Steps to use to 3D Machine Vision design

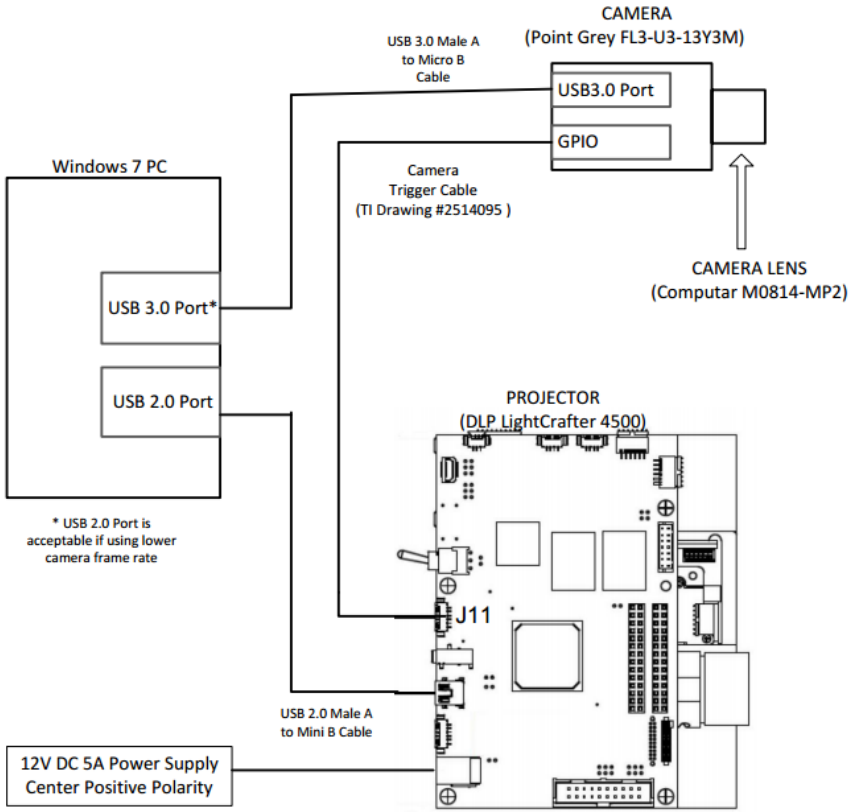
1. Install software → Done!
2. Connect the hardware
3. Make calibration board → Done!
4. Prepare the software and projector
5. Calibrate Camera
6. Calibrate System
7. Perform Scan
8. Develop your own applications!

Installing software

Software	Purpose	Required for application	Required for development
Point Grey FlyCapture2 SDK http://www.ptgrey.com/	• Camera drivers • Camera interface code libraries	☑	☑
DLP Machine Vision Reference Design Download http://www.ti.com/lit/zip/tidc535	• Precompiled application • DLP Structured Light SDK	☑	☑
Meshlab http://meshlab.sourceforge.net/	• Point Cloud Viewer • Surface Reconstruction • Analysis	(optional)	
OpenCV (source code) http://opencv.org/	• Image data management and processing code libraries		☑

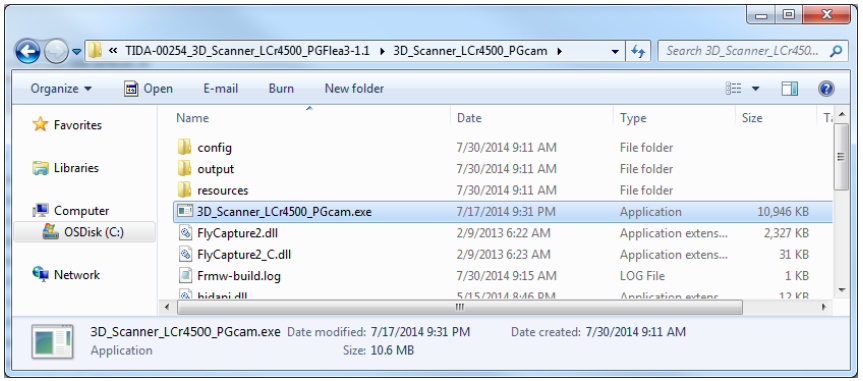
Connecting the Hardware

- Connect Camera to USB3.0 port if available
- Connect DLP® LightCrafter™ 4500 EVM to any USB port
- Connect Camera trigger cable to DLP LightCrafter 4500 EVM input trigger

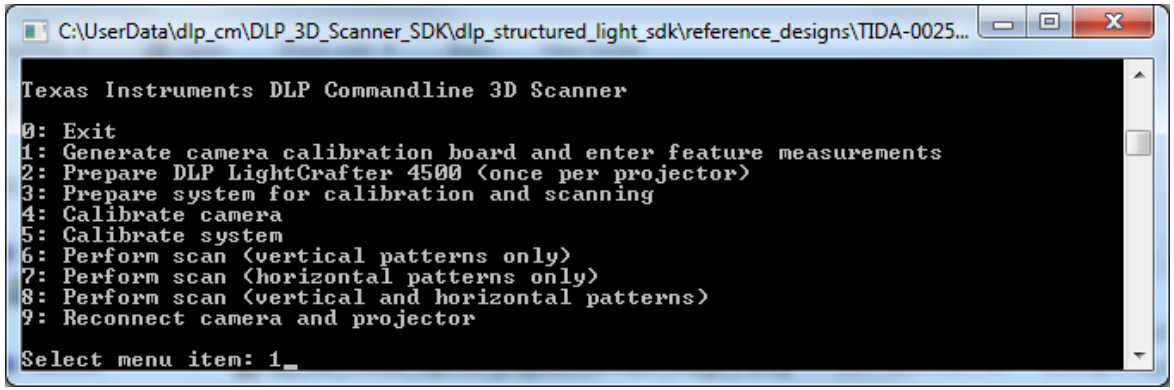


How to make the calibration board

- Open application directory and start executable

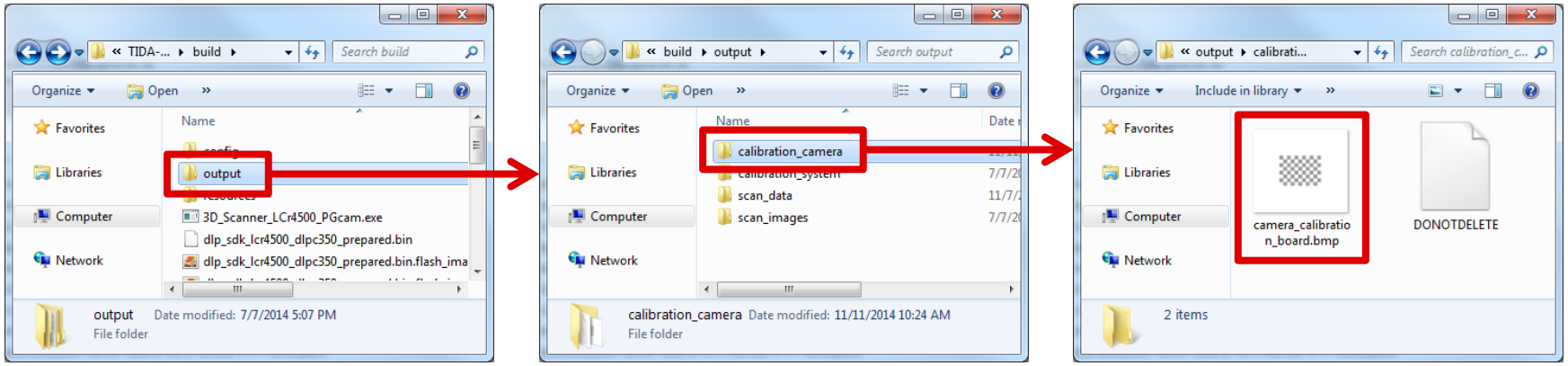


- Enter menu item “1: Generate camera calibration board and enter feature measurements”



How to make the calibration board

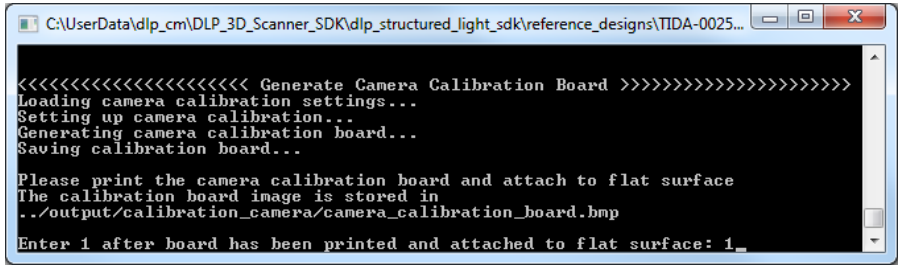
- After selecting menu item 1, a BMP file with the chessboard is generated in the “output/calibration_camera” directory



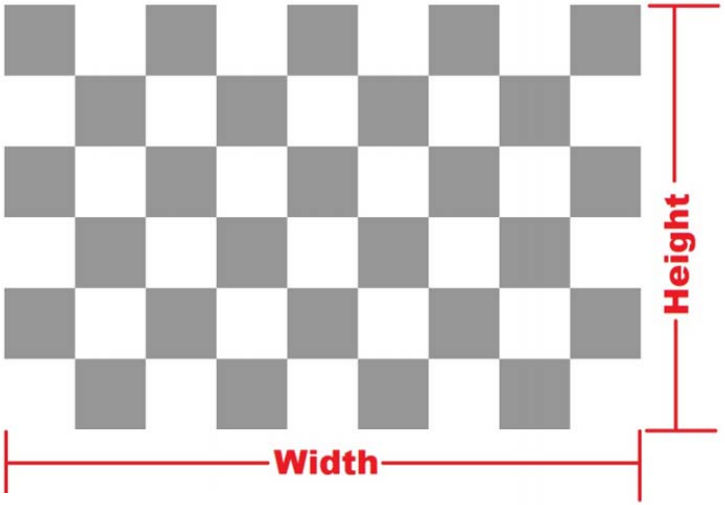
- Print the BMP file (at high DPI) and attach it to a flat surface
  - ¼” Foam core board, aluminum sheet stock, etc. all work well
  - Use spray adhesive to attach printed chessboard
  - **Your point cloud data will only be as good as your calibration board! Flatness is critical!**

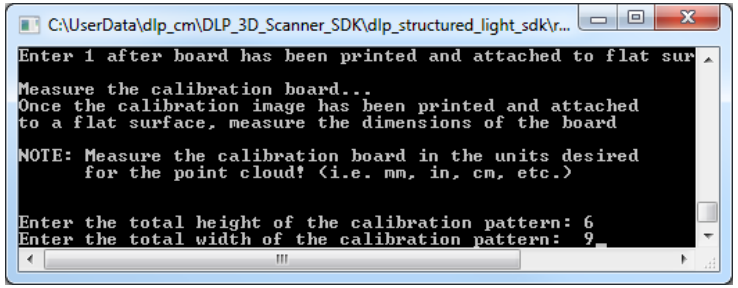
Entering calibration board measurements

- Enter “1” after printing and attaching the flat board



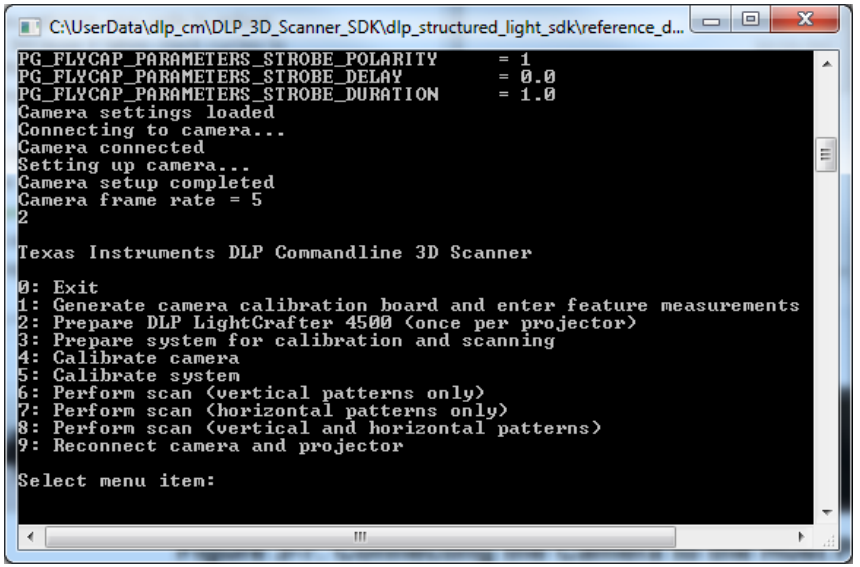
- Measure and enter the height and width of the calibration pattern
  - Note: Point cloud data units will be in the same units as are entered here





Preparing software and projector

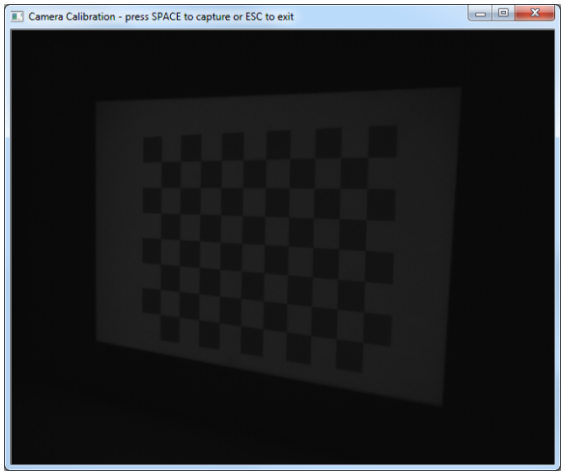
- Preparing the software and projector does the following:
  - Loads calibration and structured light settings
  - Generates projector calibration pattern
  - Generates structured light patterns
  - Uploads images to DLP LightCrafter™ 4500 EVM
- The first time you use the projector with the software or change any structured light settings, use option 2: “Prepare DLP LightCrafter 4500 (once per projector)”
  - Performs all steps listed above
- If settings have not changed and the projector was previously prepared, use option 3: “Prepare system for calibration and scanning”
  - Performs all steps above, except uploading images to DLP LightCrafter 4500 EVM
  - Must be run every time the application is run



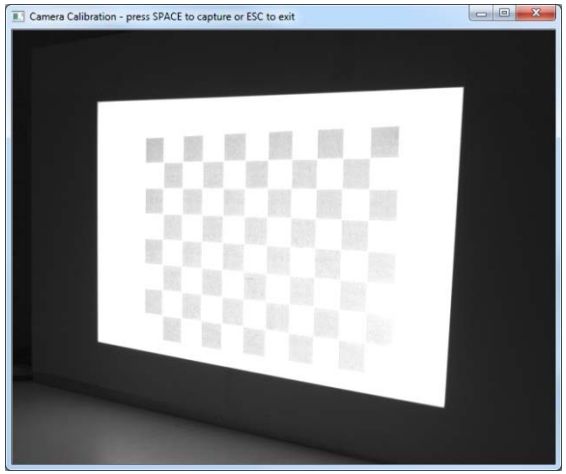
Calibrating the Camera - Setup

- Before capturing any board positions, set the aperture and focus
  - Aperture determines how much light reaches the sensor
  - Focus ensures the image plane is at the exact level of the sensor so that the image is sharp and not blurry
  - Lock everything into place!

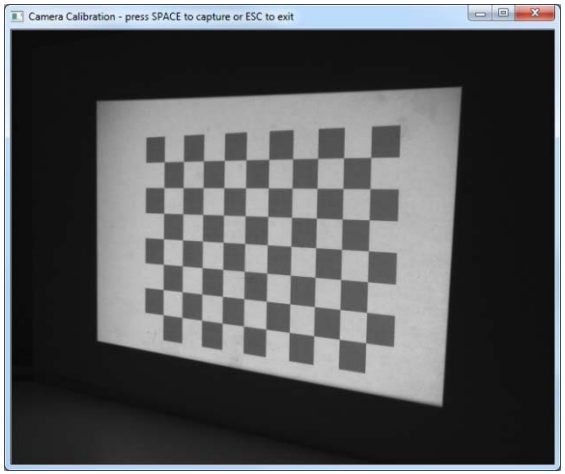
Under exposed



Over-exposed

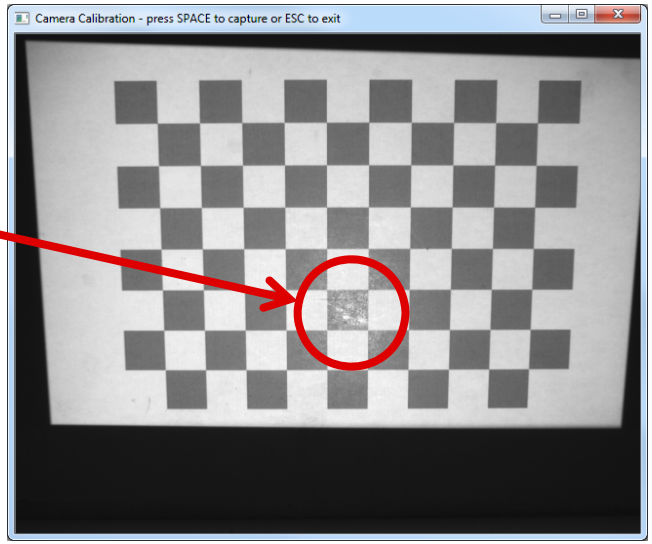


Good exposure

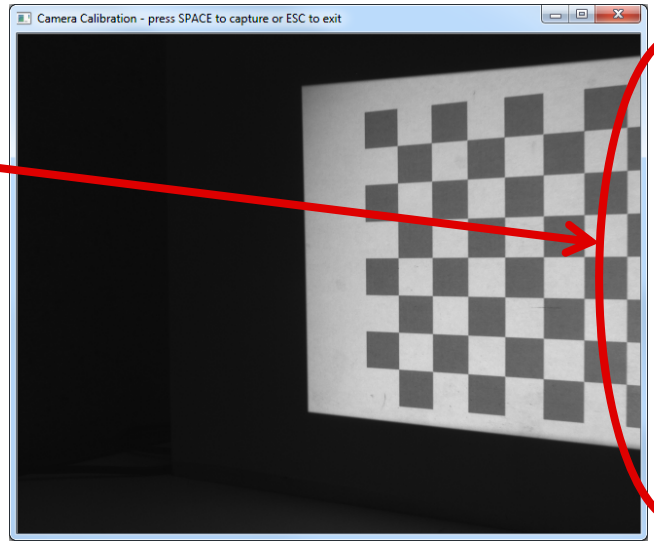


Calibrating the Camera – Watch out for…

- Software won't find the chessboard if…
  - There is too much glare
    - To remove glare, angle the calibration board

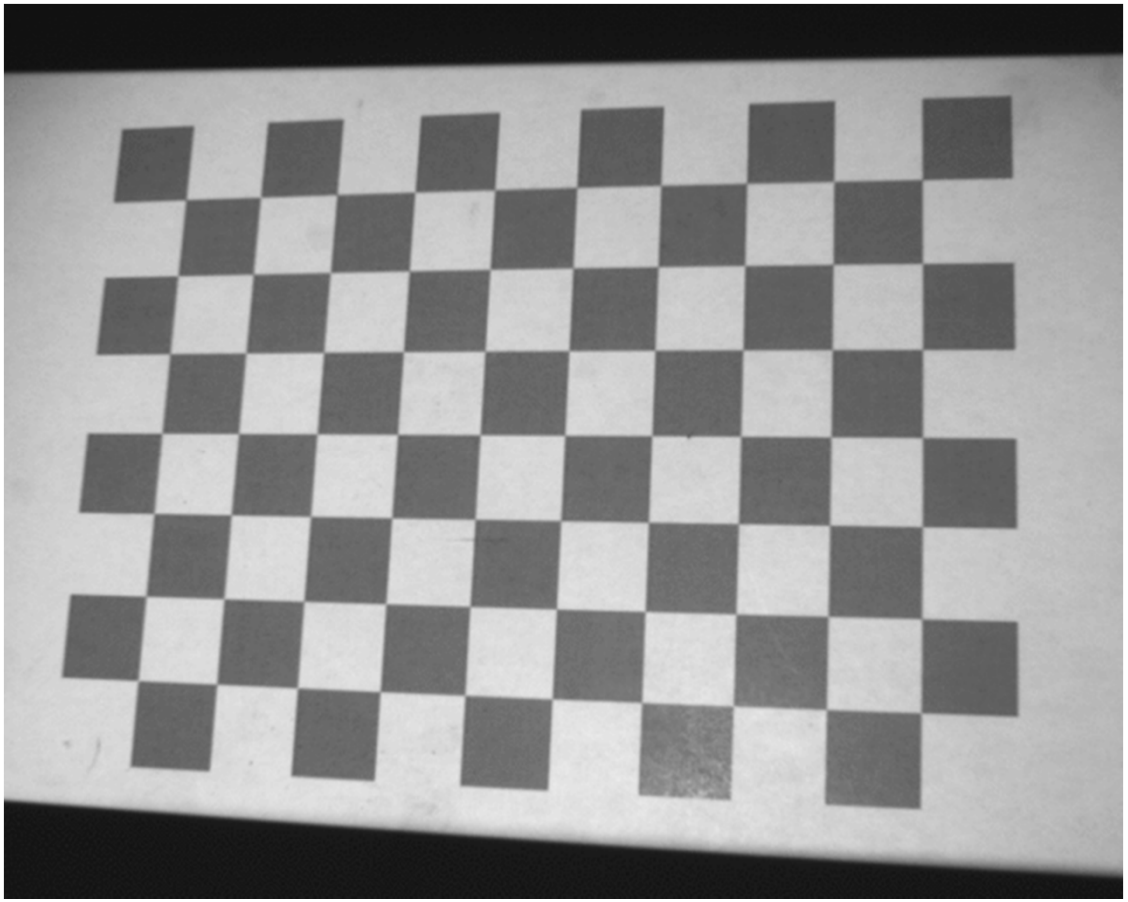


  - Part of the chessboard is missing from within the captured image
    - Parts of the squares on the border square can be cutout, so long as the inside corners are still visible



Calibrating the Camera – Example Images

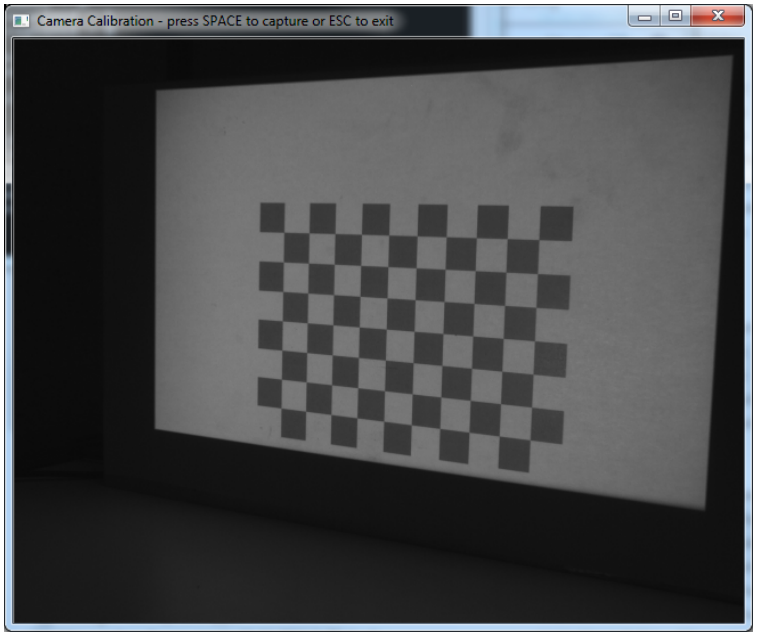
- Calibration image examples
- Measured camera reprojection error = 0.166341



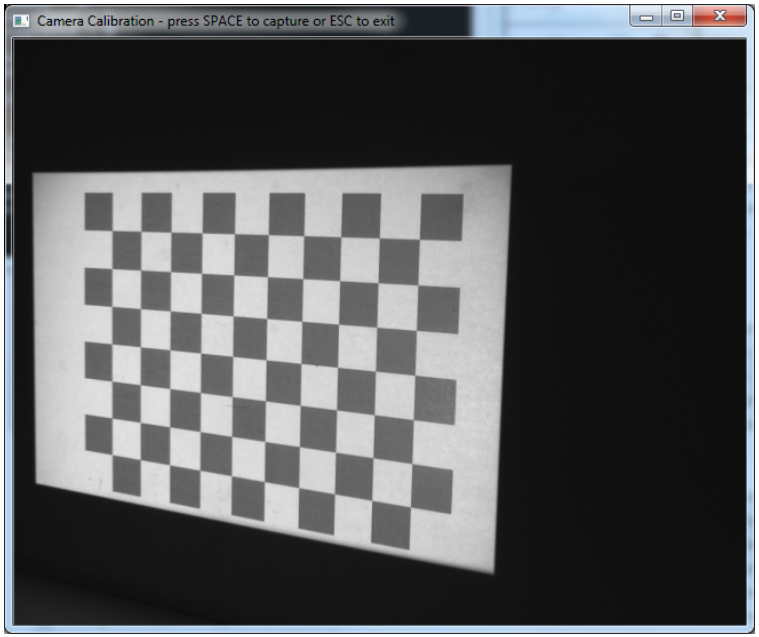
Calibrating the system - Setup

- Mount the camera so that the projected area can be seen within the camera at the minimum and maximum scanning distance
  - Try to utilize the entire camera frame if possible
- If the camera or projector are moved relative to each other, this calibration process must be redone

Furthest distance

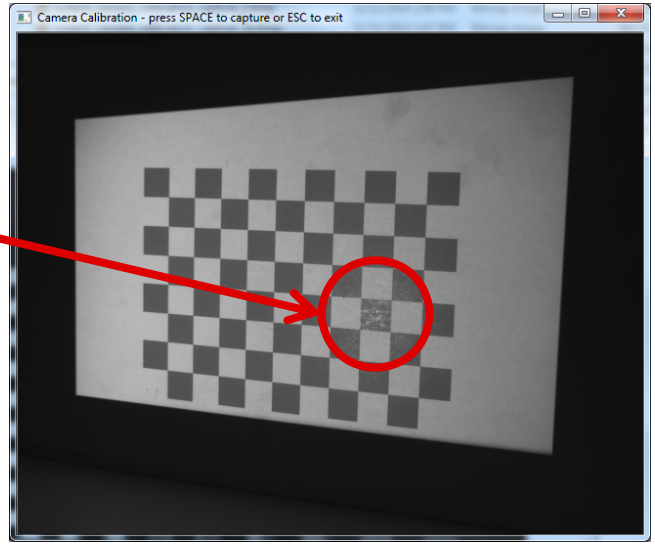


Closest distance

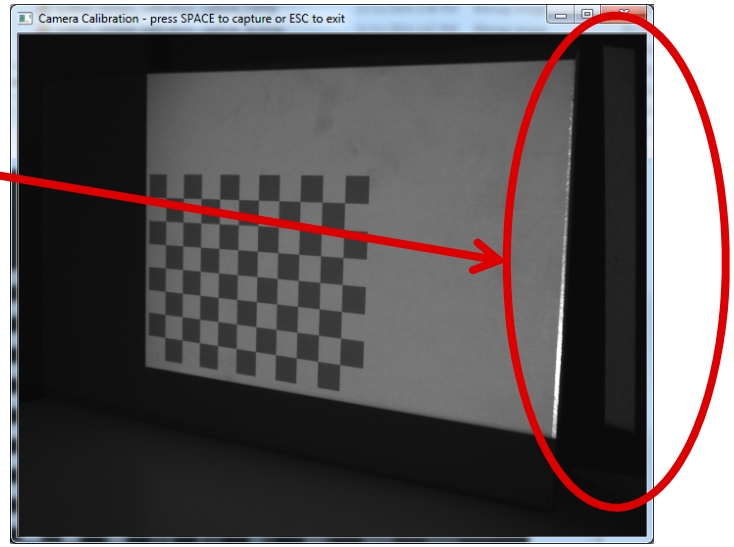


Calibrating the system – Watch out for…

- Software won't find the chessboard if…
  - There is too much glare
    - To remove glare, angle the calibration board

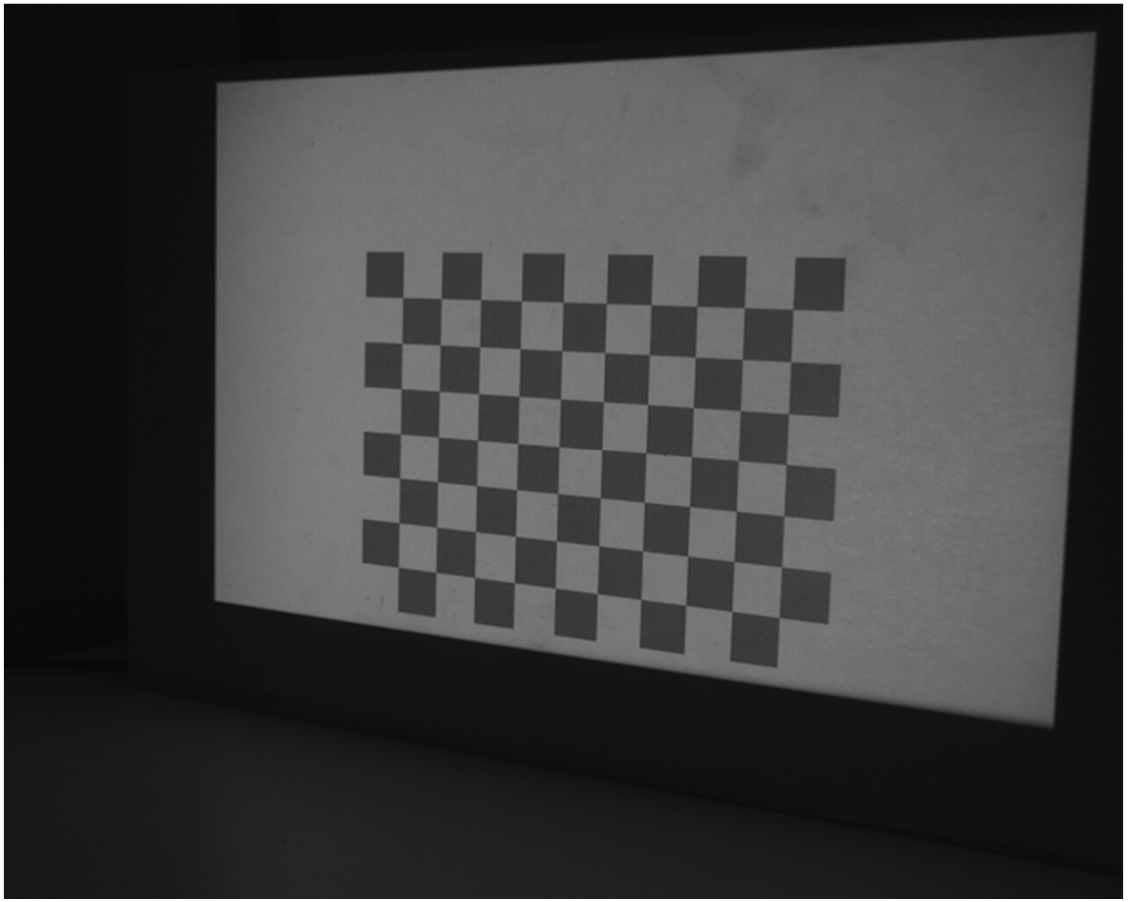


  - Part of the projected image falls off of the calibration board
    - This will cause squares to be missing on the projected chessboard calibration pattern



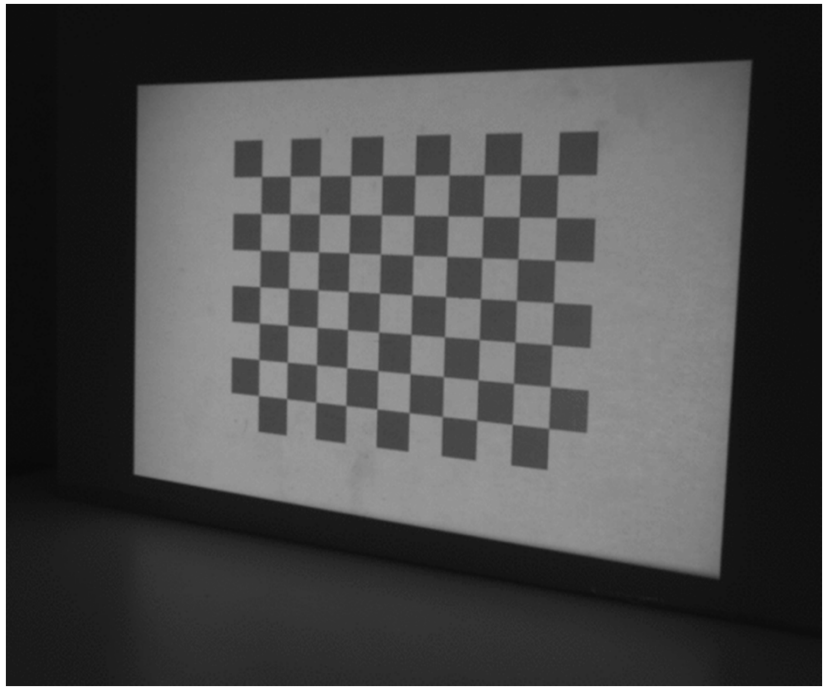
Calibrating the System – Example Images

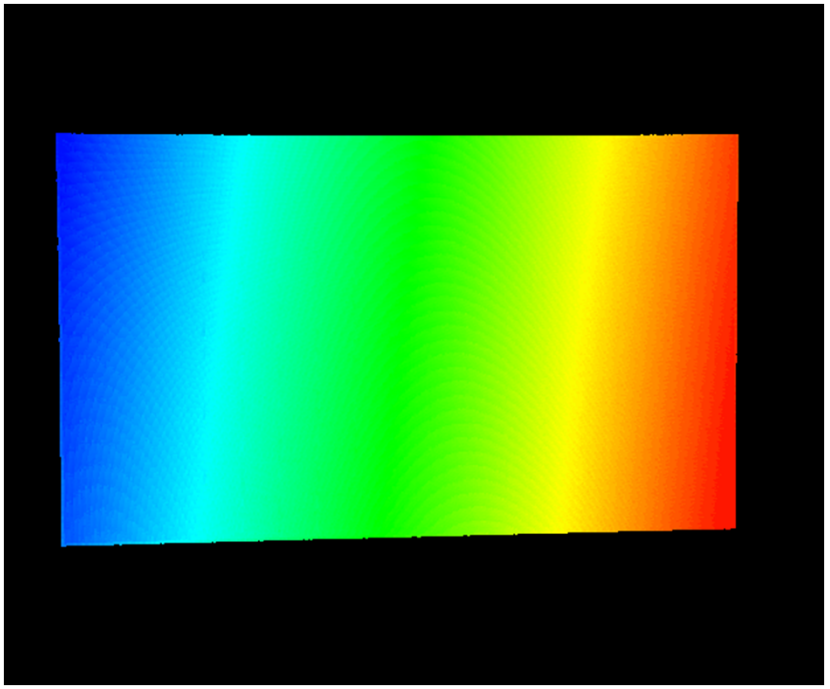
- Calibration image examples
- Measured projector reprojection error = 0.325859



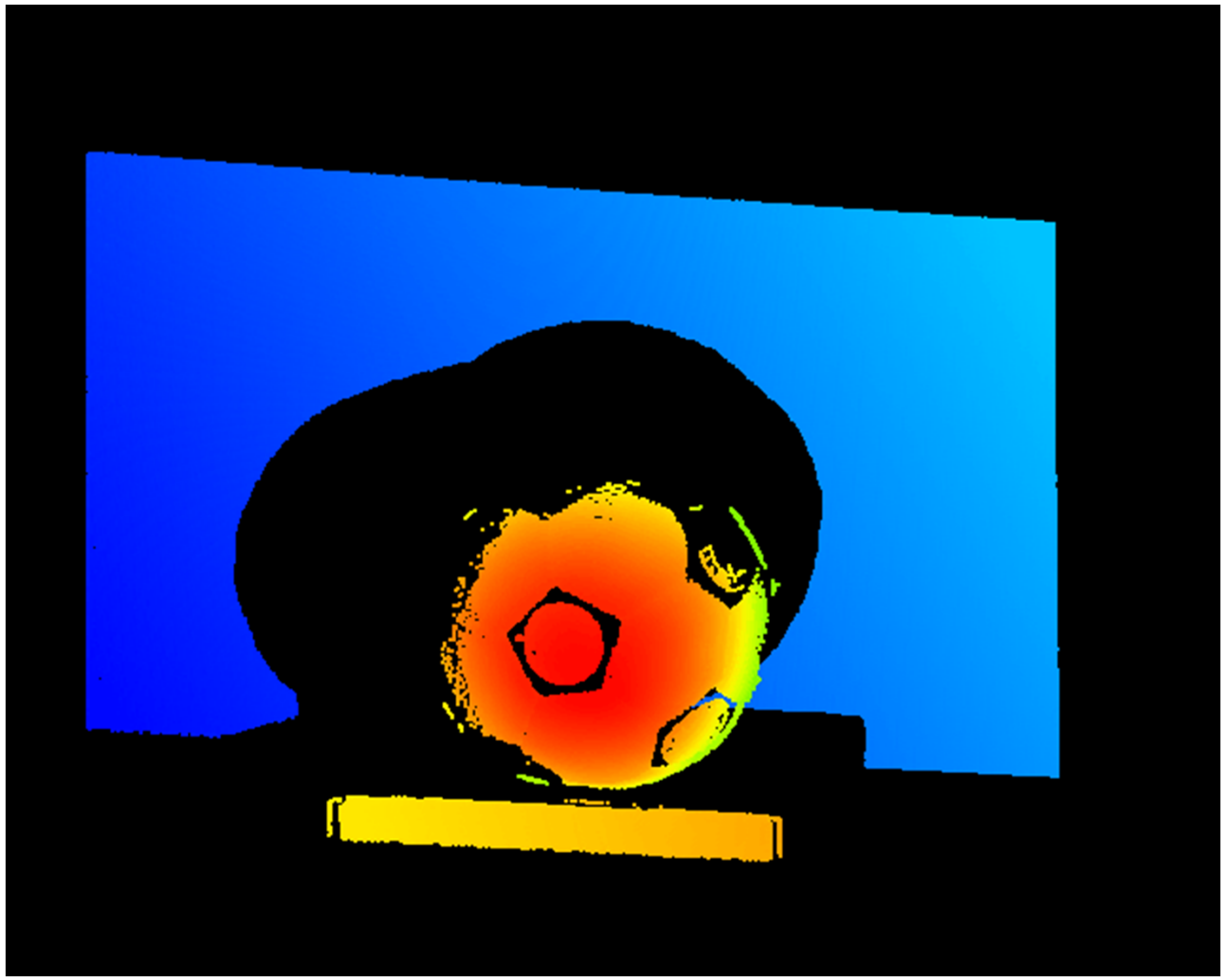
Perform Scan

- After preparation and calibration, the system is ready for scanning!
  - Use one of the “Perform Scan” menu options 6, 7, or 8



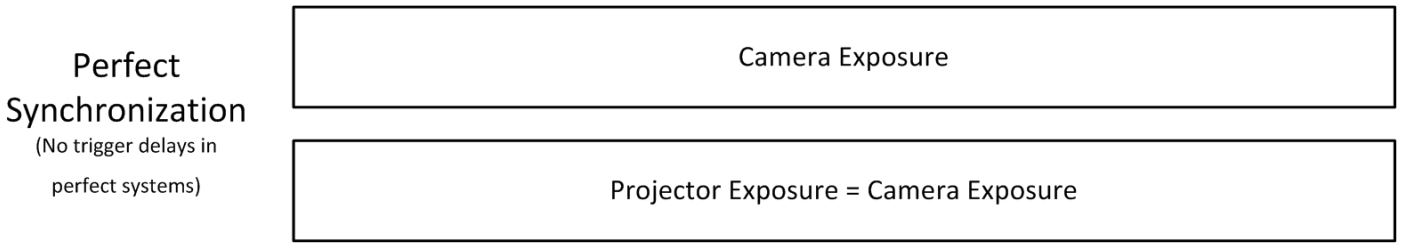


Point Cloud Example

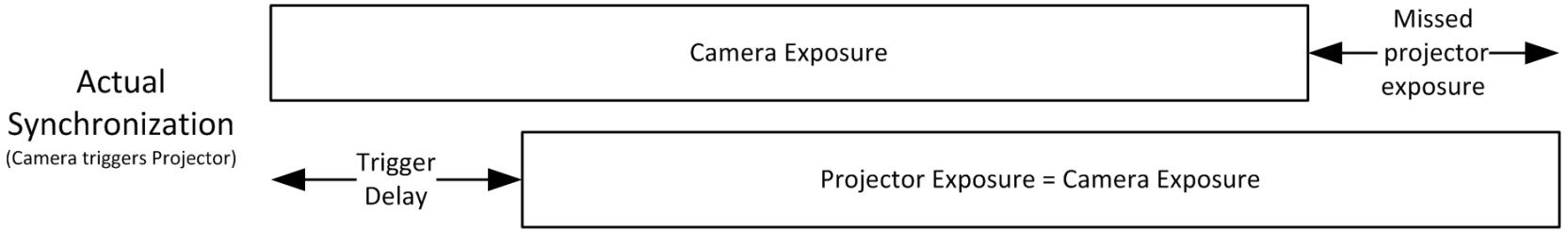


Synchronizing the Camera with Projector

- Ideally everything matches up perfectly



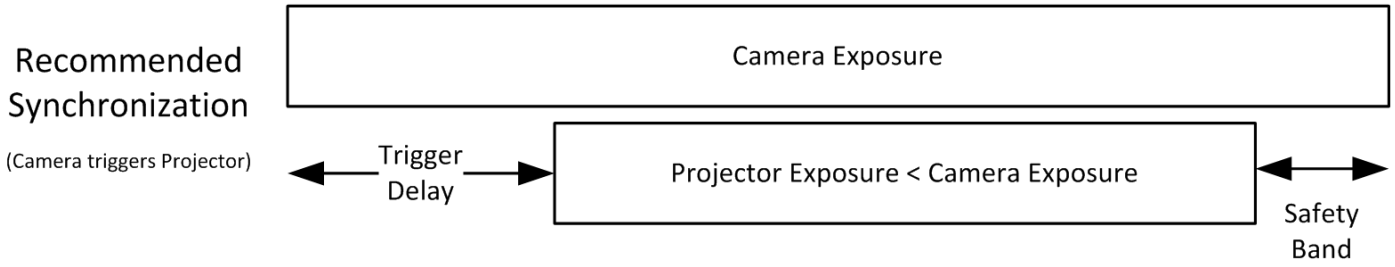
- There is *always* a delay in the triggers



  - Camera exposure may capture part of the next or previous projected pattern
  - Delay could cause the camera exposure to miss part of the pattern
    - This could cause issues in the linearity of non-binary patterns

Synchronizing the Camera with Projector

- Recommended synchronization setup



- Camera triggers projector
  - Most cameras with triggers run faster in a free run mode rather than a triggered mode
  - If the projector triggered the camera, the trigger delay would cause the camera exposure to miss part of the exposed pattern
- Projector exposure shorter than the camera exposure
  - Ensures the camera exposure captures the entire projected pattern and thus greyscale linearity remains intact