Repurposing HMD's Built-in Sensors to Increase Users' Awareness

Yu-Chun (Arthur) Ku[1], Joyraj Bhowmick[1], Anirejuoritse Egbe[1]
Instructor: Alejandro Martin-Gomez

1. Robotics MSE, Laboratory for Computational Sensing and Robotics, Johns Hopkins University, Baltimore, MD, USA

Introduction

Although the human binocular field of view (FoV) is nearly 180◦, the degree of visual information reduces from the center of vision to the extreme ends on both sides.

Main Purpose: Increase spatial awareness of user

- **Faster identification of objects:** Reduce the time to identify objects in given surroundings
- **Visualization UIs for objects:** Easily locate the objects of interest, both in and out-of-view.

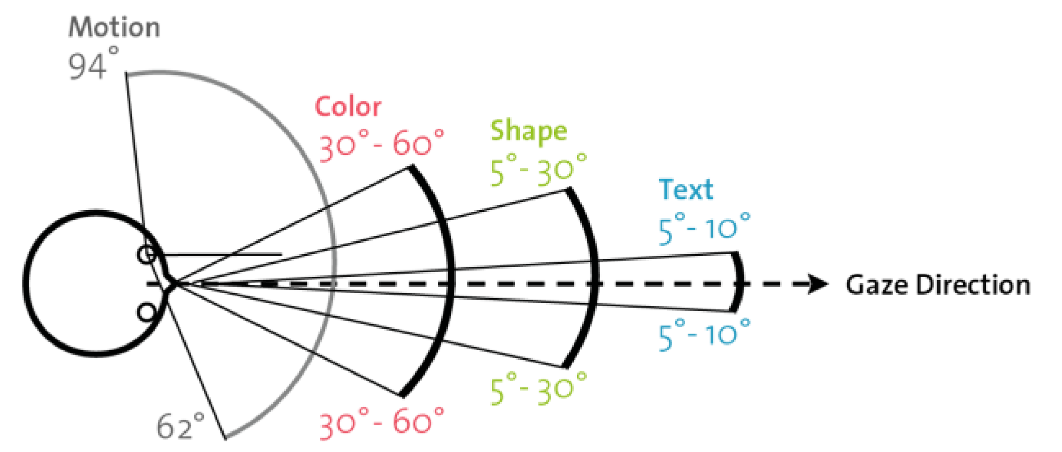


Image: https://commons.wikimedia.org/wiki/File:Visual_Perception_Human_FOV.png

Methods

Marker Detection

- Perform camera calibration for each camera to acquire correct 3D pose of ArUco Marker.
- Obtain frame transformations for each camera that with respect to L-F camera.

Interaction

- Create interactable virtual object (button) for each marker.
- Require users to click the object to check if they identified the correct marker.

Visualization Methods

- 3D Radar: A sonar that ranges 45 degrees in the horizontal direction on both sides of the user's center.
- 3D Arrows: Utilize Unity's LookAt function to point the tip of the arrow in the direction of an activated marker.
- EyeSee360: The rectangle represents the user's FoV and the out-of-view 3D space is shown between the rectangle and ellipse.

Experimental Setup

Hardware

- HoloLens 2: The subjects will be using a HoloLens 2 headset to test the visualization methods.
- Bluetooth Clicker: Allows the user to interact with the virtual objects (buttons).

Software

- HoloLens2 Research Mode API (C++): Access all gray-scale environmental cameras, expanding user's FoV.
- OpenCV (C++): Implement ArUco Marker detect functionality into Unity C# project.
- Unity 3D (C#): Develop virtual reality environment for all visualization methods

Experiment

- Randomly place 10 ArUco markers alongside two walls.
- Only one marker is activated at a time on visualization method, required the subject to find the correct marker.
- The subject will test each visualization method for identifying and interacting with markers.
- Accuracy and time of completion was recorded for each trial.

HoloLens 2

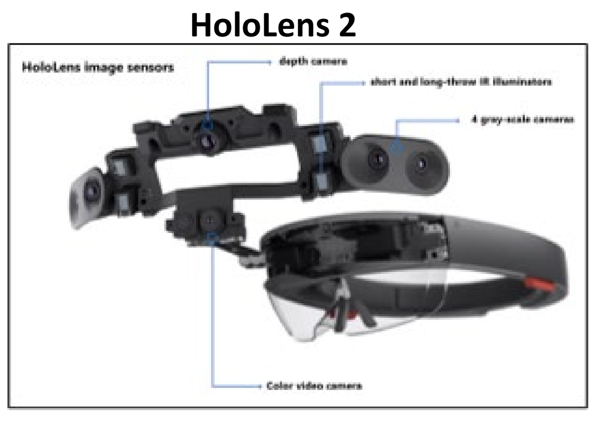


Image: https://www.microsoft.com/en-us/research/blog/microsoft-hololens-facilitates-computer-vision-research-by-providing-access-to-raw-image-sensor-streams-with-research-mode/

Bluetooth Clicker

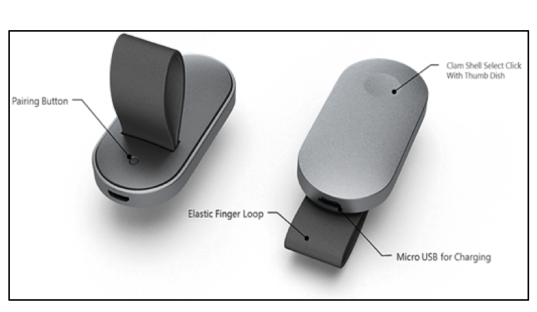


Image: https://www.geekwire.com/2016/hololens-interface-leaked-in-app-walkthrough-video/

OpenCV

Image: https://en.wikipedia.org/wiki/OpenCV

ArUco Marker

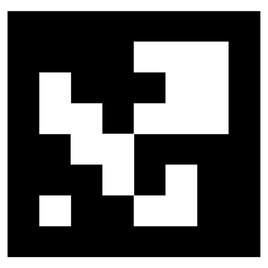
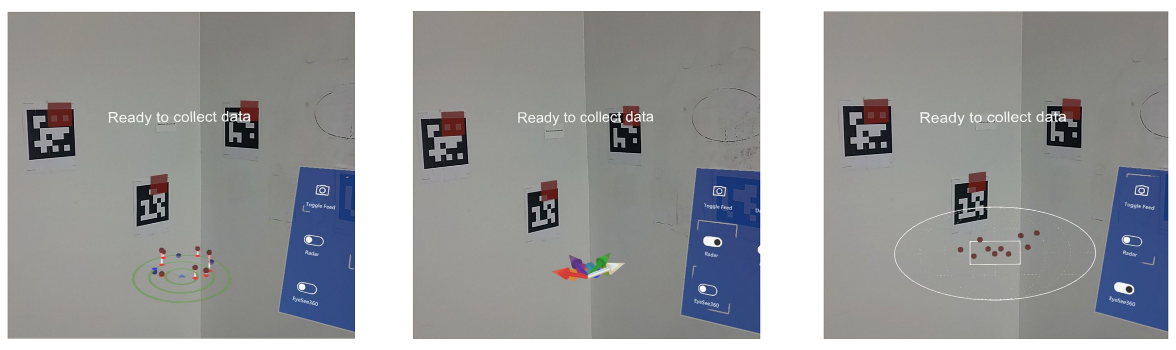


Image: https://chev.me/arucogen/

Unity 3D

Image: https://www.pngegg.com/en/png-einvk/download

3D Radar **3D Arrows** **EyeSee 360**

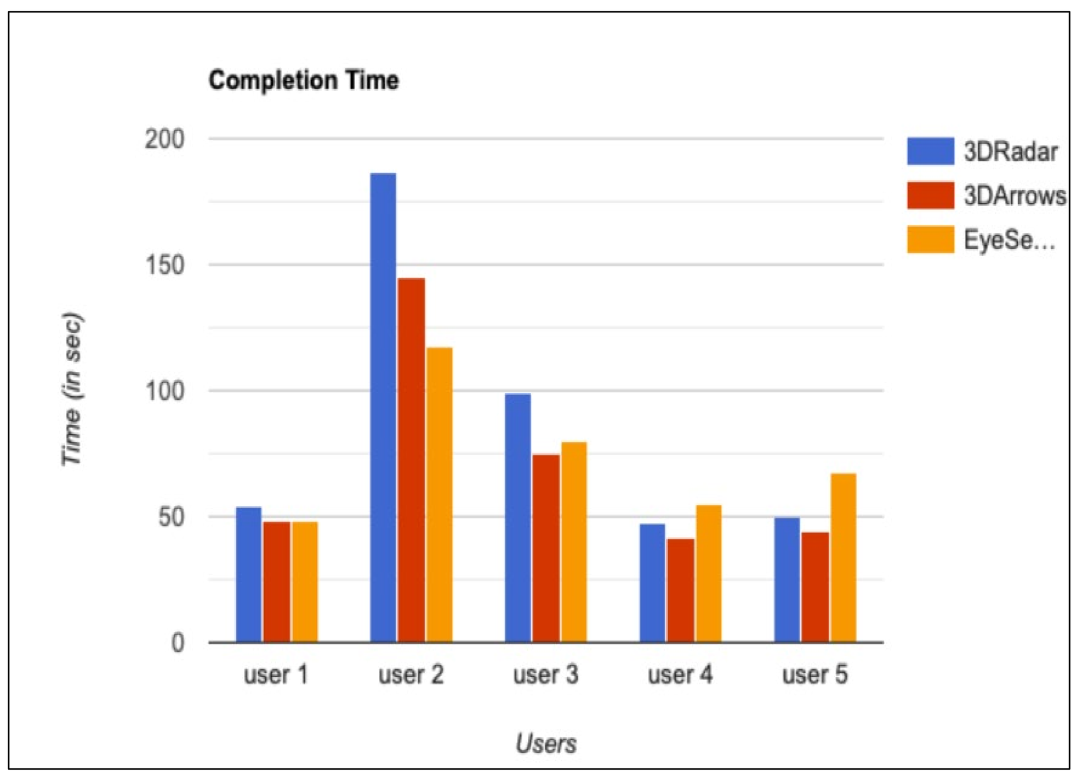


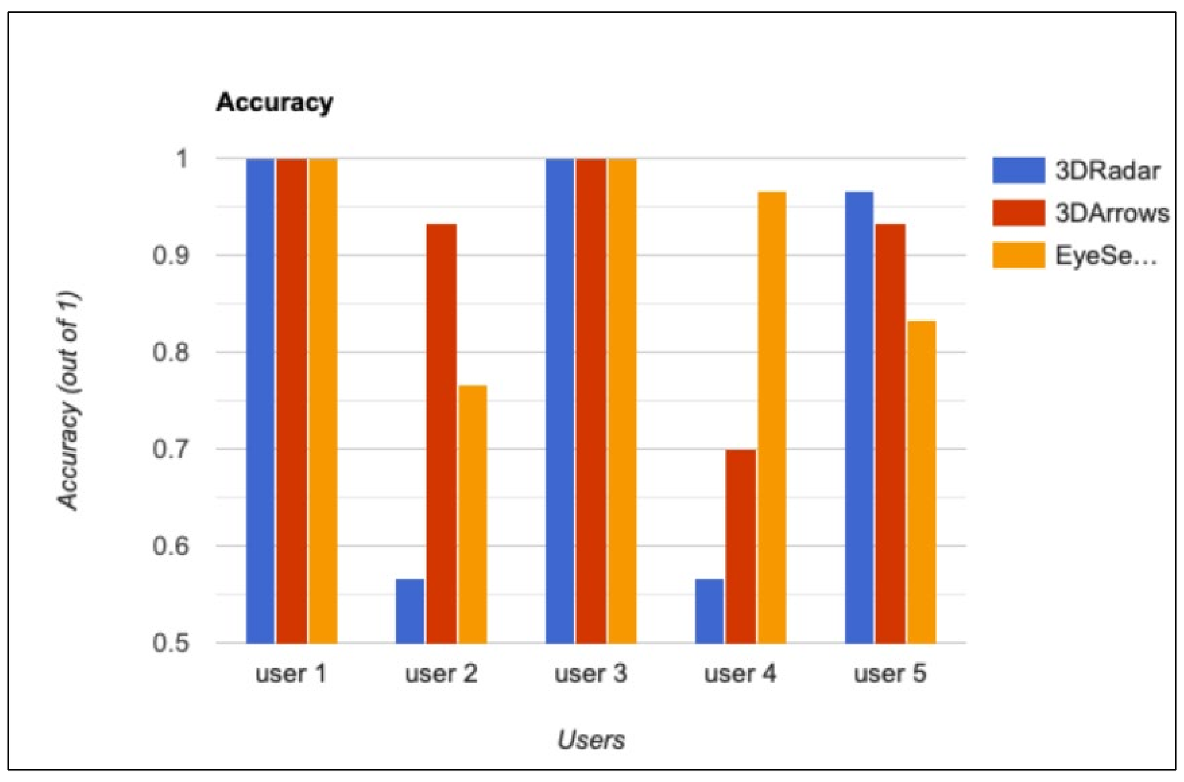
Three Visualization Methods

Results

- **Preliminary Data Collection Results:**
  - Highest Average Completion Time: **3D Radar**
  - Lowest Average Completion Time: **3D Arrows**
  - Highest Average Accuracy: **3D Arrows** & **EyeSee 360**
  - Lowest Average Accuracy: **3D Radar**
  - Most Preferred Visualization: **3D Radar**
  - Least Preferred Visualization: **3D Arrows**

	3DRadar	3DArrows	EyeSee360
Average Completion Time (in sec)	87.55	70.78	73.68
Average Accuracy (out of 1)	0.82	0.91	0.91





Conclusions

From the preliminary results, we conclude that:

- 3D Radar was most preferred due to:
  - Visualizations for height
  - Seemed more user friendly/intuitive to users
- 3D Arrows was least preferred due to:
  - Confusion between different colored arrows
  - No relation of color to object distance
- 3D Arrows took the least time due to:
  - Direct pointing to the object
- 3D Radar took the most time due to:
  - Locating the marker in Azimuth
  - Then, locating the marker in Altitude
- Interesting to note that 3D Radar took the most time but was still preferred.

Acknowledgement

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References:

F. Bork, C. Schnelzer, U. Eck and N. Navab, "Towards Efficient Visual Guidance in Limited Field-of-View Head-Mounted Displays," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 24, no. 11, pp. 2983-2992, Nov. 2018, doi: 10.1109/TVCG.2018.2868584.