Impact of Adaptation Dimensions on Video Quality

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Introduction

Scope

- Video adaptation for mobile devices
- Compressed domain video transcoding

Problem

- How to adapt a video stream to meet a certain bit rate?

Approach

- Analysis of the produced quality
- Three main adaptation dimensions

Video Adaptation for Mobile Devices

- Screen ⇒ Frame size (resolution)
- Processor ⇒ Frame size, frame rate and detail resolution
- Memory ⇒ Frame size
- Network ⇒ Bit rate

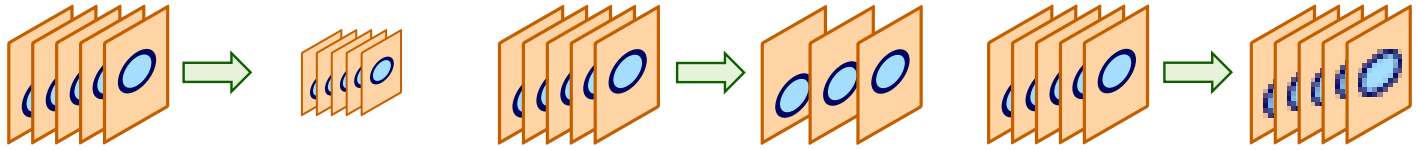
Video Adaptation for Mobile Devices

- Screen ⇒ Frame size (resolution)
- Processor ⇒ Frame size, frame rate and detail resolution
- Memory ⇒ Frame size
- Network ⇒ Bit rate

⇒ The bit rate of a video stream mainly depends on the
  - spatial,
  - temporal, and
  - detail

resolution of the stream.

How to Adapt?

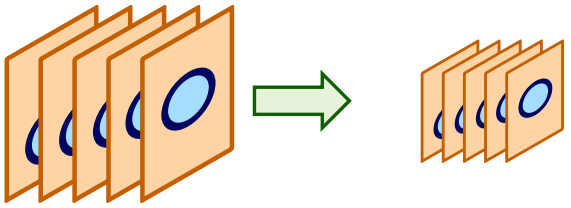


- Which dimensions should be adapted?
  - Reduce the temporal resolution and keep the detail quality?
  - Reduce the detail quality while keeping the frame rate?
  - Reduce the spatial resolution while keeping the detail quality?
  - ...
- How much should each dimension be adapted?
  - As much as needed by the device?
  - Further than needed to keep another resolution higher?
  - ...

$\Rightarrow$ Several different combinations exist

$\Rightarrow$ Which one produces the best quality?

Spatial Adaptation

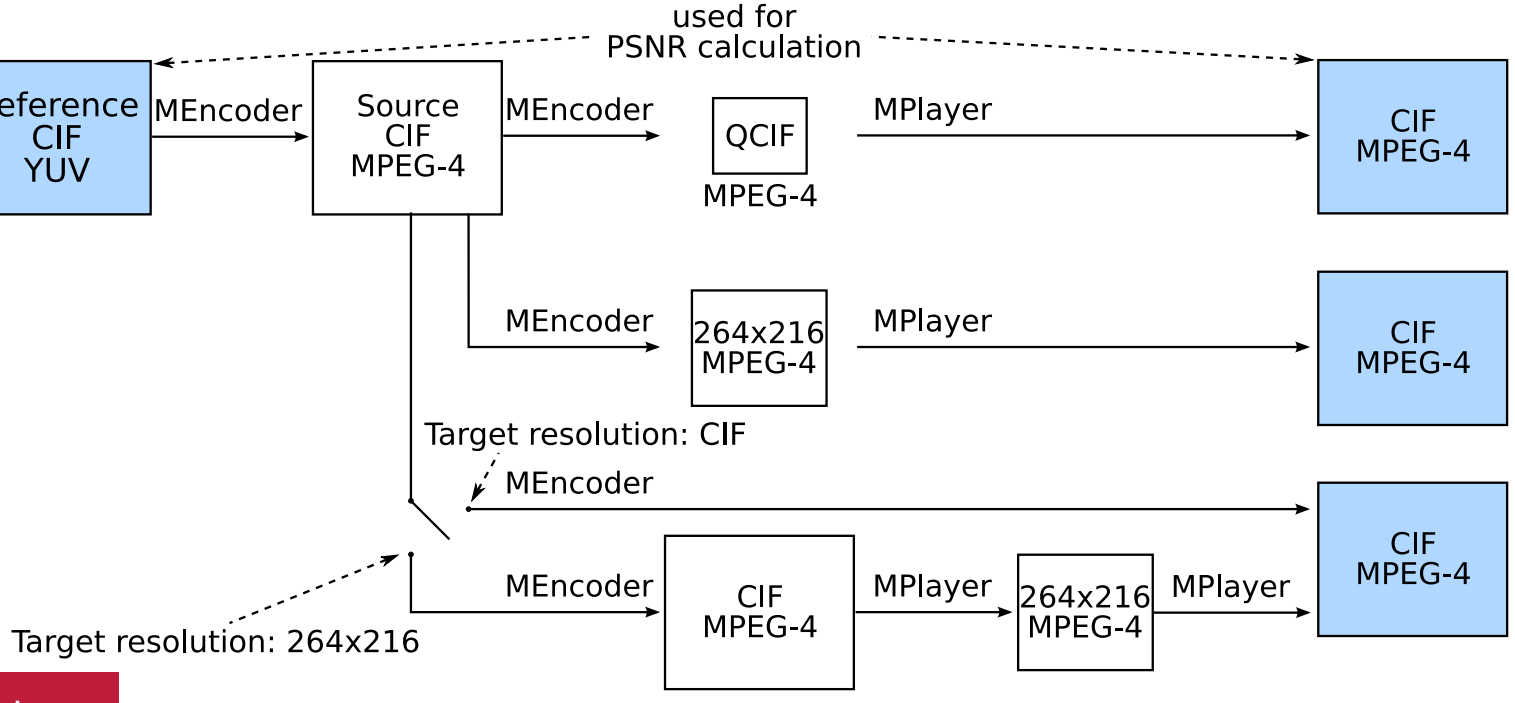


- Meet a display resolution as well as a certain bit rate
- Reducing the spatial resolution also reduces the bit rate
- Additional bit rate reduction by reducing the detail resolution
- Three possibilities for the spatial target resolution:
  1. The target resolution is higher than the display resolution.
  2. The target resolution is the same as the display resolution.
  3. The target resolution is lower than the display resolution.

$\Rightarrow$ Which target resolution produces the best quality?

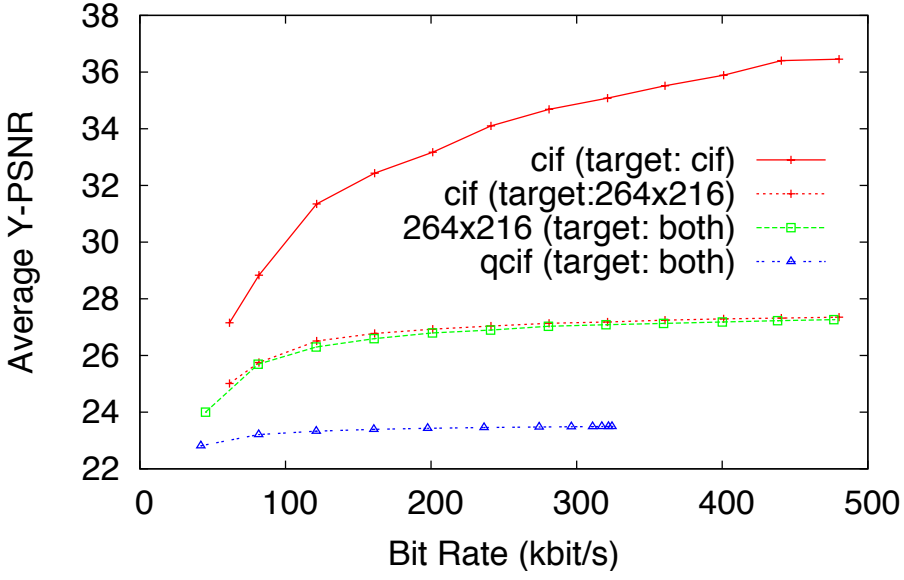
Evaluation Process

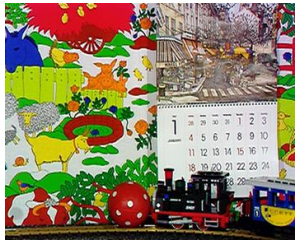
- 10 video sequences
  - Resolution: CIF, 264×216 pixels and QCIF
  - Bit rate: 40 kbit/s – 480 kbit/s
- Evaluation of average Y-PSNR values
  - Target resolution: CIF and 264×216 pixels



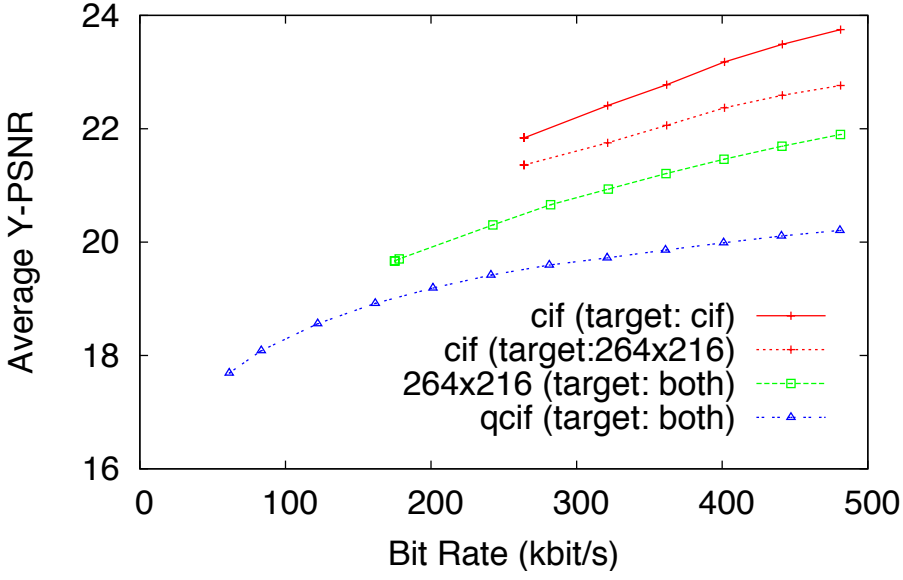
Results - Spatial Adaptation

Sequence: deadline





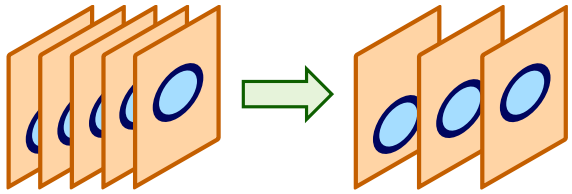
Sequence: mobile



- Similar results for all test sequences, also for higher resolutions

⇒ Resolution reduction other than needed is not beneficial

Temporal Adaptation



- Bit rate reduction by reducing the frame rate of a stream
- Which frame rate produces the best quality?
- PSNR values are not sufficient for quality evaluation
  - Interpolation of missing frames produces poor PSNR values
  - PSNR values of remaining frames do not reflect visual quality

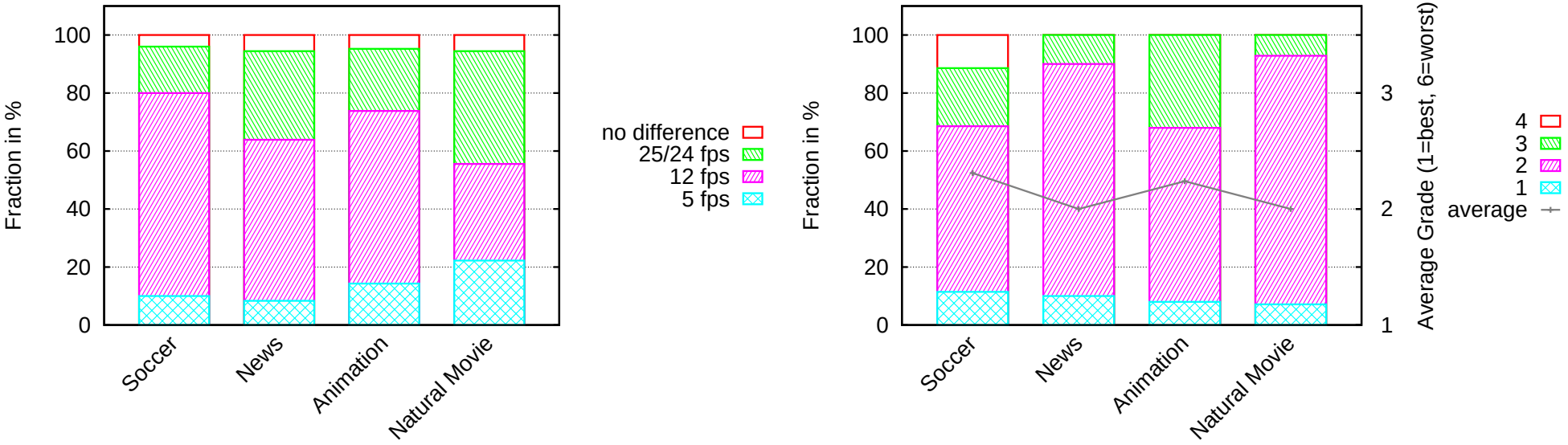
⇒ User interviews
  - Four test sequences
  - Encoded at different frame rates
  - Presented on a mobile device in changing order
  - Participants should chose a preferred version

Test Sequences

- Encoded at 5, 12, and 24/25 frames per second (fps)
- Constant bit rate of 180 kbit/s
- Fixed spatial resolution (fit to 320×240 pixels)
- Duration of 75 and 90 seconds

Results - Temporal Adaptation

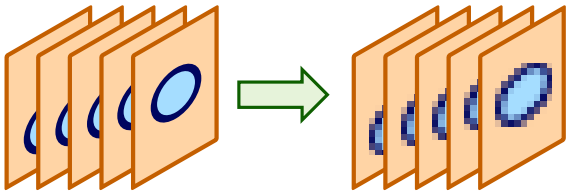
50 non-expert participants with ages between 21 and 59 years



- Dominance of 12 fps as the preferred rate
- No clear dominance for high amount of motion and scene cuts
- Good grades on average for the preferred version

⇒ Users accept lower frame rates to get more details per frame

Detail Adaptation



- High detail quality is important for users of mobile devices
- Reduction of the detail quality reduces the bit rate
- Is there a maximum detail quality?

$\Rightarrow$ User interviews

  - Test sequence encoded at different bit rates
  - Pairwise presentation on a mobile device
  - Participants should chose a version they liked more

Results - Detail Adaptation

Percentages of 41 people preferring version A over B:

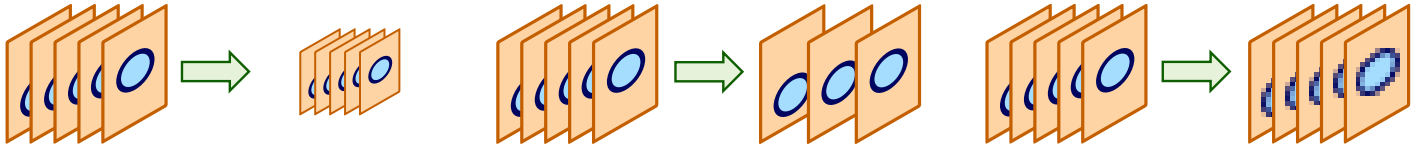
		Version A		
		500 kbit/s	700 kbit/s	1500 kbit/s
Version B	300 kbit/s	87.80 %	85.37 %	90.24 %
	500 kbit/s		70.73 %	73.17 %
	700 kbit/s			60.98 %

- 78.04 % of the users preferred the higher bit rate.
- 23.57 % of all comparisons were chose randomly.
- In 60.34 % of these cases the users chose the higher bit rate.

⇒ The higher quality is still noticeable

⇒ There is no upper bound for the quality level below 1500 kbit/s

Conclusion



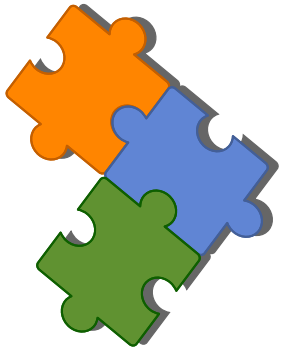
- Spatial dimension
  - Quality evaluation at different spatial resolutions

  ⇒ No benefit from resolution reduction other than needed
- Temporal dimension
  - Subjective quality tests on a mobile device

  ⇒ Users preferred lower frame rates
- Detail dimension
  - Subjective quality tests on a mobile device

  ⇒ No upper bound observable

Combined Adaptation



1. Spatial dimension
   - Spatial downscaling to the screen resolution of the client
2. Temporal dimension
   - Reduction of the frame rate if necessary
3. Detail dimension
   - Reduction of the detail resolution to fine tune the bit rate

Questions?

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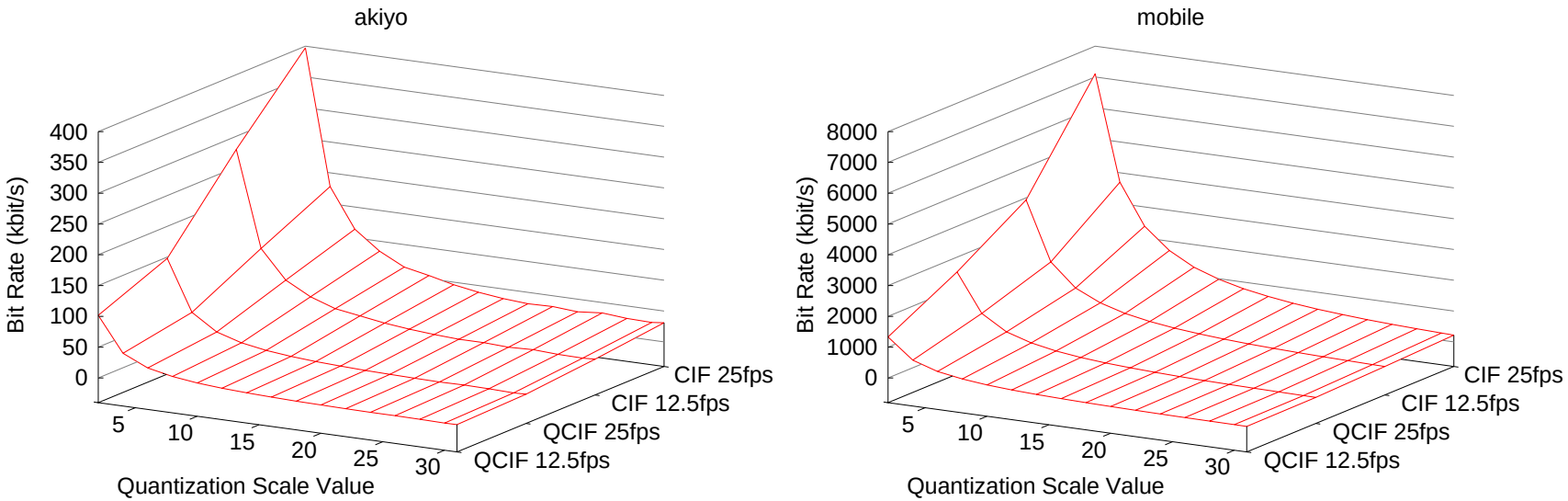
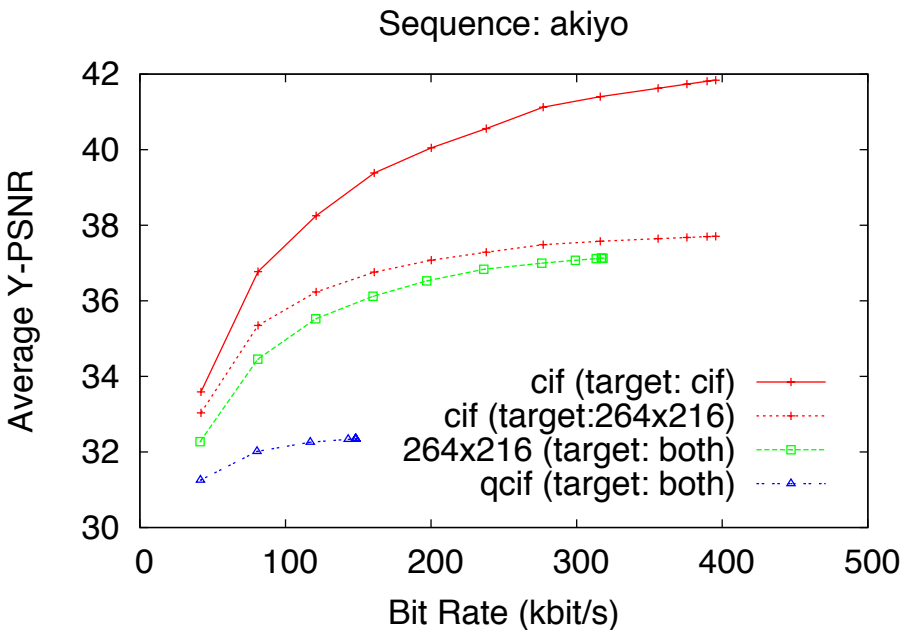
Combined Adaptation

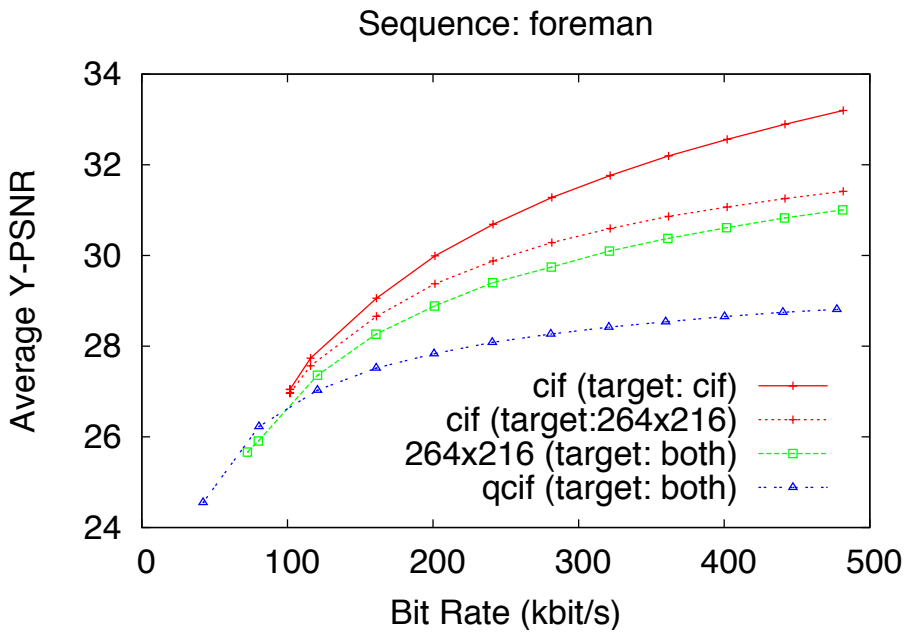
i) adaptation in the detail dimension
ii) adaptation in the temporal and detail dimension
iii) adaptation in the spatial and detail dimension
iv) adaptation in the spatial, temporal and detail dimension



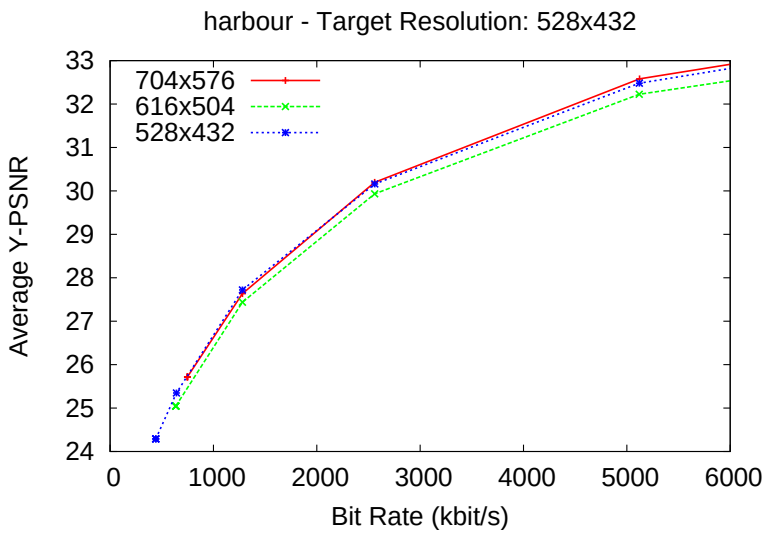
Test Sequences

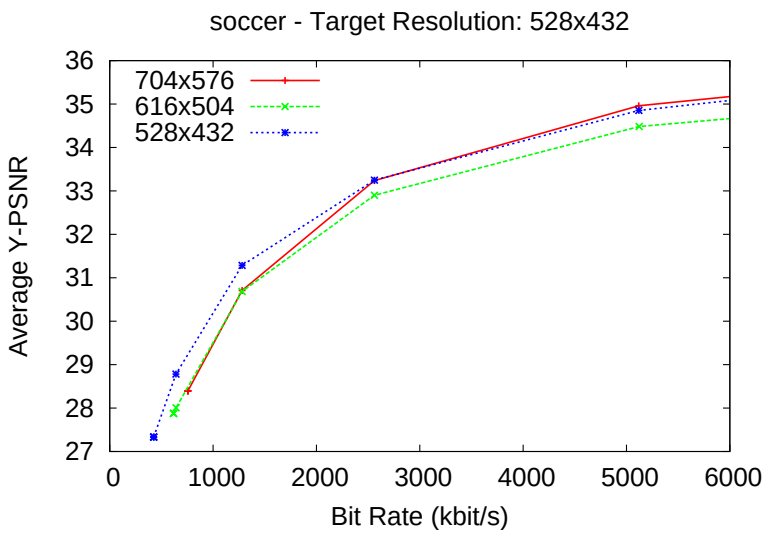
Spatial Adaptation - Akiyo and Foreman Sequence





Spatial Adaptation for Higher Resolution Sequences





Results

Percentages of 41 people preferring version A over B:

		Version A		
		500 kbit/s	700 kbit/s	1500 kbit/s
Version B	300 kbit/s	87.80 % (36)	85.37 % (35)	90.24 % (37)
	500 kbit/s		70.73 % (29)	73.17 % (30)
	700 kbit/s			60.98 % (25)

For all six comparisons, 78.04 % of the users chose the higher bit rate.

Percentages of 41 people randomly chose one version:

		Version A		
		500 kbit/s	700 kbit/s	1500 kbit/s
Version B	300 kbit/s	7.32 % (3/1)	9.76 % (4/2)	9.76 % (4/2)
	500 kbit/s		34.15 % (14/9)	39.02 % (16/10)
	700 kbit/s			41.46 % (17/11)

In 23.57 % of all comparisons the user randomly chose the preferred version. In 60.34 % of these cases the users intuitively chose the version with a higher bit rate.