METHOD SIMAGE QUALITY CONTROL IN DIGITAL TELEVISION

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Abstract. Digital television (DTV) has significantly improved the quality and reliability of video transmission compared to analog technologies. However, to ensure the highest level of image quality, effective control methods are required. This article discusses the main methods and technologies used to control the quality of images in digital television. Digital television differs from analog television in its ability to transmit images with high resolution and minimal loss. However, various factors such as compression, data transfer and display can affect the final image quality. It is important to take a holistic approach to assessing and monitoring image quality to ensure the best possible user experience.

Keywords: methods of mathematical analysis, methods of planning, conducting and statistical processing of the results of spectator examinations, methods of image processing.

Objective methods are based on mathematical and algorithmic assessments and do not depend on the subjective perception of the viewer. They provide quantitative assessment that allows large volumes of data to be analyzed automatically and quickly. Let's consider the main objective methods used in digital television.

Peak Signal-to-Noise Ratio (PSNR) is an objective method for assessing image quality, widely used in digital television and other image processing applications. This method measures the ratio between the maximum signal power and the noise power that degrades image quality. PSNR measures the ratio between the maximum signal power and the noise power that affects image accuracy. High PSNR values indicate better image quality.

How PSNR works

PSNR is based on the mean square error (MSE), which is the average of the squared differences between the original and processed images.

Where $MAXI$ MAXI is the maximum possible image intensity value (for example, 255 for an 8-bit image).

PSNR interpretation

PSNR is measured in decibels (dB). The higher the PSNR value, the better the image quality, as this indicates less noise. Typical PSNR values for various image qualities:

•   30-50dB - High quality (almost lossless)
•   20-30dB - Average quality (some loss noticeable)
•   < 20dB - Low quality (significant losses)

Advantages and Disadvantages of PSNR

Advantages

•   Easy to calculate: PSNR is easy to calculate and interpret.
•   Wide Application: Used in various fields such as image and video compression, data transmission and image restoration.
•   Objectivity: Provides a quantitative measure to compare the quality of images.

Flaws

• Does not always correlate with human perception of quality: PSNR does not take into account the characteristics of human vision and may not reflect subjective perception of quality.

• Sensitivity to small changes: May be overly sensitive to small changes that are not always noticeable to the human eye.

• Limited applicability for high noise levels: When there is significant noise or distortion, PSNR may not be an adequate estimate of quality.

PSNR is an important tool for objectively assessing image quality in digital television and other imaging applications. Despite its limitations, it remains widely used due to its simplicity and ability to provide rapid quantitative assessments. To more accurately assess image quality, it is often used in combination with other methods such as SSIM and VIF, which take into account the perception of human vision.

MSE calculates the average of the squared differences between the original and acquired images. The lower the MSE, the higher the image quality.

MSE Calculation Steps

1. Pixel Intensity Difference: For each pixel, the difference between the intensity in the original and processed images is calculated.

2. Squared differences: The resulting differences are squared so that all values are positive and highlight larger differences.

3. Average: All squared differences are summed and divided by the total number of pixels to obtain the average.

Advantages and Disadvantages of MSE

Advantages

• Easy to calculate: MSE is easy to calculate and interpret.

• Fast: Compute MSE requires minimal computational resources, making it suitable for rapid analysis of large volumes of data.

• Wide Application: Often used in combination with other quality assessment methods such as PSNR.

Flaws

• Disregard of human perception: MSE does not take into account the characteristics of human vision and may not reflect the subjective perception of image quality.

• Sensitivity to small changes: MSE can be sensitive to small changes that may not be noticeable to the human eye.

• Same value for different types of distortion: MSE does not differentiate between types of artifacts (such as blur and noise), which may result in similar values for images with different types of artifacts.

Mean square error (MSE) is an important and widely used method for objectively assessing image quality. Due to its simplicity and fast computation, MSE finds applications in various fields such as image compression, data communication, and image processing. However, due to its limitations in accounting for human perception, MSE is often used in combination with other methods such as PSNR and SSIM to obtain a more accurate and comprehensive assessment of image quality.

SSIM evaluates image quality based on the human eye's perception by analyzing changes in brightness, contrast, and structure. This method allows more accurate assessment of image quality compared to PSNR and MSE.

The structural similarity method (SSIM) is a powerful tool for objective assessment of image quality, taking into account the characteristics of human perception. Through comprehensive analysis of brightness, contrast and image structure, SSIM provides more accurate and relevant assessment compared to traditional methods. This method is widely used in digital television, image compression and transmission, and other areas of visual information processing.

Subjective methods are based on the assessment of image quality by a group of viewers, which allows human perception to be taken into account.

Mean Opinion Score (MOS) method

MOS is one of the most common subjective methods for assessing the quality of images and videos. The MOS assessment is based on a panel of observers who rate the image quality on a predetermined scale.

MOS Process

1.   Sample preparation: Selects the original and processed images to be evaluated.

2.   Observers' choice: A group of observers representing the target audience is formed.

3.   Quality Rating: Observers are shown images and asked to rate their quality on a scale, for example, from 1 (very poor) to 5 (excellent).

4.   Analysis of results: The average rating for each image is calculated.

Advantages and Disadvantages of MOS

Advantages:

•   High correlation with end user perception of quality.

•   Easy to interpret results.

Flaws:

•   Requires time and resources to conduct surveys.

•   The possibility of subjective influence of personal preferences and mood of observers.

2. Pairwise Comparison

Paired comparison involves comparing two images simultaneously. Observers are shown pairs of images and asked to choose which one is of better quality.

Paired Comparison Process

1.   Sample preparation: Pairs of images are selected for comparison.

2.   Observers' choice: A group of observers is formed.

3.   Quality Assessment: Observers are shown pairs of images and asked to choose the best one.

4.   Results Analysis: Results are analyzed to determine an overall image quality rating.

Advantages and Disadvantages of Paired Comparison

Advantages:

•   Ease of procedure for observers.

•   High accuracy of comparisons.

Flaws:

•   A significant number of comparisons with a large number of images.

•   The complexity of analyzing the results.

3. Categorical Rating

Categorical rating involves evaluating images according to predefined quality categories. Observers are provided with a scale with categories such as "poor", "fair", "good", "very good" and "excellent".

Category rating process

1. Sample preparation: Images are selected for evaluation.
2. Observers' choice: A group of observers is formed.
3. Quality Assessment: Observers are shown images and asked to classify them into one of the categories.
1. Analysis of results: Determines the distribution of images into categories.

Advantages and disadvantages of category rating

Advantages:

• Simplicity and intuitiveness for observers.
• Possibility of quick analysis.

Flaws:

• The limitations of the category scale may not reflect all the nuances of perception.
• Possibility of subjective differences in the understanding of categories.

Selecting a Subjective Method

The choice of a subjective method depends on the specific objectives of the study, available resources and characteristics of the target audience. For example, the MOS method is suitable for complex quality assessment involving a large number of observers, while paired comparison may be preferable for detailed analysis of a small set of images.

Subjective image quality control methods play a key role in ensuring end-user satisfaction as they directly address human perception. Although they require more time and resources compared to objective methods, their results provide more accurate and relevant assessment of image quality. To obtain the most reliable results, subjective methods are often combined with objective evaluation methods, which allows taking into account both mathematical indicators and the perception of the end user.

Hybrid image quality control methods combine objective and subjective approaches to provide comprehensive and accurate assessment. They aim to overcome the limitations of each method while leveraging their strengths to produce more reliable and representative results.

Basic hybrid methods

1. Weighted hybrid models

These models combine the results of objective and subjective assessments by assigning specific weights to them. The weight of each method depends on its reliability and importance in a particular context.

Example of a weighted hybrid model

1. Data collection: Obtaining objective estimates such as PSNR, SSIM, and subjective ratings such as MOS.
2. Assignment of weights: Determine weights for each score based on their significance.
3. Calculation of a hybrid indicator: Combining results taking into account weights.

Hybrid indicator = $w_{objective}$ × Objective assessment + $w_{subjective}$ × Subjective assessment

Where $w_{objective}$ and $w_{subjective}$ - weights assigned to objective and subjective assessments, respectively.

2. Machine learning and deep learning models

Hybrid methods based on machine learning and deep neural networks use trained models to predict subjective ratings based on objective data.

Machine learning use case

1.   Data preparation: Collection of a large data set including images, their objective assessments (e.g.PSNR, SSIM) and corresponding subjective assessments (eg MOS).

2.   Model training: Train a machine learning model on this data to identify dependencies between objective and subjective scores.

3.   Prediction: Using a trained model to predict subjective ratings on new data based on objective measures.

3. Models based on metric learning

Metric learning aims to develop specific metrics that take into account both objective and subjective aspects of image quality. These metrics are trained on data containing both objective image characteristics and subjective ratings.

Metric training example

1.   Data collection: Collection of data including objective characteristics and subjective assessments.

2.   Metric training: Train a model to create a metric that correlates with subjective scores using machine learning techniques.

3.   Quality assessment: Applying a trained metric to evaluate new images.

Advantages and disadvantages of hybrid methods

Advantages:

•   Accuracy: Hybrid methods provide more accurate estimates by combining objective and subjective data.

•   Flexibility: Can be adapted to different image types and conditions.

•   Representativeness: Taking into account human perception makes ratings more relevant and useful to end users.

Flaws:

•   Complexity: Implementation of hybrid methods requires significant computational resources and time.

•   Data Dependency: Accuracy and reliability depend on the quality and volume of data used to train models.

Example of using a hybrid method

Let's consider an example of using a hybrid method to assess video quality in digital television:

1.   Data collection: A test video is shot and its versions with different parameters are compressed. Objective metrics (e.g., PSNR, SSIM) and subjective scores (MOS) are collected for each video.

2.   Model training: Trains a machine learning model that uses objective metrics to predict MOS.

3.   Quality assessment: The model is used to assess the quality of new videos, which makes it possible to obtain predictions of subjective assessments based on objective data.

Hybrid image quality control methods provide a powerful tool that combines the accuracy of objective metrics with the relevance of subjective assessments. They provide a more comprehensive and accurate assessment of image quality, which is especially important in areas such as digital television, where image quality is critical to the user experience. Implementing hybrid methods requires significant effort and resources, but the results are worth the effort due to their high accuracy and reliability.

These models use algorithms based on the physiological and psychological characteristics of human vision to predict subjective perception of image quality based on objective data.

Psycho-visual models evaluate image quality based on how the human eye perceives various defects and artifacts that occur during data compression and transmission.

In practice, image quality control methods are used at various stages of digital content production and broadcasting.

During the content production stage, objective methods are used to evaluate the quality of video after shooting and editing. Automated systems that can quickly analyze large volumes of data play an important role.

At the stage of compression and encoding of video files, both objective and hybrid methods are used to minimize quality loss. For example, using SSIM when setting codec parameters allows you to achieve a balance between compression ratio and image quality.

During the data transfer phase, real-time monitoring techniques are critical. Objective methods such as PSNR and SSIM are used for continuous quality assessment, while subjective methods can be used for spot checking.

Image quality control in digital television is a multifaceted task that requires the use of both objective and subjective methods. Technological advances and the development of machine learning and artificial intelligence algorithms allow for more accurate and efficient evaluation methods, which helps improve the quality of content and meet viewer expectations.

The development of new technologies and quality control methods will continue, leading to even higher standards in digital television, providing viewers with an unrivaled level of comfort and viewing pleasure.

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