White Paper

Streaming of XR Apps

How to Master Major Challenges of Augmented and Virtual Reality with Remote Rendering

September, 2023

Executive Summary

Limited performance of mobile AR and VR devices. Time-consuming cross-platform development. Concerns about data privacy. While immersive technologies are a big driver for global digitization, the XR community faces major challenges that apply to every player in the field (developers, infrastructure providers and end users). This White Paper examines a new cross-platform approach to XR streaming. A technology that enables an unprecedented level of detail and performance for a faster and safer way of developing, experiencing and interacting with 3D content. Gain useful insights into how remote rendering works and its benefits. Read about first-hand examples of streaming entire XR applications with Hololight Stream SDK.

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HOLOLIGHT

Key Challenges for XR

Global spending on Augmented Reality and Virtual Reality (AR/VR) is forecast to grow from $13.8 billion in 2022 to $50.9 billion in 2026*. Companies across all verticals are identifying use cases and seeing the value of immersive technologies with a real return on investment. However, there are still technological challenges that affect the entire XR community, making the use of AR/VR applications difficult or, in some cases, even impossible.

Many of those challenges can be attributed to the center of our digital life: mobile devices. One significant issue many XR developers and users face, is the limited computing and graphics power of smartphones, tablets and smart glasses. An issue that will remain as there are physical barriers as well as the need to reduce the form factor to bring immersive technologies to the mainstream.

Some may also have data privacy concerns, find themselves struggling with low battery capacities of their mobile devices or investing too much time in native app development.

Low Hardware Performance

The rendering of 3D content is usually subject to technical specs (CPU, GPU, RAM) of the XR hardware. As performance of mobile devices is limited, the visualization of 3D content is also restricted. The quality and richness of effects are far below of what we are used to from modern PC programs.

Cross-Platform Development

The variety of XR devices, different game engines and tool kits as well as device-specific features like interaction methods make it difficult for app developers to provide their applications on several platforms. It is time-consuming and resource intensive to support different XR hardware.

Data Security

The protection of data is a critical task. However, confidential data or user data often is locally stored on the XR device. This makes it more vulnerable to hacker attacks. And in case the device gets lost or stolen, data security can no longer be guaranteed.

Quality of Data

The number of polygons, the file size, and the number of individual parts determine whether a 3D object can be displayed in AR/VR. Huge efforts to simplify and remove details of 3D content are necessary so that the object can run on a mobile device. As Hololight customer projects have shown, 90% of XR use cases require multiple hours of data preparation.

Enabling High-Quality Experiences in AR & VR

We are used to sharp renderings: Modern PCs have the capabilities to deliver high graphics within milliseconds thanks to their powerful GPUs and CPUs. This is not yet the case for Augmented Reality, where renderings are mostly more functional than impressive. Why is this and how can it be changed?

Building up an AR world around the user with viewpoints anywhere and always ready for interaction surely occupies a certain amount of computing and graphics power. But this is not the main reason, why XR glasses limp behind PC renderings. The speed of the GPU and CPU makes a significant difference. For example, the GPU of a PC is multiple times faster than the one in a XR device like the HoloLens. Additionally, a PC has more RAM and a vastly faster connection from CPU to GPU.

As a result, the quality of 3D scenes in XR is reduced in terms of appearance and complexity: holograms often do not look the way the user would like them to look. Sharp rendering should not play second fiddle as it can be very crucial for a quality immersive experience and a lot of use cases like design reviews, trainings, etc.

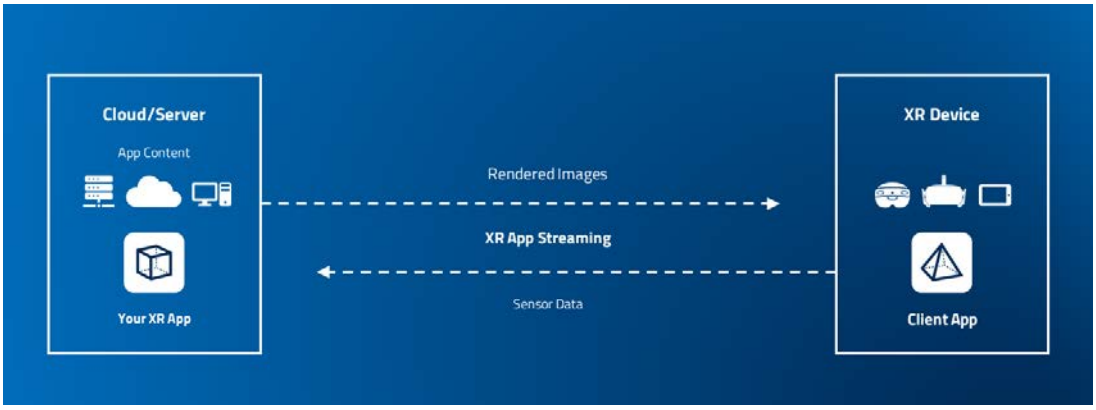
A stand-alone AR data goggle can only visualize up to 1,000,000 polygons fluently. To overcome this limitation, the key is to use external resources. This technology is called remote rendering and XR streaming. There are different approaches.

Remote Rendering Approaches

With some remote rendering solutions on the market, it is possible to bring high quality 3D objects and interactive interfaces to smart glasses. The cloud or a remote server handles the heavy rendering of a single 3D model and streams it to the device. By mixing cloud images from the virtual machine with those on the user's device, cloud content can be customized to match the UI of the application. This approach is ideal for visualizing large numbers of 3D objects.

However, a considerable disadvantage of this approach are the lacking app functionalities. In terms of logic, the app is separated from the 3D object, which makes it more difficult (although not impossible) to interact. Also, 3D objects with integrated live-computed data such as a point cloud, a building information model or an IoT environment are hard to visualize. Another disadvantage is that the app itself needs to get adjusted for this kind of approach. These shortcomings can be overcome by streaming the entire app instead of single 3D models. Read in the next chapter how the Hololight Stream approach manages to do so.

The Hololight Stream Approach to Remote Rendering



The Hololight Stream SDK is a remote rendering solution that enables real-time streaming of entire AR and VR applications. By streaming each application as a whole, Hololight Stream enables visualization and interaction with highly polygonal, data-intensive content such as graphics-intensive 3D objects, 3D CAD models or BIM data. The Hololight Stream SDK can be integrated into any XR application.

As shown in the graphic above, once the Hololight Stream SDK is integrated into an XR application, the app no longer needs to be installed on an end device. Instead, the XR app (with the server-side SDK component) is installed on a more powerful local server or in the cloud. Hololight's corresponding client application runs on the XR device and receives the image stream. The user simply connects via the client app on the mobile device to the XR app on the external server.

Now, the rendering process shifts from the low-performance XR device to the high-performance server. The client app sends data - sensor data for room tracking, gesture input, SLAM - to the server. After the data is processed on the server, the rendered images are encoded to use less network traffic and sent back to the client app, where they are decoded again.

To ensure a high quality user experience, this process must occur in real time. That's why everything in Hololight Stream - down to the socket level - is optimized for low latency (in networking terms, the total round-trip time it takes for a data packet to travel).

Latency is unavoidable due to the way networks communicate with each other. However, in the Hololight Stream client application, any latency is computed out. The result is real-time streaming of XR content. The entire application experience is the same as if the customer's application was running locally on the XR device.

The integration of Hololight Stream is simple: Download the Hololight Stream Unity Plugin, use the Unity Package Manager, press "Configure", and download the client application on the XR device to connect.

Server Requirements

- Operating System: Windows 10 Pro or Windows Server 2019
- Windows Version: Min. 10.0.17763 Build 17763
- RAM: Min. 16 GB
- CPU: Intel i7 (7. generation or equivalent)
- Graphics Card with min. 5GB memory

Network Requirements

- Network: Wi-Fi 5GHz
- Bandwidth: min. 20 Mbit
- Latency: max. 75ms

The Benefits of Hololight Stream

By rendering any AR or VR application, Hololight Stream can provide the right environment for every use case. With potentially unlimited performance, an agnostic approach to devices and server infrastructure, and an easy way to integrate applications, Hololight Stream offers multiple benefits to both application developers and end users. In addition to an on-premise solution, Hololight Stream is also available as a cloud-ready SDK.

Increased Performance for High-Quality Visualization of 3D Data

Foremost, Hololight Stream addresses the limited computing power of mobile hardware devices. Outsourcing the rendering process to an external server or the cloud brings potentially unlimited performance. It enables the visualization of GPU-intensive graphics effects and interaction with highly polygonal, data-intensive content.

Cross-Platform, Device Agnostic Approach for Faster App Development

The agnostic approach to XR devices and server infrastructure through deployed client applications reduces the development effort for XR applications. New apps can be developed with less effort and without limits or restrictions by just building a single server application. App development on new platforms is at least 10-times faster.

High Privacy Level, Confidential Data Is Only Streamed

The XR application can run on an on-premise server or in a public cloud infrastructure. The customer has full control over where his sensitive data is stored. As soon as remote rendering comes into play, the data is no longer stored on the XR device, it is only streamed. This is a crucial security aspect in the event of loss or hacker attacks. Compliance with current security standards is also made easy through centralized management.

No Reduction and Simplification of Data

Computing power is critical when visualizing 3D models with millions of polygons, high graphics, or many components. In the past, to run on a mobile XR device, data quality had to be significantly reduced. With Hololight Stream, high polygon content can now be visualized and manipulated in real time without simplifying the data.

Excursus: About Edge Computing, the Edge Cloud and 5G

While immersive technologies open up new business cases, 5G, edge computing and the edge cloud give them flexibility and bring even complex use cases to life. When rendering and streaming processes are not done on the end device anymore, a fast, secure and reliable transfer must be established to deliver a good experience. 5G as well as distributed networks are prerequisites for high quality Augmented and Virtual Reality experiences.

Edge Computing: Short distances, short response times

Edge computing architectures move functions from an adjacent physical server or nearby data center closer to the end user. Thanks to the geographically shortened path between the two, data can be sent back and forth in milliseconds. The edge cloud is of particular interest to many organizations. Because it draws computing power from the virtualized infrastructure of a geographically proximate data center, it can handle sudden spikes in workloads.

An important puzzle-piece: 5G

From virtualization to cloud and edge computing to network slicing, 5G will make a wide range of technologies more powerful with high performance, high reliability and low latency. As the total cost of ownership of these technologies tends to be low, they are fueling the exponential growth of data traffic.

5G is important to XR, especially for mobile applications in the field. As WLAN structures are geographically limited, cellular networks help to expand this area.

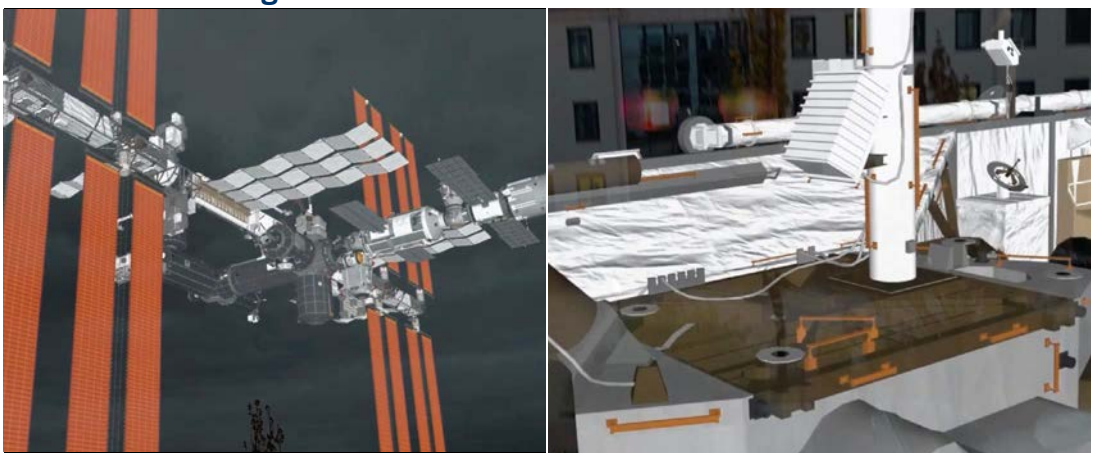
The more realistic 3D models look and the smoother the XR experience, the easier it becomes to replace in-person meetings. Massively increased and latency-free processing power enables new ways to collaborate remotely. XR does its part to make remote collaboration richer and more natural.

Hololight Stream in Action

Stand-Alone HoloLens 2 Rendering vs. Hololight Stream Remote Rendering

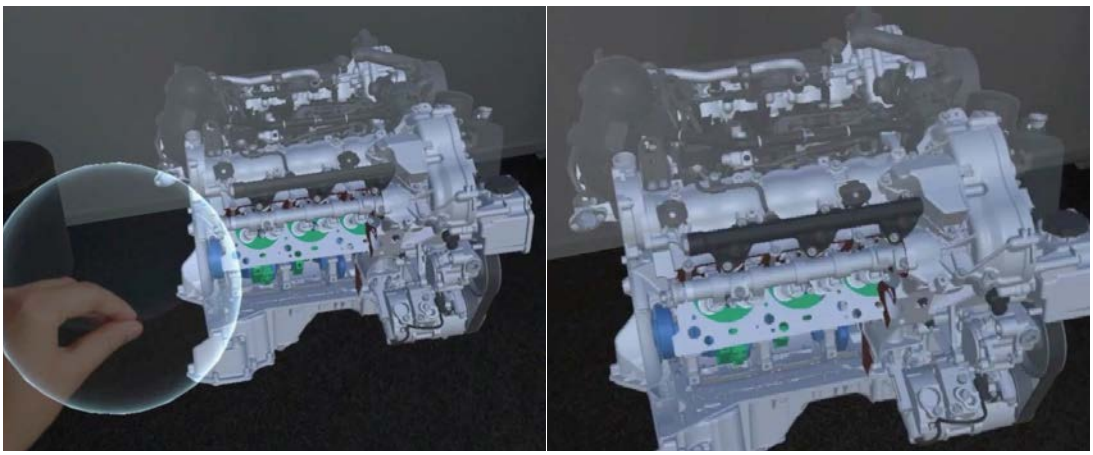
A 3D model rendered on a mobile edge device. There is almost no possibility to have any kind of realistic graphic or lighting effects. The same 3D model rendered remotely with Hololight Stream. Users are able to use the full power of the Unity HD Render Pipeline for high quality. Users can visualize, for example, CPU-intensive reflections, real metallic effects and even Raytracing will be possible.

ISS 3D Model Visualized on HoloLens2 via Hololight Stream Remote Rendering



Streamed 3D model with 10.000 parts, 50 million polygons. Impossible to run or even load locally on a mobile device. 50 million polygons and 4.5 GB of RAM processed at a rate of 60 frames per second. Visualize and interact with models at least 50 times greater in size. The same 3D model scaled up 1to1. Every detail is included and rendered remotely in real-time.

Streaming Hololight Space Applications with Full App Functionalities



Hololight Stream enables streaming of the entire application, including user interface and all interaction possibilities within the app. The full logic behind the application is processed and every part is rendered. Users can fully interact with it like it was loaded on the edge device. Big data 3D model with 5 million polygons. Every component out of the CAD hierarchy can be manipulated.

Best practices from various industries:

Enhatch Elevates Surgery with XR Streaming: Perfecting Surgery Together

Augmented Reality (AR) is rapidly growing in popularity in the medical field. Immersive streaming technology now provides the power and speed necessary to visualize complex surgical 3D data on a mobile AR device – providing surgeons access to critical information while keeping the patient in focus.

There is an astronomical amount of pressure on today's surgeons. Each year, the caseload increases, the complexity of procedures rises, creating an unsustainable workload. "We want to make surgeries better for the patient, but also create a better quality of life for the surgeon by reducing cognitive load," says Peter Verrillo, Cofounder and CEO of US medical technology company Enhatch.

Enhatch created the industry's first Intelligent Surgery Ecosystem, connecting companies, technologies, and surgeons to streamline clinical workflows and to provide insights from every surgery, patient, and device to elevate patient care.

"Our understanding of Augmented Reality and its various use cases in surgery continues to evolve. While many surgeons use this technology as a training tool, intra-operative AR is gaining significant traction within the medical community," Peter Verillo adds. Wearing Augmented Reality headsets, surgeons have sterile control over critical information, without leaving the operative field or even taking their eyes off the patient. During surgery, they can interact with unintrusive UI elements to access the patient's data records, scans, 3D models, or other preoperative notes. "The challenge is to bring this very complex data to the user's fingertips."

The Power of Remote Rendering

Surgeons often operate with a limited incision, meaning a very constricted field of view. An interactive 3D model provides a valuable perspective. Enhatch's software platform automatically converts preoperative images such as X-rays, CT scans, and MRIs into accurate 3D models. For one surgery, this typically means processing several gigabytes of data – overstraining the performance capacities of a Microsoft HoloLens 2, or other mobile AR devices. "To make it work would require us to reduce polygons and over-simplify the model. It would take more processing work and it might even produce a less accurate result to visualize," states Peter Verrillo. A definite no-go for an Augmented Reality application aimed at active surgery.

He adds that "by streaming, we can make it easy for the customer to access this valuable data." Enhatch has integrated the XR streaming component Hololight Stream into its solution.Hololight Stream is a developer tool enabling remote rendering and real-time streaming of entire AR and VR apps from cloud or on-premises infrastructures to a HoloLens 2, Meta Quest 2, tablets, or smartphones. Thus, the XR streaming solution allows the visualization and manipulation of 3D content that greatly exceeds the performance specifications of any mobile device. "The power of streaming is incredibly important to us, it literally provides the image the surgeon needs," affirms Peter Verrillo.

The Future of Healthcare

"With Hololight Stream, we save time and money processing data by just avoiding converting volumes of data from one syntax to another," he explains further. "We can simply keep the high-resolution data from the iPad or computer and stream it to the AR headset." As for the required setup, the Enhatch CEO points to a stable Wi-Fi connection between the server and client application. For the server, the company is using a laptop equipped with a powerful GPU like Nvidia's RTX 3080 series. Furthermore, Enhatch is exploring the cloud option and Hololight's XR streaming platform Hololight Hub to facilitate distribution and provide customers global

availability and easy access on all XR devices. Hololight Hub is designed for mass adoption, providing an ecosystem for XR apps from all segments and industries. Enterprises benefit from a centralized platform empowering industrial AR/VR use cases that were not scalable or even possible before.

"The beauty of AR is merging the virtual and real-world to have more successful clinical outcomes," he says. XR streaming technology will enable surgeons to analyze complex 3D medical data, without shifting focus away from the patient. At a later stage, surgeons should also be able to access the live stream of the AR headset to allow remote support during surgery. "We are taking the right steps towards faster, more personalized surgery for the patient. The use of Augmented Reality within the operating room is the future of healthcare," Peter Verillo concludes.

ShipReality's Customers Stream one Billion Points in AR

ShipReality and Hololight showcase the first holographic visualization of ultra large ship 3D laser scans merged with complex CAD design data – using the most advanced XR streaming technology available.

Ships regularly undergo large-scale retrofits, but shipowners rarely have design data in digital form at hand. To design ship modifications, an engineering accuracy of the as-built ship geometry is required, which means each vessel must be 3D laser-scanned. ShipReality, a company specialized in AR/VR ship design automation and remote ops, synthesizes these large ship laser scans with its CAD software to design directly in 3D - resulting in merged models of CAD in the as-built ship geometry point clouds.

"We want to speed up and optimize retrofit designs for 60,000 ships that require greenhouse gas emissions reduction, energy conversions & ballast water treatment system (BWTS) retrofits in the coming years", said Georgios Bourtzos, CEO and Co-Founder of ShipReality. "A major challenge we faced designing directly in large point clouds was visualizing entire vessels layered with resulting 3D designs for immersive design reviews on mobile XR devices like Oculus Quest 2 and HoloLens 2."

Exploring the Use of Point Clouds in AR

Point clouds are precise models of real environments based on 3D laser or photogrammetry scanning. Objects and space are represented in the form of "points". Millions of such points combined formulate a point cloud scan. The scan is then imported into a 3D modeling platform with the purpose of creating an as-built model. Common CAD software used for ship designs, although incorporating 3D laser scans, still rely on 2D projections and screens to visualize and design in 3D. This often results in incompatibilities with the existing ship geometry, which are only realized during installation, creating substantial delays and high additional costs.

Visualization in 3D is a key issue to address these problems. However, visualizing large point clouds requires substantial CPU and graphics power. The performance requirements are simply too high for rendering it locally on a mobile XR device. It would cause an extremely low frame rate and even software crashes. Dealing with large datasets, ShipReality had to find a solution that could surpass the limited memory, CPU and GPU resources of mobile devices.

XR Streaming Solution that Supports Point Cloud

XR streaming technology outsources the rendering process to a local server or the cloud. But not every solution on the market supports ultra large data or point clouds. "We integrated Hololight Stream into our solution to stream large 3D laser scans merged with CAD retrofit designs to a HoloLens 2," affirmed Bourtzos. Hololight Stream is a unique remote rendering software component that allows to stream entire augmented and virtual reality applications in real time. "The simplicity and ease of integration of the software development kit worked seamlessly with our large models," Bourtzos added.

Integrating Hololight Stream into their engine and software, ShipReality was able to visualize a massive model containing more than one billion points. Layered on top was also BWTS CAD design data created by the company's ShipMR-design software with additional five million polygons. To compare, a mobile XR device could only render about one and half million polygons locally. As the remote rendering server ShipReality used a moderate gaming laptop and the local WiFi, broadcasting on 2.4GHz band. More performance and bandwidth enable even greater visualizations.

Next Level Immersive Experiences

"Hololight Stream has amazing potential for AR/VR visualization of massive digital twins and real-time monitoring of projected complex 3D designs merged with as-

built environments in shipping and other industries," asserted Bourtzos. ShipReality is now able to:

- visualize ship models that are only suited for high-performance processing
- capture large assets 1:1 and integrate complex 3D CAD designs/data
- visualize detailed models for spatial analytics in augmented reality

"Hololight Stream can save us a lot of time and resources because we can directly use point clouds in mobile AR: some pre-processing steps can be avoided," Bourtzos further commented. Data availability, accuracy, density, and size of 3D point clouds are also forecast to vastly increase within the next years. "To realize the full potential of immersive point cloud experiences, streaming will play a major role," concluded Georgios Bourtzos.

Omlox Combines the World of Tracking with Augmented Reality

Omlox solves an industry-wide problem. Hololight Stream enables the implementation. With augmented reality, the omlox tracking standard and the XR streaming solution strive for the revolution of industrial indoor navigation.

Machines, people, tools, and even drones and automated transport systems. Every production site has an unbelievable number of (moving) objects, making asset tracking an essential task. With the open omlox tracking standard, the independent organization PI (PROFIBUS & PROFINET International) has introduced a worldwide industrial standard for tracking technologies. For the first time, information from all existing tracking technologies such as UWB, BLE, RFID, 5G or GPS can be used. In addition, there is an open radio interface in the omlox core-zone, which lets each manufacturer track its devices within the open infrastructure. Augmented reality (AR) should now help visualize the collected position data for on-site employees in real time, a use case that has not been possible till now due to technological hurdles.

Augmented reality should make tracking data usable

Real-time tracking data is the basis for more efficient processes. Machines and equipment can be used more efficiently and employees guided safely and quickly through industrial halls. omlox transfers all tracking data to a uniform coordinate

reference system. An augmented reality application now converts this data into information and makes it visible to the employee in real time. That is the theory.

"The limited computing and graphics power of the required smartphones, tablets or AR goggles presents a challenge here," says Eberhard Wahl, Head of New Business Technology at Trumpf Werkzeugmaschinen and leader of the omlox Use Cases Workgroup at PI. "The connection of the mobile device to the omlox hub (open data hub in omlox) must also be implemented." Complex data sets/3D models, data streams and coordinate transformations cannot be meaningfully mapped on the mobile device.

An additional factor is the open infrastructure setup of the omlox core zone. The position data is computed on a centralized server on the basis of the open omlox core zone infrastructure. This open infrastructure permits the simple and immediate absolute localization of the AR devices. In addition, the factory manager retains sovereignty over all position data in his plant and can manage them in the omlox architecture in a centralized manner, facilitating further analyses, such as the optimization of spatial processes. When classic mobile AR hardware is used, however, tracking and machine data, among other information, is stored locally on the device or compulsorily on a connected cloud server, a potential privacy problem and entryway for hackers. "The security of sensitive location data is a key issue for us, especially when mobile devices are finding their way into the home office and may get lost," Wahl says.

XR streaming technology trend

"We have made it our goal is to combine the tracking world of omlox with the world of AR, with concrete benefits for the end user and process design," Eberhard Wahl says. In order to implement the use case plus AR application and overcome the aforementioned hurdles, omlox relies on the XR streaming solution Hololight Stream. The software development kit (SDK) is a remote rendering component that enables the streaming of entire AR and VR applications. As a result, computing power no longer comes from the mobile device itself, but is provided by a powerful local server or selected cloud – potentially without restrictions.

Once Hololight Stream is built into the AR application, the app no longer needs to be installed directly on a terminal device. Instead, the AR app is installed and run on the more powerful server or in the cloud through a connection to the omlox hub. A simple receiver app (client app) on the mobile device sends data (room tracking sensor data or position data) to the server with the actual AR application. There, the data is processed and sent back to the receiver app with the 3D content to be

displayed. Through real-time streaming AR content such as a 3D machine or live tracking data can be visualized with as yet unmatched detail and complexity.

The open omlox core zone as a main enabler

"Countless location systems to support tracking in the augmented reality environment have existed for years," says Alexander Werlberger, co-founder and CTO of Hololight. "These systems, however, are all proprietary, which prevents widespread use." Here, the open omlox core zone opens up a new world for AR: The existing omlox core zone infrastructure can be used from any device. Based on the standardized interface, any manufacturer can implement an omlox core zone infrastructure or localization device. In this way, indoor navigation becomes as easy as outdoor navigation.

The open GPS used for outdoor navigation is replaced by the open omlox for indoor purposes. Just as AR can show the navigation of modern cars outdoors according to the exact position, it can also display navigation commands indoors in the same way. As a result, omlox solves two main problems for AR:

- The simple and open absolute localization of devices in the room directly after activation (omlox core zone)
- The provision of content for AR devices (where is what) via the omlox hub
- "In this way, omlox opens up new application areas for AR indoors, which were previously only feasible using expensive proprietary solutions," comments Werlberger. Even moving objects (e.g., AGVs, people, assets) can be displayed in the AR application using the omlox hub API.

Everything runs through a centralized server

All computing processes such as content rendering and application logic from the omlox system now run through a centralized server due to the XR streaming technology Hololight Stream. The centralized server component permits the performant combination of the world of tracking with the AR world – for example, the omlox core zone with the coordinate system of the HoloLens 2 AR goggles. Arrows, navigation instructions, machine data, tool positions, etc. are displayed on the AR goggles of the end user in real time. On the back-end side, the AR application can be controlled and maintained by the server as with the rest of the omlox system. The agnostic approach to devices and server infrastructure of Hololight Stream also enables integration of additional devices such as Android and iOS smartphones without further developmental effort.

"Due to the open omlox architecture, products can be tracked end-to-end," explains Eberhard Wahl. "If an AR component is added, employees on site can also profit from the data." Workers on site receive information on machine positioning, status information and safety routes on the display. The AR indoor navigation apps that are currently available, however, are often too imprecise and cumbersome to implement and use. With omlox, users can also find devices inside buildings, similar to what is already possible outdoors using GPS. With the XR streaming SDK Hololight Stream integrated into the AR application, the system is also considerably more stable.

"Using Hololight Stream, we can combine a stationary system with a mobile algorithm," says Wahl. "And all that with centralized control." At the same time, the streaming of entire AR applications increases data security in the IoT. All data is simply streamed and not saved on the mobile device. It is located on the server selected by the customer. As Eberhard Wahl concludes, "With the AR application, we are redefining indoor navigation: no need to attach QR codes, no complex preparation of halls and a precision that is significantly higher than that of comparable systems."

Conclusion

It is safe to assume that smartphones, tablets, and eventually smart glasses will drive the future of spatial computing. But the more mobile the hardware, the less processing power it has. It's also a simple way to describe a well-known problem with immersive technologies when it comes to dealing with large amounts of data. This is why offloading the rendering process through XR streaming can be a game changer for the XR community.

For example, the Hololight Stream enables streaming of entire AR or VR applications via powerful local servers or the cloud. A device-agnostic approach through deployed client applications also reduces the development effort for XR applications. New applications can be developed more easily, without the limitations and restrictions of individual devices, by building a server application. Time-consuming data simplification is no longer necessary. Streaming complete applications also increases data security. As soon as the remote rendering solution Hololight Stream comes into play, the data is only streamed from a selected server and not stored on the mobile device.

We are all looking for the next milestone to drive global digitization with Augmented and Virtual Reality. Hololight aims to realize the full potential of these technologies by providing developers with an easy to integrate remote rendering SDK. Free trials and simple licensing models are available upon request.

Imprint

Holo-Light GmbH
Maria-Theresien-Straße 1
A-6020 Innsbruck

Represented by
Florian Haspinger

HOLO-Industrie 4.0 Software GmbH
Carl-Zeiss-Ring 19
D-85737 Ismaning

Represented by
Florian Haspinger

Contact

Website: www.hololight.com
Telephone: +43 664 88 23 46 32
Email: info@hololight.com

HOLOLIGHT