Spatial Calibration of an Illumination Dome

Lindsay MacDonald FRPS
School of Printing & Publishing
London College of Communication

Stuart Robson
Geomatic Engineering
University College London

The influence of illumination geometry

Diffuse lighting flattens image and reduces contrast

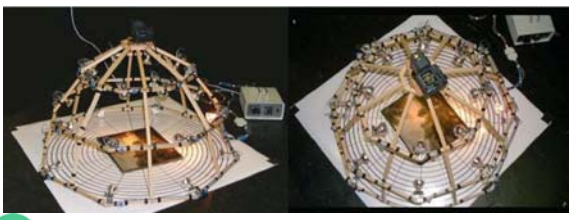
Directional lighting enhances image depth and increases contrast, enabling surface relief to be observed.

Conventional copystand

- Standard set-up for photographic copying
- Lamps at 45 degrees
- Camera normal to surface
- Minimises specular reflections from surface

Dome imaging

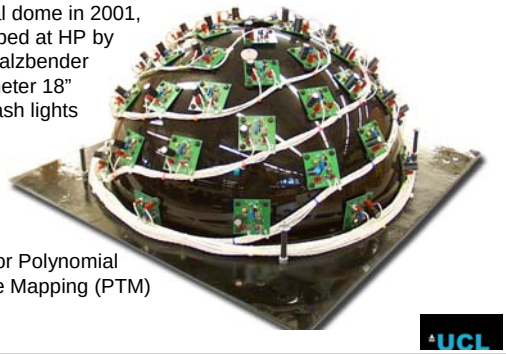
- Camera is fixed relative to object
- Illumination of object from many angles
- Capture a series of images in register



National Gallery, London (*Courtesy of Joe Padfield*)

Illumination dome

Original dome in 2001, developed at HP by Tom Malzbender
- Diameter 18”
- 40 flash lights



Used for Polynomial Texture Mapping (PTM)

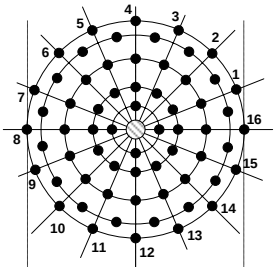
PTM surface rendering

Create the impression of a surface being illuminated interactively by a light from any direction.

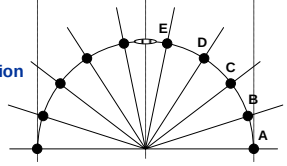
Concept layout

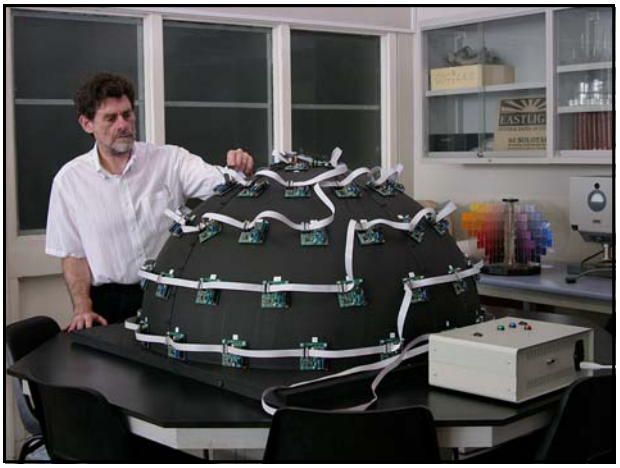
- Planned in 2003
- 64 lights in total
- 5 horizontal tiers
- Aim to distribute lights approximately uniformly over the hemisphere

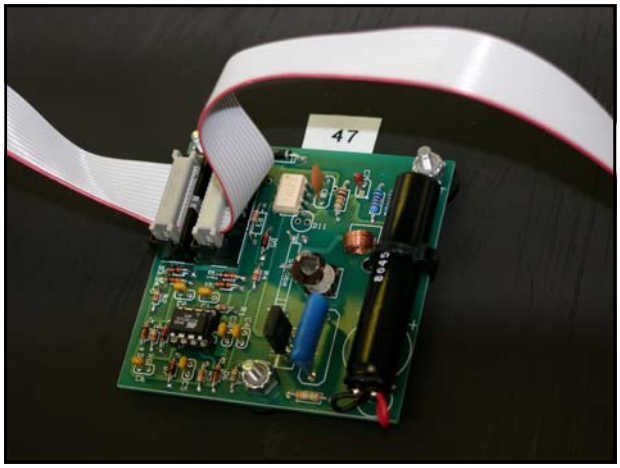
Plan



Elevation



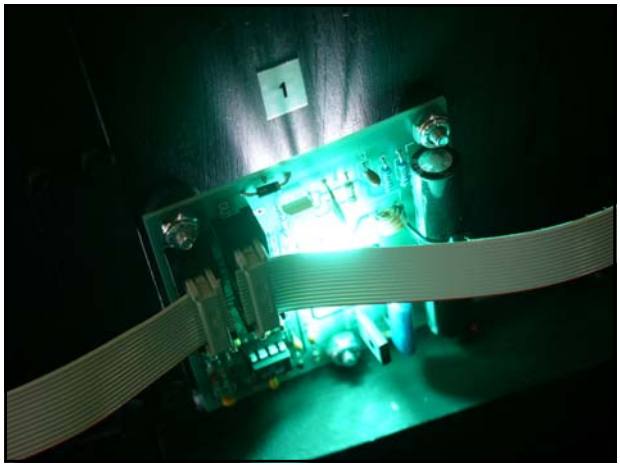




Flash board

Top view (outside)

Bottom view (inside)



Problem

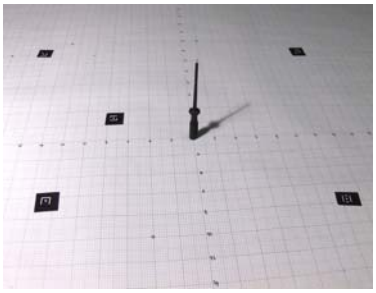
Q. How to determine the coordinates of the lights on dome?

A. Principle of the sun-dial.

Calculate from observed coordinates of shadow tip.

Pin shadow formation

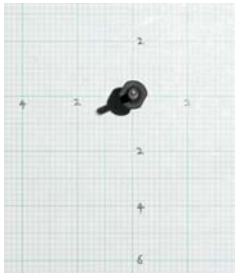
- Place steel pin vertically at centre of A1 sheet of mm graph paper.
- Capture series of pictures with the camera in normal mount, illuminated by each flash light.



Pin shadow images

Tier 4

Tier 5

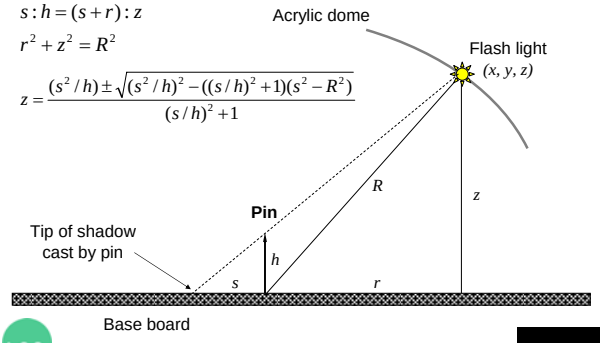


Geometry of shadows

$$s : h = (s + r) : z$$

$$r^2 + z^2 = R^2$$

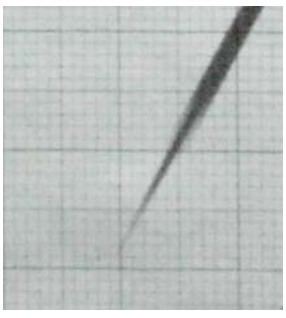
$$z = \frac{(s^2/h) \pm \sqrt{(s^2/h)^2 - ((s/h)^2 + 1)(s^2 - R^2)}}{(s/h)^2 + 1}$$



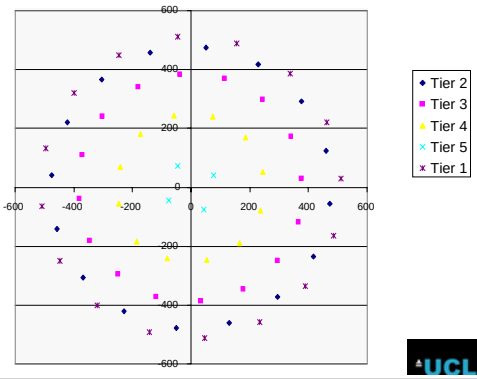
Penumbra

- Light is not a point source
- Flash discharge is approx. 6mm in length

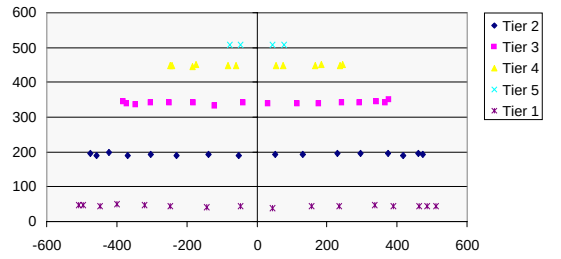
- Subtends angle of ~ 0.75 degree at pin tip
- Produces a penumbra or soft-edged shadow of pin

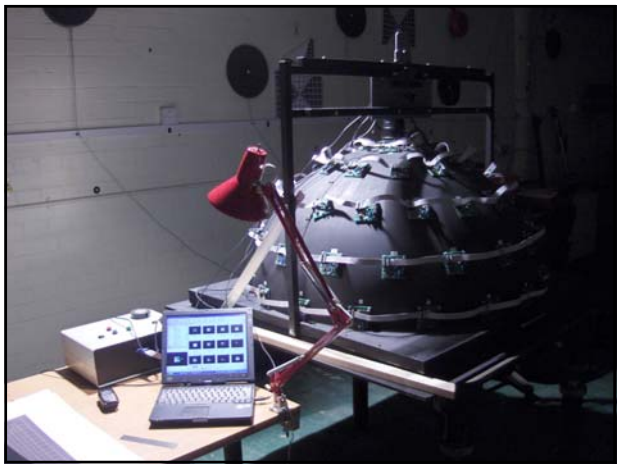


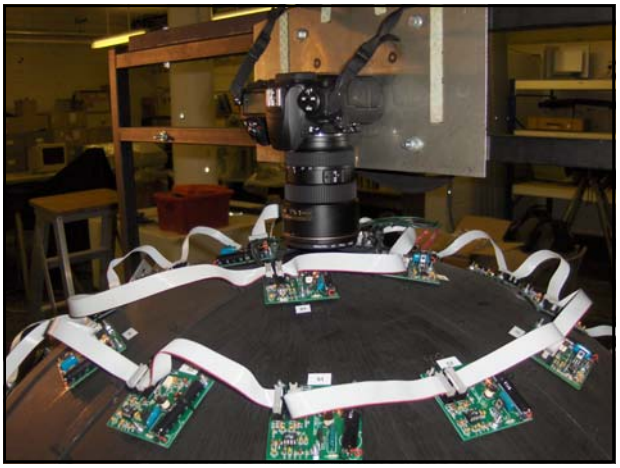
Lamp coordinates – plan view



Lamp coordinates - elevation

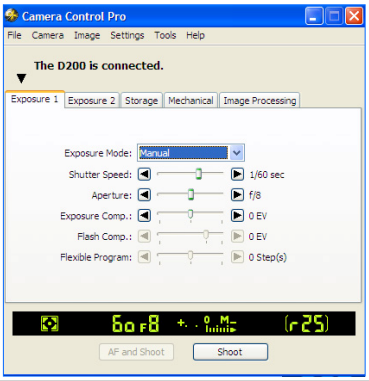






Computer control of camera

- Nikon D200 digital camera
- 17-55mm f2.8 zoom lens
- Connect to laptop PC via USB
- Camera control from graphic user interface.



Spatial Resolution

Finest detail in man-made objects is limited by:

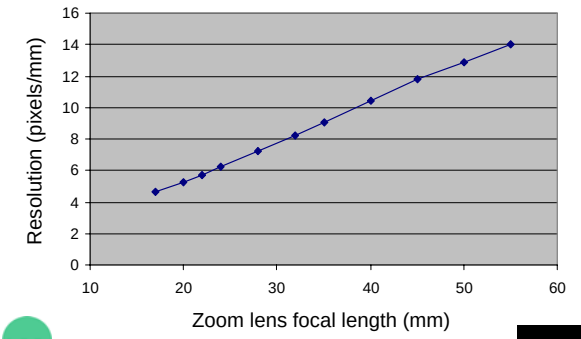
- Finest tools
- Dexterity of the hand
- Acuity of the eye

Inherent resolution limit characteristic of medium.

Limited to about 10 line-pairs/mm.

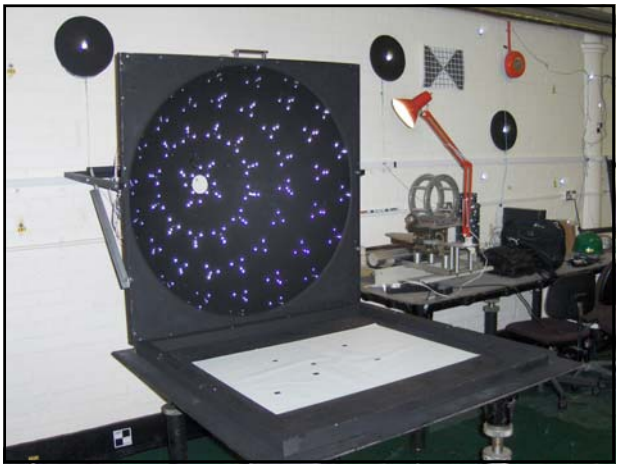
Stained glass window
Fairford Church, Gloucesershire

Zoom resolution



Alternative approach to geometry

- Use an advanced imaging technique
- Retro-reflective target on each lamp
- Capture multiple images of whole kit
- Record every point >3 times
- Apply photogrammetric technique of self-calibrating bundle adjustment to solve system and determine coordinates of every point.

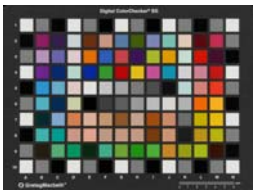


Next steps

Illumination profile

Image of white card

Colour characterisation



GretagMacbeth Color Checker SE

Application to cultural heritage

Capturing objects from the museum collections at UCL:

- Petrie Museum of Egyptology
- Grant Museum of Zoology and Comparative Anatomy

Conclusion

- Often it is not necessary to produce a true 3D image, just the illusion of an object or viewing environment.
- The PTM technique provides a convincing visualisation of moving a virtual light source over a virtual object.
- The method can be developed to extract 3D surface geometry, with a resolution comparable to laser scan.