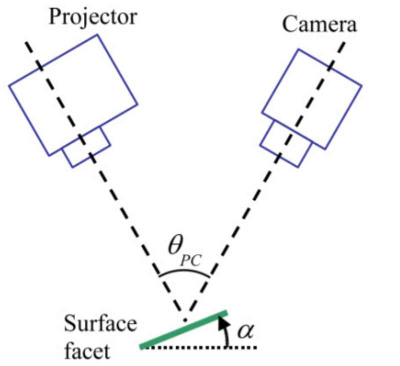
Agenda

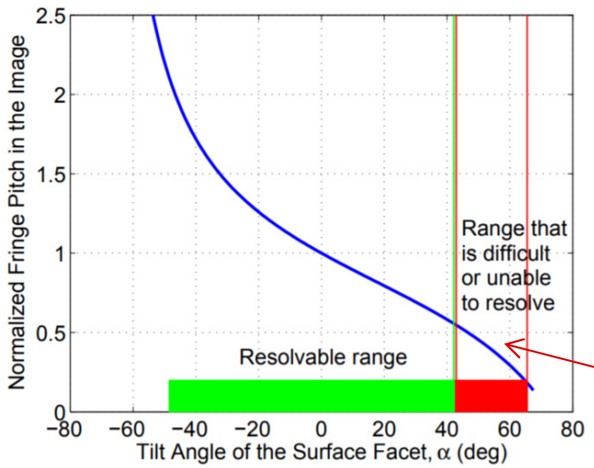
- DLP 3D scanning Introduction
- DLP 3D scanning SDK Introduction
- Advance features for existing SDK
  - Increasing scanning speed from 20Hz to 400Hz
  - Improve the lost point cloud
- **3D Machine Vision Applications: Performance of adaptive patterns**
- DMD Performance and Stability for 3D Machine Vision Applications

Performance of adaptive patterns

Relationship between the local fringe pitch and the normal direction of surface facet

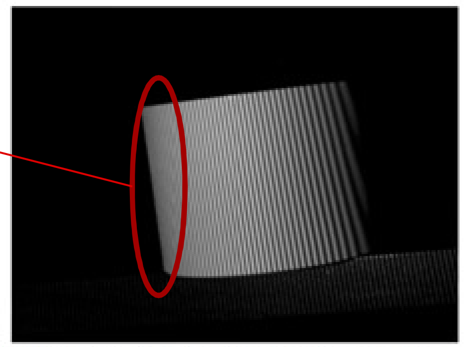


(a) Schematic diagram of the measurement setup



(b) Fringe pitch vs. the tilt angle of surface facet, α

(a) Photograph of the plastic tube

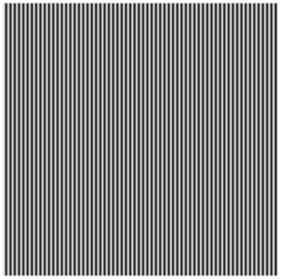


(b) Image acquired using fixed-pitch fringe pattern, $n_F = 125$

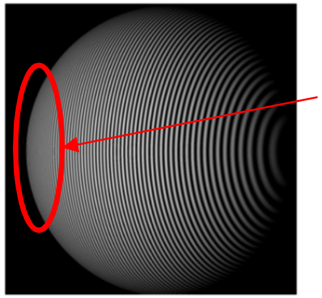
Source: Peng, T.: "Algorithms and Models for 3-D Shape Measurement using Digital Fringe Projections", Thesis, 2006, University of Maryland, Dept. Mechanical Eng.

Performance of adaptive patterns

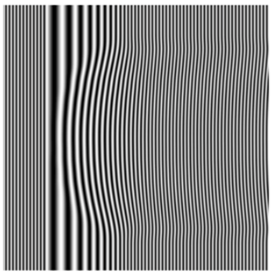
Pattern | **Camera Capture**



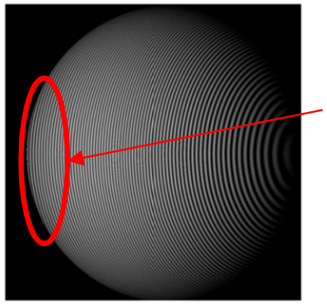
Fixed pitch pattern



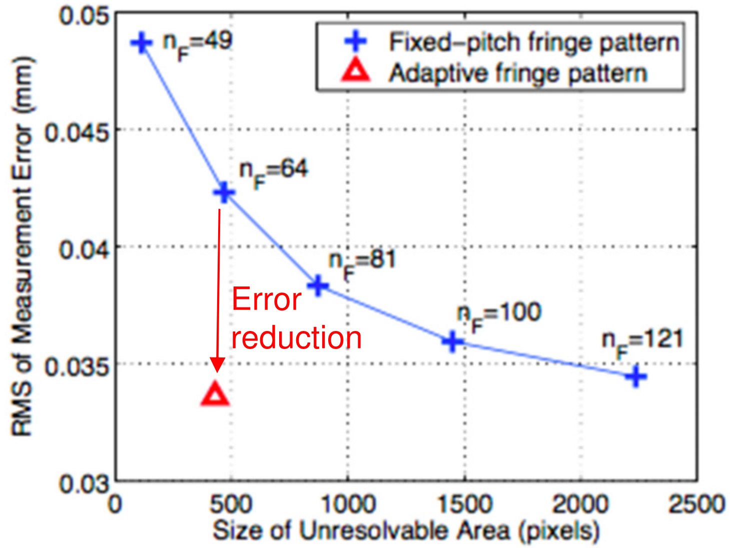
Unresolvable area due to fine pitch pattern



Variable pitch pattern



Resolvable area due to variable pitch pattern



Source: Peng, T.: "Algorithms and Models for 3-D Shape Measurement using Digital Fringe Projections", Thesis, 2006, University of Maryland, Dept. Mechanical Eng.

Performance of adaptive pattern

- Wrong intensity would generate wrong phase map

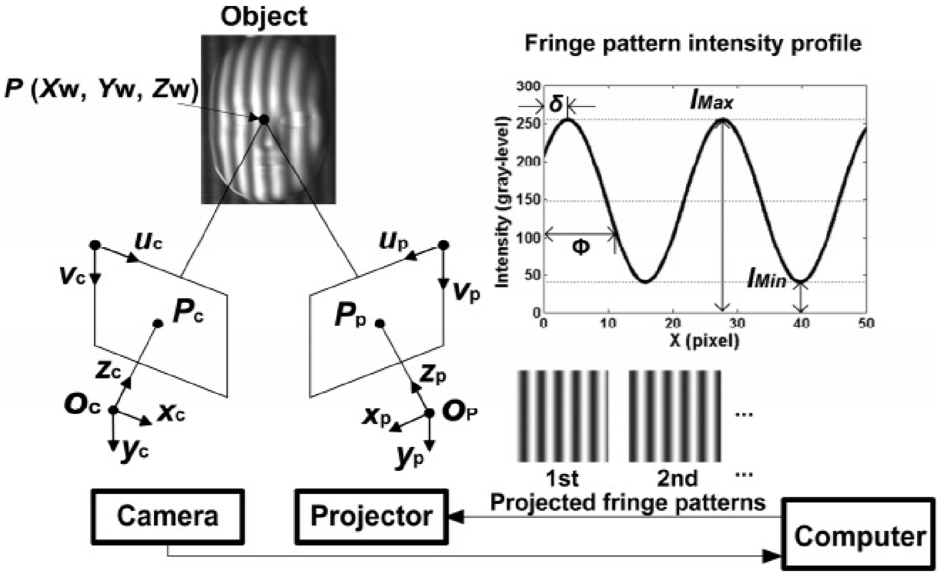


Fig. 1. Configuration of a camera-projector system for 3D surface-shape measurement showing a fringe-pattern intensity profile.

$$\Phi(x_c, y_c) = -\tan^{-1}\left(\frac{\sum_{i=1}^{N} I_i(x_c, y_c)\sin\delta_i}{\sum_{i=1}^{N} I_i(x_c, y_c)\cos\delta_i}\right)$$

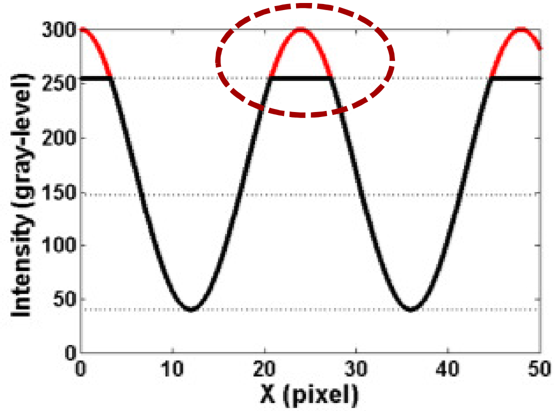


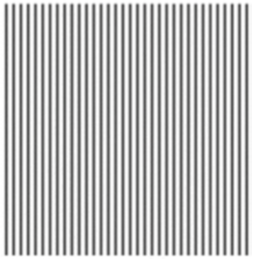
Fig. 2. Truncated fringe-pattern intensity profile (flat regions) due to image saturation.

Source: "Adaptive fringe-pattern projection for image saturation avoidance in 3D surface-shape measurement", Optics Express, 2014, Vol. 24, Issue 7, pp. 7703-7718

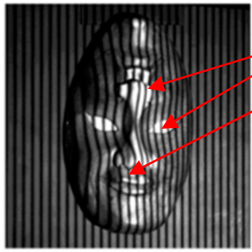
Performance of adaptive pattern

Face Mask Object

Pattern



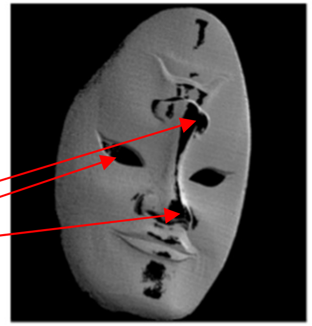
Camera Capture



Highly reflective surface causes camera saturation

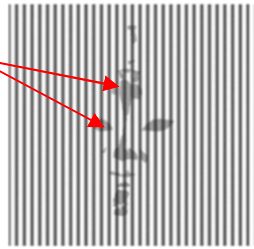
Leading to errors on scan

3D Point Cloud



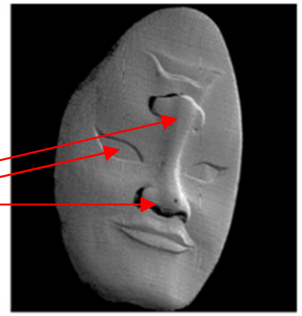
Adapted Pattern

Add masking areas to pattern



Camera not saturated

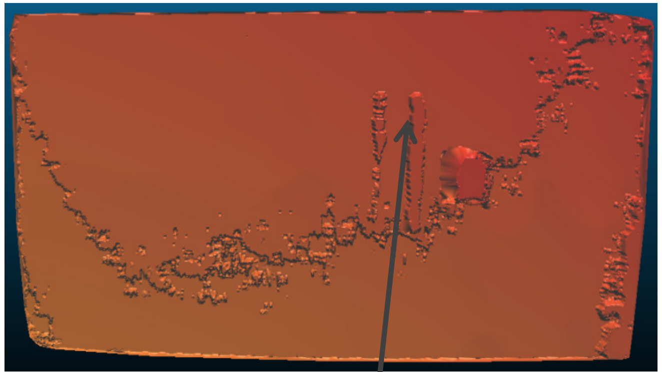
Reducing errors on scan



Source: “Adaptive fringe-pattern projection for image saturation avoidance in 3D surface-shape measurement”, Optics Express, 2014, Vol. 24, Issue 7, pp. 7703-7718

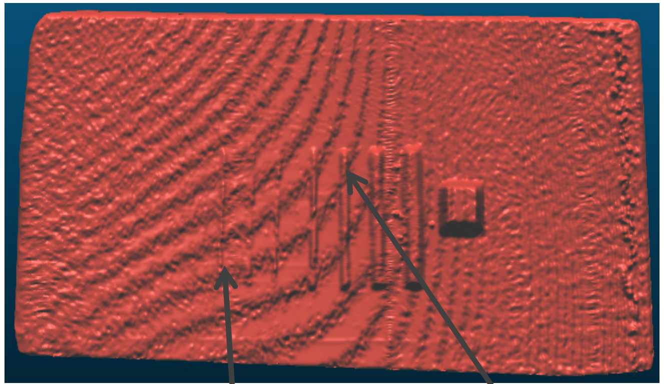
Spatial and Depth Resolution

Point Cloud with Fixed Pattern



Spatial Resolution
~9.9-13mm

Point Cloud with Multiple Pattern



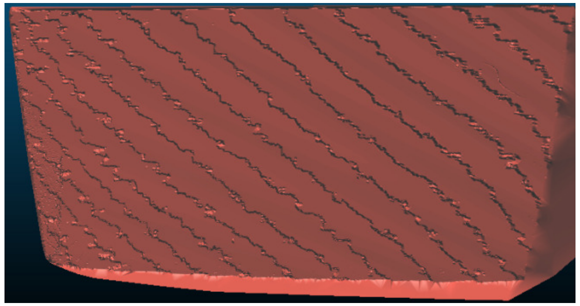
Spatial Resolution
~0.65 mm

Depth Resolution
~6 mm

- Spatial Resolution is a bigger bottleneck
- Spatial Resolution cannot be improved by sub-pixel accurate schemes
- Depth Resolution can be improved with sub-pixel schemes

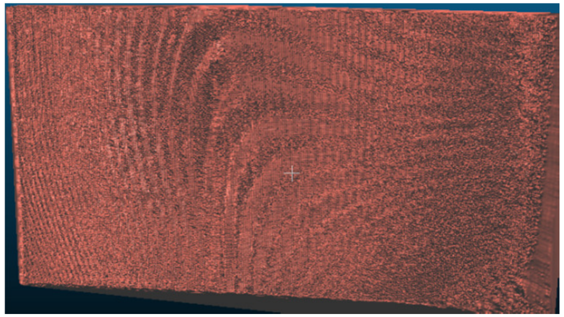
Accuracy Analysis on flat surface

Point Cloud with Fixed Pattern



- Window matching averages disparity calculation which reduces noise in depth calculation on smooth objects
- Robust to changes in ambient light due to averaging in windows

Point Cloud with Multiple Pattern



- Each point is decoded individually, thus susceptible to noise.
- Ambient light reduces SNR and increases susceptibility to noise

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- Çeliktutan, O., Ulukaya, S., Sankur, B.: *“A comparative study of face landmarking techniques”*, EURASIP Journal on Image and Video Processing, 2013, 2013:13
- NIST Face Projects

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- **DMD Performance and Stability for 3D Machine Vision Applications**

DMD Performance and Stability

Brightness efficiency over DMD lifetime is constant

– The DMD is a bi-stable device with only two stable positions (on and off). These positions are defined by the location of the spring tips upon which the mirrors rest when in the on or off state. These spring tip locations and lengths do not change over time, therefore the DMD tilt angle is very repeatable

– If the DMD operating temperature is below 45℃, testing shows the DMD should see no noticeable change to mirror tilt angle over the life of the DMD.

– Averaging a 50/50 duty cycle also helps maintain mirror tilt angle over the life of the DMD. Very important if operating at temperatures above 45℃

– Illuminating the DMDs using wavelengths above 420 nm, testing has shown no measureable DMD reflectivity degradation over the life of the DMD.

DMD Performance and Stability

<u>8 bit Grey Scale Linearity</u>

- The DMD has little to no effect on the linearity of the gray scale. Due to its fast micro mirror transition time and bi-stable operation.
- The gray scale linearity is predominantly determined by the rise and fall time of the LED solid state illuminators.
  - Slow rise and fall times of the illuminators will add errors in different proportions to the bit weights.
  - Calibration of the LED pulse durations to provide linear gray scale at time t=0
    - Integrating the illumination for each bit position and adjusting LED turn-on and turn-off times.
  - LED degradation over time is the dominate drift
- The DMD should have no impact to gray scale linearity over the life of the system

Maximizing DMD Mirror Useful Life

DMD micro mirrors should be cycled as much as possible.

- Individual DMD mirror duty cycles vary by application as well as the mirror location on the DMD within any specific application. DMD mirror useful life are maximized when every individual mirror within a DMD approaches 50/50 duty cycle..
- A suitable way to maximize DMD mirror useful life is to provide a 50/50 pattern sequence to the DMD whenever as possible.
  - This can be done whenever the system is idle, the illumination is disabled, between sequential pattern exposures, or when the exposure pattern sequence is stopped for any reason. The 50/50 duty cycle continuously flip the DMD mirrors between the on and off states.
  - See the datasheets for the DLPC900 how this can be achieved.

Thank You!