How Netflix uses it's per title encoding algorithm to create the representation best suited to consumer bandwidth.

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Introduction

In territorial, satellite or cable TV, broadcasters are provided with an allocated bandwidth. Moreover, the programs or the set of programs are encoded in such a way that the allocated fixed capacity is utilized by resulting video streams. To distribute the bitrate across simultaneous programs, broadcasters often use statistical multiplexing. However, total aggregated bitrate should still harmonize within the limited capacity, across the programs. In many cases, to guarantee rigorous constant bitrate for the respective fixed channel, even padding is added by making use of null packets; hence, data rate, which is very precious, will be wasted unnecessarily. Moreover, with pre-adjusted channel allocations, the programs or the genres, which are less popular, may be allocated the lower bitrates than the programs that are widely viewed or more popular.

Due to its internet streaming advantages, Netflix is not restricted to use pre-allocated channels constraints. Instead, it promises to deliver a video stream to a member, which has the best quality, no matter what the genre, or the program is, analogous to the device capacity and available bandwidth of the viewer. Netflix pre-encodes streams at different bitrates by applying optimized encoding techniques. The Netflix client on the member's device, which spontaneously chooses the best encode to maximize the video quality while dodging the playback interruptions caused due to re-buffering, executes adaptive streaming algorithm.

Typically, higher resolution resembles a higher bandwidth usage and higher bitrate. Transmission of videos with different resolutions can have adverse effect on the change of bitrates. However, for some bitrate ranges, low resolutions also show higher PSNR and thus changing the video resolutions can improve video quality significantly and saving user's critical bandwidth too.

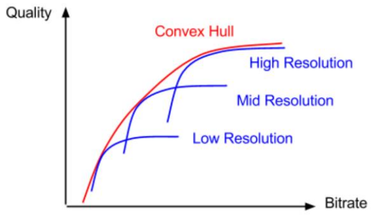

Fig1.Conceptual plot Bitrate-Quality relationship (Image -from Netflix Tech Blog Dec 2015).

Our aim is to draw a conceptual graph, which illustrates the relationship between the quality and bitrate for a sample video source encoded at different resolutions.

Method

Three resolutions i.e. 180p, 360p and 720p are used to choose the resolution, which is best, suited for representation. Firstly, RD curve for each resolution has been drawn (PSNR values generated by ffmpeg codec). The original size of the frame (sample video) that we used is 1280 x 720. The original sequence of frames needs to be downsampled to 360p and 180p respectively, by making use of ffmpeg codec. Once done, the encoded samples of 180p and 360p are decoded and up sampled to their original size to make sure that the PSNR between the decoded frame and the raw 720 frame can be calculated correctly.

PSNR- Peak Signal to Noise Ratio, this ratio is used in comparing the quality measurement between the original and restructured frames (Higher the PSNR, better the quality of representation).

The Bitrate-PSNR pairs of respective resolutions calculated in figure mentioned below.

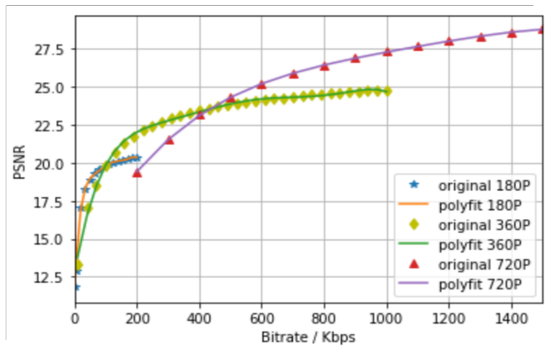

Fig. 2 Original bitrate PSNR-pairs and fitted polynomial functions plotted using python libraries and functions.

In order to perform mathematical analysis on the optimal representation, polynomial fitting is used to prepare mathematical functions of the respective RD curves. The rate of change of slope can be calculated by using second order derivative of the functions, and the resulting local maximum within the specified bitrate is the switching bitrate as shown in fig3. Similarly, the convex hull passing through all the switching points can be plotted using fourth degree polynomial.

However, there are some difficulties in substantiating these switching thresholds. Practically it is not feasible to transcode the video by every bitrate in real time; hence, selection of 'bitrate step size' of some-noticeable difference is a bit-challenging task.

Results

From the below figure, we can estimate crossover bitrates, where the quality of its low-resolution pair is better than its successor high-resolution pair.

- For bitrate interval from (88 - 421Kbps), Quality of 360p is better than 720p.
- For bitrate interval from (0 - 88Kbps), Quality of 180p is better than 360p.

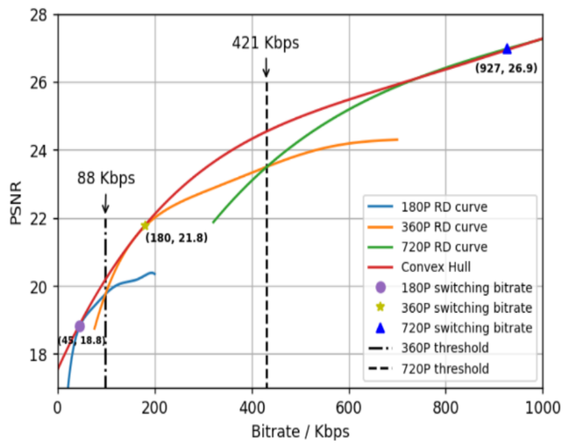

Fig 3 RD curves for three representation (180p, 360p, 720p). Switching threshold is at 88 Kbps between 180P and 360P also 421 Kbps in-between 360p and 730, plotted using python inbuilt libraries and functions.

We can observe that, when the bitrate interval is less than the threshold value 421Kbps, 720P encode may produce a low representation quality less than 360P by encoding at the same bitrate. This is because, encoding less pixels at higher precision produce better quality picture than encoding more pixels with lower precision combined with interpolation and up sampling. In addition, encoding associated with every fixed-size coding blocks preoccupy more bitrates as compared to the consumption by encoding at the actual size.

Algorithm will stick to the same representation scheme in case of stable network bandwidth. However, there may be decrease in encoding efficiency, due to the fluctuation or changing in bandwidth available. For instance, if the available bandwidth is greater than 421Kbps or less than 88Kbps, by using a 360P resolution would result in compelling drop in video quality (PSNR) and algorithm will make sure to switch the resolution to either 720P or 180P ultimately to provide better quality.

Conclusions

Netflix per title encoding supports adaptive streaming that can tune the video quality automatically, based on the two factors:

- Bandwidth of the user's device
- CPU capacity

By pre-detecting, the condition of the end devices in real time, the resolutions and the source content, which is encoded at multiple bitrates, is delivered, and player makes sure it switches between streaming the different encodings as per user's bandwidth and device requirements.

Netflix's adaptive streaming provide users a better experience of streaming media since the media server has the ability to adapt their device and network condition automatically and helps in transmitting the videos with the best possible quality to avoid any playback interruptions.

Per title encoding algorithm is designed to find the optimal bitrate-resolution pair. Netflix takes a video file and generates different versions like 1080p, 720p, 480p.It then generates RD curves to pick points as representation. The quality of the encode constantly keeps increasing with the bitrate for every resolution. When the curve breaches a certain threshold, it starts to straighten out because of the upper limit in the generation of the perceptual quality for every resolution. This bitrate quality relationship for different video resolutions can be plotted on a single graph. Every resolution beats the other resolution in some bitrate region, which together forms a border convex hull. Netflix cascades these video files and pick representations just where the RD curve touches the convex hull.

Advantage - Using this algorithm Netflix plays higher resolution video at lower bitrate using less bandwidth. Thus good quality video with higher resolution can be delivered at low bandwidths and even better resolution videos are played at adequate bandwidth.

Disadvantage - When a video file is down sampled to a lower resolution for encoding and up sampled again to previous resolution for display, the high frequency factors are lost. Also encoding extra pixels at low accuracy generates bad pictures compared to less pixels at high accuracy along with up sampling and interpolation.

Bibliography

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