ILLUMICONCLAVE I

Description:
Meeting of experts convened to rule on topics related to advanced display.

Location:
Heidelberg, Germany 2016

Article I

DEFINITIONS

Ambiguous terms in display technology were given the following definitions:

1.1. ***Volumetric Display***—a volumetric display is defined as a display in which all image points are collocated with physical scattering surfaces. Consistent with this definition, volumetric displays have perfect accommodative cues as the viewer is able to focus on a material object in space. Also consistent with this definition and contrary to long-held popular opinion, it is *not* necessarily true that a volumetric display be incapable of self-occlusion as this may be possible by employing anisotropic scattering surfaces. However, at the time of this writing no volumetric display of which we are aware, meeting the above definition, has demonstrated self-occlusion.

1.1.1. *Examples* of volumetric displays include: helical and paddle swept volume displays, particle displays, plasma ball displays, active and passive grids, multilayer tensor displays.

1.1.2. Examples of displays which are *not volumetric* by this definition in their current configuration: Leia display Systems, iO2 technology (these would be light-field as ray bundles intersect in regions space not collocated with the modulated air). Volumetric display hardware may be used to create images which are not volumetric (i.e. abandon image point colocation with physical scatters) and lose the affordances of volumetric displays such as perfect accommodation (and, in so doing, may gain other affordances instead—such as greater control over view-angle content).

1.1.3. *Display advantages* include perfect accommodation and very low bandwidth requirements for sparse scenes.

1.1.4. *Display limitations* include the fundamental inability to display virtual images, display dependent bandwidth as well as challenging scanning requirements in most cases.

1.2. ***Holographic Display***—a holographic display is defined as a display for which the viewer can draw a straight line which intersects their eye, and image point and a region containing information encoded in spatial frequency such as in a Raman-Nath or volume (e.g. Bragg) grating. In volume holograms, including Denisyuk reflection holograms and Bragg gratings, volume reflection may also augment diffraction by providing color sensitivity (Denisyuk), angle sensitivity (Bragg) or diffraction efficiency (edge-lit). In order for a holographic display to be considered 'holographic video' or 'holovideo' it should be able to update its diffraction pattern quickly enough to make possible persistence of vision (e.g. greater than ten times a second).

1.2.1. Examples include displays based on diffraction from pixelated spatial light modulators, (Qinetiq, SeeReal) and scanned aperture acousto-optic displays (MIT Mark i-iii) prototypes as well as waveguide based diffractive displays.

1.2.2. Examples of displays which are *not holographic* by this definition include nanophotonic arrays—these displays are also capable of creating arbitrary wavefronts of light by interference, but display information is contained in temporal rather than spatial phase (i.e. the spatial frequency is often fixed at some lambda/n) and for this reason may be better suited for a digital instantiation than holography. Other oft-confused, non-holographic displays include displays with employ holographic lenses or diffusers but do not encode image information in the diffraction pattern.

1.2.3. Advantages of holographic displays include: the ability to reconstruct an identical copy of an objects optical wavefront, the ability to superimpose image information to preserve display numerical aperture as image points are added.

1.2.4. Disadvantages: Very high computational complexity, vignetting.

1.3. ***Light Field Display—***a lightfield display is a display that is not holographic, but which modulates the position and direction of light rays (x, y, theta and phi).

1.3.1. Examples include lenticular and coded aperture displays. This also includes Multiview and multibeam displays (e.g. holographika).

1.3.2. Examples of displays which are not lightfield displays: Volumetric and holographic and phased array displays.

1.3.3. Advantages: Lightfield displays typically seek to match the needs of the human visual system and as a result tend to have lower computational requirements than holographic displays. Lightfield displays have demonstrated abilities not yet observed in other displays such as the ability to illuminate image objects (though this might be achievable in holograms by channeling).

1.3.4. Disadvantages: they are often limited by diffraction, in part because they do not possess the same ability to superimpose modulation information that a holographic display does (though multiple layers may provide a type of superposition).

1.4. **Geometric Imaging Display**—This type of display uses geometric optics to form real and virtual images of real objects (including other displays).

1.4.1. Examples of geometric displays include Peppers ghost, real images from concave mirrors and scratch holograms which forms images by the accumulated effect of a number of discretized reflectors or varying radius of curvature.

Article II

DECLARATIONS

2.1 The noun 'hologram' refers to the modulation material containing the diffraction pattern, not the image formed by the diffraction pattern. For example, the hologram exists even when there is no illumination present.

2.2 It is ruled, until further evidence is presented, that a 'scratch hologram,' by the definition given above in Article I section 1.2, is not a hologram (or similar to a Benton hologram as claimed) but, rather, a geometric display. The information is encoded in radius of curvature rather than in spatial frequency. It is conceded that reflection holograms may contain volumetric structures with wavefront information encoded in radii of curvature similar to that of 'scratch holograms,' but they differ in that reflection

holograms have structures that are nested in a periodic fashion creating a coherent spatial periodicity in the volume. A scratch hologram in this paradigm might be considered a reflection hologram without periodicity or with a minimal fringe coherence which is equivalent to a distributed, reflective, geometric optic.

Article III

PROGNOSTICATIONS

3.1 **Is AR/VR good enough?**

Yes, with qualifications. A number of head mounted stereoscopic displays have been refined to a level that they can be worn and used with minimal visual discomfort for distant imagery (within 10m or closer for young users). However, the voting body expresses concern about use of stereopsis for imagery from closer than 20m. Vergence and accommodation are usually tied together in the accommodation convergence reflex. Vergence without focus accommodation can be tolerated up to 2 milliradians but is much preferable below 1 milliradian. A good compromise seems to be 1.6 milliradians which corresponds to a viewing distance of 20m. Even if prolonged use can be achieved without accommodation below 20m, the lack of visual cues may require visual adaptation which could be dangerous after the headset is removed. For this reason, the voting body recommends that accommodative displays be used up for imagery up to 20m.

3.2 **Which of the following will be the dominant display technology in the year 2030?**

Results of vote by raised hands:	
Holovideo	15 (52%)
Light Field Display	13 (45%)
Volumetric Display	1 (3%)

Holographic video was favored because of its ability to provide all necessary 3d cues. Light field was considered to be a close contestant as progress in this field seems to be more rapid that in other display areas. Volumetric, despite the fact that they are most similar to the displays of popular imagination, was not favored given the formidable optical challenges, the difficulty in obtaining occlusion and the inability to create virtual images.

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