C4: HoloPyramid Design

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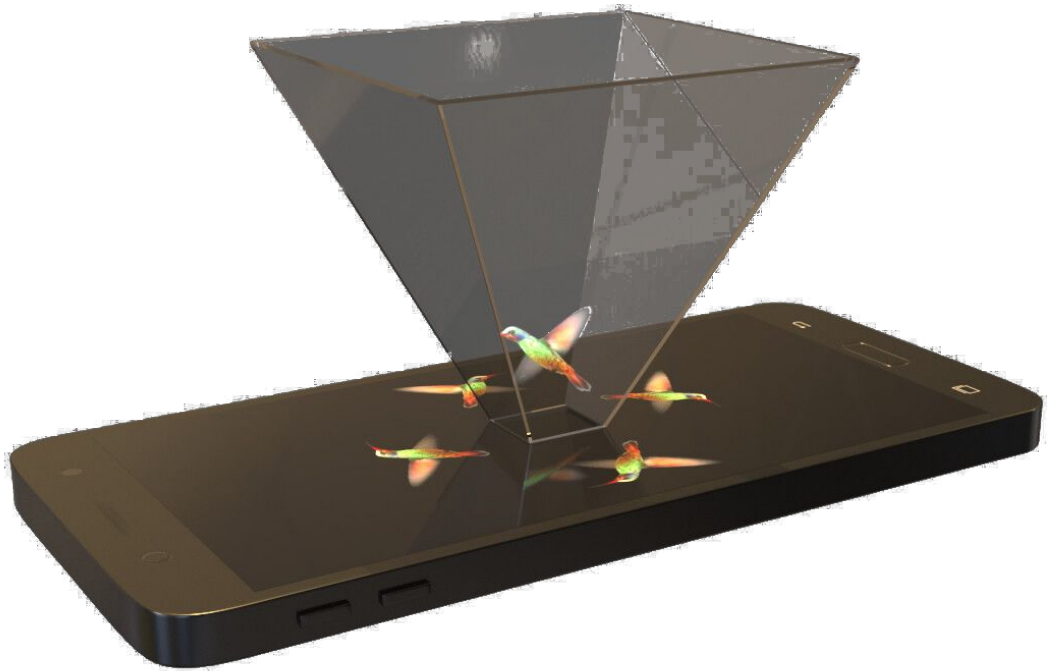
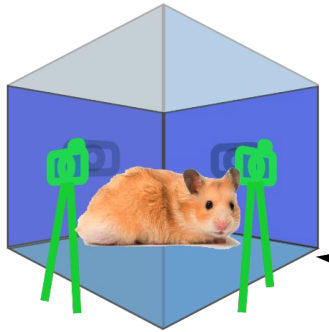


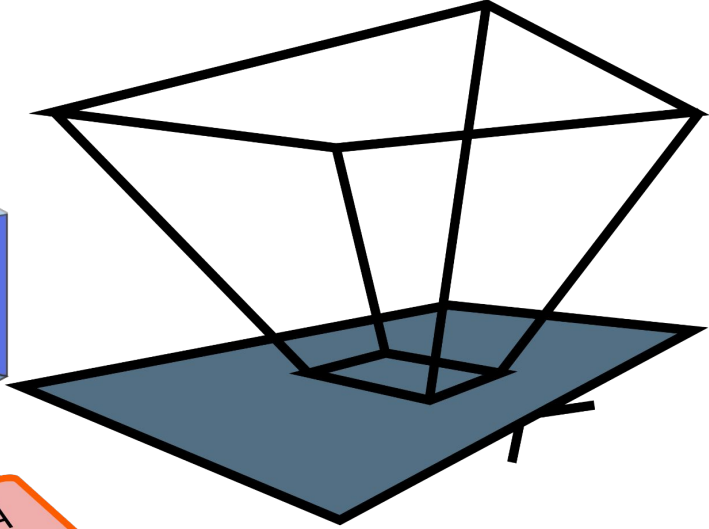
“How can we create an interactive presentation tool to showcase small objects to a larger audience?”

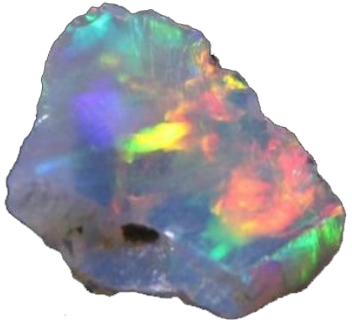
Hardware Systems, Signals and Systems

Application Area and Solution Approach

- Holographic pyramid display
  - Captures and displays objects live from a small studio
  - Enlarge and show objects that move without pre-recording a video or render
- Use Cases
  - Small Animals
  - Artifacts and archeological finds
  - Moving toys and engineering parts
  - Anything small (~3”) of interest (preferably moving)

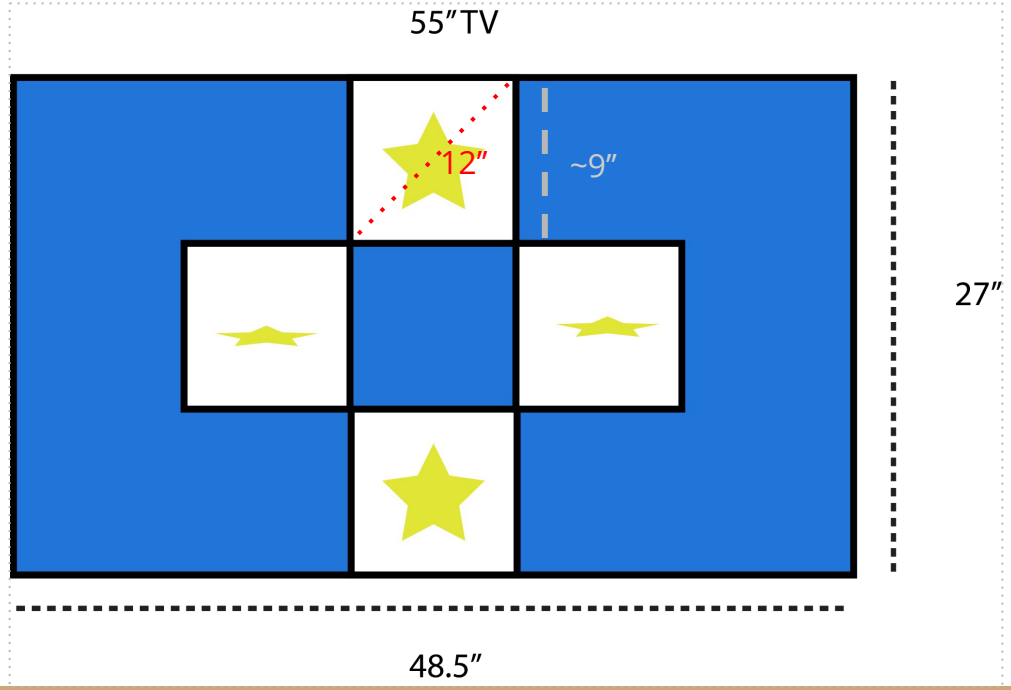




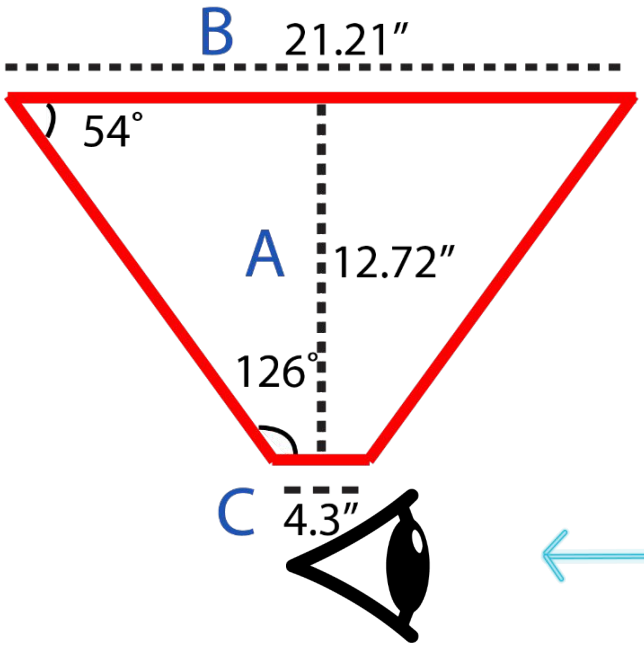


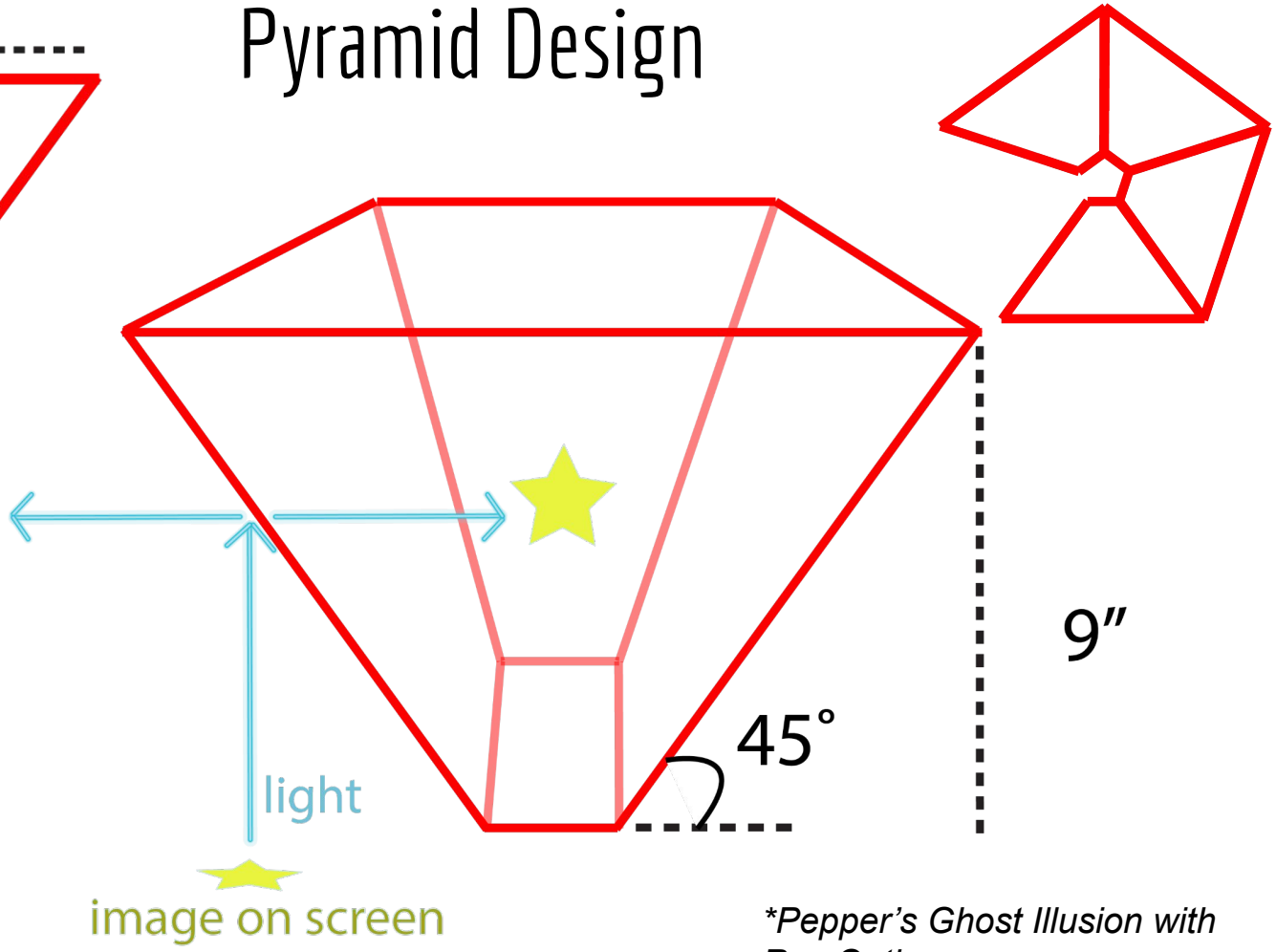
VGA Monitor

- Provides 4-5x enlargement
- 55 inch diagonal; 48.5” long; 27” vertical
- Can operate at 720p 60Hz to match our FPGA’s output



Pyramid Design





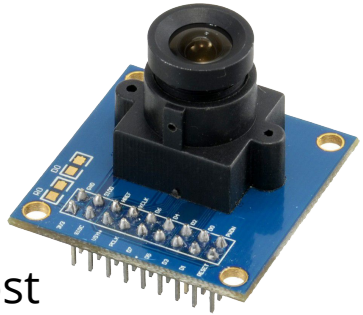
Plexiglass:

- Thin (no internal reflection)
- Easy to construct
- Lightweight

**Pepper's Ghost Illusion with Ray Optics*

Hardware

- OV7670 camera
  - Better than alternatives: OV7725 and OV5642
  - More common; better reference materials, cost
- Altera DE2-115 board

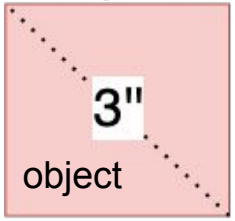


OV7670 ($8)

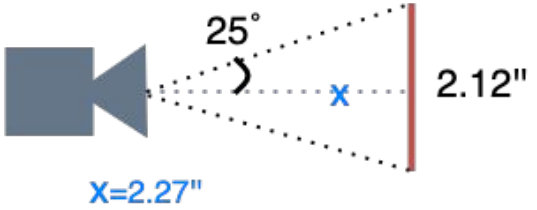
OV5642 ($40)

	Solution requirements	**DE2-115**
Embedded RAM	As much as possible	3,888 KBits
SRAM/SDRAM	Camera Min: 0.3456 MB Camera Max: 2.4576 MB Display frame: 2.7648 MB **Total Max: 5.2224 MB**	2MB SRAM 128 MB (4x32MB) SDRAM
Number of logic elements	As many as possible	114,480
Number of GPIO pins	~18 * 4 = ~72	~40 + 80 (on daughter card)

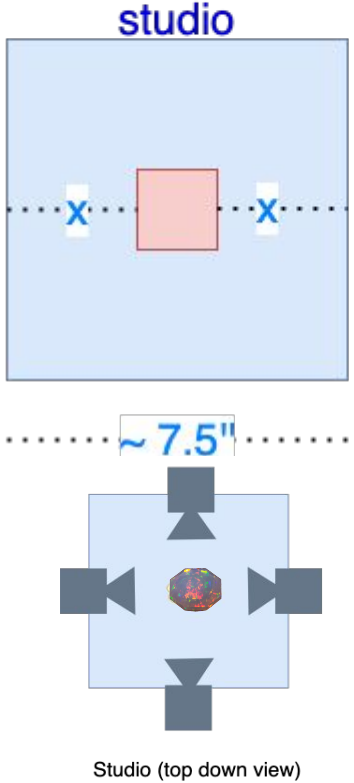
Live Studio:



=3"/sqrt(2)
=2.12"



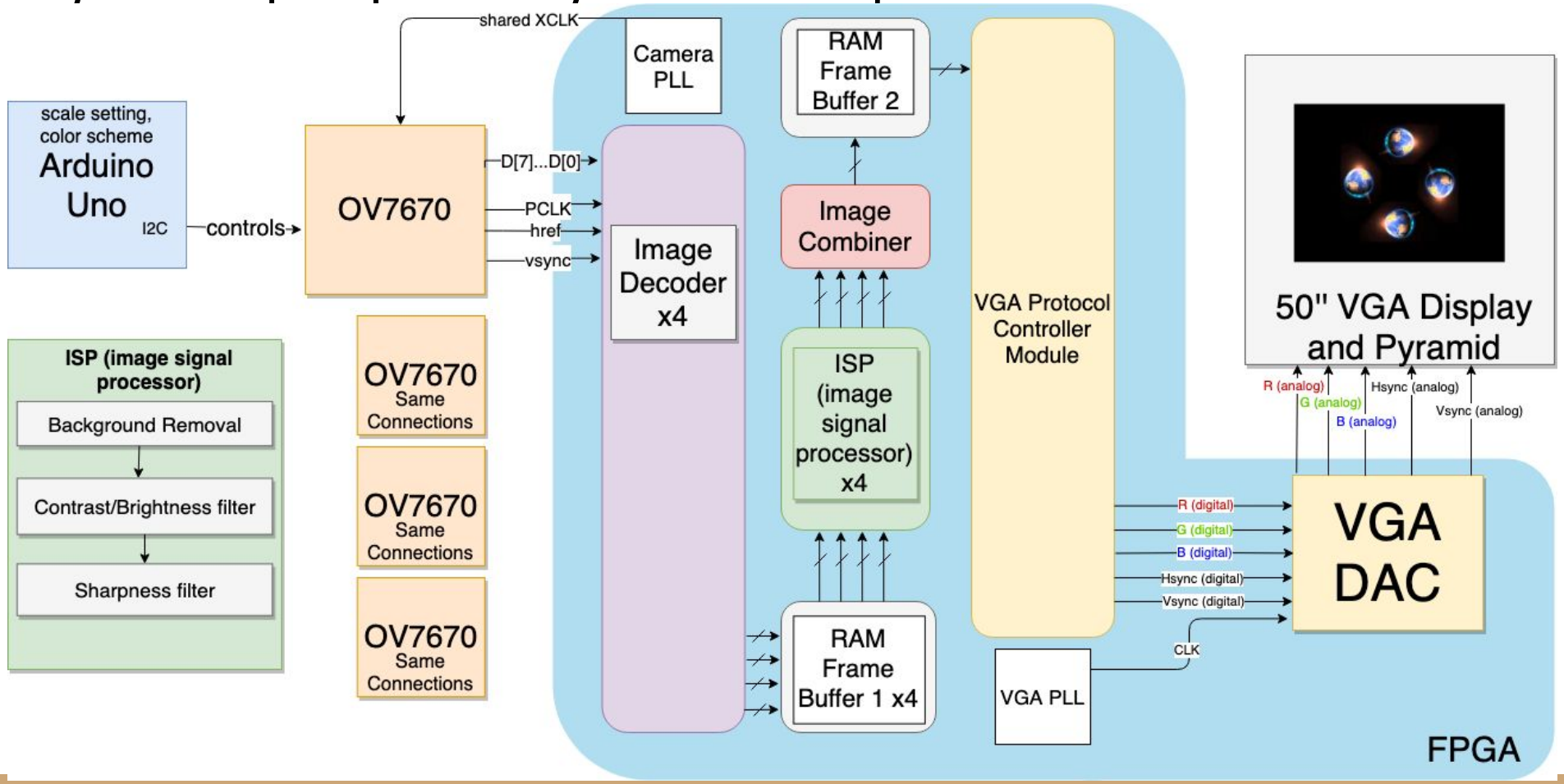
x=2.27"



Studio (top down view)

- Dimensions: 8” x 8” cardboard box
- Lighting: LED evenly spaced around corners
- Cameras: Four OV7670 cameras evenly spaced around live studio
- Blue backdrop
  - Less color spill than a green backdrop (better preservation of details)
  - Can be well-lit and then easily removed by a chroma-key filter
- Additional: Blue tweezers

System Specification / Block Diagram:



FPGA

- Image decoder
  - Handles vsync, hsync, pixel data pins
- Image combiner
  - Rotate images and arrange them
  - Framebuffer to match the output resolution
- VGA protocol controller
  - PLL generate a different pixel clock (50MHz default -> 720p 60Hz, pixel clock ~75MHz)
  - Output RGB values on VGA pins, from the 2nd framebuffer

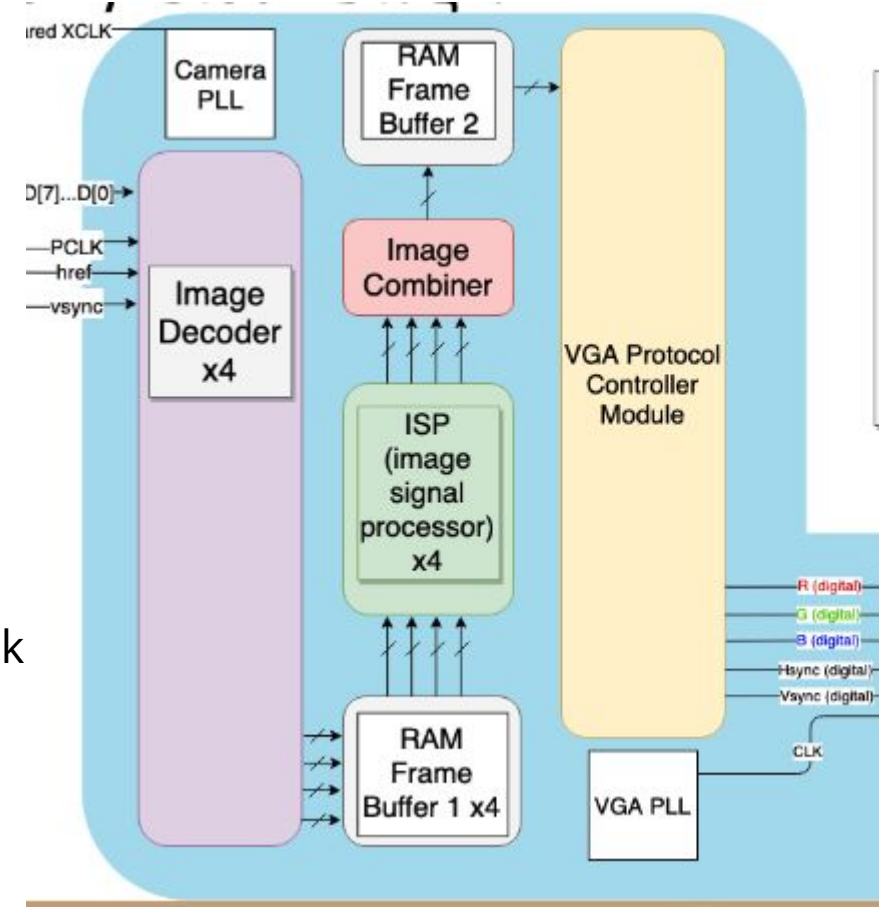


Image Signal Processor (ISP)

- Chroma-key:
  - if(distance(pixel, target) < threshold) pixel = 0
- Brightness/contrast: $f(x) = \alpha(x-128)+128+b$
  - α = contrast factor
  - b = brightness
- Sharpening filter: unsharp masking--apply 3x3 mask

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Risk Mitigation Plan

- MVP: cameras through FPGA to screen and pyramid
  - FPGA Interfacing with cameras
  - FPGA frame buffer
  - FPGA->VGA output
- Reduce video frame quality
  - 565 -> 444 color
  - 480x640 -> 240x240 camera input
  - 60 Hz -> 30 Hz
  - 1280 x 720 -> 640 x 480 VGA output
- Reduce pyramid size (Construction requirements)
- Remove image filters (FPGA LE requirements)

Metrics and Validation

Requirement	Test	Threshold value
Enlargement	Physically measure object and hologram using ruler	>=4 times
Real-time latency	Flash a light in the studio and measure the delay to the projection using a high speed camera	<250 ms
FPGA cycles	Cycle count in synthesis	<17 ms (1 frame at 60 fps)
Image sharpness	MTF test - capture increasingly thin lines	Same MTF score as 720p high-end camera
Background removal	Capture card and PhotoShop to measure background removal	>95% background removed <5% object removed
Lack of distortion	Project parallel lines on the pyramid and measure perspective distortion	<5% change in angle (as measured by Lightroom)

Project Management

- Slack Time
- Breyden Wood
- Jullia Tran
- Grace An
- Everyone