CSC 8980 Multimedia System

Project Report

Dynamic brightness scaling based on ambient light

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1. INTRODUCTION

Dynamic brightness scaling (DBS) is a technique to save mobile video display energy. The screen brightness of mobile device will be automatically changed based on the video content on display. For example, darker content only needs a lower brightness, saving the mobile energy. However, current DBS schemes do not consider how human perception would be impacted by the temporal variation of brightness. According to Yan et al., Dynamically scale the backlight as low as possible without negatively impacting users' QoE (Quality of Experience) [2]. Due to the reason ambient light also impacts brightness perception, In this paper, we will focus on how to adjust DBS technique corresponding to different circumstance luminance condition.

In 2015, the worldwide population was expected to reach 7.4 billion while the number of cellphone subscriptions is forecast to be slightly over 7.5 billion [7]. Liquid Crystal Display (LCD) has been increasingly used in displays because it has many good features such as thin, light, high resolution, long life, and good color performance.

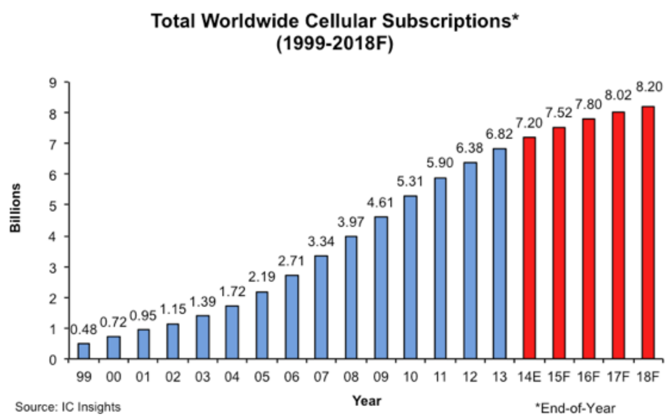

Figure 1. Worldwide Cellular Subscriptions

Therefore, it plays a dominant position on both mobile devices. Due to the work done by A. Carroll and G. Heiser (2010), the majority of power consumption can be attributed to the GSM module and the display [1]. It says that the displaying subsystem accounts for at least 38% of all consumed power, and it can be up to 68% with the maximum backlight brightness. Thus, DBS needs to be imployed to save energy.

Different from the traditional DBS algorithm which just focuses on the video content [3][4].
We adopt the Quality of Experience [2] to measure the effect of the subjective experience. However, few types of research focus on the contribution that ambient luminance makes to QoE.

In order to tackle this problem, we explore QoE when DBS is applied combined with the effect of ambient luminance, thus to maximally increase the video quality without affecting users experience in this work.

Our contributions to this project can be summarized as follows. We have adopted a comprehensive investigation on the QoE of dynamic backlight scaling [2]. We use the developed customized video App, QoEPlayer, which is used in the work of [2] to conduct our experience. Basically, for DBS base algorithm, we adopt the shot based algorithm. In addition, by combining the works done by Microsoft of ambient light [8][9]. We developed our Combine-Scaling algorithm to adjust content luminance with ambient light. In this particular aspect, we use coefficient value to linearly combined the effect of two luminance. By evaluating users accessibility, we finally find a suitable value of the coefficient. Moreover, we adopt a linear regression classifier to smooth the sudden change of the screen luminance.

Our adjusting algorithm is directly adopted QOEPlayer. In the experiment of video quality, the accessibility of human perception is relatively high. This indicates the system is fully functional. We are now on the way to test the energy consuming, thus to better adjust the coefficient of the Combine-Scaling algorithm.

2. RELATED WORK

Several works have been done to develop the DBS algorithm. Ali et al. invented a powerful image histogram “compression” technique which allows uses to reduce the dynamic range of an image topic to a given image distortion level. According to their work, a highly efficient hardware is realized by taking a minimal change on the programmable Liquid Crystal Display Reference Driver [9]. In [6], Kim introduces a contrast sensitivity function (CSF) to improve the image comparison at different levels for small-sized mobile devices. Xue et al. generate an advanced Video Quality Assessment (VQA) model to provide a context-based prediction on mobile video quality [5]. Liu et al. proposed a GPU based algorithm to execute luminance compensation as well as to reduce power efficiency [8].

However, all of these previous works do not provide a direct relationship between the DBS algorithm with QoE and ambient luminance. Current DBS schemes mostly investigate on the video-related distortion metrics such as structural similarity (SSIM) [13] and peak signal-to-noise ratio (PSNR)[14]. However, these works are not specifically developed for DBS, and they all rely on objective distortion formulations. The most similar work is done by Yan et al., they consider the relationship between content luminance and QoE under one specific ambient luminance [2].

In this study, we want to dynamically determine the brightness change of content DBS systems combines with the dynamic change of ambient light. Thus, to achieve the same human perception, the relationship between screen light and ambient light is also used in our design [10].

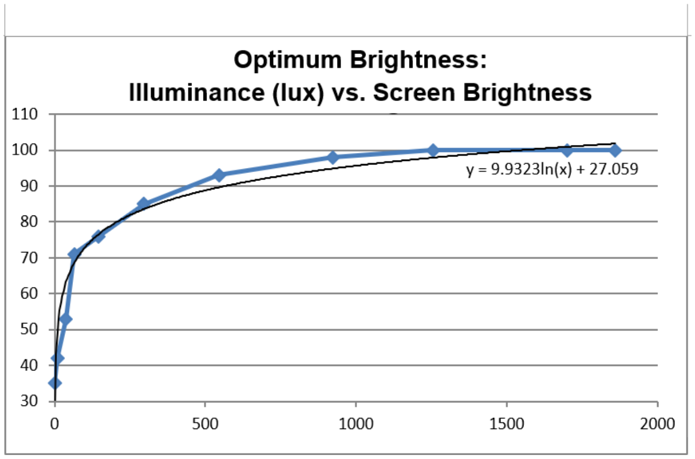

Figure 2. Ambient luminance Vs. Screen Brightness

As can be seen from figure 2, the optimal screen brightness according to ambient lighting condition is not a linear relationship. The trend line shows a mathematical representation of this data. [10].

3. SYSTEM ARCHITECTURE

As we know from previous work, the increase of the content of luminance may directly lead to an increase of backlight brightness. The same situation occurs at ambient luminance. Thus, we choose to adopt a linear combination of these two attributes to measure the brightness level of the screen.

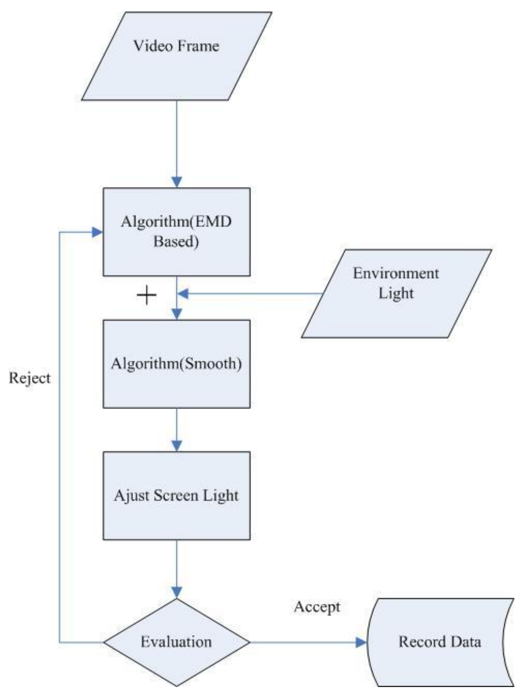

Figure 3. Block Diagram

Figure 3 is the block diagram of our design. As we can see from the figure, when the video track is catching from the server, an EMD based algorithm will first process the video frame and form a configuration file. A mobile sensor will constantly get the ambient light information. As the system combined both information. We use a down-scaling linear regression classifier to smooth the backlight luminance, therefore to prevent the screen from flicker effect. When the video is playing, we are going to evaluate the video quality and the adjusting the coefficient value of combine-scaling.

The EMD based algorithm is defined as follows:

$$EMD(P,Q) = min_{f_{i,j}} \sum_{i,j} f_{i,j} d_{i,j} / \sum_{i,j} f_{i,j}$$
$$s.t. \quad f_{i,j} \geq 0, \sum_{j} f_{i,j} \leq P_i, \sum_{j} f_{i,j} \leq Q_j$$
$$\sum_{i,j} f_{i,j} = \min(\sum_{i} P_i, \sum_{j} Q_j)$$

Where P and Q are two histograms of the video track, fij is the flow amount that transfers from bin i to bin j, dij is the physical distance between I and j. Thus, EMD algorithm calculates the cost for transferring from one histogram to the other. By adopting EMD algorithm, we follow the work done by Yan et al. to determine where a shot happens. Due to the reason that there usually a sudden change of the content luminance at the shot boundary, the EMD based shot detection is effective. The algorithm first computes the EMD between frame k and it's previous/next frame, respectively. If EMD(k, k + 1) is greater than the global threshold and sufficiently larger than EMD(k −1, k), and current shot lasts longer than Dmin, we can decide that a new video shot starts from frame k + 1 [2].

We then propose our Combine-Scaling function as:

$$\text{Brightness level} = \text{a} * \text{ContentL} + (1 - \text{a}) * \text{AmbientL}$$

In this formulation, a is the coefficient we need to adjust to help make a better human perception. The algorithm works as the following example of figure 4. Suppose the video is at shot 1, as we know the 0.2 brightness level is downloaded from the configuration file, if we set a to be 0.5, the current final Combine-Scaling result is 0.15, which is the 15% of the mobile screen brightness level.

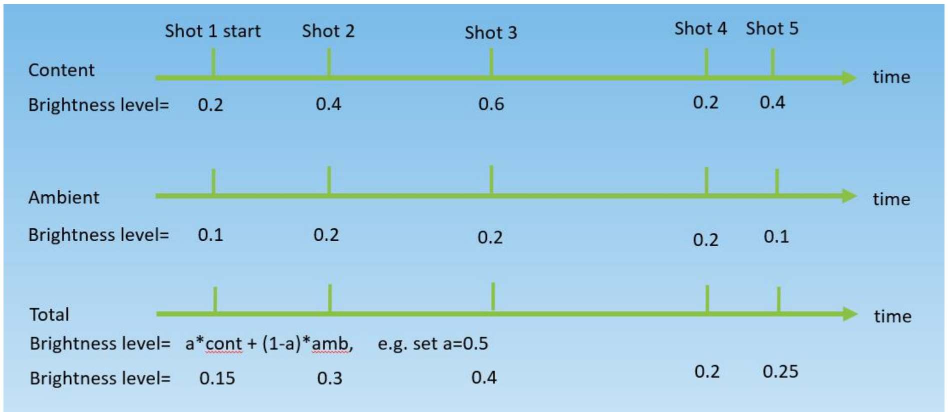

Figure 4. Illustration Example

4. IMPLEMENTATION AND EVALUATION

In our implementation part, we set a suitable interval to detect the ambient light. (0.5s) In the program, we calculate and update the average ambient light every eight intervals. In order to control the update of luminance not too sharp. We compare the ambient light value with the previous one and setup a formulation to get a threshold.

Specifically, the formulation is:

$$\Delta=\text{abs}[\ln(\text{AvgLumk})-\ln(\text{AvgLumk-1})]$$

This threshold determines whether we need to change the backlight brightness based on ambient light. If $\delta>0.5$, then the screen brightness should be updated.

E.g. $\ln(600)-\ln(400)=0.405 < 0.5$, do not need to change
$\ln(50)-\ln(30)=0.51 > 0.5$, need to change

As we can see, the luminance between 600 and 400 is 200, but from 50 to 30 is just 20. However, we only need to update the later one. This is because the change of brightness level is not linear to the human perception.

For smoothing algorithm, from the study [2], we know that Acceptability of up-scaled clips is clearly high. Thus, we only need to Train a binary classifier to detect the inconsistency at every down-scaled switch and then smooth it by using logistic regression. This part we just simply adopt the existing algorithm.

We setup our program in Android studio and plug in our mobile devices. The update information is shown at every shot boundary and also the sharp change of ambient luminance. We also asked ten friends to test the accessibility and adjusting the coefficient value. The evaluation result is shown in table 1, here adopt a=0.6 in out design at last.

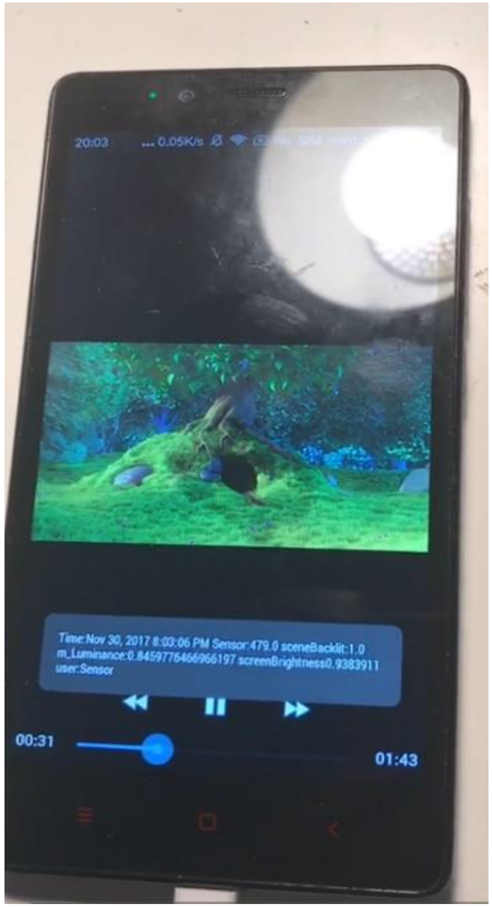

Figure 5. Demo Video

a	1-a	
0.9	0.1	Ambient light nearly does not work
0.7	0.3	Update normally
0.6	0.4	Update normally
0.5	0.5	Update normally
0.3	0.7	Ambient light updated too frequently
0.1	0.9	DBS nearly does not work

Table 1. Coefficient Adjustment

5. DISCUSSION AND CONCLUSIONS

In summary, based on a comprehensive investigation on the QoE of dynamic backlight scaling, we successfully implement our Combine-Scaling algorithm into the QoEPlayer. The accessibility of our backlight luminance is guaranteed. This is a new step to determine the brightness change of content DBS systems combines with the dynamic change of ambient light. We also considering another algorithm to determine the shot boundary corresponding to ambient light.

As figure 6 shows, this is a theoretically better algorithm to achieve higher perception. However, it is more energy to consume and also need more computation in mobile devices.

$$EMD(k, k+1) + \alpha(A_{k+1} - A_k) > \delta$$

$$|EMD(k, k+1) - EMD(k-1, k) + \alpha(A_{k+1} - A_k) - \alpha(A_k - A_{k-1})| >> 0$$

$$k + 1 - S_{pre} \geqslant D_{min}$$

Figure. 6. Theoretical Combine-Scaling Algorithm

In our future work, there are still two steps need to be modified. For QoE evaluation, we are going to require more participation such as classmates, friends to evaluate whether different videos are acceptable under different ambient luminance. Besides, we can also test whether our scaling algorithm works well for various video track.

For power evaluation, we introduce a mobile tool called Qualcomm Trepn tool to directly read hardware data from the device and then one can test the energy consumption of our design.

6. REFERENCE

[1] A. Carroll and G. Heiser. An analysis of power consumption in a smartphone. In USENIX annual technical conference (USENIXATC), June 2010.
[2] Zhisheng Yan, Qian Liu, Tong Zhang, and Chang Wen Chen, "Exploring qoe for power efficiency: A field study on mobile videos with lcd displays," in Proceedings of the 23rd Annual ACM Conference on Multimedia Conference. ACM, 2015
[3] Guangtao Zhai, "Recent advances in image quality assessment," in Visual Signal Quality Assessment, pp. 73–97. Springer International Publishing, 2015.
[4] Xiongkuo Min, Guangtao Zhai, Ke Gu, Yuming Fang, Xiaokang Yang, Xiaolin Wu, Jiantao Zhou, and Xianming Liu, "Blind quality assessment of compressed images via pseudo structural similarity," in Proc. IEEE Int. Conf. Multimedia and Expo, Jul. 2016, pp. 1–6.
[5] Jingteng Xue and Chang Wen Chen, "A study on perception of mobile video with surrounding contextual influences," in Quality of Multimedia Experience (QoMEX), 2012 Fourth International Workshop on. IEEE, 2012, pp. 248–253.

[6] Youn Jin Kim, "An automatic image enhancement method adaptive to the surround luminance variation for small sized mobile transmissive lcd," Consumer Electronics, IEEE Transactions on, vol. 56, no. 3, pp. 1161–1166, 2010.
[7] Worldwide Cellphone Subscriptions Forecast to Exceed Worldwide Population in 2015 http://www.icinsights.com/news/bulletins/Worldwide-Cellphone-Subscriptions-Forecast-To-Exceed-Worldwide-Population-In-2015/
[8] Y. Liu, M. Xiao, M. Zhang, X. Li, M. Dong, Z. Ma, Z. Li, and S. Chen. Content-adaptive display power saving in internet mobile streaming. In ACM NOSSDAV, March 2015.
[9] Ali Iranli, Hanif Fatemi, Massoud Pedram HEBS: Histogram Equalization for Backlight Scaling, Proceedings of the conference on Design, Automation and Test in Europe - Volume 1 page 346-351
[10] Integrating Ambient Light Sensors in Windows 7 https://msdn.microsoft.com/en-us/library/windows/hardware/dn613947%28v=vs.85%29.aspx?f=255&MSPPError=-2147217396