Display Options for Head-Up Information

Eric Holder & Florian Motz
Fraunhofer FKIE

E-Nav Underway North America 2014, California Maritime Academy

April 3 - 4 2014
E-Navigation: What does it mean?

- Getting in touch with the intended maritime users’ goals, tasks, and needs
- Understanding the context of use (current and future)
- Providing the maritime stakeholders the support (information and tools) to complete these goals/tasks as:
  - Safely, effectively, efficiently, satisfactorily, and intuitively as possible
Harmonization: Defined

“to bring into agreement”

➢ **What is being harmonized**: information or service that is, or could be, available

➢ **With what**: the task or goal mariners currently do or will be doing in the future

➢ **How**: In the optimal way to support that task/goal
  - Clear, complete, intuitive, prevent errors and misunderstandings, avoid clutter and overload
Display Options for Maritime Head-Up Display

Work to date:

- Simulator testing of maritime HUD CONOPS and information requirements
- HUD value shown, especially in reduced visibility, confined waters, high speed operations
- Benefits are integrating essential information where it is needed, making information visible, and reducing head down time
- Concerns include clutter and mariner acceptance
CMA Simulator Display
HUD is only means to provide supplemental information while maintaining eyes out the window. Can augment degraded reality (fog) and make the invisible visible (VAtoNs).
Moving from Simulator to Onboard

- Not easy but straightforward in a simulator
- HUD image presented on same screen as simulator visual
  - No issues with different views by different people or by two eyes of same person
  - No issues with focus and accommodation, glare, etc.
  - Can display colors directly (without reflecting/filtering)
- Need to design for these challenges as move to onboard reality
Display Options for Maritime Head-Up Display

Bringing HUD onboard has 3 primary options:

- Fixed position combiner-based image display (used in aviation HUDs and most automotive applications)
- Fixed position transparent display (image created in display)
- Movable head-worn display
Combiner Displays

Figure 10: Compact and low profile; LiteHUD® (left) next to a legacy BAE Systems F-16 HUD (right)
Transparent Displays

Image projected onto screen/glass

Physical objects behind screen/glass
Head Worn Displays

<table>
<thead>
<tr>
<th>Product</th>
<th>See through</th>
<th>Form Factor</th>
<th>&quot;Flip-Vu&quot; (2 positions)</th>
<th>AR capable</th>
<th>Diagonal FOV (Display Size)</th>
<th>Resolution</th>
<th>Weight</th>
<th>Camera</th>
<th>Other Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Glass</td>
<td></td>
<td>Monocular</td>
<td>No</td>
<td>No</td>
<td>14°</td>
<td>640x360</td>
<td>50g</td>
<td>Yes</td>
<td>Need to look at upper right corner to see image. Small display w/ low Brightness.</td>
</tr>
<tr>
<td>Epson Moverio</td>
<td>Yes</td>
<td>Binocular Glasses</td>
<td>No</td>
<td>Yes</td>
<td>23°</td>
<td>960x540</td>
<td>240g</td>
<td>No</td>
<td>Bulky, heavy, and blocks peripheral vision on both sides. Wired connection.</td>
</tr>
<tr>
<td>Optinvent ORA-3</td>
<td>Yes</td>
<td>Monocular Sunglasses</td>
<td>Yes</td>
<td>Yes</td>
<td>24° (~70° at 4m)</td>
<td>640x480</td>
<td>70g</td>
<td>Yes</td>
<td>Largest FOV and Highest brightness</td>
</tr>
<tr>
<td>Recon Jet</td>
<td>No</td>
<td>Monocular Sunglasses</td>
<td>No</td>
<td>No</td>
<td>16°</td>
<td>240x400</td>
<td>60g</td>
<td>No</td>
<td>Need to look at bottom corner</td>
</tr>
<tr>
<td>Vuzix M100</td>
<td>No</td>
<td>Monocular Eyepiece</td>
<td>No</td>
<td>No</td>
<td>16°</td>
<td>240x400</td>
<td>Not Published</td>
<td>Yes</td>
<td>Form factor issue for consumer</td>
</tr>
</tbody>
</table>
Display Options for Maritime Head-Up Display

Needs and challenges: 3 main technical issues

- Conformal information requires information display to appear focused at infinity
- Legibility/Visibility (HUD and outside visual)
  - Luminance Contrast (light source, display, background)
  - Transparency of display (> 70% transmittance)
  - Distortion through display
  - Resolution (letters vs symbols)
- Size of displayed image (field of view) available
Display Options for Maritime Head-Up Display

Others issues include:

- Accommodating for movement (viewer and ship)
  - Eye-box
  - Image Stabilization
- Cost and installation requirements
- Mariner acceptance
- Defining the content and symbology (color or not)
- Task and context specific needs
Collimated & Conformal Information

Is the essence of the HUD benefit

- Reduced accommodation time
- Obstacles, traffic lanes, other vessels, etc. displayed in correct positions out the window with augmented information as warranted

Presentation of displayed information must conform to optical focus of eye for distant objects (collimated to infinity)

- > 6 to 9 m the eye is focussed at optical infinity
- Information relevant to mariner is > 9 m away
Human Stereoscopic Field of View
Multiple Colors: Pros and Cons

- **PRO:** Familiar coding for the mariner (effective)
- **PRO:** More flexibility in display and symbology
- **CON:** Constantly changing background can alter perceived colors in display and vice versa
- **CON:** 1 color HUD „gestalt“ is lost
  - Less clear what is HUD and what is background
- **CON:** Combiner displays must reflect the spectrums for all colors displayed
  - Less transmittance
- **CON:** Symbols should be primarily lines (see through)
Combiner-based HUDs

- Infinity focus and conformal information can be achieved through various lenses, mirrors, and coatings (defraction, reflection, refraction).

- Legibility/Visibility proven as satisfactory

- Size (FoV): in existing systems is a major limitation (typically 15-30 degrees and close to eye)
  - Potential for larger display surface (cost/legibility)

- Movement
  - Stabilization achievable with sensors
  - Viewer is constrained to eye-box
Combiner-based HUDs

- Color is not a good option
  - Requires combiner to reflect more wavelengths reducing transmittance
  - Different wavelengths have different focal lengths
- Cost is currently high for certified systems due to optics required.
  - Possible reduced cost using new technologies such as wave guide
Transparent Display HUDs

- Generally cannot be collimated to infinity as the image is produced and eye focused at the display
  - Can be "faked" with use of glasses (binocular disparity) and multi-plexing but not ideal for HUD at infinity
  - Possibility to include optical components in/on display directly or between display and viewer
    - Impact needs testing (effect on light rays from outside)

- Legibility/Visibility is a problem with most available transparent displays
  - Primarily for transparency and/or resolution
Transparent Display HUDs

- Size (FoV) is only limited by display size.
  - Several larger displays exist but with limited resolution
  - Could be designed to be larger or curved for wider FoV

- Movement
  - Stabilization possible with sensors
  - Viewer is constrained to eye-box unless movement tracking system implemented (conformal still a problem)

- Color is available for use

- Cost is significantly lower than combiner-based HUD but availability is limited
  - Cost might increase when optical components integrated
Head-Worn HUDs

- Advanced Head-Mounted Displays (HMDs) can support conformal information
  - HMDs have advanced to even displaying the image plane to appear where the eyes are currently focussing.
- Commercial applications such as Google Glass show limited support for conformality (upper right)
- Legibility/Visibility is a not a problem with most available see-through displays
- Size (FoV): depends on equipment (1 vs 2 eye)
  - Glasses average 20 degrees, professional (avg. about 40 degrees H/V but exist up to 150 degrees)
Head-Worn HUDs

- Movement can be tracked and display adjusted
  - Requires motion tracking sensors
  - Allows viewing in all directions
  - Accuracy is lower than combiner (slips in equipment and need to track rapid and variable movement)

- Color is possible but depends on optics involved
  - Likely not viable for optically collimated displays

- Cost is lower than combiner displays but varies
  - Commercial starts $400 to $3500

- Mariner acceptance: resistant to anything larger than glasses
  - Additional tracking components still required (i.e., worn, carried, integrated, or infrared tracking—Kinect)
Display Options for Maritime Head-Up Display:

Conclusions:

- Display must produce conformal information and be legible/visible
  - Limits available options
- For near future onboard testing need to use sizes available (proof of basic concept and limitations)
- Movement
  - Ship movement must be factored in (stabilization)
  - For initial testing can start with seated user or assigned (calibrated) viewing position
- Cost for research is very prohibitive without direct participation by manufacturer (HUD or Optical Components)
Thank You!

Questions?

Eric Holder: eric.holder@fraunhofer.fkie
+49 (0) 228 9435-789

Florian Motz: florian.motz@fraunhofer.fkie
+49 (0) 228 9435-271
Key References:


