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Integration of stereoscopic laser-based geometry into 3D video using DLP Link synchronisation

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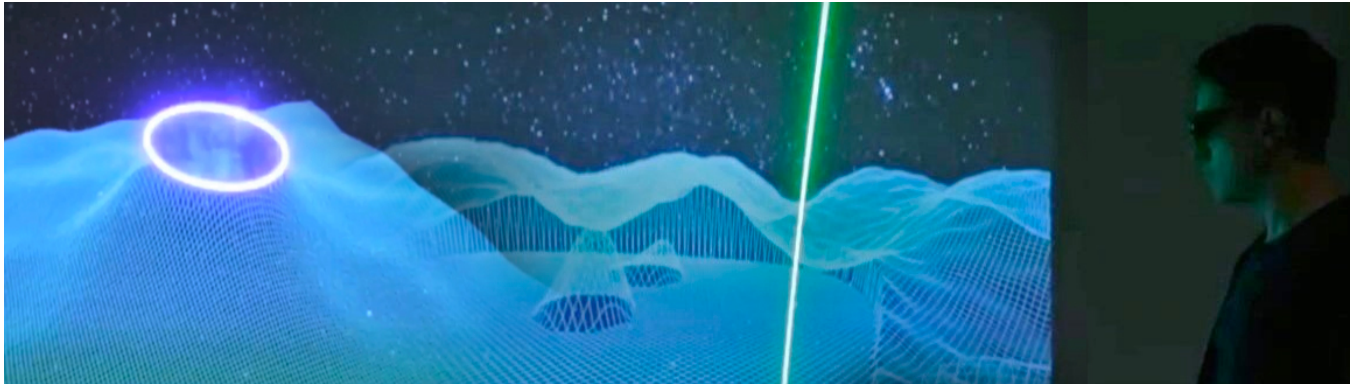


Figure 1: 3D scene augmented with stereoscopic laser projection

ABSTRACT

Stereoscopic video projection using active shutter glasses is a mature technology employed in multi-person immersive virtual reality environments such as CAVE systems. On the other hand, non-stereoscopic laser projectors are popular in the entertainment industry because they can display graphics at greater distances and cover larger areas. However, stereoscopic-capable laser-based vector graphics could enhance video-based immersive 3D experiences, due to their unique visual characteristics including extremely high contrast and arbitrarily extended gamut through the use of multiple laser sources. Their virtually infinite depth of field also allows for easy installation compared with video projectors, regardless of the size of the augmented space. In this work, we demonstrate a system integrating 3D laser-based vector graphics into a dynamic scene generated by a conventional stereoscopic video projection system.

CCS CONCEPTS

• **Computing methodologies** → **Graphics systems and interfaces**.

KEYWORDS

stereoscopic displays, 3D graphics, laser projection, CAVE, DLP

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1 INTRODUCTION

Stereoscopic video projection using active shutter glasses has a long history of development [11]. However, to the extent of our knowledge, no research exists on stereoscopic laser-based vector graphics using time-multiplexing techniques. In this work, we demonstrate a system overlaying 3D stereoscopic laser graphics onto a video-projected 3D scene. Laser graphics possess an extreme dynamic range, perfect color purity and line smoothness (no pixels), not achievable by conventional video projectors. Besides the potential use of 3D laser graphics alone (including outdoors use due to their extreme brightness) this technology can be exploited to add interesting special effects and detail into video-based 3D environments.

We synchronized a DLP projector and a (custom) laser projection system using the DLP Link protocol [7]. DLP Link synchronisation relies on the insertion of a brief white flash between consecutive left and right video frames. This brief flash is picked by an optical sensor on the LCD-shutter [7][8] and act as a synchronization clock. Given the relative simplicity of the laser graphics, and thanks to persistence of vision, a unique galvano-mirror suffices to produce both right and left-eye views.

2 BACKGROUND

While there has been previous research [9] describing the combination of laser vector graphics with raster graphics, these systems do

not generate stereoscopic imagery. There are several methods to generate stereoscopic scenes [5]. These include passive methods, i.e. strategies not relying on temporal multiplexing of views including polarised light and anaglyphs. However, active shutter glasses rely on alternatively blocking the light to left or right eye in a rapid sequence, in sync the video projector. This synchronisation can be done by broadcasting an IR or RF signal, or using the light of the projector itself, as is the case with the DLP Link technology described above.

3 METHOD AND EXPERIMENT

In our system an ESP32 micro-controller processes the signal generated by the opto-electronic demodulator circuit taken from a pair of shutter-glasses and produces an adequately time shifted signal to synchronise our custom laser controller [6]. It is important to note that although we developed the system around the DLP Link technology, other synchronisation protocols can be used without modification of the system.

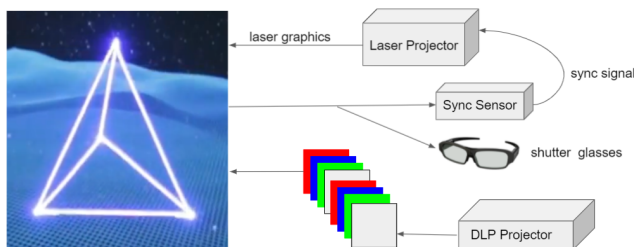


Figure 2: System overview

In our demonstration, an application written in OpenFrameworks renders a 3D wireframe landscape while at the same time sending simple geometry (in the form of a vertex array) to the custom laser controller via a high speed serial interface. The right and left eye perspective projections are calculated only when necessary on the micro-controller side, and optimal trajectories for drawing are stored in the controller memory for fast access and continuous steering of the galvano-mirrors [6]. As the background scene evolves, changes in pose of the overlaid 3D laser geometry only require the update and sending of model-view matrices.

In Figure 1, the bright ellipse and the green beam are produced by the laser, with the the remaining wireframe background generated by a video projector (the picture doesn't do justice to their very distinct perceptual characteristics). Calibrating our laser projector with a conventional DLP projector resembles the process of calibrating a multi-projector CAVE system [10], assuming that the laser-projector system can be treated as a pinhole camera. Obtaining the intrinsics and extrinsics parameters of a galvano-mirror based projector requires a special procedure though, explored and automated in [3]. However, in this preliminary work we verified that without precise calibration, both the video and laser display are matched and exhibited 3D stereoscopic properties.

4 DISCUSSION AND FUTURE WORK

The complexity of the laser content is limited by the frame-rate of the system and the speed of the galvo-mirrors. Currently the fastest available galvo-mirrors can generate 50 kilo-points per second, and since the laser switches between left and right images at 120Hz, we

are left with approximately 8 ms to draw each frame. This limits the graphic primitives to relatively simple geometry [1]. Future automation of the calibration process will facilitate the integration of multiple laser projectors dedicated to the left or right frames or even to different parts of the scene, thus allowing for an increase in the complexity of the graphic primitives.

This research paves the way to novel creative uses of lasers projection in virtual reality environments such as the CAVE, leveraging the unique characteristics of laser light. For example, laser projection can be used to render very bright elements such as explosions, lighting bolts, or laser beams that contrast strongly against the video projections while the video projection can render more nuanced, textured and complex backgrounds. Other interesting uses include annotation, highlighting of geometry and contours, or rendering 3D user interfaces, including navigation grids, 3D menus or pointers such as described by Daschelt and Hübner [4] or projecting lines extending from the user's hand and into the scene, similar to those used for menu selection in commercial Virtual Reality headsets.

Future work will also involve the integration of the "Laser Sensing Display" technology developed in previous works by the authors [6]. This technology uses a visible LIDAR for projection, and is thus capable of measuring distance and surface reflectance along the projection path. This enables real-time compensation for variations in the geometry or spectral reflectance of the surface [1][2], but also direct interaction with the stereoscopic content without using markers or tracking cameras [6].

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