Augmented Reality Information Displays
Psychology 6135: Psychology of Data Visualization

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What is Augmented Reality?

- **Augmented Reality (AR)** displays composite computer graphics/visualizations with the user's view of the physical world.
- Visualizations presented by placing some display into the optical path between the scene and the retina.
  - **Optics**: Lens, mirrors, prisms, etc.
  - **Opti-electronic**: Wave-guide, raster (LCD, OLED), etc.
- Display units may be head mounted, or placed somewhere in the environment.
- Visualizations could be text to complex 3D models.
- AR displays are not limited to visual information, other sensory modalites can be included (outside the scope of this talk).

Applications of Augmented Reality

- ▶ Advancements in electronics miniaturization and display technology for mobile devices has lead to a resurgence of AR in recent years for consumer applications (van Krevelen, 2007).
- ▶ **Optical:** Google Glass, Microsoft HoloLens, HUDs, etc.
- ▶ **See-through video:** smartphones and measurement tools now can overlay graphics and information atop live camera feeds in real-time.
- ▶ Automotive manufacturers are adding AR to vehicles to move information on the dashboard to a windscreen HUD.
- ▶ There are additional applications in the medical, military, industrial, and educational fields.

Heads-Up Displays (HUDs)

- A heads-up display (HUD) is one of the earliest applications of AR, dating back to WWII.
- HUDs present task-critical information within visual field of the viewer using a semi-transparent display.
- This reduces the need to shift attention and gaze away from some point of interest during a complex task (e.g. flying an aircraft or driving a car).
- Additional imperceptible information from on-board instruments can be visually encoded using "retinal variables" (Bertin) to enhance one's awareness (e.g. night vision).

Heads-Up Displays (HUDs)
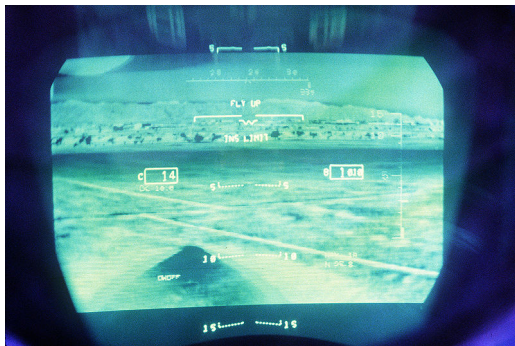
Fighter aircraft HUD example with IR imaging (Wikipedia)

Heads-Up Displays (HUDs)

Automotive AR HUD (image from Continental Automotive)

Augmented Reality Headsets

- Head mounted AR displays can account for the user's viewpoint. Allowing visualizations to reflect what the observer is attending to in the world.
- The first augmented reality display headset was developed at Harvard by Ivan Sutherland, described in the paper "A Head-Mounted Three Dimensional Display" (Sutherland, 1968).
- Images presented on miniature CRT displays were combined with the observer's view of the real-world using half-silvered mirrors.
- The display presented 3D line graphics, transformed in relation to the user's head position in space using head tracking.

Augmented Reality Headsets
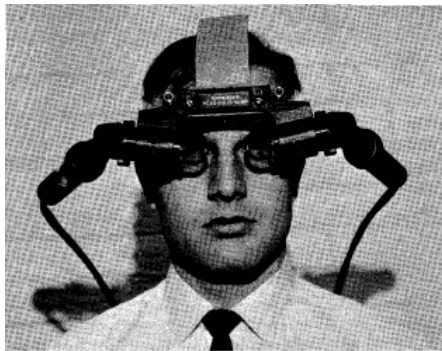
Ivan Sutherland's head-mounted display (from Sutherland, 1968)

Augmented Reality Headsets

- Head-tracking and independent eye displays enabled stereoscopy.
- There was a compelling illusion of 3D since binocular disparity, motion parallax, and perspective depth cues were present.
- Users reported wire frame figures presented tended to be ambiguous, causing them to misinterpret the shape of some objects, possibly due to the lack of monocular cues such as occlusion, texture, and shading.
- Rendering monocular information was too complex at the time, however this is no longer a limitation with modern graphics hardware.
- However, all modern AR headsets approximately follow the pattern of Ivan Sutherland's original design.

Augmented Reality Headsets

Retrieved from https://blogs.solidworks.com/solidworksblog/2017/04/meta-ar-headset-might-help-designers-break-cads-screen-based-paradigm.html

Display Considerations

▶ When displaying visualizations, considerations must be made given the current state of AR technology.

▶ Images presented are semi-transparent, a mixture of light from the display and background depending on the transmissivity of the optics (does not apply to see-through video).

▶ Virtual images must be at least one just-noticeable-difference (JND) along the brightness or color dimension from the background values to be perceptible.

▶ Color correction is required for various environments to maintain color and lightness constancy.

Display Considerations

- High-resolution displays are desired since the real-world is being presented in conjunction with the virtual image.
- Restricted field-of-view due to resolution requirements, limits the amount of information that can be presented at one time.
- Registration of the virtual image within the real scene must be precise, latency in the system should be minimized to maintain a sense of stability.

Advantages of Augmented Reality Displays

- Places computational elements within our physical reality (van Krevelen, 2007).
- Expands our perception by re-encoding imperceptible information into some visual representation.

Advantages of Augmented Reality Displays
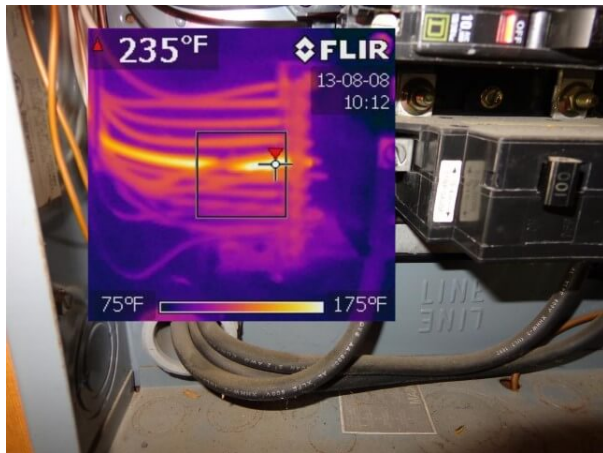
From "Using an infrared camera to find an overloaded circuit" retrieved from
https://structuretech1.com/using-an-infrared-camera-to-find-an-overloaded-circuit/

Advantages of Augmented Reality Displays

- Augmented reality displays have been shown to improve task performance in many cases.
  - Improves the speed of assembly task by reducing cognitive load when visual references are provided (Tang et al. 2003).
  - Can be used to distort visual information, for instance, the visual image of food items can be re-scaled as a means of controlling caloric intake (Narumi, 2012).
  - Objects in a scene can be labeled, improving task performance when interacting with complex objects. (Azuma & Furmanski, 2003).
  - Improves taxi performance of aircraft in low-vision environments (McCann et al. 1996).
- However, over-reliance on the technology can result in cognitive capture and tunnel vision (van Krevelen, 2007).

Advantages of Augmented Reality Displays

Object labelling example from Azuma and Furmanski (2003).

Inattentional Blindness and AR

- While one may expect AR displays to generally improve task performance, human factors research has also shown it may overwhelm one's attentional capacity.
- Task fixation caused by the presence of the visual overlay may distract the user from other critical cues in the physical environment.
- Aircraft HUDs have been shown to increase performance during aircraft landings, however caused pilots to react more slowly or completely miss obstacles on the runway (Fischer, Haines & Price, 1980)

Inattentional Blindness and AR

▶ An application of AR displays within the medical field is image-guided surgery (IGS), which composites visual models with with an image from an endoscope.
▶ Dixon et al. (2012) examined if inattentional blindness associated augmented reality visualizations can cause surgeons to miss critical information.
  ▶ Groups of surgeons performed surgery on a cadaver with and without visualizations of the target structure.
  ▶ In the FOV of the endoscope at the target site, the researchers placed a complication (pucture hole in the skull) and a foreign body (a metal screw).

Inattentional Blindness and AR

Endoscopic view in control and AR conditions (Dixon et al. 2012)
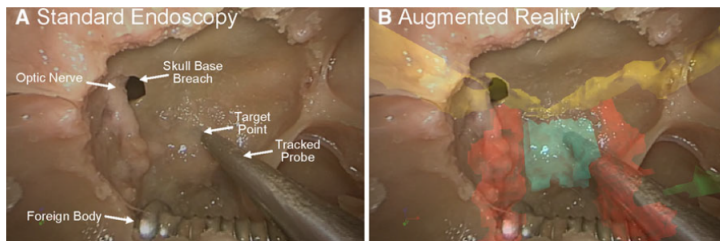
- On average, surgeons using the AR system performed the surgery faster and with higher accuracy, however only 1/15 noted the presence of the screw. Oppose to the control group where 12/17 noted either issue.

Summary

- Augmented-reality displays composite data visualizations with views of the real world.
- AR displays can be wearable or placed in the environment, with a wide range of applications.
- Displays can transcode information from imperceptible forms to visual representations, expanding our awareness.
- While this technology can dramatically improve human performance, it has drawbacks such as inattentional blindness.

Discussion Questions

- ▶ Are HUDs in cars a good idea given the effects of cognitive capture?
- ▶ What are the potential social impacts of AR technology once it becomes more acceptable?

References

▶ McCann, R. S., Foyle, D. C., Andre, A. D., & Battiste, V. (1996). Advanced navigation aids in the flight deck: Effects on ground taxi performance under low visibility conditions (No. 965552). SAE Technical Paper.

▶ Van Krevelen, D., & Poelman, R. (2007). Augmented reality: Technologies, applications, and limitations. Vrije Univ. Amsterdam, Dep. Comput. Sci.

▶ Dixon, B. J., Daly, M. J., Chan, H., Vescan, A. D., Witterick, I. J., & Irish, J. C. (2013). Surgeons blinded by enhanced navigation: the effect of augmented reality on attention. Surgical endoscopy, 27(2), 454-461.

▶ Sutherland, I. E. (1968, December). A head-mounted three dimensional display. In Proceedings of the December 9-11, 1968, fall joint computer conference, part I (pp. 757-764). ACM.

▶ Tang, A., Owen, C., Biocca, F., & Mou, W. (2002). Experimental evaluation of augmented reality in object assembly task. In Proceedings. International Symposium on Mixed and Augmented Reality (pp. 265-266). IEEE.

▶ Narumi, T., Ban, Y., Kajinami, T., Tanikawa, T., & Hirose, M. (2012, May). Augmented perception of satiety: controlling food consumption by changing apparent size of food with augmented reality. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 109-118). ACM.

▶ Azuma, R., & Furmanski, C. (2003, October). Evaluating label placement for augmented reality view management. In Proceedings of the 2nd IEEE/ACM international Symposium on Mixed and Augmented Reality (p. 66). IEEE Computer Society.

▶ McCann, R. S., Foyle, D. C., Andre, A. D., & Battiste, V. (1996). Advanced navigation aids in the flight deck: Effects on ground taxi performance under low visibility conditions (No. 965552). SAE Technical Paper.