# Three-Dimensional Test Target for Illuminant Analysis

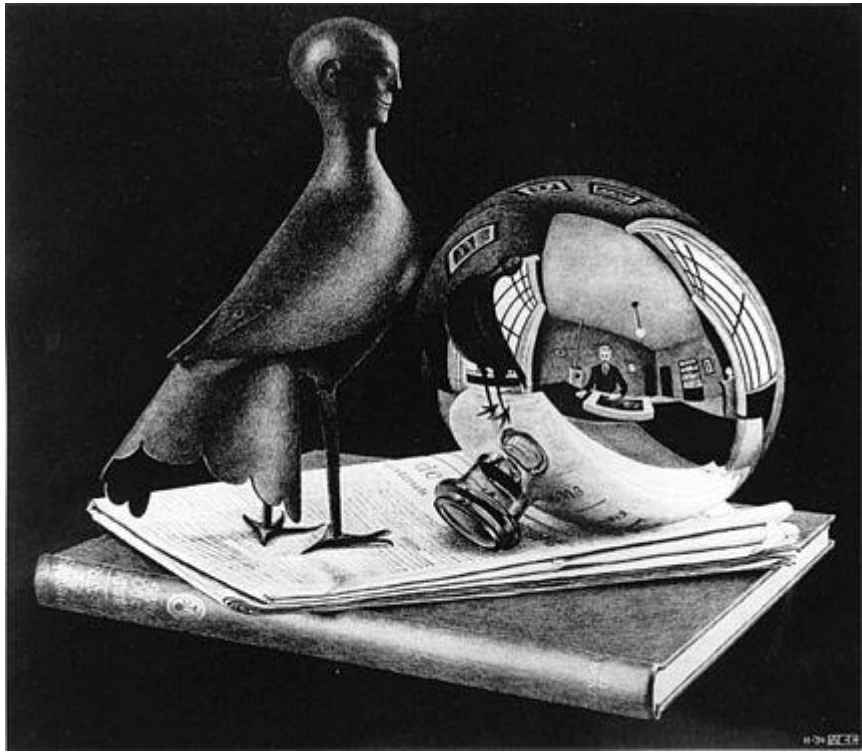
N. Moroney, I. Tastl & M. Gottwals
HP Labs
24th IS&T Color Imaging Conference
November 2016

# Outline

- Related research
- Sinusoidal chart design
- Experimental analysis
  - Strongly directional
  - Diffusely illuminated
  - Relative diffuseness
  - Variation in azimuth
  - Multiple illuminants
- Conclusions

# Related Research

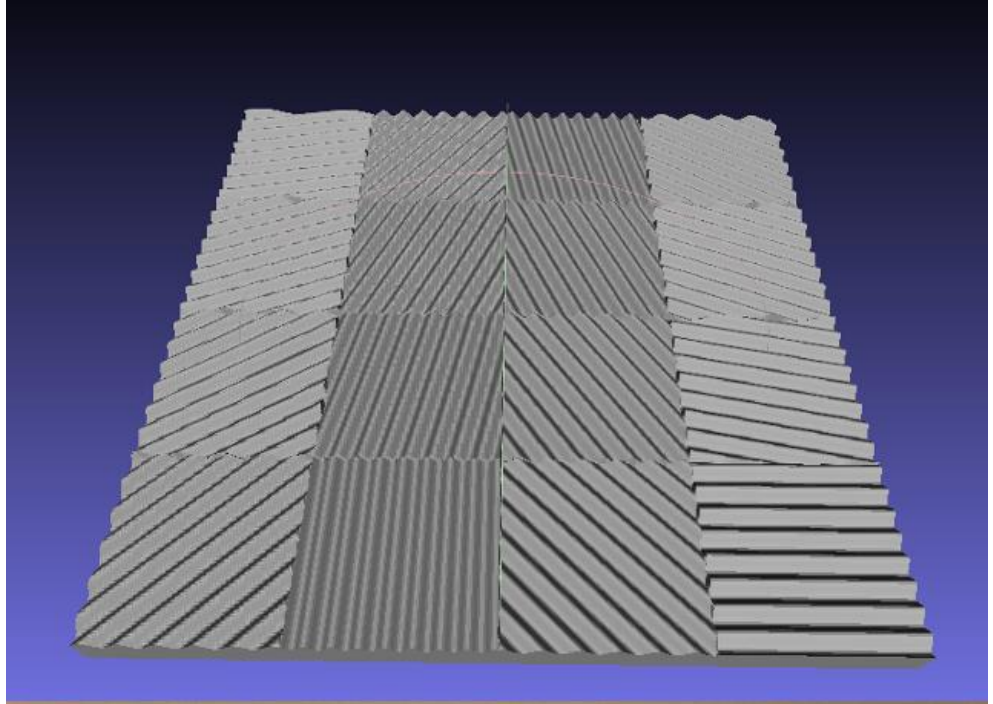
- Spherical mirrors
  - Zhang & Yang (2001) & others
- Chromatic illumination
  - Finlayson & Powell (2014)
- 3D printed optics
  - Willis (2012)
- Sun dial design
  - Vincent (2008)
- Chart-based color correction
  - Marguier, Bhatti, Baker & Süsstrunk (2009)
- Basic question
  - How to use images to quantify the illumination conditions?



*Still Life with Spherical Mirror*, M.C. Escher (1934)
Source: en.Wikipedia.org

# Sinusoidal Chart

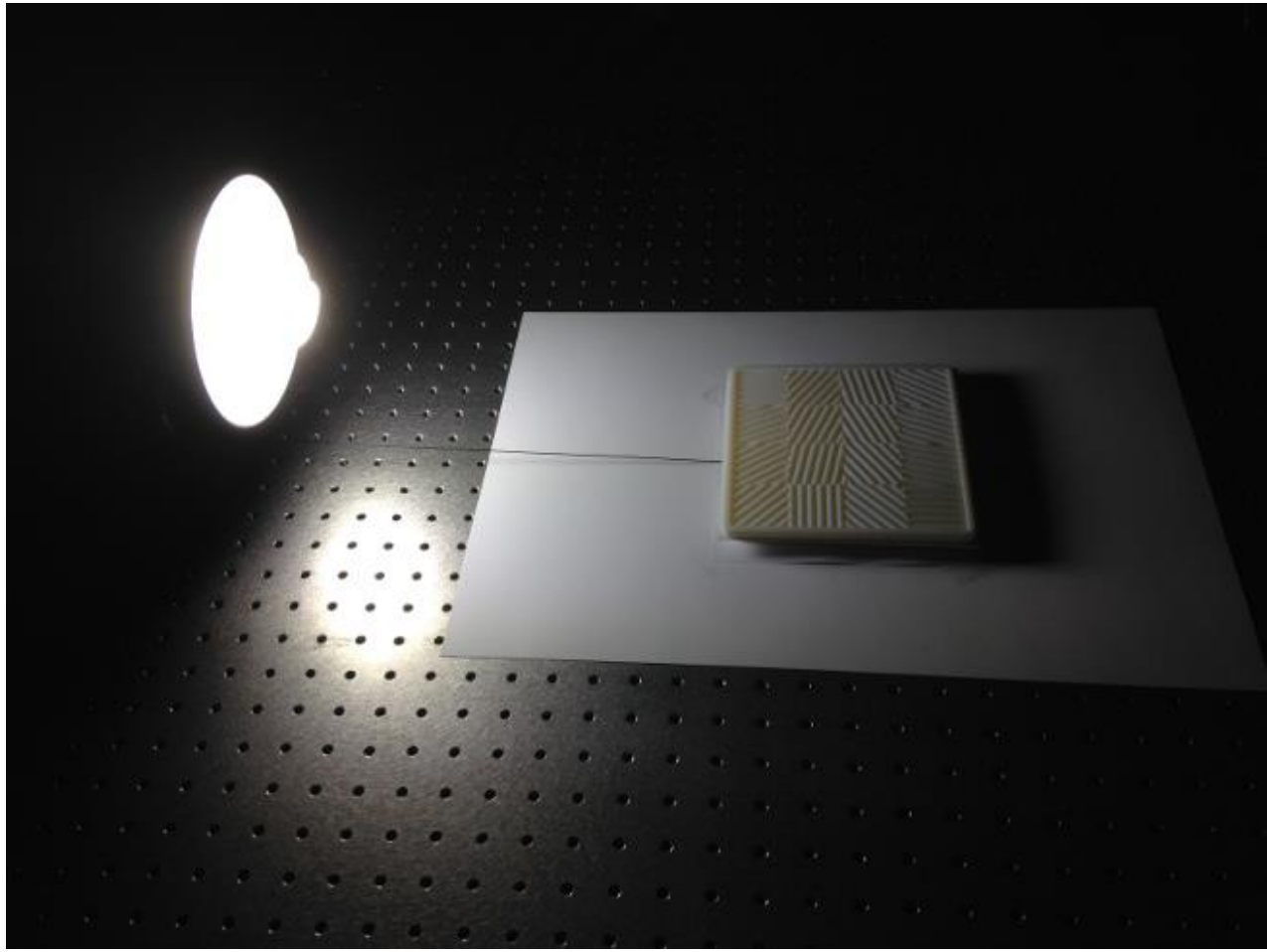
- A 4x4 array of 3D sinusoids
- Sample angles every 11.25 degrees
- 3D printed
- 15 by 15 by 0.7 cm*
- Sinusoids had amplitude of 3 mm and frequency of 5 mm
- Transform direction of illumination to contrast of imaged patch



- If there are no questions after the presentation I will ask myself to estimate the size the chart should be if it was to be constructed on the surface of the moon.

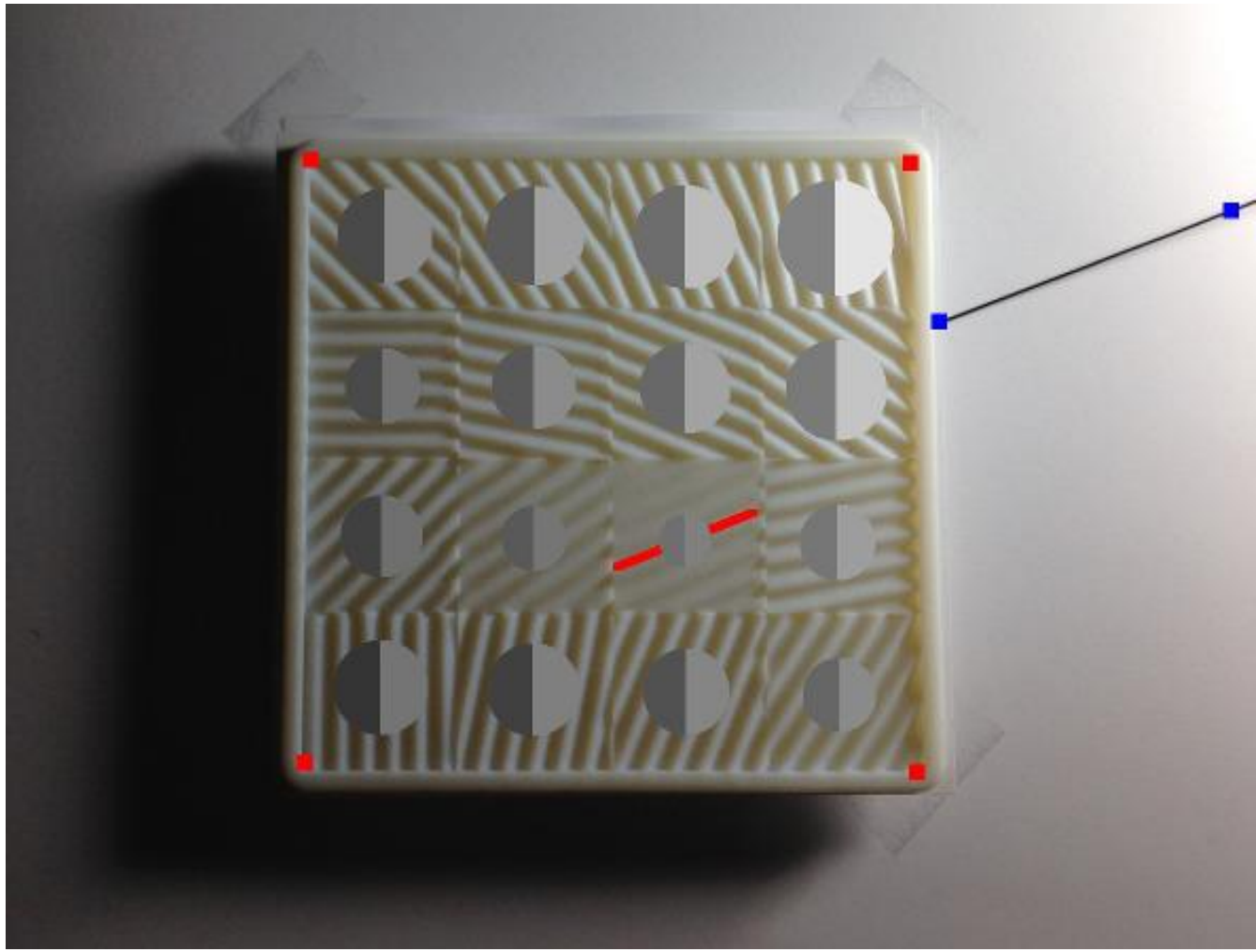
# Experimental Testing: Directional

- Chart on white backing on optical bench
- Guide wire (black)
  - 35 cm from chart center
  - Basis of the “ground truth” angle
- Strongly directional illumination
  - D55 & 30 watts
- Sample 0 to 90 degrees every 10 degrees



# Analysis: Directional Illumination

- Chart corners (red)
- 5th and 95th percentile luminance per patch
  - Shown as scaled circles
- Ground truth is guide wire (blue)
- Estimated orientation are red lines
  - Lowest contrast patch
  - Least difference between 95th & 5th percentiles
- Average absolute error was 6.6 degrees

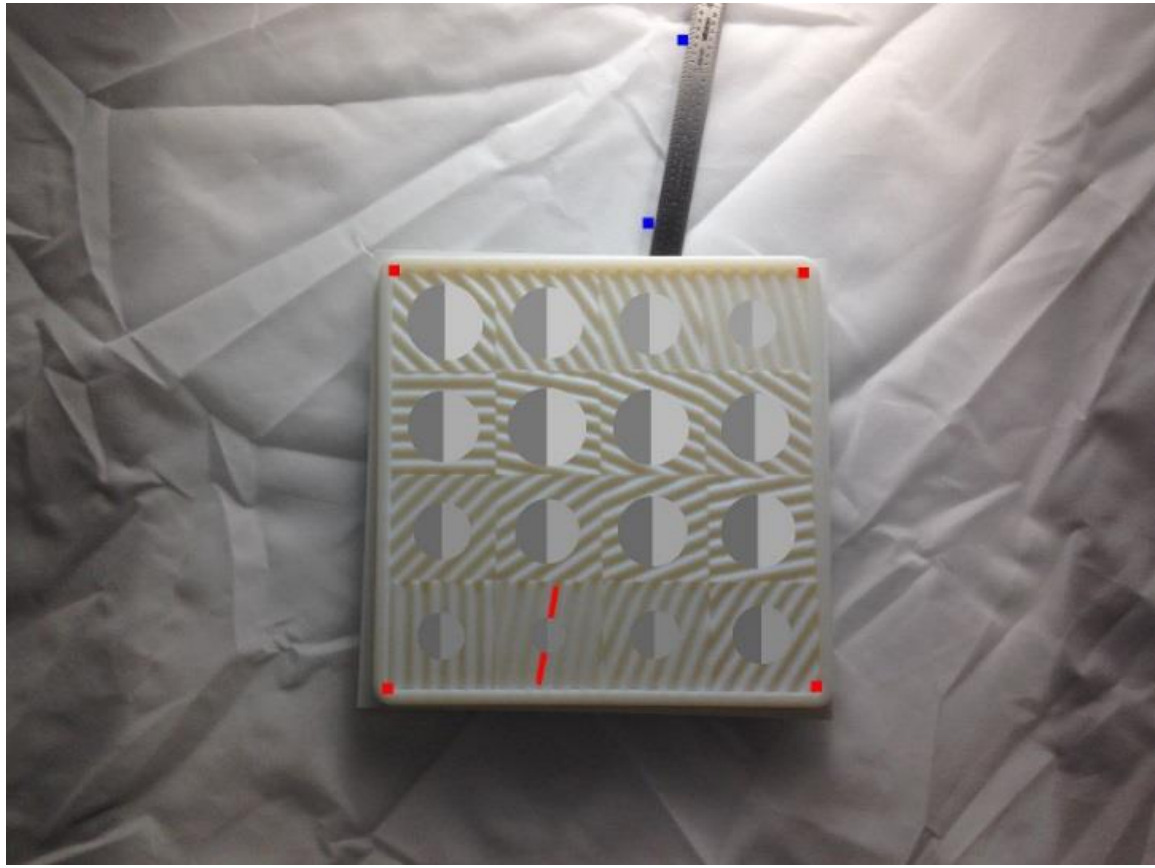


# Experimental Testing: Diffuse Illumination

- Identical to directional but, inside light tent
  - Five sided fabric light tent
- Ruler shown positioned over ground truth
- Repeat the capture and analysis steps

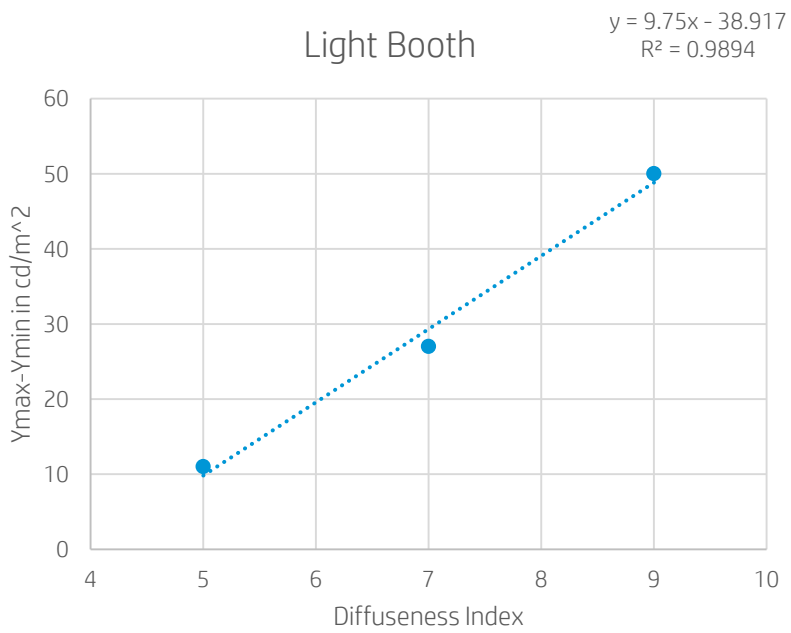
# Analysis: Diffuse Illumination

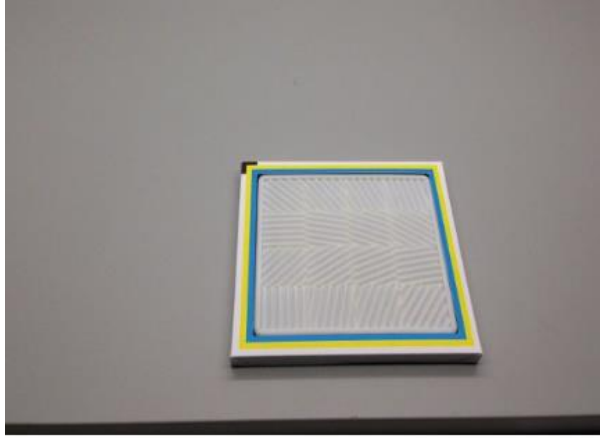
- Has no impact on estimation of angular orientation
  - Average absolute error of 5.1 degrees
- Similar accuracy to the directional illumination
- Visualization similar to previously shown

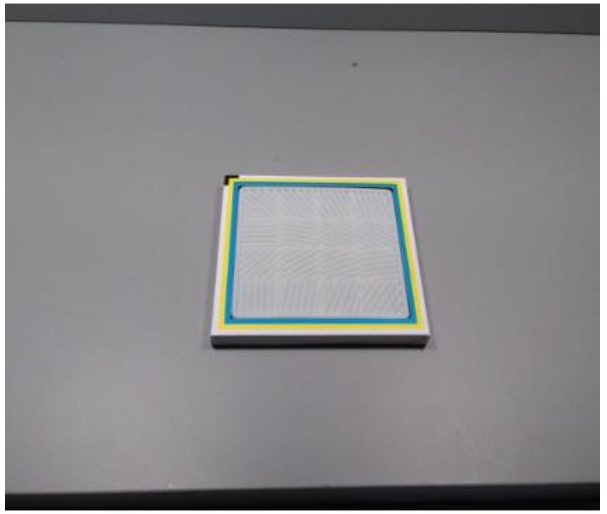


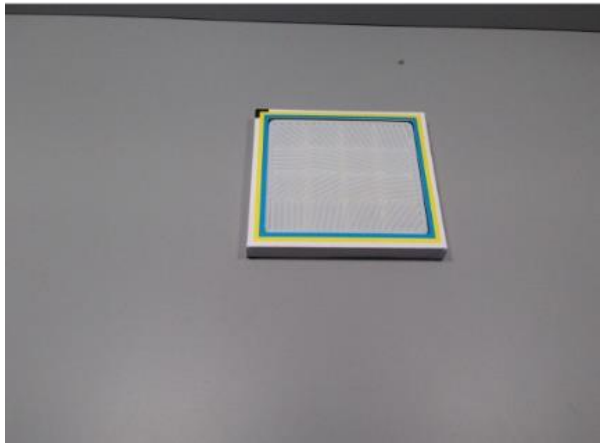
# Quantifying Relative Diffuseness

- Photograph chart at multiple locations in bottom of light booth
- In this case, use the minimum luminance difference as “diffuseness index”
  - That is location of chart with minimum contrast difference is the most diffuse location
- Ground truth with Minolta CM-100 luminance measurements
  - Solid white reference, but compute luminance range
- Correlation of measurements with estimates $R^2$ of 0.989



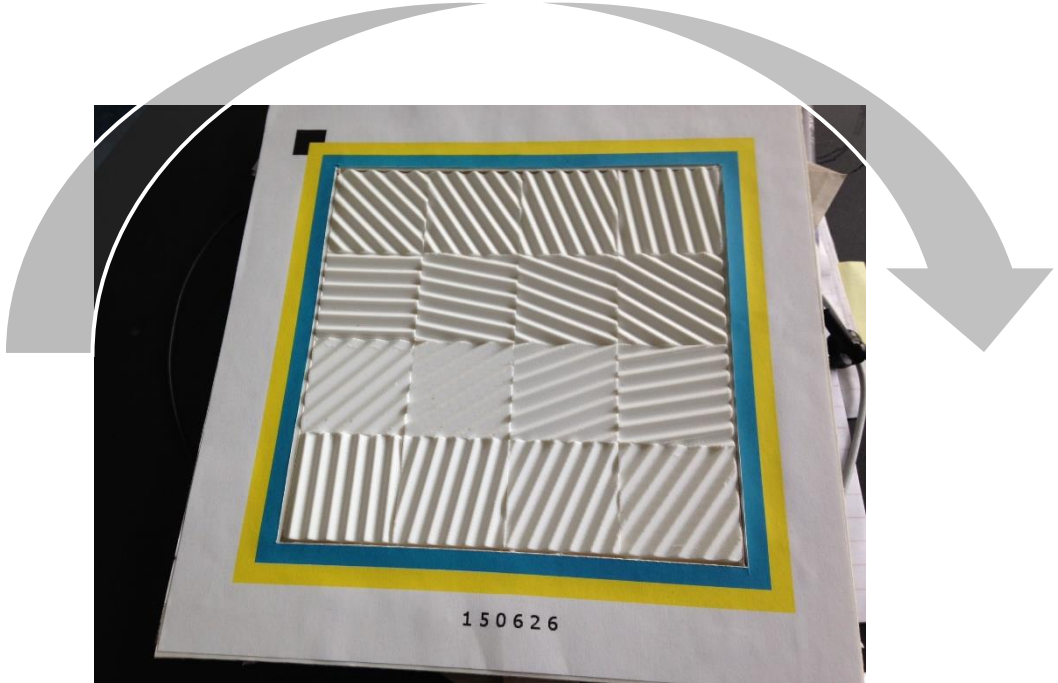







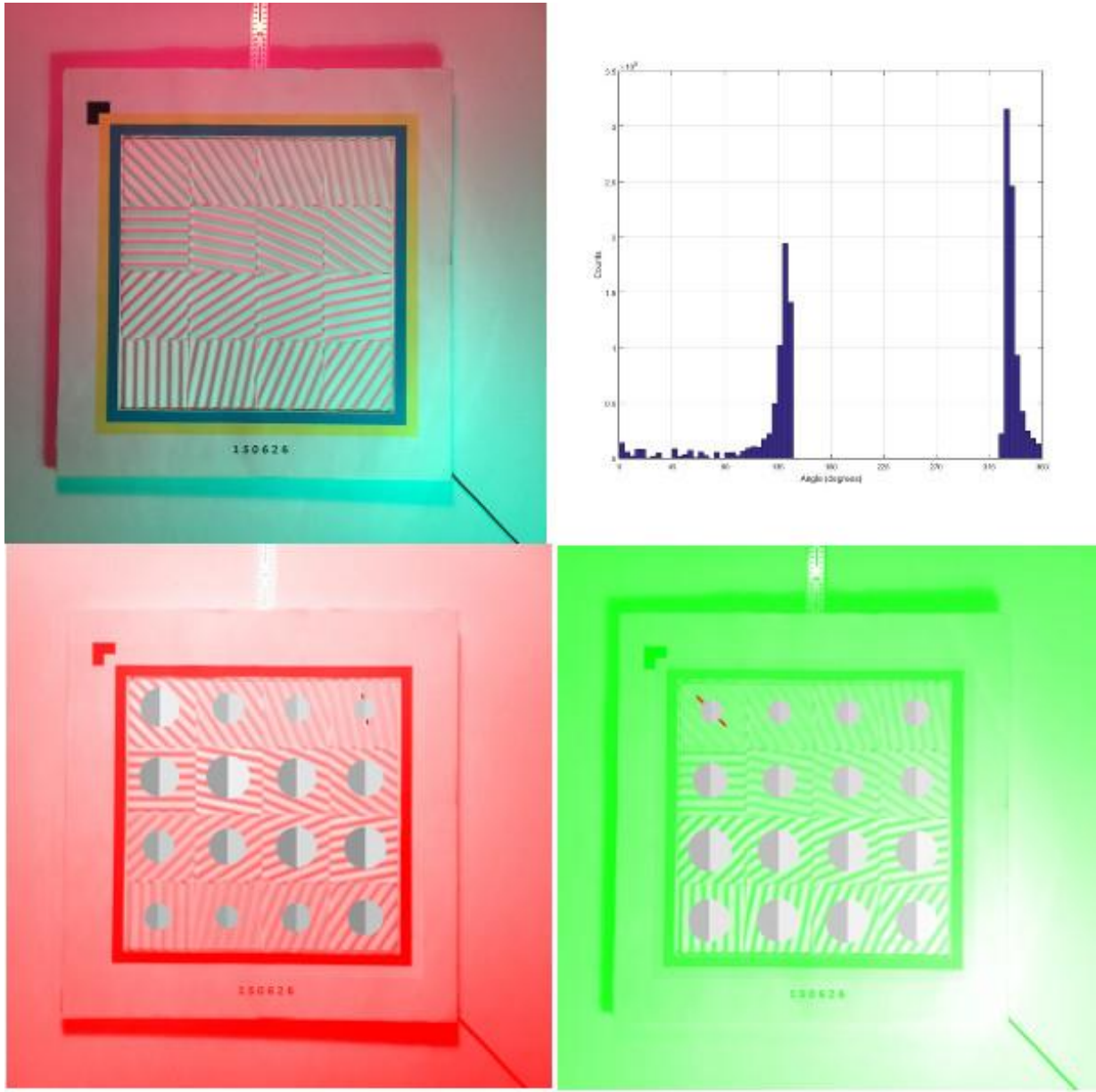
# Variation in Azimuth

- If previous angular estimates are “polar” or a single angle with respect to the chart in the image coordinates, what is the effect of varying the angle with respect to the plane of the chart?
- In the extreme what happens if the illuminant is behind the camera?
- Repeat analysis from the directional and diffuse illumination
- Over a range of 40 to 80 degrees in steps of 10 degrees, robust up to 70 degrees
  - And at 80 and above approaches a case where perhaps the diffuseness index is more appropriate…



# Two Illuminants

- Given a chromatic red & green (upper left), how to analyze?
- Compute hue histograms (upper right) for chart pixels
- Use the peaks to compute custom color separations
- Lower left shows the “red” channel
- Lower right shows the “green” channel
- Treat as monochrome & repeat previous analysis
- Comparable performance to single illuminant



# Discussion

- OK but what are the applications?
  - Configuration of controlled photographic illumination – especially for more diffuse
  - Analysis of multi-illuminant scenes
  - Application to computational camera calibration
  - Also helpful to see where virtual illuminants are, such as when using 3D model or STL preview software
- Accuracy and the discrete angular sampling, 16 patches used for convenience
- Mostly planar form factor is also nice, fits in laptop bag
- Patches were rectified or perspective correction was applied before computations

# Conclusions

- The introduction of known three dimensional structure into test targets is a promising area for the design of targets for evaluation of image capture systems.
- Use of 3D printed sinusoids at varying angular orientations provides several estimates of scene illumination, such as angular orientation and relative diffuseness
- Anticipate additional designs and experimental applications
- ( and as aside, first time the author was able to go from concept (via software) and then directly to 3D print – exciting to be able to go from concept to physical prototype )