SC1096
Head-Mounted Display Requirements and Designs for Augmented Reality Applications

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Course Outline

1) Introduction
- What is an HMD?
- What is a visually coupled system?
- Terminology, definitions, taxonomy
  - Immersive/non-see-through HMDs
  - Compact Offset HMDs
  - Electronic see-through HMDs
  - See-through HMDs
- User and task definition: What do I need?
- Display imagery considerations
- Color blending in AR/see-through displays

2) Optical and display design
- Optical forms
- Exit pupil and eye relief definition
- HMD examples
  - Projection displays
  - Prism displays
  - Waveguide displays
- Image source technologies and resolution
- Color imagery methods
- Luminance & contrast requirements

3) Monocular/biocular/binocular designs
- Monocular HMDs
- Binocular HMDs
- Overcoming the FOV/resolution invariant
- Binocular HMD forms

4) The Human Perceptual System
- The eye, visual acuity and focus
- Binocular vision and eye movements
- Binocular alignment, visual comfort
- Biomechanics and head/neck anatomy
- Anthropometry, fit and sizing
- Potential issues & consequences

5) Recommendations

6) Summary

The presentation will be accompanied by examples and exercises throughout. The goal is to help you as a developer, user or buyer of the technology.
HMD Taxonomy

- **Occluded/Non see-through/“Virtual Reality”**
  - All visual information via the HMD, no real world imagery

- **Compact Offset/“Look Around”**
  - Electronic visual information plus user can “look around” display to see real world

- **Video/Electronic see-through**
  - Uses camera(s) to provide electronic real world information overlaid with electronic information

- **Optical see-through/“Augmented Reality”**
  - Electronic visual information is overlaid optically on real world via a partially transmissive combiner

We will address each type of HMD and discuss their advantages, disadvantages and who is selling them.

Taxonomy courtesy of Kirk Moffitt, PhD, www.kirkmoffitt.com
We will discuss HMD requirements from a user and task perspective. No reason to buy or wear more than you need!

- Luminance, contrast, uniformity, color, resolution,
- Field of view, binocular overlap, focus, alignment
- See-through transmission, color, angular deviation
- Monocular/biocular/binocular
- Exit pupil, eye relief, eyeglass compatibility
- Fit, sizing, comfort, don/doff, hygiene/cleaning
- Weight, center of gravity
- Cable routing, weight, stiffness
- Appearance/aesthetics
- Durability, reliability
- Interface/adjustments

User Definition (Who?)
Task Definition (What?)
Environment (Where?)
Needs/Requirements
Tradeoffs
Suboptimize

Thales TopMax for commercial aircraft pilotage
Waveguide-based Optics for HMDs

1. Light from the collimating optics is diffracted by the Input Coupler
2. Light propagates down waveguide.
3. Output Coupler diffraction grating diffracts light out of the waveguide a little at a time

- Two different optical architectures
  1. Reflective (Lumus, Oorym)
  2. Diffractive (Digilens, Hololens, Vuzix)
- Waveguide display is a pupil replicator (small pupil in is replicated creating a larger array of exit pupils) breaking the Etendu invariant (“Bed of Nails”). Giving us (potentially):
  - Larger viewing eye box
  - Smaller, less expensive, image sources and/or projectors

We will deep dive into Projection, Prism, Waveguide and “Conventional” displays and discuss examples of each.

Example: Digilens Dual Axis Display
**Recommendations**

1. *Understand User and Application* Who are they? What are they trying to do?
2. *Ocularity/Configuration* - Compact Offset, Opaque/Immersive, Video-see-through, Optical See-Through
3. *See-through versus non-see-through* – advantages and disadvantages
4. *Field-of-view* – Task dependent! *As small as possible to get the job done*
5. *Pupil-forming versus non-pupil-forming optical designs*
6. *Exit pupil and eye relief* – Key to comfortably viewing imagery
7. *Resolution* – *Task dependent*: what does the user need to see?
8. *Luminance and Contrast* – Different requirements for see-through, non-see-through. Task and environment dependent.
9. *Obscurations* – too much peripheral obscuration may be a safety concern.
10. Color – Task-dependence, color palette and human factors implications

*In summarizing, we will review key points, looking at user needs and requirements, examining important visual and physical human factors issues to ensure user comfort and safety. This will help you if you are a developer, user or buyer.*