Using 2D Image Composition to Model and Evaluate Soldier Camouflage in the Visible Wavelengths

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Abstract

The development and evaluation of camouflage systems is usually very time-consuming. Any evaluation that could be done using simulation prior to a field deployment would significantly shorten the development cycle. One could for example use simulation to evaluate the effectiveness of a new concept soldier camouflage pattern within a specific environment without having to print and manufacture sample uniforms. We present a 2D image composition simulator to do exactly this. If one assumes a diffuse material bidirectional reflectance distribution function then the target to be camouflaged may be used as a diffuse light probe that adequately captures the direct and diffuse scene lighting. The simulator results are visually very close to the photographs of reference uniforms. The remaining discrepancies between the simulation results and the validation references do however show that the material BRDF is not perfectly diffuse and that the point spread functions of the camera and fabric printing process still need to be taken into account.

1. Introduction

The development of camouflage systems can become quite expensive if one has to do pairwise comparisons or probability of detection evaluations of many concept camouflage patterns using only field exercises. The majority of evaluation strategies are based on the Law of Comparative Judgement, sliding scale methods, probability of detection [Peak 2006] methods and the Analytical Hierarchy Process [Baumbach 2008]. If one does not make use of simulation then all of these evaluation strategies involve the set up of multiple field scenarios in the environment under consideration, with manufactured camouflage systems and groups of observers to evaluate each system in each scenario.

Any evaluations that could be done using simulation prior to a field deployment would therefore significantly shorten the development cycle. We present a camouflage simulator based on a 2D image composition approach to do exactly this for the design of soldier camouflage in a bushveld environment. The simulator digitally paints a concept camouflage pattern onto a target in a 2D background scene.

2. The Simulation Method

The simulation method includes a background measurement process, a background and digital camouflage pattern calibration process and a 2D image composition process.

2.1 The Background Measurement Process

It is important to note that the background scene must already contain the target to be digitally camouflaged as shown in Figure 1. To ease the calibration of the measurement process the target to be camouflaged must be of a grey colour with a known CIELAB lightness (L*) value and a standard colour reference should be included in the background photo. In order to minimise compression errors and approximations it is preferable to use a camera that can output images in a raw format (such as Nikon's .NEF format).

If one assumes a diffuse material Bidirectional Reflectance Distribution Function (BRDF) and isotropic scene lighting (identical upwelling and downwelling scene illumination) then the grey target adequately captures the direct and diffuse scene lighting. In other words, one could use the colour and lightness of the target to modulate the applied digital camouflage pattern without the need to consider the scene and local target geometry.

2.2 The Background and Digital Camouflage Calibration Process

The colour reference should be located near the target and we use a standard Macbeth ColorChecker. In this version of the simulator we use the colour reference only to white balance the raw (.NEF) background image and it is of course important to use a reference grey in the colour reference which is not overexposed. We make use of the open source image editor Gimp, which has a UFRaw plugin that allows one to white balance on a colour sample from the raw image. Once the background is white balanced the target to be camouflaged is also assumed to be grey i.e. to have a* and b* values of zero.

To calibrate the concept camouflage pattern the CIELAB values of each colour used in the pattern are measured from test prints or colour references. We do the measurements under the standard illuminant C using a Konica Minolta CECF-9 Color Reader. The digital pattern is then re-coloured with the measured CIELAB colours. We use Photoshop to convert the CIELAB camouflage pattern to the Red, Green and Blue (RGB) colour space (under the D50 standard daylight illuminant) for use by the 2D image composition process.

2.3 The 2D Image Composition Process

A simulator, using the MATLAB scripting language, has been developed to automate the 2D image composition process. Once the background is white balanced the target is assumed to be grey and may be used to modulate the camouflage colour to be applied to the target without the need for further colour calibrations or corrections.

A simple heuristic is used to automatically isolate the grey uniform from the background scene. The heuristic makes use of the assumption that colours in the bushveld environment is more green and red than blue. Note that the heuristic therefore fails for background images that also contain sky, but if the user selects a target bounding box then this limitation could be overcome.

The grey uniform's pixel brightness is used to modulate the RGB colour of the concept camouflage according to :

$$RGB = \mu \frac{100}{L^*_{Uniform}} RGB_{Camou} ,$$

where RGB_{Camou} is the colour of the digital camouflage pattern and μ is the pixel brightness in [0.0 ,1.0] of the grey coloured target to be camouflaged. Although the image composition process is a simple 2D overlay of the concept camouflage pattern on the target, the shading information provided by the grey uniform creates the illusion of 3D camouflage.

3. Results

Figure 1 shows the CamouSim GUI and Figure 2 shows an example simulation scenario and concept pattern. Figure 3 shows a side by side comparison of the concept patterns and reference uniform prints.

In the middle pane of Figure 3 the virtual camouflage on the left matches the reference image on the right well on the shoulders, but not so well on the soldier's back. Also, in the rightmost pane of Figure 3 the virtual camouflage pattern on the left-hand soldier is much sharper than the reference pattern on the right-hand soldier. This is because we have not taken the material BRDF and the Point Spread Functions (PSFs) of the camera and camouflage printing process into account.

4. Conclusion

We have shown that colour matched results can be achieved when designing the camouflaged patterns in the measured CIELAB colours using the target as a light probe.

From the results and from recent BRDF measurements it is clear that the material does not have a diffuse BRDF. There is in fact a much larger Fresnel reflection component than we originally considered. It is also clear that we still need to take the PSFs of the camera and fabric printing process into account when applying the concept pattern to the grey target.

Acknowledgements

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References

Baumbach, J. 2008. Using the analytical hierarchy process to evaluate target signatures. In Land Warefare Conference 2008*, Proceedings*, ed. by V. Puri and D. Filippidis. Brisbane Convention Centre, Australia, 29-34.

Peak, J.E. 2006. *Guidelines for Camouflage Assessment Using Observers*. The Research and Technology Organisation (RTO) of NATO.

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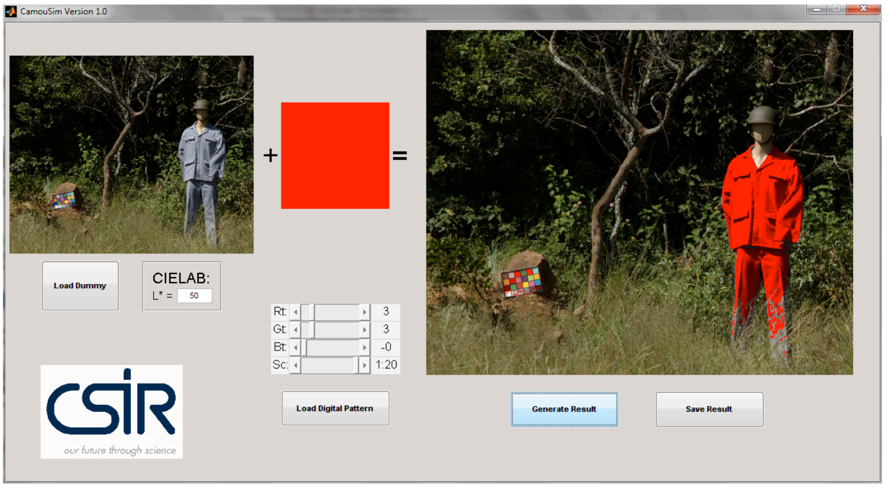

Figure 1. CamouSim GUI with red camouflage pattern to demonstrate the image composition.

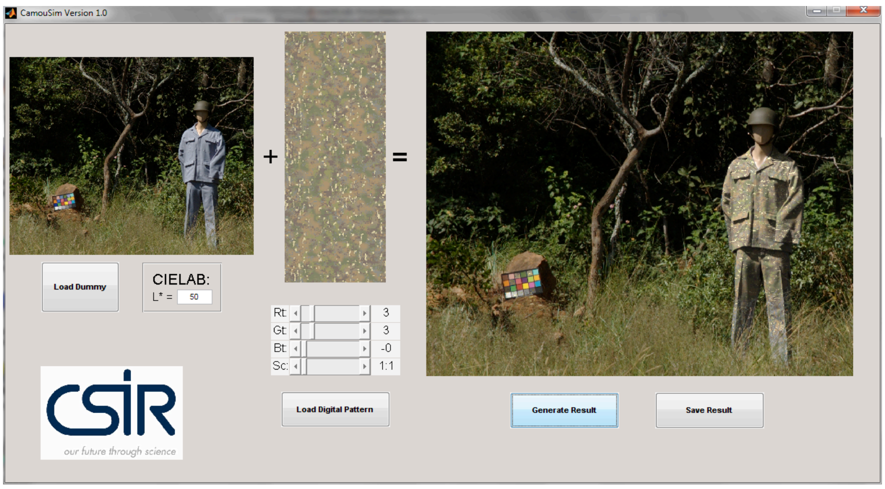

Figure 2. Demonstration of CamouSim with an example concept pattern.

Figure 3. CamouSim results. (Left: Input image with validation reference; Middle&Right: Virtual camouflage on left compared to validation reference on right.)