南京航空航天大學
NANJING UNIVERSITY OF AERONAUTICS AND ASTRONAUTICS

机器视觉测量与建模

Machine vision based surveying and modelling

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6. 双目立体视觉

6.1 双目视觉系统介绍

6.2 密集匹配

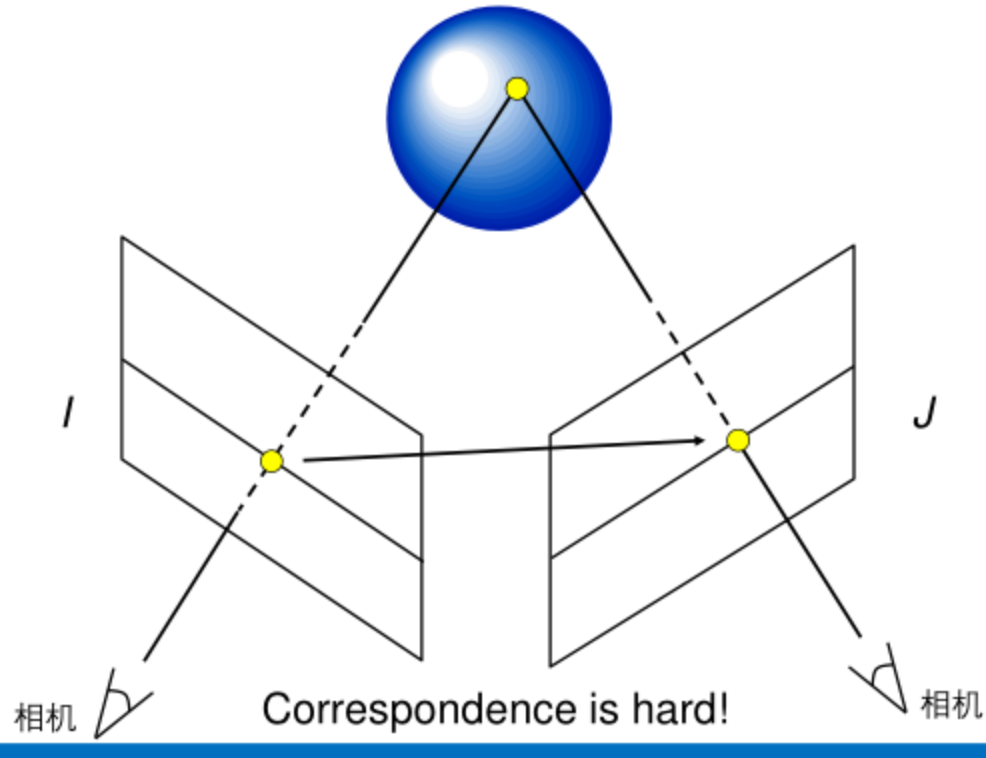
6.3 结构光三维成像

Structured Light

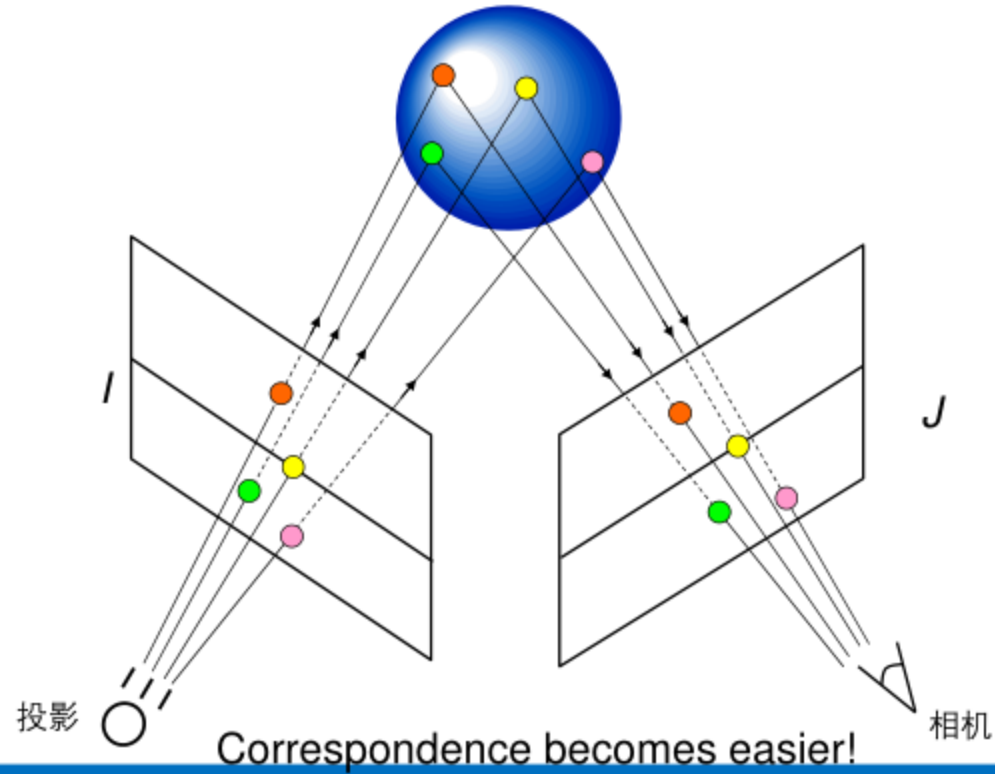
Ref: Slides from Levoy, Rusinkiewicz, Bouguet, Perona

播放

Stereo Triangulation

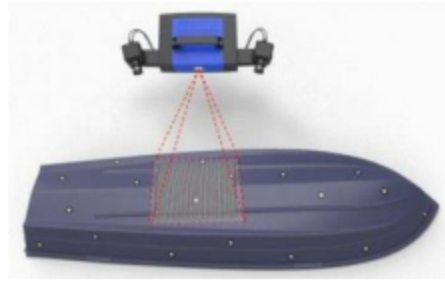


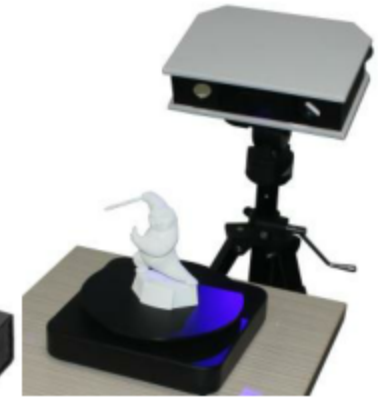
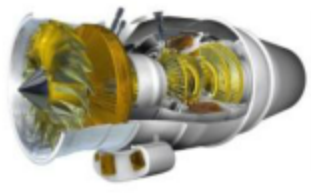
Structured Light Triangulation



Structured Light Reconstruction

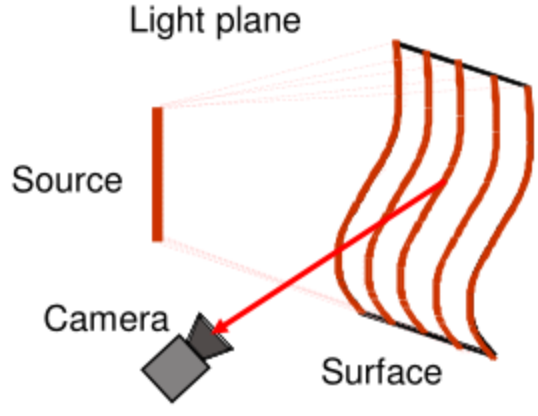
- Avoid problems due to correspondence
- Avoid problems due to surface appearance
- Much more accurate
- Very popular in industrial settings



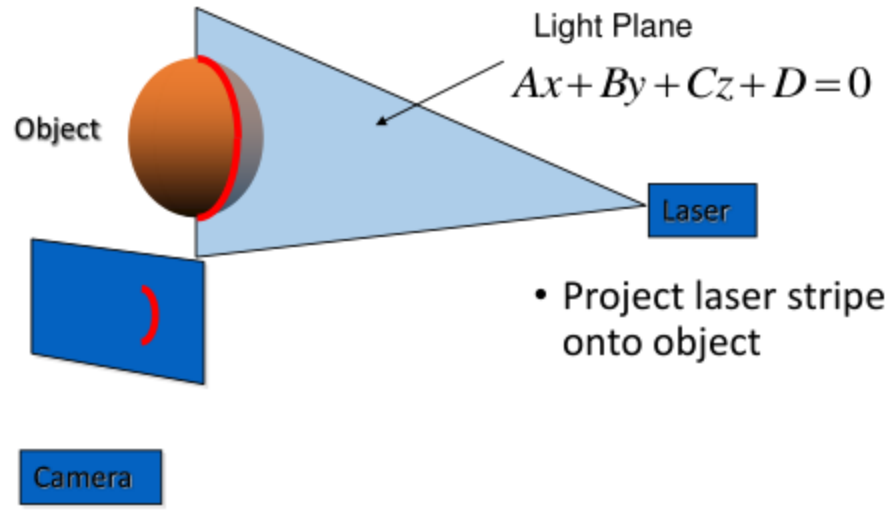

工业部件　2D图像　3D 模型　特性分析

Light Stripe Scanning – Single Stripe



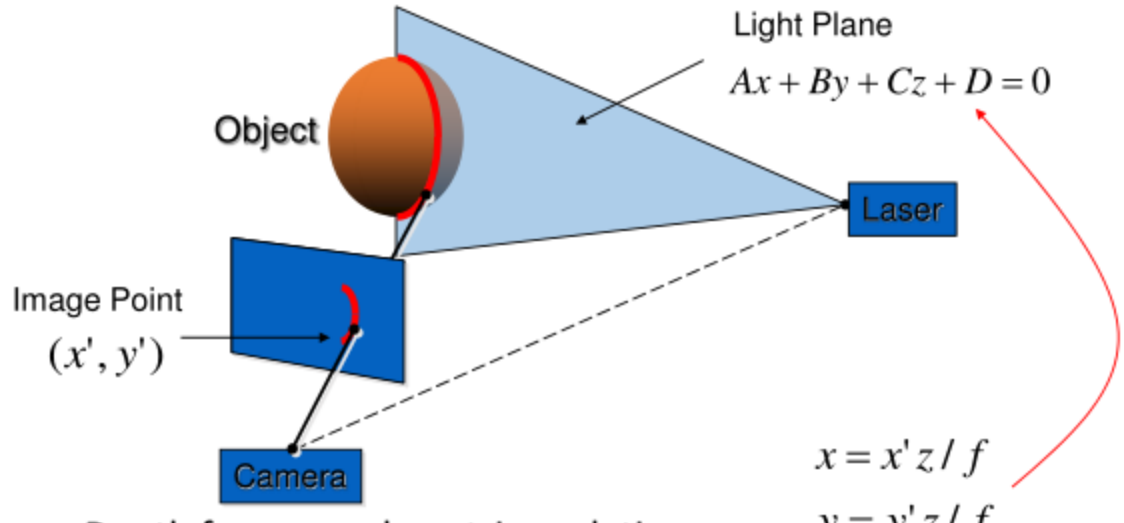
- Optical triangulation
  - Project a single stripe of laser light
  - Scan it across the surface of the object
  - This is a very precise version of structured light scanning
  - Good for high resolution 3D, but needs many images and takes time

Triangulation



- Project laser stripe onto object

Triangulation

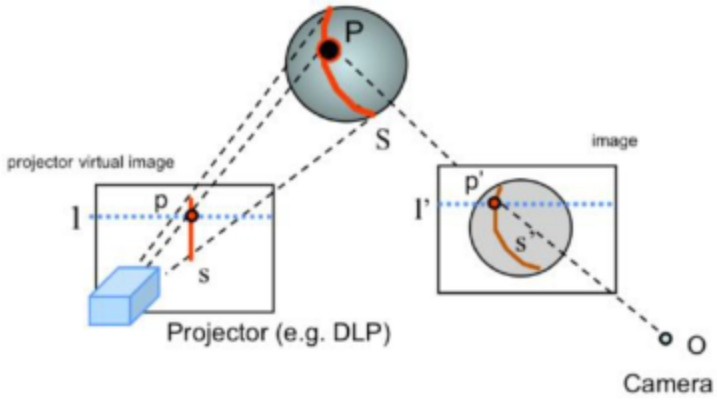


- Depth from ray-plane triangulation:
  - Intersect camera ray with light plane

$$z = \frac{-Df}{Ax' + By' + Cf}$$

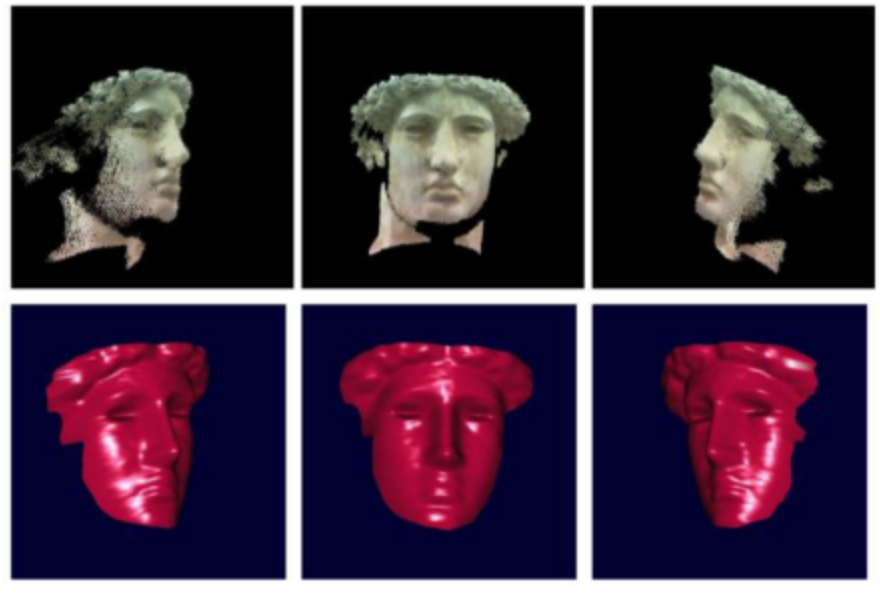
Light Stripe Scanning – Single Stripe

Use controlled ("structured") light to make correspondences easier



图像中同一扫描线上激光点之间的视差
决定了激光点在物体上的三维坐标

Light Stripe Scanning – Single Stripe

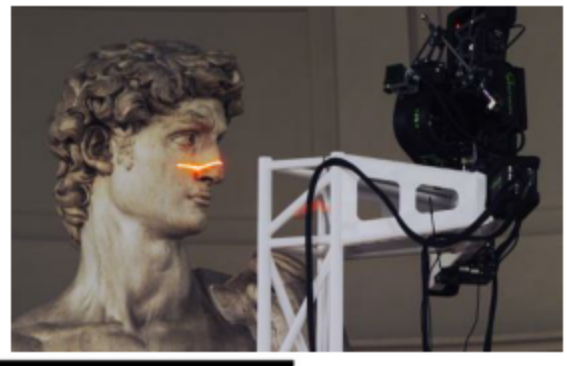


优点 + very accurate < 0.01 mm

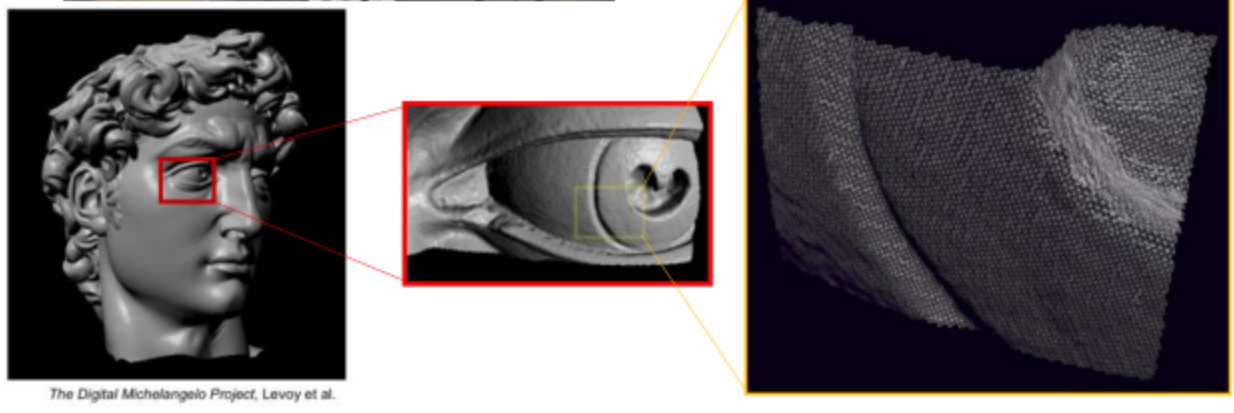
缺点 − more than 10sec per scan

Light Stripe Scanning – Single Stripe

Example: Laser scanner



Digital Michelangelo Project
http://graphics.stanford.edu/projects/mich/

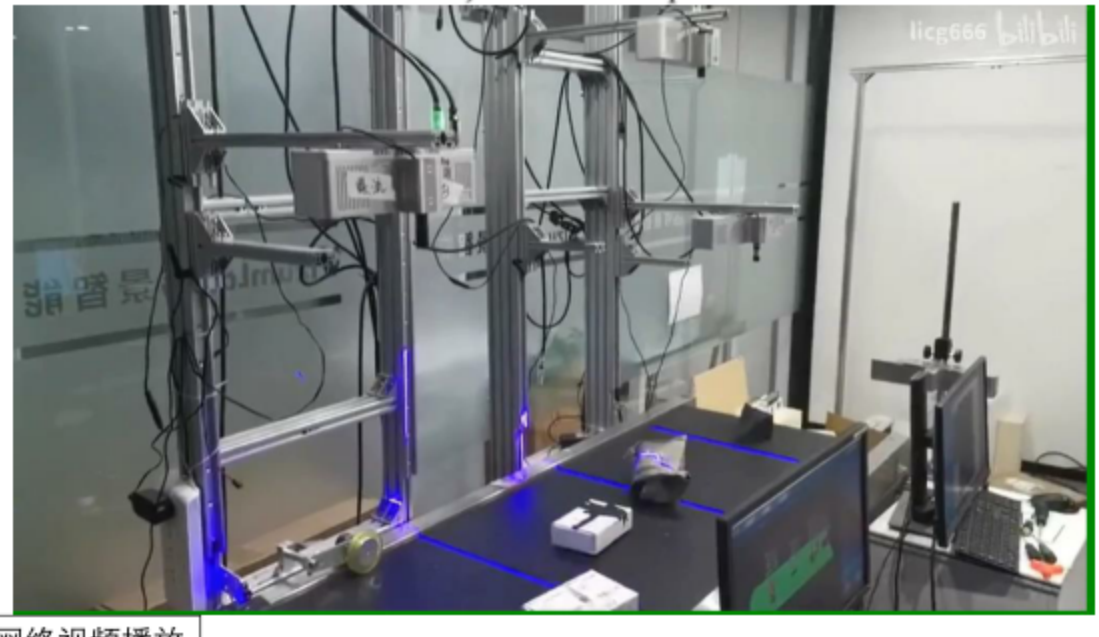


The Digital Michelangelo Project, Levoy et al.

Light Stripe Scanning – Single Stripe

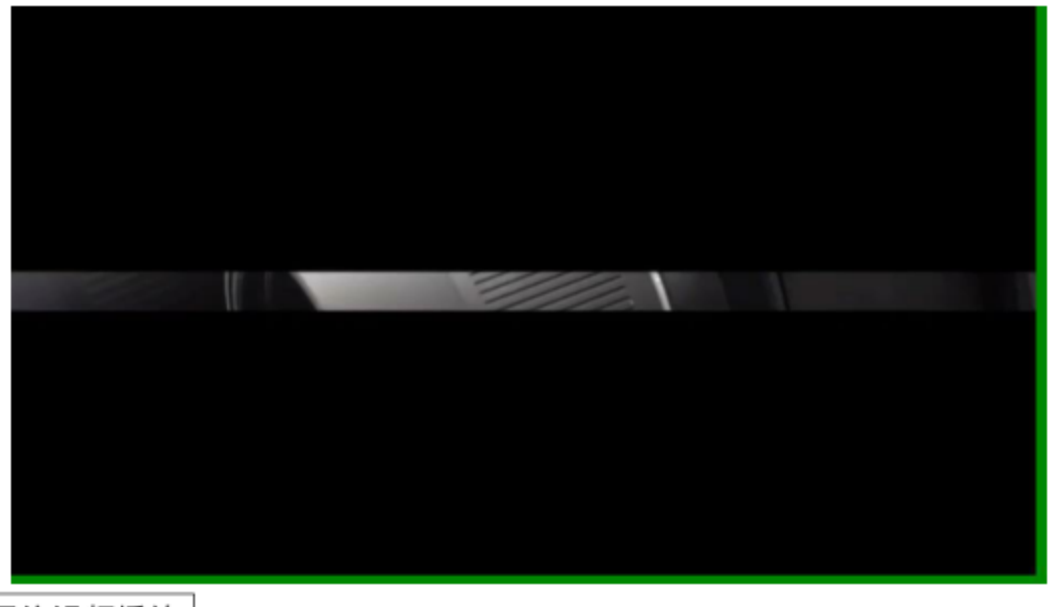
工业测量应用

Structured light is the projection of a light pattern (ray, plane, grid, encoded light, and so forth) under calibrated geometric conditions onto an object whose shape needs to be recovered.



网络视频播放

工业测量
应用

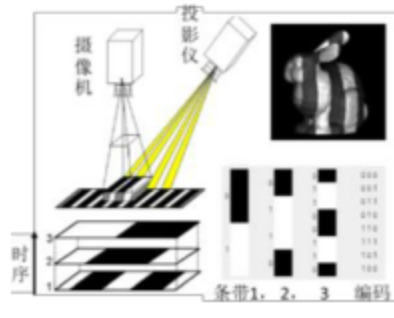


网络视频播放

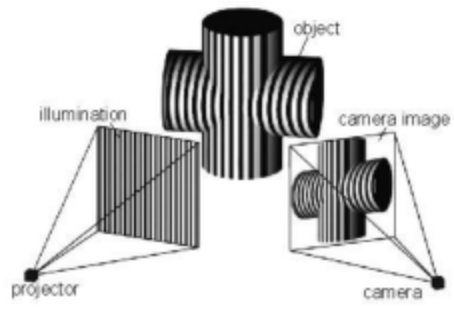
Faster Acquisition?

- Project multiple stripes simultaneously
- Correspondence problem: which stripe is which?

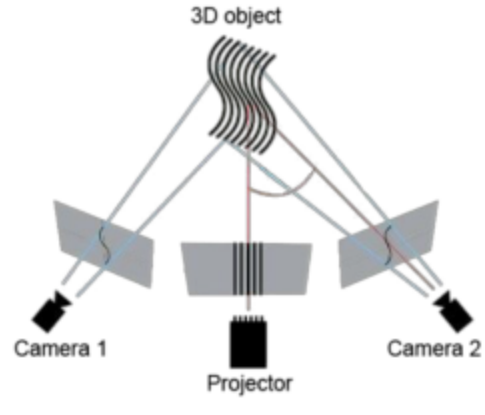
- Common types of patterns:
  1. Binary coded light striping
  2. Gray/color coded light striping

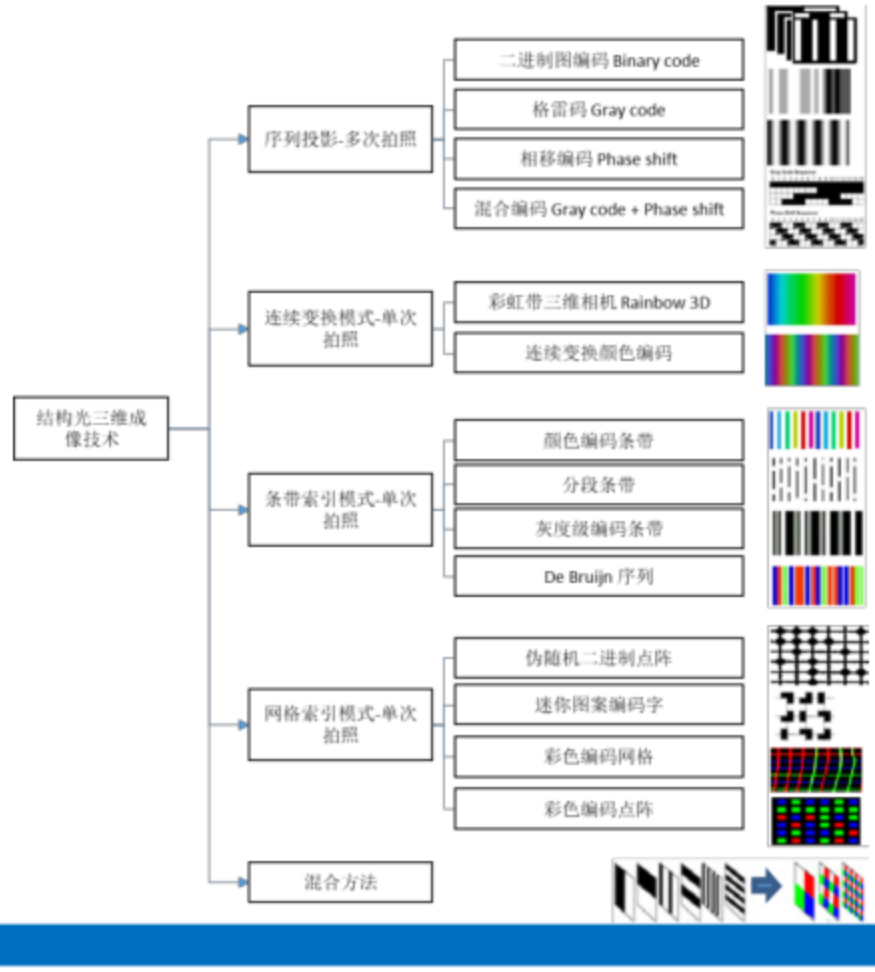


单相机组合



双单相机组合



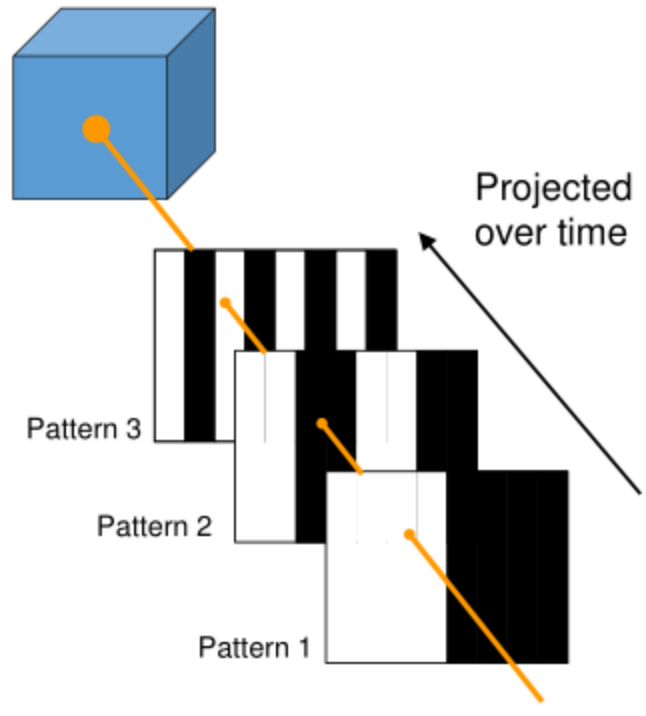


Binary Coding

Faster:

Example:

3 binary-encoded patterns which allows the measuring surface to be divided in 8 sub-regions



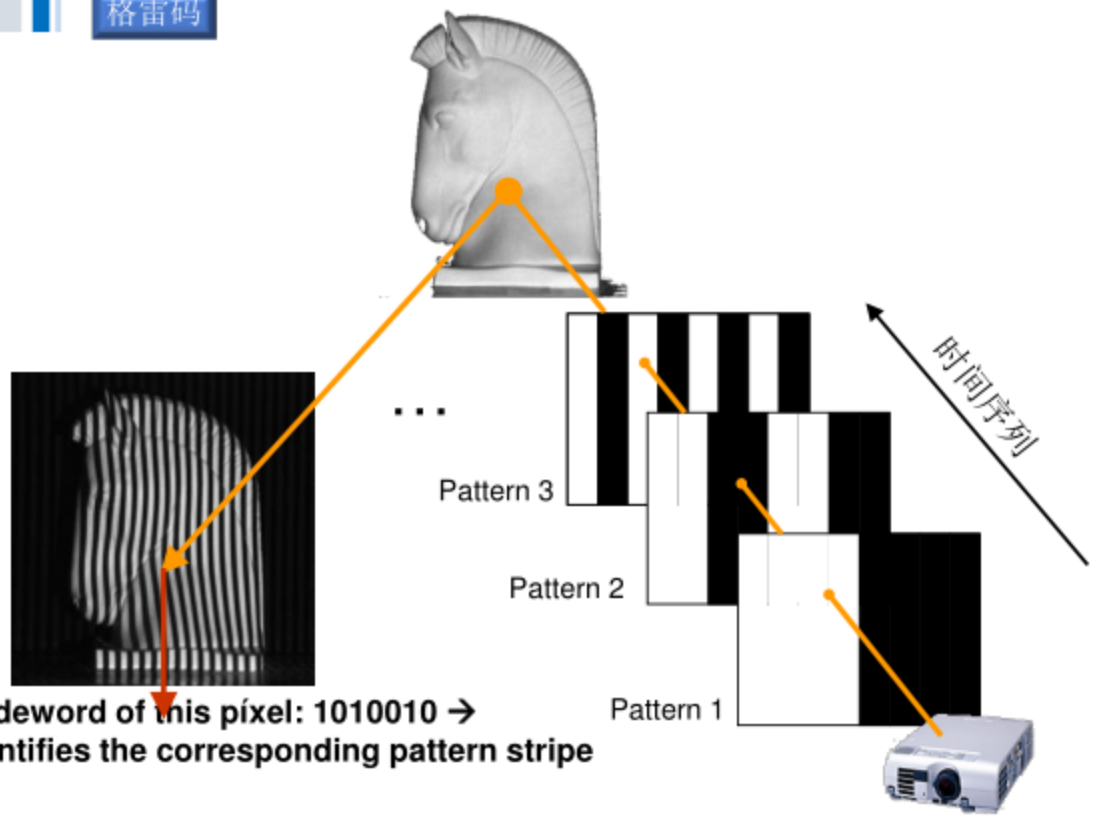
格雷码

- Assign each stripe a unique illumination code over time

格雷码的转换过程中只需进行一次位运算，而普通二进制码可能需要多次位运算来转换。

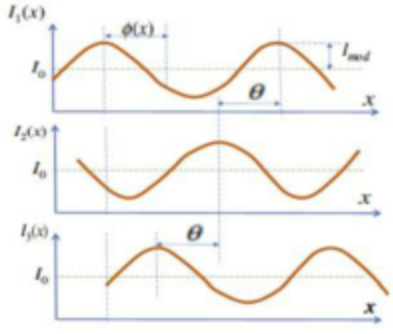
[Posdamer 82]

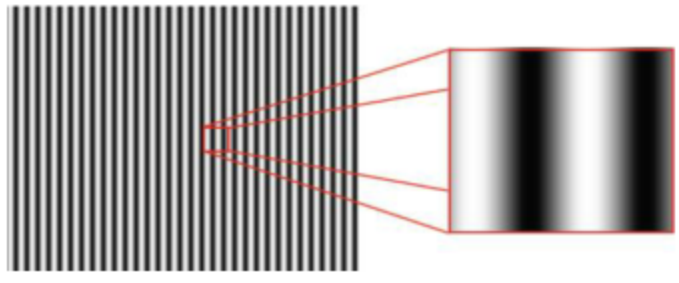
格雷码



Codeword of this pixel: 1010010 → identifies the corresponding pattern stripe

相移法编码





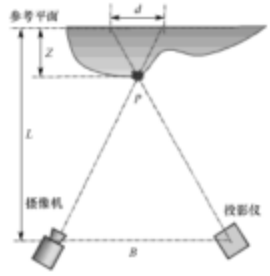
三个条带的影像强度

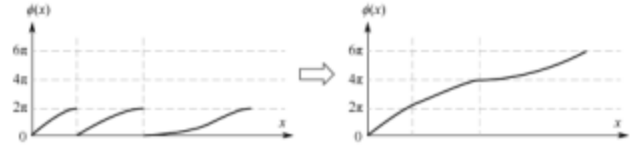
$$I_-(x,y)=I_{base}(x,y)+I_{var}(x,y)\cos(\phi(x,y)-\theta)$$
$$I_0(x,y)=I_{base}(x,y)+I_{var}(x,y)\cos(\phi(x,y))$$
$$I_+(x,y)=I_{base}(x,y)+I_{var}(x,y)\cos(\phi(x,y)+\theta)$$

$$\frac{I_- - I_+}{2I_0 - I_- - I_+}=\frac{I_{base}+I_{var}\cos(\phi-\theta)-I_{base}-I_{var}\cos(\phi+\theta)}{2I_{base}+2I_{var}\cos(\phi)-I_{base}-I_{var}\cos(\phi-\theta)-I_{base}-I_{var}\cos(\phi+\theta)}$$

推导见参考书

$$\phi'_{(0,2\pi)}=\arctan\left[\tan\left(\frac{\theta}{2}\right)\frac{I_- - I_+}{2I_0 - I_- - I_+}\right]$$

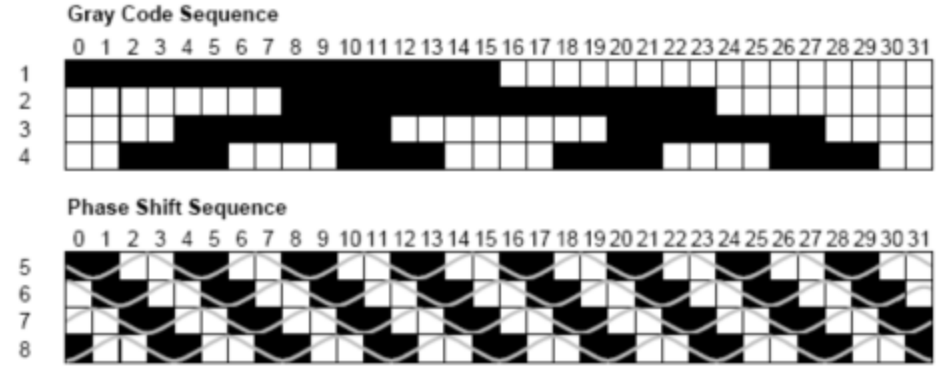




$$Z\approx\frac{L}{B}d\propto\frac{L}{B}(\phi-\phi_0)$$

混合方式：相移法+格雷码

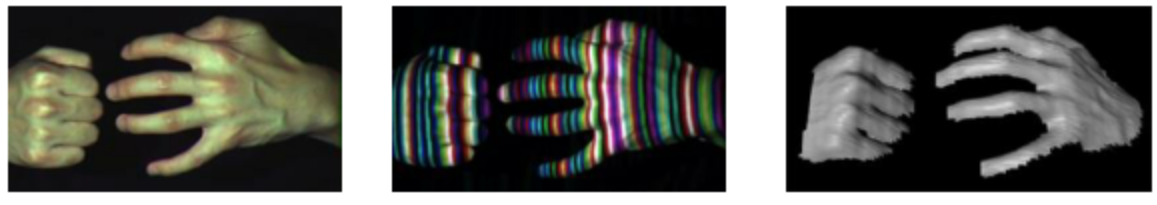
相移技术主要存在的问题是相位展开方法只提供相对展开，而不能求解绝对相位。如果两个表面的不连续性大于 2π ，则基于相位展开的任何方法都无法正确地展开这两个互相关联的表面之间的关系。这些通常被称为“整周期模糊度的问题，可以通过结合使用灰度码投影技术和相移技术来解决。



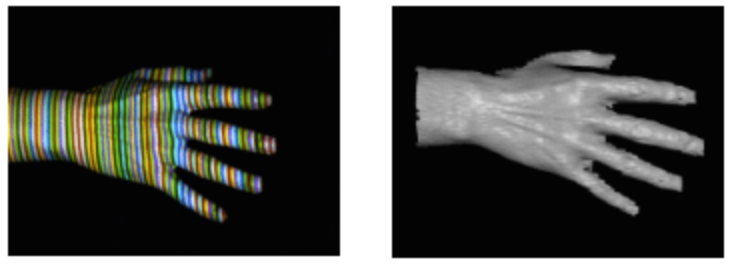
上例中，在32个条带编码序列中结合灰度码投影和相移的示例。

- 灰度码确定不存在任何模糊性的相位的绝对范围
- 同时相移提供的亚像素分辨率超过了灰度码提供的条带数

其他编码



Works despite complex appearances

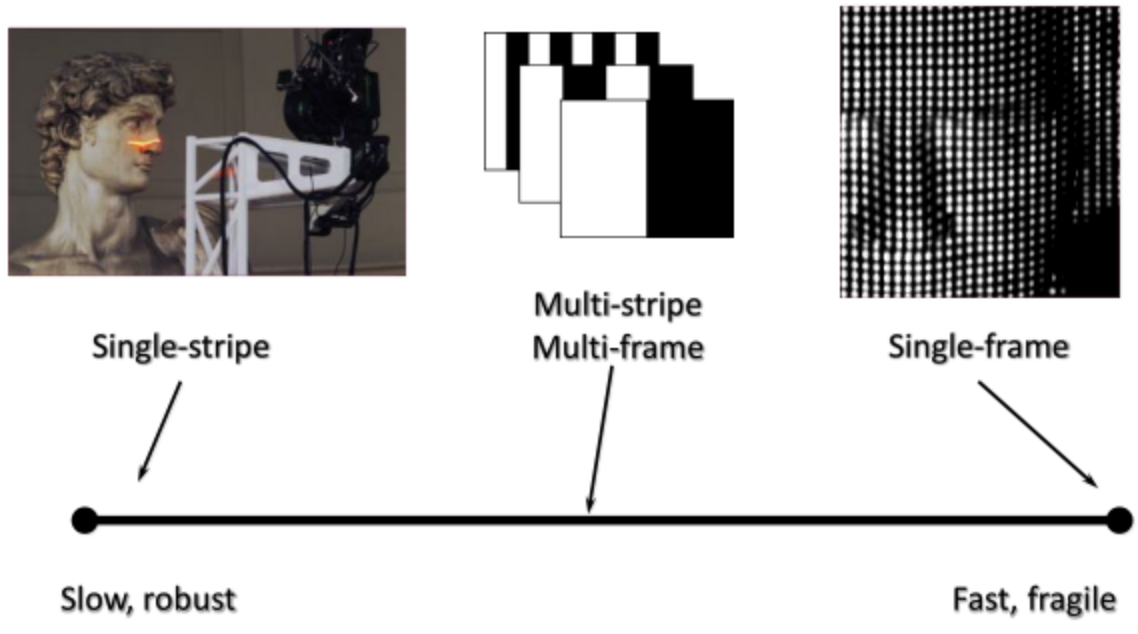


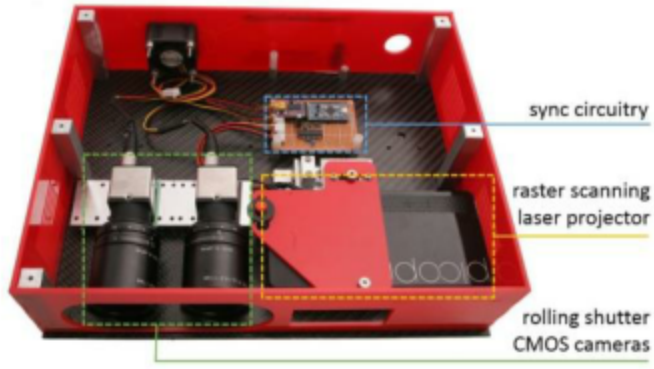
Works in real-time and on dynamic scenes

- Need very few images (one or two).
- But needs a more complex correspondence algorithm

[Zhang et al]

Continuum of Triangulation Methods





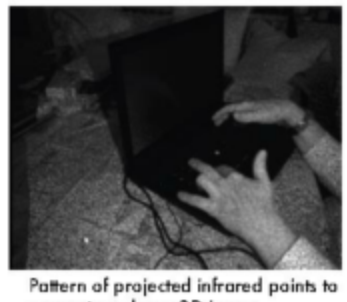
Measure photons selectively

[O'Toole et al., SIGGRAPH 2015]

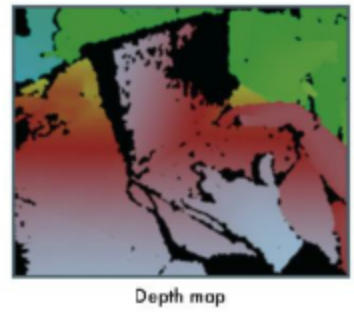
南京理工大学智能计算成像实验室（SCILab）

Active stereo – the kinect sensor

- Infrared laser projector combined with a CMOS sensor
- Captures video data in 3D under any ambient light conditions.



Pattern of projected infrared points to generate a dense 3D image



Depth map

Source: wikipedia

3D Model Acquisition Pipeline

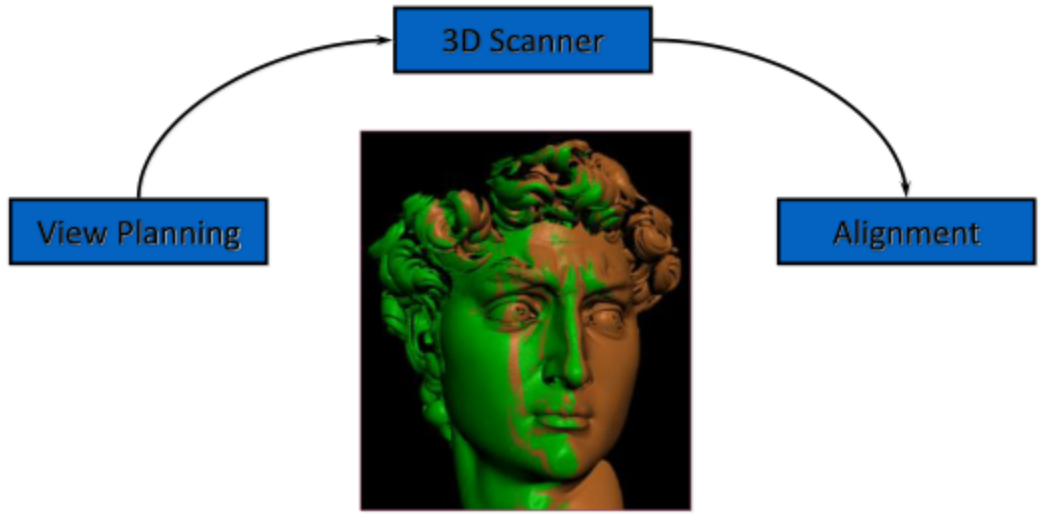
3D Scanner

3D Model Acquisition Pipeline

3D Scanner

View Planning

3D Model Acquisition Pipeline



3D Model Acquisition Pipeline