Off-line Foveated Video: Effects on Compression and Perception

Marcus Nyström*, Kenneth Holmqvist†

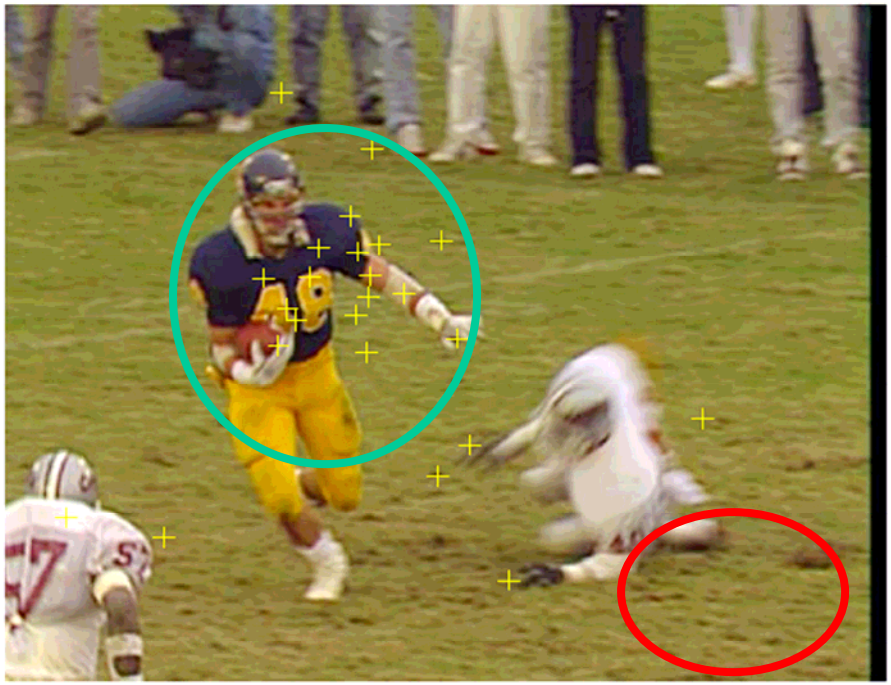
*Dept. of Information Technology, † Laboratory for the Humanities
Lund University, Sweden

Outline

- What is off-line foveation?
- Research questions
- Evaluating quality of off-line foveated video
  - Experiment I
    - Eye-movement behavior during free-viewing off-line foveated video
  - Experiment II
    - Eye-movement behavior during subjective quality evaluation of off-line foveated video
- Conclusions
- Future work

Off-line foveation

Original frame



Off-line Foveated frame

- Findings and observations
  - Visual acuity reduced in the periphery
  - Gaze positions *generally* coincide across people watching video
- Goal: Introducing off-line foveation without decreasing subjective video quality for *later viewers*

Off-line foveation

- Do not confuse with real-time foveation, which has investigated in several papers

Real-time foveation

- Gaze coordinates (from one or many viewers) fed back to foveation algorithm i real time.
- Display updated (at least) each time a viewer shift his gaze
- Fast update rate of the display required

Off-line foveation

- Gaze coordinates from many previewers collected
- Collected ET-data used to derive ROIs
- Use ROIs to manipulate display resolution ”off-line”

Questions

- Would this approach really work…?
  - Possible to predict where people will look?
  - Viewing behavior controlled by bottom-up and top-down processing of video
  - Top down processing
    - Task
    - Background
    - Interest
    - Cultural background (Asian people tend to look more at the background than Europeans)

Research Questions

- How do people look at videos?
  - Eye-tracking experiments to study the nature of eye-movement behavior
- How to control video fidelity based on recorded eye-data from several viewer?
- How to optimize compression algorithms to code off-line foveated video?
  - R(D)?
  - R(Subjective D)
- How to evaluate the quality? Can we use traditional methods?

Off-line foveation

Previous Attempts:

Stelmach & Tam (1994): “*. . .gaze contingent processing is not suitable for general purpose image processing*”

Duchowski (1998):

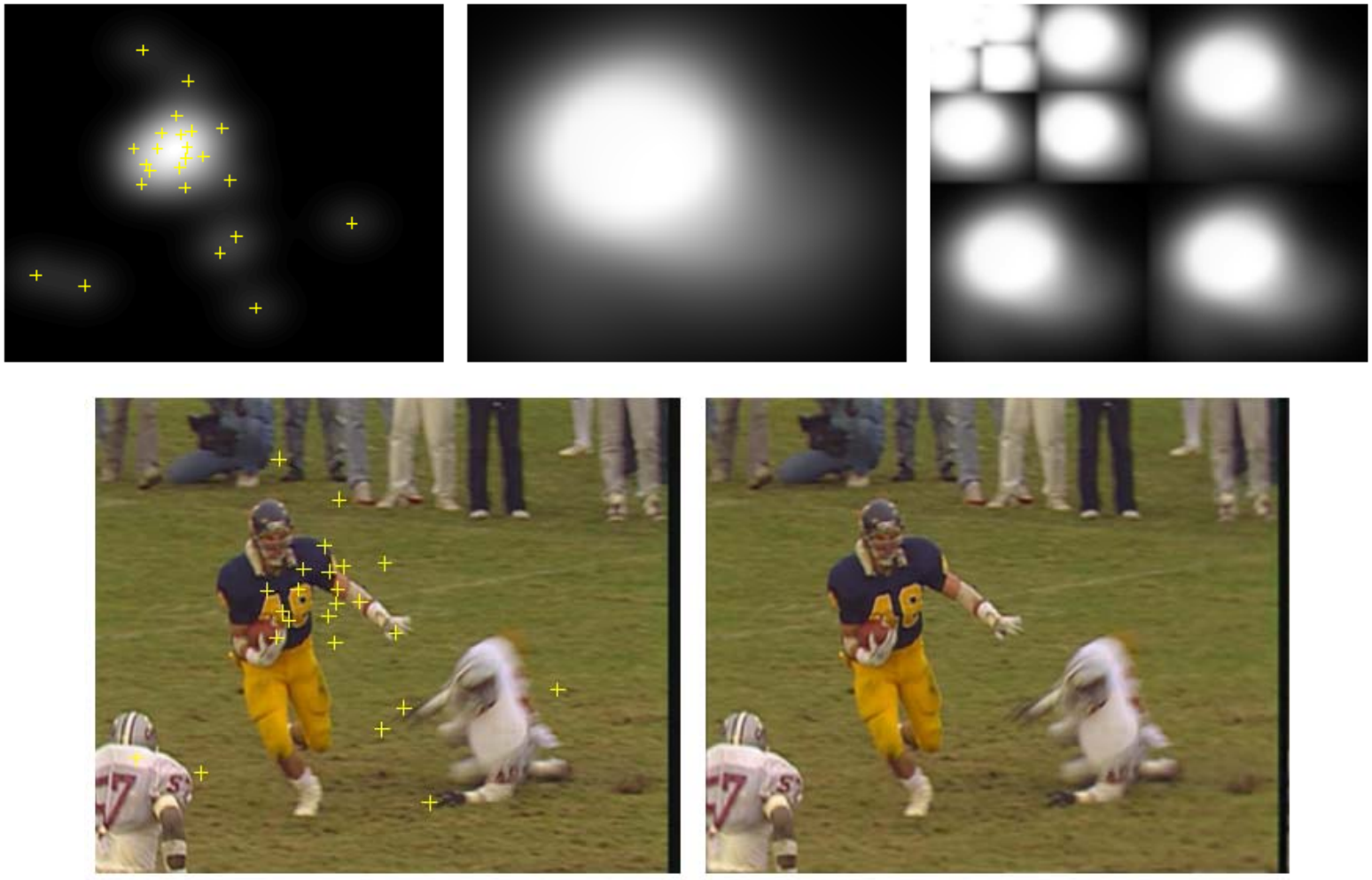
“*…VOI based prediction of eye movements may not be effective for natural (free) viewing*” ,

“*…aggregate VOIs impair perception (or perhaps more fairly natural eye movements*)”

Our strategy (**Nyström & Holmqvist, Journal of Electronic Imaging, 2007**):

- Convert gaze positions to Volumes of Interest (VOIs)
- Let new VOIs emerge and disappear gracefully
- Model the uncertainty in where new viewers will look
- Let VOIs control off-line foveation

Off-line foveation



Off-line foveation

- Study perceptual effects (eye-movements, subjective quality) of off-line foveated displays.
- Video compression!

Ex: Off-line foveation prior to encoding with H.264 gave, on six tested videos, an average bit-rate reduction of 20 %

	Quality factor					
Video	Lowest	Low	Medium	High	Highest	Average±SD
aikyo	0.02	0.013	0.014	0.059	0.16	0.054±0.063
football	0.13	0.15	0.16	0.16	0.19	0.16±0.023
hall	0.034	0.027	0.063	0.2	0.18	0.1±0.082
alte	0.13	0.29	0.52	0.45	0.33	0.34±0.15
dolphin	0.19	0.27	0.34	0.35	0.29	0.29±0.063
fish	0.14	0.24	0.32	0.29	0.21	0.24±0.071
all	0.11	0.16	0.24	0.25	0.23	**0.2±0.13**

Evaluation

- Objective quality measures
  - PSNR?
  - Weighted PSNR?
- Subjective quality measures
  - Videos viewed at least twice before judged
    - ⇨ Viewing behavior changes with repeated viewings?
    - ⇨ Regions normally not gazed at are visually attended?
- New measures to estimate quality
  - Eye-movements combined with subjective evaluations.
  - Investigate effects after one, two and three consecutive viewings

Evaluation

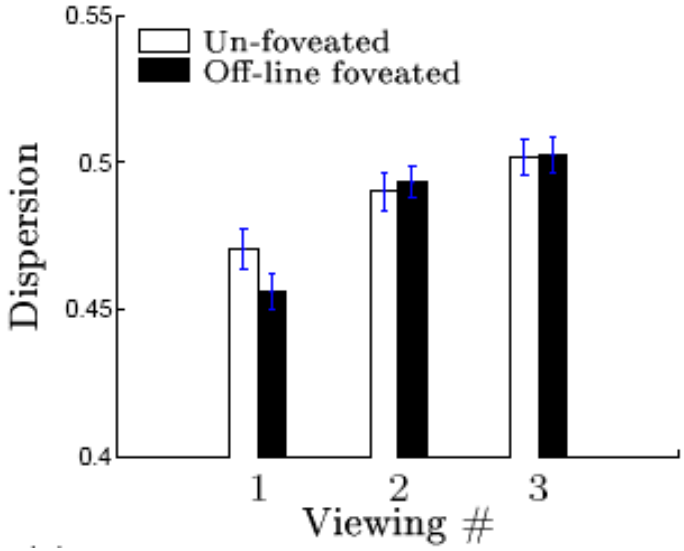
Experiment I: Free-viewing

- Simuli: Six videos compressed at high bit rates, before and after off-line foveation (hence 12 videos in total).
- Videos shown in random order together with 12 pictures. Repeated two times.
- 15 naive subjects free-viewing (measure pupil size)
- Eye-tracking: SMI iViewX Hi-Speed, 240 Hz

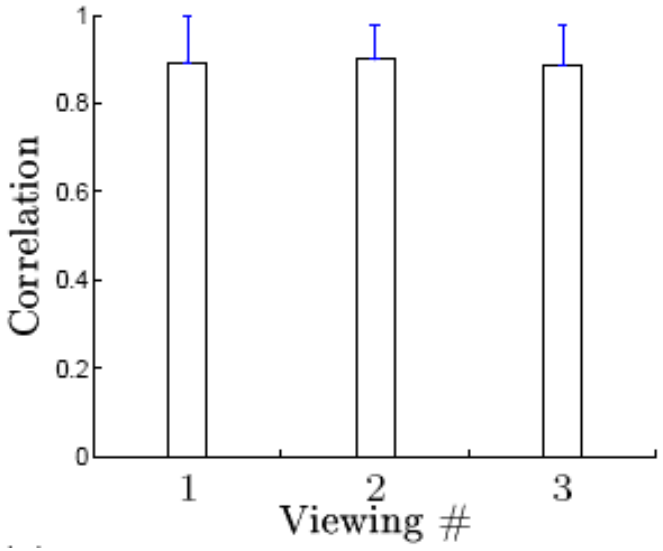
Evaluation

Experiment I: Free-viewing

Dispersion across viewers gaze positions



Correlation in gaze positions between viewers watching the unfoveated, and the off-line foveated videos



Observations:

1. Off-line foveation essentially does not change subjects' gaze locations during free-viewing
2. Fixation duration and saccade amplitude not affected by off-line foveation during free-viewing

Evaluation

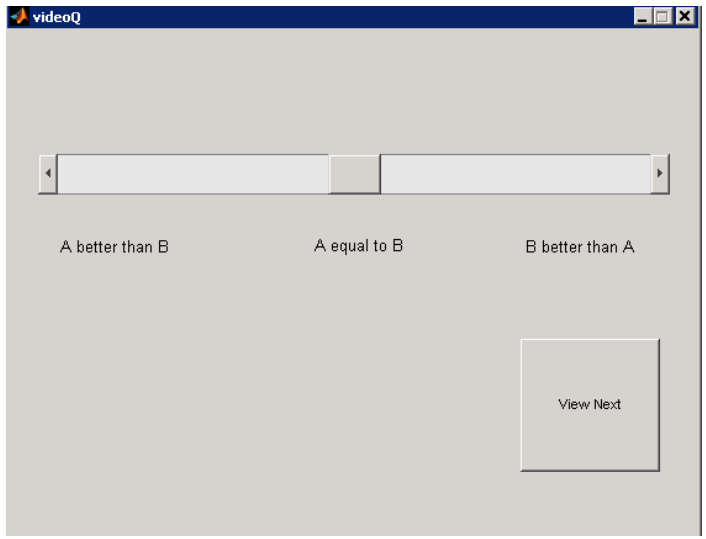
Experiment II: Quality Assessment

- Same simuli as in Experiment I
- 17 naive subjects assessing the difference in quality between the two versions A and B

Method:

1. AB X trials (first viewing. Did not know that further chances would be given)

VOTE!

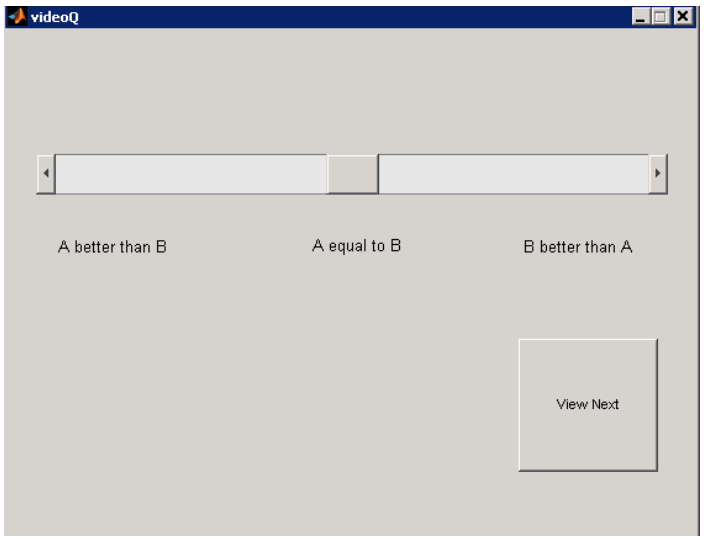


Evaluation

Experiment II: Quality Assessment

2. ABAB X trials (second and third viewing)

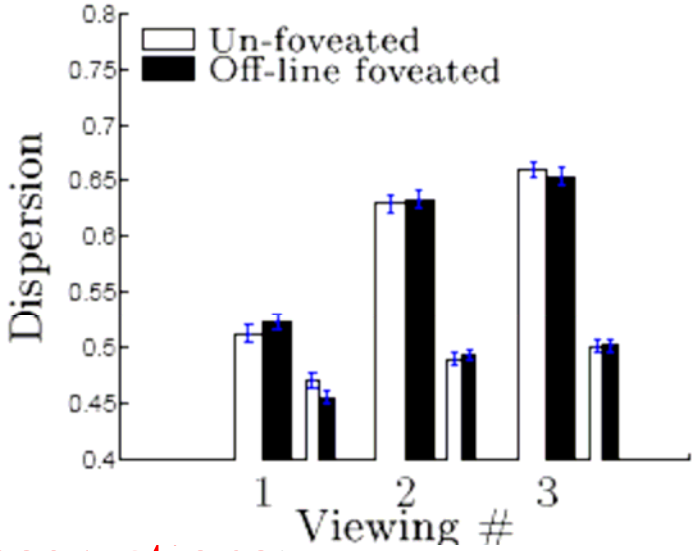
VOTE!



Evaluation

Experiment II: Quality Assessment

Dispersion across viewers gaze positions



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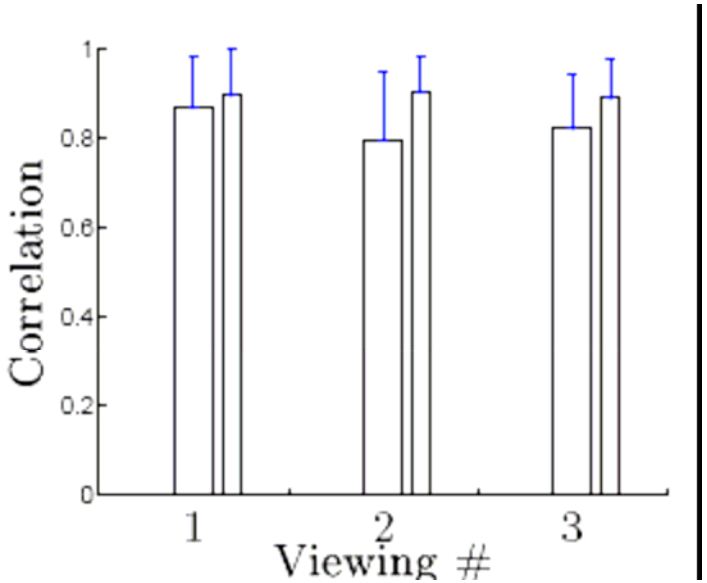


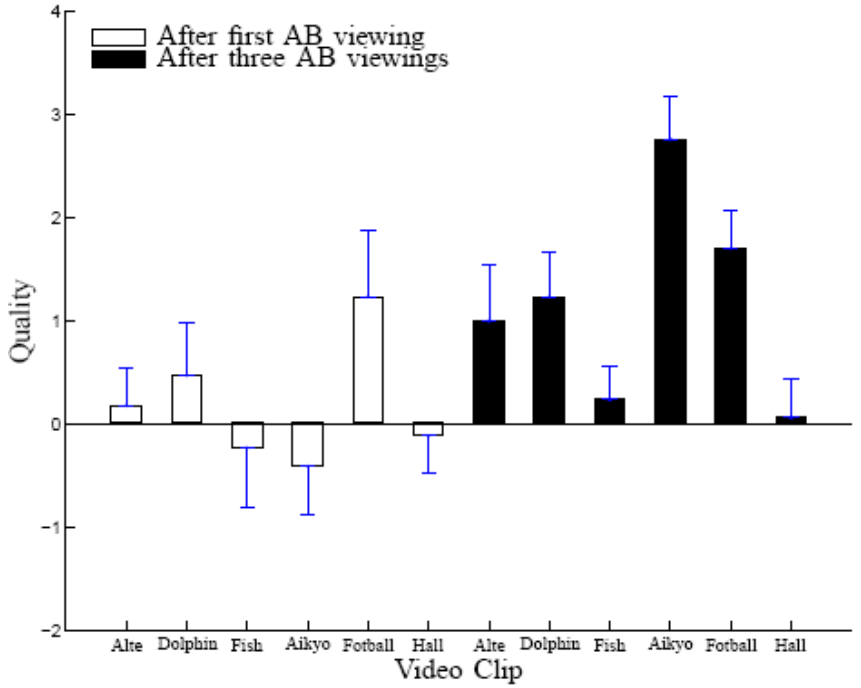
Observations:

1. Off-line foveation essentially does not change subjects' gaze locations during quality assessment
2. A quality assessment task changes the eye-movement behavior, in particular after repeated viewings!
3. Fixation duration and saccade amplitude not affected by off-line foveation during quality assessment

Evaluation

Experiment II: Quality Assessment

Subjective quality assessment: Results



Observation:

1. Off-line foveation essentially does not decrease subjective quality (during first time viewing)

Conclusions

- Off-line foveation essentially *does not*
  1. Change peoples' eye-movement behavior
     - Where they look
     - Fixation duration, Saccade amplitude
  2. Decrease subjective quality
- Off-line foveation *does*
  1. Significantly reduce information required to store/transmit videos digitally

Future work

- Progressive image/video transmission
  - Is it beneficial in terms of visual quality to transmit region of high density a priori?
    - Only at low bit rates (< 0.25 bpp) for JP2K coded color images with automatic ROIs (maxshift) prediction (Bradley,2003)
  - Implementation/Validation of a eye-tracking controlled PIT system for (moving) pictures.

Comments

- Practical usage?
  - Eye-movements have to be collected prior compressing each video
  - In a near future: Eye-trackers embedded in web cameras.
- Do algorithms that can predict where people will look exist?
  - Yes!
  - Are they any good?
    - Maybe…