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Interviews
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Technology
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Features
Unveiling the next act: Exploring the latest tech reshaping live events

Case study
A 360 CAVE install is redefining research at Tilburg University

BACK TO THE BIG BANG

CERN visitor centre brings particle physics to a new audience

INSIDE

28

REGULARS

FEATURES

CASE STUDIES

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CAVE DIVING

A new 360 CAVE environment is redefining research at Tilburg University. **Reece Webb** discovers what makes this immersive environment tick.

Innovation is the key to opening new pathways in the world of education, and for Tilburg University, nothing but the best would do to achieve cutting-edge research.

CAVE virtual environments are nothing new, but creating a space that can fully immerse participants without compromise is a challenge. Enter the DAF Technology Lab, a new CAVE system that brings immersion to the world of education and research.

Max Louwerse, professor and DAF Technology Lab founder and scientific director, Tilburg University, explains: "I'm the founder of the lab, so I guess the idea more or less started with me. I wrote a research proposal where I argued that education may benefit from bringing content closer to the learner and the learner closer to the content, not in an individual VR setting, but a collaborative setting.

"This is where the CAVE came in with virtual reality presentations projected onto the walls. We were building a new educational building and that was the perfect place for these CAVEs. These two [identical] CAVE systems stand apart because they are 360-degrees environments. Many CAVEs have two or three walls, but not 360-degree visuals. When they are 360, they often don't have tracking systems that allow for the VR simulation to adjust itself to the user walking around the space; the CAVEs that I know about that almost match these systems focus on visuals but not audio, whereas we have immersive video and audio, creating a fully immersive environment."

Stepping into the CAVE, students will find themselves in a seamless, four-wall experience that combines spatial audio, high-quality projection and a collaborative VR environment within a space that has no obvious doors or immersion-breaking elements.

"What we came up with is an affordable solution for education, given its needs and what is available technologically," says Louwerse.

Surrounded by sound

A spatial audio system was critical to the design of this immersive environment, with the university turning to Genelec and a unique approach to installation that maximises visual and audio immersion.

Maarten Horden, advisor, DAF Technology Lab, says: "For the first time, we used smart speakers over IP from Genelec. We used these as [the system] was cheap to build. You don't have to put both electrical and signalling cables for 42 speakers into the room. It's a power over Ethernet solution which is a lot easier to install."

Forty-two Genelec 4420 Smart IP active networked loudspeakers and two 7360 smart active subwoofers were selected for the installation. All of the speakers are calibrated differently within the CAVE, meticulously tweaked to create an audio dome environment.

"For us, this was a jump into the dark as IP speakers are still fairly new, and our AV partner was concerned about latency," adds Horden. "We haven't had any problems with latency. It's perhaps a few microseconds worth, and it's not something that the ear will notice. While building a spatial audio system is not that difficult, having it incorporated with your Unreal or Unity 3D game platform is a whole different story. We want to control the audio dynamically, so it is responding to your behaviour in the CAVE, and this is something that you can create with spatial audio."

Creating an environment that immerses both the eyes and ears

of participants is no small feat, requiring a smart audio system that not only fit the bill, but worked seamlessly with the CAVE's 12 Volfoni 3D VR glasses.

Horden explains: "Our solution required a lot of creativity, DIY, and invention. One of the most unique aspects of this CAVE is the spatial audio combined with the VR glasses. Normally, you have back projection, which is a wonderful way of creating a CAVE, as all the noise, disturbances and heat from the projectors can be put outside and projected on to a screen or glass. The disadvantage is that you can't have audio behind the screen.

"Our idea was to put speakers behind a screen, and everybody thought I was crazy as it was believed that you cannot put a spatial audio system behind a screen... but it turns out that you can. We used a perforated screen from Gerriets. This is a perforated screen which you can put speakers behind; it's basically an audio dome over a cube which can create a 360-degree spatial audio system. You can't put speakers under the floor in our setup, but you can fool anybody into thinking that there are speakers underneath them if you create the illusion, that's where the VR glasses come into play. You're trying to fool people into thinking that this is a true-to-life audio system, and it works really well."

A Sennheiser Teamconnect Ceiling 2 microphone is also installed overhead, ensuring that every participant can be heard throughout the space at the same time. Zones can be excluded to enable virtual avatar interaction in specific spaces of the CAVE, avoiding the feeling of a 'god voice' that permeates the entire space and thus retaining the illusion.

"If we put you in a church environment, we can create echo or record sound through the microphone and bring it back into the room as an echo as the latency is so low", adds Horden, "It's all in the same acoustic environment and you can fool people into thinking that they are in a much bigger space. Because you are in a close environment with a lot of people, you often have to do something about the climate and the heating/cooling. This creates white noise, which manifests as humming in the background. As we are using a spatial audio system to bring in sound, the white noise is not that noticeable."

A soft approach

On the software side, the university uses Unreal Engine and Unity 3D in combination with Volfoni 3D VR glasses, developing simulations and games within these platforms. "This combination of software allows us to use the tracking system to interact with the controls, whether you're using an Xbox controller or your hand." says Horden.

A QSC controller is used to ensure that Dante protocols are used for steering audio, controlling the room's projectors, controlling the door, generating input from the microphones to speakers and offering control controlled via Unreal or the Unity 3D engine. Controllers have full control of volume and lights.

"That is the heart of the system," explains Horden, "there is also an Extron control panel to give people easy access to buttons to turn the system on and off."

Each CAVE is home to four Digital Projection E-Vision 4K laser projectors, each installed high above the CAVE with short-throw lenses to allow participants to get up close and personal with the content.

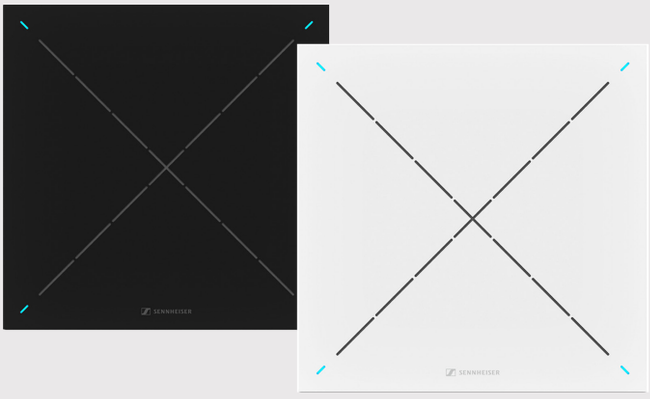
Horden says: "Back in 2019, if you wanted a 3D stereoscopic image, from the 20,000 projectors that you could choose from, you whittle it down to eight projector models that will do the trick. As we were building two CAVE environments, we chose Digital Projection as they were able to achieve the dual pipeline necessary to create 3D stereoscopic images while also working with the Volfoni glasses.

"We used short-throw lenses so that each participant can get closer to the wall, within 50cm without standing in their own shadow or creating disturbances. The projectors were installed 4.5m high so that you don't have noise from the projector itself, though they are already relatively silent, and as they are laser projectors, they produce less heat."

Follow me

The university uses OptiTrack infrared tracking cameras in combination with tracking devices to identify precise movements of participants during research sessions. The objective was to gather as much data as possible without creating a tracking system that was too bulky and obtrusive, restricting movements or encouraging unrealistic responses.

Horden says: "We can make the CAVE completely dark, so there are no distractions from LED



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lights. All of the reflections from the projectors are masked, creating a true black environment. We can track every movement from everybody in all light conditions; OptiTrack makes sure that it comes together, and you can feed that interaction back to the Unity 3D or Unreal Engine to make live interactions with an avatar. One of the challenges in the CAVE is to have as many people in and to track their behaviour. We aim for five to seven people maximum, which means we can track those people as accurately as possible (head movement, eye movement etc.), and can deliver to have a good experience. The tracking system is all about monitoring and tracking every precise movement meticulously."

The CAVE system ensures that the tracking system is unobtrusive for participants, ensuring that each gesture, behaviour and direction of view can be tracked in this 360 environment.

Trussed up delivery

Systems integrator Levtec stepped in to provide the trussing system for the CAVE's technology, creating the correctly shaped environment for the CAVE system with a discreet and unobtrusive technology installation.

Horden says: "One of the most challenging things in a CAVE is getting the screens in a square; you want the shape to be square and the screens to be perfectly aligned. Levtec created the steel construction for the doors, projectors and speakers. They created the entire framework that the system is mounted to.

"One of our biggest challenges was creating a CAVE without a door. There is no (obvious) entrance and exit door once the CAVE is closed. This is one of the hardest parts, as you typically see CAVE environments made with three walls or an ordinary door, as we had with our old CAVE. We didn't want to see a door or hinge, so Levtec created an ingenious door from a screen, so that when the door is closed, you cannot see the exit. The speakers also move with the closing door to create the audio dome effect. Putting projectors and speakers up is easy, but getting the screens up in a sub millimetre position is quite difficult and this is what they created, it's a very precise screen system with transparent screen material, it's second to none."

Seamless solutions

Mounting the entire setup and creating a CAVE without a door proved to be a major challenge, all the while creating a system that is fully integrated for research and educational purposes.

Horden explains: "Creating the spatial audio engine so that it interacts with Unity 3D or an Unreal simulation was challenging. That takes a lot of time to make a working system, plus getting the projection, tracking, audio and 3D glasses synced with research equipment was also tricky, it's important to have it running on the same clock, at the same time. Getting these various parts to come together and be synced to a thousandth of a second, was a massive hurdle."

Systems integrator Kinly provided the cabling for the projectors and the QSC system, ensuring that the door can be opened and the lights can be operated. Kinly worked closely with the university team and Levtec to deliver the full experience. Horden adds: "This is a modular system. There are lots of mounting points to mount all sorts of cameras, research equipment, on top or behind the CAVE.

"I don't think there is a CAVE supplier in the world that has the complete package for research and education purposes. I'm proud that it all came together in a working environment where you can bring your research and education projects to life at a high technical level."

Today, Tilburg University is home to a one-of-a-kind CAVE solution that provides participants and researchers with unparalleled levels of control over simulations and access to a wealth of data.

Louwerse closes: "We have empirical evidence that students learn more in the CAVE environment than through traditional means of learning such as textbooks, and they find it more enjoyable. Ultimately, we aim to create a VR simulation that adapts itself to the quality of the learner in that CAVE environment, where an intelligent tutoring system in the embodiment of a virtual human helps you out when needed.

"So many questions remain unanswered with VR and CAVE systems, so we look forward to continuing to explore these in detail."

KIT LIST

- Digital Projection E-Vision Laser 4K laser projectors, Ultra Short Throw Lens
- Extron MediaLink Plus controller
- Genelec 4420 Smart IP active networked loudspeakers, 7360 smart active subwoofers
- Gerriets perforated front projection screen
- OptiTrack Prime 13W infrared tracking cameras, tracking system
- Panasonic WX-X4170 dome network camera
- QSC Core 110f processor
- Sennheiser TeamConnect Ceiling 2 microphone
- Volfoni Edge VPEG-05010 VR 3D glasses

> The installation itself is one of the best spatial audio systems in combination with a virtual reality experience.
>
> *Maarten Horden, DAF Technology Lab*

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