An Image Quality Requirement Quantified Control Method in Display Development Life Cycle

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Abstract
A novel quantified method based on requirement analysis of image quality to improve display image quality was proposed. Nowadays, the image quality was limited by the poor understanding of the image quality requirement, which led to the critical factors of image quality could not be controlled during display development. Our method was set up to resolve this problem by clarifying the relationship between the image quality level and the effect factors in image processing. Moreover, the subjective factors were eliminated extremely by the image quality quantification. The method was applied in the RPTV development life cycle and its efficiency was demonstrated.

Keywords
Image quality, Requirement analysis, Critical factor, Measurement, Assessment, Life cycle.

1. Introduction
How to ensure and improve the image quality during the display development life cycle is the primary goal to the display developers. Nowadays, the subjective assessment results have not been utilized adequately as an approach of improve the image quality in display industry. The developer could not obtain the sufficient information from the assessment results to identify clearly what or how affect the image quality and determine their influence during display development life cycle. Moreover, the specific levels or fine differences could not be clarified based on the current assessment standards at the image quality comparison session.

This was resulted from three aspects as following:

1. The understanding and requirements of image quality are changing with the variation of appreciation concepts. The basic definition of image quality is formaulated in terms of the degree to which two imposed requirements are satisfied: usefulness (that is discriminability of image content) and naturalness (identifiability of image content)[1,2]. Image quality assessment become more difficult due to the great difference between the requirement of image fidelity and image aesthetics in various applications[3,4]. Recently, in the area of television, since the subject impression to image perceived is emphasized rather than the fidelity reproduced, the processes such as image enhancement have to be operated specially to cater to the customer's preference.
2. There are also a great amount of subjective factors involved in the image quality testing and assessment. These subject factors interrupted the image quality assessment heavily, and increase the complexity and difficulty to the objective evaluation. The vision sensitivity and understanding of image individually impact on the results of subjective assessment as well. Moreover, the reliability of the assessment session, including the systematic shifts or local inversions is also considered although these two undesirable effects could be avoided.
3. It was evidence that poor understanding of requirement resulted in the projects cancelled or time and budget estimation exceeded significantly[5]. Frequently, image quality requirements are poorly identified or conflicting. They are given in terms of adjectival descriptions, ambiguous and incomplete. If such requirements could not be transfer to be testable and evaluable, they would be difficult to communicate between designer and customer, and hard to be controlled in process. Furthermore, this also led to the test results were not coordinate with the causes, or even conflict, then such result analysis could not be the workable tools to guide the development.

In order to improve the display image quality and settle with the conflicts of image quality related in development and assessment, a great amount of efforts have been done in industry.

The works of image quality improvement were focused on the aspect of the features of display devices, manufacture, electronics systems, algorithms and so on. The partial benefits have been obtained but less attention have been paid to the process improvement during the development life cycle[6].

Especially, in test and assessment area, image quality models[7,8] were applied in the objective assessment method to compensate for the limitation of measurement device and reduce the subjective effects, meanwhile a great deal of subjective assessment methods[9-11] and the image quality quantification methods[12-14] as supplement have been used more and more although they were so difficult to keep consistent during display development life cycle. Unfortunately, these methods also could not eliminate the subjective factors efficiently.

Furthermore, the International Telecommunication Union (ITU) and the display developers have defined the image quality grading as 5-grade levels to be the scales to the subjective assessment[15]. Practically this grading method is too simple and superficial to quantify specification of image quality comprehensively. It is hard to get enough information to determine how to adjust appropriate setting according to the factors in the image processing chain, even the information about the factors is not adequate, or is difficult to gather.

In practical, the improved process is an important approach to ensure and improve the image quality. During display image quality improvement activities, we found that the lack of the information fed back from the analysis of the results was the main problem to deduce critical factors and their contribution to the image quality. The critical factors out of control were the major obstacle to block the image quality improvement and exceed the schedule and cost estimation in display development life cycle.

A new quantification method for image quality level control based on the requirement analysis of image quality and was proposed to solve the problems introduced by the poor image quality requirement analysis and management. This paper focused on developing the solution of the display image quality improvement in the phases of life cycle through analyzing the relationship between the image quality requirement and the video processing chain.Moreover, eliminating the subjective factors extremely through this quantitive control method was expected.

The main contents are included as following: Section 2, 3 and 4 introduce the procedure of the new method setting up, in section 2, the approach of refining and quantifying the image quality performance based on the image quality requirements analysis was introduced, then the effect factors to image quality were identified combining to the analysis of video image processing architecture. The method of regression analysis which used to derive the critical factors to form the refined image quality level achieved of each effect factor was discussed in section 3. How to control the critical factors to image quality in display development life cycle was presented in section 4. Finally, the conclusions were drawn as an evaluation of the solution according to the verification results in the last sections.

2. Requirement Analysis of Image Quality

The proposed method was the requirement analysis of image quality. Interpreting the image quality requirements with the technique terms as deterministic, unambiguous, complete, non-redundant and so on was the first thing to be done. This is the process of quantifying the image quality requirement, includes refining the image quality performance by decomposed the appearances of image quality and defining the fine image quality level based on the hierarchy of requirements.

The effect factors to image quality could be obtained by the analysis of image processing chain. Meanwhile, the effect degree to image quality of each factor could be deduced from the fine testing based on the results of image quality analysis. The critical factors to image quality were selected from the effect factors by regression analysis according to the effect coefficients related.

2.1 Refine the Image Quality Performance

The technical terms of image quality requirements in display are brightness, contrast, color reproduction, resolution, viewing angle and so on. In general, there are several aspects of performance in one image quality requirement. The requirement was decomposed to the independent image quality performance which can be tested and evaluated clearly based on the rules of acceptance[21] . Since the requirements were converted into the relevant refined and elaborate technical parameters, the performance would be ensured by the process of quality control. The additional purpose of requirements analysis was to set up the objective circumstance to eliminate the impact of the subjective factors contained in the image quality requirements.

For instance, the performance of the gray scale was one of the most important system related characteristics to the ability of luminance gradation, and it was involved in most image quality requirements. The description of performance of gray scale was decomposed to the features of discernible, brightness linearity, color stricking, dark area noise, white saturation and color temperature tracking and so on. These descriptions are complete and testable to the performance of gray scale as referred to column 1 in Table 1.

Table 1 Image Quality Level of Gray Scale

Quality Level / Test items	3	4	5
Discernible	Only the bars at the two end can not distinguishable.	Overall gray bars are distinguishable	Overall gray bars are distinguishable
Brightness linearity	Nonlinearity is not conspicuous	Linear	Linear
Color sticking	light color appears within 3 bars in two areas	No implict color percipitable	Overall no color percipitable
Dark area noise	Percipitable, but not very annoying	Percipitable, but not annoying	Impercipitable
White saturation	White bars at top end merged	White bars at top end tinted	Impercipitable
Color temperature tracking	Overall color temperature appears difference in levels	Color temperature slight different at partial area	Overall color temperature consistent

2.2 Define Image Quality Level as Criteria

Image quality level represents what performance of the display has achieved. There are two classes of assessments to evaluate the performance thoroughly under the kinds of conditions currently. The quality assessment is to establish the performance of systems under optimum conditions, and impairment assessment is to establish the ability of systems to retain quality under non-optimum conditions that relate to transmission or emission.

The definition of image quality level depends on the hierarchy of requirements and the refined image quality performance results according to the ITU-R quality scale standard [15]. The adequate format to identify the image quality level is a two-dimensional matrix with image quality level along one axis and the image characteristics to be tested along the other axis, descriptions of the performance to each level are listed in. Table 1 is the template of the criteria of the image quality of gray scale.

3. Critical Factors Identification

The effect factors of image quality are related to the video signal processing architecture, including the hardware and software to implement the algorithms for image processing and the properties of display devices. When mapping the characteristics above to the image processing chain[16-19].

3.1 Identify the Effect Factors of Image Quality

For example, the performance of gray scale is determined by the luminance conversion in the video process chain. One of the key image processing is Gamma correction both related to the front-end and panel driving electronics. To classify the technique terms according to the display system, there are three stages of processing related to Gamma correction: A/D conversion, video decoding and panel driving. The accurate of A/D conversion, the property of luminance decoding, the RGB gains and the E-O transfer function of display panel etc. are the main effect factors to all the six parameters of gray scale mentioned above.

Once the work of image quality requirement translated into technical parameters had been completed, the critical factors to image quality would be identified by the results of fine testing, while the degree of their influence would be determined by the quantification of the image quality criteria elaborately as well.

3.2 Deduce Critical Factors of Image Quality

In order to realize the control of image quality to be achieved, the critical factors to image quality should be selected from all the effect factors. The critical factor identification was based on quantifying the degree of influence to each effect factor according to the image quality level achieved when they changed.

The relationship between the measured image quality levels and the effect factors has been deduced by regression analysis. The linear regression model was introduced as equation 1:

$$y_i = \beta_1 x_{i1} + ... + \beta_k x_{ik} + u_i \qquad (1)$$

In the above regression equation 1, the dependent variable y_i is assumed to be a linear function of one or more independent variables plus an error introduced to account for all other factors. x_{i1}, …, x_{ik} are the independent or explanatory variables, and u_i is the error term. The goal of regression analysis is to obtain estimates of the unknown parameters β_1, …, β_k which indicate how a change in one of the independent variables affects the values taken by the dependent variable. The usual method of estimation for the regression model is ordinary least squares (OLS) [20].

In this case, the dependent variable is the final image quality level achieved, and the independent variables are the image quality levels of the parameters which can be obtain from the video processing chain, such as the properties of the video decoding, de-interlacing, spatial scaling and so on. The unknown parameters are the effect coefficients which indicate the degree of influence. These variables are the factors that would affect the final image quality level could be achieved The results were normalized between 0 and 1, then the critical factors could be selected depending on the values of effect coefficient as shown in Figure 1.

4. Critical Factor Control Method in Display Development Life Cycle

The final image quality implementation correlated closely to the image quality achieved in each phase of the development life cycle. The requirements of image quality in each phase of the life cycle are different, so the critical factors to be determined for control purpose should be defined in each phase[21].

In the phases of development, determining the elaborate image quality characteristics was very important to identify the critical factors and the order of adjustment in each phase. Since the hierarchy of the requirements to phases and the focus of the testing were different and increasing gradually, image quality level to be achieved should be clarified in coordinate with the specification. Thereafter, the critical factors to be controlled to each phase could be identified with the method mentioned in section II. According to the approach of process management, the critical factors must be controlled due to it was defined in the specification of product development[22].

The requirements are different in each phase, which means the focuses of the image quality control are different, therefore the critical factors to be controlled must be identified carefully to reduce the time of recycle of development life cycle with the incremental mode.

5. Results Analysis and Conclusions

5.1 Result Analysis

This method had been applied to three types of RPTV with DLP™ (Digital Lighting Process) development, and compared the effects with one type which did not use the new methods originally. Not only the image quality of these TV sets were compared, but also the items, such as budget, schedule, effort, which evaluate the maturity of development life cycle were also taken into account.

According to Figure 1 as the regression analysis model, for example, RGB gain, A/D and panel driving are the top three effect factors to brightness linearity, and RGB gain and luminance decoding are the major two effect factors to color temperature tracking. Therefore, based on the regression model, these factors can be defined as critical factors, and they will be controlled thoroughly in the development life cycle.

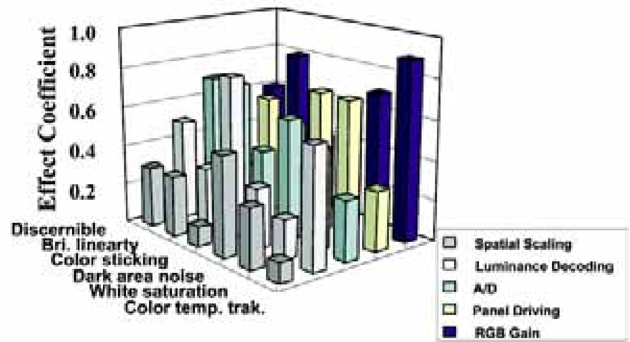
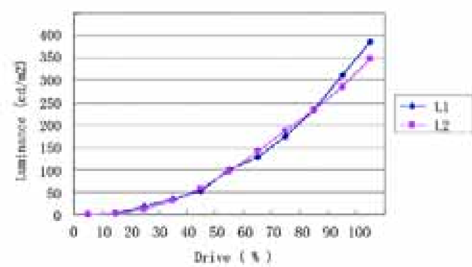
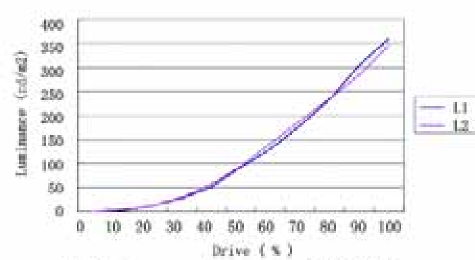


Figure 1 The Effect Coefficients of Critical Factors to Image Quality Characteristics

The comparison results of gray scale characteristics in the two phases as EVT (Engineering Validation Trial) and DVT (Design Validation Trial) were illustrated in Figure 2 and Figure 3. The performance of gray scale was tested by observation firstly, then measured by luminance meter.



(a) Grayscale curves @EVT

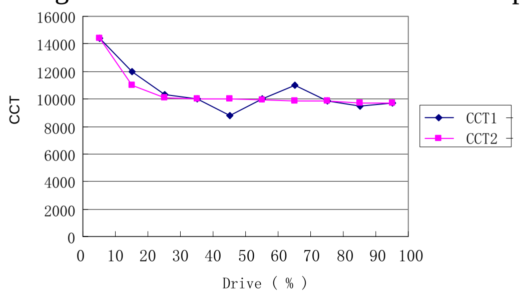


(b) Grayscale curves @DVT

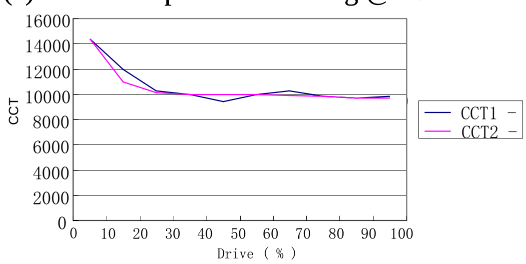
Figure 2 The Compared Results of Brightness Linearity at EVT and DVT Phases

In Table 1, brightness linearity and color temperature tracking are the two major characteristics to describe the gray scale performance. Figure 2 shows the comparison of the performance of brightness linearity, Curve L1 is for the result without the new method applied while L2 is the result with the new method respectively. In Figure 2 (a), brightness linearity of L1 is not consistent with signal level varying as L2 at EVT while such phenomena still exist at DVT shown in Figure 2 (b). Moreover, the Curve L1 is also not smooth as L2 in Figure 2 (b).

Color temperature tracking is to check the convergence of R, G, B primary color during signal varying in level. The Curve CCT1 of Figure 3 shows the results without using the new method while CCT2 used. Compared with the results, the variance of Curve CCT1 is more obvious than CCT2 both in the two phases. It also shows that the final image quality level could be improved significantly if the R, G, B convergence had been controlled in the earlier phases.



(a) Color temperature tracking @EVT



(b) Color temperature tracking @DVT

Figure 3 The Compared Results of Gray Scale at EVT and DVT Phases

5.2 Conclusion

Image quality improvement has been obtained with the application of image quality level control method based on the image quality requirement analysis during display development life cycle. It was profit from the control of the critical factors to image quality in each phase. The new method proposed here was from the viewpoint of process improvement to resolve the problem of image quality requirements management during development life cycle. Further more, the subjective factors were eliminated to assure the image quality level could be achieved without confusion. It was proved that the method was practical and efficiency in the activities of display image quality improvement issues.

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