Projector Keystone Correction using FPGA

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Background

- Portable projectors are everywhere today!

- What's the catch?

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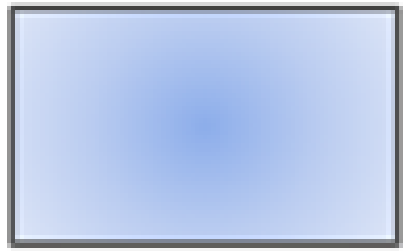
- What's the catch?
- They are often tricky to setup due to the keystone effect

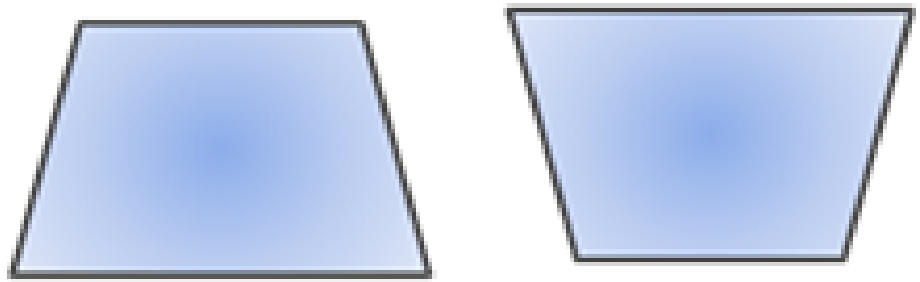
Keystone Effect

KEYSTONE EFFECTS



Correct image

Keystone effect occurs when the projection is inclined



Vertical Keystone

Previous Work

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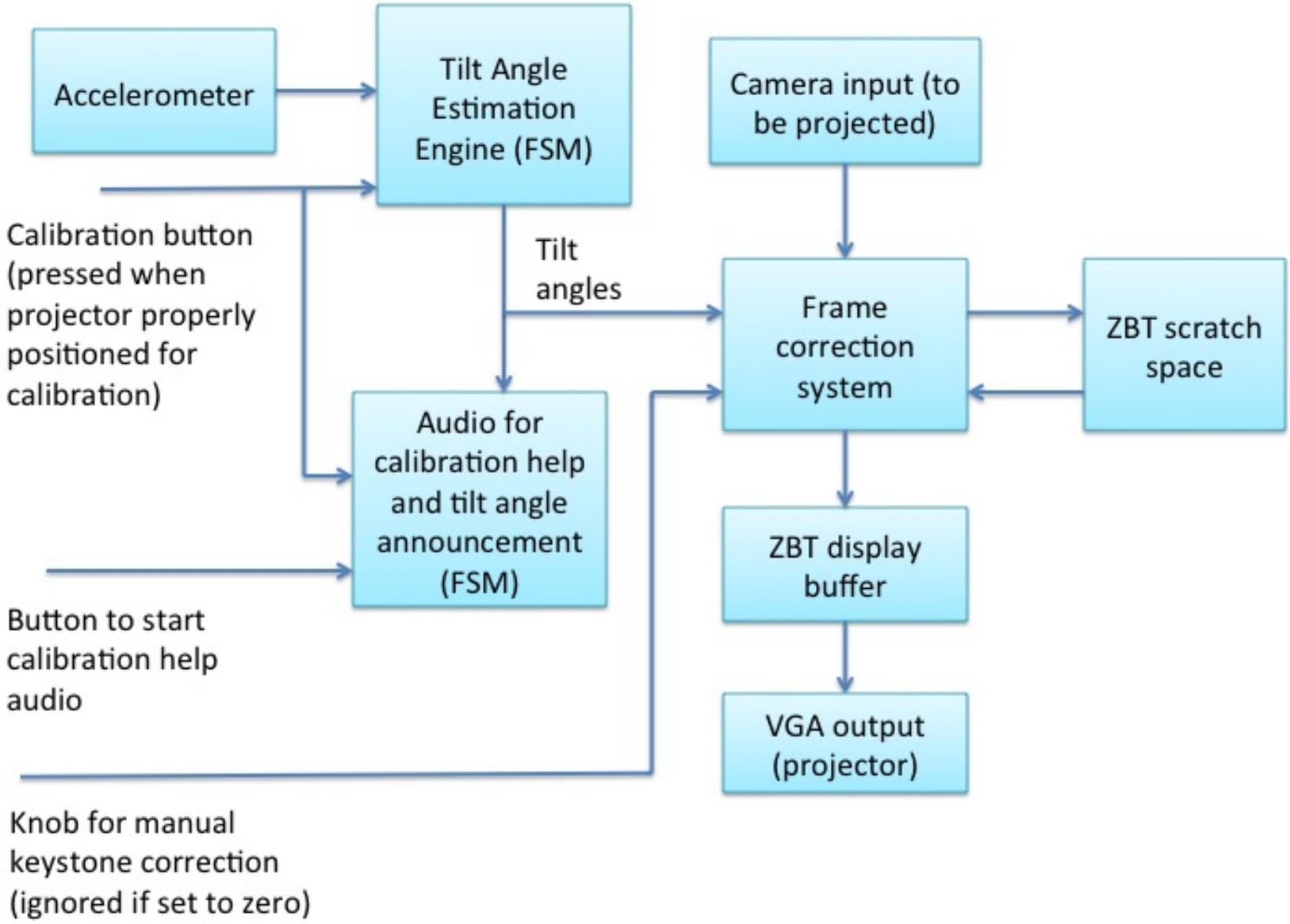
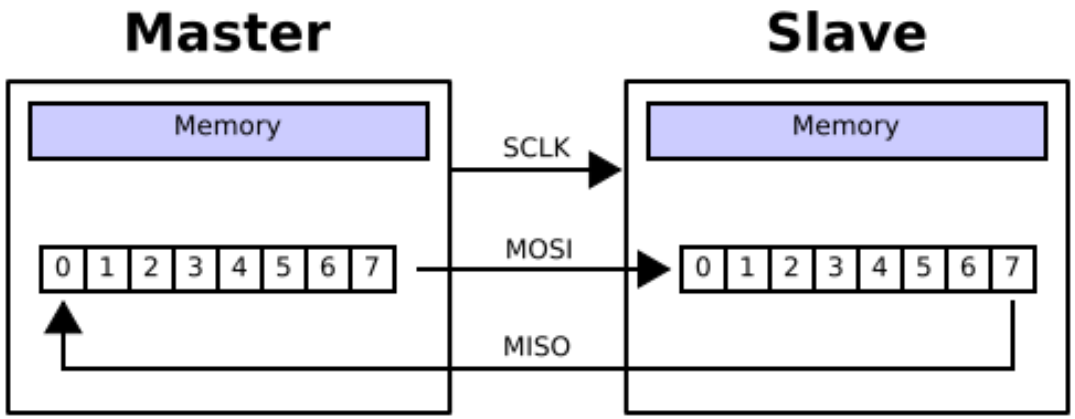
- Both of these use complex software algorithms
- Our contribution is creating a simple, FPGA prototype

Block Diagram

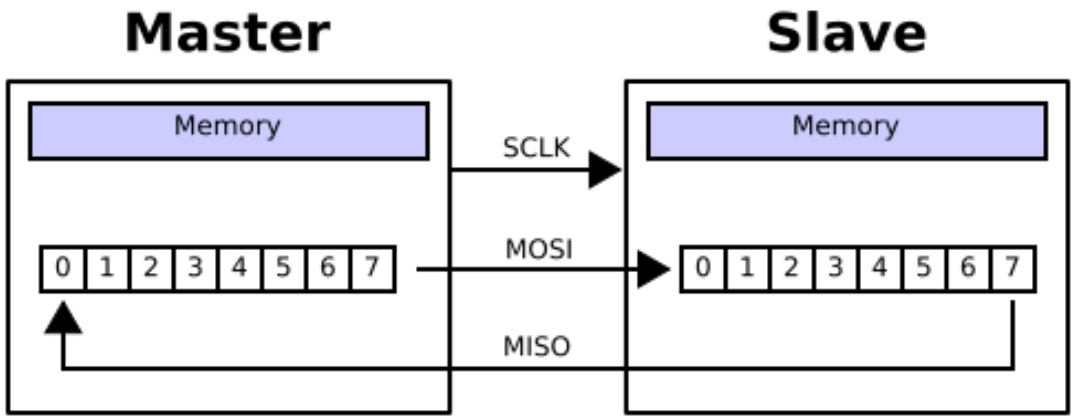


Accelerometer



- SPI digital interface – FPGA is master, accelerometer slave
- Accelerometer has different registers for x, y, z acceleration, signal which register to read
- Configurable SPI clock, but will still need to cross clock domains

Accelerometer



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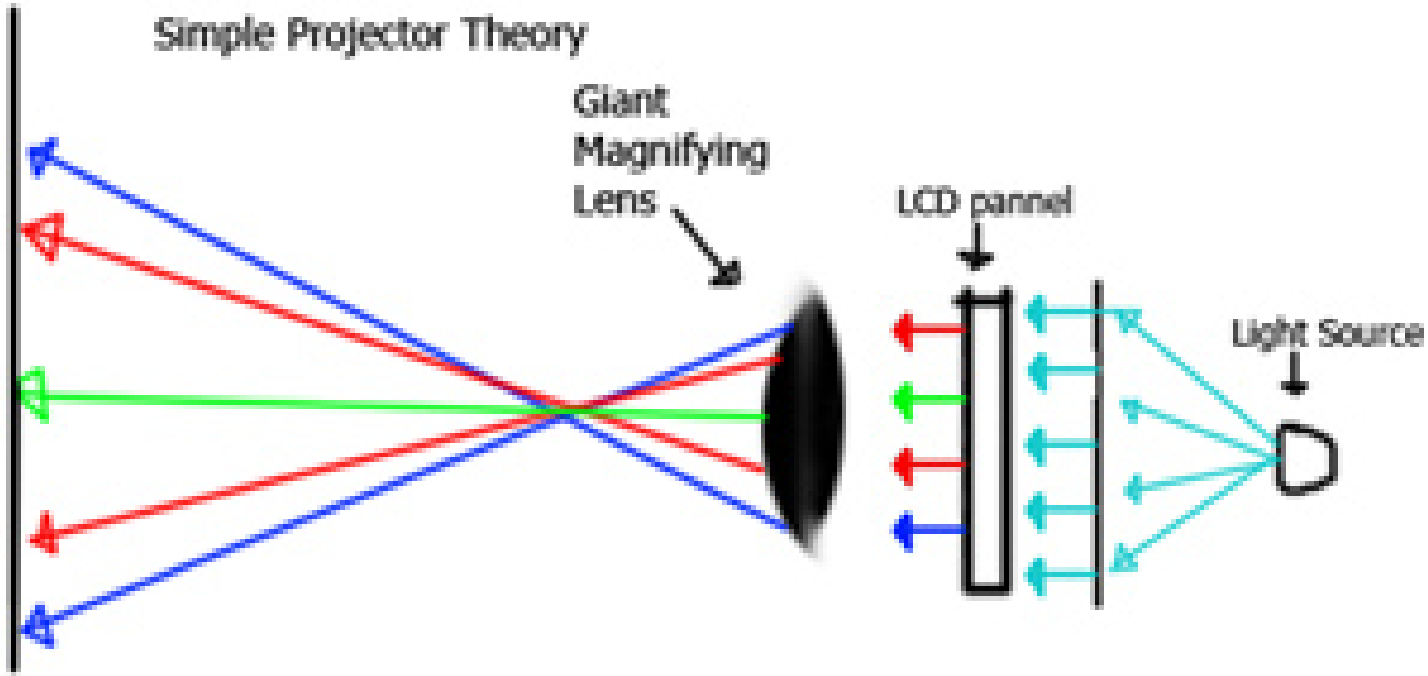
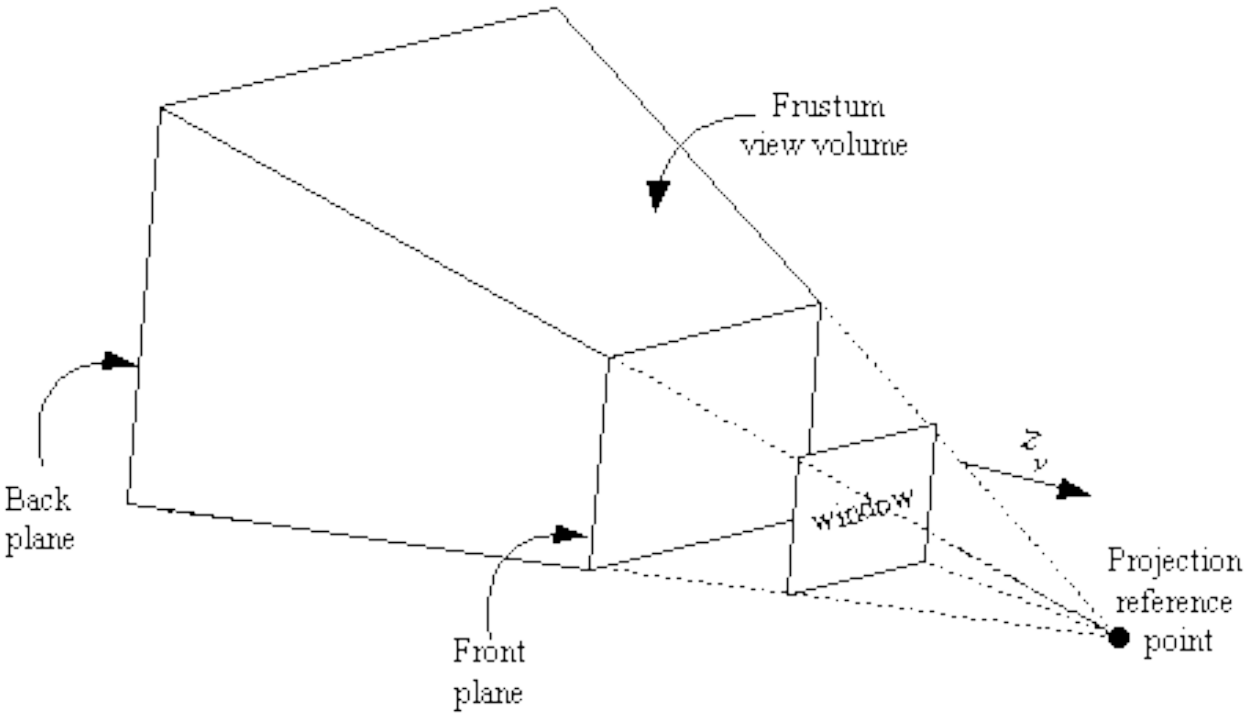
- Configurable SPI clock, but will still need to cross clock domains
- Accelerometer is noisy – some sort of low pass filter needed
- Accelerometer nonlinearities – lookup table needed?

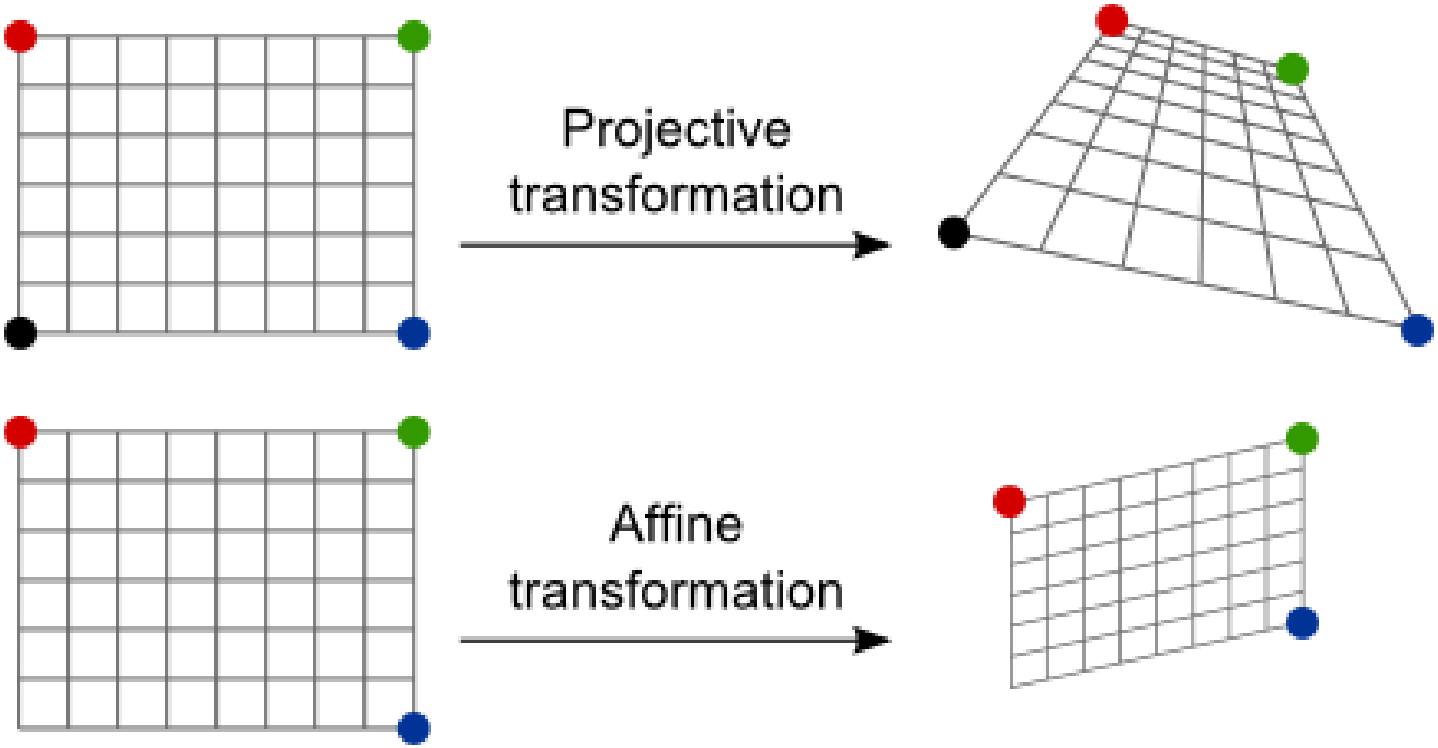
The Physics of a Projector



A Mathematical Model



Projective Transformation



The Projection Equation

- Let (x, y) denote the source image coordinates
- Let (X, Y) denote the coordinates on the screen
- $(X, Y) = \left(\frac{p_1 x + p_2 y + 1}{p_3 x + p_4 y + 1}, \frac{p_5 x + p_6 y + 1}{p_7 x + p_8 y + 1} \right)$
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- Coefficients depend on the tilt of the projector through trigonometry
- By projecting a known image, we have 8 equations in 8 unknowns
- Will require implementing a full-fledged Gaussian elimination routine on the FPGA
- Too hard, will be final (unlikely) stretch goal
- How can we simplify?

The Simplification

- Focus on the 2 axes of interest, and compute inverse mapping
- Vertical direction is relatively easy
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- Focus on the 2 axes of interest, and compute inverse mapping
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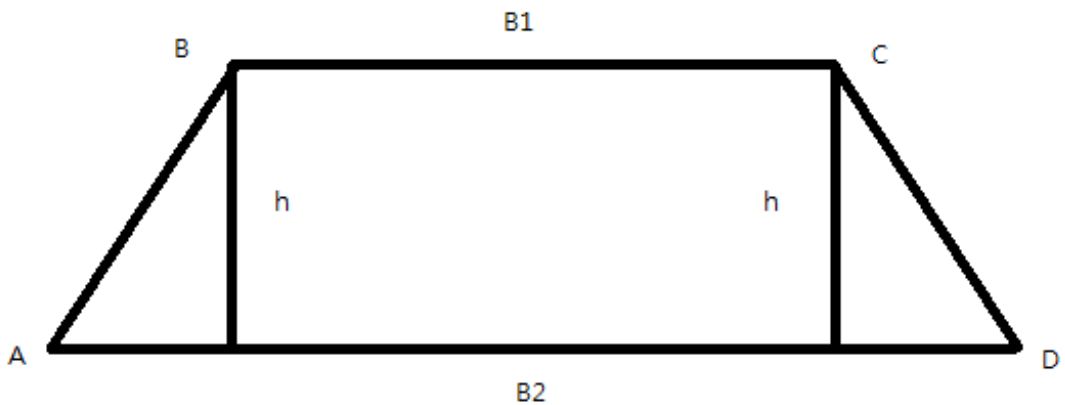
- Side-to-side direction is harder
- Have to compute maximum rectangle of correct aspect ratio



Audio System - Motivation

- Auditory feedback is more effective
- Important for frequent setups or adjustments
- Highlight important details without affecting UI

Audio System - Functionality

- Calibration instructions
- Two-Axis Tilt Angle
- Percentage of pixels utilized

Audio System - Implementation

- Wave files $\rightarrow$ Bit Files $\rightarrow$ Labkit $\rightarrow$ CF Card
- Pre-recorded audio samples on CF Card

Audio System - Interface

- Set of triggers and data as interface.

Responsibilities

- Ganesh
  - Tilt Compensation Algorithm
    - Complexity
    - Hardware constraints
    - Implementability
  - Transform Module
- James
  - Accelerometer
    - Interfacing
    - Noise reduction
  - Calibration module
- Shantanu
  - Audio system design
    - Audio Samples
    - Triggers for each output
  - Audio module
  - Test Setup

Timeline

Week of:

November 10

- Initial module implementation

November 17

- System integration & module debugging

November 24

- System integration debugging

December 1

- Real-world testing & Stretch goals

References

Ramesh Raskar and Paul Beardsley. A self-correcting projector. In *Computer Vision and Pattern Recognition, 2001. CVPR 2001. Proceedings of the 2001 IEEE Computer Society Conference on*, volume 2, pages II–504. IEEE, 2001.

Rahul Sukthankar, Robert G Stockton, and Matthew D Mullin. Smarter presentations: Exploiting homography in camera-projector systems. In *Computer Vision, 2001. ICCV 2001. Proceedings. Eighth IEEE International Conference on*, volume 1, pages 247–253. IEEE, 2001.