Image Generation of Night-Vision Goggles for Training in Flight Simulator

Alexander Chori
ITMO university
Saint Petersburg, Russia
alexandrchori@gmail.com

Vasili Kononenko
SimLabs LLC
Saint Petersburg, Russia
vasily.knk@gmail.com

***Abstract*—This paper proposes a framework for rendering scenes as they would be visible through a night-vision device. This framework takes into account the spectral characteristics of materials or lights and reproduces image artefacts such as bloom and eye adaptation.**

I. Introduction

Night vision goggles image generation is used mainly in two areas: games [1] and simulators. These areas differ in a way that games admit more artistic approach, and simulators aim for night-vision simulation to be as physically correct as possible.

One of the crucial things in night-vision simulation for simulators is the ability to reproduce all the effects and visual artefacts as they appear in real night-vision device [2]. It is important because, with an absence of these artefacts, the operator will not expect it to be in a real-world night-vision device thus making all the training with the simulator to be useless.

The main visible artefacts in night-vision goggles are:

- **bloom** – a halo appearing near bright objects (like lamps or automobile headlights), example depicted in Fig. 1
- **lack of contrast** and depth perception – due to much shorter dynamic range than a human eye, some colours that are distinguishable by the human eye, look almost identical through a night-vision device
- **eye adaptation** (also referred to as auto-exposure) – dynamically changing the brightness of a scene when an operator moves from dark to bright surroundings

II. Proposed Framework

Our approach consists of several components: extended scene colour representation, colour modifications to take device sensitivity into account and colour modifications to take visual artefacts into account.

We utilize an ACES [3] colour transformation workflow to build this framework. In this terminology, we suggest a pipeline that by IDT and ODT will output a night-vision goggles perceived image.

IDT is Input Device Transform – a transformation that takes device colour sensitivity into account. ODT is Output Device Transform – a transformation from ACES colour space to exact device colour space intended for colours to look the same to the human eye, independent from a device that shows this image. ACES colour space is theoretically infinite colour space dedicated to being intermediate colour space to allow colour transformations that pick colours such that they look the same on different devices.

Fig. 1. Example of bloom effect in night vision device. The distance to light sources is about 1.5km

A. Scene color representations

There is not enough information while having just three colours to represent, how an object will look through the night-vision device [2]. One of the most notable examples a grass or tree leaves. The chlorophyll, contained in such green plants reflects up to 80% of infrared radiation. Night vision goggles in turn are sensitive to infrared wavelengths, so for an operator looking through such goggles, most of the green plants will look very bright.

In our model we represent a colour using two 3-component float vectors: one is classic RGB, and the other represents three infrared wavelengths: 800, 850 and 900 μm. Those wavelengths were chosen because a huge amount of night-

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vision devices is sensitive to these wavelengths [4]. Although, it is possible to adjust these numbers to achieve desired (more accurate) effect.

B. Device sensitivity

To take device sensitivity into account, we are transforming scene colours. The transformation is a convolution of colour with a device sensitivity curve. This curve represents how strong will react night vision device to a wave with specified length. High values mean that a night-vision device will register even small amount of such wave. Example of such curves for devices of 2 and 3 generation depicted at Fig. 2 With this transformation, it is possible to achieve visual effects such as:

- the blue colour most of the time will be almost invisible through a night-vision device [2]
- dominating colour will be on infrared wavelength, thus helping to achieve the effect, when plants seem to be bright

At this stage, we transforming 6-component float HDR colour representation to single-float HDR colour.

The device sensitivity curve acts as a parameter here. It should be specified depending on the exact device model to be simulated.

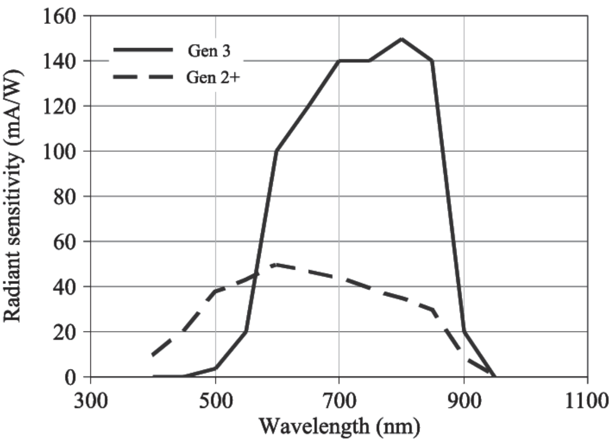

Fig. 2. Color sensitivity of night-vision devices of 2 and 3 generation

C. Bloom, Eye Adaptation and Tone Mapping

Using HDR buffer values we should add a bloom effect near bright light sources. If a value v is greater than a certain

The next stage is eye adaptation. At this stage, the device adjusts its exposure for the image to have an optimal brightness. For this, we are calculating the median histogram pixel value to consider it to be a half-white point and adjust exposure based on this value.

threshold V, then this pixel considered to be too bright and the bloom should be applied. The intensity of bloom depends on the difference between the value and threshold $v-V$. The base intensity and threshold are parameters of this stage, because it is very device-dependent, how it will be affected by bright light sources.

As a result in dark scenes, the image will have many visible details in dark areas, but bright objects will be almost completely white. There is a peak threshold when night-vision goggles will just display a completely white image. We consider it to be the amount of light on clear sky daylight.

After all these steps our model transforms these values using a filmic tone mapper to be displayed on a screen.

III. Future Work

It will be very useful to have light scattering in this model. There is one unaccounted effect – the pillars of light. It happens when some light source like a street light becomes visible. Observer will clearly see something like a cone of light. For such effect the model needs to be able to calculate light scattering.

Another effect that will even more increase physically correctness is the fog. It is very complicated effect for night vision simulation, because it non-trivially changes colour sensitiveness (depending on shape of fog and even it's chemical composition). Also the fog affects the blur radius of light sources.

IV. Conclusion

This paper suggested a framework for night-vision goggles image generation. Its main advantage is the ability to use information about infrared colours of the scene, thus making the final image more realistic.

This model exposes parameters such as device colour sensitivity to have the ability to fine-tune it to represent a wide spectre of night-vision devices.

References

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