THE POTENTIAL OF THREE-DIMENSIONAL DISPLAY-TECHNOLOGIES FOR THE VISUALIZATION OF GEO-VIRTUAL ENVIRONMENTS

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ABSTRACT

Three-dimensional display-technologies offer a great potential to being used in digital cartography and GIS, since the information can be shown from the user´s three-dimensional perspective and is no longer, as yet, left to someone´s spatial sense. This article focuses on the advantages and disadvantages of certain 3D-technologies and their potential to visualize geo-spatial data. Including the latest developments in the field of 3D-displays, two main categories will be established: virtual-three-dimensional systems and real-three-dimensional systems. The latter group is still in the fledgling stages and its field of application has yet to be determined. However, it is implied by the developing companies, that geo-visualization may play an important part in future applications. Thus, a lot of research is required in order to tap the full potential of a 3D-presentation and to ensure a better interpretability when compared to conventional cartographic means of expression.

TYPES OF THREE-DIMENSIONAL DISPLAY-TECHNOLOGIES

Three-dimensional display-technologies can be categorized, according to the nature of the creation of the 3D-visualization, as follows:

- **Virtual-three-dimensional systems (pixel-based systems)**
  The spatial image appears exclusively as a **three-dimensional illusion**. Most of these systems take advantage of the fact that the human brain is able to create a spatial image from a pair of two-dimensional images, each providing a slightly different perspective for the left an the right eye, respectively (horizontal parallax). Virtual-three-dimensioanl systems are:
  - Spectacles-and-screen systems (e.g. anaglyph method, systems working with polarized light)
  - Head-mounted displays (HMDs)
  - Autostereoscopic displays (e.g. lenticular displays, parallax-barrier displays)
  - Quasi-holographic displays
- **Real-three-dimensional systems (basically voxel-based systems (voxel = volumetric pixel))**
  A three-dimensional projection is being created as a quasi-real existing body of light; that is to say the **three-dimensional expansion** of the visualization is indeed being carried out **in real space**. These are mainly **volumetric** and **electro-holographic** displays. Real-three-dimensional systems don´t require any kind of additional viewing devices. Special forms of real-three-dimensional systems are **spherical displays**, being used in case of tactile hyperglobes or in case of immersive reality-systems (pixel-based techniques, featuring a real-spatial expansion of the screen (e.g. „Cybersphere“; see Fig. 7)).

Virtual-Three-dimensional Systems

Spectacles-and-screen systems:

The oldest and probably the best-known way of viewing stereoscopic imagery is the **anaglyph method**. It has already been in use since the middle of the 19^{th} century. The basis is a pair of stereo-images, whereas the left image is being colored in red, while the right image is being colored in a complementary color (cyan or blue or green). Both pictures are then being overlaid and merged to a single frame, which has to be viewed by the use of red-green- or red-blue- (red-cyan-) spectacles. Because of the color filters, each eye can only perceive those parts of the image that can permeate the filters which, in succession, causes a stereoscopic impression. Concerning digital imagery, the red color-channel is being extracted from the left picture and then pasted into the right picture. The advantage of the anaglyph method is the fact that it is cheap and that the stereo-effect can be achieved with little effort, but the displayable colors (if it is not a grayscale-image, which is recommended) are limited and the 3D-impression is rather unnatural, causing eyestrain after a short while.

A better and even more progressive technique is the use of **polarized light and filter glasses**. Two projectors serve as light sources; aligned in a way, so that their objectives are positioned like a pair of human eyes. Each projector emitts either horizontally or vertically polarized light. While being reflected from a screen, filter glasses once again only let the „right“ image reach the respective eye of the viewer. The great advantage of this sytem is the unaltered display of true colors; shortcomings are a certain loss of polarization and the fact that two (synchronized, when showing movies) projectors are needed (expensive!). This method is being used in theme parks and for IMAX 3D-movies.

The **Pulfrich-spectacles**, invented by Carl Pulfrich in 1922, take advantage of the fact, that it takes longer for the human brain to perceive a scene if it is underexposed. By the use of differently toned filter-glasses, each eye gets to see a scene at a different level of lightness. These spectacles, like the anaglyph glasses, can be easily manufactured; however, the stereo-effect is limited to motion pictures. This technique has been used – from time to time – for special 3D-television broadcasts and has also been applied to certain computer games.

For the human brain, objects colored in blue appear more distant than objects colored in red (chroma-stereopsis). The use of **chromadepth-spectacles** causes a separation of the spectral components in such a way as to optimize the focus on the greenish picture-elements, while the reddish picture-elements are being less refracted (longer wavelength, the lense is more convex and those objects appear nearer) and the bluish elements are being more refracted (shorter wavelength, the lense is less convex and those objects appear more distant). It can be seen as the main disadvantage of this method, that colors are needed for the creation of the stereoscopic effect; hence the application of colors as a cartographic variable is not possible.

A highly sophisitcated method is the application of **shutter-glasses**. Shutter-glasses are being synchronized with the image build-up of a CRT (Cathode Ray Tube)-screen via infrared-emitter; i.e. the glass for the left and the right eye is being „masked“ alternately at each build-up of the image – in order to ensure, that the right eye can only see the right image and the left eye can only see the left image. Because of the constant change between the two slightly differing perspectives, the effective refresh rate of the screen is reduced to 50%. For that reason, the technology was limited, just until a short while ago, to CRT-monitors – the only displays that could be operated at a sufficient refresh rate of 120Hz and more. Shutter-glasses are still the only spectacles-and-screen system to show stereoscopic imagery on a conventional monitor with true colors. The reduction of the effective image-refresh rate, however, could be perceived as a disturbing flicker, leading to exhaustion after a while.

Head-mounted displays:

HMDs are essential to Virtual Reality- and Augmented Reality-systems. Here, the spectales do not only make for the stereoscopic effect, they´re the screen, too. The simultaneous display of the two horizontally slightly differing perspectives is granted via special optics before each eye. The main advantage of these systems is the (limited) mobility and the unlimited immersion. That is to say the virtual environment litteraly surrounds the user, without him being distracted by the real world, since he can only observe what´s on the HMD. Disadvantageous is the need for a tracking system and the (as yet) low resolution of the displays as well as the fact, that even these systems cause some eyestrain and exhaustion after a while.

Autostereoscopic displays:

Because of their usability, displays without additional viewing devices will be of great interest in the future. The segment of autostereoscopic displays in particular, has expanded significantly the product line in the last few years. Almost every well-known display-manufacturing company introduced an autostereoscopic variant of one of its monitors, featuring different technological approaches to meet specific demands. As a result, each system has its own advantages and shortcomings, according to the emphasis placed on that system. All autostereoscopic technologies feature **directional multiplex-techniques**. These techniques differ primarily in the method of separation of the left and right image. The following classification of directional multiplex-techniques is geared to the classification of Klaus SCHENKE and Sigmund PASTOOR [SCH-02], both at the Berlin Heinrich-Hertz-Institute for Communicatons Engineering:

- **Diffraction-based method** (lens-raster displays – lenticular technique; a pair of stereo-images, pixel-layer plus lens-raster-plate; three small zones for stereoscopic viewing; limitations: one-person display, head-tracker required, bisection of the horizontal resolution, 60% loss of brightness, barrier-stripes are visible; developer: the Berlin Heinrich-Hertz-Institute for Communications Engineering, A.C.T. Kern Ltd. (prototype: „Cabrio Screen"), University of Kassel (Germany) – IPM Institute)
- **Refraction-based method** (LCD-panel with prisms-mask plus field-lens and a collimator; developer: Dresden University of Technology (Dresden 3D))
- **Reflexion-based method** (retro-reflective process, light is being reflected to the original angle of incidence by a system of mirrors; advantage: full display-resolution; disadvantages: one-person display, head-tracker required, brightness reduced to 25%)
- **Parallax-based methods**
    - *Single parallax-barrier method* (features a single pair of stereo-images; benefit: horizontal resolution of the screen „only" reduced to 50% when compared to multiview-parallax-barrier systems; disadvantage: one-person display (stereo-effect is limited to a „sweet spot", which is a small area in front of the display); manufacturer: e.g. Sanyo)
    - *Multi-view parallax-barrier method* (multiple pairs of stereo-images of slightly different perspectives are being placed horizontally in a row, a wavelenght-selective filter-array (WLSFA) is included: three filters for the basic colors red, green and blue block the complementary colors of the subpixels of every single image, depending on the angle of vision; the usual count of different horizontal perspectives in current systems is about eight pairs of stereo-images, but it is possible to apply up to 24 perspectives, depending on the resolution of the display; the edge of these systems, when compared to other autostereoscopic techniques, is the multi-person- and multi-view-capability, but the downside is a significant reduction of the horizontal resolution of the display as well as the loss of brightness and a strong optical crosstalk („jumps") between perspectives; manufacturers: Opticality Corp. / X3D Technologies Ltd. and several licensees)
    - *Parallax-illumination method* (an illumination-raster resides behind an LCD-array; advantage: can be switched between 2D and 3D; restrictions: one-person display („sweet spot"), bisection of the horizontal resolution, significant loss of brightness when operating in 3D-mode; manufacturers: e.g. DTI, Sharp)
    - *Moving-slit method* (a CRT-monitor shows complete images of different perspectives in sequence (60 times 16 perspectives per second = 960 Hz); a field-lense maps the slit upon the viewer´s eye, at each position of the slit x image-stripes are being displayed, the image-stripes correspond across all slits, through a slit the user gets to see parts of the image from x perspectives; developer: Holotron)

Quasi-holographic displays:

The quasi-holographic principle is based upon the idea of controlled directing of light beams of different color and intensitiy upon a display by the use of optical modules (microdisplays) in such a way as to receive an impression as if there were spots of light before or behind the screen level. Thereby a software manipulates the deflexion of the light beams which, in succession, creates a light spot that reconstructs a „quasi-voxel" of the virtual 3D-object. This technology, which distantly can be compared to the principle of holography, has been developed by the hungarian company „Holografika" (www. holografika.com). Important advantages of these quasi-holographic displays are the continuous motion-parallax (hidden details appear while others disappear when viewers move in front of the screen; no „jumps" between perspectives), high image-resolution and color depth and a field of view of more than 50°, making it possible to look at displayed objects from a wide range of angles – altoghether providing a realisitic 3D-presentation. This system belongs to the category of multi-person / multi-view displays and doesn´t need any additional viewing-spectacles, just like the autostereoscopic and real-3D-systems. The image-refresh rate of current models accounts for 50Hz internally, bisecting to 25Hz externally. The screens feature a tv-like diagonal of approx. 66cm (aspect ratio 4:3) and approx. 80cm (aspect ratio 16:9).

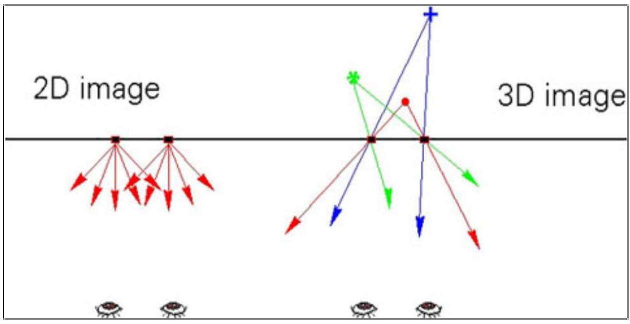

Figure 1: The path of rays of the three primary colors red, green and blue inside a quasi-holographic display (right) (www.holografika.com)

Real-three-dimensional systems

Among the real-three-dimensional systems are all **voxel-based techniques** as well as – a special form – **spherical displays**, but unlike the voxel-based systems, with spherical displays the spatiality is rendered by the shape of the screen. In case of voxel-based techniques, the following categorisation will be applied (modified, according to SCHENKE & PASTOOR [SCH-02]):

- **Electro-holographic technique** (a system consisting of laser, scanner and mirrors, including a vertical diffusor; diameter of the 3D-object: 15cm; field of view: 30°; refresh rate: 30Hz (= 2GPixel/sec.); restrictions: monochrome, required data rate extremely high, only computer-generated objects are presentable; developer: M.I.T. Media Lab)
- **Volumetric techniques** (limitations: the displayed objects appear transparent, given that the voxel in the foreground cannot absorb the light in the background (therefore all subsurface parts / objects are visible), only computer-generated objects are presentable); depending on the range of viewing angles, volumetric displays can be further sub-categorized in:
    - *Multi-directional systems* (the range of viewing angles is similar to common LCD-screens)
        - ♣ *Dual-level displays* (e.g. from Deep Video (www.deepvideo.com))
          These screens consist of two stacked TFT-layers. Specific software shifts the screen content between these two layers. Because of the fact that the layer-count is not more than two, a plastic 3D-display of the content is not possible. Instead, the user can only experience a separation of objects in the foreground (1st layer) and objects in the background (2nd layer) – much like a backdrop. Advantage: reasonable
        - ♣ *Multi-level displays* (e.g. "Depth Cube Z1024 3D" from Lightspace Technologies (see Fig. 2), comprising a volumetric projection screen of 20 stacked LCD-layers (www.lightspacetech.com))
          These are displays made up of multiple LCD-layers, whereas – according to the information about the spatial depth of objects – certain parts of the displayed objects do appear on the respective layers, while the remaining layers are being switched to transparent. A DLP-high speed projector projects images onto the several LCD-layers. In order to show parts of an object that are supposed to be situated between layers, in case of the Z1024 display an elaborate anti-aliasing algorithm allows for continuous perception of an object´s depth instead of displaying discrete image-layers just like "slices" of an object. That means if a voxel is supposed to appear between two layers because of its depth-value, it is being projected with different intensity of light upon both layers (e.g. 75% of the intensity upon the 15th and 25% upon the 16th layer). Thus, an appropriate display of smoothed visual transitions between the single layers is granted. A drawback of the system, however, is the low refresh rate (50Hz) because of the augmented technical complexity by triggering the different layers of the display.

Figure 2: "Depth Cube Z1024 3D" – a volumetric multi-directional, multi-level display made up of twenty stacked LCD-layers (www.lightspacetech.com)

- *Omni-directional systems* (a real 360°-visualization which can be looked at from all sides by walking around the display)
  - ♣ *Vector-scan method* ("Felix 3D-Display" (see Fig. 3))
    (laser-scanner system containing a rotating double-helix of white synthetics inside a transparent hemisphere; a computer-guided laser projects RGB-beams onto the helix, whereas a deflector redirects the laser beams upon the desired position of the projection screen (diameter: 30cm); maximum resolution: 10 000 voxel at a refresh rate of 20Hz (current model of the University of Stuttgart: 40 000 voxel per color); optional projection of vector graphics; limitations: dead space around the rotation axis, susceptible mechanics; hence a new method of resolution is under way: current model "solid Felix" works without moving parts: the display is based on a transparent cuboid of crystals, two infrared lasers are being positioned in such a way as to obtain that the laser rays meet inside a certain crystal, thus building up a fluorescent point (voxel) inside the crystal. However, the yet small size of the drawn crystals is still a problem; developer: Vincent-Lübeck high school in Stade / Germany (www.felix3d.com) as well as affiliate universities of Hamburg, Stuttgart, Jena and Chemnitz)
  - ♣ *Raster-scan method* ("Perspecta" (see Fig. 6))
    (contains a rotating disc for projection (diameter: 50cm) creating 198 radially shifted images per revolution of a high-speed projector, each image is made up of 768 x 768 pixels which equals a spatial resolution of approximately 100 Mio. voxel (at a maximum refresh rate of 30Hz); disadvantageous are a the complex hardware and the poor maximum color depth (eight colors are presentable, but by using a special dithering method, several hundreds of colors can be simulated); developer: Actuality Systems Inc. (www.actuality-systems.com))

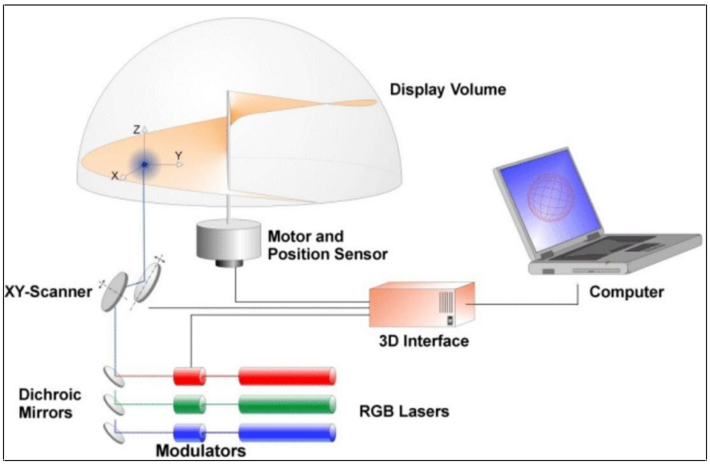

Figure 3: Functional drawing of "Felix 3D" – a volumetric, omni-directional vector-scan display (www.felix3d.com)

Among the first prototypes of **spherical displays** is the **“Fully Immersive Spherical Projection System”** (also called “Cybersphere” or “SPIN” (**S**pherical **P**rojection **In**terface); manufacturer: VR Systems UK). It has been developed as an immersive-reality system to overcome the limited freedom of movement of comparable systems (e.g. the limited range of head-tracking systems). The core of this spherical projection system is a translucent sphere (diameter: 3,5m), which is bedded in an apparatus that allows for free rotation of the sphere in all directions. The user can get into the sphere by a closing entry area and sets the sphere in motion by walking on the inside. There is practically no visual contact to the outside world and the user is totally surrounded by a virtual environment, which is being projected upon the sphere by four (five, if an additional projector is arranged above the sphere) projectors (see Fig. 7). In order to assure correct geometry of each projection upon the sphere, the images have to be preprocessed (i.e. they have to be distorted before projection in order to compensate the curved surface of the spherical screen). Other spherical displays feature the screen on the outer surface of the sphere. These displays are mainly being used as **(tactile) hyperglobes**, i.e. the spherical display is in fact the surface of the hyperglobe – just like in case of analogue globes [RIE-04].

APPLICATIONS IN CARTOGRAPHY, GIS AND SPATIAL PLANNING

The use of 3D screens could in fact help many people to better understand spatial relations and make it easier to perceive the shape of certain geo-objects when compared to conventional 2D visualizations. However, because of the need for wearing spectacles and due to many other limitations, the acceptance of traditional 3D-techniques has been quite poor in common, but also in case of geo-visualization in particular, except for photogrammetric analysis. That may change in the years to come by the spread of the new technologies that go without any kind of glasses. It has already been mentioned above that autostereoscopic techniques may play a major role in the future, since they will soon be affordable to the general public. Especially those models that feature multi-person and multi-view capability (e.g. multi-view parallax-barrier displays) seem to be suitable for various presentations in the field of geo-visualization: e.g. in order to show virtual hyper-globes, virtual planetaria, virtual block diagrams, terrain models, city models, etc. that could be realized and, in addition, updated and / or modified with little effort. From there, they could help save costs, when compared to the elaborate process of manufacturing real, material models (not to mention the material costs). In some cases, computer-generated spatial 3D models could even supersede the creation of real models: for instance if a spatial model is required in best time or if variants of a model with different geometries and / or different textures are needed in order to switch between the models for evaluation. New drivers like “X3D OpenGL Enhancer” (not to be mixed up with the open standard of the 3D-modelling language X3D) even provide the opportunity – by means of the computer graphics-standard OpenGL – for interactive panning and tilting of digital stereo-3D-models, using a graphical user interface (GUI) on a conventional 2D-screen as a control panel, while several people can simultaneously watch the autostereoscopic 3D-scene from different perspectives on a secondary, wavelength-selective filter-array (WLSFA)-equipped 3D-TFT-screen, as it has only been possible by the use of real material models before. The company “Opticality Corp.” has announced on its website that, by the application of “OpenGL Enhancer”, many widely used (web3D)-standards (e.g. VRML, Shockwave3D, etc.) are supported. Another software-tool from the same company, the “zWarper”, allows for conversion of 2D-images to 3D-views by the use of a depth map (a special grayscale version of an image). The downside of this technique, however, is a backdrop-like effect without plastic rendering of the displayed objects or environment. Nevertheless, this should be an appropriate method in order to process image-based (photographic) Virtual Reality-scenes on the basis of interactive 360°-panoramas and -objects (QuickTimeVR, etc.) for an autostereoscopic virtual tour.

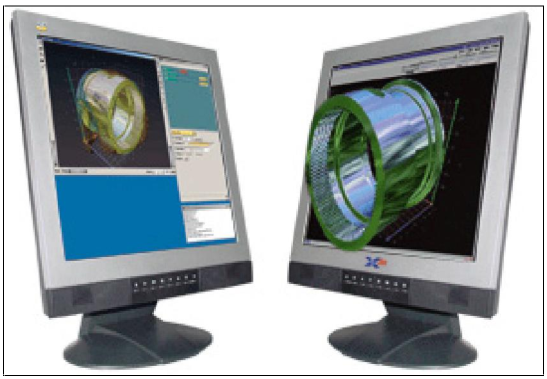

Figure 4: An interactive autostereoscopic application, based on the “OpenGL Enhancer”; left side: conventional display, including the GUI; right side: autostereoscopic visualization via multi-view parallax-barrier method (www.x3dworld.de or www.opticalitycorporation.com)

The voxel-based real-three-dimensional systems, as the latest level of development, have actually not yet reached the stadium of mass production. As stated by Lightspace Technologies, the manufacturing company of the multi-directional volumetric display "Depth Cube Z1024 3D", any applications are presentable on their screen by the use of special OpenGL-drivers. The company has tested several CAD- and animation-software as well as adaptations of computer games. Comprising 20 layers, the "Depth Cube", at a resolution of 1024 x 768 pixel per layer, accomplishes a volumetric resolution of 15 million voxel, whereby it is far superior to the autostereoscopic multi-view systems in terms of displaying details. The manufacturer envisioned possible applications for this kind of display in the field of visualization, medicine, CAD and military training. The developers of the omni-directional, volumetric "Felix 3D" display also see their product as a means for visualizing complex multidimensional data structures (surely including terrain models as well), CAD/CAM, medicine, aerial surveillance and air traffic control, but also in the field of education and training, physics/chemistry (e.g. computational fluid dynamics, models of molecules, etc.), art, entertainment and advertising. The application of real-three-dimensional systems to geo-sciences should definitely be a goal in the long run, the more so as in case of omni-directional systems the displayed volumes can be interactively studied like a material model by walking around the electronic model, without the need for a dedicated GUI. The main advantage of digital models when compared to material models is that with the existing data short-term update cycles or modifications could be achieved with little effort. A digital model of a landscape could, for example, be edited or updated via internet, and scientist or even interested people all over the world – if they had such a volumetric display (and a web connection) at their disposal – would be able to study this real-three-dimensional landscape-model, independently of there whereabouts. Thus, the electronic model does not need to be transported and, as a matter of fact, does not run the risk of being damaged (not to mention the cost savings for transport). But above all, volumetric and (quasi)-holographic displays seem to be particularly suitable for visualizing three-dimensional dynamic issues: e.g. for supervising the air traffic in the terminal area of an airport. As a matter of fact, Hungary has brought a national project into being in order to evaluate the applicability of quasi-holographic displays (from the Hungarian company Holografika) for air traffic control, including the digital map of Hungary (Fig. 5).

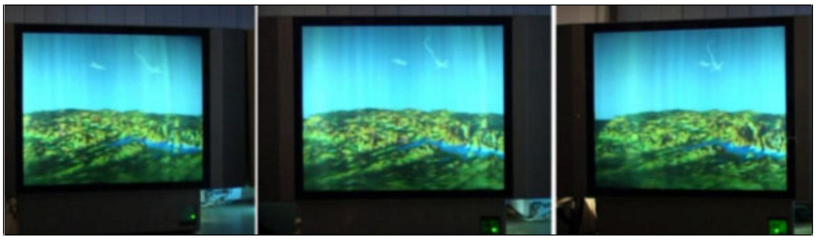

Figure 5: Visualization of a real air traffic situation in 3D by means of a quasi-holographic display and the digital map of Hungary ("HoloVizio"-display from Holografika) (www.holografika.com)

The first commercial volumetric display of the world, the sphere-shaped "Perspecta" from Actuality Systems, has already been presented to the public. Via a system of rotating mirrors (a rotating diffusor-screen, respectively), 198 radially shifted images are being utilized to create more than 100 million voxel. The company has cited medical, military and geo-spatial (e.g. petroleum exploration) applications as an example. Furthermore, a usability study of the US Navy has proven that such volumetric 3D-displays are far superior in order to perform certain tasks when compared to conventional or autostereoscopic screens. The test persons had to attend particular docking-exercises and, by doing this, they had to avoid collisions. With the aid of "Perspecta" the success rate was about 93%, while in case of stereoscopic displays it was only about 75%, being just marginally better than with conventional 2D-screens (72%).

Figure 6: "Perspecta" – the worldwide first commercial volumetric display, demonstrating a possible future application (aerial surveillance, including a projected digital terrain model) (www.actuality-systems.com)

Concerning spherical displays, a possible future field of application might be tactile hyperglobes that can be availed in order to show animated dynamic global phenomena and / or different topics (e.g. the global weather, continental drift, etc.). In case of the “Fully Immersive Spherical Projection System” (“Cybersphere”), simulations in the range of spatial planning could be achieved at an unprecedented high degree of realism by walking through computer generated geo-virtual environments that surround the viewer (e.g. a virtual walk through a planned asset in a recreation area). However, since the environment has to be rendered at real-time, “Cybersphere” cannot match the level of detail and photorealism provided by recent versions of non-interactive 3D-modeling and -animation software (like Maya, 3DStudio Max, Cinema 4D, etc.). But once again it seems to be only a matter of time until the appropriate software and adequate powerful supercomputers will be available to obtain such a high level of realism. Nevertheless, an Immersive Reality-system like “Cybersphere” appears to be too sumptuous and bulky for the mass market. From there, a thrust of innovation can rather be expected in the range of Desktop VR-systems – triggered by the fall in the price of autostereoscopic displays over the coming years.

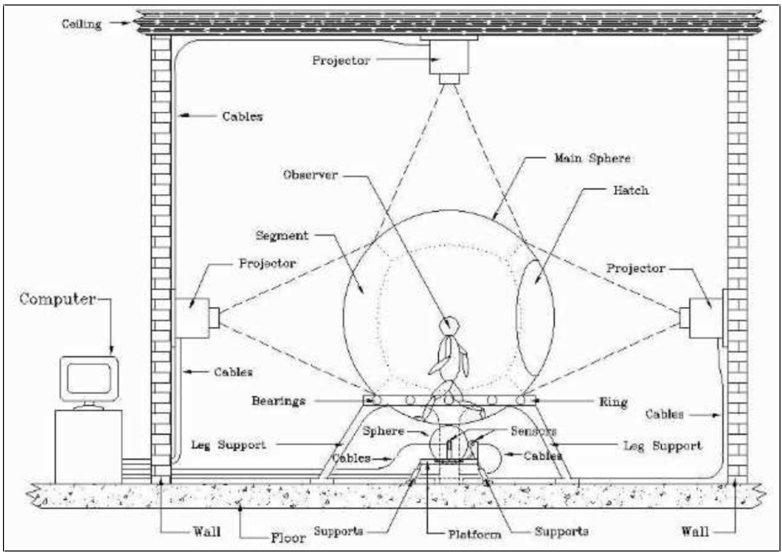

Figure 7: “Cybersphere” – an Immersive Reality System, implemented by the use of a spherical screen (www.vr-systems.ndtilda.co.uk)

Recapitulating, the “ultimate” 3D-display should meet the following demands (modified, according to SCHENKE & PASTOOR [SCH-02]):

- High-grade imagery (spatial resolution, color depth, contrast, etc.)
- No spectacles needed
- Unlimited view from all perspectives (omni-directional)
- Multi-user capability
- No optical crosstalk (no “jumps” between perspectives)
- Compact design
- Reasonable

OUTLOOK

Regarding the latest market development of various 3D-display technologies, the category of autostereoscopic systems will most likely play a major role over the coming years. The advantage of showing content three-dimensionally without the need to wear spectacles and their yet comparatively moderate price (other than quasi-holographic or real-three-dimensional displays) will definitely make them attractive as a new visual medium for the presentation of three-dimensional data – especially since recent displays feature multi-person-/multi-view-capability. However, due to the multi-view-capability of these displays, the significantly reduced effective horizontal resolution cannot deliver satisfying results in many cases. This disadvantage will eventually become obsolete by the availability of high-resolution screens in the future. Nevertheless, optical crosstalk instead of continuous motion-parallax and a certain minimum viewing distance will remain a drawback of autostereoscopic displays. Time will tell if the quasi-holographic technique can compete with autostereoscopic systems, since it is superior in many respects, yet not very common. Cost-effectiveness will be – as always – an important factor on that score. Real-three-dimensional technologies show a huge potential, but they are still in the fledgling stages; especially the omni-directional techniques. Volumetric and holographic systems might be a premium tool for scientific visualization in the long run. They could literally become *the* ideal media in order to visualize three-dimensional spatial data, including geo-spatial applications in cartography, GIS and spatial planning. However, to achieve this objective, a lot of research is required. Last but not least it should be mentioned that if spherical displays in the form of (tactile) hyperglobes once will become as reasonable as the usual analogue globes are today, they could be widely utilized to show dynamic global phenomena in animated form (e.g. continental drift, global weather, sea currents, etc.).

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Display developers (sample)

www.vr-systems.ndtilda.co.uk	VR Systems – spherical displays (“Cybersphere”)
www.actuality-systems.com	Actuality Systems – omni-directional volumetric displays („Perspecta“)
www2.automation.siemens.com	Siemens – multi-view parallax-barrier displays
www.ddd.com	Dynamic Digital Depth – parallax-barrier displays
www.sharp3d.com	Sharp – parallax-illumination displays
www.dti3d.com	Dimension Technologies Inc. – parallax-illumination displays
www.actkern.info	A.C.T. Kern GmbH & Co. KG – lens-raster displays
www.4d-vision.de	X3D Technologies GmbH – multi-view parallax-barrier displays
www.opticalitycorporation.com	Opticality Corp. – multi-view parallax-barrier displays
www.holografika.com	Holografika Kft. – quasi-holographic displays (“HoloVizio”)
www.deepvideo.com	Deep Video – volumetric dual-level displays
www.lightspacetech.com	Lightspace Technologies – volumetric multi-level displays
www.felix3d.com	Vincent-Lübeck-high school of Stade / Germany – omni-directional volumetric display („Felix 3D“)

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Born in Vienna in 1974, Alexander Schratt started studying at the University of Vienna, Institute for Geography and Regional Planning, Cartography and Geoinformation, in autumn 1994. Since 2001 he worked on various projects and holds tutorials in multimedia cartography. In his diploma thesis, he analyzed the potential of image-based Desktop Virtual Reality-systems in digital cartography. After graduating in May 2004 (Master of natural sciences), he started working as a scientific assistant at the University of Vienna, Institute for Geography and Regional Planning, Cartography and Geoinformation, contributing to the “MUGL” project for the National Library of Austria. This project aims in creating multimedia applications containing virtual globes and computer-generated animations explaining earth- and sky-globes as well as further information for being presented in the new Globe Museum in Vienna, Austria. Furthermore, he gave lectures at several geo-scientific symposia. He is currently working on his PhD-thesis.

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Assistant Professor Dr. Andreas Riedl, born 1965, studied cartography at the University of Vienna, Department of Geography, between 1987 and 1992. Subsequently, he was employed as a research assistant in the cartographic office of the department, and he worked freelance in the field of geoinformation and geovisualization. In addition to that, he carried out research work at the Simon Fraser University in Vancouver, Canada and he participated in the development and programming of courses for multimedia-CBT ("Computer Based Training"), topics GIS and remote sensing, at the ITC (Enschede, Netherlands). Since 1997, he has been assistant professor at the University of Vienna, Department of Geography and Regional Sciences. He finished his dissertation, which has been published 2000 as a book entitled “Virtual globes in geovisualization - Studies in the use of multimedia techniques in geocommunication”, after more than two years research work. His scientific priorities are applied geoinformation (GI) and the integration of multimedia techniques (3D-visualization, web-mapping, virtual worlds) into geocommunication. He is board member of the Austrian Geographic Society, responsible for inner affairs of the Austrian Cartographic Commission and corresponding member of the ICA Commission on Visualization and Virtual Environments.
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