https://doi.org/10.2352/ISSN.2470-1173.2017.14.HVEI-124

Do gaze disruptions indicate the perceived quality of non-uniformly coded natural scenes?

Yashas Rai, Patrick Le Callet
LUNAM University, University of Nantes, IRCCyN UMR CNRS 6597
Polytech Nantes, Rue Christian Pauc BP 50609 44306
Nantes Cedex 3, France

Abstract

Subjective video quality evaluation techniques usually involves a subject voluntarily attending to several regions in a video in order to scrutinize its quality. These techniques often tend to over-estimate the visual thresholds and in cases of non-uniform quality/coding, subjects mostly perceive the underlying video content in worse quality. This occurs due to a process known as Attentional Modulation occurring in the higher visual cortical areas V2 to V4. Examining disruptions in free viewing gaze patterns on the other hand, are said to be a more naturalistic method to measure the perceived video quality in such cases. To explore the feasibility of such a gaze disruption based quality metric, we examine the dependency between the two indicators: gaze disruptions and perceived subjective quality, obtained from a carefully controlled subjective test. By the examination of eye-tracking data and subsequent statistical analysis of difference opinion scores given by users, we are able to see that disruptions are indeed excellent indicators of perceived quality achieving a correlation 0.84. Several state of the art objective video quality metrics like SSIM, VIFp, VQM and PSNR-HVS (designed mostly for evaluation of uniform-quality) on the other hand, only produce a correlation ranging from 0.01 to 0.10. We conclude therefore that gaze disruptions may be used as excellent natural indicators of perceived quality in cases where quality is non-uniform, and may serve as new ground truth indicators for objective algorithms like Scanpath disruption(prediction) metrics that measure video quality in a more real-world like(naturalistic) manner.

Introduction

In traditional subjective video quality evaluation, subjects commonly scrutinize the video content (often several times) in order to search for the distortions present in them and then present an opinion score. In natural viewing conditions however, humans do not view the image or video sequences with the sole aim of identifying the possible degradation in the content. Our attention in these cases is not *sensitized* to such distortion targets. In vision science, it is well known that attentional modulation can strongly vary the response towards visual tasks, especially quality evaluation. Several experiments performed with a simultaneous foveal and peripheral task [1, 2] and also using intrusive methods like electrodes placed within monkey receptive fields[3] have indicated that the response of the extra-striate cortical areas strongly depend on whether the effective stimulus was directly attended to or not. The experiments have therefore suggested that, given an object of interest, it is not only important to bring it within the range of the receptive field, but also attend to it directly, in order to maximize the cortical response. Similar results have been found in the case of [4, 5] when they measured the influence of space-based attention on responses of single neurons in area V4. Cell responses to the preferred direction were enhanced, if attention was directed to the receptive field of the cell.

Although visual thresholds have traditionally been measured when stimuli are fully attended, several newer studies use a concurrent task to determine thresholds when stimuli are poorly attended as well[6, 7, 8]. The comparison of fully and partially attended thresholds reveal that when targets in the visual periphery were fully attended, contrast detection thresholds were about 20 percent lower, contrast discrimination thresholds about 40 to 50 percent lower, spatial frequency and orientation discrimination about 60 percent lower and orientation thresholds about 70 percent lower than the partially attended case[7].

Several past studies have therefore used eye-tracking data or saliency as a more sensible choice[9] to obtain a more real-world like measure of video quality [10] or as an additional aid to improve traditional quality metrics [11, 12, 13]. Such metrics are in fact the only way to measure quality in the case of *Interactive Video streaming*[14, 15] or *Gaze Contingent Displays*[16, 17] where the quality adapts according to the user gaze behavior or regions of interest in the scene. Although quality metrics that are based on the change in viewing startegy have been proposed earlier in [18], a clear link between disruption and percieved quality is still not well explored.

For the verification of the connection between the two, we examine the results of a subjective experiment in which quality scores along with eye-tracking patterns have been recorded for several videos with different types of distortion. Although such an experiment deviates from a strictly *Free-Viewing* type of scenario, earlier studies have indicated that in case of videos, users behave in a similar manner during both these types of viewing tasks[19].

After a brief review of the experimental setup and test stimuli in section 2, we move to section 3 where the relation between disruptions and perceived quality is explored. Section 4 finally concludes the article.

Subjective Experiment

The experiment was performed at the University of Nantes in which 30 subjects participated. The subjects provided a score on the five point impairment scale after watching each video in addition to their gaze-points also being recorded.

Experimental Setup and Test Subjects

The experimental setup is described in [20, 21] and we restrict ourselves only to the relevant details here. 30 naive human subjects were involved in the experiment, each of whom viewed all of the 20 different test stimuli under 5 different conditions.

The experiment was designed according to ITU Rec. BT.500 and the videos were presented on a LVM-401W full HD screen by TVlogic with a size of 40" and a native resolution of 1920×1080 pixels and frame rate 25fps.

Test stimulus

Twenty different videos were used from the VQEG dataset as indicated in Figure 1. The videos were all played at 25fps and lasted exactly 6 seconds.

The videos were each shown under 5 different test conditions : (a) Control condition where no transmission impairment is embedded. Transmission impairment in a (b) salient or (c) non-salient area for 400ms or (d,e) 1200ms. The Joint Video Team (JVT) loss simulator was used to introduce packet loss into the H.264/AVC bit stream to produce a transmission impairment that lasted either 0.4 or 1.2 secs. The exact duration of the impairment is not an independent variable in this work and we consider all visual stimuli over 400ms to be assimilated equally in the conceptual memory and hence be equally perceptible[22], therefore treating HRCs 2,4 and also 3,5 in the same manner (result also visible in the respective raw MOS scores). To have a better control regarding the location and extent of the loss patterns, a fixed number of 45 macro blocks (MB) per slice was chosen, and the error was restricted to this single slice only. An overview of the various test conditions can be found in Table I.

TABLE I : TEST CONDITIONS AND STIMULI

HRC	Distortion type	Distortion time	Distortion region
1	-	-	-
2	AVC Trans.	0.4	salient
3	AVC Trans.	0.4	non-salient
4	AVC Trans.	1.2	salient
5	AVC Trans.	1.2	non-salient

Measuring Subjective opinion

The five point impairment scale was used to assess the annoyance of the distortions in the sequences. Here, the subjects assigned one of the following adjectival ratings to each of the sequences: 'Imperceptible (5)', 'Perceptible, but not annoying (4)', 'Slightly annoying (3)', 'Annoying (2)', and 'Very annoying (1)'. Scores obtained for the pristine un-distorted sequences were then subtracted from the scores obtained for each of the impaired cases, for each individual subject and video, in order to obtain the 2400 difference scores (30 observers $\times$ 20 videos $\times$ 4 impairments) for the analysis.

The Eye-Tracking experiment

The eye-movement patterns of the subjects were recorded throughout the test, with the scoring also performed using the eye-tracker. The SMI Hi-Speed eye-tracker was used to obtain 500

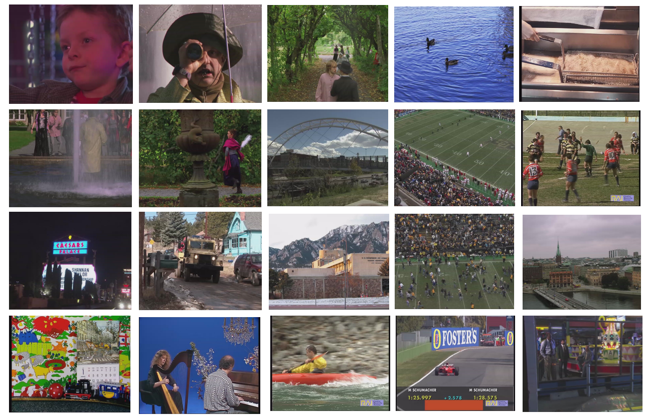

Figure 1: Sequences from the VQEG dataset that were used in the subjective test (Referred to as seq1, seq2, $\cdots$ and so on in the article), as seen rowwise

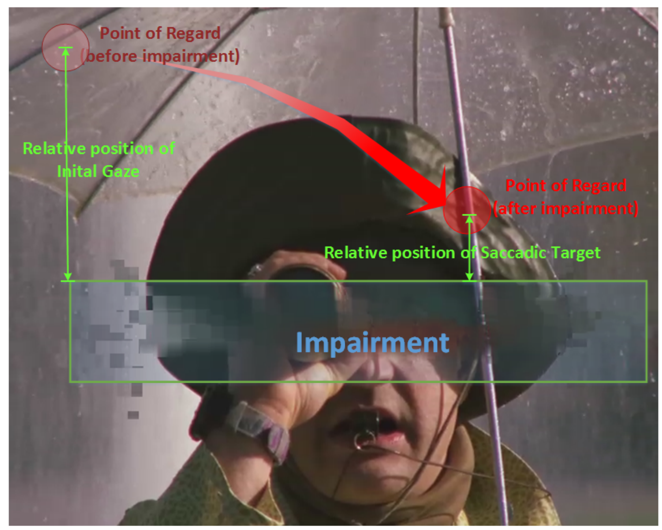

Figure 2: Point of initial gaze refers to the region that the subject was initially looking at before the distortion appeared. On the other hand, saccadic targets refer to the region where the user shifted his gaze, as soon as the distortion was presented

gaze data samples per second. Calibration was performed before displaying the actual video in order to minimize the errors due to bad calibration.

Relative position of initial gaze and relative position of Saccadic Target

Two important measurements are extracted from the eye-tracking data of observers: the eccentricity of viewing just before the distortion is presented (known as the *Relative position(RP) of initial gaze*) and the eccentricity of viewing after the presentation of the transmission impairments (known as *Relative position(RP) of saccadic target*) as shown in Figure 2. These quantities serve as an important indicators of disruption caused due to the impairment.

Eccentricity in this context is defined as the shortest distance (in degrees) between the point of gaze and the impaired region in the video.

Disruption

Impairments often disturb the natural viewing behavior of an observer, in turn strongly affecting the RP of the saccadic target. Examining the probability of an observer being drawn towards the impairment therefore serves as a measure of disruption. Assuming that a viewer was in a RP of initial gaze X and that the impairment makes him saccade towards a RP of saccadic target say Y, we define disruption D as the probability that the saccadic amplitude $X-Y$ caused by the impairment is greater than a finite threshold δ, when examined at every possible X ranging from δ to the maximum possible viewing angle A_{max}, as shown in equation 1

$$D = \sum_{x_i=\delta}^{A_{max}} p((X-Y) > \delta | X = x_i) p(X = x_i) \quad (1)$$

It is therefore clear that disruption can be completely and sufficiently deduced by just examining X and $X-Y$ at every possible $X = x_i$. We therefore analyze the joint behavior of X, Y and the difference scores in the following section.

Results

The *RP of Initial Gaze* and the *RP of Saccadic Target* obtained from the gaze data of a given observer for a given impaired video is compared with the corresponding difference score obtained for that particular impaired video from that observer, in order to draw several meaningful conclusions.

Disruptions and difference scores

Grouping all the 2400 difference score responses (across subjects, stimuli and test-conditions) in accordance to the two independent variables: RP of initial gaze and the RP of saccadic targets (obtained from the corresponding eye-tracking data), gives us the result indicated in Figure 3. The two parameters were quantized (at an interval of half degree of viewing angle) and all difference scores corresponding to that particular gaze interval averaged together, to perform statistical significance calculations. Subjects maintaining the same saccadic target as the initial gaze point values (values on the line of logarithmic slope unity where $X-Y=0$) shows the cases where no disruption was present. The values below this line indicates the subjects who were disrupted in the direction of the impairment $X-Y>0$, whereas the ones above it shows the subjects who saccaded away from it where $X-Y<0$.
As expected, it is seen that the subjects who were closer to the impairment ($X<\delta$) are in general more likely to perceive the bad quality than observers who were at a distance, as indicated by the higher difference scores for smaller abscissa. The variation of the score at higher values of abscissa ($X>\delta$) is however more important in this work. For users at a far-off initial gaze position ($X>\delta$), higher disruptions or smaller values of ordinates ($X-Y>\delta$) seem to be directly correlated with a higher difference score.

Correlation and Statistical Significance

Disruption as a *quality metric* was compared with traditional global quality assessment metrics and it was clearly observed that in cases where distortions are local in nature, objective metrics are rather weak indicators of the perceived subjective quality.

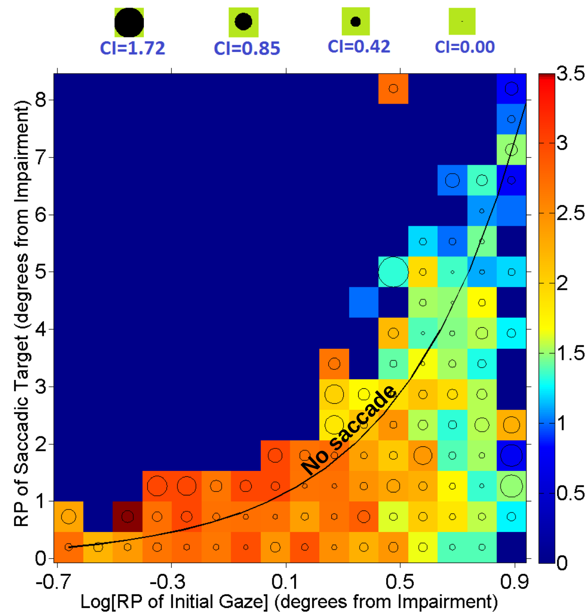

Figure 3: The difference opinion scores(indicated by colors) as a function of the RP of initial gaze and RP of the saccadic target point. The horizontal axis is plotted on a logarithmic scale as most observations are concentrated in the lower range. The circle sizes indicate the confidence intervals(CI) of the difference scores.

Traditional full reference quality metrics SSIM[23], VIFp[24], PSNR-HVS[25] and VQM[26] were first computed for each of the 80 SRC-HRC combinations as indicated in Table II. The overall score for each case was computed using the average of the score obtained for all frames. The average objective scores were then compared with the DMOS scores obtained in the subjective experiment for the particular SRC and HRC. The Linear (LCC) and Spearman Rank Order (SROCC) correlation coefficient was computed in addition to using ANOVA to check the statistical significance of the relation between the subjective difference opinion score and objective scores from each metric.
In case of the disruption metric however, as the difference score Z is defined to be a joint function of the RP of initial gaze X and RP of saccadic target Y, we compute the multiple correlation coefficient using Equation 2, where r_{XZ}, r_{YZ} and r_{XY} indicates the linear correlation between the two factors.

$$R_{Z,XY} = \sqrt{\frac{r_{XZ}^2 + r_{YZ}^2 - 2r_{XZ}r_{YZ}r_{XY}}{1-r_{XY}^2}} \quad (2)$$

Additionally, a two way ANOVA was performed with the null hypothesis that the difference score was the same irrespective of the independent variables: the RP of initial gaze (quantized) and RP of saccadic targets (quantized). The ANOVA indicated a significant effect of each of the two factors ($p=0.0.0$,$p=0.00$ respectively), and also the interactions between them ($p=0.00$). Further, a Tukey HSD post-hoc test revealed that the difference score differed at all of the quantized intervals of the *RP of Saccadic Target*.

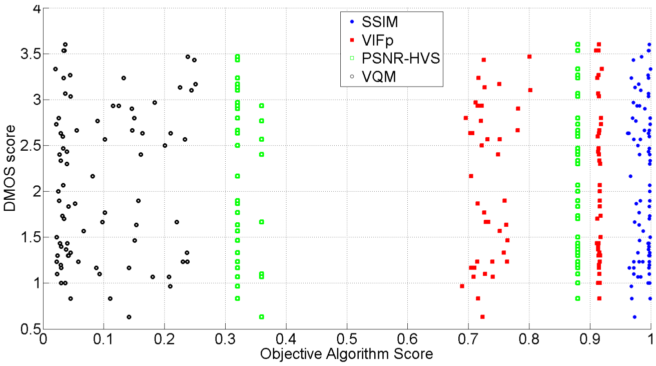

Figure 4: Response of the objective quality metrics (a) SSIM[23], (b) VIFp[24], (c) PSNR-HVS[25] and (d) VQM[26] to the various sequences and test conditions in the dataset along with the respective DMOS score obtained in each case.

TABLE II : PERFORMANCE OF OBJ.METRICS

Metric	Type	LCC	SROCC	Stat.Sig.(p)
SSIM	Obj.	0.01	0.01	0.89
VIFp	Obj.	0.02	0.02	0.88
PSNR-HVS	Obj.	0.01	0.06	0.93
VQM	Obj.	0.08	0.11	0.48
Disruption	**Subj.**	**0.84**	**0.84**	**0.00**

Content dependence

The exact extent to which the difference scores are correlated with the disruptions is also a function of the underlying content. While dynamic stimuli (larger motion) and darker luminance levels resulted in reduced opinion scores, stationary and non textured stimuli have higher perceptual quality scores for a fixed amount of disruption. Figure 5 shows the variation of these difference scores with saccadic target lengths for each of the sequences. While all sequences show the trend wherein higher disruptions lead to a higher difference score, the variations are sequence dependent. Further, we try to fit an exponential curve for the difference score vs saccadic targets for each of the sequences tested. The curves obtained are shown in Figure 6. A more detailed representation of the data is also provided in Figure 5.

Conclusion

In the present work, we examine the eye-tracking data and the associated difference opinion scores of a subjective test involving videos containing localized distortions. Two important quantities known as *RP of initial gaze* and *RP of saccadic target* are first extracted from the eye-tracking data and are then examined pairwise with the respective difference opinion score.
We especially concentrate on those subjects who were not attending to the distortion and were suddenly disrupted when the distortion appeared. A statistically significant(p=0.00) correlation of 0.84 was found between the difference score and the disruption in the case of such observers. On the other hand, observers who were little/not disrupted were much less likely to reduce their scores. Traditional objective quality metrics(that are often used to measure quality of uniformly coded videos) like SSSIM, VIFp, PSNR-HVS and VQM on the other hand only produced a correlation of 0.01 (p=0.89),0.02 (p=0.88),0.01 (p=0.93) and 0.08 (p=0.48) respectively on this dataset.
The exact extent of the relation between disruption and perceived quality, is to some extent also determined by the content. For scenes with high motion and(or) low luminance, the drop in score is much higher for an equivalent amount of disruption as compared in other cases. The monotonic exponential decrease in general, holds good for all of the 20 sequences tested however.

Implications

Traditional objective video quality metrics that measure the global quality of videos often fail considerably in scenarios where the distortion is localized in nature. Analyzing disruptions in free viewing gaze patterns are hypothesized to be one of the most real-world like approaches to measure the perceived quality of such non uniformly coded videos, which also avoids the problem of the subject scrutinizing the video unnaturally. In this experiment, we clearly observed that disruptions are strongly correlated with the perceived quality of the video and may therefore serve as a new ground truth measures for future algorithms that may for example utilize scanpaths to measure video quality. Several scanpath metrics[27, 28, 29], that are capable of predicting a users gaze pattern based on top-down and bottom-up information are now available and maybe used in the future as quality indicators.
Although the current experiment deviates slightly from a strictly *Free-Viewing like* scenario (as it involves the subjects presenting a quality score), it provides us with a means to test whether such a disruption based approach to measure perceived quality is feasible and realistic. From the results, we understand that disruptions found in gaze patterns might indeed be very strong indicators of the underlying quality of non-uniformly coded video sequences. There is however a non-linear relation between these disruptions and the actual perceived quality due to the underlying source content acting as a confounding factor.

Acknowledgment

This work was supported by the Marie Sktodowska-Curie under the PROVISION (PeRceptually Optimized VIdeo CompresSION) project bearing Grant Number 608231 and Call Identifier: FP7-PEOPLE-2013-ITN.

References

[1] B. Khurana and E. Kowler, “Shared attentional control of smooth eye movement and perception,” *Vision research*, vol. 27, no. 9, pp. 1603–1618, 1987.
[2] H. Daimoto, T. Takahashi, K. Fujimoto, H. Takahashi, M. Kurosu, and A. Yagi, “Effects of a dual-task tracking on eye fixation related potentials (efrp),” in *Human-Computer Interaction. HCI Intelligent Multimodal Interaction Environments*. Springer, 2007, pp. 599–604.
[3] J. Moran and R. Desimone, “Selective attention gates visual processing in the extrastriate cortex,” *Science*, vol. 229, no. 4715, pp. 782–784, 1985.
[4] C. J. McAdams and J. H. Maunsell, “Effects of attention on orientation-tuning functions of single neurons in macaque cortical area v4,” *The Journal of Neuroscience*, vol. 19, no. 1, pp. 431–441, 1999.
[5] J. H. Maunsell and S. Treue, “Feature-based attention in

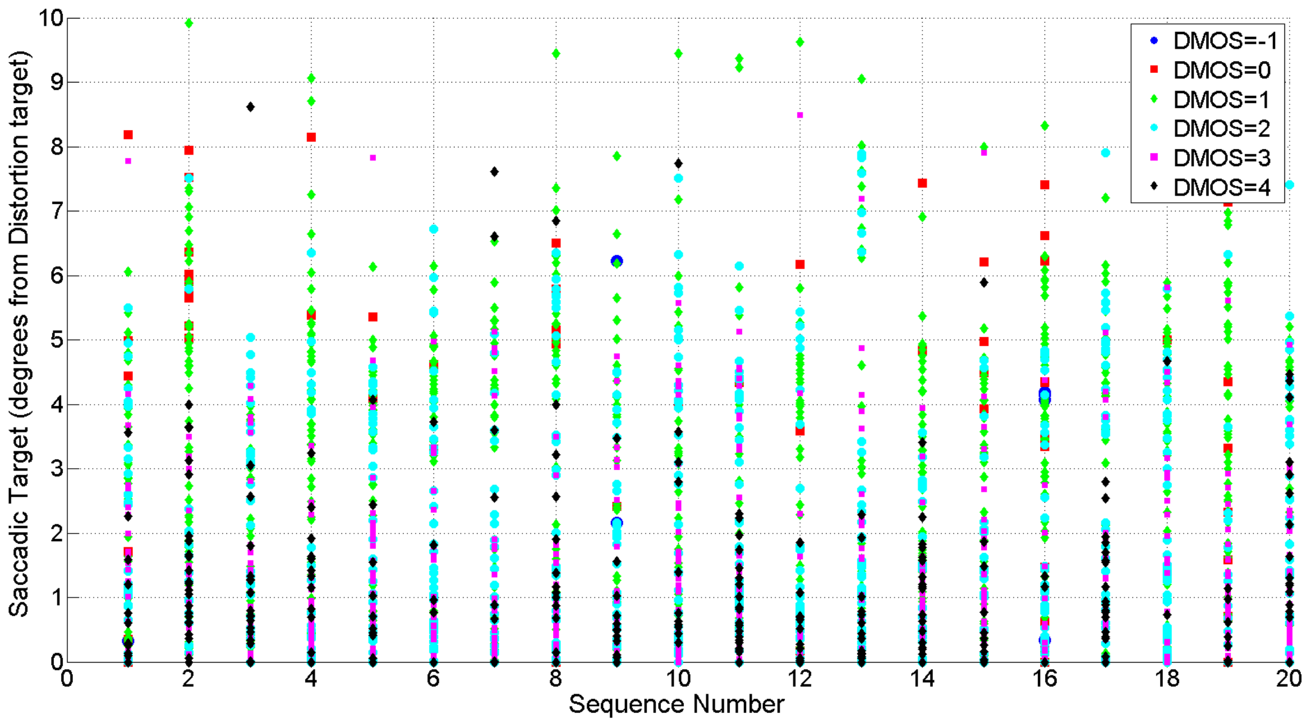

Figure 5: Difference opinion scores plotted as a function of the Saccadic Target length for each of the twenty sequences. While smaller saccadic targets implies high disruption, larger values indicate little/no disruption. We clearly see that disrupted observers often tend to reduce the score much more than undisturbed observers.

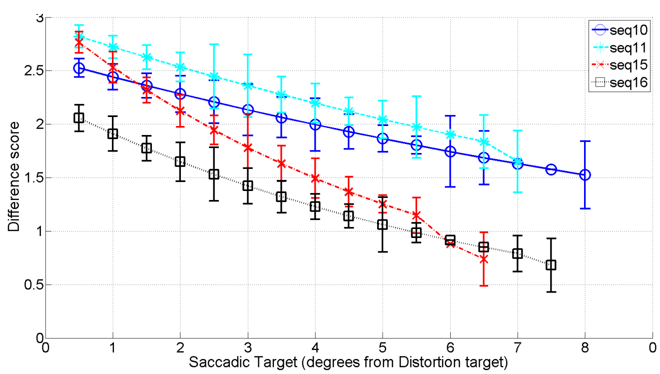

Figure 6: Exponential fitted curves that show the fall in difference score with saccadic targets (along with the resp. confidence intervals) for each of the sequences. Sequence 10 containing a high amount of motion and Sequence 11 containing a dark background show unique fall-off characteristics

visual cortex," *Trends in neurosciences*, vol. 29, no. 6, pp. 317–322, 2006.

[6] J. Braun and B. Julesz, "Withdrawing attention at little or no cost: detection and discrimination tasks," *Perception & Psychophysics*, vol. 60, no. 1, pp. 1–23, 1998.

[7] D. K. Lee, L. Itti, C. Koch, and J. Braun, "Attention activates winner-take-all competition among visual filters," *Nature neuroscience*, vol. 2, no. 4, pp. 375–381, 1999.

[8] J. H. Reynolds, T. Pasternak, and R. Desimone, "Attention increases sensitivity of v4 neurons," *Neuron*, vol. 26, no. 3, pp. 703–714, 2000.

[9] U. Engelke, H. Kaprykowsky, H. Zepernick, and P. Ndjiki-Nya, "Visual attention in quality assessment," *Signal Processing Magazine, IEEE*, vol. 28, no. 6, pp. 50–59, Nov 2011.

[10] H. Boujut, J. Benois-Pineau, T. Ahmed, O. Hadar, and P. Bonnet, "A metric for no-reference video quality assessment for hd tv delivery based on saliency maps," in *2011 IEEE International Conference on Multimedia and Expo*, July 2011, pp. 1–5.

[11] H. Liu and I. Heynderickx, "Visual attention in objective image quality assessment: Based on eye-tracking data," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 21, no. 7, pp. 971–982, July 2011.

[12] H. Alers, J. A. Redi, and I. Heynderickx, "Quantifying the importance of preserving video quality in visually important regions at the expense of background content," *Signal Processing: Image Communication*, vol. 32, pp. 69–80, 2015.

[13] W. Zhang, A. Borji, Z. Wang, P. L. Callet, and H. Liu, "The application of visual saliency models in objective image quality assessment: A statistical evaluation," *IEEE Transactions on Neural Networks and Learning Systems*, vol. 27, no. 6, pp. 1266–1278, June 2016.

[14] S. R. Gulliver and G. Ghinea, "A perceptual comparison of empirical and predictive region-of-interest video," 2009.

[15] Y. Rai, P. Le Callet, and G. Cheung, "Role of hevc coding artifacts on gaze prediction in interactive video streaming systems," in *Image Processing, 2016. ICIP 2016. IEEE International Conference on*, vol. 2. IEEE, 2016, pp. II–169.

[16] W. S. Geisler, J. S. Perry, and J. Najemnik, "Visual search: The role of peripheral information measured using gaze-contingent displays," *Journal of Vision*, vol. 6, no. 9, pp.

1–1, 2006.

[17] L. Pomarjanschi, M. Dorr, P. J. Bex, and E. Barth, *Simple gaze-contingent cues guide eye movements in a realistic driving simulator*, 2013, vol. 8651.

[18] M. G. Albanesi and R. Amadeo, "A new algorithm for objective video quality assessment on eye tracking data," in *Computer Vision Theory and Applications (VISAPP), 2014 International Conference on*, vol. 1, Jan 2014, pp. 462–469.

[19] O. Le Meur, A. Ninassi, P. Le Callet, and D. Barba, "Do video coding impairments disturb the visual attention deployment?" *Signal Processing: Image Communication*, vol. 25, no. 8, pp. 597–609, 2010.

[20] F. Boulos, W. Chen, B. Parrein, and P. L. Callet, "A new h.264/avc error resilience model based on regions of interest," in *2009 17th International Packet Video Workshop*, May 2009, pp. 1–9.

[21] U. Engelke, M. Barkowsky, P. Le Callet, and H.-J. Zepernick, "Modelling saliency awareness for objective video quality assessment," in *International Workshop on Quality of Multimedia Experience (QoMEX)*, 2010.

[22] M. C. Potter, "Short-term conceptual memory for pictures." *Journal of experimental psychology: human learning and memory*, vol. 2, no. 5, p. 509, 1976.

[23] Z. Wang, A. C. Bovik, H. R. Sheikh, and E. P. Simoncelli, "Image quality assessment: from error visibility to structural similarity," *IEEE Transactions on Image Processing*, vol. 13, no. 4, pp. 600–612, April 2004.

[24] H. R. Sheikh, A. C. Bovik, and G. de Veciana, "An information fidelity criterion for image quality assessment using natural scene statistics," *IEEE Transactions on Image Processing*, vol. 14, no. 12, pp. 2117–2128, Dec 2005.

[25] K. Egiazarian, J. Astola, N. Ponomarenko, V. Lukin, F. Battisti, and M. Carli, "New full-reference quality metrics based on hvs," in *CD-ROM proceedings of the second international workshop on video processing and quality metrics, Scottsdale, USA*, vol. 4, 2006.

[26] M. Pinson and S. Wolf, "A new standardized method for objectively measuring video quality," *Broadcasting, IEEE Transactions on*, vol. 50, no. 3, pp. 312–322, Sept 2004.

[27] O. L. Meur and Z. Liu, "Saccadic model of eye movements for free-viewing condition," *Vision Research*, vol. 116, Part B, pp. 152 – 164, 2015, computational Models of Visual Attention. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0042698915000504

[28] W. Wang, C. Chen, Y. Wang, T. Jiang, F. Fang, and Y. Yao, "Simulating human saccadic scanpaths on natural images," in *Computer Vision and Pattern Recognition (CVPR), 2011 IEEE Conference on*. IEEE, 2011, pp. 441–448.

[29] Y. Rai, G. Cheung, and P. Le Callet, "Quantifying the relation between perceived interest and visual salience during free viewing using trellis based optimization," in *Image, Video, and Multidimensional Signal Processing, 2016 International Conference on*, vol. 9394, July 2016.

Author Biography

Yashas Rai received his B.Eng degree from the Visvesvaraya Technological University in India and M.Sc from the RWTH Aachen University in Germany where he studied under the RWTH-Synopsys Ltd joint scholarship. He has been involved in pattern recognition and image understanding starting from the days of his bachelor thesis in which he investigated the application of learning algorithms for Iris recognition systems. At the small town of Aachen in Germany he also worked for a Computer Vision startup during his free time, developing algorithms that helped in the recognition of human hand gestures. At about the same period, he also performed his Master Thesis at the RWTH Aachen University which focused on the latest video coding standard- H.265 more specifically- Scalable Video coding. Further, he continued his work at the Ericsson Video Research Lab in Sweden analyzing a close competitor to the former video coding technology that was called H.265 Transcoding. Yashas now works at the IRCCyn Lab at the University of Nantes as an ESR, developing new metrics and algorithms to evaluate Short term video quality.

Patrick LE CALLET is currently full professor at Ecole polytechnique de l'université de Nantes. He has teaching as an Assistant professor from 1997 to 1999 and as a full time lecturer from 1999 to 2003 at the department of Electrical engineering of Technical Institute of University of Nantes (IUT). Since 2003 is teaching at Ecole polytechnique de l'université de Nantes (Engineer School) in the Electrical Engineering and the Computer Science departments. In 1997, he joined the Image and VideoCommunication group at CNRS IRCCyN. Since 2006, he is the head of this group that includes 9 permanent professors, 16 post doc and PhD students and 5 research engineers. He has coordinated and is currently managing for IRCCyN several National or European collaborative research programs representing grants of more than 3 millions US dollars (JEDI on 3DTV, HD4U on HDTV, Scalimages on H264 SVC, SVC4QoE on the scalability management using ad hoc quality assessment tools, Futurimages on HDR Image rendering and autosteroscopic TV, Safimages on content traceability over Internet, TSAR on storage and distribution of High Resolution cultural heritage paintings, Equimose on quality of experience related to medical Imaging and PACS systems). Moreover, he is supervising several research contracts with companies such as Orange labs or Thomson Corporate Research.