insights

"WE SEE A FUTURE WHERE 3D SENSORS COMPLETELY REPLACE 2D SENSORS."

Eric Krzeslo

3D VISUALIZATION TECHNOLOGIES

Transforming the way we deal with information - from consumption to interaction

EXECUTIVE SUMMARY

> "THE HOLOGRAPHIC FUTURE MAY BE MUCH CLOSER THAN THE 8 TO 10 YEARS CURRENTLY EXPECTED."

ARE YOU READY FOR YOUR HOLOTABLE?

3D imaging is already part of our visual environment, not only in the forms of 3D movies and TV shows but also as the backbone of countless 2D visualization systems. As it becomes more immersive, 3D will enable whole new types of entertainment and professional applications. Yet true holographic 3D visualization—3D that won't require viewers to wear special glasses and stare at a flat screen—lies on the other side of solving some key research challenges. iMinds is taking an end-to-end approach to enabling next-generation 3D visualization, investigating the required techniques and technologies from image capture to processing and presentation.

ELIMINATING THE FRAME

COMPILING THE PICTURE

One way of generating next-generation 3D images is to capture multiple viewing angles with multiple cameras. Yet it's financially and physically impractical to deploy a camera for every possible view. This is why researchers are seeking ways to fill the gaps between captured viewpoints—for example, mining available image data and statistics to fill blanks between recording angles, interpolating and creating backgrounds, matching repeating images and recreating blocked objects. Researchers are also seeking to better understand what underlies our ability to perceive 3D images in the first place, tackling the problem of stereoblindness that makes today's 3D techniques ineffective—and in doing so, helping to open up new possibilities for 3D visualization.

RENDERING THE PICTURE

With 3D visualization, what was once a single, flat image is now a massive block of data requiring immense processing power to render. Full holographic 3D today would need exascale computing power and a massive supply of energy. Today, researchers are investigating compression approaches to streamline processing demands and relieve network pressure. That's been the focus of iMinds' work with Graphine, a Flemish company whose innovative texture-streaming technology improves graphics quality and load times while reducing memory usage, disk and download size.

ADVANCING 3D VISUALIZATION TECHNOLOGY

While holography is the most advanced 3D application being pursued, researchers are also working to improve traditional stereoscopy as an interim step—for example, by using autostereoscopic imaging that doesn't require special glasses. iMinds is collaborating with companies like Belgian TV manufacturer TP Vision to advance this technology and more fully explore the potential of autostereoscopic 3D TV.

For holography, the lynchpin technology will be spatial light modulators. Currently costing tens of thousands of dollars apiece, researchers are working to make these more economical to realize the holographic future.

ENVISIONING THE FUTURE

The impact of successful 3D visualization will be immense. iMinds will be working with industry and research partners to further investigate the potential applications of 3D technology. An example includes its research with SoftKinetic, a company looking to use 3D sensors and software to revolutionize the way our devices interact with the environment around us. The ultimate aim: bringing the advantages of holographic 3D technology to domains such as culture, health and the economy.

FOR MORE INFORMATION

about iMinds' expertise in the field of 3D visualization, please contact
Peter Schelkens
peter.schelkens@vub.ac.be
+32 2 629 1681

ARE YOU READY FOR YOUR HOLOTABLE?

> “NEXT-GENERATION 3D MARKS A TECHNOLOGICAL STEP FORWARD.”

HOW HOLOGRAPHIC 3D WILL REVOLUTIONIZE OUR VISUAL EXPERIENCE

Picture it: the World Cup final has gone into extra time and a penalty kick is about to decide the match. The striker lines up the shot, shifting tensely from foot to foot... and you’re right beside him. Virtually, that is—thanks to holographic 3D visualization technology. You and millions of other fans are there at field level, each choosing your own unique vantage point to watch the critical moment unfold.

It may sound fanciful, but in fact Japan made delivering that kind of 3D experience a key part of its bid to host the 2022 FIFA World Cup. Over the coming decade, 3D visualization will advance by leaps and bounds, enriching sports, entertainment and gaming as well as professional, collaborative applications such as telesurgery and computer-aided design. In each case, next-generation 3D marks both a technological step forward and, more profoundly, a shift away from simple, one-way visual consumption to immersive, visual interaction.

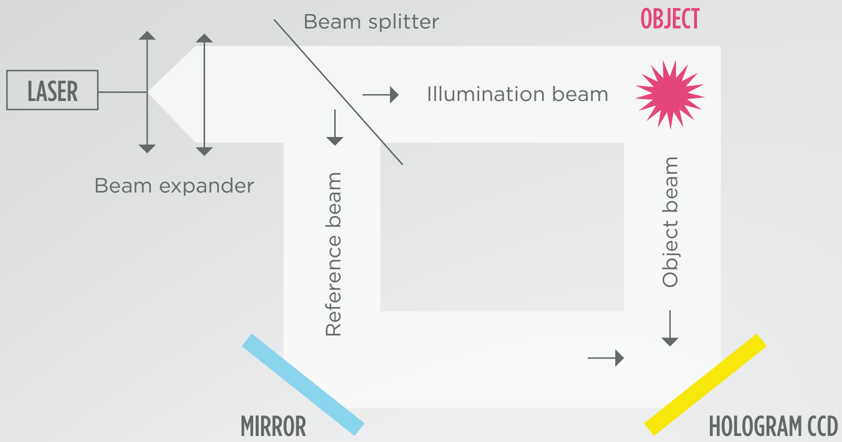
3D imaging is already a growing part of our visual environment—most conspicuously in the form of 3D movies and TV shows, but also as the backbone of countless 2D visualization systems. Yet true holographic 3D visualization lies on the other side of solving some key challenges related to capturing, processing and presenting 3D images. Research organizations around the world are working actively to address those challenges, including iMinds, where teams are taking a uniquely end-to-end approach to enabling next-generation 3D visualization.

3D: THEN, NOW AND NEXT

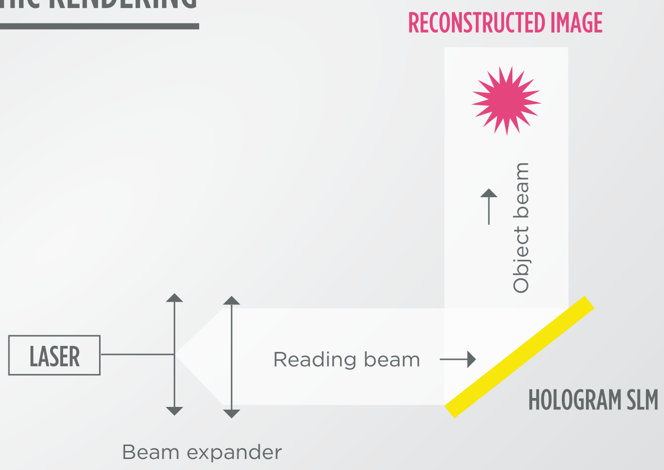
3D imaging is hardly a new phenomenon. The first 3D patents were filed in the 1890s and the first 3D film, The Power of Love, screened in 1922. Early 3D technologies simulated the functioning of human eyes by using dual cameras to capture slightly overlapped images. With considerable technological refinement, that stereoscopic approach continues to be what most viewers would associate with 3D today: walk into a movie theater during summer blockbuster season and you'll find ushers handing out '3D glasses' to help the brain interpret the stereoscopic images.

HOLOGRAPHIC CAPTURING

Setups for recording and reconstructing a hologram.



HOLOGRAPHIC RENDERING



TERMINOLOGY: PLENOPTIC CAMERA

Plenoptic cameras capture information about a 'light field' versus a conventional photographic image. The light field provides 4D information and requires an array of microlenses for recording.

> "THE NEXT WAVE OF HOLOGRAPHY REQUIRES THE USE OF DIGITAL TECHNOLOGIES IN AN END-TO-END SYSTEM."

While stereoscopy simulates depth in a two-dimensional image, it is not truly 3D and has limitations related to image quality and usability. To start with, today's audiences are used to very high-definition 2D images, making the relatively low image quality of stereoscopic 3D unsatisfying. On top of that, many viewers find 3D glasses or headgear annoying, and a small percentage reports headaches and nausea when watching stereoscopic 3D content.

Initially emerging from physicist Dennis Gabor's efforts to improve the electron microscope, holography involves recording the scattering of light around an object, then recreating the pattern as a 3D image. The invention of the laser in the 1960s made holography more practical, enabling a wide range of current applications for everything from data storage to anti-counterfeiting. Yet laser-based holography also has its limitations, especially when it comes to representing complex, multi-angle imagery.

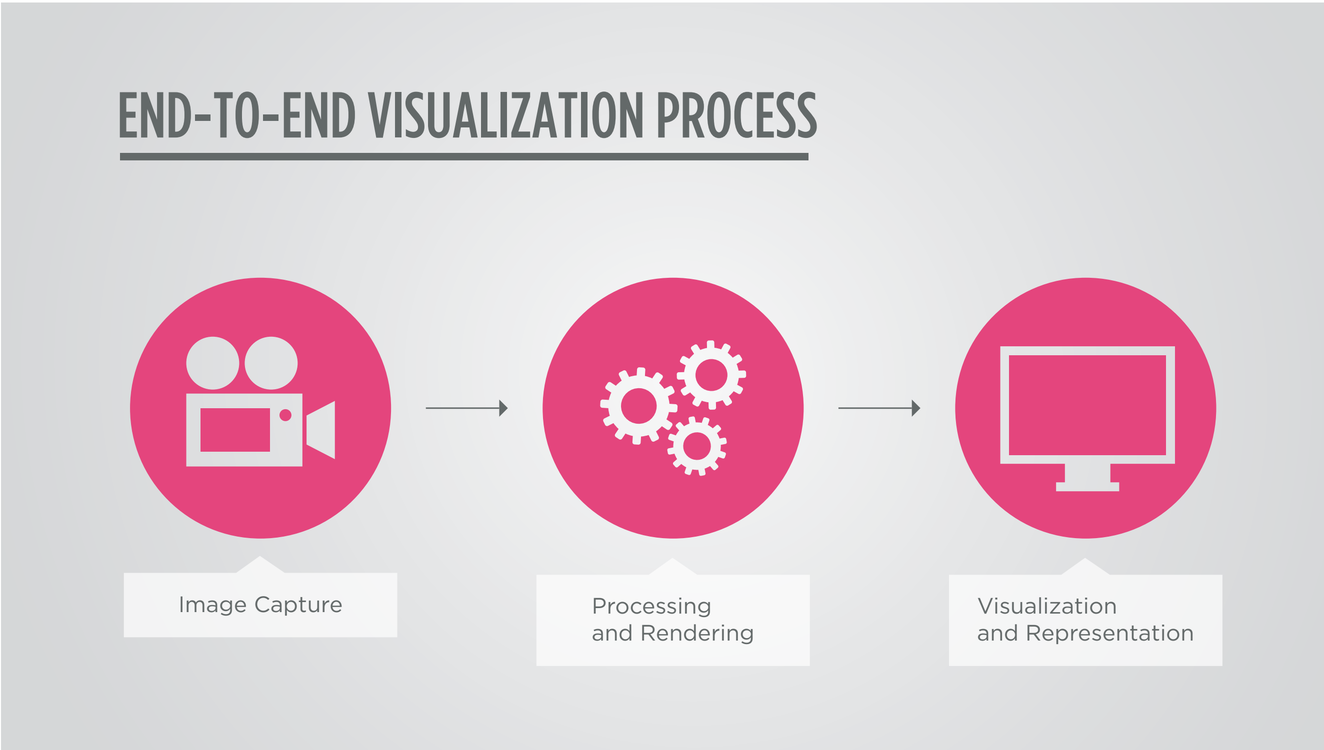
The next wave of holography—the kind required to realize Japan's vision for the 2022 FIFA World Cup, for example—requires the use of digital technologies in an end-to-end system that is ultimately capable of projecting three-dimensional moving images in space.

In such a scenario, viewers will be able to interact with the image in any number of ways—adjusting the viewing angle, zooming in or out, rotating objects—to personalize the viewing experience. Many of the foundational technologies for this kind of next-generation 3D solution have already been developed and are in use today, often to augment traditional 2D imagery.

TOWARD HIGH-DEFINITION HOLOGRAPHIC 3D

Anyone who has used Google's Street View application has had a taste of one of today's key pre-3D technologies: free viewpoint visualization. Free viewpoint captures data from multiple angles and synthesizes it into a single image that can be rendered in either two or three dimensions.

This kind of capture usually involves deploying standard or slightly augmented 2D cameras in an array, or a single standard camera outfitted with plenoptic cameras to capture different pixels. With these technologies, individual images are captured in two dimensions and provide the basis for a panoramic or 3D model that's created, rendered and transmitted to the viewer. 3D images can also be created from imagery captured by a standard 2D camera in motion.



Beyond capturing a view of the world outside the narrow rectangle of a two-dimensional frame, 3D developers also need tools for analyzing the movement of objects with depth and in motion—consistently and realistically. Video game creators have done a lot of pioneering work in this area already, creating synthetic 3D content with support from technologies like time-of-flight cameras that interpret 3D environments.

Time-of-flight cameras calculate depth based on the speed of light: an object is illuminated with a laser and the time it takes for the light to return to its source is measured. Belgium's SoftKinetic used time-of-flight technology in Sony's PlayStation 4 console to track human gestures—for use with games like the latest edition of the popular Just Dance franchise. The potential applications of time-of-flight technology extend far beyond gaming, however. From robotics to topography, a vast number of fields could make use of its ultra-sensitive depth data.

While multi-camera and time-of-flight technologies provide a basis for 3D imaging, a number of research challenges need to be addressed before they can be incorporated into an end-to-end holographic visualization solution—'end-to-end' because it has to cover the full chain of production from capture and rendering to re-creation and presentation.

TACKLING THE RESEARCH CHALLENGES

IMAGE CAPTURE: COMPILING THE PICTURE

In the multi-camera setup required for free viewpoint visualization, image capture is a phased process. First, visual data is gathered by the various cameras. Next, those images have to be calibrated—in other words, linked together seamlessly. After calibration, the content needs to be assembled in a step developers refer to as registration.

Once registration is done, the final set of visual contents will likely contain some occlusions: regions that have been recorded imperfectly, blocked from view >>

> "RESEARCHERS TODAY ARE LOOKING AT TECHNIQUES TO FILL BLANKS BETWEEN RECORDING ANGLES."

or simply left out of the capture. With today's multi-camera approaches, occlusion is more or less unavoidable. Today's most sophisticated screens can support roughly 200 different viewpoints, but it would be expensive and unwieldy to deploy 200 individual cameras to cover them all.

So the research challenge becomes one of finding a way to fill the visual gaps—both textures and depth cues. Researchers today are looking at techniques for mining the image data and statistics that are available to fill blanks between recording angles, and at other methods for interpolating and creating backgrounds, matching repeating images and recreating blocked objects.

The process of producing accurate 3D videos with a mixture of recorded and artificial imagery is called inpainting. Its success depends on it being seamless—by avoiding 'artifacts' or obvious flaws that remind the viewer what he or she is watching is not wholly real. Currently, inpainting is done in a semi-automated way: the technology has not yet matured for computers to perform it automatically in real time.

PROCESSING AND RENDERING: BUILDING THE PICTURE

With 3D visualization, what was once a single, flat image is now a massive block of data containing a figure, its surroundings and background viewed from almost every possible angle. Today, each additional view adds about 10 percent more bits to the overall file size. By the time 200 views are reached, a file can be massive—and complex.

Rendering such an image requires immense processing power, especially if it happens in real time as the image is being recorded. Full holographic 3D currently would require exascale computing power, roughly 100 times greater than is available, and about 30 or 40 megawatts of energy. iMinds is currently involved with developing standards for MPEG Free View

THE IMINDS TELESURGERY PROJECT

While holographic surgery is still far away, iMinds has been researching ways to create digital operating rooms that allow real-time consultation by experts all over the world. The research contributed to Barco's Nexxis product, an IP-centric video management tool currently used in more than 100 operating rooms across Europe.

Television (FTV), looking at ways multi-view video can be efficiently compressed.

Fortunately, not all views have to be rendered at once. Reconstructing a subset of all possible views conserves processing power and bandwidth. iMinds researchers and others are investigating various compression approaches that would allow a system to extract only the views needed at a given moment.

To better create 3D models and optimize transmission, researchers are also exploring a variety of alternate presentation systems—such as point clouds, which plot data using a three-dimensional coordinate system and are easier to compress. Moving in parallel to this research are efforts to advance compression standards, including a volumetric extension of the JPEG 2000 standard as well as the development of mesh- and voxel-based encoding algorithms and texture-coding approaches.

Even when a subset of views is transmitted, extremely low latency is essential. For applications like telesurgery, patient safety depends on an end-to-end information delay of no more than 20 milliseconds. For entertainment applications, the tolerance might be as much as 150 milliseconds—though no sports fan wants to hear neighbors through the wall cheering about a goal that hasn't yet been displayed on his or her own TV.

iMinds has conducted research into latency requirements and thresholds, including the iCocoon project, which looked at low-latency video conferencing in collaboration with Alcatel-Lucent.

Much about processing, rendering and the like remain open questions today. Researchers continue to work to understand what's really required to reconstruct an image in holographic 3D. Based on the outcome of those investigations, teams will be able to tune their compression algorithms and visualization devices for optimal performance.

>>

TERMINOLOGY: MESH AND VOXEL

Voxel-based encoding is closest to reality but, because of that, requires more data. Its ideal application would be, for example, a hospital environment where verisimilitude is vital. Mesh-based encoding is leaner and less realistic, but its lighter data demands make it ideal for gaming.

> “THE LYNCHPIN TECHNOLOGY FOR FIRST-GENERATION HOLOTABLES WILL BE SPATIAL LIGHT MODULATORS.”

VISUALIZATION AND REPRESENTATION: AUTOSTEREOSCOPIC TECHNOLOGY

The last (and in some ways most significant) research challenge with respect to 3D has to do with visualization itself. While holography is the end goal, it is not fully achievable in the short term. But researchers are actively advancing models that will deliver a marked improvement upon traditional stereoscopy.

One of the most promising of these is autostereoscopic imaging, producing 3D images that can be viewed without special glasses or headgear. Autostereoscopy can be created in one of two ways: by using microlens arrays or by using light-field technologies.

The light-field approach currently supports a maximum of 200 views, resulting in a relatively low resolution, especially given that consumers are used to 4K visuals on their TV screens. (Current light-field autostereoscopic displays would be the equivalent of VGA quality, by comparison.) With microlenses, the number of views is unlimited but a problem of ‘angular resolution’ can arise that makes it hard for the eye to discern small details in the image.

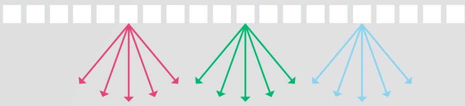
Unlike classical stereoscopic imagery, with autostereoscopic visualization viewers can physically rotate the image or move themselves around it. At current resolutions, these shifts in views are noticeable—but work is underway to increase the available views to 500, which should yield a significant improvement in image quality.

>>

DISPLAYS

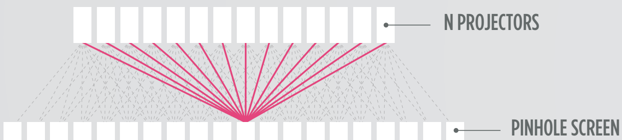
Conventional (2D), light field,multiview
and holographic display technologies.

2D LCD DISPLAY



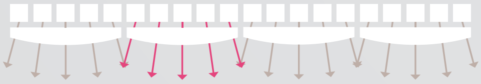
- HD-4K-8K Resolution
- High Frame Rate
- High Dynamic Range
- Stereoscopy with glasses
- Green Power

HALF/FULL PARALLAX LIGHT FIELD DISPLAY



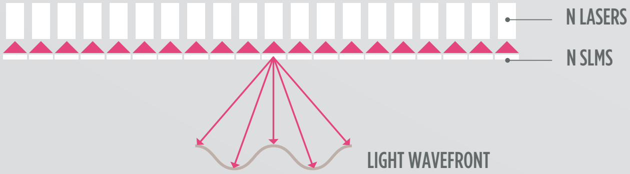
- Reduced horizontal/vertical resolution (70Mpel)
- 200+ viewing angles, 180° field of view (FOV)
- Large set-up, High Computing Power

HALF(/FULL) PARALLAX MULIVIEW LCD DISPLAY



- Reduced horizontal resolution
- 32 viewing angles, limited FOV
- Compact display
- Green Power

HALF/FULL PARALLAX HOLOGRAPHIC DISPLAY



- Reduced horizontal/vertical resolution
- 1 view per arc-min, 180° FOV
- Compact set-up
- MW power consumption

THE 'HOLOTABLE' AND OTHER HOLOGRAPHIC DISPLAYS

In its 2022 FIFA World Cup bid, Japan envisioned establishing holographic viewing centers in 208 countries that would allow spectators to watch the action in real time, projected up from the horizontal surface of a holographic table.

The lynchpin technology for first-generation holotables will be spatial light modulators (SLMs)—thousands of which are required to generate the display's visual field. Ideally, these SLMs would have the same pixel size as a wavelength of light: at two microns currently, they are roughly five times too large to produce an optimal image (SLM-generated holographic images have a resolution of about 2K).

Moreover, SLMs are time-consuming to manufacture and cost thousands per piece, making mass production or consumer applications prohibitive in the short term. Manufacturing SLMs from carbon nanotubes is a focus for several research teams today, however, and if this reveals a way to efficiently mass-produce SLMs, the holographic future may be much closer than the eight to 10 years currently expected.

THE WAY FORWARD

Solving the various research challenges surrounding 3D visualization demands the dedicated effort of multidisciplinary research teams that can collectively address the end-to-end requirements from capture to representation.

In addition to a strong history conducting this type of collaborative, multidisciplinary research, iMinds also has the infrastructure to host teams in pursuing visualization-related research.

3D technologies are already integrated into the way we consume information. As they become more fully immersive—en route to true holography—3D will shift that consumption to a new kind of interaction, enabling whole new types of entertainment and professional applications.

“

3D WILL SHIFT INFORMATION CONSUMPTION TO A NEW KIND OF INTERACTION, ENABLING WHOLE NEW TYPES OF ENTERTAINMENT AND PROFESSIONAL APPLICATIONS.

”

MAKING VIRTUAL WORLDS LOAD FASTER

The gaming industry is pushing the boundaries of 3D graphics, creating larger and fuller worlds, levels and objects. But the more detailed the graphics, the more memory and storage are required. Founded by researchers who met on a former iMinds project, Flemish company Graphine has developed an innovative approach to texture-streaming technology that improves graphics quality and load times while reducing memory usage, disk and download size. We spoke to Graphine co-founder ***ALJOSHA DEMEULEMEESTER*** *to find out how the Granite SDK technology is revolutionizing 3D gaming graphics.*

Q: What is texture mapping, and how is it used?

Aljosha Demeulemeester: In 3D gaming, objects are represented by two types of data: geometric data and texture data. Geometric data represents the structure of an object. Texture data defines its surface properties: the bark on a tree, the features of human skin. The level of detail can be quite complex. Structurally, the side of a building can be represented by as few as four geometric data points, one for each corner. Texturally, though, you have bricks, windows and doors with different properties like colour, roughness, reflection. These elements can be very intricate.

Q: That has an impact on a gaming system's resources.

Aljosha Demeulemeester: Pro-cessing all that detail can be very draining in terms of memory and storage. You can only have as much detail and texture as you have memory on your graphics card. Big worlds mean a lot of textures, and that creates long load times. And you have to get the game to the customer somehow, either physically or via download, making storage space another limitation. Game developers are always hitting the boundaries of hardware. That's why we developed our Granite technology. It cuts video memory usage by 50 to 75 percent and storage requirements by 60 percent or more. Those savings allow us to improve graphics quality by a factor of four and reduce load times by a factor of five.

Q: How does it work?

Aljosha Demeulemeester: Tradi-tionally, textures are loaded in bulk. When you start a new level, the game will load every texture in that part of the world. Granite uses a concept called texture streaming to dramatically shorten load times: the textures in the level are broken up into smaller pieces and load incrementally.

Q: Is texture streaming a new concept?

Aljosha Demeulemeester: No. What is new is how small we're able to make those pieces, which we call 'tiles'. Other texture-streaming technologies might have a player walk up to a building, and the textures both inside and outside the building will be loaded even if the player hasn't entered yet. With Granite, we load only the textures in front of the virtual camera. As the camera moves, new textures are

>>

> “GRANITE IMPROVES GRAPHICS QUALITY BY A FACTOR OF FOUR AND REDUCE LOAD TIMES BY A FACTOR OF FIVE.”

> "GRANITE CUTS STORAGE SIZE BY 60 PERCENT AND TEXTURE MEMORY CONSUMPTION BY 80 PERCENT."

loaded. That helps us dramatically reduce load times, freeing up memory for even better graphics and gameplay. You get bigger worlds, more detailed images and sharper, higher quality textures. Think of watching a feature length HD movie on YouTube. If you had to load the full movie before you started playing, you'd have to wait for quite a while—hours on a slow connection. But if you load the movie frame by frame as you watch, you can start watching instantly.

Q: What games are using this technology?

Aljosha Demeulemeester: iMinds helped us connect with Belgium's largest game developer, Larian, during the Language Learning in an Interactive Environment project—LLINGO. Larian included our technology in their Dragon Commander title in August 2013. It's been a very productive partnership. Normally, a development team makes technology decisions early in the process—years before a title ships. But with Dragon Commander, they were able to integrate Granite in the final months of development, cutting storage size by 60 percent and texture memory consumption by 80 percent. We are providing our tech for other games as well—including the just-announced sci-fi title, Get Even, from The Farm 51, the studio behind the Painkiller series.

Q: What was iMinds' role in helping Graphine get started?

Aljosha Demeulemeester: It all came from iMinds' LLINGO project, which was looking at different ways of using game technology for education. My section focused on improving high-quality graphics, with the idea that the better the graphics are, the more immersive and effective the learning experience will be. That's where I met the rest of the Graphine team. We formed the company using a lot of the technology and concepts developed during LLINGO.

Q: How has iMinds remained involved?

Aljosha Demeulemeester: We took part in iMinds' iBoot program, which is sort of a boot camp in running a start-up that, at the time, was delivered through six twoday workshops. At each stage we refined our pitch, and even made a 15-minute presentation to potential investors. Our pitch was selected as the best, but the most important part was the opportunity for us to work together as a team outside of the lab. We knew we meshed well with our research, but we needed to find out how to work as business partners.

The other iMinds program we were involved in was iStart. It provided seed funds for initial research, helped us test our assumptions, investigate the market and contact potential customers. And it gave us office space to work from, which is critical for a small company in its early stages. Through all of this, we had the support of the iMinds team, who provided not only technical expertise but also connected us to other researchers, potential investors and customers.

Q: Do you foresee any applications for Granite outside of gaming?

Aljosha Demeulemeester: Absolutely. Flight and military simulators, architectural visualization and design… we're looking into all of these. Anything that uses real-time 3D visualization can benefit from this type of technology.

Q: What's next for your research into 3D visualization?

Aljosha Demeulemeester: Well, one of the biggest challenges we're facing now is storage. Breaking a huge virtual world up into smaller, discrete pieces certainly helps with loading and displaying the graphics, but the size of the world doesn't change—and that requires storage. If you've got a 600 gigabyte world, you still need to get that to the customer somehow. So one of our research paths is focused on storage and texture compression. We are already boosting Blu-Ray capacity by a factor of 2.5. We're hoping to increase this even further with similar or better graphics quality.

A second research area is looking at bringing our technology to mobile platforms, where it will have a lot of utility because of the memory and storage limitations associated with mobile devices. We're working on that with iMinds. Along with our texture-streaming technology, we think this research will give game developers the tools they need to create bigger, better and more expansive worlds—on whatever platform they choose.

ABOUT GRAPHINE

Combining academic roots with industry experience, Graphine delivers rock-solid middleware and high-quality services to the gaming and 3D visualization industries. Its middleware—Granite SDK—minimizes memory usage, storage size and loading times while allowing the use of massive amounts of unique texture data. Graphine also helps clients integrate its technology into their products, providing guidance and best practices on how to deliver high-fidelity, real-time 3D graphics as well as optimization of technology stacks.

3D VISUALIZATION

CASE STUDY

BRINGING THE FUTURE TO YOUR TV

For television manufacturers like TP Vision, innovation is all about the viewer experience. New features need not only to enrich people's enjoyment of their favorite programs but also do so in ways the marketplace may not yet fully expect. ***RIMMERT WITTEBROOD,*** *Innovation Lead for Picture Quality and Displays at TP Vision, explains how that mission has led TP Vision to explore the potential of 3D TV.*

Q: What is driving TV companies' efforts to add 3D as a feature?

Rimmert Wittebrood: If you look at TV technology as it has evolved—in terms of picture quality, sound, etc.—3D is a big experience that has been missing. Television makers need to cater to the potential wishes of consumers, so 3D has been on our minds for many years. Of course, consumers haven't necessarily been saying, "We would really like our television to deliver a 3D picture." But one doesn't always know what's missing if one hasn't experienced it in the first place. Nobody asked for a smartphone, for example: the telecom industry started adding smart features to devices and consumers awakened to the possibilities. 3D could be the same.

Q: Given that, what's involved in bringing 3D to the market?

Rimmert Wittebrood: It requires the full chain of supply: you need the right technology, the right content and the right cost point. Things started to come together for 3D a few years ago, which led to the introduction of the first 3D-enabled TVs in 2010. I think, though, that we need to see big investments by the content industry and the panel suppliers—the companies that make LCD screens—to deliver the best 3D viewing experience.

Q: How big of a market are you looking at?

Rimmert Wittebrood: Maybe the current market estimates for 3D are over-positive, but it's hard to project how any feature will evolve or mature. You see, we don't make '3D TVs': 3D is a feature of televisions, along with many other features. From that perspective, 3D has been implemented in more than half the TVs made by any given supplier. And of course there are millions and millions of TV sets in the world, so the potential market is enormous.

Q: You mention the need for LCD panel advancements. What are some of the other barriers currently limiting the adoption of 3D in televisions?

Rimmert Wittebrood: One of the biggest hurdles is that current stereoscopic 3D technology requires glasses, which makes it cumbersome to use. As well, crosstalk—interference between the right and left eyes that causes strain—can make the experience less comfortable. Autostereoscopic 3D

>>

> "WE DON'T MAKE 3D TVS: 3D IS A FEATURE OF TELEVISIONS, ALONG WITH MANY OTHER FEATURES."

does not require glasses, but it has other drawbacks: cost, quality and restrictions on where the viewer can sit in relation to the display. For those reasons, autostereoscopic 3D is likelier for business-to-business markets in the near term, not the consumer TV marketplace. For commodity televisions today, stereoscopic is the only option.

Q: You did some research into autostereoscopic 3D as part of the iMinds 3D 2.0 project. How did that project come about?

Rimmert Wittebrood: In 2010, we were involved with the JEDI project—Just Exploring DImensions—an EU-wide ultra-high definition and 3D initiative focused on exploring the next image formats and how we must prepare the broadcast chain to support them. It was through the other Belgian participants in that project that we got invited to join iMinds' 3D 2.0. That project was multifaceted: there was our company, there was Alcatel-Lucent looking at videoconferencing, there was GrassValley working on camera systems, and a network of university partners supporting it all. We worked very closely with the universities on our own applications, including processing for autostereoscopic displays. This led to the development of a fully working prototype, which has been displayed at various large trade shows like the IFA in Berlin and the CES in Las Vegas.

Q: What did that research yield?

Rimmert Wittebrood: We gained a good understanding of the challenges and where more research needs to be done. For autostereoscopic 3D, you put a lens overtop of an ultra-HD panel to steer the light of the pixels in various directions. This effectively reduces the resolution of the display by the number of viewing angles, or views, that you create. So if you have nine views, your resolution is reduced by a factor of nine. What this means is you need to start with a very high-resolution display. In 2012 we were working with 4K by 2K. Using that in combination with our proprietary lens design, the 3D picture quality would have been comparable to High-Definition TV, but that's no longer sufficient for a market where Ultra High-Definition is rapidly being introduced. There are trends now toward 8K displays. That might be the innovation we need.

The other issue to resolve relates to the limited viewing positions. Because of the way the 3D image is created, the viewing positions are divided into a number of cones in front of the TV. If you're outside the cone, the image inverts. This is very uncomfortable, so we have been looking into this as well. The most basic solution is user tracking via a camera—face detection—so the TV can direct the cone at the viewer. But this requires robust face detection, complex processing and adaptations in the display itself, which has an impact on the image quality, the TV specifications and cost. So today, 3D TV is necessarily stereoscopic.

Q: But there have been advances on that front as well. What differentiates the newest generation of stereoscopic 3D from the previous?

Rimmert Wittebrood: There are two aspects, not so much related to processing as to the panel technology. One has been making the liquid crystal in the displays faster to react. This increases quality, with less crosstalk. The other is cost: the panel industry is focused on driving costs down, delivering better quality at a lower price.

ABOUT TP VISION

TP Vision develops, manufactures and markets Philips-branded TV sets in Europe, Russia, the Middle East, South America and select countries in Asia-Pacific. A leader in the hospitality industry, it provides televisions to the majority of the world's major international and national hotel groups, as well as individual hotels, hospitals, cruise ships and other professional facilities.

“THE iMINDS’ 3D 2.0 PROJECT LED TO THE DEVELOPMENT OF A FULLY WORKING PROTOTYPE, WHICH HAS BEEN DISPLAYED AT VARIOUS LARGE TRADE SHOWS.”

SEEING A 3D FUTURE

*3D sensors and software will revolutionize the way devices interact with our environment—and how we interact with those devices. Formed by the merger of two companies spun out of research groups at the Vrije Universiteit Brussel, with support from the Université Libre de Bruxelles, SoftKinetic has become a leader in both 3D cameras and 3D gesture-recognition software. We spoke with co-founder **ERIC KRZESLO** about how new 3D vision technologies will affect our daily lives.*

Q: What will we gain from more advanced 3D sensors and software?

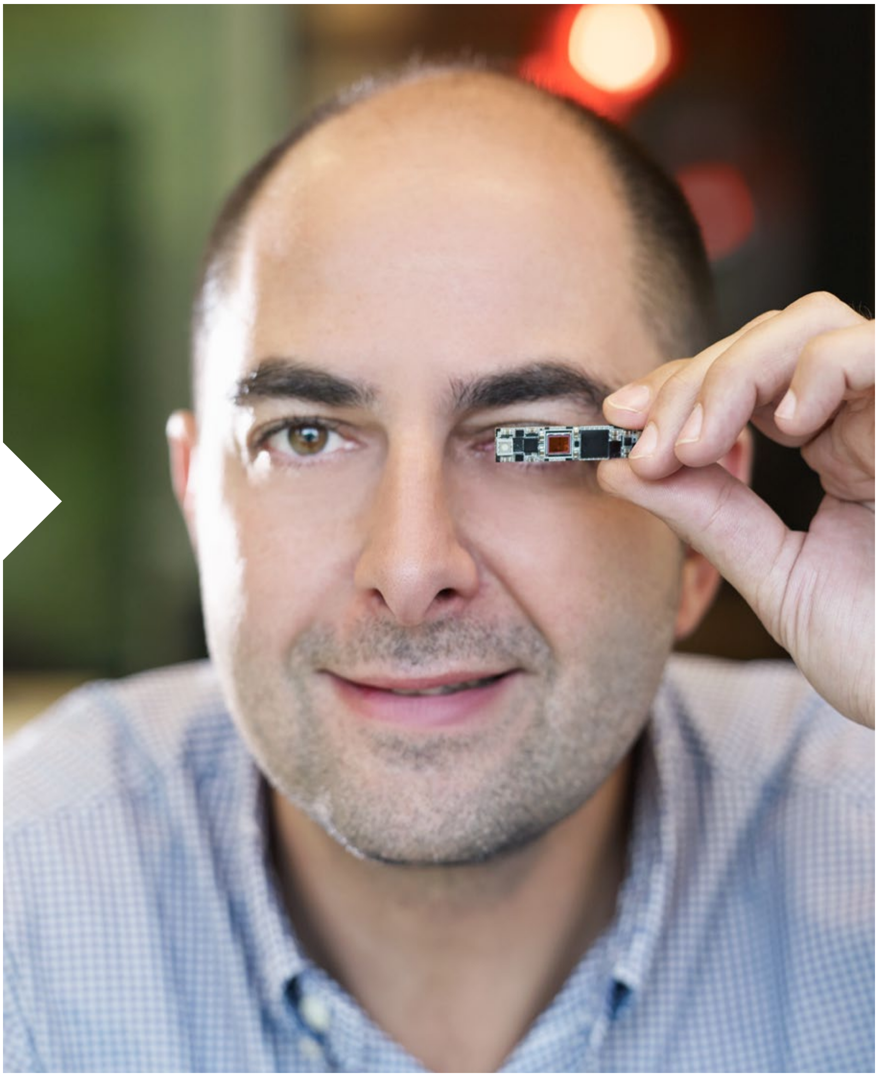
Eric Krzeslo: At the highest level, 3D vision can bring a real sense of human vision to our computers, making them much more intelligent. Take our mobile devices, for example. We call them smartphones, but really they're quite dumb. You always have to interact with them, tell them what you want them to do. Instead of constantly asking for inputs and information, a device enabled with true 3D vision will understand the user and the user's environment, anticipating the user's needs much better by actually 'seeing' what's going on around him or her and responding intelligently.

Q: How far away are we from that?

Eric Krzeslo: We're getting to that point pretty quickly. Sensor technology is getting small enough and cheap enough to use in a wide variety of devices, and there are viable applications for these types of technologies. There are improvements to be made in resolution, the distance our sensors and cameras can see, how they deal with lighting... we're working on all that. But we're really not all that far off.

>>

"ONE OF OUR PATENTS LETS US CAPTURE 3D IMAGES MUCH MORE EFFICIENTLY THAN COMPETING TIME-OF-FLIGHT CAMERAS."



Q: SoftKinetic develops sensors and software. What are the key applications and use cases you're looking at?

Eric Krzeslo: We started with gesture recognition, which we call 'active control', with the user controlling a device; providing it with input. Gaming is a big use case here, obviously, with motion-sensing technology like what you'd find in a PlayStation 4. We're also looking at something we call 'context awareness', where the device gathers information about its environment and analyzes what's happening without direct input from the user. There are already early applications of this kind, for instance, in the automotive industry. You might have a device that analyzes road conditions, weather or even the driver—and then sounds an alert if he looks like he's falling asleep or is driving too fast for the traffic conditions. The third area we're looking at is 'real-world acquisition', which is basically 3D scanning for 3D printing: a technology that could be used in a wide variety of industries, from tailoring custom clothes to making perfectly fitted braces for healthcare.

Q: What technologies have you developed to enable these use cases?

Eric Krzeslo: Key to our products and research is our time-of-flight camera, which is a 'true' 3D sensing technology. While stereoscopic technologies simply compute 3D images using 2D data, the time-of-flight camera actually senses the 3D by emitting infrared light that accurately measures depth. That gives us much more data and precision to work with. One of our patents, the Current Assisted Photonic Demodulation (CAPD), lets us capture 3D images much more efficiently than competing time-of-flight cameras. We use the depth of the sensor to collect more photons—and more information—more efficiently, using less energy and fewer pixels.

We've also developed middleware called iisu (which stands for "the interface is you"), which is designed to improve human gesture recognition. Full-body tracking identifies the user, separates him or her from the environment, and tracks the position and movement of the hands, shoulders, feet, chest, etc. This becomes a skeleton model that game or app developers can use to create an avatar that responds to the users' movements. We also have a second part to the iisu middleware that is much more focused on hands and fingers and can be used for close-range applications such as mobile devices—for things like virtual keyboards and controlling applications and games on your smartphone without actually touching the screen.

Q: Your gesture-recognition technology has already hit the market, correct? How far away are your other technologies?

Eric Krzeslo: Our software is part of the PlayStation 4 and has already been incorporated into Ubisoft's Just Dance 2014 game. We've also announced other new games that will use our technology: Just Dance 2015, Rabbids Invasion: The Interactive TV Show and a game called Commander Cherry's Puzzled Journey. That game is quite interesting, as it uses the shape of the user's body to build layers and platforms in the game. In our context-awareness division, we'll have technology on the market next year. We're working with Delphi in Detroit to develop sensor technology for cars. And for our 3D reconstruction software, we're

>>

“OUR SOFTWARE IS PART OF THE PLAYSTATION 4.”

working with MakerBot to develop a high-precision 3D scanner for use with 3D printers that is accessible for consumers. Most of these scanners run up to $10,000; ours will retail for a few hundred.

Q: How did SoftKinetic come to be?

Eric Krzeslo: We were born when iMinds was initiated at ETRO in the Vrije Universiteit Brussel's Department of Electronics and Informatics, where a lot of research was being done in 3D sensing and processing. Simultaneously, the Université Libre de Bruxelles gave its support to our visionary entrepreneurs in need of computer vision expertise. Two companies resulted of that research. SoftKinetic SA was looking at a natural way of interacting with 3D content, while Optrima NV was building 3D cameras. We started using Optrima's prototypes for 3D interaction research and found them much more effective than the fully developed cameras already on the market. We brought the two companies together so we could control both the software and the hardware. Now we can optimize the complete technology flow, from the pixels to the camera system to the software.

Q: What's next for the company?

Eric Krzeslo: Well, in the mid-term, we're looking to strengthen our position in gaming, mobile devices, 3D scanning and the automotive industry. This may sound strange, but over the long term we want to be invisible. We see a future where 3D sensors completely replace 2D sensors. I mean, we've got cameras in almost everything. You've probably got two on your phone, one on your laptop, maybe one on your TV. And we want to be providing that technology. We want to be ubiquitous, in all these devices, helping interpret what's happening and anticipating user needs—not reading minds, but close to it. And we'll get there by developing sensors that are smaller and less expensive with greater resolution, can cover longer distances, and with software extremely optimized for active control, context-awareness and real-world acquisition. Basically, we want to bring you and your environment into your devices—making them smarter and more responsive, without you even noticing.

ABOUT SOFTKINETIC

SoftKinetic is a Brussels-based semiconductor and software development company that provides 3D time-of-flight sensor and cameras as well as advanced middleware for building real-world acquisition, context awareness and active control applications. Its patented technologies provide a direct way of acquiring 3D information about objects, people and the entire environment. SoftKinetic's 3D vision solutions will revolutionize man/machine and machine/world interactions in domains such as entertainment and gaming applications, automotive, security, automotive, and health and lifestyle by providing real-time easy-to compute 3D images.

"WE FOUND STRONG DIFFERENCES IN HOW GOOD PEOPLE PERCEIVE STEREO WITH 6 TO 10 PERCENT BEING STEREOBLIND."

SEEING A WAY AROUND STEREOBLINDNESS

*Today's consumer 3D technology is stereoscopic—imitating the way people's brain interprets visual information to perceive depth in a process known as stereopsis. Yet for a portion of the population, stereoscopic 3D doesn't work: they are affected by what's known as stereoblindness. At Ghent University, iMinds' Media and ICT (MICT) research group has developed a new, cheaper and easier way to test for stereoblindness. We spoke to researchers **JAN VAN LOOY** and **JASMIEN VERVAEKE** about their test and the potential impact of stereoblindness on the future of 3D visualization.*

Q: What is stereopsis and how does it factor into 3D visualization technology?

Jan Van Looy: Because our eyes are located in slightly different positions, they give our brains slightly different images of the world. These images are compared and combined in the brain, creating a single, 3D image of the world. That process is called stereopsis, and it's one—but just one—of the many ways we can perceive depth.

Jasmien Vervaeke: Most 3D visualization technology is based on stereoscopy, which mimics stereopsis by making your brain believe that a flat, 2D image has depth. In its most basic sense, think of watching today's 3D films with coloured 3D glasses. On screen, you'd have one image projected with a red tint, and an image with a cyan tint, filmed by cameras that were offset by the distance between your pupils. Your glasses would have one cyan lens and one red lens too, ensuring that each eye would only receive a single image. Your brain combines the two images into one and interprets this as a 3D picture.

Q: How does stereoblindness affect that?

Jan Van Looy: Stereoblindness is a condition that interferes with stereopsis, preventing you from seeing the stereopsis in stereoscopic imagery. It tends to affect all types of stereoscopic imagery, since the various technologies function in basically the same way. So whether you have coloured glasses or polarizing filters, someone suffering from stereoblindness won't be able to make a 3D image using either.

Jasmien Vervaeke: It's caused by a variety of factors—there's not really one single cause. The literature suggests about 10 percent of the population has stereoblindness to a certain degree. It can be caused by several eye disorders, such as a lazy eye or a substantial difference in visual acuity between your eyes, among others. And there's no immediate treatment or cure for it at the moment.

>>

Jan Van Looy: Most people with stereoblindness don't even know they have it. There are so many other ways to perceive depth, as we mentioned before, that your brain would more than make up for it in the real world. It's only when you're trying to watch a 3D movie, for example, that you might notice. And, of course, if you get tested.

Q: What made you investigate a new stereopsis testing method? Was something wrong with the previous tests?

Jasmien Vervaeke: The traditional tests for stereopsis are expensive, for one, and they require special equipment. Ours is very simple, by comparison. It's basically a random dot stereogram, so two images that look like random noise, with one to 10 squares shifted slightly within the images. It's displayed on a 3D TV, and we have participants put on glasses and count the squares. If you're not stereoblind, the squares pop out of the screen. Each number of squares is shown twice, resulting in 20 trials, and the participants end up with a score out of 20.

Our test can be used on any 3D screen, and we've made it open-source and free for download through SourceForge at sourceforge.net/projects/stereogramtest.

“OUR TEST IS FREE AND OPEN SOURCE SOFTWARE AND EASY TO ADMINISTER ON ANY HARDWARE.”

Q: You performed the test at an iMinds conference, is that right?

Jan Van Looy: We had about 130 volunteers and tested them all to see how well they were able to perceive the squares. About six percent couldn't see any squares at all. Some had had scores that were higher than random, but still not very good. But the large majority scored 15 or above.

Jasmien Vervaeke: This suggests the generally accepted figure of 10 percent of people suffering from stereoblindness may be a little high. It may be more between six and 10 percent, and there's gradation. In other words, it's not necessarily binary—that is, that you have stereoblindness or you don't. There are stages in between.

Q: How are you following up on your initial research?

Jasmien Vervaeke: We're working on a new project right now, an exploratory study of how well children perceive stereoscopic 3D: looking at which age stereoscopy develops, when children reach an acceptable level and what factors might affect this ability. It's generally assumed that stereopsis develops after age three, but we don't know much more than that.

Jan Van Looy: We're taking a look at kids aged six to 12, using our test as well as examining physical features such as the distance between pupils—which changes with age—and cognitive factors, things like that. We want to see if there are correlations between these factors and the children's performance on the stereoscopy test. Early results seem to indicate that it is not the distance between the pupils, as is often assumed, but the development of the brain—more particularly, how well both sides of the brain communicate with one another—that determines how well you see stereoscopic 3D.

Q: From your perspective, why is this research important?

Jan Van Looy: Well, stereoscopy is really coming back into the spotlight. Many people have noticed that 3D stereoscopy in the home, such as 3D TV, for example, hasn't really taken off. And that's due to a number of factors. People don't like wearing the glasses, for one, but it also has to do with quality of experience, which of course is affected by how well people see 3D.

Jasmien Vervaeke: As 3D visualization develops and we start looking at autostereoscopic screens that don't require glasses, knowing more about how the brain sees 3D will help refine the technology. Being able to measure stereopsis and detect stereoblindness will help unlock a larger 3D market and also potentially unearth new applications for 3D visualization.

Jan Van Looy: In iMinds projects like ASPRO+, we're working with engineers and companies that are developing new technologies using autostereoscopy and multiview displays, different screens and processes. Our test can support the development of these technologies by providing valuable information about the consumers of 3D content. Before you create the technology, you need to understand the audience. We're contributing to that understanding.

PETER SCHELKENS

Professor & Research Director at iMinds - ETRO - VUB

FOR MORE INFORMATION

about iMinds' expertise in the field of 3D visualization, please contact **Peter Schelkens**
peter.schelkens@vub.ac.be, +32 2 629 1681

iMinds editorial team: Sven De Cleyn, Koen De Vos, Thomas Kallstenius, Els Van Bruystegem, Wim Van Daele, Stefan Vermeulen

Copy: Ascribe Communications
Design: Coming-Soon.be
Photography: Lieven Dirckx

Additional content will be published on www.iminds.be/insights.

LIST OF SUBJECT-MATTER EXPERTS WHO CONTRIBUTED TO THIS PAPER

ALJOSHA DEMEULEMEESTER
CEO Graphine

ERIC KRZESLO
CMO SoftKinetic

PETER LAMBERT
iMinds - MMLab - Ghent University
Associate Professor

JAN VAN LOOY
iMinds - MICT - Ghent University
Assistant Professor

HIEP LUONG
iMinds - IPI - Ghent University
Postdoctoral Researcher

ADRIAN MUNTEANU
iMinds - ETRO - VUB
Professor

PETER SCHELKENS
iMinds - ETRO - VUB
Professor

JASMIEN VERVAEKE
iMinds - MICT - Ghent University
Researcher

RIMMERT WITTEBROOD
Innovation Lead Picture Quality
& Displays TP Vision