



Quality impact of video format and scaling in the context of IPTV.

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Abstract

In this paper we investigate the influence of the video format and of re-scaling on the perceived video quality in the context of IPTV. Addressed resolutions are typical of IPTV: Standard Definition (SD, 720 x 576 pixels) and High Definition (HD, 1920x1080 pixels). Re-scaling comprises SD to HD (4:3, 1350x1080) upscaling and cropping from HD 16:9 (1920x1080) to HD 4:3 (1350x1080) format. In parallel, we analyze the influence of IPTV typical degradations (compression, loss-induced slicing and freezing) on the quality-impact of video format and re-scaling. In addition, we investigate the possibility of modelling the effect of up-scaling on quality and of having one video quality model for both SD and HD by including video format related parameters as additional inputs to the model. A further analysis is provided for discussing the choice of the employed subjective test design. Results show that the quality impact of video format and of re-scaling depends on the amount and type of degradations.

Index Terms: video, quality, perception, format, resolution, picture size, scaling, IPTV, compression, packet-loss.

1. Introduction

SD and HD video formats are both used in IP-based TeleVision (IPTV). It is thus interesting to investigate the quality impact due to the video format. In particular, we want to know which video format is better perceived in terms of quality for a given bitrate. Moreover, since today's consumer displays typically upscale the SD video to HD, it is interesting to know if an SD video re-scaled to HD, and thus more blurry but with a bigger size, yields better perceived quality than a non re-scaled and thus smaller SD video. At last, since several degradation types can occur when transmitting video over IP, we investigate the influence of IPTV typical degradations on the quality-impact of video format and re-scaling. Indeed, the visibility of some degradations might decrease when reducing the video format while other degradations are similarly visible independently of the video format. Those IPTV typical degradations are compression, packet loss yielding either slicing¹ or freezing².

With the emergence of wider screens, several studies have been conducted in the 90's on the influence of video-format-related parameters on the perceived quality. Knoche et al. give in [1] a broad overview of the previous researches conducted on image size, resolution and viewing distance user preferences.

¹a slice typically corresponds to a certain area of the image that – if affected by loss – the decoder fills with data from the same, previous or following video frame. The decoder can resynchronize based on the next available slice header.

²in case of packet loss, the picture freezes until the next intact I-frame arrives; the frames in between are skipped in the considered IPTV case.

They also provide us with recommendations on size and resolution for mobile TV applications – thus small screen sizes – and compare results obtain in labs and real environment. Some of the previous studies present in addition models of the perceived quality as a function of video-format-related parameters. For instance, Westerink et al. analyze in [2] which measure is the most appropriate for describing the subjective quality sensation. Among a large number of observations, they note that the angular resolution (in periods per degree) and the picture angle (the arctan of the ratio of picture width and viewing distance) influence the perceived quality independently. More precisely, the perceived quality is expressed as a linear function of the logarithm of the picture angle plus a third-order function of the logarithm of the angular resolution. In [3], Barten follows a different modelling approach but uses similar parameters as Westerink et al. for describing the effect of picture size and resolution on perceived quality: the angular spatial frequency at the eye of the observer (in cycles per degree) and, for low spatial frequency, the angular display size (in degrees). The author includes the display luminance as additional information. Those parameters are used for computing the Contrast Sensitivity Function (CSF). Then, by integrating the square-root of the CSF, the authors obtain an expression which is linearly correlated with the perceived image quality.

Those studies are highly relevant for finding the optimal viewing distance for a given number of pixels to be displayed at a given display size. Note that those results have been obtained without the presence of degradations. In our case, the viewing distance is calculated from the displayed picture size and is optimal for each video format. The viewing distance and picture size are thus fixed during the whole test for each video format. The objective of our study is then to assess whether, for an optimal viewing distance, the picture size impacts the perceived quality, and if this influence depends on a given degradation type.

This is in line with the work conducted by Pinson et al. in [4], by Péchard et al. in [5] and by Bae et al. in [6]. In [4], the authors compare the quality of 720x486 video on a 20" professional CRT to the quality of CIF video on a 5.5" LCD. The video sequences cover a wide range of quality and degradation types. Separate tests were conducted for each display. No significant difference is found between the quality ratings for each display, except for one impairment which barely occur in real application. In [5], the authors compare on the same professional CRT screen HD video (1080i) with half-band filtered HD (960x540, close to real '16/9' SDTV 1024x576), for different bitrates. Results show that distortions as well as a larger image influence the observer's preference, but that distortions are the predominant factor when HDTV sequences are compared with low quality SDTV. At last, in the case of high quality SDTV, the image-size effect becomes more important, showing that image

size is a visual comfort factor; it becomes a drawback when the level of distortions increases. In [6], Bae et al. present a trade-off between the spatial resolution and the visibility of compression artefacts on still images encoded by JPEG and JPEG2000, concluding that for obtaining higher spatial resolution, users are willing to accept some visible (encoding) distortion, the amount of acceptable distortion increasing as the spatial resolution decreases. In our study, we go one step further by taking into account the quality impact of up-scaling and the influence of other types of degradations, such as error-transmission, on the quality impact of the video format.

This study is part of a larger work in which we have developed a parametric video quality model for IPTV [7, 8]. So far, the models – one for SD, one for HD – take as input parameters such as video bitrates and packet-loss-rates. Those parameters yield typical IPTV degradations occurring during the encoding, transmission and decoding of the video sequences. The current study extends the previous work by taking into consideration other factors such as image-size, resolution and scaling. We also investigate the possibility of modelling the quality impact of up-scaling and of having one video quality model for both SD and HD by including video format related parameters as inputs of the model. In [9], the authors also include a display-format related parameter into a parametric packet-layer video quality model for video-telephony applications. However, their modelling is based on quality ratings coming from subjective tests in which display formats have not been merged. For reflecting a “context-effect” [10] more appropriate to our case, we have merged all video formats in one subjective test.

This subjective test will be described in Section 2. One test using SD video sequences only and another test using HD video sequences only will also be described. The results of those two latter tests will be used for illustrating the “context effect” and the need of merging video formats in a single test in order to model the quality impact of the video format. In Section 3, we will analyze the results and will describe several modelling aspects.

2. Experimental Design

In order to investigate the quality impact of the video format and of scaling, a perception test (Test 1) was conducted using a mix of non-re-scaled SD videos (*sdn*, 720x576), SD re-scaled to HD videos (*sdr*, 1350x1080), HD (1920x1080, ratio 16:9) cropped to the same ratio as SD (*hdc*, 1350x1080, ratio 4:3) and non-re-scaled HD videos (*hdn*, 1920x1080). The different formats are shown in Figure 1. All video sequences were displayed on the same native 1920x1080 professional display (42” Barco LCD screen LCN-42). For video sequences smaller than 1920x1080 pixels, a black frame was added around the picture. The same five video contents were used for all resolutions. They are representative of various TV-programs: Movie trailer, Interview, Soccer, Movie and Music video. Typical IPTV degradations were applied on the five uncompressed un-degraded native SD and HD video sequences, resulting in 13 test conditions as described in Table 1. Degradations cover H.264 encoding, packet loss with freezing or slicing, resulting in sequences characterized by various perceptual dimensions. Up-scaling and cropping were applied on the processed video sequences using the Lanczos3 filter [11]. As a consequence, a given video sequence in *sdn*, *sdr* and *hdc* formats contains exactly the same content – *sdr* and *hdc* have in addition the same resolution – while a given video in *hdn* format contains a slightly different content since its “aspect-ratio” differs from the other formats.

Cropped-HD video sequences have been introduced in the test for studying the effect of the “aspect-ratio” – and thus slightly different content – between SD and native-HD. Indeed, if the quality ratings differ between re-scaled-SD and native-HD, we don’t know if this difference is due to the aspect-ratio or to the degradations the videos contain. By introducing cropped-HD as comparison point, cropped-HD having the same aspect ratio as re-scaled-SD but containing the same degradations as native-HD, we can separate the two effects.

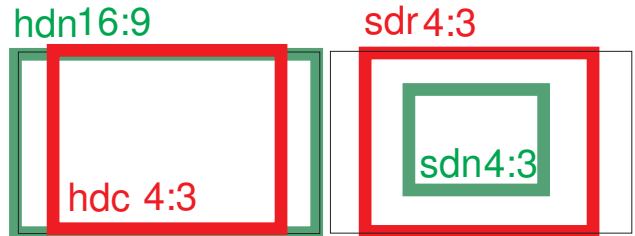


Figure 1: *hdn*, *hdc*, *sdn* and *sdr* format.

Viewing conditions were compliant to ITU-R Recommendation BT.500-11 and ITU-R BT.710. For SD, the subjects were located at six times the picture height, and for HD, at three times the picture height, yielding the same viewing distance and allowing the subjects to stay at the same location during the whole test. A professional high performance system (DVS ProntoHD) were used for playing-back the video sequences. An absolute category rating using the continuous 11-point quality scale recommended in ITU-T Recommendation P.910 was employed for collecting subjective quality judgements. 24 subjects participated in the test.

In order to develop a quality model, one additional set of subjective tests was conducted for each SD-only video and HD-only video. For each resolution (SD and HD), the second test set (Test 2) included the same conditions as Test 1 (see Table 1) and used the same video contents. 24 subjects participated in each test, and each subject was allowed to participate in one test only.

Test 1 (<i>sdn</i> & <i>hdc</i>) & Test 2	Test 1 (<i>sdr</i> & <i>hdc</i>)
uncompressed	
H.264, 5 bitrates	H.264, 3 bitrates
freezing:	freezing:
3 plr (low to high)	2 plr (medium & high)
slicing:	slicing:
3 plr (low to high)	2 plr (medium & high)

Table 1: Test conditions for all tests. plr: uniform packet-loss rate applied to the high bitrate coded video; bitrates for HD are 4 times the bitrates for SD; *sdn*: native SD, *hdn*: native HD, *sdr*: re-scaled SD, *hdc*: cropped HD.

3. Data Analysis

For all tests, subjective ratings are averaged over all subjects and contents, i.e. considered per condition.

The video format includes several aspects: the “aspect-ratio”, the picture size and the combination bitrate-resolution. The picture size refers to the dimensions of the picture, i.e. how big the picture is, independently of the number of bytes required

for coding the picture. In the following, the resolution designates the number of pixels per frame. The combination bitrate-resolution is a consequence of the picture size: bigger picture size, and thus higher resolution, requires more bytes per frame, thus higher bitrate, than small picture size for achieving equivalent perceived quality. The distinction between those two latter aspects is important since they have a different quality impact. For instance, native-HD has a bigger picture size than native-SD. Its bigger picture size might compensate for the quality impact of the degradation. Its higher resolution requires higher bitrate for achieving high quality. As a consequence, higher bitrates are usually selected for HD. However, a higher bitrate – and thus a higher number of bytes per frame – increases the probability of having a frame hit by uniform loss, as shown in equation (1),

$$pf = 1 - (1 - p)^{N_{ppf}} \quad (1)$$

where N_{ppf} is the number of packets per frame and pf is the probability of hitting a frame. The higher the number of packets per frame (N_{ppf}), the higher the overall probability of hitting the frame. In particular, the probability of having loss in a reference frame (I- or P-frame) is increased, leading to longer loss duration, since losses in a reference frame are propagated to other frames. However, since there are less bytes per frame in the case of SD, one lost packet yields wider spatial extent of the loss, and thus more visible loss. All those aspects impact the perceived quality and need to be taken into account when studying the quality impact of the video format.

3.1. Analysis of test design

In this section, we compare test results obtained in Test 1 (Figure 2(a)), in which video formats (*sdn* and *hdn*) are merged in one test, with Test 2 (Figure 2(b)), in which independent tests are conducted per video format. We observe a shift of the intersection point (red X) between the SD curve and the HD curve. Indeed, the bitrate at which HD yields equal quality as SD is almost three times higher in Test 2 than in Test 1, as it is apparent from the comparison of Figures 2(b) and (a). This difference can be explained by the “context effect” [10] present in all subjective tests. It includes the “corpus effect”, which refers to the rating-impact of the range of degradations used in the test. In other terms, the SD pictures might be rated lower in a corpus including high-quality HD pictures than in a corpus with only SD pictures. As a consequence, if the objective of the study is to compare the influence of the video format, it is more appropriate to merge the various video formats in the same test.

In the following, we analyze only the subjective ratings of Test 1.

3.2. Cropping vs. degradation type

As mentioned earlier, *hdc* format has been introduced in the test for analyzing the effect of the “aspect-ratio” between *hdn* and the other formats. As shown in Figures 3,4 and 5, the difference between the quality ratings of *hdc* and *hdn* is minor, especially compared to the quality impact of the degradation and to the difference with the quality ratings of the remaining formats *sdn* and *sdr*. Surprisingly, *hdc* obtains slightly better ratings than *hdn* in the case of slicing. A possible explanation for this difference is that HD sequences were cropped after transmission, thus potentially removing lossy parts. However, this difference of ratings remain minor. As a consequence, we will consider in the following the effect of “aspect-ratio” as negligible. Note

that, considering the processing tools available at the time the tests were run, cropping the video sequences before transmission would have prevented us from removing lossy parts but would have conducted to different spatial and temporal location of the losses between *hdn* and *hdc*, making the comparison between *hdn* and *hdc* difficult to interpret.

3.3. Video format vs. degradation type

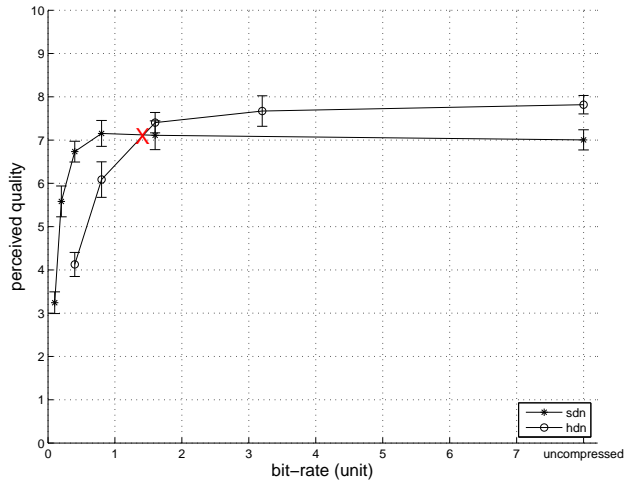
As mentioned in the previous section, in the absence of packet-loss, *sdn* yield better quality than *hdn* up to a certain (medium) bitrate (B). From this bitrate, *hdn* yields better perceived quality. In other words, the combination bitrate-resolution dominates over the picture size up to the bitrate B , since *hdn* requires more bytes per frame than *sdn* for achieving similar quality, then the picture size dominates.

We want to check if this conclusion is still valid with other degradation types, such as slicing and freezing. We expect different results due to the nature of the degradations: in case of compression artefacts due to low bitrates, the degradation is spread over the whole picture and the whole sequence. The degradation is not totally uniform since the artefacts might be more visible in some parts of the pictures due to higher spatial and temporal complexities. In the case of slicing, the degradation is more spatially localized and shows a more expressed temporal dynamic. The size of the degradation depends on how many slices have been hit by the causing packet loss. In the case of freezing, the picture itself is not degraded but repeated till the next error-free I-frame has been received. The degradation is thus temporal.

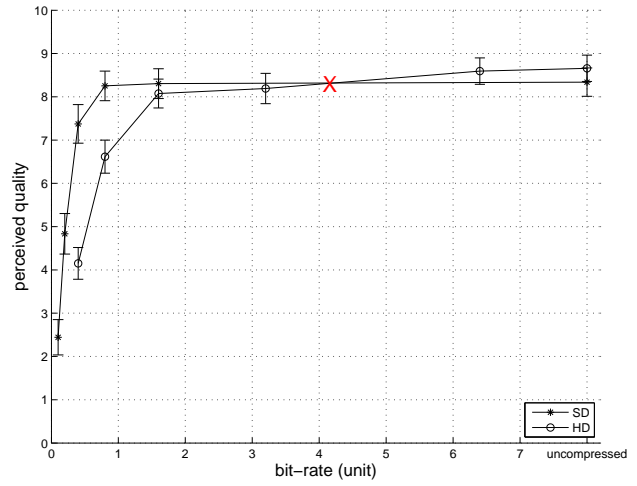
As shown in Figure 3, in the case of packet-loss with slicing, *sdn* and *sdr* yield slightly better perceived quality than *hdn* and *hdc*, especially at low packet-loss-rates. As previously mentioned, due to a higher bitrate (bitrate for HD is four times the bitrate for SD), packet-loss yields more distortions in the case of HD than in the case of SD, and a bigger picture size does not compensate for this effect. At higher bitrate, qualities tend to be the same for all video formats, the distortions being probably high, and thus the quality low in all cases. Those results show that the combination bitrate-resolution influences the amount of degradation which is the dominant factor impacting quality. Picture size does not seem to impact the quality in the case of slicing.

Further parameters such as the spatial extent and loss duration of the loss are necessary for providing an insight into the actual impact due to the loss and thus a better understanding of the results. As previously mentioned, since there are less bytes per frame in the case of SD, one lost packet yields wider spatial extent of the loss, and thus more visible loss, which is in contradictory with the results since SD yield better quality than HD. However, since HD video frames contain more bytes than SD video frames, this increases the probability of having a frame hit by a loss, including reference frame, and thus yields longer loss duration. This might balanced and even be dominant over the spatial extent of the loss, which would be in agreement with the obtained results. We have not checked this hypothesis in the case of slicing.

We obtain different results in the case of packet-loss with freezing. Instead of depicting quality as a function of the loss rate, we here chose to use the overall freezing duration as the independent variable. This balances out the probabilistic effect of hitting a certain frame and thus causing a freezing event. As shown in Figure 4, for low packet-loss-rates – and in this case low loss duration – *hdn* and *hdc* obtained higher ratings than



(a) One single test with mixed video formats.



(b) One video format per test

Figure 2: One video format per test (1 SD, 1 HD) vs. single test with mixed SD (*sdn*) and HD (*hdn*) video formats.

sdn and *sdr*. Thus, when loss duration are short, the picture size still seems to have a positive effect on the quality ratings. We assume that in the case of *sdr*, the base quality of *sdr* was too low due to up-scaling and canceled the positive effect of picture size.

3.4. Upscaling vs. degradation type

We can observe in Figures 3, 4 and 5 that for all degradation types *sdn* yields better quality than *sdr*, indicating that in the case of laboratory tests, subjects do not seem to pay attention to the size of the picture, but rather to the impairment within the visible area. This observation needs to be made with caution, since in a home environment, people might still prefer to have a lower quality upscaled picture than a smaller picture with better quality that does not fill the whole screen.

As shown in Figures 3 and 4, the difference between the quality ratings for *sdn* and for *sdr* is minor in case of packet-loss. This means either that picture size is compensating for the degradation induced by up-scaling, or that the effect of both picture size and up-scaling is negligible compared to the quality impact due to packet loss, the latter being more probable.

As shown in Figure 5, quality ratings for *sdr* significantly differ from those of *sdn* in the absence of packet-loss. Indeed, *sdr* yield better quality than *hdn* only up to half the bitrate up to which *sdn* does. As a consequence, up-scaling has a significant negative effect on quality in the absence of packet-loss. This negative effect is not compensated by the bigger picture size of *sdr*.

Note that, to our knowledge, Lanczos3 is the best freely available filter for resizing videos [11]. Lower perceived quality should thus be achieved by up-scaling the video sequences with other (freely available) algorithms than Lanczos3. As a consequence, we expect the conclusions drawn above – or at least the tendencies they describe – to be still valid even with other up-scaling algorithms.

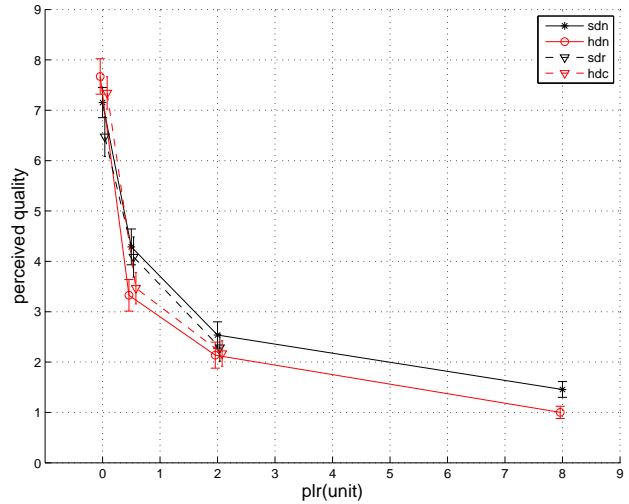


Figure 3: Perceived quality as a function of the packet-loss-rate (*plr*) for slicing degradation. *sdn*: native SD; *hdn*: native HD; *sdr*: SD res-caled to HD; *hdc*: HD cropped.

4. Modelling

It is assumed that the perceptual impairments linked with certain kinds of degradations may be considered as additive on an appropriate rating scale, such as the 100-point model scale (R) used in ITU-T Rec. G.107. As a consequence, in the following, the results (quality ratings averaged per condition) are transformed to the R -scale using the conversion also defined in ITU-T Rec. G.107.

The basic formula of the parametric packet-layer video quality model presented in [7, 8] is shown in equation (2):

$$Q_V = Q_{OV} - I_{cod_V} - I_{trav_V} \quad (2)$$

where Q_V is the predicted video-quality and Q_{OV} is the base quality level the transmitted video signal can reach for the

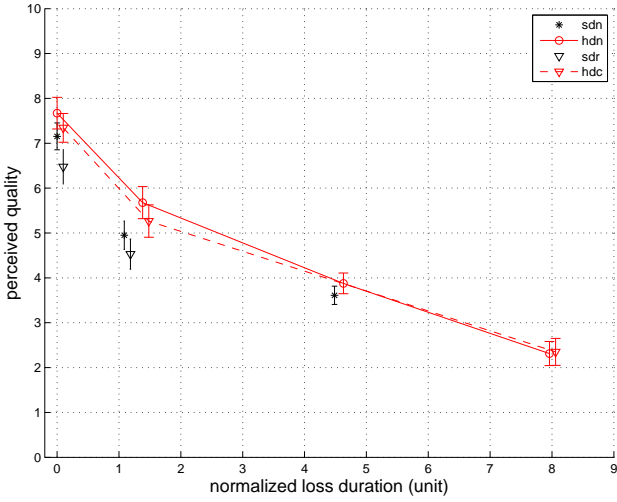


Figure 4: Perceived quality as a function of the loss duration for freezing degradation. sdn: native SD; hdn: native HD; sdr: SD res-caled to HD; hdc: HD cropped.

respective target service. $Icod_V$ is the quality impact due to video compression (i.e. no-loss case) and is shown in equation (3). $Itrav$ is the quality impact due to video packet loss and is shown in equation (4). The frame-rate is considered as fixed. The predicted quality is given on the R -scale.

$$Icod_V = a1 \cdot \exp(a2 \cdot bitrate) + a3, \quad (3)$$

where $a1$, $a2$, and $a3$ are coefficients that depend on the used codec and on the video format.

$$Itrav = (b0 - Icod_V) \cdot \frac{Ppl}{(Icod_V \cdot (b1 \cdot \mu + b2) + Ppl)} \quad (4)$$

where $b0$, $b1$ and $b2$ are coefficients that depend on the packet-loss-concealment (freezing or slicing), on the video codec and on the video format. The parameters Ppl and μ are resp. the average packet-loss-rate (in percent) and the average number of packets lost in a row.

So far, we use different coefficients a_i , $i \in \{1, 2, 3\}$ and b_j , $j \in \{0, 1, 2\}$ for SD and HD. We thus have one model for each video format (for each native resolution). As a complement, we here investigate the development of a single model for both formats and propose the following approach. Note that since we have only two native resolutions (*sdn* and *hdn*) in our tests, we have only two values per video-format related parameter and can not validate the proposed modelling approach. Additional subjective tests including more formats have to be considered for this purpose.

We have seen in the previous sub-sections that both the combination bitrate-resolution and the picture size influence the perceived quality. Their effects depend on the amount and type of degradation.

In the no-loss case, the combination bitrate-resolution impacts the perceived quality. The influence of the bitrate is already taken into account by the *bitrate* parameter in equation (3). For capturing the effect of the combination bitrate-resolution, the coefficients a_i , $i \in \{1, 2\}$ of equation (3) can be expressed as a function of a resolution-related parameter, such as

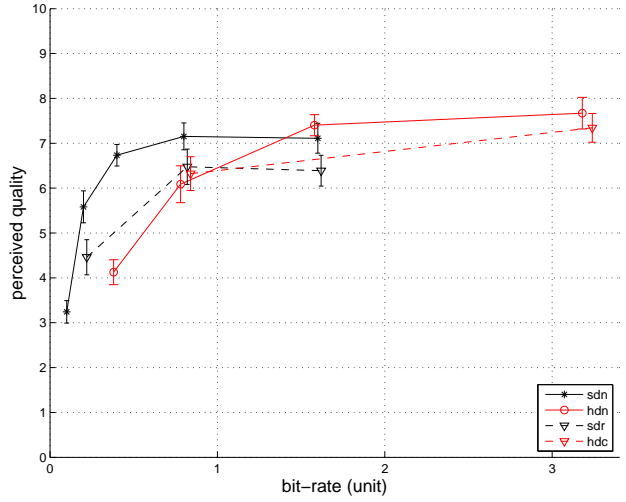


Figure 5: Perceived quality as a function of the bitrate (H.264 encoding). sdn: native SD; hdn: native HD; sdr: SD res-caled to HD; hdc: HD cropped.

the resolution itself in terms of the number of pixels per frame. Picture size influences directly the quality for high bitrate only. In particular, it impacts the maximum quality the video can reach. As a consequence, the insertion of a picture-size-related parameter in equation (2) for modulating Qov should improve the model performance. Following [3] and [2] results, the picture angle seems to be a good candidate. This parameter includes both the variation of the picture size and of the viewing distance, in case this latter one is varied. The inclusion of those parameters can be written as followed in equation (5):

$$\begin{aligned} Qov &= g(\alpha) \\ a_i &= f_i(res), i \in \{1, 2\} \end{aligned} \quad (5)$$

where α is the picture angle, *res* is for instance the number of pixels per frame, and f_i are a set of functions to be determined with the use of additional subjective tests. Note that at this stage, $Icod_V$ is independent of the content, $Icod_V$ could be directly expressed as a function of a parameter representing the combination bitrate-resolution-content, like a parameter linked to the number of bytes per frame (*bsize*).

In the case of slicing, the combination bitrate-resolution impacts the amount of degradation itself while picture size does not seem to impact quality. A parameter linked to the number of bytes per frame is a good candidate for representing the combination bitrate-resolution and thus modulating the b_j coefficients of equation (4), as shown in equation (6).

$$b_j = h_j(bsize), j \in \{0, 1, 2\} \quad (6)$$

where *bsize* is the parameter linked to the number of bytes per frame and h_j is a set of functions to be determined with further subjective tests. As mentioned above, *bsize* is in addition taking into account the influence of the content.

In the case of freezing, as shown in Figure 4 and in equation (7), the impact of the combination bitrate-resolution should be captured by replacing Ppl and μ parameters by a loss duration related parameter in equation (4). An additional parameter

related to the picture size – like the picture angle previously mentioned – should be introduced in the same equation and in combination with the loss duration related parameter for capturing the impact of the picture size (or picture angle, if we take into account the viewing distance) in case of low loss duration, as shown in equation (8).

$$Itra_V = (b0 - Icod_V) \cdot \frac{ldur}{(b1 + ldur)} \quad (7)$$

with

$$b_k = k_k \left(\frac{\alpha}{ldur} \right) \quad (8)$$

where $ldur$ is the loss duration related parameter, $b_k, k \in \{0, 1\}$ are the regression coefficients depending on the video codec, α is the picture angle – which has more effect when $ldur$ is short – and k_k is a set of functions to be determined with further subjective tests.

We are also interested in modelling the quality impact of up-scaling. We have seen in Section 3.4 that upscaling influences the quality only in the case of compression and in the absence of packet loss. Moreover, we observe in Figure 5 that there is a vertical shift between the quality ratings of sdr and those of sdn . As a consequence, the coefficients a_i and b_j of equations (3) and (4) for sdr are the same as for sdn , but the Qov values differ between sdn and sdr in the absence of packet loss. In other words,

$$\begin{aligned} a_i(sdr) &= a_i(sdn), i \in \{1, 2, 3\} \\ b_j(sdr) &= b_j(sdn), j \in \{1, 2, 3\} \\ Qov(sdr) &= Qov(sdn) - F \\ F &= 0, if Ppl \neq 0 \\ F &= 6, if Ppl = 0 \end{aligned} \quad (9)$$

where Ppl is the packet-loss-rate and F is the up-scaling factor. Applying the up-scaling factor decreases the RMSE by 63 %.

5. Conclusion and outlook

In this study we have shown that the video format has an impact on the quality. However, this impact depends on the amount and type of degradations. In particular, in the no-loss case, bigger picture sizes yield better quality only for high bitrates, and thus almost no compression artefacts. In the case of low packet-loss-rate, high-resolution pictures yield better quality than lower-resolution pictures in the case of freezing but lower quality in the case of slicing. In the case of high packet-loss-rates, the quality impact of video format becomes negligible. The quality impact of re-scaling depends on the amount and type of the other degradations. In case of compression, re-scaling has a significant effect. This effect is low in presence of packet-loss yielding to slicing and freezing. In addition, we have proposed a modelling approach for having a single-model covering SD and HD formats as well as a scaling-factor parameter for modelling the quality impact of up-scaling from SD to HD. Next steps include the inclusion of additional formats in the subjective tests for validating the proposed modelling approach.

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