Stay Square:

Realtime Frustum Normalization for Projectors

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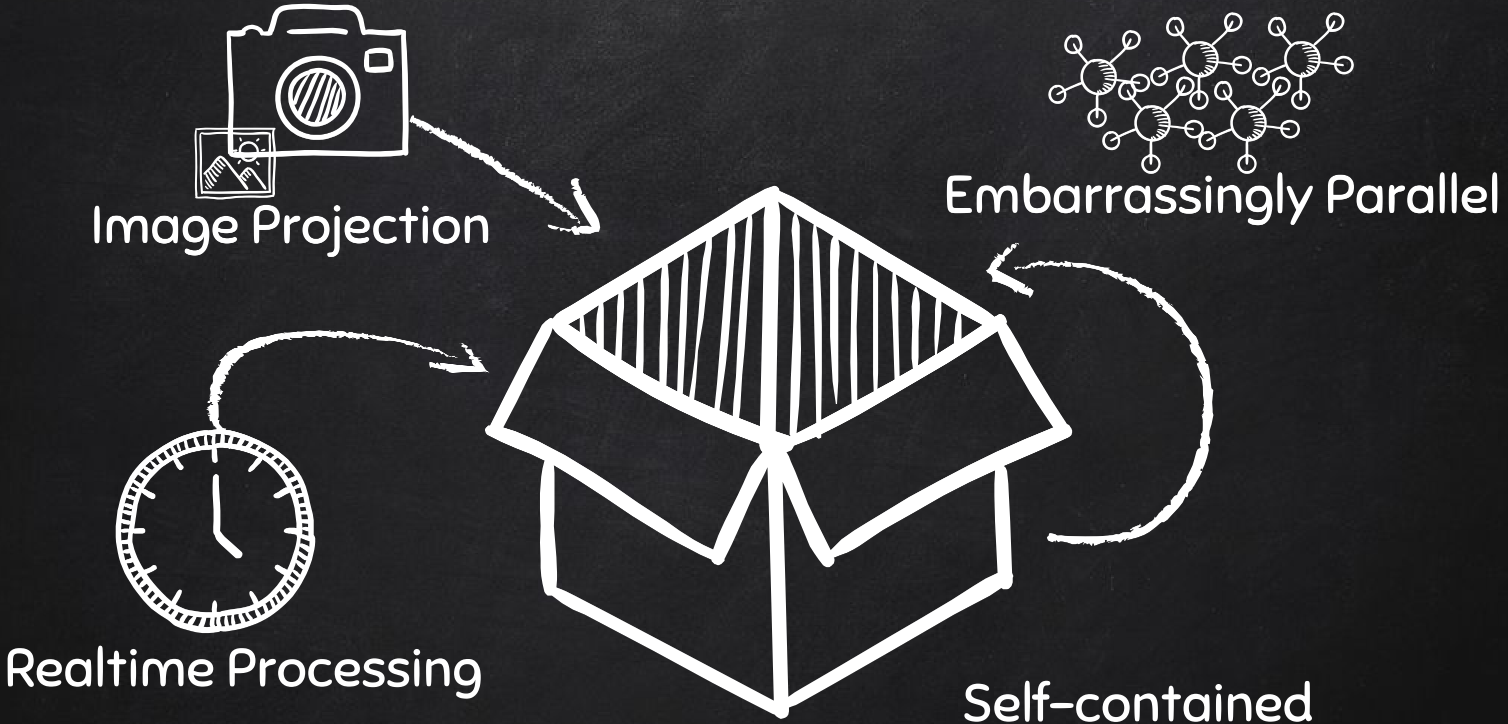
Project Objective

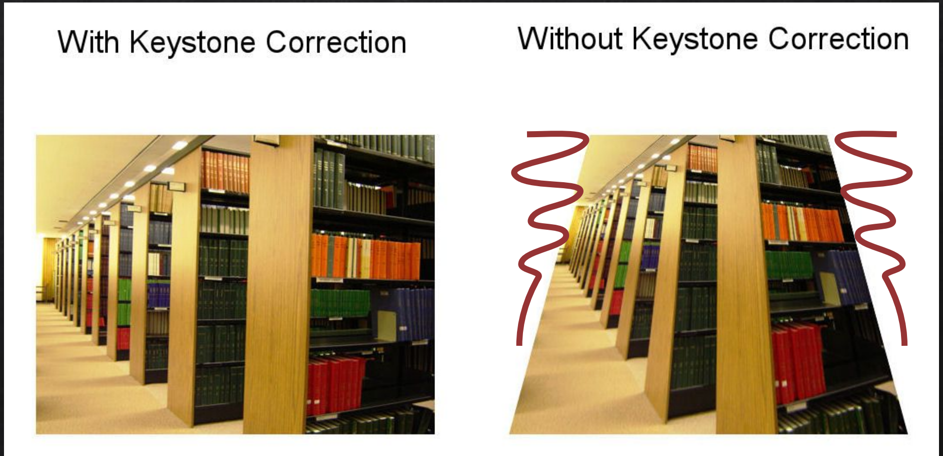
Projector Keystone Correction



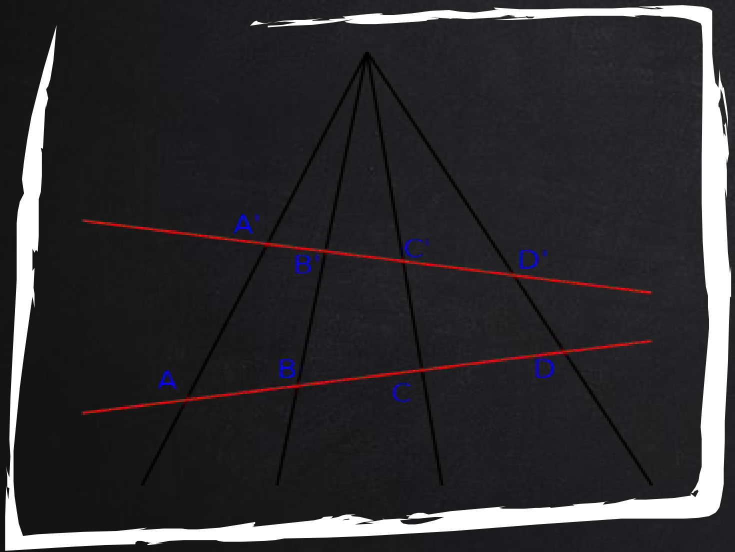
Project Scope

Projector Keystone Effect

- Common issue with consumer-grade projectors
  - Software correction (expensive)
  - Manual adjustment (limited)



Keystone Correction In Action



- In Computer Vision, notion of *Homography*
    - *"Relationship between images projected onto two skew planes"*
- Rotation, warping, translation
- Independent of scene structure
- (Much, much more...)

Keystone Correction Overview

$$(x,\ y) = \left(\frac{H_1\,X + H_2\,Y + H_3}{H_7\,X + H_8\,Y + H_9},\ \frac{H_4\,X + H_5\,Y + H_6}{H_7\,X + H_8\,Y + H_9} \right)$$

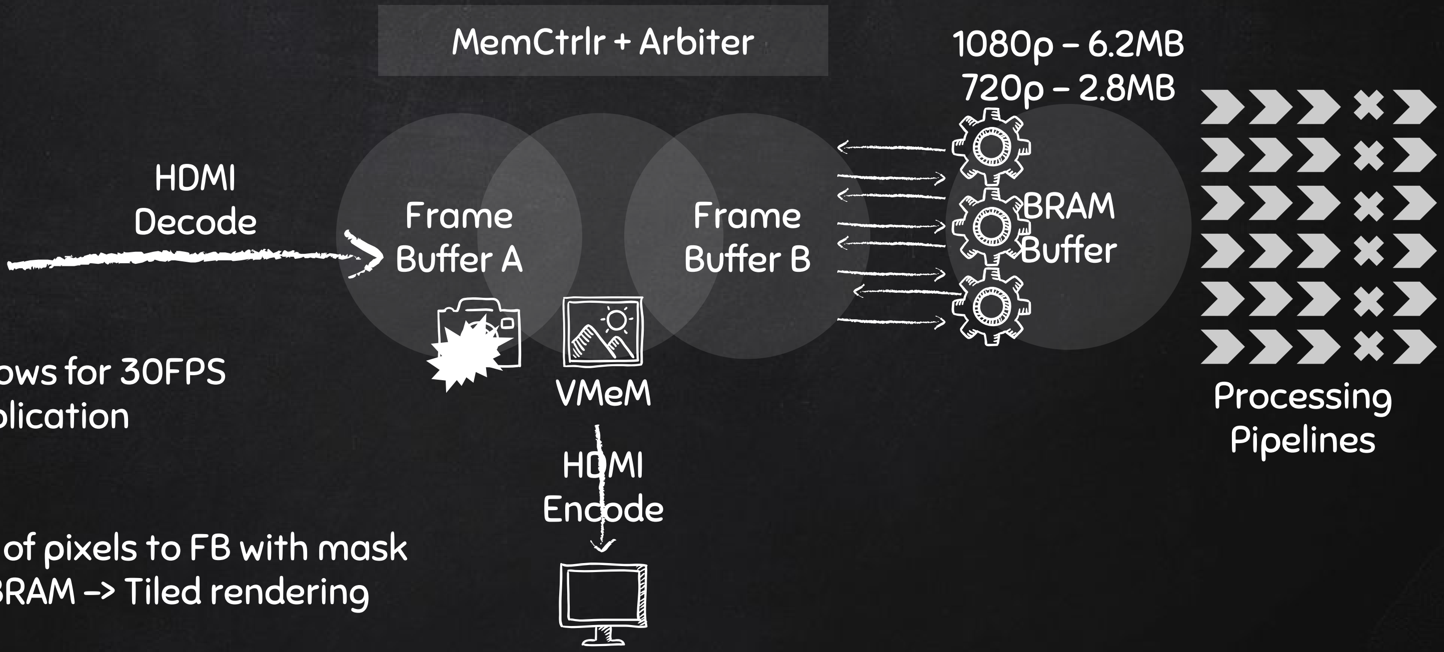
$$\begin{pmatrix} \tilde{x} \\ \tilde{y} \\ \tilde{z} \end{pmatrix} = \begin{pmatrix} H_1 & H_2 & H_3 \\ H_4 & H_5 & H_6 \\ H_7 & H_8 & 1 \end{pmatrix} \begin{pmatrix} X_{sc} \\ Y_{sc} \\ 1 \end{pmatrix}$$

- ✘ Fundamentally, matrix ops.
- ✘ Simplifications
  - ○ Flat screen at fixed distance
  - ○ 8 d.o.f. –> Preprocess weights
  - ○ Pixel vs. Region
  - ○ Compute inverse mapping
- ✘ Transformation pipeline
  - ○ Preprocess, Warp, Rotate

Minimum Viable Product

- ✘ Pass-through device that connects laptop to a projector
- ✘ Projector has near-perfect (possibly jagged) keystone correction
  - Keystoning due to pitch in a ~30 degree range at fixed distance
- ✘ Severity of tilt input to FPGA via a sensor
  - Continually updated
- ✘ Prioritize throughput over latency (e.g. PowerPoint vs. Movie)

Processing: High Level Overview



Triple Buffering allows for 30FPS
output w/ field duplication

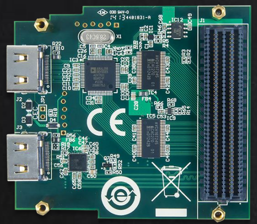
Pipelines

Map regions of pixels to FB with mask

Insufficient BRAM –> Tiled rendering

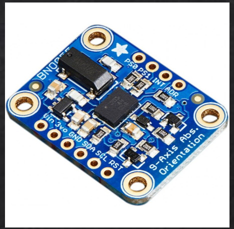
Implementation: Parts

FMC-HDMI Decoder



Consumer-grade Projector

9 D.O.F. IMU



Projector Screen / Testbed

Mechanical testbed might be useful for testing and demoing

FPGA (Virtex 7 / Ultrascale ?)

- ✘ Large embedded memory
- ✘ MACs
- ✘ Lots of logic resources
- ✘ HDMI encoder
- ✘ Peripheral interface
- ✘ High FMAX
  - 1080p PCLK ~ 74.25 MHz
- ✘ Large, fast external memory

App. scales directly with resources and memory BW

Timeline (– Mid Semester)

Week	Due Date	Goal, Feature, Progress
0	9/22	Present project proposal on Thursday and turn in project proposal paper on Friday.
1	9/29	Preliminary parts list submitted; substantial progress on keystone correction using Python library on a hard coded test image, without FPGA; Sensors have been explored.
2	10/6	FPGA can be used to output a static test image via on-board HDMI; Means for interfacing with sensors has been determined and tested.
3	10/13	Substantial progress has been made on FPGA datapath.
4	10/20	FPGA can be used to apply keystone correction to a static test image and output the result via on-board HDMI, given a distance from wall and degree of offset.
5	10/27	FPGA can function as a video pass-through device. Sensor interfacing works perfectly and can be used to input meaningful, well-structured data to the FPGA.

Timeline (– Final)

Week	Due Date	Goal, Feature, Progress
6	11/3	FPGA can receive video input of a test image, apply keystone correction given a manually input distance from wall and degree of offset, and output the result via on-board HDMI.
7	11/10	Substantial progress has been made towards integrating sensor input, video input, and FPGA image correction datapath. FPGA datapath has been polished and improved.
8	11/17	FPGA receives input from sensors, uses the degree of offset of the projector to apply keystone correction to an input test image, and outputs the result via on-board HDMI.
9	11/24	MVP implemented.
10	12/1	Distance sensor, yaw support, and pitch support are added. Datapath is optimized to allow for decent throughput for video projection. (Early reach goals)
11	12/8	Means for demoing device are finished. Device is demo-friendly. Any casing, housing, or dress for the device has been polished, finished, and integrated.

Task Distribution

Adam Pinson	Anthony Kuntz	Daniel Stiffler
Sensors, HDMI decoding, Interfacing	Datapath, Visual output	Frame buffers, Arbitration, Allocation, Memory

Questions?