LCD-TVの動画質改善に関する一検討

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A Guideline for Motion-Image-Quality Improvement of LCD-TVs

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1. Introduction

✓ Motion-image-quality of LCD-TVs has been significantly improved in recent years.

- Many LCDs with improved motion-image-quality have been put into market .
- Improvement techniques: scanning BL, Black insertion, 120 Hz, etc.
- SONY put 240 Hz LCDs into the market, in March, 2009.
- LG demonstrates a 480 Hz LCD at IMID 2009.

CEATEC 2009
(Oct. 6-10, Japan)

240 Hz

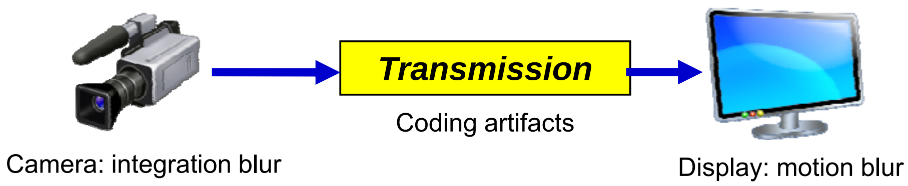
Conventional
(60 Hz?)

What is the Target of Motion-Image-Quality Improvement?

✓ However, the motion-image-quality of LCDs seems to be still insufficient for pictures containing fast and/or fine motion images.

✓ On the other hand, there is another cause of motion-image-quality deterioration in video system, or cameras.

✓ Some people are in doubts about the target of motion-image-quality improvement of LCDs and video system.



What is the Target of Motion-Image-Quality Improvement?

✓ A guideline for deciding desirable parameters on temporal characteristics of LCD-TVs and video system will be presented, based on:

- <u>Dynamic spatial frequency response analysis</u>
- <u>Past results of subjective evaluation tests on motion-image-quality</u>

2. Short Review of Motion-Image-Quality of LCD-TVs

✓ Main issue on motion-image-quality of LCDs is motion blur.

✓ There are two causes of motion blur of LCDs:

- Response time of liquid crystal (LCRT)
- Hold-type display by active-matrix driving

✓ Improvement of LCRT has progressed in recent years.

✓ Hold-type display of active-matrix has become major factor of motion-image-quality deterioration on LCD-TVs.

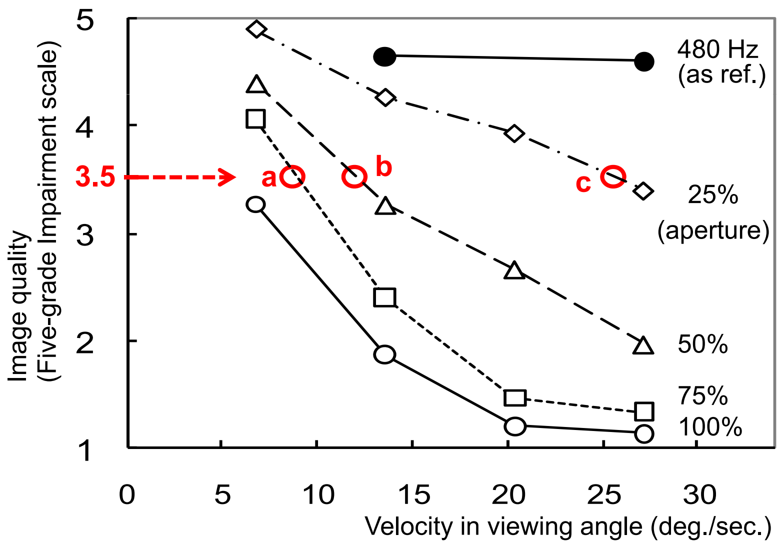
✓ Characteristics of motion-image-quality of hold-type display:

- Degree of the deterioration of the quality varies with images or pictures.
- Motion-image-quality is simply deteriorated with an increase of motion velocity of images by motion blur.
- The quality falls below the acceptable level at a medium motion velocity.
- There are two basic methods to improve the motion blur:
  - Setting a temporal aperture to displayed light (e.g. scanning BL, B.I.)
  - Increase of frame-rate of display (e.g. 120 Hz, 240 Hz)

"Acceptable Limit (AL)" of Motion-Image-Quality

✓ A result of a subjective test on motion-image quality of hold-type display (Kurita, SID '01 [1])

- For several temporal apertures
- Scored by "Five-grade Impairment Scale" (ITU-R BT.500)
- Score 3.5 is called "Acceptable Limit (AL)" of image-quality deterioration.



Frame-rate: 60 Hz

Picture: "Yacht"

A critical picture for motion blur

3. Dynamic Response of Video System

✓ MTF (Modulation Transfer Function, or spatial frequency response) is a common measure to estimate blur of image devices, or video systems.

✓ It has been confirmed that perceived dynamic MTF of hold-type display is degraded with a sinc (sin(x)/x) function. (Kurita, Saito, IDW '98 [3])

✓ Another motion blur, camera integration blur, exists in video system.
- Dynamic response of camera is degraded with a sinc function.
- The integration blur also can be improved by setting a temporal aperture, or camera shutter.

✓ How is the total dynamic response of video system?

✓ Knowing the system response is important to find the target of LCD-TVs.

Definition of Dynamic Spatial Frequency Response (1)

✓ Horizontal spatial frequency characteristic is discussed, as an example.

✓ It is assumed that an image is moving in horizontal direction, with a constant velocity.

✓ Notation:
- Spatial frequency: fx (cycle/pixel)
- Spatial frequency in TV lines: f'x = fx × 2Ny (TV line)

  （Ny: vertical number of pixels or scanning lines in a video frame）
- *Frame-rate: F (Hz) (common for camera and display)*
- Motion velocity of the image: vx (degree/second)

✓ Assume that an observer watches a display at the standard viewing distance (3H for HDTV, ITU-R BT.710).

✓ In this condition, a pixel corresponds to a minute or 1/60 degree in viewing angle from the observer
- Displacement of motion image in a frame: X = vx × 60 /F (pixel)

Definition of Dynamic Spatial Frequency Response (2)

✓ Introduction of ***Temporal Aperture***

- Temporal aperture ratio: *At* (0 to 1, 1: a whole frame)
  - Camera temporal aperture: *Atc* (0 to 1) (e.g. camera shutter)
  - Display temporal aperture: *Atd* (0 to 1) (e.g. scanning BL)

✓ Dynamic spatial frequency responses

- Camera response:

  $Rc(fx) = \sin(\pi \cdot fx \cdot X \cdot Atc) / (\pi \cdot fx \cdot X \cdot Atc)$

- Display response:

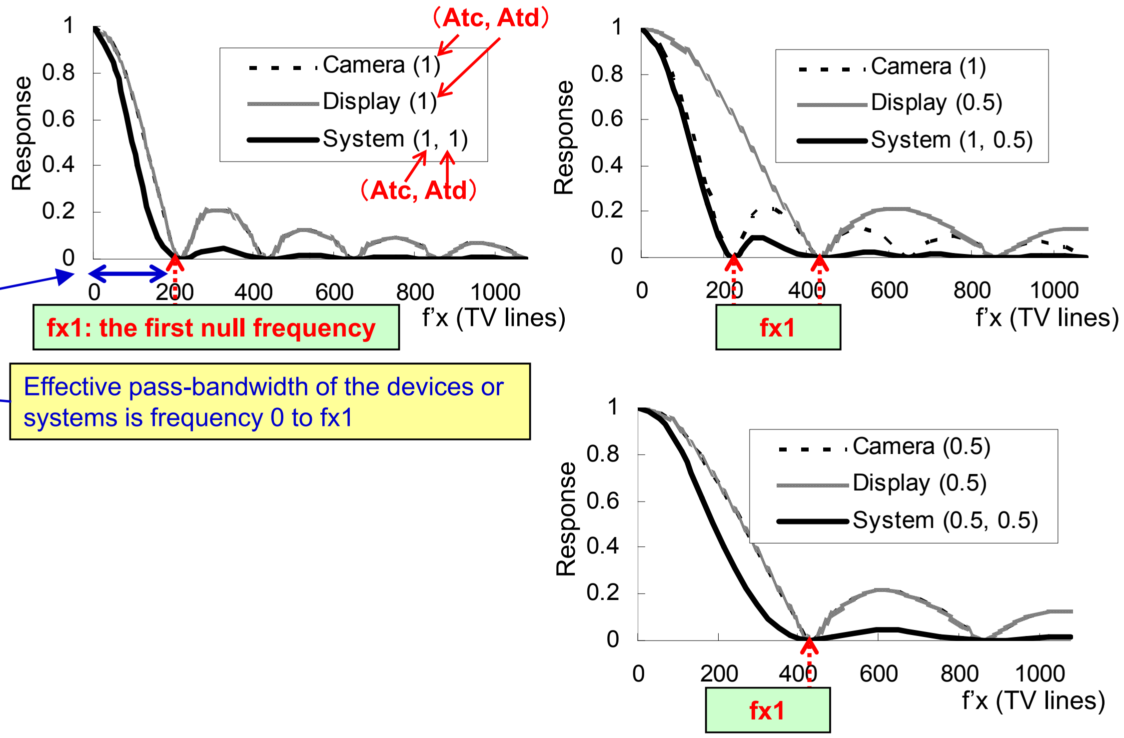
  $Rd(fx) = \sin(\pi \cdot fx \cdot X \cdot Atd) / (\pi \cdot fx \cdot X \cdot Atd)$

✓ System response is the product of camera response and display response.

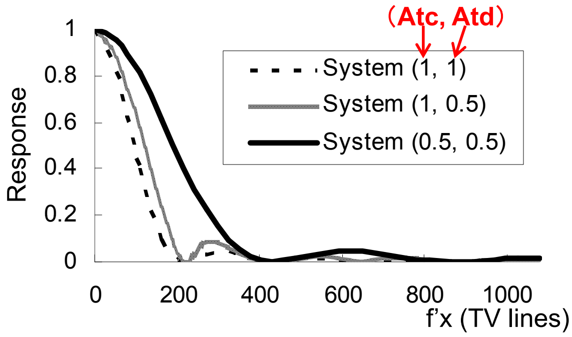
- System response: $Rs(fx) = Rc(fx) \times Rd(fx)$

Calculated Responses for Different Temporal Apertures

✓ Conditions: F=60 Hz, Ny=1080 (HDTV), vx=10 deg./sec.



Comparison of System Responses



✓ The response of System (1, 0.5) is little improved compared with that of System (1, 1), because of the camera response with Atc of 1.

✓Response will be significantly improved, if both temporal apertures are improved, as System (0.5, 0.5).

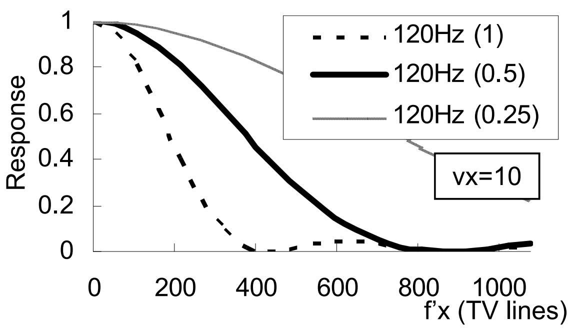
✓ The both motion blur in camera and display should be improved for achieving a good motion-image-quality.

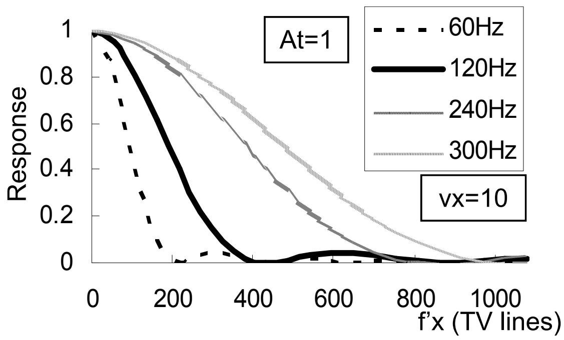
✓ Setting temporal apertures of camera and display to the same value is efficient on a viewpoint of system cost.

✓ We set the temporal apertures to common parameter At, or Atc = Atd = At.

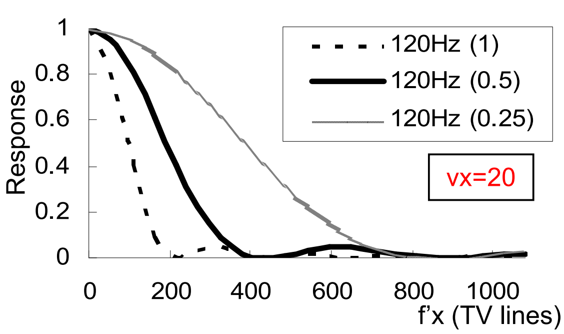
4. Improvement of Dynamic Response

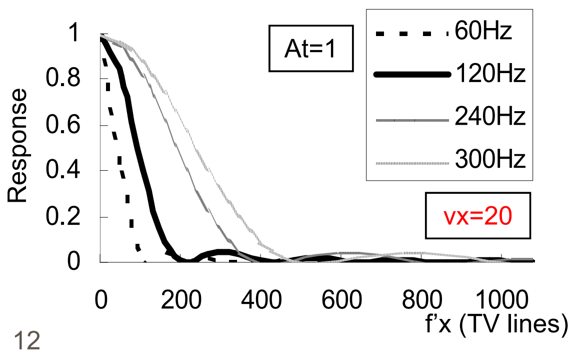
✓ System Response can be improved by a smaller At and/or a higher F.





✓ System Responses in the case of a higher velocity of 20 deg./sec.



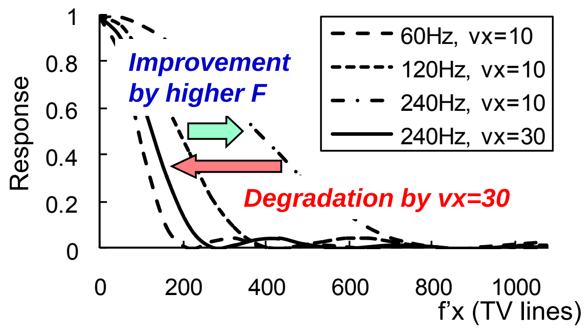


Points of Improvement of Dynamic Response

✓ A smaller temporal aperture (At) and/or a higher frame-rate (F) can significantly improve system dynamic response.

✓ However, *an increase of motion velocity easily cancels the improvement.*

An example for higher frame-rates



✓ Setting frame-rate to extremely high, to overcome the increase of vx, will make devices and systems difficult to realize.

✓ Setting At to extremely small will cause other deterioration on performance and motion-image-quality, such as lower sensitivity, flicker or jerkiness.

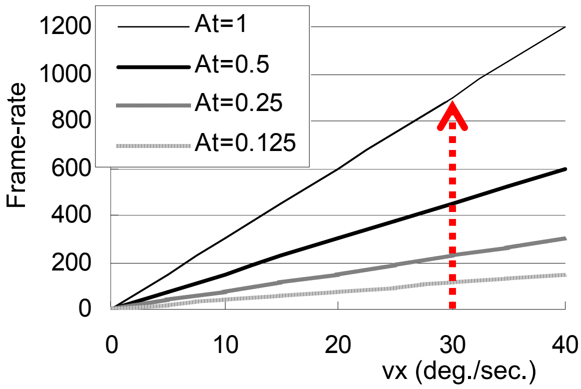
✓ All artifacts should be negligible to achieve a true fine motion-image-quality.

5. Discussion

✓ How should we decide the temporal aperture At and frame-rate F?

✓ A desirable condition will be setting the first null frequency fx1 to maximum available frequency, or Nyquist spatial frequency of the system, fxm (1080 TV lines for HDTV).

✓ **fx1 = fxm = ½** (cycle/pixel):
F = 30•vx•At



✓ It is known that our eye can trace motion object up to around 25 to 30 degree per second.

✓ To improve motion-image-quality up to 30 degree per second:

- An extremely high frame-rate of F=900 Hz (At=1)
- An extremely small aperture of At=1/15 (F=60 Hz)

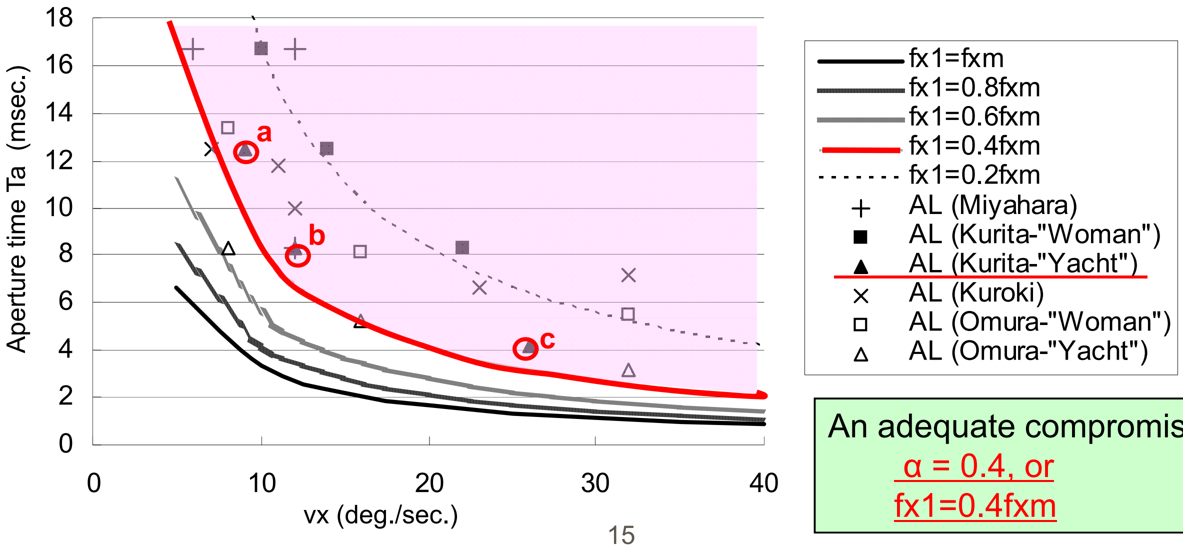
✓ These requirements seem not to be realistic on system design.

✓ An adequate compromise will be necessary

A Compromise Based on Acceptable Limit of Image Quality

✓ *An idea of the compromise*

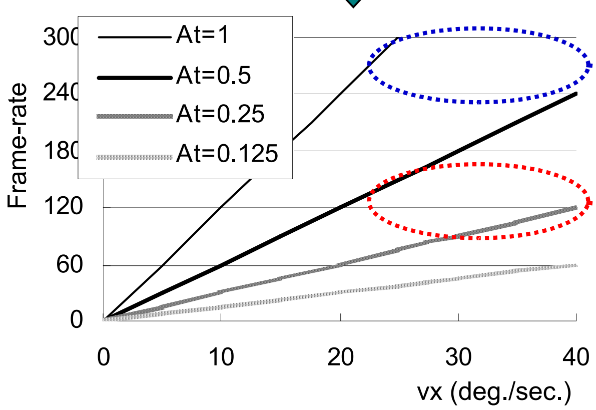
- Set fx1= α•fxm (α= 0 to 1) and select the α adequately.
- F = α•30•vx•At
- Set the target to acceptable limit (AL) of motion-image-quality.
- Extract the pairs of vx and "aperture time" Ta (= At/F), corresponding to AL.



An adequate compromise:
α = 0.4, or
fx1=0.4fxm

System Parameters and Display

✓ **α = 0.4: F = 0.4•30•vx•At**



✓ *Examples of target system with a good motion-image-quality*

System 1:
F = 240 or 300 Hz, At = 1 ~ 0.5

System2:
F = 120 Hz, At = 0.5 ~ 0.25
- **Flicker is free over 100 Hz**
- **Jerkiness will be at AL or lower**

✓ *Two ways of implementation on displays*

1) Temporal aperture
Example: (input) 120 Hz ⇒ (25% scanning BL) ⇒ (display) 120 Hz, At=0.25

2) Up-conversion
Example: (input) 120 Hz ⇒ (up-conversion) ⇒ (display) 480 Hz (At=1)

Conclusions

✓ Motion-image-quality of LCD-TVs and video system was investigated by dynamic spatial frequency response, as a measure to estimate motion blur.

✓ A common frame-rate is assumed for camera and display.

✓ **Setting temporal apertures of camera and display to the same value is efficient on a viewpoint of system cost.**

✓**An ideal device or system with perfect motion-image-quality seems not to be realistic.**

✓ **Two sets of parameters** for camera, display and video system with a universally good motion-image-quality **are proposed based on acceptable limit on image-quality for critical pictures.**

System 1:
F = 240 or 300 Hz, At = 1 ~ 0.5

System2:
F = 120 Hz, At = 0.5 ~ 0.25

✓ *The realization of devices and systems with those parameters is desired.*