Ray-Tracing Simulation Software for Designing and Optimizing Auto-Stereoscopic 3D Displays

Version 1.0

White Paper

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Title:	Ray-Tracing Simulation Software for Designing and Optimizing Auto-Stereoscopic 3D Displays
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1 Introduction

The design of autostereoscopic 3D display devices is mainly based on the formation of different viewing zones with respect to the expected positions of the observers [1]. We have developed a generic model approach for the description of light ray distributions through common kinds of optical image splitters [2][3][4]. Furthermore, our simulation could be used for automatic design optimization by predetermination of constrain parameters [5]. The evaluation of luminance and crosstalk profiles is an integral part of this procedure [6]. Finally, possible misalignments of the 3D display could be investigated in the design process before starting the display production [4][7]. The visualization of real image content allows an inside view of the final prototype display. In conclusion, a novel simulation tool has been developed for spatially multiplexed 3D displays. The general concept of this novel approach is described in the following chapters.

2 General Concept

Main purpose of our software is the autostereoscopic 3D display design for LCDs with different optical image splitters - in particular, parallax barriers, lenticular grids or wavelength-selective filter barriers [8]. The simulation program, illustrated in Figure 1, represents a stepwise quasi-static functionality and control of the chosen display arrangement by the integrated design optimizer. A main capability is the rendering of the light ray emission and calculation of the luminance distribution by the optical engine at chosen viewing distance. Visible image sections at the viewer's eye positon were determined by a ray tracer based on subpixel area model (SAM) and can be visualized by the imager module. The software itself has a shell structure. There are different layers starting on the pixel level fixed by the LCD resolution. The image processing is overlying and determines the allocation of image content in the pixel plane. Subsequently, the optical modeling and calculations will be executed. Finally, at the outer shell the program addresses the image viewing space and provides final content visualization. The next chapter will describe some details of the simulation process.

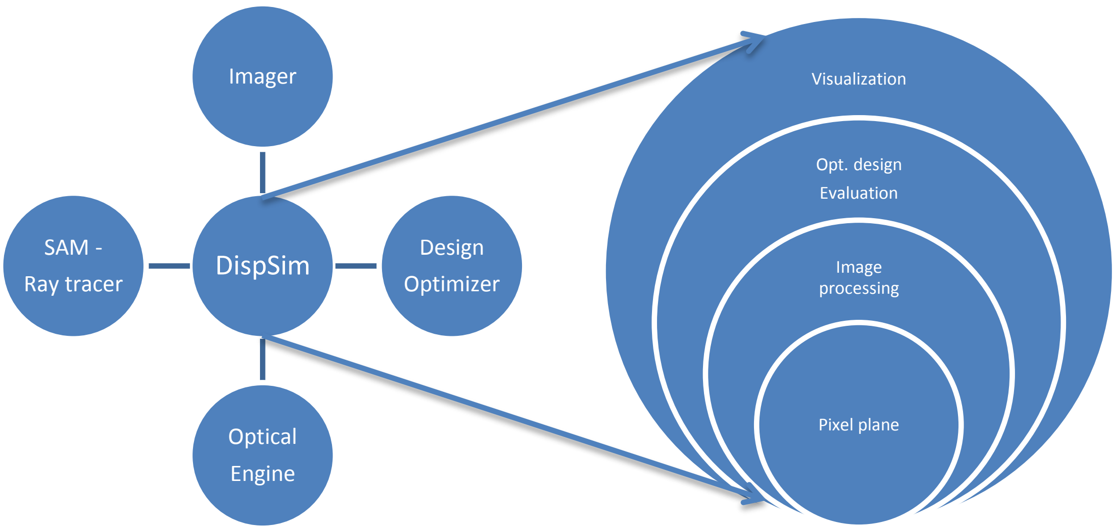

Figure 1: Schematic structure of simulation software

3 Description of Simulation Features

3.1 Ray-Tracing Light Distribution

As illustrated in Figure 2, simulated light rays emitted from the subpixels in the matrix pixel plane can be mathematically analyzed and visualized for the prediction of the viewing zones. In the viewing zones of the nominal plane precise calculations of luminance level and crosstalk are provided by the SAM routine. It can be used for the simulation of different optical image splitter devices. Figure 3 gives am example for a lenticular model. Specific input parameters like pixel and gap size, maximum panel luminance and image splitter properties have to be defined for the simulation process. The estimated intensity distribution of single subpixels, dependent of the used content, can be simulated for common viewing distances. The quality of the obtained simulation results, especially for crosstalk solutions, was proved by measurement data [2][3][4][6].

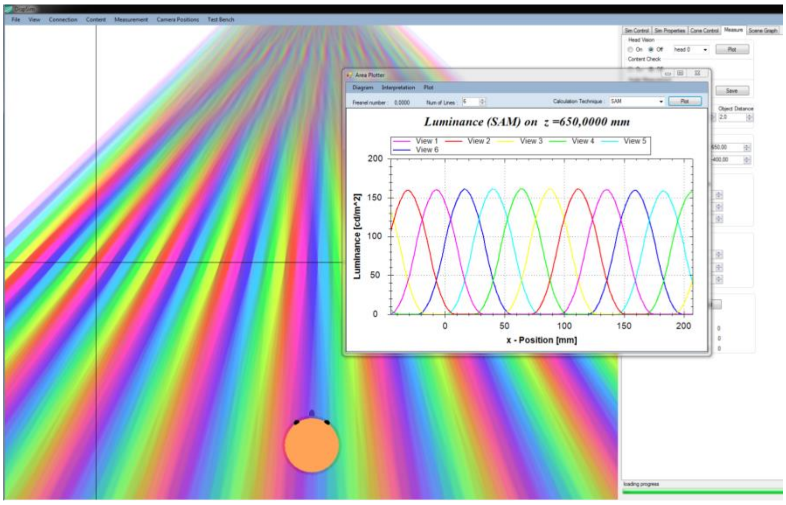

Figure 2: Illustration of GUI with intensity and light distribution at viewing space

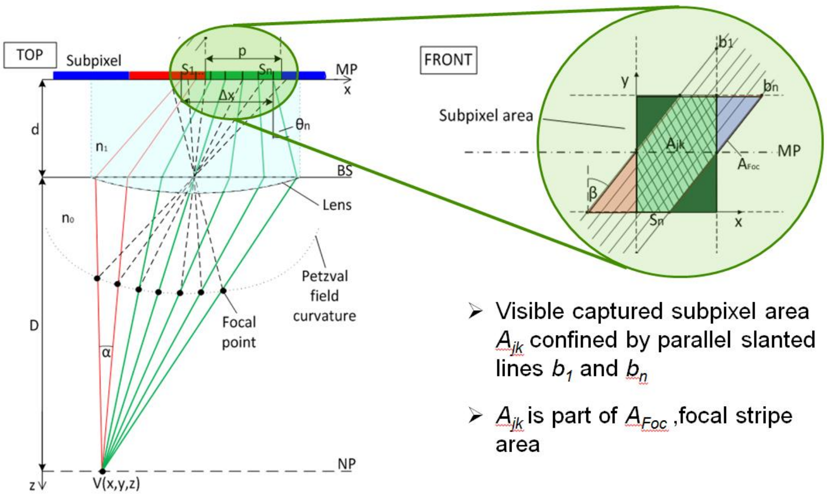

Figure 3: Scheme of lenticular barrier model (SAM) for luminance calculation

3.2 Optical Aberrations and Misalignments

In the process of 3D display design for prototype realization it is mandatory to determine the possible influence of optical aberrations and misalignments, exemplarily illustrated in Figure 4 and Figure 5. Errors in the pixel allocation caused by the angle dependent Petzval field curvature are considered in the simulation model. Furthermore, geometrical errors like linear and non-linear deviations in the optical image splitter or pixel plane can also be investigated.

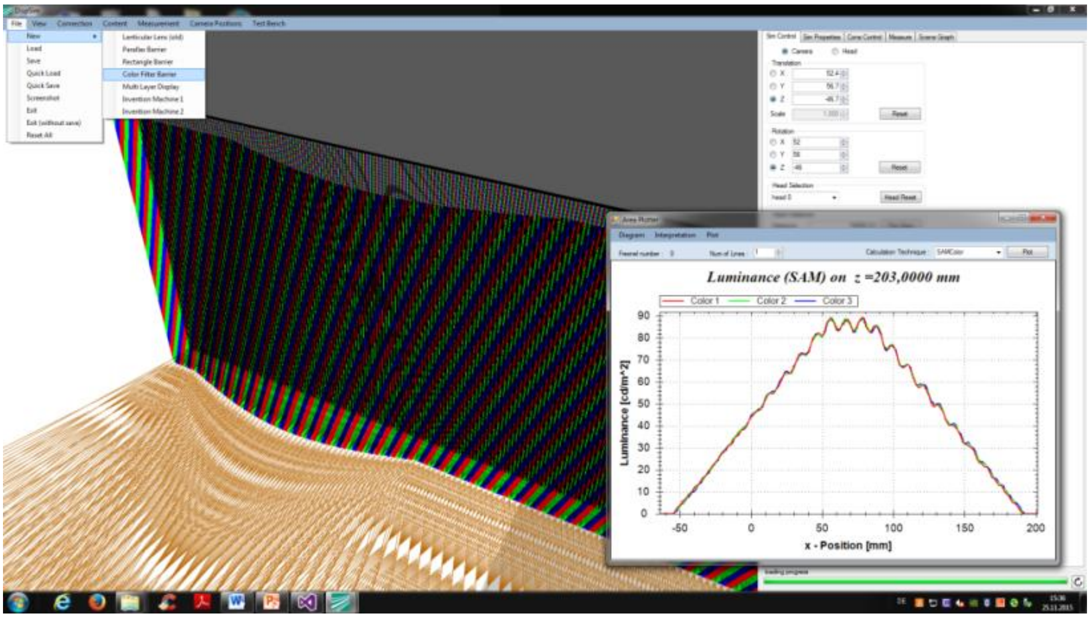

Figure 4: Wavelength selective color barrier with a bump as grid error

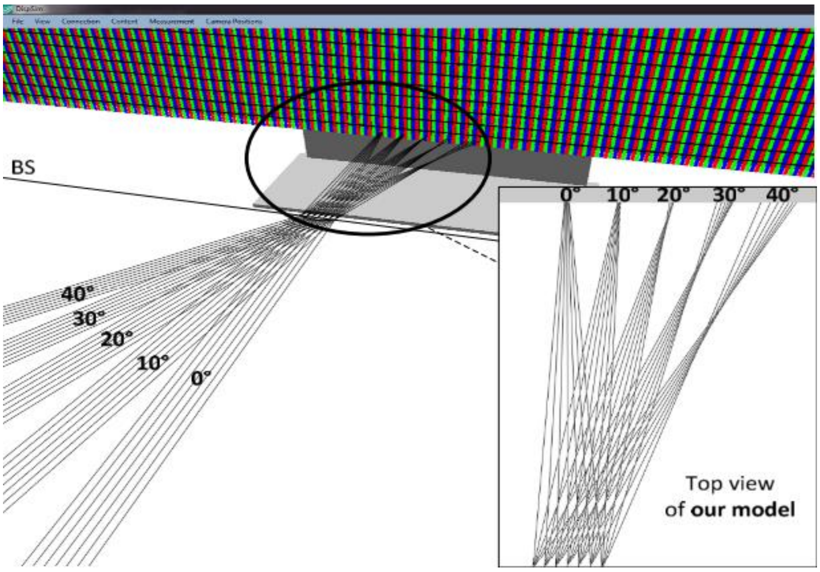

Figure 5: Optical aberration of single lenticular lens by off-axis illumination [4]

3.3 Automated Design Search

It can be difficult to find well working arrangements from complex display designs. Hereby, the simulation was expanded by a complex algorithm for automated search and validation of possible solutions in the multi-dimensional parameter space. For the multiview 3D display design a combination of ray-tracing and 3D rendering is used. Therefore the emitted light intensity distribution of each subpixel has to be evaluated in terms of color, luminance and visible area by using different content distribution on the subpixel plane. The analysis of the accumulated data will deliver different solutions distinguished by specific evaluation criteria. The number of valid solutions depends on the choice of threshold values (see Figure 6).

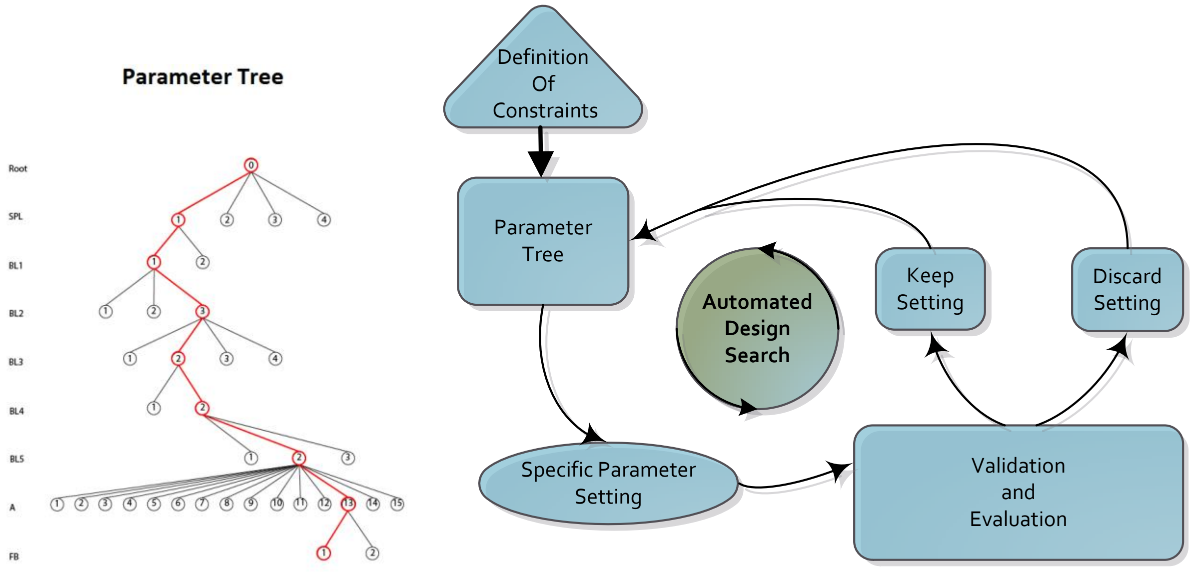

Figure 6: Automated design search diagram.

The simulation is using its existing validation and evaluation functionality by processing and using specific parameter settings from a parameter tree. The evaluation process was improved by requirements that are important for every autostereoscopic system by considering the quality for observer. A design example for a single color filter arrangement is depicted in Figure 7.

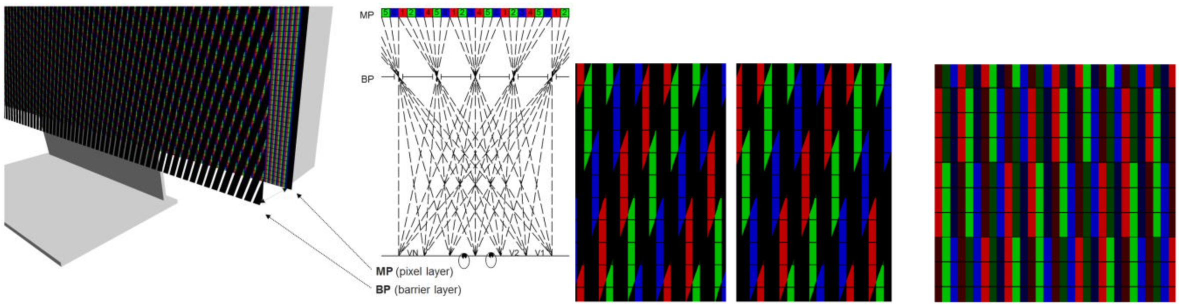

Figure 7: Exemplarily chosen result by automated design search for wavelength selective filter barrier as optical image splitter [5][8], from left to right: display model, top view of ray scheme, left and right view of filter barrier and pixel image allocation

3.4 Visualization of Image Content

Every single unit in the matrix pixel plane can be allocated with individual image content. Thus, the image parts visible in the viewing zones in different distances and angles in front of the 3D display can be visualized for any given observer position. For better visibility the display model in Figure 8 is showing exemplary content without an autostereoscopic image splitter.

Figure 8: Visualization of image allocated pixel panel without image splitter

4 References

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