Super Resolution Display for Virtual Reality

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1. Motivation

The focus on resolution of virtual reality headsets has been the forefront of this technology for the last number of years. Today headsets can reach around 2K by 2K pixels per eye. At a typical distance of around 2-3 inches, this is still well above the visual threshold of pixel detection at around 15 pixels/degree. This resolution limitation causes major pixel artifacts to be visible when utilizing virtual reality technology. It has become a road block in the advancement and adoption of virtual reality.

Even more, building arrays of tighter packed and smaller pixels is a very difficult task and it will likely be many years before a significantly improved system natively below visual threshold becomes available. In the mean time, the industry is in need of an interim solution to get perceived high enough resolution while still being limited to the lower resolution displays.

2. Project Overview

For this project, I plan to take advantage of the flicker fusion threshold of human vision to create an apparent higher resolution image on a lower resolution display. In class, we have explored the concept of sub-pixel capture from camera shake which can be taken advantage of to render super-resolution imagery. In this project I will build a display prototype and image processing pipeline that will systematically judder the display at sub-pixel resolution in a similar manner.

The display will show imagery at a high frame rate (120 frames per second) where each 4 frames represent a different sub-pixel. As the motor shifts the display up and left, the top pixel of an assumed 2X upsample will be shown. This will be followed by the bottom left, in a circle. The frame rate will be high enough that our eyes will not notice the shake, but will perceive higher resolution from the blending of frames over time.

It will be assumed that we have the higher resolution image available and it is solely the display that is the limitation. This will be especially beneficial for industries such as virtual reality where resolution limitations are holding back quality of experience. As we've learned from days of interlaced television, it will be extremely important to keep the video rate high so that observers don't see striping and so that small objects don't flicker in and out of our visual field.

3. Related Work

Some work in the realm of microdisplays such as in [4] shows promise. However this has the disadvantage of being both costly and potentially inefficient. Over time mircodisplays may afford high enough resolution to be visually lossless, however this may be yet a long time away.

In the interim, a less expensive alternative is needed to both utilize the benefits of higher resolution capture, and to improve the quality of experience for extreme close display viewing such as occurs in virtual reality.

Optical approaches have been taken to solve the issue such as in [1]. This approach uses an optical system (no gaze tracking required) to increase the perceived resolution at the display. This approach also has the advantage of a larger field of view. It has the disadvantage of multiple moving and heavily elements that require extremely precise calibration.

Two final methods of super resolution that will be covered in this preliminary background involves an optical method of multiplexing imagery from [2] and [3]. Both of these methods utilize different optical methods. Similar to the proposal in this paper, it time multiplexes the data assuming the visual system will blend the results together. The main difference is the complexity at which this reference is being implemented and the efficiency at which is can be incorporated.

4. End Goal / Deliverable

At the end of this project I plan to prove that this super resolution display is visually equivalent to truly showing an image at higher resolution. This will be accomplished through a user study. The user study will ask observers to select the image of higher resolution (super resolution display versus native high resolution display).

The point at which observers cannot tell the difference between the two displays will be the point of a visually lossless experience. I plan to show a demonstration of the project during the poster presentation session.

5. Timeline

The project deliverables will be split into a few smaller short term pieces. These are made up of the following tasks:

1. Design the optimal shake for visually lossless experience (where pixels are below visual threshold)
2. Create structure to split high resolution image into subpixel imagery
3. Run simulations on a high resolution display
4. Implement with motor on a low resolution display
5. Run user study to subjectively compare results

The timeline will be split by weeks. Items 1 and 2 shall be done within the first week. Then item 3 and 4 the second week. The final week will be on tweaking the algorithm and running the small user study to compare results.

References

[1] G. et al. Super-resolution optics for virtual reality. *SPIE*, 10355, 2017.

[2] M. et al. Time multiplexing for increased fov and resolution in virtual reality. *Digital Optical Technologies*, 1033504, 2017.

[3] Z. et al. Improving near-eye display resolution by polarization multiplexing. *Optics Express*, 27(11), 2019.

[4] G. Haas. Microdisplays for augmented and virtual reality. *SID*, 49(1):506–509, 2018.