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HDR Images from Photos of Car Paint with Sparkling Effect

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Abstract

High dynamic range (HDR) photos created by conventional photo camera is a promising tool for a sparkling visualization. We investigate and propose a technique to generated HDR images of car paint from near focus photos. Our setup is good for clear reconstruction of sparkling effect. Reconstructed HDR images are then visualized with different tonemapping operators or directly shown on a HDR display. Our observations show that Mantiuk's or Reinhard's operator is sufficient tool for sparkling visualisation on LDR monitors.

Keywords: HDR, Car paint

1 Introduction

High Dynamic Range is set of techniques to capture greater dynamic range (ratio between bright and dark regions) of exposure than normal imaging technique. While with classic photo technique we can capture only limited dynamic range, HDR can be created as composition of images with various dynamic range that represents wide range of intensity found in real world.

Car paint with sparkling effect contains great amount of very small particles, tiny mirrors, that in different light conditions reflects light in various intensity. Image consists of dark, bright areas and very bright dots that often cover a spherical angle less that $1°$. We use composition of 3 images with different exposure settings to create HDR image.

The aim of this paper is to enhance the capturing techniques of sparkling effects for the purpose of reproduction of the sparkle appearance in car paints. The closest work to ours is [Durikovic 2002], but unlike to our work, this approach explicitly modeled the particles with a triangular mesh. [Ershov et al. 1999; Ershov et al. 2001] introduced a surface model for pearlescent paint that includes sparkling effects based on a statistical approach for static scenes. The camera setup with settings is described in Section 2. Next section describes the composition technique of captured photo images and the parameter setting of response curve for best sparkle capture. As discussed in Section 4 the sparkle visualization on HDR monitors was disappointing and the following section describes the visualization on conventional monitors with comparison of different tone mapping operators. The results are concluded in final section.

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2 Exposition

Creating photographs of car paint with sparkling effect with different exposure presets is very sophisticated process. Single car paint consists of layers with embedded particles. As top layer is very glossy, it could be hard to capture the scene without reflection of illuminators. Distinct feature of modern car paint is that it is orientation dependent. When turned around, different sparkles begin to sparkle. This effect is caused by random orientation of sparkles in car paint. During HDR image capturing it is needed that individual photos capture the same scene, that means the same set of sparkles should be illuminated. Otherwise the resulting image will be blurred. This can happen even when camera slightly moves by touching.

Paint particles are very small, hence we use camera with high resolution to gain high quality of each photo. To achieve very detailed photo we use macro lens and to avoid reflection of light flash from top layer, we will use macro flash. Of course a remote switch will prevent camera movements.On figure 1 is the whole configuration which consists of Canon 30D, Canon EF-S 60mm Macro USM lens, Canon Macro Twin Lite MT-24EX flash and remote switch, was arranged upright to car paint at a distance $10 - 15$ centimeters.

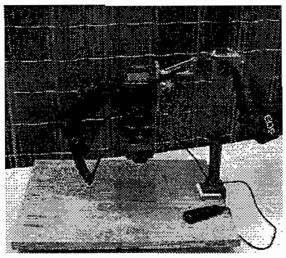

Figure 1: Camera configuration: Canon 30D, Canon EF-S 60mm Macro USM lens, Canon Macro Twin Lite MT-24EX flash and remote switch.[Svirec 2008]

The first camera setting need to be set is aperture. With low aperture number picture is unsatisfactory, because the outer part of photo will be blurred. Sufficient setting for our purpose is $F16$. Shutter speed, second setting, is set to $1/15$ sec. To simplify shooting process and avoid camera shaking, we use remote shutter and set on flash AE bracketing, begin in -2 EV with 1 EV increment. This enable us to capture 3 pictures of same scene, each with different exposure setting, particular with -2 EV, 0 EV, 2 EV, as you can see on figure 2. While at HDR creating is possible to use various image formats, we store photos in RAW and JPEG with resolution 8 MPix.

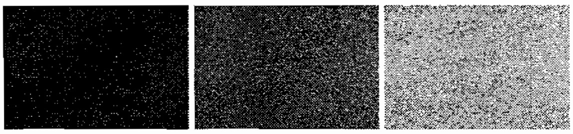

Figure 2: Images of same car paint with different exposure setting. From left to right: -2 EV, 0 EV, 2 EV

3 Creating HDR Images

For creating HDR images, we use the Open Source software Qtpfsgui [Rota], which dispose many additional options. The first advantage is capability to make HDR from different image formats. In our research we are making HDR from both formats we shoot, RAW and JPEG. To create result image properly it is important to set the exposure value for each photo to same value as it was shot (in our case it was -2 EV, 0 EV and 2 EV). Another part consists of HDR creating options, where individual options are camera response curve, weighting function and HDR creation model. Camera response curve is a curve showing the relation between amount of incoming light and image pixel values of a digital camera. When making HDR from RAW format data the response curve is linear, because RAW images contain linear sensor data. Next setting related to response curve is a Gamma parameter. The weighting function assigns a weight to all pixels (a value between 0 and 1 multiplied with the pixel value) it determines the trust of every pixel. In Qtpfsgui it is possible to set three different weighting functions: triangular, Gaussian and Plateu. Each function makes a bit different effect to final image. Last option, HDR creation model, has two possible values, Debevec model and Robertson model. We will use only Debevec's model.

At creating HDR images, we use the source photos in RAW and JPEG formats with different settings of weighting function and response curve. We compared the results from RAW and JPEG to find out which one reproduces the best sparkling effect and have the same color appearance as car paint sample. At first sight the best results has had images created with linear response curve and triangular weighting function. As best result in comparison between HDR images created from RAW and JPEG seems to be the image made from RAW. Careful investigation of HDR images from RAW data shows that various settings of weighting function and response curve have almost similar results, but we find out that darker samples had best results with different settings than brighter ones. Shown dark sample had the best result with triangular weighting function, on the other hand brighter sample best reproduces the HDR with Gaussian weighting function. As was mentioned above the response curve is set to linear when using the RAW format.

4 Sparkles on HDR Monitor

All this research was made on LDR monitor, so we can't see all the visual information that HDR could interpret. We observer the HDR images of car paints with strong sparkling on HDR monitor. We use the BRIGHTSIDE^{TM} HDR display for this project. It is a 18-inch LED-based HDR monitor, and its luminance range is $0.05-3000$ cd/m^2. By limiting its maximum and minimum luminance values, we can simulate the broad range of conventional displays. We found out that image was brighter and also highlight got much brighter comparing to conventional monitors, unfortunately, there was still not enough dynamic range to see details in the highlight and sparkles. We could not get to the point that the image looked well exposed and highlight looked realistic. Regarding this finding, we tried tonemapping to Low Dynamic Range (LDR) as another alternative to processing the HDR result.

5 Sparkle Visualization - Tone Mapping

While HDR display is not good for rendering sparkling effect, we want to find out which tonemapping operator is good enough for rendering sparkling effect in LDR. Software Qtpfsgui offers the most known operators developed by Mantiuk, Fattal, Drago, Durand, Reinhard, Ashikhmin.

First operator we tried was gradient domain operator [Fattal et al. 2002]. We believed in local enhancement of sparkle luminance according to sharp gradient changes near the sparkle. The algorithm manipulates the gradient field of the luminance image by attenuating the magnitudes of large gradients. Smaller details are amplified thus becoming more evident. This operator has 2 main parameters, α and β. Parameter α is the threshold, with the meaning the details whose luminance derivative is less than α are amplified, those whose derivative is greater than α are decreased. We used default value of this parameter, which was 0.1. Second parameter β expresses how much the algorithm will be effective. Setting $\beta = 1$, the algorithm will perform no operation on the HDR, and there will be only a linear shrink of the dynamics. Decreasing β will increase the effectiveness of the algorithm, in other words you will increase the compression of the dynamics making the details much more evident. Default value of this parameter is 0.8, but with this value resulting image has the blurred areas. Figure 3 shows the tonemapped HDR image and Figure 4 the marked blurred area with red line.

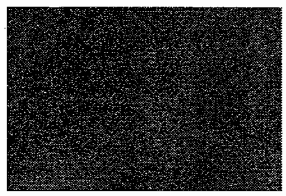

Figure 3: Tonemapped HDR image with gradient domain operator. Parameter $\alpha = 0.1$, $\beta = 0.883$.

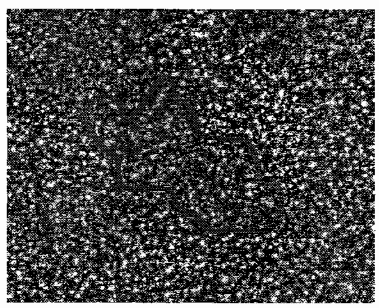

Figure 4: Detail of the blurred area in tonemapped image with gradient domain operator.

Second operator is adaptive logarithmic mapping [Drago et al. 2003]. This algorithm is intended to imitate the human eye's response, and is useful when a true tone result is desired. It is a global spatially uniform operator. At the beginning, it calculates the average luminance of the image and, using this value and the external parameter "bias", it creates a non-linear logarithmic function that is applied to each pixel separately, without considering the neighboring pixels. This operator isn't very good for our purpose because details are not amplified more than other parts of the image. Result on figure 5 was blurred and even the color appearance wasn't the same as original car paint sample has.

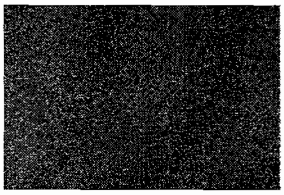

Figure 5: Tonemapped image generated with adaptive logarithmic mapping. Only one parameter bias was set on 0.85.

Next operator is a tone mapping algorithm for high contrast images [Ashikhmin 2002]. The operator is performed in three steps. First, it estimates the local adaptation luminance at each point in the image. Then, a simple function is applied to these values to compress them into the required display range. Since important image details can be lost during this process, algorithm reintroduces details in the final pass over the image. Resulting image shown on Figure 6 is better than image from Drago's operator, but because of resulting luminance of color, the tone mapped image isn't sufficient.

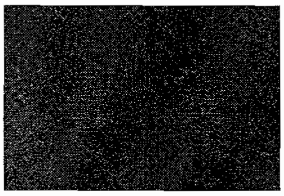

Figure 6: Ashikhmin's tone mapping algorithm with local contrast treshold set to 0.5.

Fast bilateral filtering [Durand and Dorsey 2002] is very popular tonemapping operator, because it produces most realistic images from HDR of classic outdoor scenes. This operator reduces the contrast while preserving detail. It is based on a two-scale decomposition of the image into a base layer, encoding large-scale variations, and a detail layer. Result in our testing on samples with sparkling effect was quite good as you can see on figure 7.

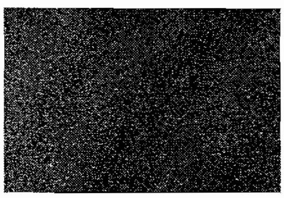

Figure 7: Fast bilateral filtering with default parameters: "spatial kernel sigma = 8", "range kernel sigma = 0.4", "base contrast = 5".

Dynamic range reduction [Reinhard and Devlin 2005] operator is a relatively simple algorithm with only minimum processing on the original image. Resulting color was almost gray-scale (figure 8) with this operator and its default parameters brightness, chromatic adaptation and light adaptation. Changing the parameters we couldn't reproduce the image with color information corresponding with the sample paint. On the other side, sparkling effect on this image was very good.

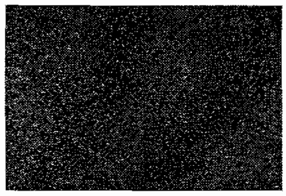

Figure 8: Reinhard's dynamic range reduction produced with brightness set on -10, chromatic adaptation set on 1 and light adaptation set on 1.

Another operator from Reinhard is a Photographic tone reproduction [Reinhard et al. 2002]. This algorithm is simple and produce very good results on our image sets. Color representation is better than in previous operators and sparkling effect is one of the best. Figure 9 is generated picture with only default parameters.

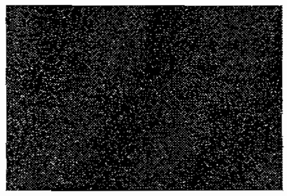

Figure 9: Image generated with Photographic tone reproduction, where "key value was 0.18" and $\phi = 1$.

The last operator is a Perceptual framework for contrast processing [Mantiuk et al. 2006]. Images are processed in a visual response space, in which contrast values directly correlate with their visibility in an image. This framework involves a transformation of an image from luminance space to a pyramid of low-pass contrast images and then to the visual response space. After modifying response values, the transformation can be reversed to produce the resulting image. To predict the visibility of threshold contrast, a transducer function was derived for the full range of contrast levels that can be found in High Dynamic Range images. Operator posses two parameters, contrast factor and saturation factor. We achieved best color information with saturation parameter set between 1.9 and 2.0. Sparkling effect was good enough when contrast factor was set on 1 (Figure 10).

Figure 10: Tonemapped image with perceptual framework for contrast processing. Contrast factor set on 1 and saturation factor on 1.9.

6 Conclusion

operator	summary
Fattal	This operator isn't good enought for sparkling effect, because of blurred area on whole image
Drago	Final image is blurred, color appearence isn't as original and dynamic range is small
Ashikhmin	Images produced from this operator was sharp enought, but dynamic range and color was insufficient
Durand	Color and sharpness was very good with this operator, but most of sparkles had medium lightness
Reinhard 2005	If the color wasn't grey-scale, this operator would be one of the most sufficient
Reinhard 2002	This operator is one of the best for sparkling effect. Color is similar to created HDR image.
Mantiuk	This is another sufficient operator for sparkling effect, color appearence is quite different from Reinhard's and images poses a bit less sharpness.

In this paper we have presented another method for sparkling effect visualization. We have found out that displaying generated images on HDR monitor is insufficient. Refereing to above table Reinhard's dynamic range reduction is the most suited tone mapping operator for visualization of sparkling effect on car paints captured by our photographic setup.

7 Acknowledgements

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