MediaEval 2013 Visual Privacy Task: Holistic Evaluation Framework for Privacy by Co-Design Impact Assessment

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ABSTRACT
In this paper, we describe a privacy filter proposed for the Visual Privacy Task (VPT) 2013, as a case study to validate the efficacy of the User-Intimate Requirements and Evaluation Methodology (UI-REF). This comprises an automated objective evaluation phase supported by a subjective user study to cross-validate and complement the results of the objective assessment. The performance of the proposed filter, as well as the overall performance trends and tradeoffs of the alternative filtering techniques are highlighted. The results demonstrated the consistency and high resolution evaluation capabilities of the Holistic Evaluation Framework for Privacy by Co-Design and Impact Assessment for benchmarking privacy filtering solutions.

Keywords
Video Privacy, Privacy Protection, Video Analytics, Filtering, Evaluation Framework, Privacy Impact Assessment, UI-REF

1. INTRODUCTION
A variety of image processing techniques have been proposed to mitigate privacy protection failure risks. These video privacy filtering approaches have essentially applied filtering techniques to obscure the privacy-sensitive parts of the captured video; in a similar way as the established practice in the film and television sector. The trade-off between the levels of masking, and, the informativeness of a video image means that naïve deployment of such privacy filters could lead to video surveillance systems that are potentially ineffective in either adequately protecting the privacy of the citizen or in retaining the essential information for the intended security monitoring in the given situation. Thus, systematic and comprehensive evaluation of the privacy filtering solutions is necessary. Many reported attempts at evaluating the performance and impact of privacy filtering have adopted a relatively limited analysis perspective. The VPT2013 task evaluation methodology has responded to the need for a more inclusive, holistic and high resolution assessment of privacy filtering requirements as well as the evaluation of the efficacy and impacts of the resulting privacy filtering solutions based on the UI-REF methodology [1]. The PEViD dataset [2] was used for the impact assessment of alternative privacy protection solutions.

2. THE PROPOSED FILTER
As a case study, we proposed a privacy filter that could be applied automatically to CCTV video feed. This aimed: **i)** to preserve maximum privacy (anonymity) by applying the filter to the foreground regions including the human body, and, **ii)** to retain the non-privacy-sensitive information so as to deliver some surveillance value (intelligibility); **iii)** to minimise the potential viewer's distraction and annoyance caused by the deployed privacy filter. The sections below describe the steps.

2.1 Object segmentation
To meet the first requirement, the privacy filter was applied to the subject region within the scene. A state-of-the-art object segmentation algorithm as described in [3] was used in order to obtain the initial foreground mask followed by morphological operations to smooth it further. The generated mask has been used as a basis for privacy filter applications.

2.2 Transform domain scrambling
To hide the details of the appearance of the viewed subject, a Discrete Cosine Transform (DCT) was applied over each 8x8 sub-block of the subject bounding box. Then the sign was flipped for four (4) coefficients selected randomly within the first five (5) DC coefficients of one of the colour channels. In a second pass, a median blur filter was deployed to mitigate the scrambling distortion effect.

2.3 Edge detection
A Sobel filter was applied to the human figure to outline the strong edges using the saturation component of the HSV colour space. The saturation channel was chosen as it yields good contrast under all lighting conditions as well as preserving the outline edges. The edges were thresholded and attenuated by modulating their pixel value by the inverse of the squared distance to the centre, keeping only the strongest central ones.
The results of the scrambling and edge detection were applied to the subject mask area and then blended into the original image with a radial attenuation so as to prevent the occurrence of highly visible and irritating edges around the filtered areas of the video. Figure 1 shows the output of the proposed approach.

Figure 1: Outputs of the proposed filter

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3. THE EVALUATION FRAMEWORK

The objective and subjective evaluation criteria were based on the UI-REF Co-design, Evaluation and Impact Assessment Methodology [1, 4, 5]. A subset of the Key Performance Indicators (KPIs) was deployed from: Efficacy, Consistency, Intelligibility, Disambiguity, Aesthetics (structural, textural, tonal, harmony and symmetry maps), Selectivity, Sensitivity, Computational efficiency, real-time Web-Scalability and Vulnerability to attack. Subjective evaluation was based on UI-REF Quality-of-Experience, Effects, Side-Effects and Affects.

3.1 Objective evaluation

The objective criteria to assess the optimality of the balance of privacy protection and security assurance as may be offered by a given privacy filtering solution were defined as follows:

(1) Intelligibility: The post-privacy-filtering consistency, visual tracking, and persistence matching levels of subsequent states.

(2) Privacy: The post-privacy-filtering capability to prevent the evaluator from detecting/re-identifying any face/person.

(3) Appropriateness: Pre-versus-post filtering colour histogram and visual effects comparison; the structural similarity (SSIM) index was used to assess the filter performance suitability.

3.2 Subjective evaluation

A user study was conducted to complement and cross-validate the results of the objective test. The questionnaire probed for the Likert-Scale based assessment of the same KPIs as the above.

(1) *Intelligibility*: The activities seen in the scene post-filtering, users' confidence levels re this; the informativeness of the video.

(2) *Privacy*: The post-filtering level of distinguishability of the gender, ethnicity and personal accessories - as person identifiers.

(3) *Appropriateness*: The perceived level of pleasant and blended visual effects as seen by users -pre-versus-post-privacy-filtering.

4. EVALUATION RESULTS

This section provides the evaluation results of the proposed filter plus an overview of the performance trends in VPT 2013. The reported results of the objective test are the average score of eleven (11) videos which were objectively evaluated in terms of the defined criteria. Figure 2, shows the performance of the proposed filter as markedly above the average of all VPT 2013 submitted solutions for the *Intelligibility* and *Appropriateness* criteria. As for *Privacy*, the proposed filter performed below the average score. This was partially because a few submissions were strong filters in which the other criteria were compromised to achieve higher privacy. However, the overall trends across all the alternative privacy filtering solutions emphasised the trade-off between the *Intelligibility* and *Privacy* as well as showed a direct relationship between *Intelligibility* and *Appropriateness*. The subjective study involved over sixty (60) participants who were equally distributed to examine five (5) videos of each of the submissions. Figure 3 depicts the subjective performance of the proposed filter under this evaluation; the corresponding objective and subjective evaluations are almost completely consistent; thus cross-validating the UI-REF based assessment.

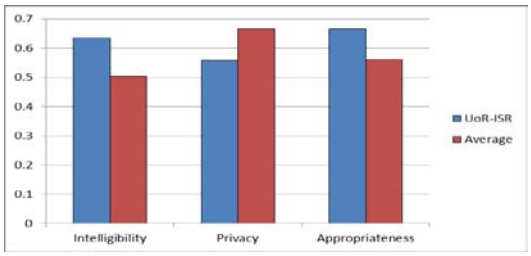

Figure 2: Objective evaluation scores vs. average

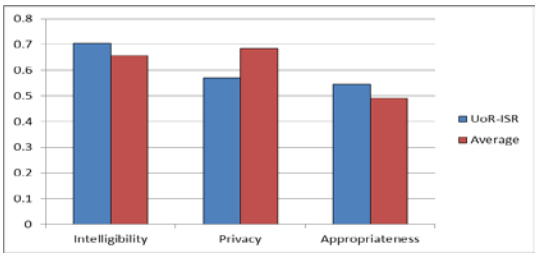

Figure 3: Subjective evaluation scores vs. average

5. CONCLUSION

This paper has proposed a video privacy filter using a transform domain scrambling method and edge detection; to achieve the highest privacy with minimum content distortion and viewer distraction. The UI-REF based Holistic Evaluation Framework has deployed a sub-set of its KPIs to provide an integrative and consistent set of objective and subjective assessment criteria with demonstrated consistency. This has built on a similar approach as for VPT 2012; the successful deployment of this framework motivates further innovation in assessment metrics for evaluation of privacy-filtering and risk mitigation technologies.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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