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Estimation of Degraded Video Quality of Mobile H.264/AVC Video Streaming

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Introduction

Quality control of videos from the input (capture device) to the final output (display and its environment) presented to the human user is essential for video applications and services. Peak signal to noise ratio (PSNR) and other similar measures long time have been the most popular quality criteria used by engineers and researchers to evaluate and optimize the performances of digital video processing schemes [1, 2]. Over the two past decades, objective video quality estimation methods have been extensively studied, and many criteria have been designed [3-5].

Depending on the application considered and the type of information accessible, video quality estimation methods can be classified into three types: full reference metrics, reduced reference metrics, and no reference metrics. Various groups, including the Video Quality Experts Group (VQEG), now consider all these types of visual quality metric for standardization.

The full reference video quality metrics are quite well analyzed and understood. A lot of such metrics were developed based from the simplest pixel-based metrics to the more sophisticated system-specific metrics. In no reference quality estimation essentially there are two ways of measuring the video quality. The first approach is based on detection of typical artifacts introduced by respective systems. However, because of application of adaptive deblocking filter in H.264/AVC encoder and decoder, such artifact detection is highly complicated or even impossible (Slanina and Ričny, 2008). The second approach is based on examination of the encoded video bit stream and finding its parameters related to the actual video quality [6, 7].

However, there still is a need for more efficient and generic video quality estimation algorithms that are more robust to the video content and the different types of impairments introduced by the degrading systems, have good correlation to human visual quality judgment, and at the same time, simple-to-compute (for implementing in handled devices).

Here we introduce the streaming video quality estimation technique that is targeted to mobile applications and is based on H.264/AVC video bit stream structure, i.e., loss or presence of sequences of I and P frames.

Mobile Video Streaming

Mobile video streaming is characterized by low bit rates and low resolutions. The commonly used resolutions are Quarter Common Intermediate Format (QCIF, 176×144 pixels) for cell phones, Common Intermediate Format (CIF, 352×288 pixels) and Standard Interchange Format (SIF or QVGA, 320×240 pixels) for data-cards and palmtops. The mandatory codec for UMTS (Universal Mobile Telecommunications System) streaming applications is H.263 but the 3GPP release 6 [8] already supports a baseline profile of the new H.264/AVC codec (ITU-T Rec. H.264) [9]. Due to video compression improvement of the newest video coding standard H.264/AVC, video streaming for low bit and frame rates is allowed while preserving its perceptual quality. This is especially suitable for video applications in 3G wireless networks.

The H.264/AVC is based on conventional block-based motion-compensated video coding, but has several new features that significantly improve rate-distortion performance over prior standard such as MPEG-2, MPEG-4 and H.263 [1]. Also special attention is given to the improvement of robustness to data errors or losses that appear during video transmission through different networks. The standard defines a network abstraction level (NAL) that maps H.264/AVC video coding layer (VCL) data to different transport layers.

The H.264/AVC standard has eleven profiles and sixteen levels. The profile specifies encoding algorithms and the level presents bit-rate constraints on parameter values and thus restricts computational complexity [10].

In general, mobile digital video transmission systems consist of a video encoder, a digital transmission method (e.g., Internet Protocol—IP), and a video decoder. The H.264/AVC encoder produces a sequence of compressed video frames named slices. The standard defines five slice types: I-slice (intra coded), P-slice (predictive coded), B-slice (bidirectionally predictive coded), SI and SP (switching slices), allowing an encoder to direct a decoder to jump into an ongoing video stream for such purposes as video streaming bit rate switching and “trick mode” operation (ITU-T Rec. H.264). In such situation the transmission impairments usually result in dropped or repeated video frames (slices) that causes the decoder to produce pauses in the video clip. There are two primary reasons for this behavior. The first reason is that the video encoder may decide to reduce the video frame transmission rate in order to save bits. For example, an original video stream with a frame rate of 30 frames per second (fps) may be reduced to 15 fps by dropping every other video frame. The second reason is that the video decoder may decide to freeze the last good video frame when errors such as IP packet loss are detected. This is a simple error concealment algorithm that is used by many video decoders (Wolf, 2009).

In this article we will focus on H.264/AVC baseline profile that was approved by 3GPP and it is designed for lower-cost applications with limited computing resources such as wireless applications, video telephony and video conferencing.

Bit streams conforming to the baseline profile generally shall obey the following constraints: only I and P frame (slice) types may be present, NAL unit streams shall not contain type values in the range of 2 to 4, inclusive, and max bit rates are 64 kbps (level 1), 128 kbps (level 1b), 192 kbps (level 1.1), 384 kbps (level 1.2) and 768 kbps (level 1.3).

Video Quality Measuring Technique

Objective video quality estimation metrics for measuring digital video performance are required by Government and industry for specification of system performance requirements, comparison of competing service offerings, service level agreements, network maintenance, optimization of the use of limited network resources, etc. To be accurate, digital video quality measurements must be based on the perceived quality of the actual video being received by the users of the digital video system rather than the measured quality of traditional video test signals (e.g., color bar). This is because the performance of digital video systems is variable and depends upon the dynamic characteristics of both the original video (e.g., spatial detail, motion) and the digital transmission system (e.g., bit-rate, error rate).

The VQM is a standardized reduced reference method of objectively measuring video quality that closely predicts the subjective quality ratings that would be obtained from a panel of human viewers. The technology is covered by four U.S. patents owned by NTIA/ITS. End-users and service providers can utilize VQM tools to specify/verify system performance, compare competing service offerings, maintain and monitor the quality of their networks, and optimize the use of limited network resources such as bit-rate. Due to its excellent performance in the International Video Quality Expert’s Group (VQEG) Phase II validation tests, the NTIA/ITS VQM methods were adopted by the ANSI as a U.S. national standard (ANSI T1.801.03-2003), and as international ITU Recommendations (ITU-T J.144, and ITU-R BT.1683, both adopted in 2004).

The process to compute VQM include sampling of the original and processed video streams, calibration of the original and processed video streams, extraction of perception-based features, computation of video quality parameters, and calculation of VQM models. VQM tracks the perceptual changes in quality due to distortions in any component of the digital video transmission system (e.g., encoder, errors in digital channel, decoder). The output of such process is video quality estimate in common subjective quality scale, where “0” represents no perceived impairment and “1” represents maximum impairment. With the subjective mapping procedure used, occasional excursions less than 0 (zero) (quality improvements) and more than 1 are allowed [11].

Experimental Results

In our experiments we performed several objective video quality tests using VQM algorithm of a H.264/AVC decoder performance in a case of dropped I and P encoded video frames (slices). The tested codec were obtained from x264 a free software library for encoding video streams into the H.264/MPEG-4 AVC format. It is released under the terms of the GNU General Public License. The codec was setup to operate in the baseline profile level 1.3.

Three progressive video sequences in the raw format YUV 4:2:0 have been coded in our experiment. We have used the sequences Foreman (talking head, with pan to construction site, geometric shapes, shaking camera), Hall-monitor (an example of video supervision, stationary camera, two moving persons) and Mobile (a lot of small moving objects) all in CIF and QCIF resolutions with 25 fps and with total of 300 frames. These sequences have been coded at three different coding rates: 64, 128 and 192 kb/s. The chose of sequences was based on their very distinct content.

As we already motioned, after packet loss of P or I frame (slice) in the H.264/AVC video stream decoded video freezes and playback is resumed only after successful decoding of next I frame. During our experiment we observed the influence of lost frame type (P or I) and its place in video stream on quality of decoded video. The quality was estimated using VQM algorithm. A place of loss frame – a number of P frames until next successful I frame.

In all experiments we used video clips with duration of 10 seconds (300 frames) as VQM algorithm estimates quality of video sequences of duration 10–12 seconds. During these 10 s coded video stream contains only three I frames, so we can loose only one or two consequent I frames and at most two series of P frames, by one in each block between two I frame. Thus quality of one video clip was estimated two times after loss of P and one I frames, and once after loss of two I frames.

The Figs. 1 and 2 shows VQM quality estimates (each data point is an average from two estimates when P or one I frame is lost) for three types of video clips of two different resolutions – QCIF and CIF, respectively. In each figure is shown quality characteristics of all three types of video clips encoded at three different bit-rates (represented by line of same type) – nine curves, totally.

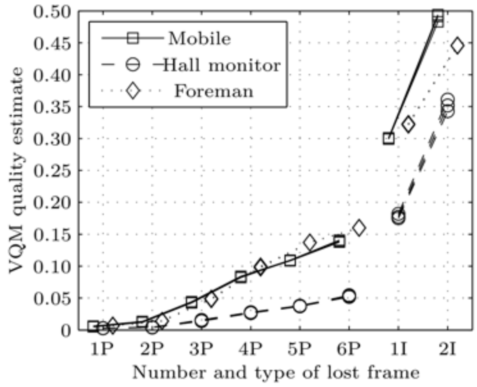

Fig. 1. VQM quality estimates for three types of video clips of QCIF resolution

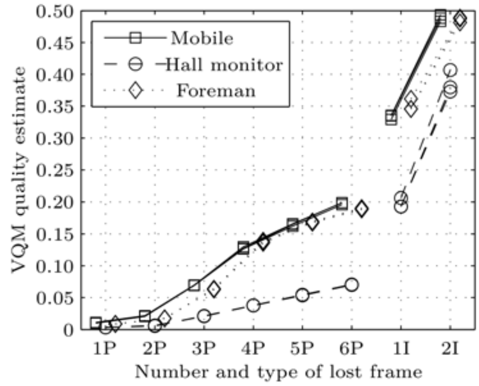

Fig. 2. VQM quality estimates for three types of video clips of CIF resolution

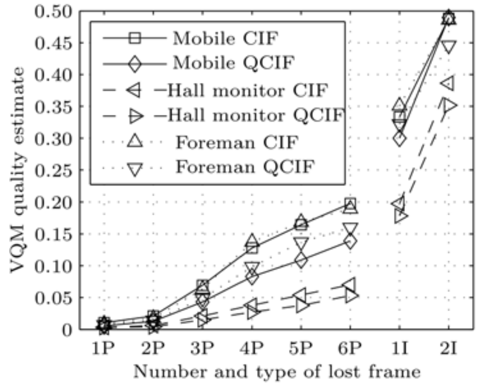

Fig. 3. Average VQM quality estimates

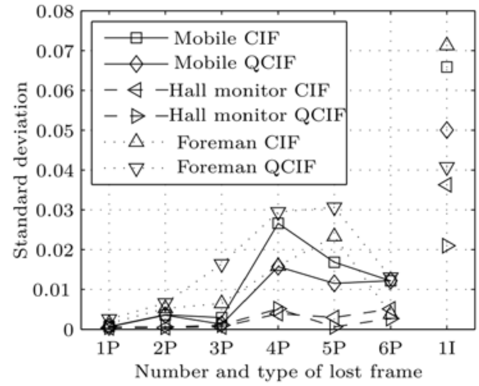

Fig. 4. Standard deviation of VQM quality estimates

As expected, main influence on video quality has loss of I frames (bigger VQM estimates means greater distortions). The losses of P frames also have influence on quality. Quality decreases when distance of lost P frame until next successful I frame increases. Also, it can be seen that the bit-rate does not affect the quality of video under frame loss. All lines of same type are very close. The quality is more affected by video content and less by resolution.

In order to determine character of curves of video quality dependency on place of P and I frame loss, we averaged quality estimates at different bit-rates of same content type and resolution video clips. Obtained results are shown in Fig. 3. As it can be seen quality curves have linear character and quality of higher resolution video is more influenced by frame loss.

So, basing on experimental results, it is possible to predict the quality of video clip of known content using only parameters that can be easily obtained from coded video stream: resolution, place and type of lost frame. However, it should be mentioned, that increasing distance (indicated by number before frame type in all Figs.) of lost P frame until next successful I frame in general increases dispersion of individual quality estimates as shown in Fig. 4 (standard deviation for case of 2I frame loss does not calculated, because of too small amount of data points—one estimate for each video clip) and liner character of quality curves must be taken into account very carefully.

Conclusions

1. Quality of degraded video does not depend on bit-rate of coded video stream. It is very likely result, because of determining quality using VQM algorithm we compared two video clips (reference and degraded) of same bit-rate. Such approach let us determine only influence of frame loss but not effectiveness of H.264/AVC coding at different bit-rates.
2. Video quality depends on video resolution. Increased distance of lost P frame until next successful I frame less degrade video of lower resolution.
3. Average dependence of video quality on place of lost P frame is almost linear. However, increasing distance of lost P frame until successful I frame increases dispersion of individual quality estimates.
4. Video quality also depends on content of video clip. Less influence to video quality under frame loss have video clips with static background and small amount of moving objects.

Obtained experimental results let assume that it is possible to construct method to predict the quality (with some probability) of video clip of known content using only parameters that can be easily obtained from coded video stream: resolution, place and type of lost frame.

Acknowledgements

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The problem of estimation of subjective video quality of distorted video sequences for mobile video streaming is addressed. Widely spreading mobile communication systems and increasing data transmission rates expand variety of multimedia services. One of such services is video straming. So it is important to asses quality of this service. Consumers of video streaming are humans, and quality assessment must account human perception characteristics. Most of the well-known video quality estimation methods, such as Peak Signal to Noise Ratio (PSNR), Structural Similarity (SSIM), Video Quality Metric (VQM), etc. are based on the presence of full or reduced reference video sequence. However, in order to estimate user experienced video quality, methods with no reference must be employed. Such existing methods as quality metrics usually use bit-error rate that has low correlation with by human perceived video quality. More advanced methods usually require too much processing power that cannot be obtained in handled mobile devices. It is shown that video quality estimation method with no reference and low computation complexity could be developed basing on H.264/AVC video stream structure. Such method is suitable for implementation in mobile devices with low processing power. Ill. 4, bibl. 11 (in English; summaries in English, Russian and Lithuanian).

Ш. Пауликас. Оценка качество искаженного видео изображения в мобильной H.264/AVC видео трансляции // Электроника и электротехника. – Каунас: Технология, 2010. – № 2(98). – С. 49–52.

Рассматривается проблема оценки субъективного качества искаженного изображения в мобильной H.264/AVC видео трансляции. Широкое распространение систем мобильной связи и увеличение скорости передачи данных расширяет различные мультимедийные услуги. Одной из таких услуг является видео трансляция. Поэтому важно оценить качество этой услуги. Потребители услуги видео трансляции являются люди, поэтому оценка качества должна учитывать характер человеческого восприятия изображения. Большинство известных методов для оценки качества видео изображения, такие, как пиковое отношение сигнала к шуму (PSNR), структурное сходство (ДНЮС), метрика видео качества (VQM) и т.д., основанны на наличии полного или частичного видео оригинала. Однако, в целях оценки качества изображения полученного пользователем, названные методы обычно требуют слишком много вычислительной мощности, которая не может быть получена в мобильных устройствах. Показано, что методы оценки качества изображения ненуждающиеся в наличии полного или частичного видео оригинала и имеющие низкую сложность вычислений могут быть разработаны на основе структуры H.264/AVC видео потока. Такой метод является подходящим для осуществления в мобильных устройствах с низким энергопотреблением. Ил. 4, библ. 11 (на английском языке; рефераты на английском, русском и литовском яз.).

Š. Paulikas. Sugadinto vaizdo kokybės vertinimas mobiliajame H.264/AVC vaizdo transliavime // Elektronika ir Elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 2(98). – P. 49–52.

Nagrinėjama vaizdo kokybės vertinimo mobiliajame H.264/AVC vaizdo transliavime problema. Plintant mobiliojo ryšio sistemoms bei didėjant duomenų perdavimo spartai, daugėja ir multimedijos kategorijos paslaugų pasiūla. Viena iš tokių paslaugų yra vaizdo transliavimas. Taigi tampa aktualu įvertinti šios paslaugos kokybę. Vaizdo perdavimo paslaugos vartotojai yra žmonės, todėl kokybės vertinimas turi būti atliekamas atsižvelgiant į žmogaus suvokiamą vaizdo kokybę. Dauguma taikomų metodų yra paremti perduoto (sugadinto) vaizdo palyginimu su originaliu vaizdu. Tačiau siekiant įvertinti vartotojo patirtą vaizdo kokybę minėti metodai nėra tinkami, nes originalaus vaizdo nėra arba jo gavimas yra per brangus. Parodoma, kad vartotojo patirtą subjektyvią vaizdo kokybę galima susieti su skaitmeninio vaizdo srauto parametrais – vieno ar kelių tam tikro tipo (I ar/ir P) kadrų praradimu. Tai įgalina sukurti nesudėtingą skaičiavimo požiūriu vaizdo kokybės vertinimo metodą tinkantį įgyvendinti mobiliuose įrenginiuose, kurie turi ribotus apdorojimo pajėgumus. Ill. 4, bibl. 11 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).