



# Visual ergonomics in a car

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## **Abstract**

More and more visual information has to be displayed in a car. For safety reasons, and in order to avoid tiredness this information must be seen as clearly as possible by the driver, in any light conditions. Light intensity, homogeneity and color variation must be handled and can now be simulated by SPEOS simulation software from OPTIS. This new tool is based on photometric simulation, and a new physics-based approach in light propagation. The simulator includes real light emission with real spectrum, exact instrument geometry and 3D environment inside and outside the car, plus a unique LCD simulation model from NEMOPTIC. Due to its physics-based approach to light, a real life measured library of materials is used to calculate the level of reflection of light anywhere in the car.

A human vision model has been developed in collaboration with Mr. MENU a worldwide specialist in eye perception. This model, based on physiological effects, handles eye responses to light level, color, contrast and ambient luminosity according to the spatial response of the retina. Results are given which respect automotive standards and specifications. An additional application extends the properties to the infrared band, and night-vision devices.

## I. Introduction

Color occupies an increasingly important place in our everyday life, but also in the field of automotive which is the subject of this document. In the past, very few colors were actually used apart from red to signify "stop" and green to signify "ok".

Today, color is used on the instrument panels of most cars, either in the dashboard, in head up display (HUD), or liquid crystal displays, all of which use fairly complex, differently colored symbologies.

In most cars devices display a variety of colored alpha-numerical and analogical data, for driving management and control.

These are polychromatic data (more than eight colors, each of which can be displayed at different light intensities) with varied graphics, ranging from very small areas (alphanumeric, scale graduations) to larger areas (backgrounds, sky, ground). They also represent the majority of the problems encountered with the new generation of windshield.



Human vision is one of the most complex processes ever modeled. The entire chain from the light source to the eye as far as the brain is a part of the signal processing.

Part of this process is modeled, thanks to a new spectral photometric approach to light propagation. Since displays are becoming more and more common in a car, we have developed a precise physics based model for displays, handling light transmission and reflection into their components.

The second step is the light perception simulation of the illuminated scene, including a sensitive model of the human-eye, with both a spectral and a spatial approach.

Image interpretation, which is the "brain" process, is at this stage, treated as a detected/non-detected signal, with a probability of detection.

This new application gives totally new safety information when designing a cockpit.

## **2. Problem definition**

The use of color and lighting signal in information displays requires the designer to use special skills, in particular when designing for the harsh light environment encountered in the car.

This paper presents the result of a research and development program lasting more than 10 years, focused on photometry simulation and recently including human vision modeling, in order to answer the visual ergonomics question.

The following areas of interest are addressed by this project:

- the choice of display technology (LCD).
- the use of ISO visual standards related to the use of color on displays.
- the position of the displays and information
- the problem of contrast reduction due to reflected ambient light
- the problem of contrast reduction due to direct light and background
- the detection of information
- Night Vision Devices

The displays in a car can be quite complex and have to function in a harsh visual environment that may strongly affect the image quality of the displayed information.

Therefore, the visual ergonomics of display design require special attention, in particular when color displays are involved.

There are two main problems to be considered in the design of a visual display interface of a car, that is, the image quality (contrast, color palette, graphics, etc.) and the cognitive aspects (structuring, feedback, human-machine dialogue etc.). Here we shall address the aspect of image quality, thereby focusing on the use of color.

Color has always been a problematic medium in visual ergonomics. Displaying more and more information on a screen must be done with caution.

Although there is a huge difference between working in an office and in a car, we can expect that, as was the case for office work using visual displays, requirements for other display applications (even military) will eventually follow suit.

An important consideration in display design is the amount of ambient light that strikes the display.

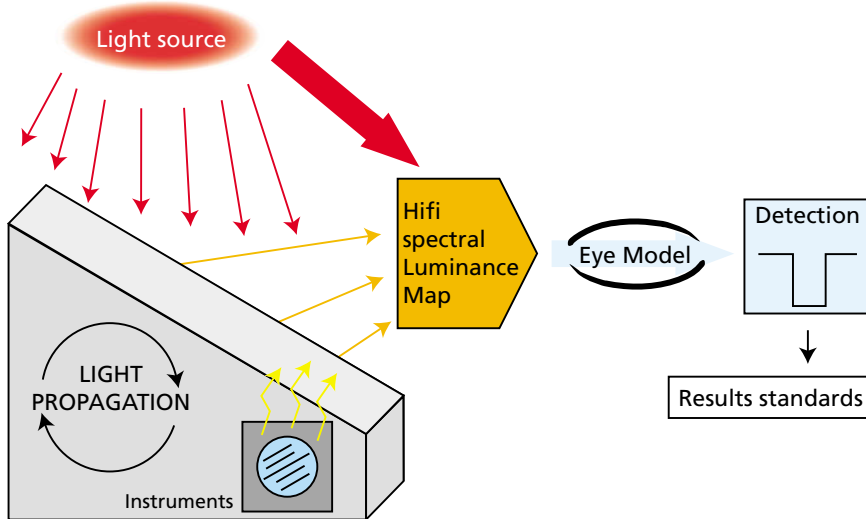
Since this may well be the decisive factor in knowing whether a display will function at all, it is necessary to be aware of the potential of current display technology.

The software developed in this project is able to answer all the questions around the interior of a car a designer may have regarding the level of light he will obtain anywhere in the 3D space, and also about where the light comes from.

### 3. Analysis

#### 3.1. General presentation

The global algorithm of this development can be represented by the following drawing :



3D scene (CAD/CAM) with optical properties

1-Light is coming from :

- Natural environment,
- Inside lighting systems
- Instruments panels
- Head-Up displays

2-Light is propagated inside the 3D Scene (here the dashboard)

3-The part of the light going in the observer's direction is stored with a view to building a spectral luminance map (Photometric rendering)

4-Information is transformed through a human eye model, modeling eye response (spectral/spatial) to the energetic image

5-A detection box then analyzes and compares results with standards and physiological parameters of human vision

6-Results are displayed as hyper-realistic energetic image, informing the real color seen by the driver, and the seen/non seen information

#### 3.2 Photometric simulation

The first step in the simulation must perfectly describe the level of light level inside the scene. That means a photometric approach, fundamental for generating the signal so as to obtain the eye response.

Over the last ten years, OPTIS has developed efficient photometry simulation algorithms, using ray-based method, Monte-Carlo approach and analytic photometric computation.

Thanks to a physics based approach simulation, the important information necessary to compute eye-vision simulation, is fully integrated in the obtained results.

This approach has been explained in different papers and is not the object of this one. The important fact is that it allows the user to handle and simulate accurately source emission, light propagation, light interaction with surfaces

and light detection, with a spectral management of data.

The level of precision obtained with SPEOS software is better than 10 % and, as many other simulation software, depends a lot on the precision of the input data themselves. Another major benefit is the time needed to simulate the system : in most case between 10 and 50 time faster than other simulation software.

We will resume here the main characteristics of the SPEOS software application developed by OPTIS :

Data entry :

#### **GENERAL**

- The software is operational connected to CAD/CAM software and will be available inside CATIA V5
- Data entry is added to CAD/CAM models
- Optical data can be measured on a bench (BRDF, BSDF and BTDF, volume scattering, intensity diagram for sources)
- Propagation is based on optical laws
- Results are displayed in view to make post-processing analysis

#### **SPECTRAL CHARACTERISTICS**

- The software is operational at any wavelength. Possibility of using UV and IR parts of the spectrum for medical & defense applications. Possibility of entering the data using a standard RGB table. Possibility of connecting an OPTIS color acquisition hardware
- Color is defined by spectral absorption of the material
- Access to colorimetric function which locates the color in the color triangle and shows color coordinates in standard color space (CIE Lab)

#### **RESULTS**

- 3D Map for irradiance level on the system : energy that hits the surface + transmitted energy + refracted energy + absorbed energy in a powerful dedicated specific viewer
- 2D map result for the vision representation : no limitation of resolution for the Ergonomics Application
- Intensity distribution : for the LCD simulation

#### **CALCULATION**

- Possibility to have up to 500 light/matter interaction
- High speed of calculation
- Automation OLE recording function available
- Possibility of parallel computation

#### **SURFACE**

- Standard optical surfaces : mirror, polish, coating
- Catalogue of BRDF/BTDF/BSDF measured surfaces including aluminium, charmilles, ...
- User defined surfaces able to handle (gaussian + lambert + specular dimension entered with interactive graphic) + spectral absorption

#### **SOURCE**

- Ability to emit light from any mechanical part generated by a CAD/CAM software
- Possibility to associate a spectrum to any source
- Emitting displays characterized by an image file + intensity distribution
- Catalog of sources (OSRAM, Philips, ... ) + association of standard spectrum

#### **MATERIAL**

- Catalog of standard optical material (SCHOTT, HOYA, CORNING, ...)
- Catalog of plastic optics (Bayer, Röhm, ...)
- Catalog of rubber coatings for dashboards
- User defined Optical material
- User defined Plastic material including colored and diffusing material

**Source modeling**

With SPEOS any kind of light source can be modeled by entering a geometry and defining its emission properties : spectrum and type of emission. So it is easy to model tungstenhalogen incandescence lamps, short arc discharge lamps, using xenon or metal halogenide technology. A laser system may be defined too.

The level of light inside the cars may have an important dynamic. It depends especially on the ambient light conditions. This light can come from the sky, from the sun, and from the internal lighting of the cockpit itself. We have to pay attention to the exact physical modeling of this light and the effects on the instruments. These sources are part of the input data defining the scene.

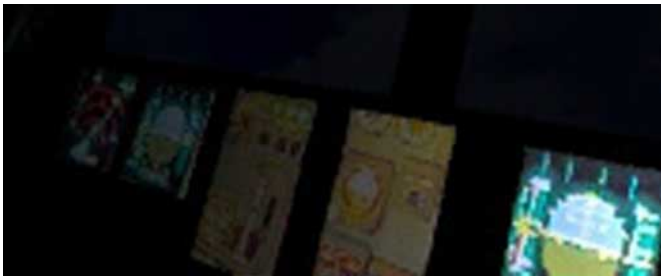


Figure 1 : LCD : Luminosity degradation versus observation angle (obtained by simulation)

**Propagation : Effect of the ambient light**

The surface of a display will always reflect a certain percentage of light, partly as specular reflection from the glass shielding, and partly as diffuse reflection from the display surface itself.

This reflected light adds to the light emitted by the display and thus causes contrast degradation.

The amount of contrast reduction depends on various factors, the display itself, and all the sources.

Contrast can be defined in various ways, but for the present purpose the simplest expression may suffice, i.e. the luminance ratio where  $L_{max}$  and  $L_{min}$  refer to the higher and the lower luminances defining the information ( $L_i$ ) and background ( $L_b$ ), respectively.

$$C = L_{max}/L_{min} \text{ (Luminance is given in } cd/m^2 \text{)}$$

The luminance of the reflected ambient light ( $L_a$ ) adds to both  $L_{max}$  and  $L_{min}$  .

The ambient light ( $L_a$ ) consists of a diffuse ( $L_d$ ) and a specular ( $L_s$ ) component, so  $L_a = L_d + L_s$

The diffuse component,  $L_d$ , is characterized by a BRDF (Bi-directional Reflectance Diffusion Function) that gives the 3D phase function of the surface. Going further, the diffusion function is defined by a BSDF = BRDF + BTDF(Transmission) function. So, light hitting a LCD screen, may be retro-diffused and diffused onto the display itself. BSDF function depends on the direction of the incident light.

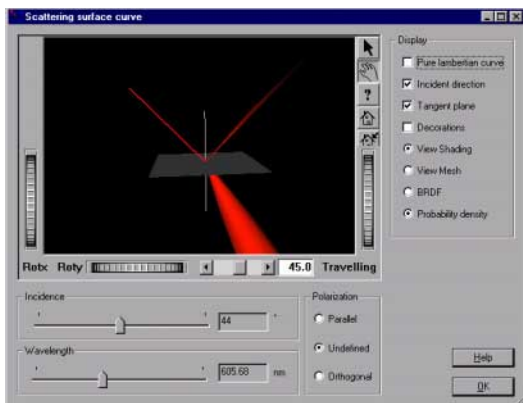
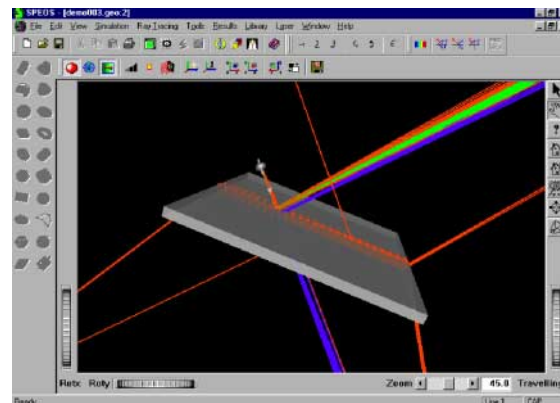


Figure 2 : BSDF function in 3D space



Ray-tracing on an optical coating

The specular reflection component,  $L_s$ , is determined by the reflectance of whatever objects are reflected in the screen (with average reflectance  $R_o$ ) and the specular reflection factor of the glass shielding of the display (with average reflectance  $R_g$ ).

These data are automatically calculated by SPEOS software, taking into account the dependence on the incident angle.

To give an idea of the level of illuminance, for a worst-case horizontal illuminance of 110,000 lx, and a sun diameter of 0.5, the corresponding specular reflection from the sun luminance amounts to  $10^8$  cd/m<sup>2</sup>.

In this way, the sun, the sky, the artificial lighting and the instruments themselves will emit light, which will be reflected inside the car, and decrease display's contrasts.



### Ambient Light in the car

In order to evaluate the effect of ambient light on the legibility of a car display, we can directly proceed to photometric measurements simulation. What one needs to know is the illuminance measured at the location where displays might be installed. This illuminance depends on the luminance outside the car. In the case of an overcast sky, there is no direct sunlight and the illuminance is diffuse. The maximum horizontal diffuse illuminance produced by the West-European sky is in the order of 56,000 lx (Hunt, 1979). The maximum illuminance produced by direct sunlight can be as high as 110,000 lx (Hunt, 1979), which would imply, taking into account the transmission of the window (in the order of 70%), that the display illuminance can be as high as  $0.7 \cdot 110,000 = 77,000$  lx. This should be compared to normal office illumination, which is typically less than one percent of that value.

### Reflected Light Computations

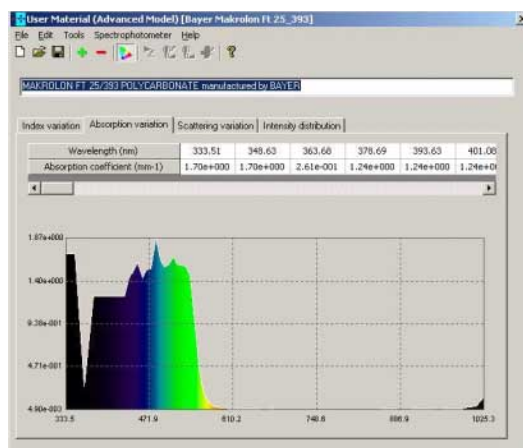
Knowing the illumination at the display surface we can compute the reduction in contrast of the displayed information. The software will automatically determinates which part of the ambient light will hit the display surface. The calculation is automatically computed with the Fresnel's law, by defining the index of refraction of the glass. For the LCD, a diffuse reflection factor of 0.0015 is assumed, consistent with current technology (e.g. Krantz et al., 1992).

The transmission of the front glass (T) is about 0.8. The specular reflection (Rs) is for both display technologies the same, that is, in the order of 0.04. For a special treated front glass the reflection can be lowered to 0.005 (by using  $\lambda/4$  coating).

The reflection of the interior of the car is given by the optical data, (diffusion and color) added to the different surfaces in the scene.

The LCD provides for much better contrast than the CRT, due to its very low diffuse reflection. It is also clear that an anti-reflection coating is very effective (1 to 20 for LCD).

Considering that we assumed an initial display contrast of  $C=50$ , it is clear that ambient light causes a considerable contrast reduction, down to values between 1 and 20. If there is no way of reducing the incident ambient light, contrast can only be increased by increasing the luminance of the display. (cf colorimetry)



### 3.3. Colorimetric simulation

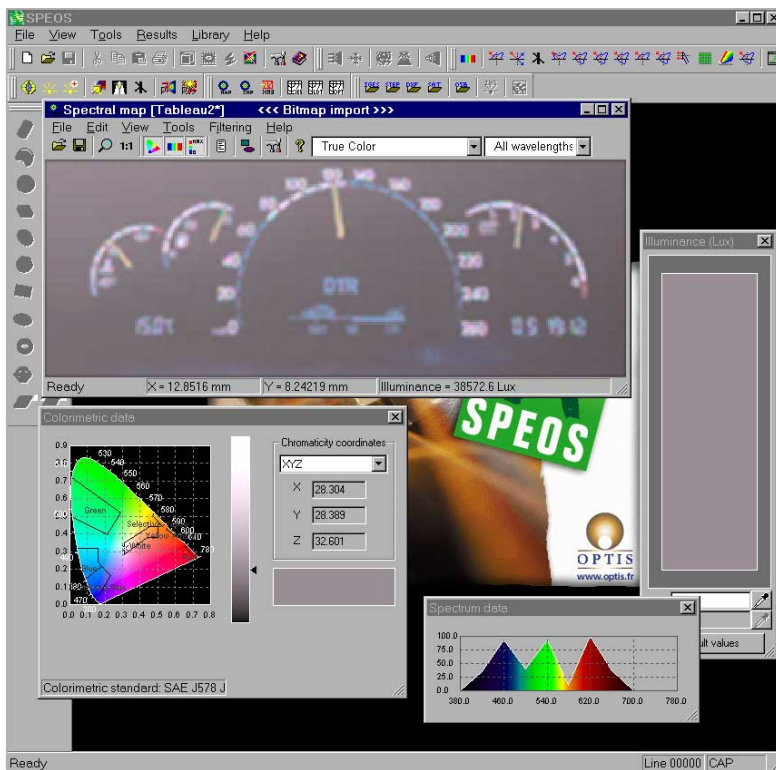
Knowing the spectral luminance at any point, allows us to determine its exact color. OPTIS has innovated by developing its colorimetric simulation tool, that locates the final color inside the usual graphical representations of the perceptible colors.

Use of color filters and selective band filters

The final result may be observed using any type of colored filter, by adding it to the system, and giving its absorption spectrum.

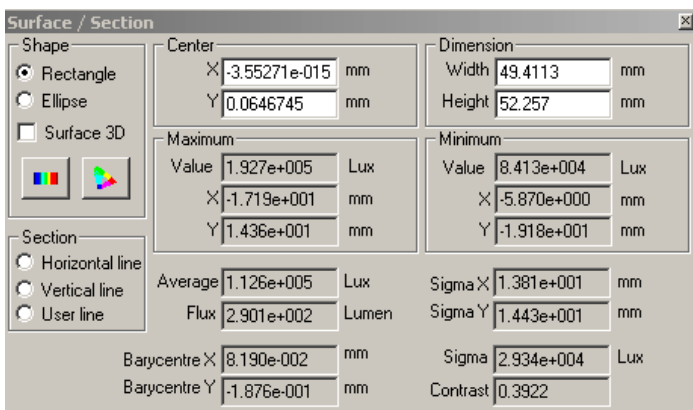
### Color Washout

Adding white light to a colored light reduces the purity of the color (deep blue may turn into pale blue), an effect called desaturation. Ambient (white) light also adds to the colored light emitted by a display, so when computing a required color difference one should include the (additive) effect of the reflected ambient light into the calculations. The colorimetries involved in computing the color shift due to the additive effect of ambient light are discussed in ISO/FDIS 9421-8. The procedure involves the computation of the X, Y, and Z CIE units of both the displayed color and the ambient light component. The X, Y, and Z values are added and the resulting corrected values imputed in the equations for computing the color coordinates in the CIELUV system. The final result informs us about the color on any area, pointed by the mouse directly on the results Map. On this luminance map, color can be represented directly on the CIELUV system, where the standards of color are represented by contours.



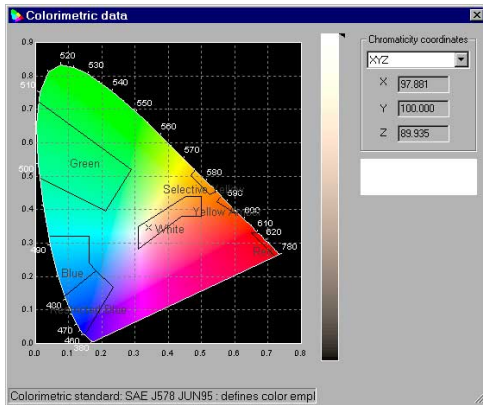
### Energetic, contrast analysis

Analysis tools have been developed to instantaneously obtain principal photometric data in any user-defined area, of any shape. These data are obtained in the top right window, and present the minimum, maximum and the average level of luminance, the total flux received by the area, and the contrast inside the area.



### Visual standards

International standards are gradually replacing national standards. The general consensus is that the standards developed by the International Organization for Standardization (ISO) will become the most likely candidates for future international standards. Military and aeronautics standards are also applicable in the color management results of SPEOS software.



### 3.4. Displays model : LCD Displays

We will not repeat here the technology used for the different types of display. We have developed specific functions with a view to modeling as accurately as possible any kind of display system, with the information available.

Depending on whether you are specifying or designing the display, and depending on the data known about it, we propose two ways of defining the display.

Specifying requires the definition of the global characteristics of the display.

In SPEOS, a display can be obtained by assembling :

- An emissive area, characterized by a bitmap, thus giving the resolution of the display. This BMP is transformed as a spectral emissive map, each color (R,G and B) giving the % of R, G and B corresponding spectrum,
- An intensity distribution, characterizing the emission diagram of any pixel,
- An associated glass, characterized by its material, thickness and its diffusion properties
- The total flux emitted by the display

Designing means using specific tools to work on the backlighting, and the LCD properties. With that goal we have developed a powerful model, which is accessible using common data given by LCD manufacturers.

This model is available for backlighting and frontlighting behavior of the LCD.

Head-up displays are easy to define knowing the optical lenses and the source associated to the LCD. Also the screen is part of the optical system and must be entered in the CAD/CAM file. Once the optical properties are defined, the image projected on the field of view will automatically appear on the final simulation.

### LCD Simulation

OPTIS and NEMOPTIC have developed an innovative solution : the SPEOS-VLCL combination which enables the user to simultaneously compute the light propagation in all the components and the physical behavior of the liquid crystal display.

This software combination computes the luminance levels, color coordinates, illuminance and intensity diagram for any LCD based system in any lighting configuration

SPEOS is a ray tracing based lighting software for computing backlighting and ambient lighting and provides the tools needed to analyze simulation results.

VLCL is a very powerful LCD modeling tool, which has been developed by NEMOPTIC. Initially NEMOPTIC developed this tool to achieve the maturation of its innovative bi-stable LCD technology (BiNem). This technology is based on a complex physical mechanism into the LC cell involving in particular weak anchoring layers and the effect of the hydrodynamic flow generated by one surface onto the other. To date there is no LC simulation software able to simulate such effects. This is why NEMOPTIC developed its highly realistic and accurate VLCL simulation software.

VLCL computes molecular arrangement (hereafter called texture) in the liquid crystal and then computes the optical properties of light rays passing through the stack realized by the LC cell and the surrounding substrates constituting the LCD screen.

Both computations, textures and optics, are achieved in using the most enhanced physical models.

The main problems solved by this solution are :

- The handling of light guide's complex geometry, including thousands of 3D micro structures for the backlighting design,
- Photometric calculations using a full polarization description,
- The analysis of the losses in a light guide,
- Providing a unique and powerful solution to model simultaneously backlighting and LCD as a single virtual prototyping package.

With SPEOS it is possible to import the geometry of any lighting system from any CAD software. Then the optical properties of each surface and material have to be added to the CAD/CAM file and once the light sources are placed in the system, it is possible to propagate photons inside it with a full polarization description.

Simulations that can be done are luminance simulations and illuminance simulations. From them it is possible to get intensity diagrams for angular characterization and irradiance maps to control uniformity of the display. It is also possible to get realistic luminance views of an LCD as if it was held in the hand.

It is possible to get the intensity diagram of the light emerging from the LCD, to get the chromaticity effect and to observe the contrast evolution while changing the viewing angle

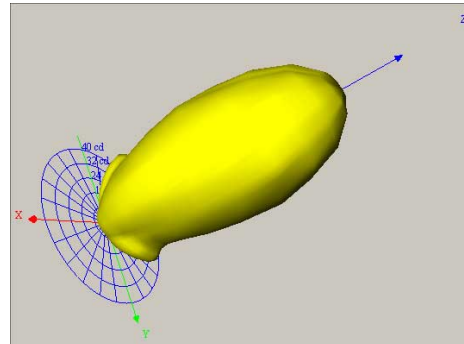
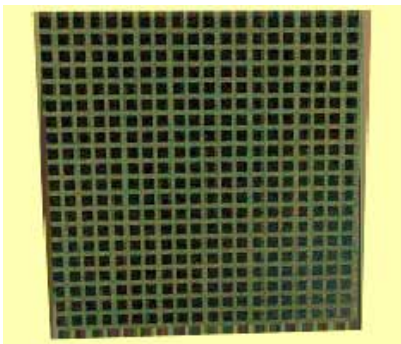


Figure 3 : A luminance map and an intensity diagram obtained with SPEOS-VLCL simulation

Moreover it is possible to improve the uniformity with the use of 3D textures on the backlighting system as shown in the picture below :

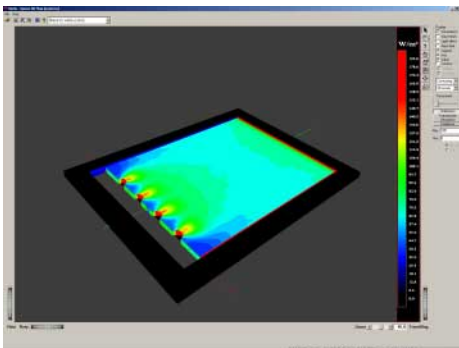


Figure 4 : light uniformity in a light guide with its LCD

Using that function, the reflected ambient light, that causes contrast degradation, is perfectly modeled.

Optical computations used in VLCL model are accurate by solving Maxwell's equations of propagation for a laminated medium exactly using the 4X4 matrix formalism. This is an ondulatory type calculation which integrates all the interference phenomena and in particular the length of coherence of the light is taken into account to generate possible interference pictures.

### 3.5. Photometric rendering

The photometric based rendering, is a HiFi hyper realist rendering, fully based on physics. At this stage, the result is a luminance seen from a defined observer position. Luminance corresponds to the light coming from the 3D scene, going in the direction of the observer. Unit is in  $\text{cd/m}^2$ .

The goal of this rendering is to visualize the global scene, knowing the high spot and low signal. The information is only energetic. On any point given by the mouse, the luminance level is instantaneously given.

Color position is also given at any point of the results, by using the CIELUV graph.

Although there are many filtering tools associated to results visualization, the image generated by SPEOS may contain high dynamic of light variation. This dynamic is so large that exact result can't be displayed on the screen.

### 3.6. Eye model

Using the rendering function, and knowing the response of a human eye to a light signal, it is possible to simulate what a human will really see.

As explained in the last paragraph, the human eye has a high range of luminance detection : able to detect luminance level from  $10^{-6} \text{ cd/m}^2$  to  $10^8 \text{ cd/m}^2$ . Displays don't have such a high dynamic : for instance a CRT display has a dynamic of less than 100. That's why we have developed special functions better able to display the final image, as if the scene were seen by a human.

To approach that process, we have decided to model the eye response to a light signal, handling the properties of the different eye-photoreceptors.

Cone photoreceptors (Color cells) contain pigments that catch light and convert the information into electrical signals that are processed and sent to the brain. Three classes of pigments are present, with peak absorption in the "red", "green" and "blue" regions of the spectrum. Color cells are more present in central vision.

Luminosity cells are more present in peripheral vision. They are sensitive to very low levels of light ( $0.0056 \text{ Cd/m}_2$ ) when cones are not sensitive.

Properties of these cells have been modeled and allow us to estimate how a human will see a real scene.

Depending on the level of light, color cells will or will not be activated. With low levels, we say vision is in scotopic mode. With high levels, vision is in photopic mode. Between the two modes, vision is said to be in mesopic mode. In case of scotopic mode, by night, only Luminosity cells are active, explaining loss of color perception.

As presented in the last paragraph, SPEOS simulates a luminance Map, giving all the photometric information that will reach the eye.

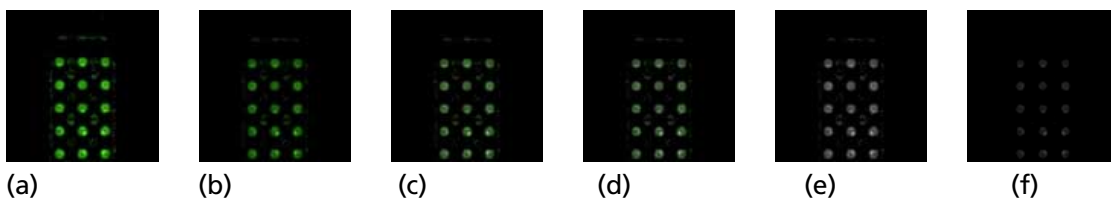
To adapt the luminance level obtained with SPEOS, to the screen used to display the result we have used the Ward method where we estimate the M factor, giving :

$$L_d = m \cdot L_w$$

where  $L_d$  is the luminance of the screen and  $L_w$  the luminance level obtained by simulation.

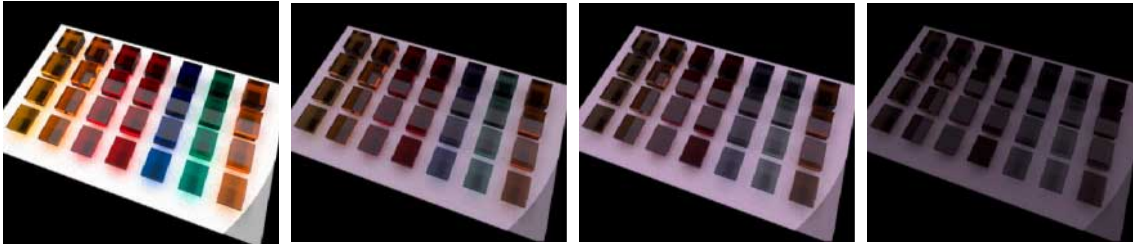
This M factor, depends on the adaptation luminance of an observer located inside the virtual scene, and also depends on the environment light level where the screen to display the results is located.

Using that method, we can obtain the results below which correspond to a lit keypad, observed by night, for different levels of luminance :



(a) result corresponds to the luminance result obtained directly by SPEOS (photopic mode), without applying the Human-Vision model. (b) is obtained after applying the Human-Vision model. (c) (d) (e) results are obtained for a decreasing level of luminance, corresponding to a mesopic mode of vision. Note that without applying our Human-Vision model, we would obtain the same results as (a). (f) results is obtained for a scotopic vision mode.

Same observation for a colored scene lit by ambient light :



We can notice there a progressively spectral shift due to the fact that Luminous cells progressively become non-saturated.

### 3.7. Detection

In addition to reducing the contrast of the display image – a physical effect – the ambient light also affects the sensitivity control (adaptation) of the eye – a physiological effect. Visual sensitivity control is not instantaneous, so whenever the eye is confronted with a sudden change in the prevailing luminance, it takes some time to re-adjust sensitivity. This is particularly noticeable when the luminance change is from light to dark. This is what happens in the car when the driver shifts his gaze from the outside view to the relatively dark instrument panel inside the car. Results from a study by Boynton et al. (1969) indicate that adaptation times begin to add significantly to reaction times when there is about a hundred-fold change in luminance, when shifting from adaptation to target luminance. For viewing the display at night the lighting conditions are reversed. Now it will be the display that may be too bright compared to the ambient illumination. Dimming the display luminance might seem the logical solution for this problem, but it may be necessary to also change the polarity of the display.

The next simulation shows the effect of a high level of ambient light, affecting the sensitivity control. The scene is based on two disks, a larger white one, with high level of luminance, on which we place an absorbing cross. A smaller blue filter is added, partly covering the white one.

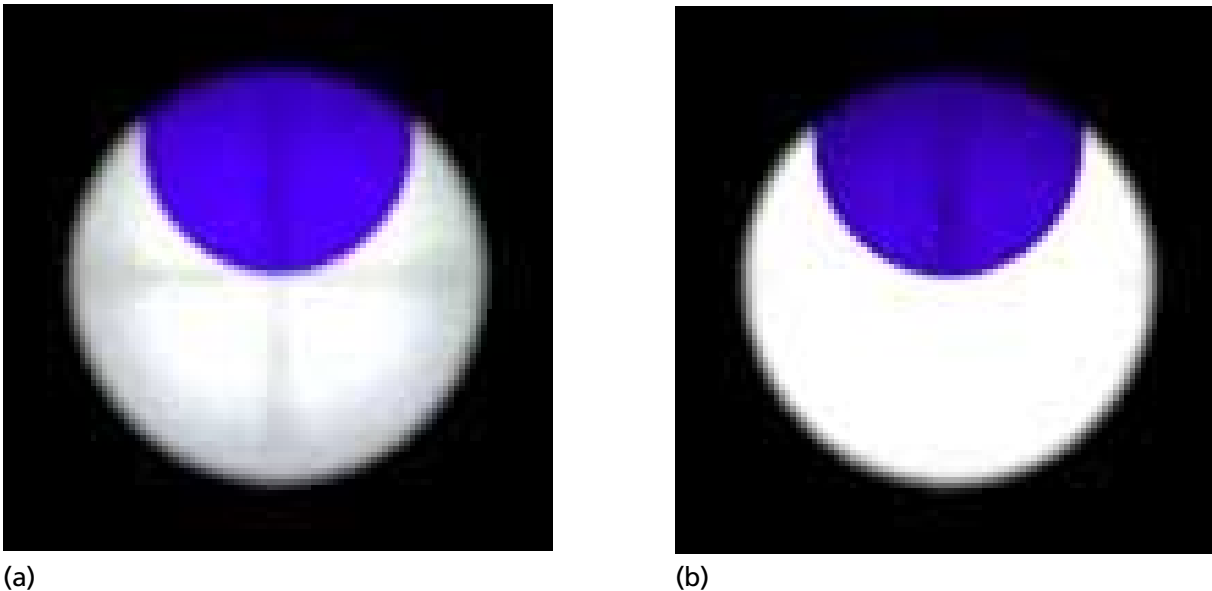
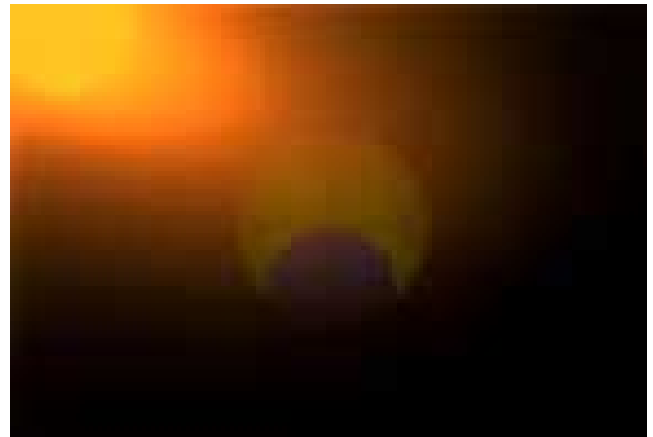


Figure (a) is directly obtained with SPEOS, giving the luminance level without our Human-Vision treatment. We can distinguish the gray cross, which can let us think we will see the cross. After applying the Human-Vision function, fig.(b), we are unable to see the cross any more.

In reality the eye adjusts itself to the luminance level inside a solid angle of 1° around the fixed point. As this is done very quickly we must take into account many levels of luminance in the same image for the eye adjustment. For example imagine that you are into a room and you are looking at the window. If we adjust the image with the luminance level of the window all the objects inside the room will not be seen.



(a)



(b)

Figure (a) is directly obtained with Speos, giving the luminance level without our Human-Vision treatment. Figure (b) is the same image but displayed after applying the Human-Vision function. We are now able to see the object in the center of the image and the glare effect due to the high level of the luminance of the source in the upper left corner.

We can also simulate the contrast perception according to the level of the luminance.



(a)



(b)

Figure (a) is obtained after applying the Human-Vision function. In the original image the average level of luminance is around  $5\text{cd/m}^2$ . Figure (b) is obtained after applying the Human-Vision function on the same image with an average level of luminance around  $500\text{cd/m}^2$ .

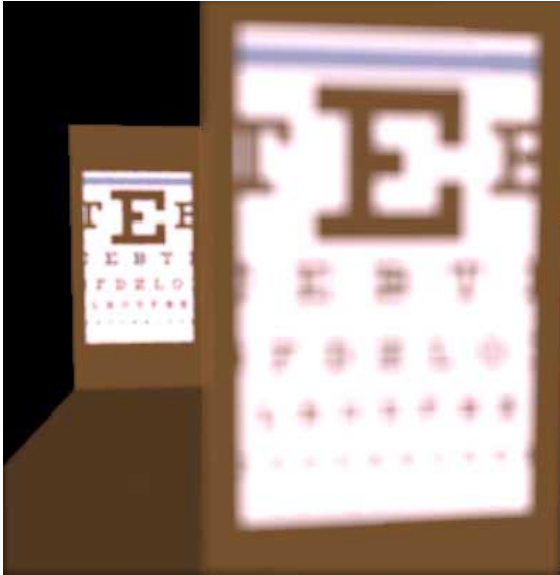
To go further, we have developed an additional algorithm, able to handle a high level of luminance, like the sun and its reflection. This method is well adapted to the light fog effect. This effect is due to the fact that sources located in the peripheral vision area are diffused by the different surfaces and material encountered in the human eye itself, then illuminating the retina. This parasitic illumination causes decreased sensitivity that may prevent the driver from identifying an important signal.

In the illustration below, we have simulated what a driver see in 3 configurations :  
By day with no sun, with the sun in the field and with more sun. We can observe the decrease in visibility due to the sun effect.

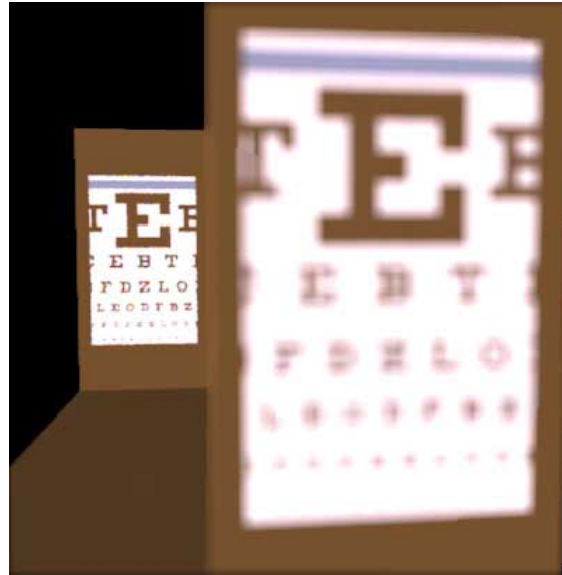


### 3.8. Depth of focus

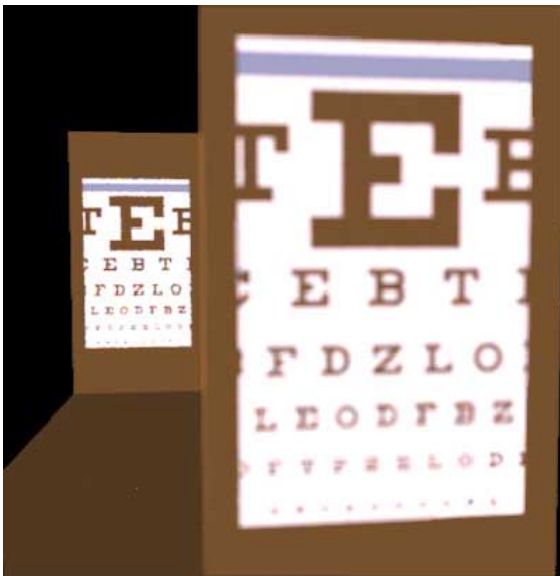
In most of software the observer model is called « pinhole camera ». This model cannot take into account the depth of focus neither the spherical aberrations when we look at a scene through an objective. Thanks to this optical approach, knowing the distance of any point of the scene, OPTIS can handle the depth of focus, generating a blurring effects for non-focused objects.



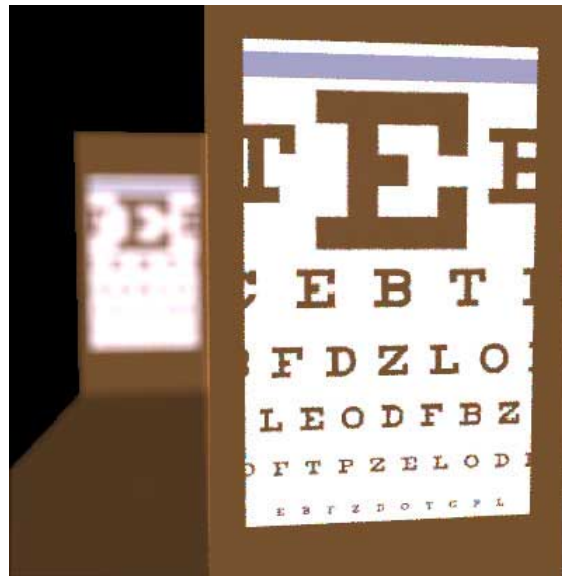
(a) Accomodation distance = 10m



(b) Accomodation distance = 5m



(c) Accomodation distance = 3m



(d) Accomodation distance = 1m

### 3.9. Night Vision Devices and Infrared equipment

As SPEOS software is based on general optical laws, radiometric simulation is obtained using energetic properties of light. The important fact is that the optical data must be informed in the different wavelength bands where the sources are defined. With these spectral properties, it is then easy to add a red filter to adapt wavelength of the LED emission.

A fluorescent surface model has been developed to transform infrared flux into visible signals.

#### **4. Discussions**

Main difficulties come from the validation of the software. Vision simulation has to be compared to what you see in an experimental way. We mustn't forget that human vision process and detection involves post-treatment by the brain. This will be probably one of the limits of our application. However, working on experiments, may lead us to determine a probability of detection, taking into account vision defects, age of the observer, presence of goggles, ...

The fact that the entire photometric part of the software has been validated previously, helps us to identify the vision points to be validated.

#### **5. Conclusions**

This approach to vision simulation is a new way of understanding visual perception with a view to going further with the visual ergonomics of cars. It is now accessible because OPTIS has developed a 12 year R&D program in optical and photometric simulation. This basic part has been fully validated over more than five years by worldwide users in optonics, lighting, display, automotive and consumer goods applications. In the last two years, OPTIS has been able to generate spectral hyper realistic images fully based on physics in its SPEOS software. This development was certainly a key to obtaining the light information essential for vision simulation.

This application can be generalized to automotive industry, and control room, by defining the usual standards.

The results obtained with this vision simulation have been compared with success to common visual tests with a view to being validated.

The next steps will include more and more automatic detectable/non detectable functions, to lead to a understandable/non-understandable function.

An integrated version inside CATIA V5 from Dassault Systemes will be available in 2002.

#### **6. Acknowledgements**

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#### **7. References**

CATIA is a registered trademark of Dassault Systemes

SPEOS is a registered trademark of OPTIS

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