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GemVR Corp

High Dynamic Range (HDR) Upconversion Technology

SDR to HDR: Enabling a Robust HDR Ecosystem for
Content Owners, Service Providers, and Industrial Applications

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Executive Summary

In this paper, Will Gaddy discusses High Dynamic Range (HDR) Images and Video, specifically, a critical component of the ecosystem for HDR – the need to convert legacy Standard Dynamic Range (SDR) content to HDR at very high quality. This is a very difficult technology problem not unlike upconverting SD to HD resolution. Most solutions are not good enough and do not meet the bar for “true” SDR to HDR upconversion.

Will explains how GemVR’s SDR-to-HDR Upconversion plus image amd video optimization technologies, plays a central role as a powerful tool set in making HDR a mainstream feature that will transform a competitive market. This will be a key differentiator for those who intend to take a lead in today’s highly competitive emerging media and image data landscape.

Introduction

GemVR's SDR-to-HDR upconversion can solve one of the biggest problems within the new HDR ecosystem.

In this whitepaper, we will provide an overview what HDR is, and define a very large unsolved problem within the HDR ecosystem.

The Science Behind the HDR Experience

Why is HDR video "better"?

The answer becomes clear if we discuss the two dominant HDR display types: OLED (Organic LED) and Quantum Dot LED. These pixel types have immense contrast ratio (for example, the blackest black is completely dark, with no photons at all) and a very high maximum luminance output of 1,000–4,000 nits.

Conventional displays, on the other hand, have a contrast ratio of 5,000:1 at most, and a typical luminance of 100 nits. Suffice it to say that with the right content, the impact of displaying images on these types of devices is like the difference between murky twilight and broad daylight.

1. **A Much Wider Range of Colors:** While conventional TVs only display about 33% of the colors that the Human Visual System can perceive (known as Rec.709 colorspace), HDR transmission and display standards raise this to approximately 66% (known as Rec.2020 colorspace).

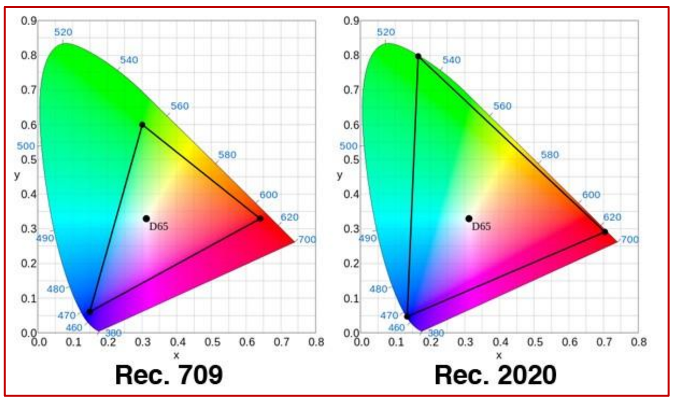

Figure 1: Conventional TVs display about 33% of the colors that the Human Visual System can perceive.

HDR transmits and displays approximately double this number.

2. **Increased Range of Brightness:** Even more important than the range of colors, HDR standards allow for a much greater range of brightness (up to 40 times that of non-HDR systems, as mentioned before).

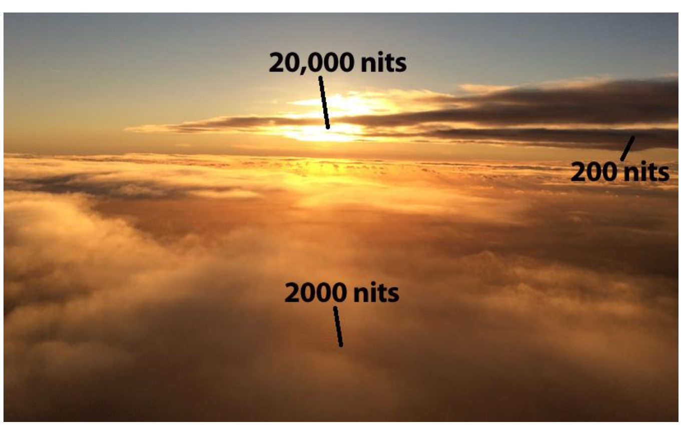

Figure 2: Depicting reality requires a large range of luminance (nits).

3. **Greater Contrast Ratio:** And finally, HDR allows for up to a 2,000,000:1 contrast ratio versus 5,000:1 for conventional displays**.**

These three elements come together to vastly expand the perceived visual quality and information conveyed, as long as the content production, distribution, and display ecosystem are all working together. However, this brings up a problem. Not everything has been created with HDR in mind. What about legacy SDR (Standard Dynamic Range) content?

Figure 3: What's missing, in order to perform legacy Standard Dynamic Range (SDR) to High-Dynamic Range (HDR) Upconversion?

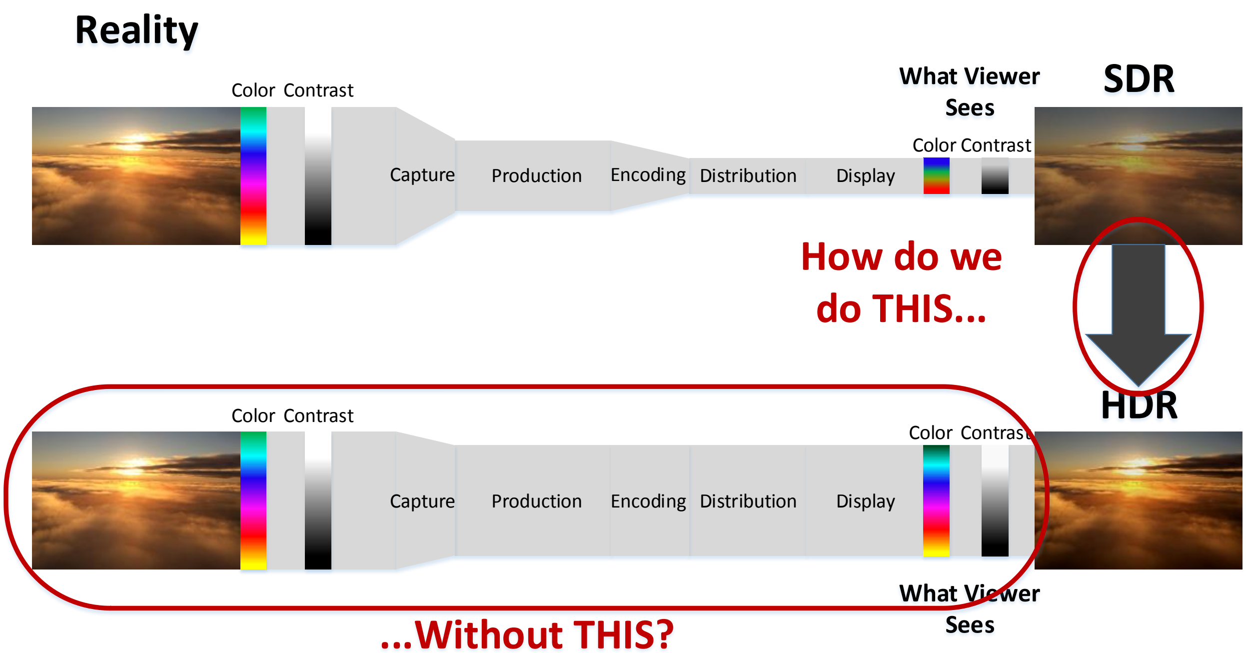

Figure 3 points out an important distinction. While there may be proposed distribution formats that allow for HDR production, with SDR distribution… and the reconstruction of HDR at the playback end w

- Even with small amounts of metadata from an HDR production pipeline, can REAL HDR playback be ensured on the playback device with this reconstruction?
- Further, 99.9% of content was never shot with HDR production and post production in mind. This leaves the problem of legacy SDR content, which was captured, produced, encoded, and stored without HDR in mind.
- How can content providers and distributors take advantage of their legacy SDR content, while providing market value to consumer participating in the new HDR ecosystem? GemVR SDR-to-HDR Upconversion provides the answer.

In the next few pages we will explore what it takes to convert a low dynamic range and limited color gamut image to a high dynamic range image and full color gamut image – without artifacts or degradations.

Figure 1a: 6-bit per channel with 75% Rec. 709 Color Gmut

Figure 1b: Color histogram of the image in Figure 1a.

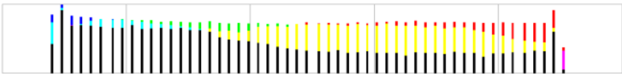

Figure 1c: Closeup showing banding and lack of dynamic range in sky gradient above mountain peak.

Since you're likely reading this in a PDF reader, which doesn't support HDR (and it's also likely that your display is only 8-bit as well) we can demonstrate the technology by using a reduced dynamic range image to start with – namely 6-bit instead of 8-bit. We will proceed to increase the dynamic range by 33% to 8-bit.

Since your monitor is also not likely compatible with the new Rec.2020 format, to demonstrate upconversion from Rec. 709 to Rec. 2020 (wide color gamut) we start with a reduced color gamut Rec. 709, and we will increase the gamut by 25%.

Of note, the histogram in Figure 1b shows gaps in-between color values – this is due to the reduced dynamic range. Further, note that there are no histogram lines at the leftmost side and rightmost side of the histogram. This is due to the reduced color gamut range.

In Figure 1c, we can see the practical effect of this limited dynamic range and gamut – banding is visible in the sky gradient and colors appear "muted", highlights are overexposed and shadows are "dark greyish".

Figure 2a: Output of GemVR HDR upconversion: 8-bit per channel with 100% Rec.709 Gamut

Figure 2b: Color histogram of the image in Figure 2a.

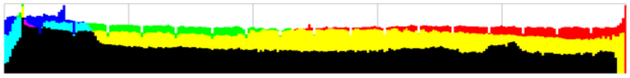

Figure 2c: Closeup of high dynamic range and increased color gamut in sky gradient above mountain peak.

In Figure 2a, we show the result of applying GemVR SDR-to-HDR upconversion. Note that the sky gradient is much more colorful, with no banding or stepping of colors. Additionally, the sun is no longer blown-out (capped at completely white), and the shadow portions are completely black.

The empirical effect of this can be seem in the histogram in Figure 2b – it covers the full range, with no gaps.

Most importantly, this is performed without the addition of any artifacts such as "ringing" around edges. Furthermore, there is no loss of detail, such as in the tower at the mountain peak of Figure 2c, or in the grass of the foreground.

To understand why this is important, we will show some naïve approaches to solving the SDR to HDR upconversion problem, the artifacts and issues they introduce, and then conclude with a synopsis of GemVR's patent-pending approach.

Figure 3a: Simple image blur of the image in Figure 1a.

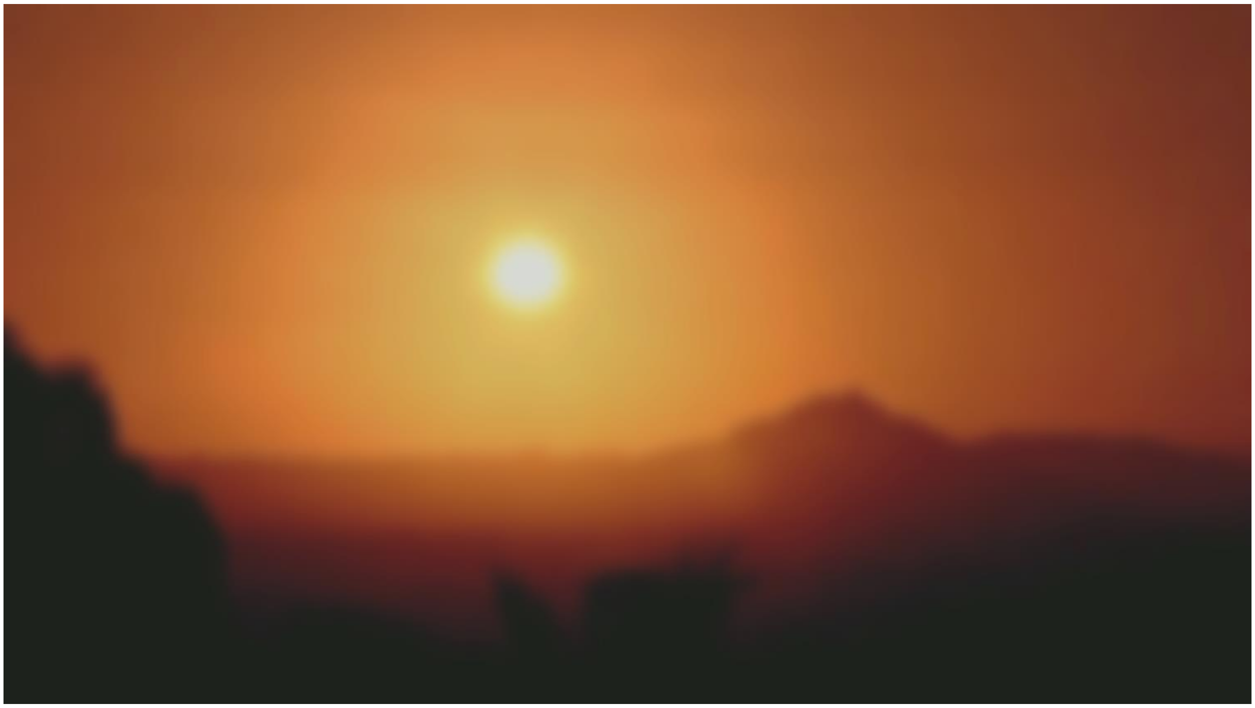

Figure 3b: Color histogram of the image in Figure 3a.

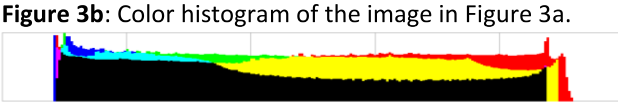

Figure 3c: Closeup of increased dynamic range in sky gradient above mountain peak.

One way to get increased color dynamic range is to simply blur the image, as in Figure 3a. While this certainly increases color dynamic range, it's a strict trade of spatial dynamic range (detail and edges) for color dynamic range (less banding).

Figure 3b bears this out – there are no gaps in the histogram anymore. While color dynamic range is increased this occurs at the expense of spatial detail.

Note that simple blurring doesn't expand the color gamut at the left and right of the histogram, so the image still looks "washed out".

Figure 3c shows this clearly. The tower is completely gone, and the edges of the mountain horizon are blurred severely.

What if we use an edge-preserving blurring filter, and automatic contrast enhancement, such as in Adobe Photoshop?

Figure 4a: Using Photoshop's "Smart Blur" and "Auto Contrast" upon image in Figure 1a.

Figure 4b: Color histogram of the image in Figure 4a.

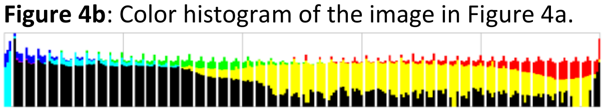

Figure 4c: Closeup of increased dynamic rangeand gamut in sky gradient above mountain peak.

In Figure 4a, we see the result of applying Photoshop's "Smart Blur", which tries to preserve edges. This is certainly much better than a naïve blur. Additionally, Photoshop's Auto Contrast has been applied. While the image is much more pleasing, there are some significant ill effects.

Figure 4b shows that while color dynamic range is increased, there are still gaps. Overall there are still some banding artifacts visible in the sky, especially toward the right hand side of the image. Additionally, the sun is still "blown out" and overexposed.

Figure 4c also shows why this is still an imperfect approach. While the edge of the mountain is clear, much of the tower has been blurred out. Other areas of the image show significant detail loss such as the tuft of grass in the bottom middle of the frame. Additionally, significant new artifacts have been introduced there.

GemVR SDR-to-HDR is a new, patent-pending approach that solves all these issues simultaneously.

The key to solving this problem is that the up-conversion system needs a highly-accurate understanding the "structure" of elements in the image. This means understanding which parts are foreground and background (or in the "middle" of the field, plus what parts of the image are edges, textures, noise, and artifacts. This is challenging because to an image processing system these things largely are difficult to distinguish.

GemVR's patent-pending approach uses a method called Eigensystem analysis. This is done upon something called the "structure tensor" for each pixel. Without breaking into Einstein-level mathematics, this results in three "Eigenvalue" numbers for each pixel, which can be used to distinguish whether the pixel is noise, in a textured region (and how much texture is there), if the pixel is in an edge region (and the orientation of the edge), or in the background.

Figure 5: Eigenvalues of the structure tensor for each pixel of the image

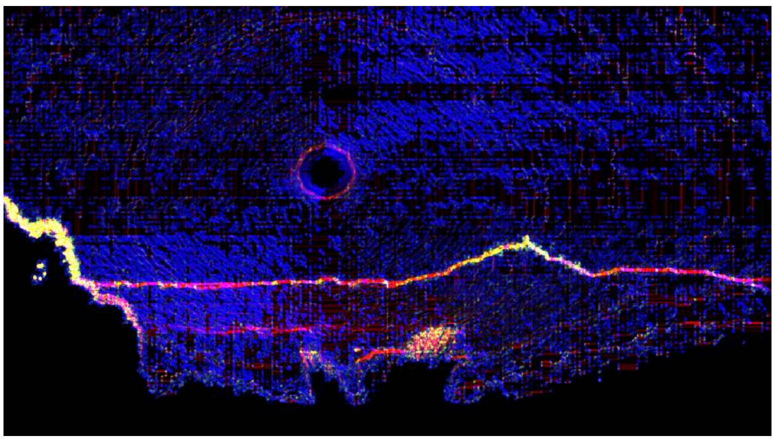

Figure 5 shows such an eigenvalue field for the entire image of Figure 1a. This in turn can be used to create a graduated mask, which can be used to selectively remove banding artifacts (black areas are completely excluded from processing), grey areas are partially processed.

Figure 6: Processing mask

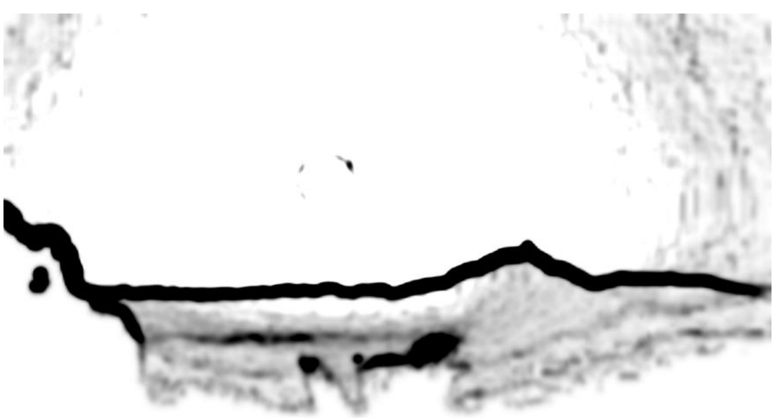

Figure 6 shows an example processing mask for the image shown in Figure 1a. Additionally, the blurring process applied is itself an edge- and –texture preserving filter, providing a further assurance against loss of detail, blurring of edges, and introduction of other artifacts.

Figure 7a: Image with dynamic range expanded to 8-bit via GemVR with preserved spatial detail and edges – but color gamut still limited to 75% of Rec. 709.

Figure 7b: Color histogram of the image in Figure 7a.

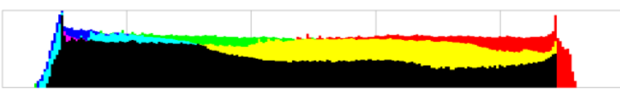

Figure 7c: Closeup of increased dynamic rangeand gamut in sky gradient above mountain peak.

Figure 7a shows the image of Figure 1a expanded to a color-space dynamic range of 8-bits per channel without affecting edges or textures nor adding or exacerbating artifacts with GemVR.

In Figure 7b, all of the gaps in the histogram are very smoothly filled in. However, the color gamut is still limited to 75% of the Rec.709 colorspace, as can be seen by the fact that the histogram is not utilizing the left-most and right-most extent of the available color gamut.

Figure 7c shows that unlike other naïve methods, all detail and edges are successfully preserved. However, the color gamut must still be addressed in order to provide a full solution.

An intelligent, structure aware tone-mapping operation is performed (recall that we previously used Eigensystem analysis of the structure tensor to figure out what kind of structural region each pixel was in) for each pixel, individually.

Next, a full comparison is shown.

Figure 8: Direct comparison – Original vs. Final Output of GemVR HDR upconversion: 8-bit per channel with 100% Rec.709 Color Gamut

Of particular note, it is apparent that GemVR image structure-adaptive tone mapping has rectified the abrupt cutoff of the sun from yellow to bright white – becoming a smooth gradient to brilliant yellow.

Next, shown are direct closeups of original, naïve approaches, and GemVR SDR-to-HDR Upconversion.

Figure 9a: Select close-ups – original low dynamic-range and small color gamut image.

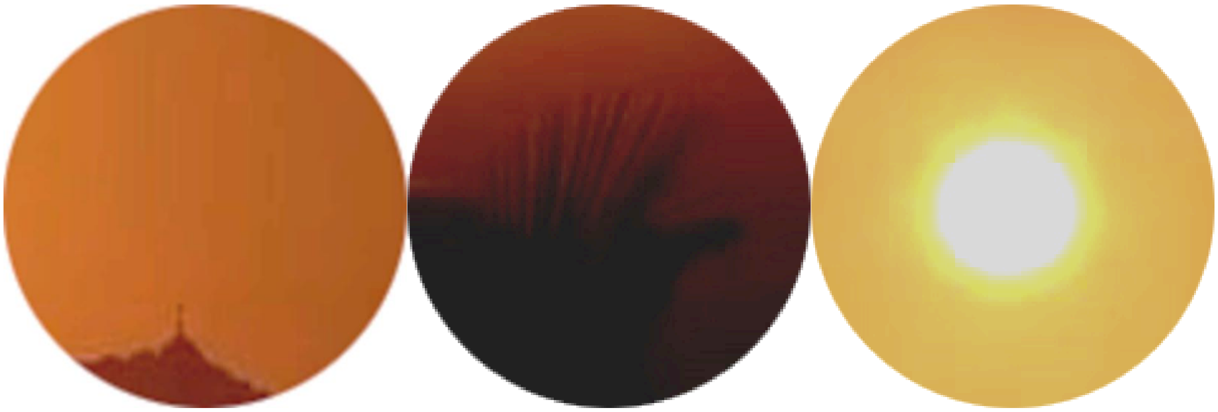

Figure 9b: Select close-ups – using PhotoShop Smartblur and Auto-Contrast.

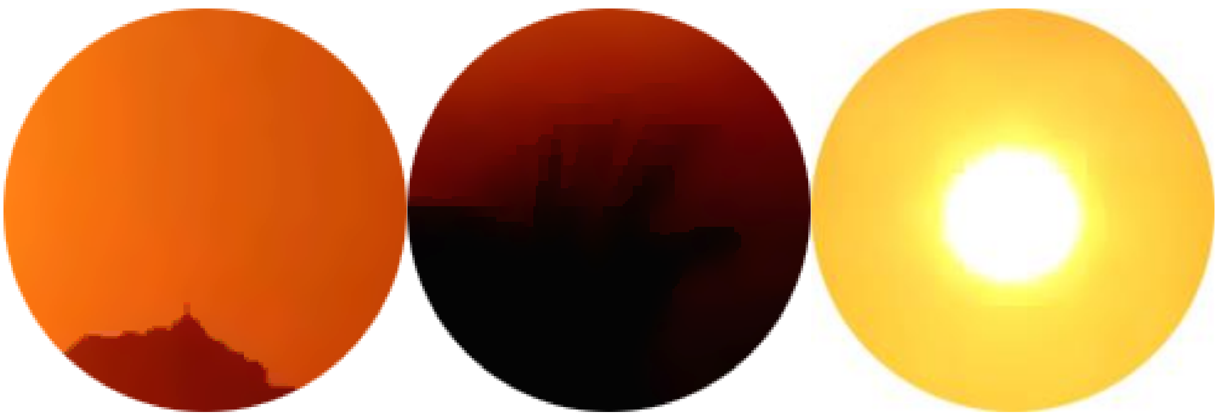

Figure 9c: Select close-ups – using GemVR SDR-to-HDR Upconversion.

Contact GemVR Corp

GemVR's SDR to HDR Upconversion is ready for low-BOM and parts-count-sensitive consumer electronics applications, cloud based applications, offline workflows, and real-time applications. For further information about GemVR support for HDR technology and the value it can add to an organization, please contact Will Gaddy at wgaddy@gemvr.net.

Will Gaddy, A2Zlogix CEO

Will's 30 years of experience managing audio, image, and video signal processing research and development teams, along with his experience developing mass-market software and electronics products, forms the foundation of GemVR's video technology and product development initiatives. As CEO, Will sets the sales, technology and IP strategy for GemVR and its holding companies. He has been awarded over twenty patents that underlie the core technologies.

While founding GemVR, Will was CTO of A2Zlogix, VP of Research at Clique Communications, Chief Systems Architect at LegatoVideo, and Team Lead at IBM Software's Web Content Management Group. He has also held positions as a member of IBM TJ Watson Research's Visualization and Geometric Computing Group. In addition, he founded and constructed successful exits for an ISV/publishing company and a technology licensing company. He studied Computer Engineering at the University of Illinois at Urbana-Champaign. His memberships include IEEE, IEEE Communications Society, IEEE Computer Society, IEEE Broadcast Technology Society, ACM, SIGGRAPH, SMPTE, AOPA, AMA, and SCTE.

About GemVR Corp

GemVR Corp. is the global industry leader in developing solutions that address the creation, delivery, and monetization of media and industrial content across the CME industry sectors, industrial and commercial markets. .GemVR Corp is a B2B company whose suite of strategic technology solutions addresses the industry's need for safety. speed, and deep data, and the effective monetization of reduced risk, reduced costs, and new solutions not previously available. GemVR provides instant ROI, enabling customers to deliver higher quality digital media services and actionable data. The company's solution portfolio includes Aviation products and services, with a focus on VR, AR, computer vision, AI, and avionics.

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