blending filter was found to give sufficient selection of main image features requiring modification to prevent visible artefacts. In order to retain as much of the original main image information as possible, it is desirable to minimise the modification produced by the filter. It was found that the minimum degree of blending was different for different main image content (e.g. black-on-white text and vice-versa. The filter was therefore combined with a simple main image content analysis and case detection feature. The six cases detected and consequent pixel blending function applied in each are shown in Fig. 7. This filter has sufficiently low resource requirement to allow inclusion on the modified driver IC along with the processing for retrieving the LUT output values based on the input main and side image data. This allowed main images of the native display resolution to still be displayed in the private mode, with only a minor blurring effect apparent to prevent noticeable image artefacts. Example main image content and the resulting output image, with and without the pre-filtering applied, are shown in Fig. 8.

Additionally, as can be seen from Fig. 3 (b), the available contrast of the side image is strongly main image value dependent. The greatest side image contrast is available for main image regions of luminance equal to half the maximum. For this reason, it is effective to pre-compress the main image to increase privacy strength at the expense of contrast.

Despite a maximum side image contrast ratio of only 1.9:1 at a viewing angle of 50° to the display normal, and reduced main image resolution and brightness (which may be offset by an increase in backlight power during private mode use), a satisfactorily strong multiview effect for privacy purposes was obtained using the method outlined above. 64 side image colours were found to be sufficient to accurately reproduce the side image. Functionality was also included to allow animation of the side image and the use of user generated content as the side image. In order to optimise the privacy effect for the type of main image content which was most likely to require privacy protection (fine text in SMS messaging, email and web browsing) the main image was pre-compressed to half maximum luminance.

5. Summary

The "Colour Veil View" multiview image processing method described above has been commercialised on all Sharp mobile phone models in Japan since 2008, replacing the additional LC cell based "Veil View" technology. "Colour Veil View" provides users of mobile LCDs with effective privacy, with a fully reconfigurable masking side image, without any loss of image quality in the public display mode. The user switching of the privacy function was incorporated into the Android operating system's display settings menu, and as an option in the drop-down settings menu, making the privacy function an easily accessible feature unique to Sharp phones in the Android device market.

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