Fraunhofer Heinrich-Hertz-Institut

White Paper

# Advanced Video Processing for Future Autostereoscopic 3D Displays

Version 2.0


White Paper

Title: Advanced Video Processing for Future Autostereoscopic 3D Displays

Authors: S. Jurk, R. de la Barré, P. Kauff

Date: November 08, 2017

# Table of Contents

## Table of Figures

## 1 Introduction

3D presentations on autostereoscopic 3D displays should consider ergonomics and usability of the viewing situation. This includes size and resolution of the display, its capability to present depth, as well as to consider the viewing distance of the user(s). Such a display is called adaptive. In commercial mass products the capability to adapt has to be a property of the display und has to be therefore integrated in the display interface. HHI developed an automatically stereo analysis, an eye tracking algorithm as well as a number of render solutions for special 3D presentation modes. These components can be implement preferably on display controller hardware but can also run on the graphics controller unit of a computer to realize the functions and modes described in that whitepaper.

## 2 Real-time processing chain

The presented system covers the whole real-time processing chain from a given stereo stream to its visualization at arbitrary autostereoscopic (i.e. glasses-free) 3D displays. Figure 1 shows a block diagram of the existing processing chain with multifold output options. The 3D content can be shown on either tracked single-user displays or multi-user multi-view displays as well as on upcoming integral imaging displays. For this purpose it can flexibly be configured such that the same processing and system architecture supports a multitude of different 3D display formats and operating modes. A further outstanding feature is its future-proof performance enabling perfect quality at auto-stereoscopic 3D display panels with very high resolution (4k and beyond) and extremely small pixel pitches. In summary, it allows highest quality for a wide range of 3D applications by only one common and cost-effective processing system.

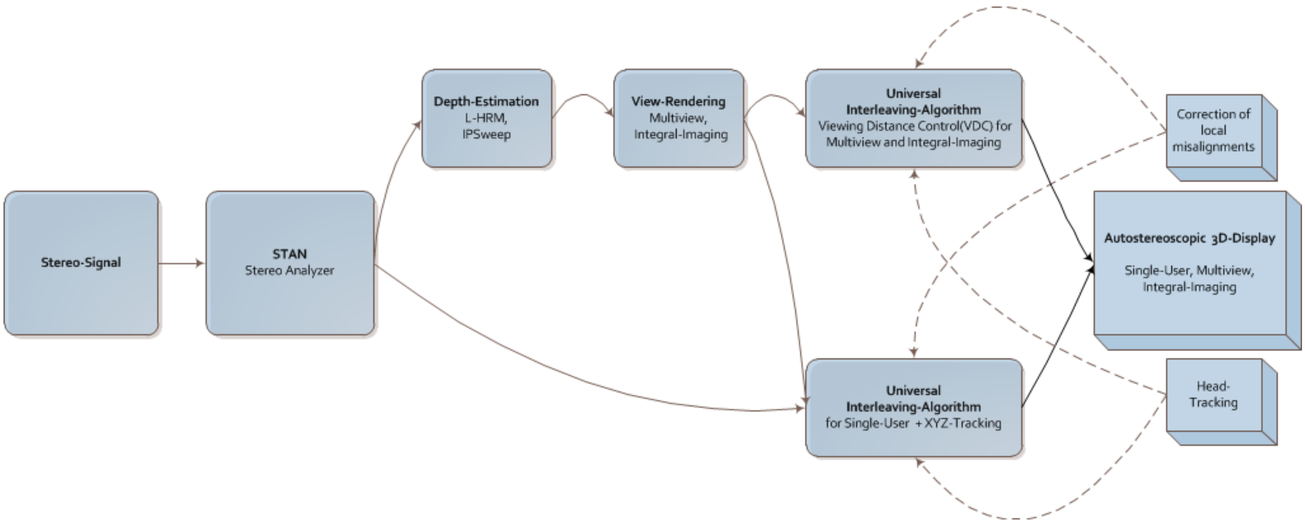


**Figure 1. Block diagram of the existing process chain with multifold output options**

## 3 STAN – Stereoscopic Analyzer

The Stereoscopic Analyzer (STAN) is used as the initial processing step. It ensures that the stereo stream respects basic quality requirements such as line alignment, color matching, avoidance of perception conflicts and compliance with comfortable viewing conditions. It controls the stereo quality and corrects the stereo input in real-time if necessary. It summary, the STAN is a system for producing perfect stereo by combining real-time image analysis with intelligent automated tools [1][2][3][4][20].

## 4 Depth Estimation

Based on the corrected stereo input from STAN output, depth information is extracted from the stereoscopic video by using a hybrid recursive matching (HRM) technique [5]. The current system of the processing chain uses a fast, robust and efficient version called L-HRM. It enables an estimation of disparity maps in real time [6]. Furthermore texture-adaptive multi-lateral post-filtering detects and corrects mismatches, resulting in reliable disparity maps of highest quality [7][8][9][21]. Currently, a new enhanced depth estimator is under development and will be integrated soon. The most significant advantage of this new so-called IPSweep algorithm is the furtherly improved real-time performance based on a high degree of parallelization especially suitable for GPU implementations [10][22].

## 5 View Rendering

Using the depth information from L-HRM, a depth-image based renderer (DIBR) calculates all virtual views that are needed for the specific 3D display to be supported. The view renderer is optimized for autostereoscopic 3D displays and runs in real time. Number and position of the virtual views depends on the display design and its operating mode. The renderer has a lot of options in order to get configured accordingly. Thus, it represents the core component of the entire system allowing the high flexibility to support any kind of display type and to be able to switch on-the-fly between different operating modes (e.g. tracked single-user, multi-view or integral imaging). Moreover, it allows to calibrate the alignment of display panel and optical lens precisely to each other, just by electronical processing – an important feature, especially in case of high resolution panels with extremely small pixel or sub-pixel pitch.

## 6 Autostereoscopic 3D Displays

Furthermore, HHI has developed a couple of algorithms for the fusion of several display formats and different operational modes such as single-user, multi-view and integral imaging by same image rendering process, just by different configurations of the on-board processing of the same 3D display without any modification of the optical lenses properties. The only restriction is that the given 3D display uses arbitrary horizontal or slanted optical image splitter. For instance, a multi-view 3D display with lenticular lenses can be converted to an integral imaging device, just by electronical means without modifying the optics themselves and vice versa. Furthermore, 3D displays with tracking units can be switched on-the-fly from tracked single-user mode to a multi-view multi-user display and vice versa. In addition, the technique allows for adapting the viewing zones to a tracked user position or desired viewing distances in case of multi-view multi-user displays or integral imaging devices [19].

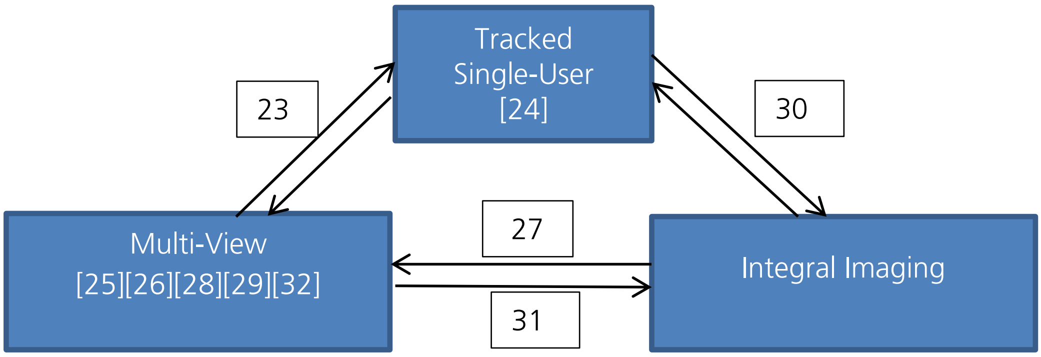


**Figure 2. Options to transform properties of a given 3D display by just electronical processing**

The following sections describe some concrete applications of this universal processing pipeline.

## 6.1 Universal Interleaving-Algorithm for Adaptive Two-View Mode

This mode offers a generic method for interleaving of two stereo images for each given autostereoscopic 3D display design and allows a precise electronical calibration between display panel and optical lens. It is applicable for single-user, multi-view, integral imaging [12][13][23][24].

- Universal interleaving-algorithm for autostereoscopic 3D displays
- Adaptation of the viewing-zone in XYZ space corresponding to a tracking signal
- Local correction of misalignments between display-panel and lens grid
- Hardware implementation on FPGA board for 5K Display

## 6.2 Continuous Multiview with Viewing-Distance-Control (VDC)

The Viewing Distance Control algorithm (VCD) is a generic method which adapts the interleaving pattern in dependence on the optical design of a given autostereoscopic 3D displays to the desired viewing distance [14][15][16][25][26].

- Adaptation of optimal viewing distance in front of or behind the nominal distance
- Enables continuous lateral displacement of the viewing zone
- Flexible technology for all autostereoscopic 3D displays
- Continuous change of perspective at a the lateral head movement
- Image content can be produced by depth-image based rendering (DIBR) or computer generated imagery (CGI)
- Lateral adaption by using additional views [32] is applicable

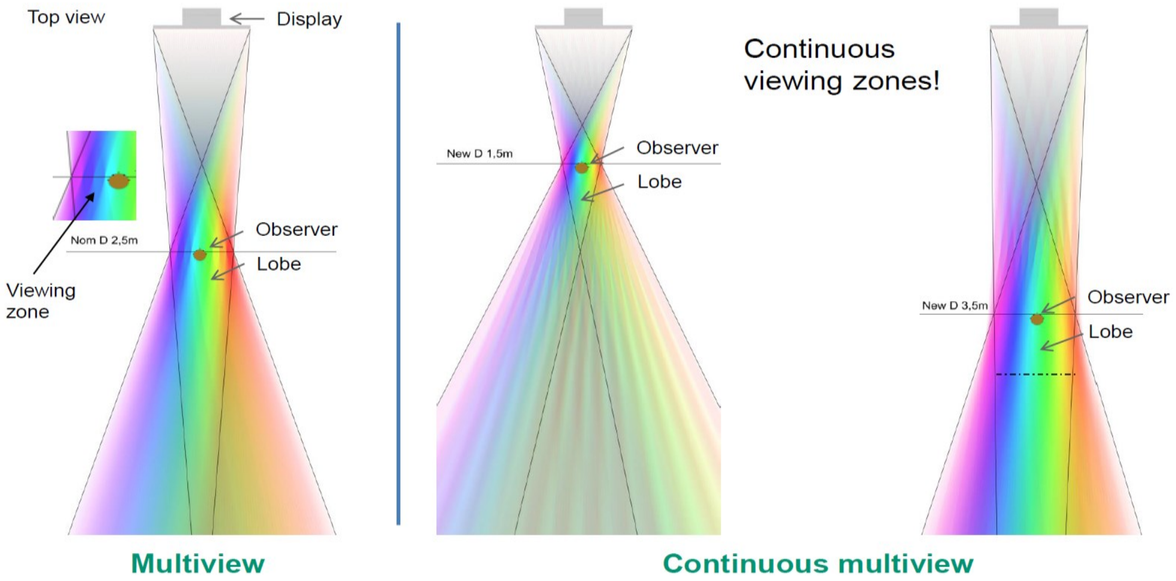


**Figure 3. Multiview display left with separated stereo zones (discrete multiview) and right with continuous adaptation of viewing zones to changing viewing distances by VDC (middle, right)**

## 6.3 Integral to Multiview Presentation with VDC

This mode enables the transformation of a 3D display with radiation properties from integral imaging to a multi-view 3D display by using similar processing as the one described in 5.2 [27].

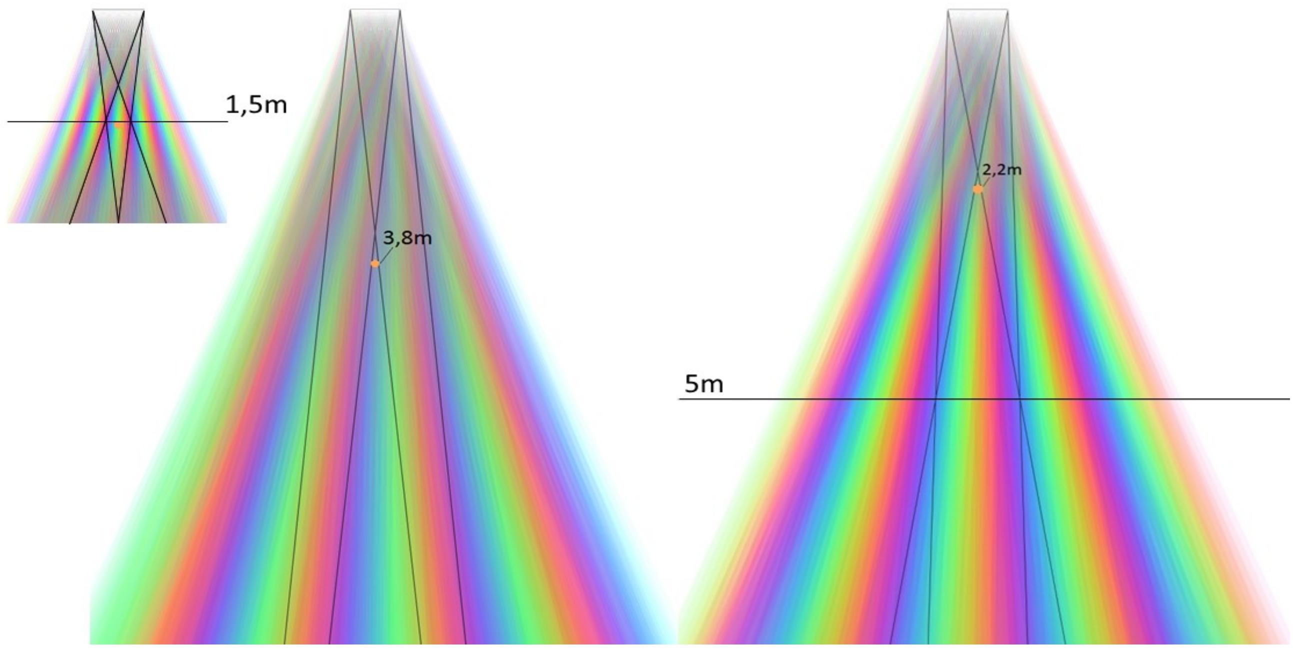


**Figure 4. Example for the viewing space at same 3D display: a multi-view mode (left), conventional integral imaging (middle) and optimal trade-off (right) for the desired viewing condition**

### 6.4 Depth Enhanced Integral Imaging

In addition, the opposite direction addresses a transformation of a multi-view 3D display with perspective ray geometry in an integral-imaging 3D display with parallel geometry. This special application has the advantage to find an optimal trade-off between both features, a large depth of field and large viewing angle, for a desired viewing condition [31].

- Increasing the depth of field compared with conventional integral imaging displays
- Reducing the blurring effect
- No adaptation of the viewing area in the Z-direction necessary
- Allows a reduction of the minimum viewing distance
- Allows the correct 3D perception at different viewing distances

### 6.5 Multi-Modal Super Hi-Vision 3D Representation

Super High-Vision panels with resolutions of 8k or 16k or even beyond will be available in near future. Due to these high resolutions autostereoscopic 3D display (multi-view or integral imaging) will be able to offer completely new features. In particular, it might be feasible to create a high number of separated stereo channels with wide viewing angles. Hence, in combination with tracking technologies, several persons at different viewing positions can watch individual stereo views under optimal conditions or even with different content, a viewing format known as multimodal representation [13][17][19]. Our universal processing chain is also able to support these future applications.

- Multiview 3D displays with mixed viewing zones, e.g. a tracked stereo zone and a wide angle 2D viewing zones for special application like surgery [23]
- Multiview 3D displays with a few tracked stereo zones and minimized crosstalk [28]
- Multi-Content representation where several people can watch with tracked stereo views of different content [29]
- Transformation of an integral imaging display with parallel ray geometry into a tracked single-user display with two views [30]

### 6.6 Correction of Misalignments

Increasing panel resolution also means an increase of pixel density and a minimization of pixel structures. As a consequence, the probability of local misalignment between the optical grid and the display panel during construction and manufacturing will also increase considerably. These misalignments can also be corrected by our processing system [18].

- Flexible method for the correction of allocation errors between the display panel and the lenticular
- Applicable to single-user, multi-view and integral imaging displays
- Correction can also compensate after inaccurate bonding
- Reduced fabrication costs due to electrical adaptation instead of mechanical calibration

## References

[1] Frederik Zilly, Peter Eisert, and Peter Kauff, "Real-Time Analysis and Correction of Stereoscopic HDTV Sequences", 6th European Conference on Visual Media Production (CVMP 2009), London, UK, November 2009, Short Paper.

[2] Frederik Zilly, Marcus Müller, Peter Eisert, and Peter Kauff, "The Stereoscopic Analyzer - An Image-Based Assistance Tool for Stereo Shooting and 3D Production", Proceedings of International Conference on Image Processing (ICIP10), Hong Kong, pp. 4029-4032, 2010.

[3] Frederik Zilly, Marcus Müller, Peter Kauff, and Ralf Schäfer, "STAN — An assistance system for 3D productions: From bad stereo to good stereo", Proceedings of 14th ITG Conference on Electronic Media Technology (Dortmunder Fernsehseminar), Dortmund, Germany, 2011.

[4] Frederik Zilly, Christian Riechert, Peter Eisert, and Peter Kauff, "Semantic Kernels Binarized – A Feature Descriptor for Fast and Robust Matching", Proceedings of European Conference on Visual Media Production (CVMP), London, UK, 2011.

[5] Nicole Atzpadin, Peter Kauff, and Oliver Schreer, "Stereo Analysis by Hybrid Recursive Matching for Real-Time Immersive Video Conferencing", IEEE Transactions on Circuits and Systems for Video Technology, special Issue on Immersive Telecommunications, vol. 14, no. 3, pp. 321-334, 2004.

[6] Christian Riechert, Frederik Zilly, Marcus Müller, and Peter Kauff, "Real-Time Disparity Estimation Using Line-Wise Hybrid Recursive Matching and Cross-Bilateral Median Up-Sampling", International Conference on Pattern Recognition (ICPR 2012), Japan, 2012.

[7] Christian Riechert, Frederik Zilly, Marcus Müller, and Peter Kauff, "Advanced Interpolation Filters for Depth Image Based Rendering", 3D TV Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON), Zürich, Switzerland, 2012.

[8] Marcus Müller, Frederik Zilly, Christian Riechert, and Peter Kauff, "Spatio-temporal consistent depth maps from multi-view video", 3DTV Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON), pp. 1-4, 2011.

[9] Christian Riechert, Frederik Zilly, Marcus Müller, and Peter Kauff, "Real-Time Disparity Estimation Using Line-Wise Hybrid Recursive Matching and Cross-Bilateral Median Up-Sampling", International Conference on Pattern Recognition (ICPR 2012), Tsukuba Science City, Japan, November 2012.

[10] W. Waizenegger, I. Feldmann, O. Schreer, P. Kauff, P. Eisert, "REAL-TIME 3D BODY RECONSTRUCTION FOR IMMERSIVE TV", Int. Conf. on Image Processing, ICIP 2016, Phoenix, Arizona, USA, September 2016.

[11] Christian Riechert, Frederik Zilly, Peter Kauff, Jens Güther, and Ralf Schäfer, "Fully Automatic Stereo-to-Multiview Conversion in autostereoscopic Displays", IBC 2012, Amsterdam, The Netherlands, September 2012.

[12] Silvio Jurk, René de la Barré, "A new Tracking Approach for XYZ-User-Adaptation of Stereoscopic Content", Electronic Displays, Nuremberg, 2014.

[13] Silvio Jurk, Rene de la Barré, "Improvements of aid free 3D Presentation", Electronic Displays Conference, Nuremberg, 2011.

[14] Silvio Jurk, Mathias Kuhlmey, René de la Barré , "A new Type of Multiview Display", IS&T/SPIE Electronic Imaging 2015, Stereoscopic Displays and Applications XXVI, At San Francisco, California, USA, Volume: 9391, 2015.

[15] Silvio Jurk, Bernd Duckstein, Sylvain Renault, Mathias Kuhlmey, René de la Barré, Thomas Ebner, "Enhancing multi-view autostereoscopic displays by viewing distance control (VDC)", IS&T/SPIE Electronic Imaging 2014, Stereoscopic Displays and Applications XXV, At San Francisco, California, USA, Volume: 9011, 2014.

[16] René de la Barré, "Viewpoint Adaption for Multiview 3D Displays", https://www.hhi.fraunhofer.de/en/departments/vit/research-groups/capture-display-systems/research-topics/multiview-and-integral-imaging-displays/viewpoint-adaption-for-multiview-3d-displays.html

[17] René de al Barré, „Adapting of Electronic Image Content for Autostereoscopic Presentation", https://www.researchgate.net/profile/Rene_De_La_Barre2/publication/264157821_Adapting_of_Electronic_Image_Content_for_Autostereoscopic_Presentation/links/53cfee990cf25dc05cfb3955.pdf

[18] Silvio Jurk, Mathias Kuhlmey, Bernd Duckstein, René de la Barré, "Electronical correction of misalignments between optical grid and pixel panel on autostereoscopic displays", IS&T Electronic Imaging 2016, Stereoscopic Displays and Applications At San Francisco, 2016.

[19] René de la Barré, Klaus Hopf, Silvio Jurk, Ulrich Leiner, "34.1: Invited paper: TRANSFORMERS - Autostereoscopic displays running in different 3D operating modes", SID Symposium Digest of Technical Papers 42(1):452-455, 2011.

[20] Peter Kauff, Christian Riechert, Frederik Zilly, “Feature descriptor for image sections”, WO Patent App. 2012/136642 A1,

[21] Peter Kauff, Marcus Müller, Christian Riechert, Oliver Schreer, Frederik Zilly, “Apparatus and method for real-time capable disparity estimation for virtual view rendering suitable for multi-threaded execution”, US Patent 9,158,994 B2,

[22] Wolfgang, Waizenegger, Oliver Schreer, Ingo Feldmann, Peter Eisert, Peter Kauff, “Apparatus and method for performing 3D estimation based on locally determined 3D information hypotheses”, EP Patent-application 16172527.0,

[23] René de la Barré, Silvio Jurk, “Method for displaying image information on auto-stereoscopic display screen”, US Patent 8,633,972 B2,

[24] René de la Barré, Silvio Jurk, “Autostereoscopic screen and method for reproducing image information”, EP Patent 2 708 029 B1,

[25] René de la Barré, Silvio Jurk, “Autostereoscopic display and method of displaying a 3d image”, US Patent 9,628,784 B2,

[26] René de la Barré, Silvio Jurk, “An autostereoscopic screen and method for reproducing a 3D image”, US Patent 9,398,291 B2,

[27] René de la Barré, Silvio Jurk, “Method for reproducing image information, and autostereoscopic screen”, WO Patent-App. 2014/183774 A1,

[28] René de la Barré, Silvio Jurk, “Method for displaying image information and autostereoscopic screen”, US Patent 8,358,335 B2,

[29] René de la Barré, Silvio Jurk, “Screen and method for representing picture information” US Patent 8,687,051 B2,

[30] René de la Barré, “Image display using matrix screen and periodic grating having a fixed period”, US Patent 9,319,663 B2,

[31] René de la Barré, Silvio Jurk, “Method for reproducing image information and autostereoscopic screen”, WO Patent App. 2014/048512 A1

[32] René de la Barré, Silvio Jurk, “An autostereoscopic screen and method for the simultaneous reproduction of more than two different pictures”, CN Patent 104541504 B,
Originally published as WO Patent App. 2014023321 A1

Fraunhofer
Heinrich-Hertz-Institut

White Paper

Fraunhofer
Heinrich Hertz Institute
Einsteinufer 37
10587 Berlin
Germany
Phone +49 (0) 30 310 02 - 0