Picture Quality Measurement

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ABSTRACT

The introduction of digital Broadcasting services based on MPEG-2 encoded video over the last years has initiated the discussion on the evaluation of MPEG-2 specific artefacts and their impact on the objective measurement of picture quality.
The major influence on picture quality is expected to stem from the parameters chosen for the encoding process. The transmission systems for DVB (Digital Video Broadcasting) are supposed to provide quasi error-free bit streams. However, the contractual relations between the various providers in a transmission chain may require the verification of this assumption.
This approach led to research activities (amongst others in the ACTS Project QUOVADIS) which intend to correlate the MPEG-2 specific artefacts to parameters describing the subjective impression on the viewer.
This paper describes a potential solution for the requirements for various applications of objective picture quality measurement in a live bit stream and without access to a reference signal for comparison.

INTRODUCTION

All DVB transmission systems have a very important thing in common: they have input and output interfaces for the MPEG-2 Transport Stream. For standard applications such as video Broadcasting, the first choice is for video streams which are compressed according to the parameters defined for MPEG Main Profile at Main Level (MP@ML).
The transmission of MPEG-2 Transport Stream packets is also the backbone of other transmission standards. Therefore, it is possible to say that the transition from analogue to digital in Broadcasting owes a lot to the MPEG-2 compression system.

When it comes to picture quality assessment, the experts working in this field are able to identify certain impairments quite easily, and attribute them to certain parameters that can be measured with conventional test and measurement instruments.
Is the same true for the new digital signals as well? Not quite. The parameters with a strong influence on the picture quality as perceived by the viewer are normally the parameters set at the MPEG-2 encoder. The bit rate for the output video stream is obviously very important, so is the length of Group-of-Pictures (GOP length).
To assess the analogue picture quality, certain methods have been standardised over the last decades.
Over the last years the emphasis was put on an objective measurement of picture quality. Within the ITU, the Video Quality Experts Group (VQEG) is addressing this issue and is preparing for an extended test series of many algorithms.
As for any method that claims to measure picture quality, the comparison between the measurement values and the associated subjective assessment results are the ultimate test.
For the subjective assessment, there are today two methods of similar importance. The Double Stimulus Continuous Quality Scale method (DSCQS) as described in ITU-R Recommendation BT.500-7 is based on the presentation of a test sequence and the respective reference sequence (where the test person does not know in which order they are presented). The test sheet for the rating of both sequences is filled in after the presentation.
More recently, another method has gained a certain importance: the Single Stimulus Continuous Quality Evaluation method (SSCQE). With this method, only the test sequence is shown and the rating is given simultaneously by the test person. This method allows also for the assessment of longer sequences.
Any method for the measurement of picture quality aims at best correlation with the respective subjective assessment results.
One way is the development of a psycho-optical model of the human visual system.
Another approach takes a pragmatic look at the impairments which are normally visible in a MPEG-2 encoded and decoded signal and seeks to measure them.
Such an approach is described hereafter.

MEASUREMENT OF MPEG-2 ARTEFACTS

For a video sequence that has passed a MPEG-2 encoding/ decoding chain, the picture quality depends on several parameters. Very important is the bit rate to which the encoder had been set.

Nevertheless, the resulting picture quality depends even more strongly on the video material itself. Is it a sequence with much activity or is there rather little movement in the scene?
What all sequence that underwent the MPEG-2 process have in common, is the block structure that may be visible or not but is always present.

In a transmission system where the accessible interfaces between the various links of the chain are normally MPEG-2 Transport Stream interfaces, the most common parameter to measure for information on the quality of the transmission system is the bit error rate (BER). Although all DVB transmission system have been defined to perform quasi error-free data transmission under normal conditions, even low BER values may result in impairments which influence the perceived picture quality.
Examples are blocks which are overwritten with an additional DCT (Discrete Cosine Transformation) patterns, blocks which only contain a single DCT pattern, or shifted blocks.

THE SOLUTION OF THE PROBLEM

During a research project of the Technical University of Braunschweig and Rohde & Schwarz, it became apparent that the visual impression of the MPEG-2 inherent blocking structure has the greatest impact on the picture quality in an otherwise normal video stream.
To describe this effect, a parameter was defined, the Digital Video Quality Level (DVQL-W).

The Digital Video Quality Level is computed from vectors which contain information on the averaged differences between adjacent pixels (Fig. 1).

The MPEG-2 encoding process is based on blocks of 8x8 pixels and macro blocks of 16x16 pixels.
An analysis of the differences between all pairs of horizontally adjacent pixels shows a MPEG-2 specific characteristic.
Normally the differences between adjacent pixels are reduced by the encoding process. The exception are the pairs of pixels across the borders of blocks or macro blocks.

Figure 2 shows the result of the calculation of the average differences carried out on the original 'Flowergarden' sequence.

$$AD(i) = \begin{pmatrix} AD(i=0) \\ AD(i=1) \\ \cdot \\ AD(i=8) \\ \cdot \\ \cdot \\ AD(i=15) \end{pmatrix}$$

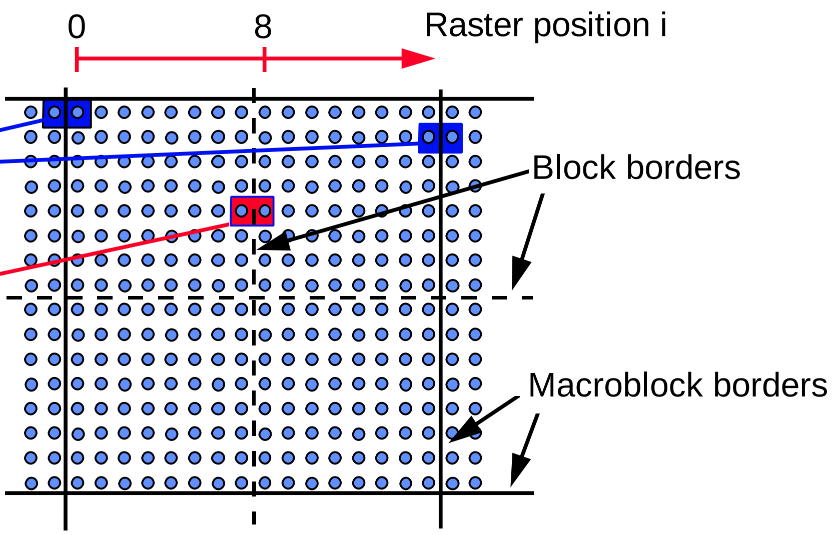

Figure 1: Evaluation of amplitude differences of adjacent pixels

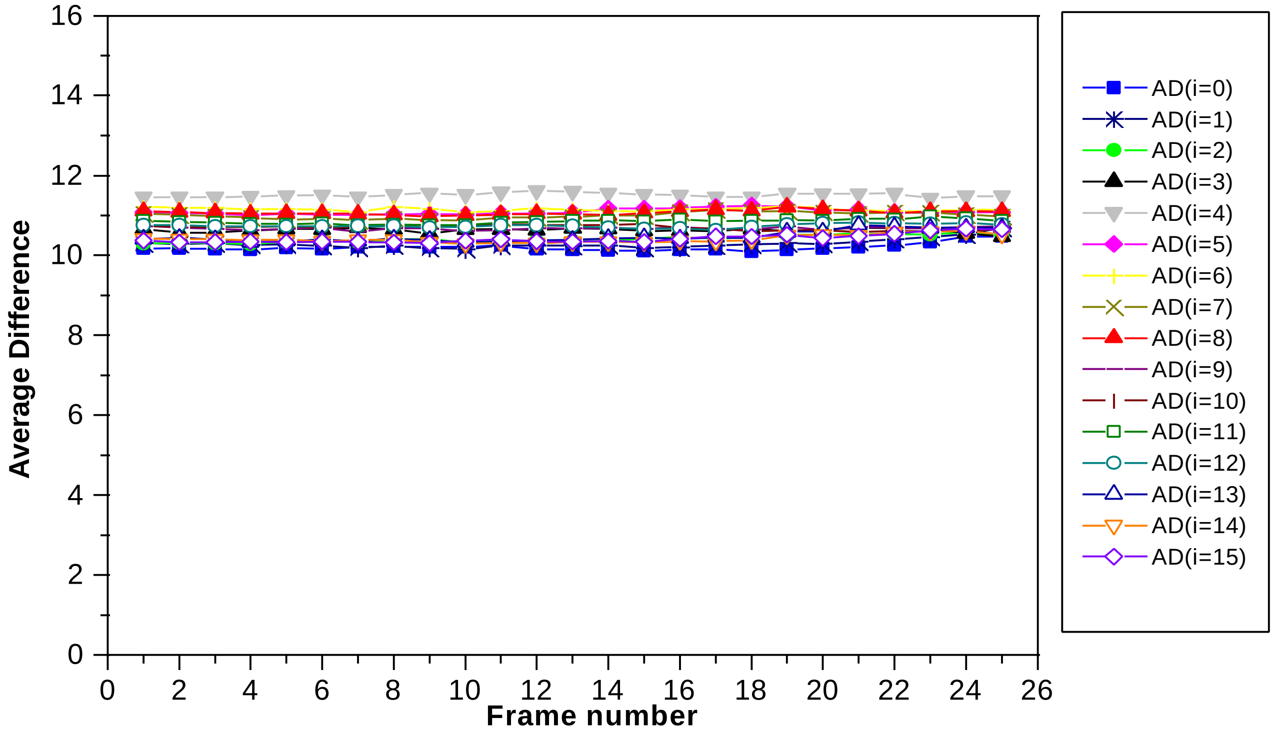

**Figure 2: Averaged pixel amplitude differences,
Example: Flowergarden (Original)**

The calculated values for all pairs of pixels (i. e. elements of the AD vector) are very close.

After encoding the same sequence with 2 Mb/s and subsequent decoding, the average differences show a particular pattern. (Figure 3)

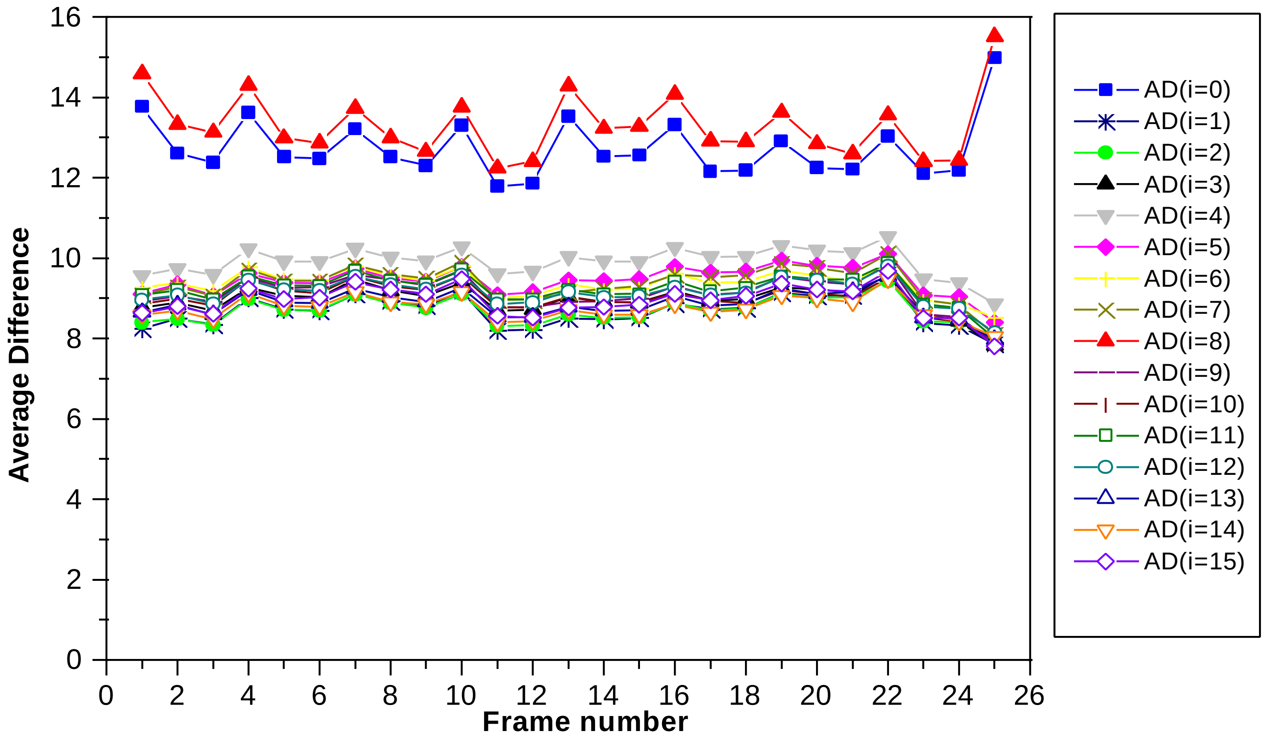

**Figure 3: Averaged pixel amplitude differences,
Example: Flowergarden (MPEG-2 coded/decoded with 2 Mb/s)**

In this diagram the values for the element AD(i=0) and AD(i=8) are enhanced. They characterise the influence of the blocking structure in a MPEG-2 decoded picture. The Digital Video Quality Level is calculated from these values.

Since the computation of the DVQL-W parameter is mainly based on DCT related effects, the same algorithm can be applied to other DCT-based compression systems.

As long as masking effects that may result from spatial activity and/ or temporal activity are not considered, the whole parameter is very sensitive to any blocking structure even far below the threshold of visibility.
In this sense it can be compared with the measurement of the signal-to noise ratio (S/N) as it is applied on analogue video signals.

If the appropriate masking is incorporated, the DVQL-W delivers the equivalent of the Mean Opinion Score (MOS) but as a predicted value.
With the masking included, the algorithm shows an excellent correlation with subjective assessment results (Figure 4).
These results were obtained by the Single Stimulus Continuous Quality Evaluation (SSCQE) method. The compiled test sequence is approximately 8 minutes long and consists of 11 well-known test sequences such as 'Flowergarden', 'Mobile & Calendar', 'Table tennis', etc. The data rates for the sequences varied between 1 MBit/s and 9 MBit/s.
From the subjective assessment about 1000 measurement values were obtained. Their scaling factor was re-based and a fixed delay of 1 second was introduced.
With this optimisation, an overall correlation of more than 94 % was achieved.

APPLICATIONS

Rohde & Schwarz is currently in the process of implementing the algorithm for the calculation of the Digital Video Quality Level on a platform that allows for the real-time computing of this parameter. For each frame the related value will be available.
An important feature of the applied algorithm is that it makes use of the decoded video stream only. It can therefore be carried out at each point in a network where an interface for the connection of a MPEG-2 decoder is available. These are in principle all Transport Stream interfaces.

Nevertheless will the instrument provide two inputs for video data streams in SDI (Serial Digital Interface) standard. The analysis on both input signals is done in parallel, so that a comparison between two signals is equally possible in real-time.

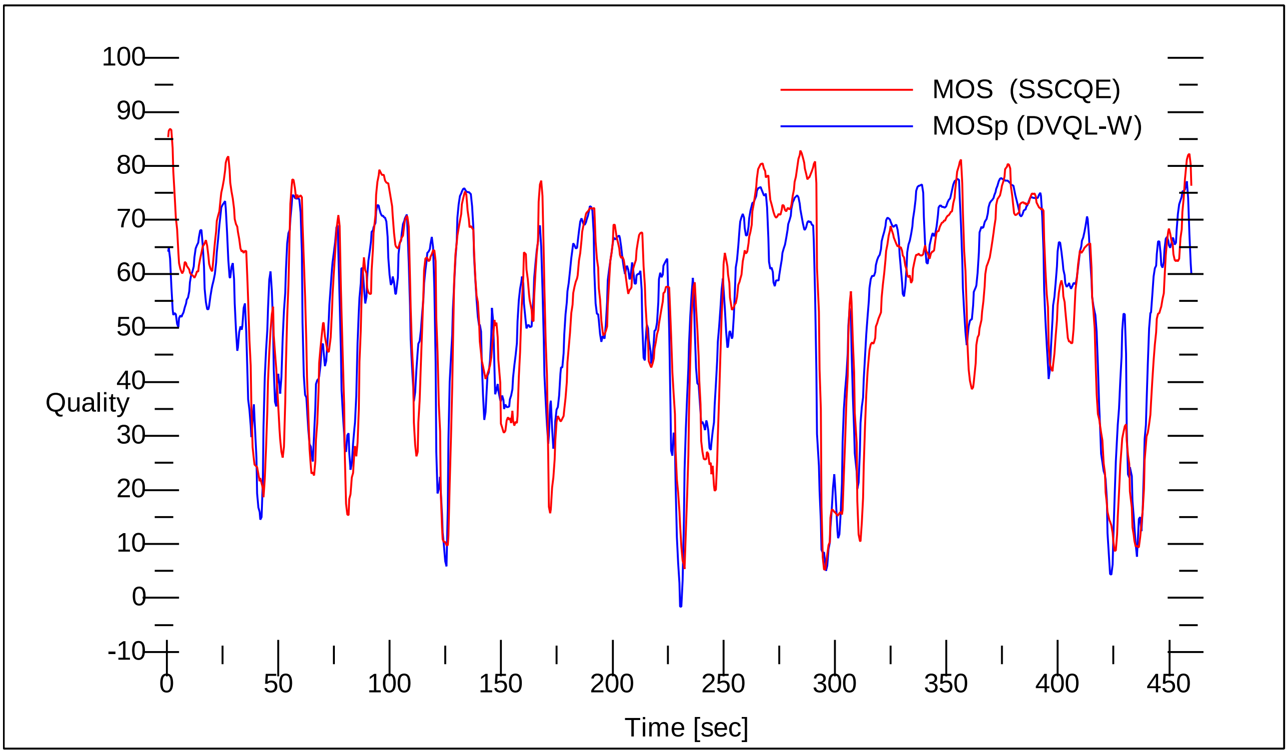

Figure 4: Comparison of subjective and objective picture quality

The same instrument will also provide additional information on the decoded video signal, such as 'Picture Freeze' and 'Picture Loss'.

In general, the instrument can determine the influence of the encoder and the influence of the transmission system on the picture quality.
If the transmission system does not produce any additional impairments, the measured picture quality at the output of the network should correspond to the picture quality at the input of the network.

An application that might be of interest for service providers and/ or network operators is the control of encoder parameters such as bit rate and GOP length by the DVQL-W parameter. The same seems to work for the adjustment of bit rates in a statistical multiplexer.

Set top box manufacturers may be interested in testing their products with impaired sequences. In such a case not only the decoders could be integrated in the tests but also the efficiency of any implemented concealment strategy could be verified.

Although the largest field of applications is foreseen in the environment of MP@ML applications, the inclusion of 4:2:2 and High Profile is a potential extension.

As soon as the computer based implementation has been transferred to a normal prototype, extended field tests are planned in the framework of the ACTS project MOSQUITO.

REFERENCES

Trauberg, M., 1998. Ein neues Verfahren für die Bildqualitätsüberwachung in MPEG-basierten Übertragungssystemen. Proceedings of 18. Jahrestagung FKTG 1998 Erfurt/ Germany.