

MediaEval 2013 Visual Privacy Task: Physics-Based Technique for Protecting Privacy in Surveillance Videos

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ABSTRACT

This paper describes a physics-based technique for protecting the privacy of people in videos as defined by the MediaEval 2013 Visual Privacy task. We propose a physics-based approach which estimates the full spectrum of the surface spectral reflectance from the video. Whereby the wavelength which corresponds to the global minimum of the spectral curve (an intrinsic feature of the material) at a pixel is calculated and converted to RGB values which are used to filter pixels that belong to a moving object. This effectively implements visual privacy protection by replacing foreground pixel colour by another which is related to intrinsic optical properties of the original pixel. Both objective and subjective evaluations are performed using both video analytics algorithm and user studies in order to evaluate the proposed technique.

1. INTRODUCTION

While advances in surveillance technologies are generally welcomed by employers, there is a growing sense of unease amongst academics, employees and interest groups as to the ethical boundaries that such technologies may cross [1]. There is a concern that new technologies will leave people under surveillance open to abuse and discrimination. In addition to this, video surveillance represents a threat to individuals' privacy and dignity [2]. Social scientists started more than two decades ago, a discussion about the implications of video surveillance and the privacy of people under surveillance [3].

The Visual Privacy task focuses on the problem of privacy protection in video surveillance, aiming to find new technologies to ensure an appropriate level of privacy protection [4].

In this challenge, we propose a physics-based technique to protect privacy in surveillance videos. Privacy protection approaches may be classified depending on the image representation used as physics-based or non-physics-based. Non-physics based approaches use one of the known colour spaces, with no explicit physics underpinning, as a cue to model the object. The word physics refers to the extraction of intrinsic features about the materials contained in the object based on an understanding of the underlying physics which govern the image formation. This process is achieved by applying physics-based image formation models which attempt to estimate or eliminate the illumination and/or the geometric parameters in order to extract information about the surface reflectance.

Conventional video cameras, analogous to a retina, sense reflected light so that colour values are the integration of the product of incident illumination power spectral distribution, object's surface

spectral reflectance and camera sensors sensitivities. Humans have the ability to separate the illumination power spectral distribution from the surface spectral reflectance when judging object appearance, such ability is called colour constancy [5].

2. SYSTEM DESCRIPTION

Our proposed privacy-protection technique consists of two steps. First, a change detection step segments moving objects (the foreground). Second, a filter changes foreground pixels, so as to achieve visual privacy, by converting the surface spectral reflectance at these pixels into RGB values as perceived by humans.

2.1 Change Detection

Spectral-360 [6], a novel change detection algorithm has been used. The algorithm uses colour constancy techniques to computationally estimate a consistent physics-based colour descriptor model of surface spectral reflectance from the video and then to correlate the full-spectrum reflectance of the background and foreground pixels to segment the foreground from a static background. The rationale behind this approach is that the segmentation between foreground and background objects can be done through the matching between the surface spectral reflectance over the visible wavelengths of a reference background frame and each new frame. The challenge of this approach arises from the new idea of processing the full-spectrum of the surface spectral reflectance instead of the three samples used by other colour spaces. The spectral representation uses a linear model, which consists of a number of basis functions (pre-trained from a set of materials) and weights (calculated for the object under investigation). A numerical estimation of the physics-based model for image formation and the real-time transformation from the video to the physical parameters is carried out.

2.2 Privacy Filter

In order to build a computational physical model, the illumination is estimated by segmenting areas in the image which represent high specularities (highlights); McCamy's formula [7] is then applied and the correlated colour temperature is calculated. The illumination spectral power distribution is then calculated using Plank's formula [5]. Using the dichromatic model, and by assuming diffuse-only reflection and the existence of a dominant illuminant, the surface spectral reflectance is then recovered. The wavelength that corresponds to the global minimum of the surface spectral reflectance is then calculated and converted to RGB values as perceived by humans.

Figure 1, shows the recovered surface spectral reflectance for one pixel for the foreground and the background as well as the corresponding RGB value of the foreground surface spectral reflectance global minimum. The rationale behind this approach is that the global minimum of the surface spectral reflectance represents an intrinsic feature of the material. This would allow objects such as the face to be easily segmented and filtered.

3. RESULTS

The resulting filtered videos have been evaluated using both objective and subjective procedures. The objective metrics compare each pair of original and filtered video in terms of: face detection accuracy, human body tracking accuracy, image quality metrics [4].

Table 1 provides the average objective evaluation values for the videos analyzed. The subjective evaluation, shown in Table 2, provides a measure for the protection of privacy of individuals, intelligibility of activities recorded and the visual appropriateness.

As a whole, our technique shows a high degree of privacy, and an average level of intelligibility, but low level of visual appropriateness. The visual appropriateness of our proposed filter can be adjusted for future improvement.

4. CONCLUSIONS

This paper argues that image formation models offer interesting new alternative physics-based cues for privacy protection compared with other representations. Features such as surface spectral reflectance have not been applied yet in the field of privacy protection. The reason is the computational complexity of such models, and hence possible unfeasibility of real-time implementation. This challenge was tackled, firstly, by choosing an appropriate reflection model, the dichromatic reflection model. Secondly, by setting a feasible set of assumptions for such model which best match the reduction of model complexity and does not contradict with real-world operational conditions. In this paper we have proposed a physics-based approach which segments the moving objects and then estimates the full spectrum of surface spectral reflectance from the video, where the wavelength that corresponds to the global minimum is calculated and converted to RGB values as perceived by humans. This effectively replaces foreground pixel colours by others, as a simple privacy protection mechanism. Our ongoing work is investigating enhanced pixel replacement schemes, beyond the obfuscation mechanism described here, so as to protect privacy while minimizing the change of the semantic content of the image.

Table 1. Objective evaluation

Team: CISS ¹	Our Score	Average (9) Score
Intelligibility	0.453317	0.502378
Privacy	0.812541	0.664903
Appropriateness	0.284307	0.560480

Table 2. Subjective evaluation

Team: CISS	Our Score	Average (9) Score
Intelligibility	0.561667	0.655741
Privacy	0.790000	0.683843
Appropriateness	0.304167	0.492130

¹ Centre for Information, Intelligence and Security Systems (CISS)

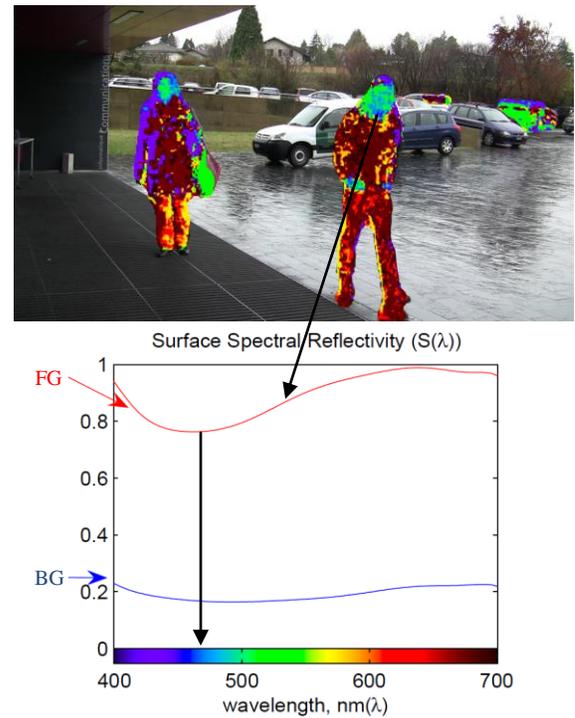


Figure 1. Reconstructed Surface Spectral Reflectance for one pixel, Foreground (FG) and Background (BG).

5. REFERENCES

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