Adaptive CRF Formula Derivation

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You have a H.264 source that you wanna compress to a lower target bitrate with similar quality settings (motion estimation, I/P/B frame placement, etc, the presets (not to be confused with output quality)). You can do 1-pass average bitrate (bad quality) or 2-pass average bitrate (slow). Werner Robitza suggests that a good compromise is to use CRF with VBV to constrain bitrate (Understanding Rate Control Modes (x264, x265), http://slhck.info/video/2017/03/01/rate-control.html). The author wrote the following about CRF+VBV:

"

When you apply VBV to CRF encoding, the trick is to find a CRF value that, on average, results in your desired maximum bitrate, but not more. If your encode always "maxes out" your maximum bitrate, your CRF was probably set too low. In such a case the encoder tries to spend bits it doesn't have. On the other hand, if you have a high CRF that makes the bitrate not always hit the maximum, you could still lower it to gain some quality.

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How to do the trick? Well, CRF values of ±6 "will result in about half or twice the original bitrate". (http://slhck.info/video/2017/03/01/rate-control.html), other things equal. If we know the bitrate of the source video, and it uses non-constrained CRF, we can derive the proper CRF.

B	bitrate
C	CRF
lossless	uncompressed video stream (YUV) decoded from source
master	given source video with known CRF
target	target video transcoded from master

Table 1. Definition of terms

$$
\begin{aligned}
B_{\text{lossless}}/2^{C_{\text{master}}/6} &= B_{\text{master}} \\
B_{\text{lossless}}/2^{C_{\text{target}}/6} &= B_{\text{target}} \\
\frac{1/2^{C_{\text{master}}/6}}{1/2^{C_{\text{target}}/6}} &= \frac{B_{\text{master}}}{B_{\text{target}}} \\
\frac{2^{C_{\text{target}}/6}}{2^{C_{\text{master}}/6}} &= \frac{B_{\text{master}}}{B_{\text{target}}} \\
\ln(2^{C_{\text{target}}/6}) - \ln(2^{C_{\text{master}}/6}) &= \ln(B_{\text{master}}) - \ln(B_{\text{target}}) \\
(C_{\text{target}}/6)\ln(2) - (C_{\text{master}}/6)\ln(2) &= \ln(B_{\text{master}}) - \ln(B_{\text{target}}) \\
\frac{\ln(2)(C_{\text{target}} - C_{\text{master}})}{6} &= \ln(B_{\text{master}}) - \ln(B_{\text{target}}) \\
C_{\text{target}} &= 6 \cdot \frac{\ln(B_{\text{master}}) - \ln(B_{\text{target}})}{\ln(2)} + C_{\text{master}}
\end{aligned}
$$