Introduction to 3D Machine Vision

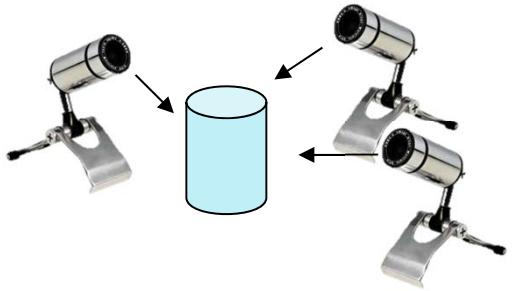
Many methods for 3D machine vision

Use Triangulation (Geometry) to Determine the Depth of an Object

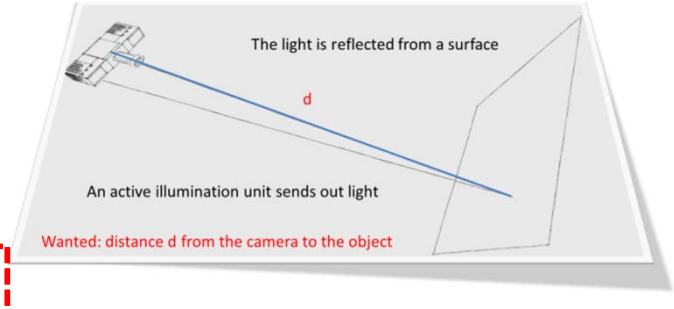
By Different Methods:

Single Line Laser Scan

Stereo Triangulation or Photogrammetry



Time of Flight



Structured Light

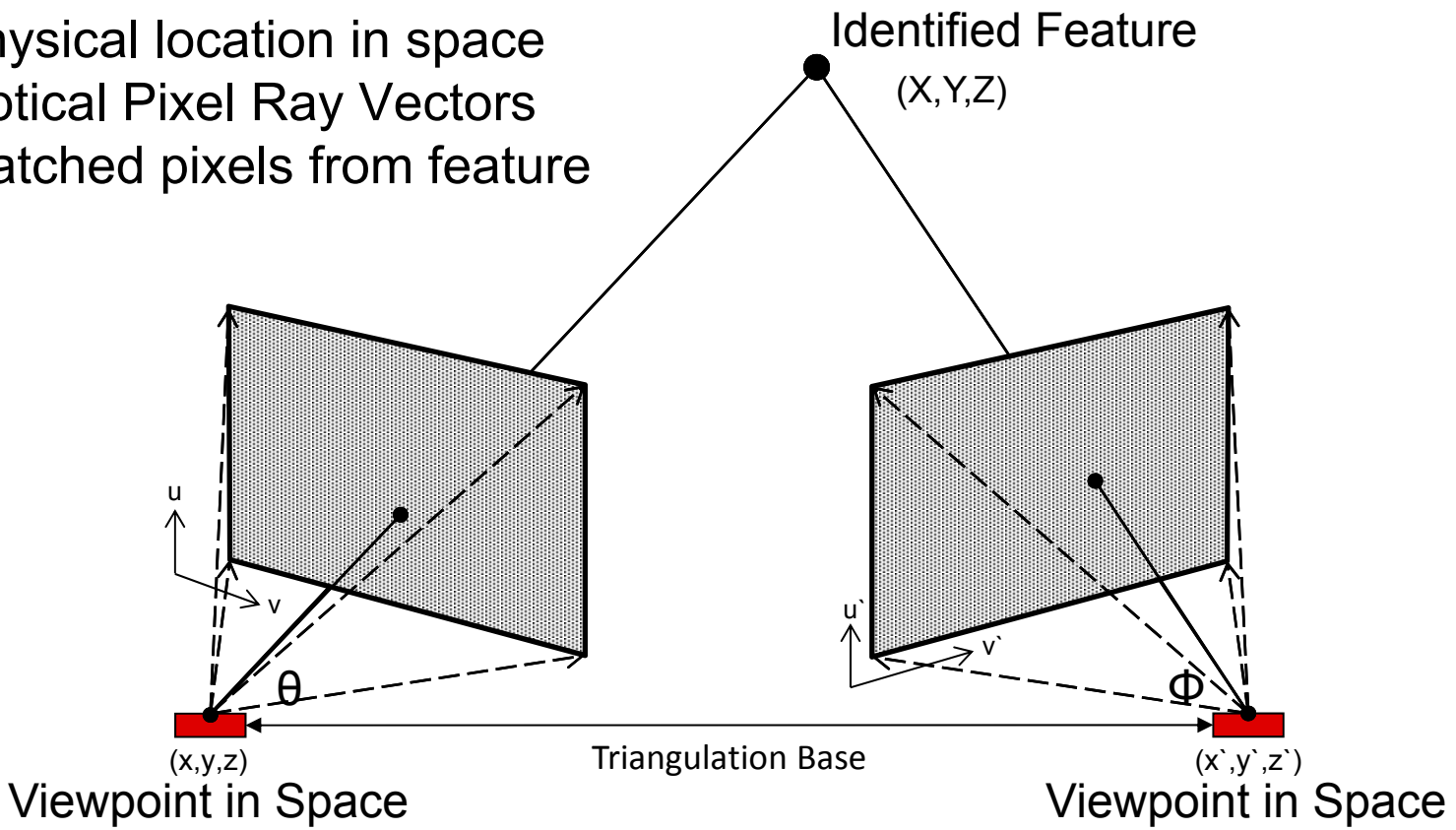
Depth calculated with triangulation

Use Triangulation (Geometry) to Determine the Depth of an Object

By Different Methods:

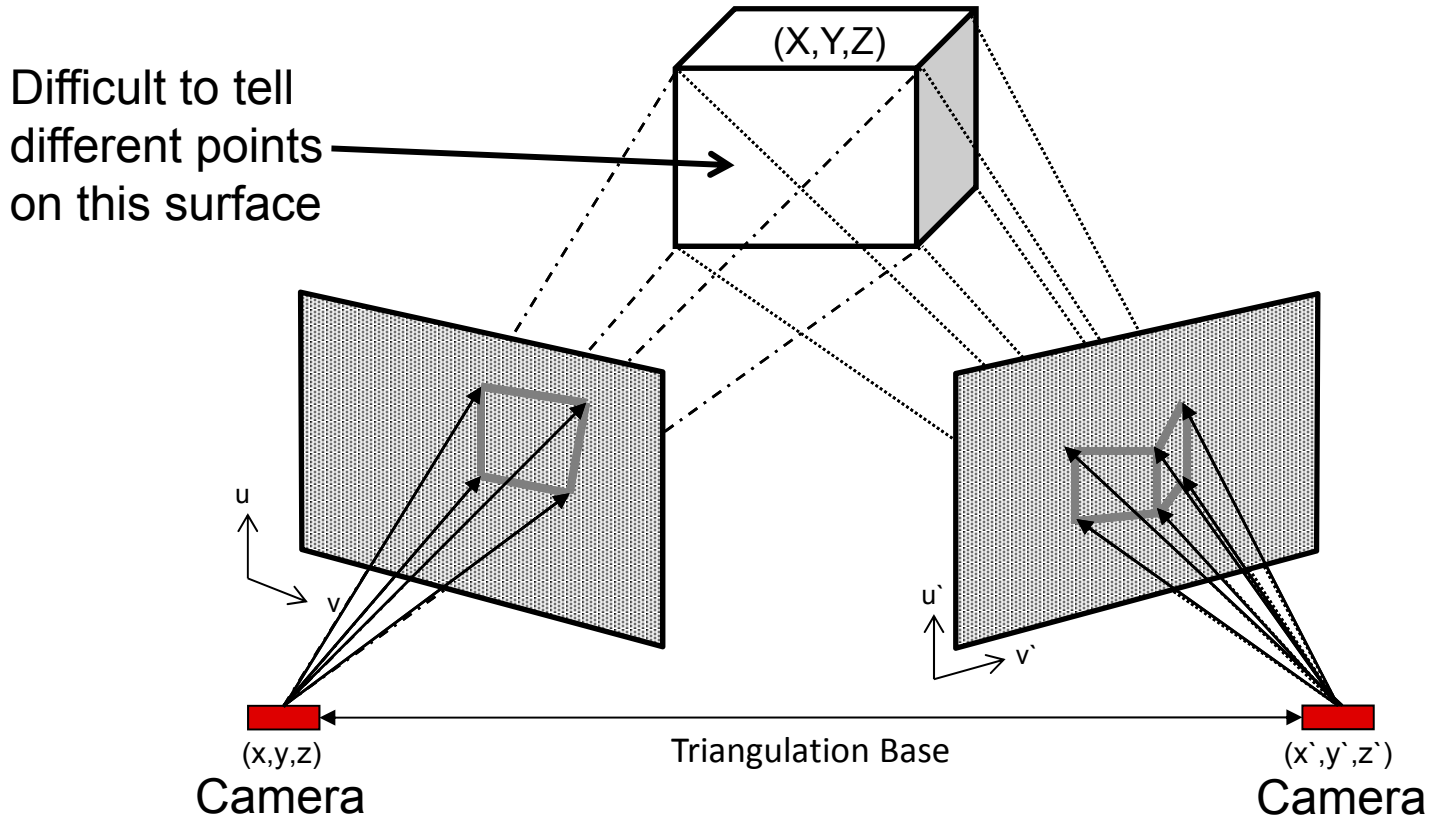
What do we need to know?

- Physical location in space
- Optical Pixel Ray Vectors
- Matched pixels from feature



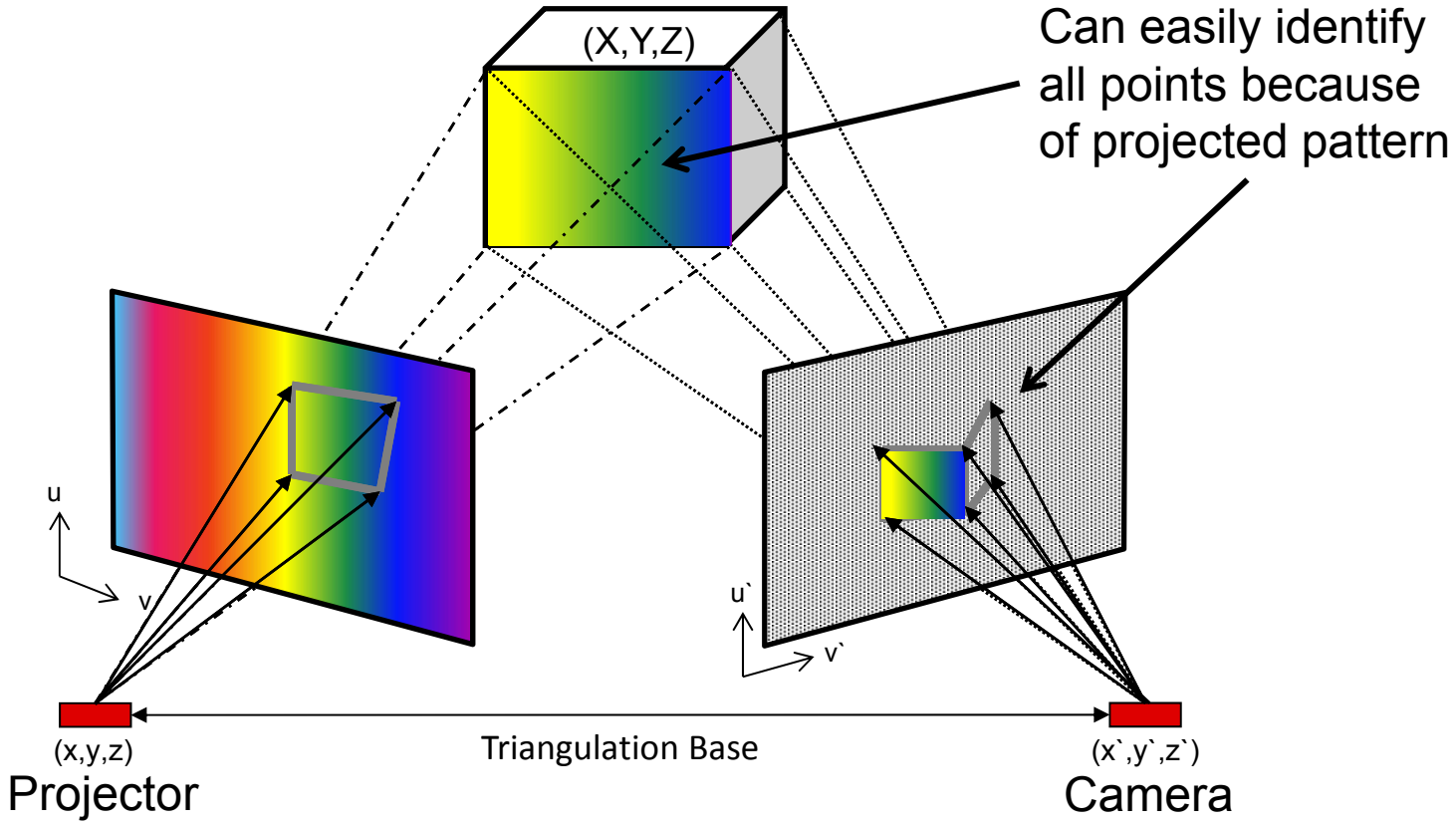
Using Cameras for 3D Machine Vision

- Two cameras capture different viewpoints of the same object
- What if object does not have many identifiable features?



3D Machine Vision with Structured Light

- One camera captures projected patterns
- The projected patterns inherently create identifiable features

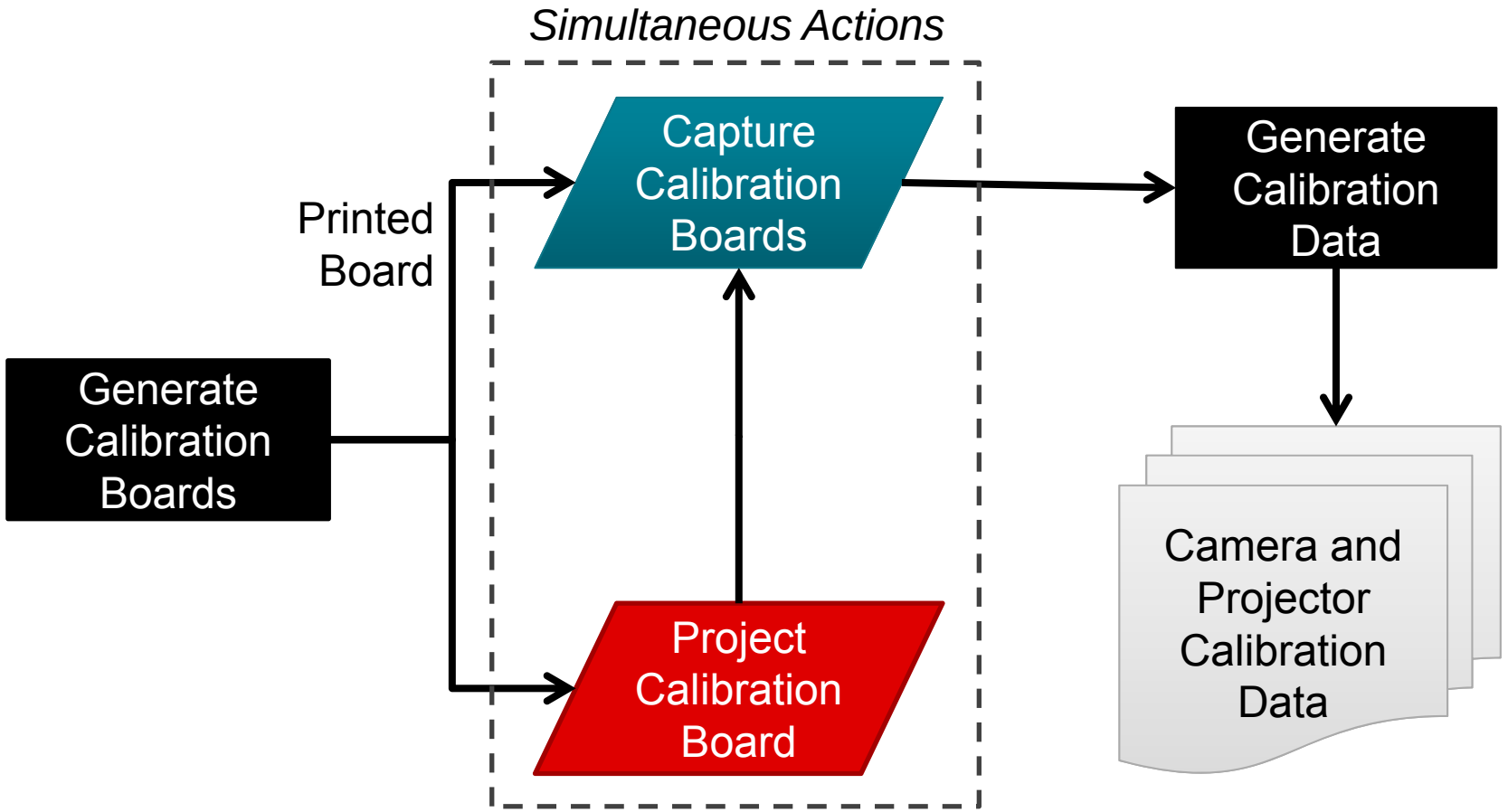


What subsystems are needed?

Subsystems	Purpose
Calibration	• Determine physical locations and directions • Determine optical parameters of camera and projector o Focal length o Focal point o Radial distortion coefficients
Geometry	• Uses calibration data and feature identification to reconstruct (X,Y,Z) point
Structured Light	• Generate structured light patterns • Decode captured images and generate disparity map which details which projector pixels are viewed by camera
DLP Platform	• Project high-speed patterns
Camera	• Capture high-speed patterns for analysis

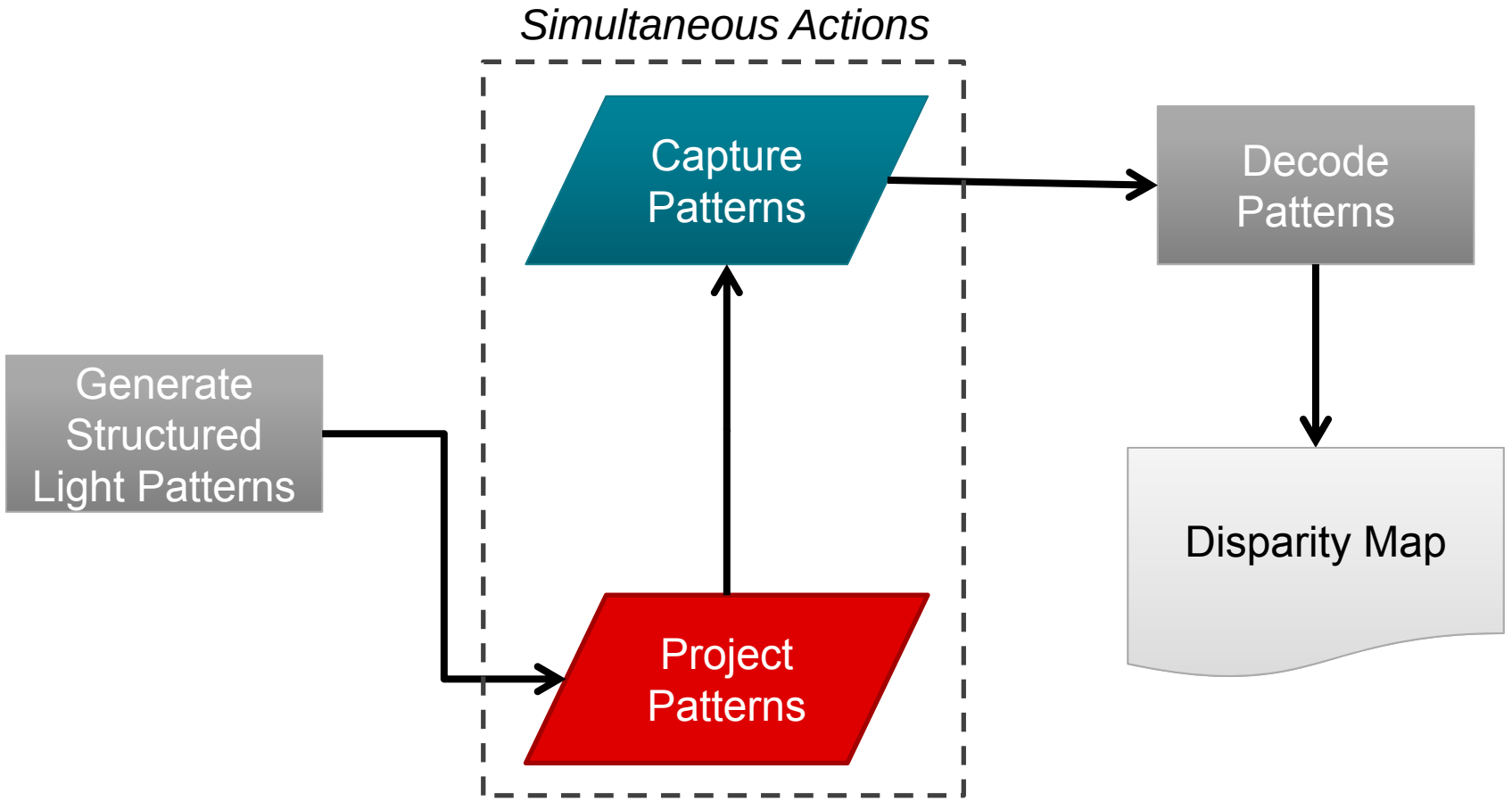
Process Flow: Calibration

Calibration | Camera | DLP® Platform | Structured Light | Geometry



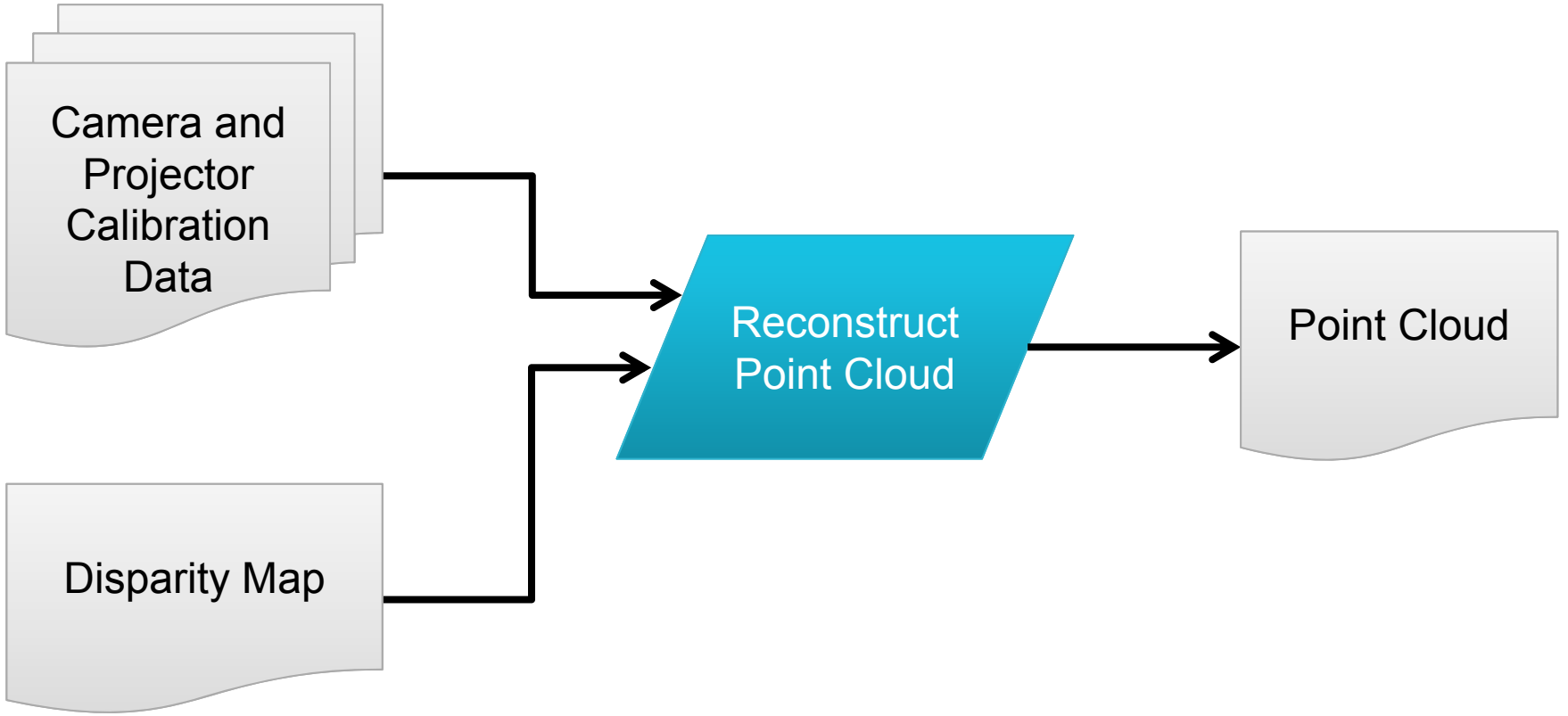
Process Flow: Scanning

Calibration | Camera | DLP® Platform | Structured Light | Geometry



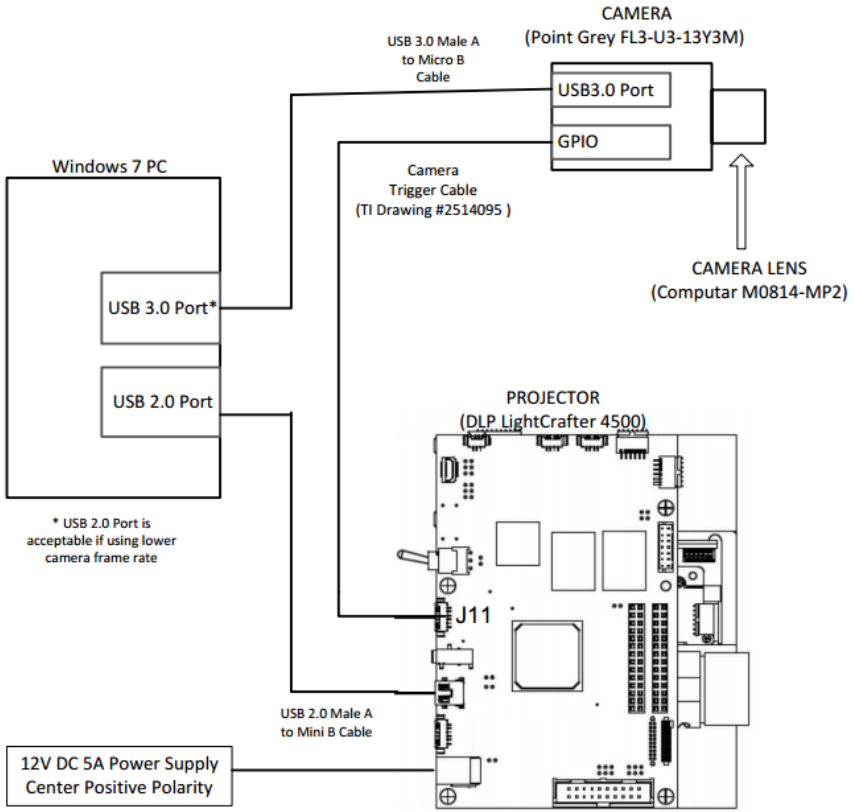
Process Flow: Reconstruction

Calibration | Camera | DLP® Platform | Structured Light | Geometry



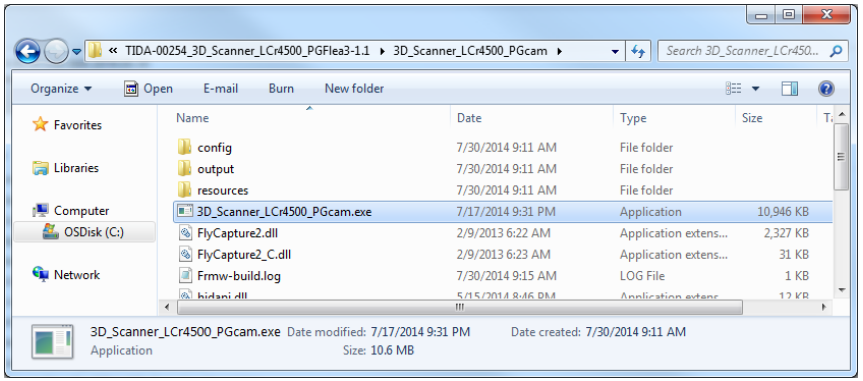
Connecting the Hardware

- 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

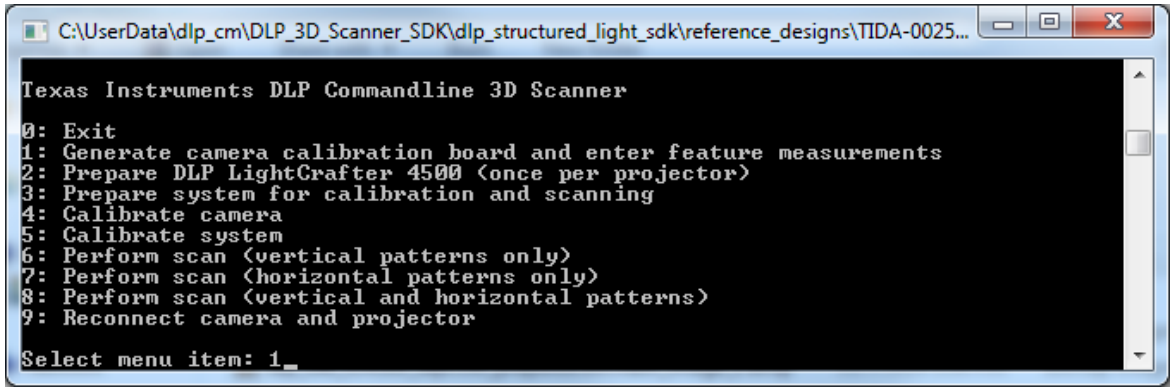


How to make the calibration board

- Open application directory and start executable

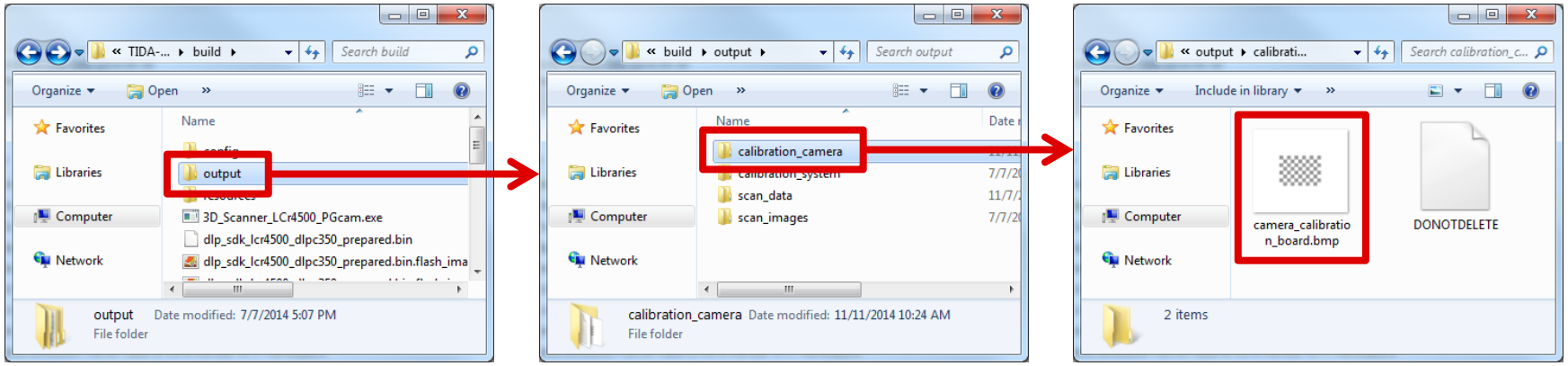


- Enter menu item “1: Generate camera calibration board and enter feature measurements”



How to make the calibration board

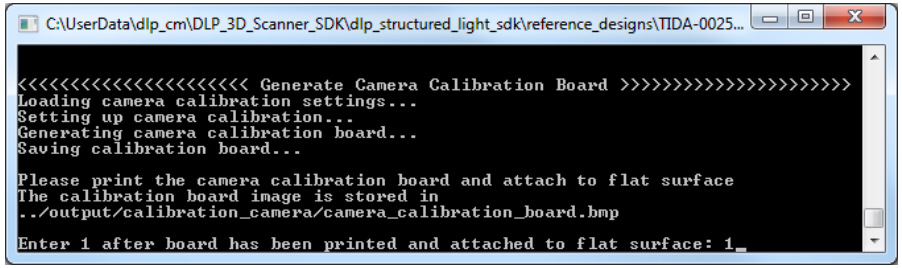
- After selecting menu item 1, a BMP file with the chessboard is generated in the “output/calibration_camera” directory



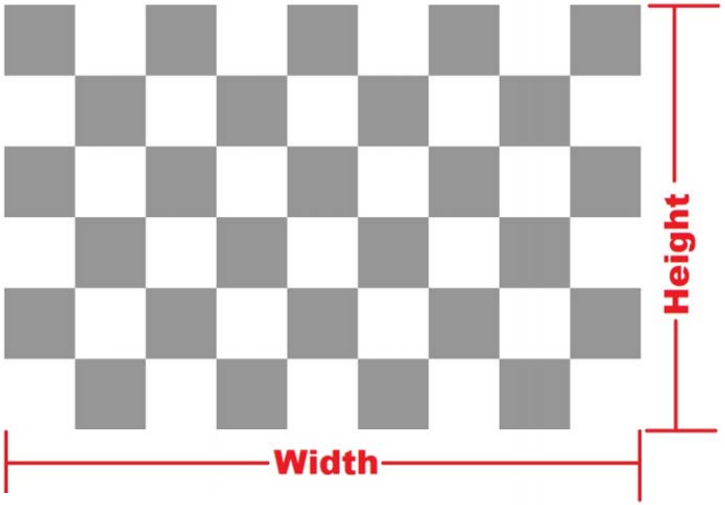
- Print the BMP file (at high DPI) and attach it to a flat surface
  - ¼” Foam core board, aluminum sheet stock, etc. all work well
  - Use spray adhesive to attach printed chessboard
  - **Your point cloud data will only be as good as your calibration board! Flatness is critical!**

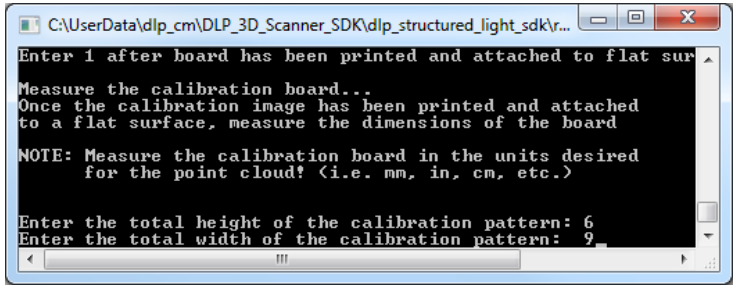
Entering calibration board measurements

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



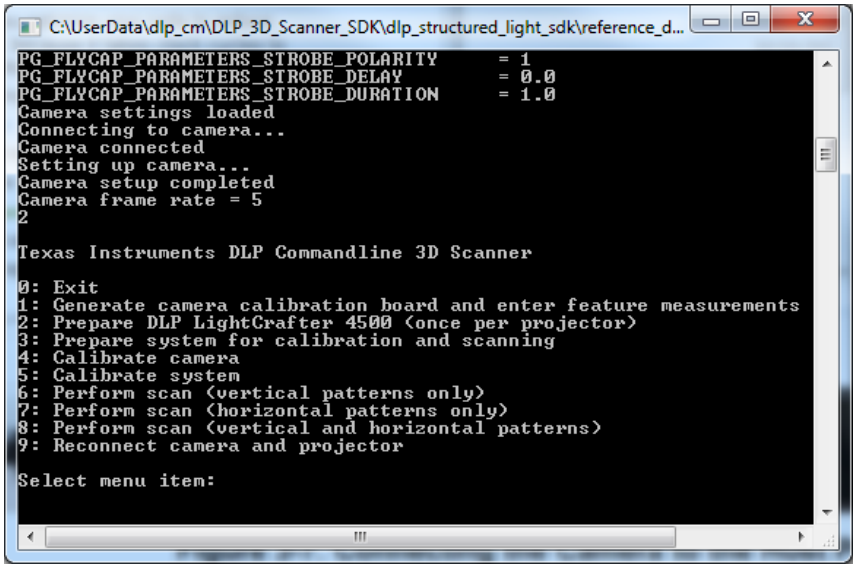
- Measure and enter the height and width of the calibration pattern
  - Note: Point cloud data units will be in the same units as are entered here





Preparing software and projector

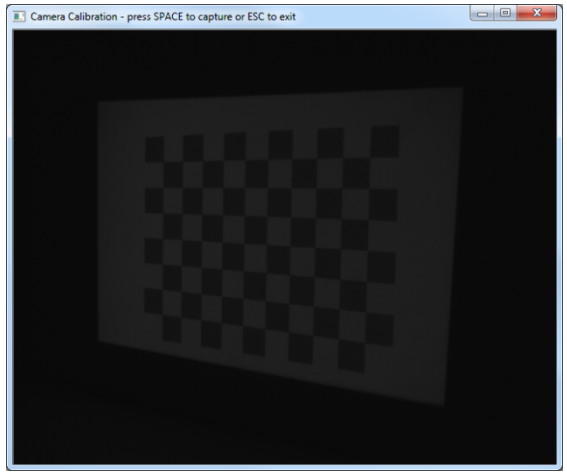
- Preparing the software and projector does the following:
  - Loads calibration and structured light settings
  - Generates projector calibration pattern
  - Generates structured light patterns
  - Uploads images to DLP LightCrafter™ 4500 EVM
- The first time you use the projector with the software 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



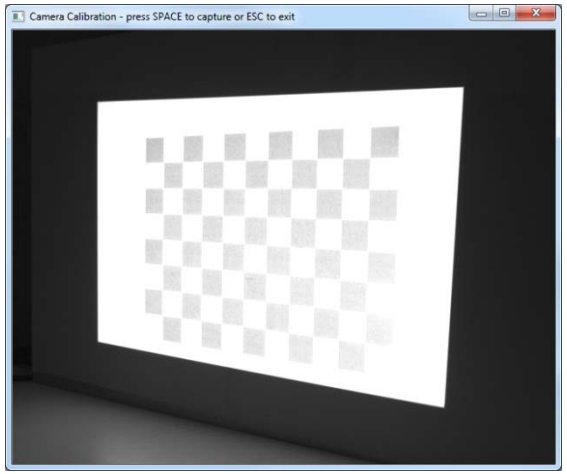
Calibrating the Camera - Setup

- 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!

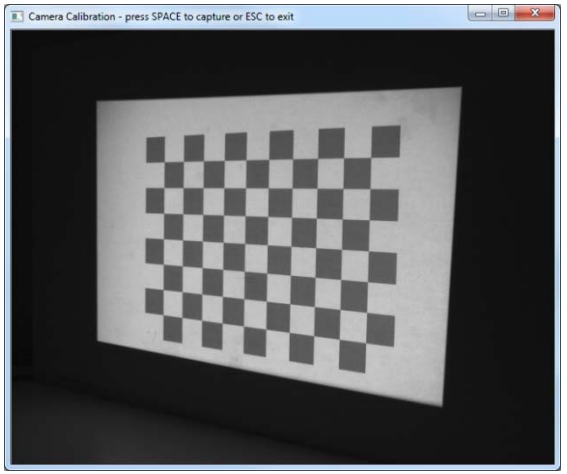
Under exposed



Over-exposed

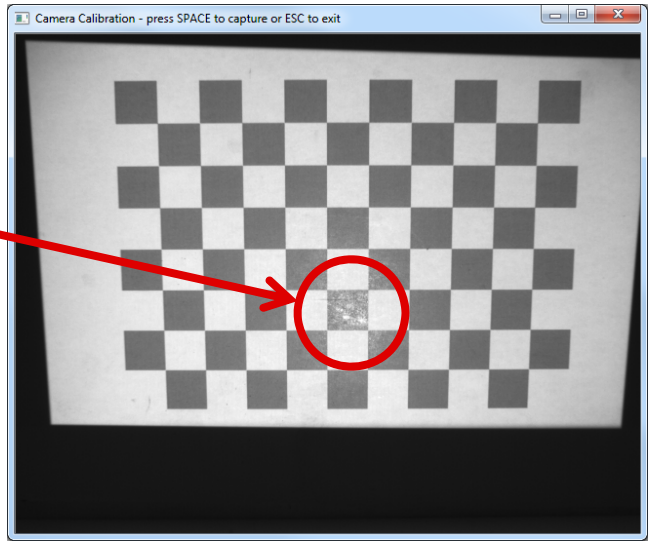


Good exposure

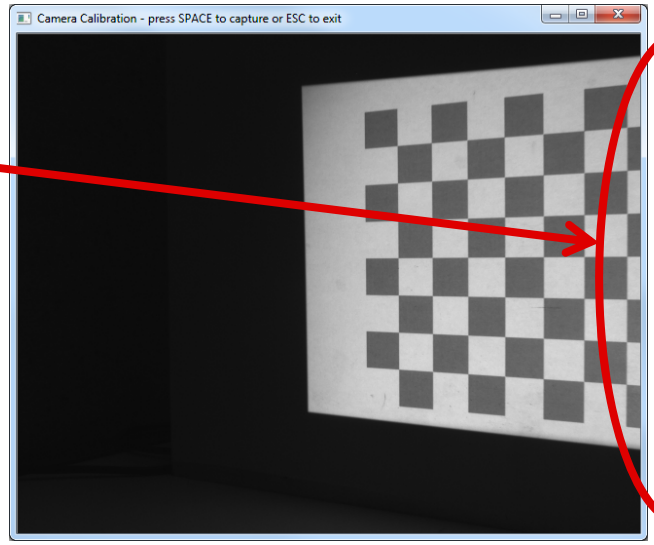


Calibrating the Camera – Watch out for…

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

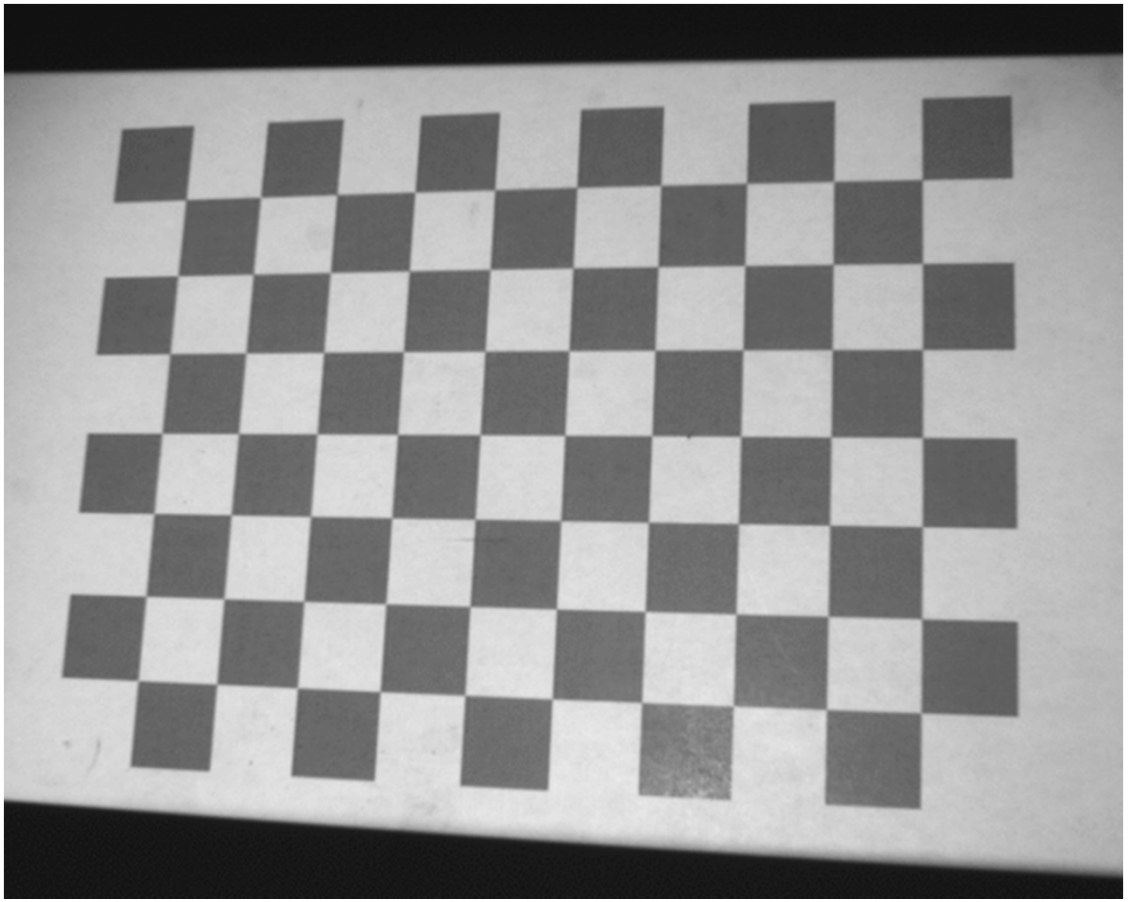


  - Part of the chessboard is missing from within the captured image
    - Parts of the squares on the border square can be cutout, so long as the inside corners are still visible



Calibrating the Camera – Example Images

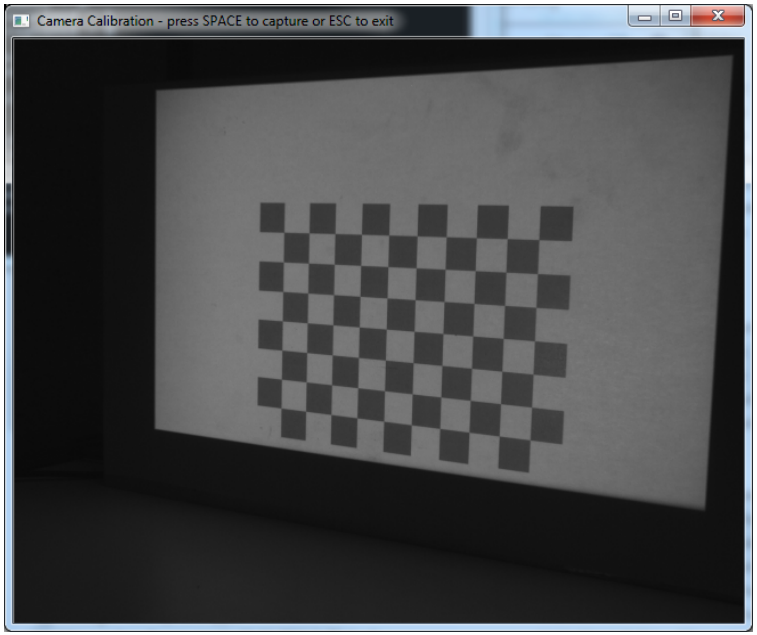
- Calibration image examples
- Measured camera reprojection error = 0.166341



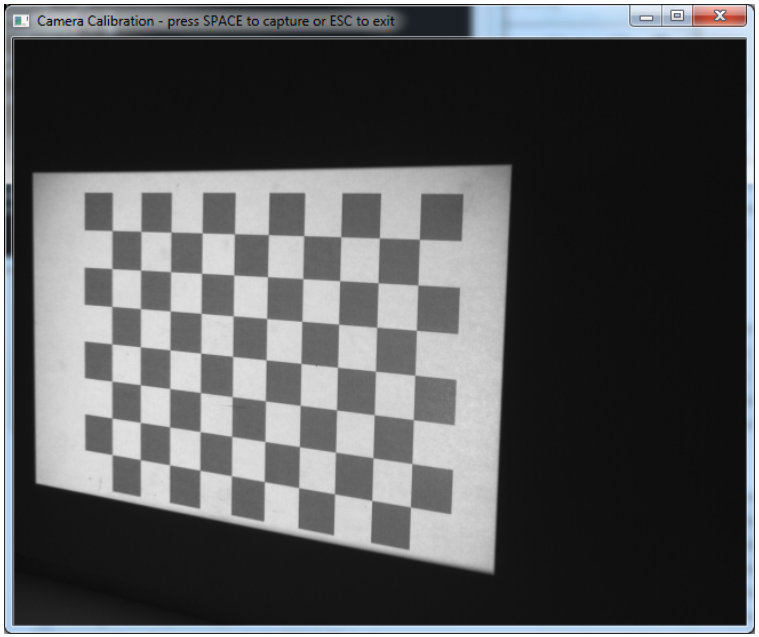
Calibrating the system - Setup

- 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

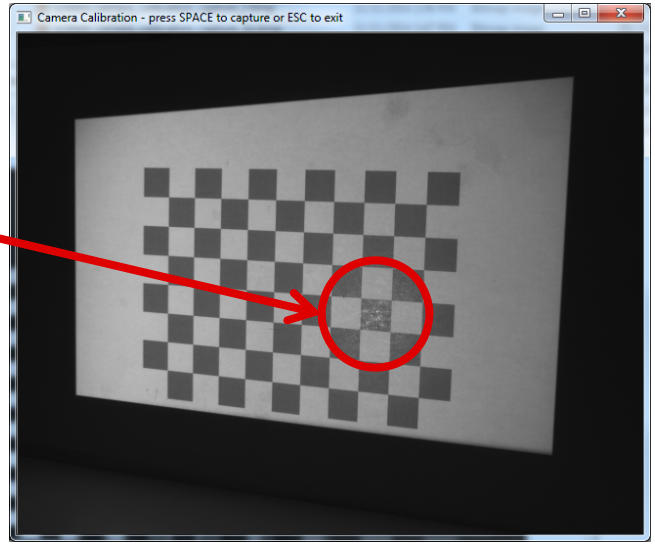


Closest distance

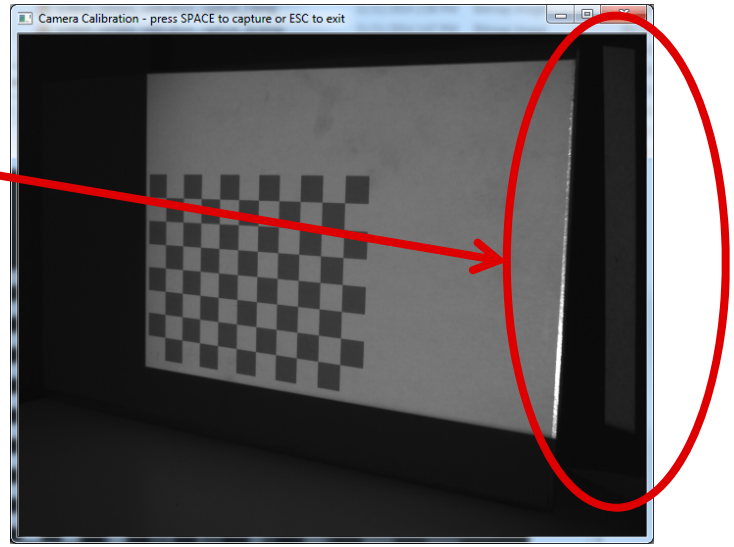


Calibrating the system – Watch out for…

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

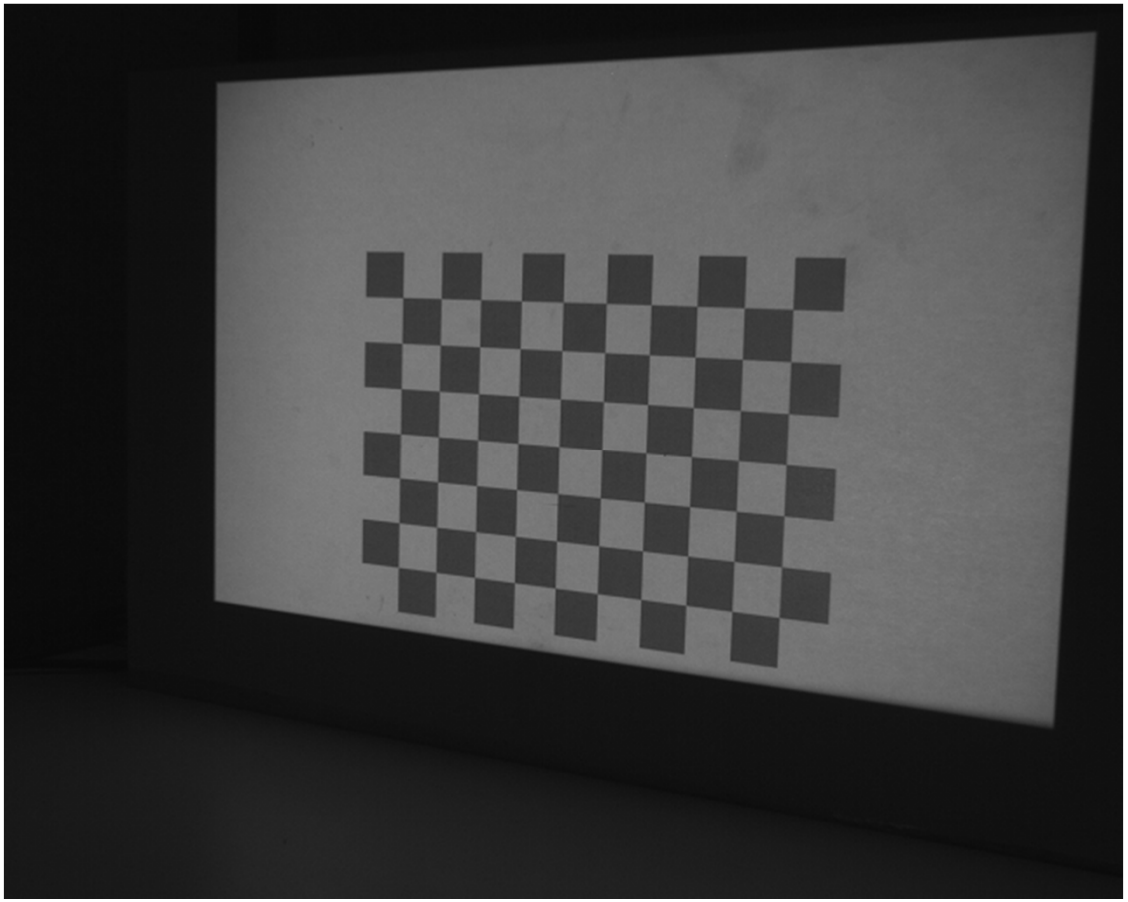


  - Part of the projected image falls off of the calibration board
    - This will cause squares to be missing on the projected chessboard calibration pattern



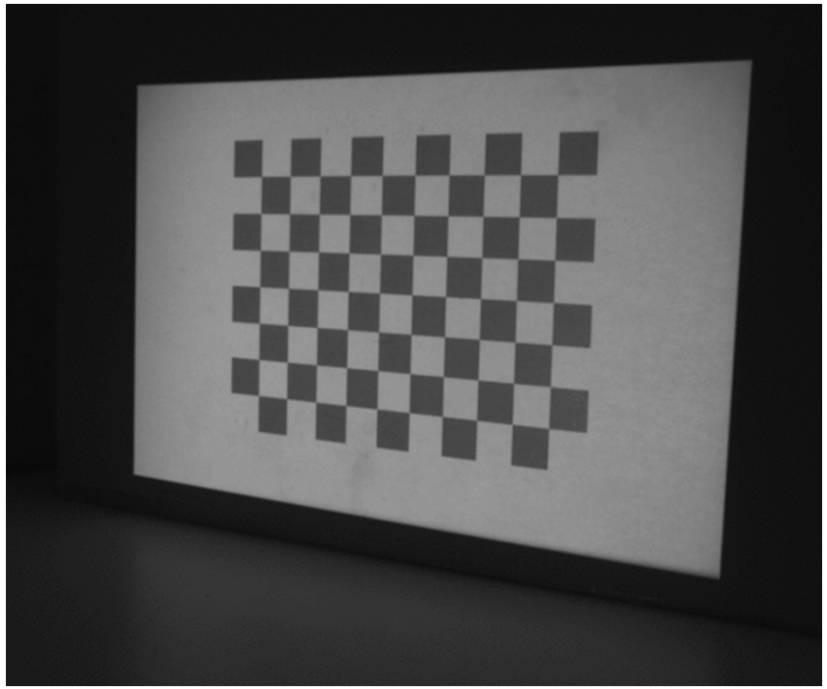
Calibrating the System – Example Images

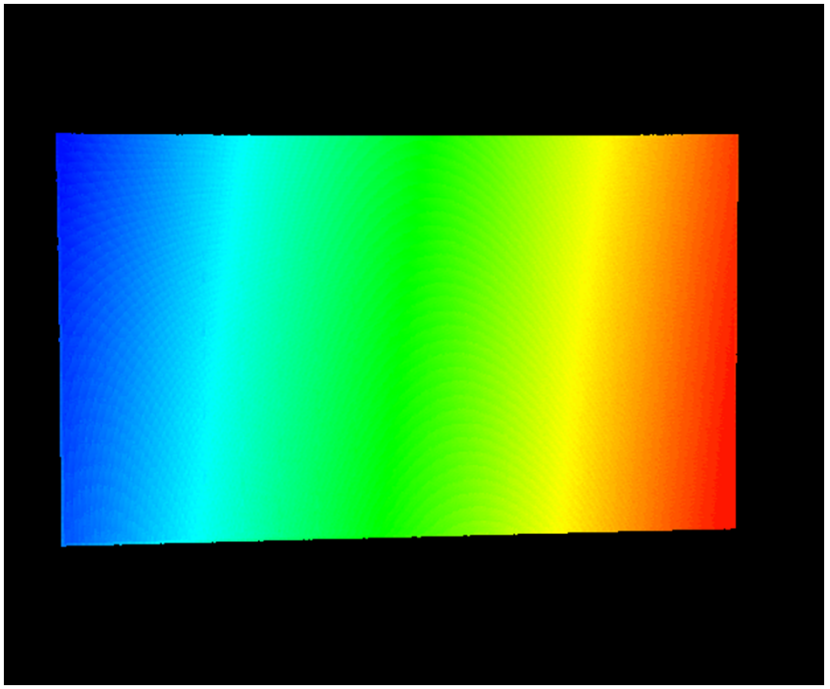
- Calibration image examples
- Measured projector reprojection error = 0.325859



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