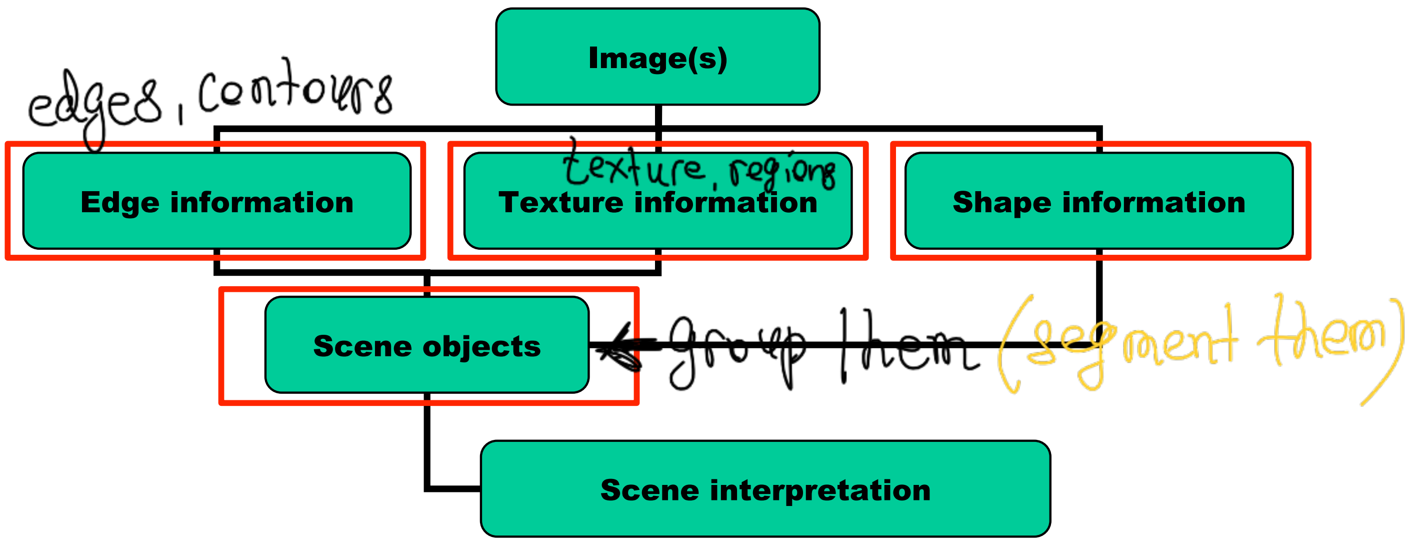
Reminder: A Teachable Scheme



Decomposition of the vision process into smaller manageable and implementable steps.

--> Paradigm followed in this course

--> May not be the one humans use

Shape From X

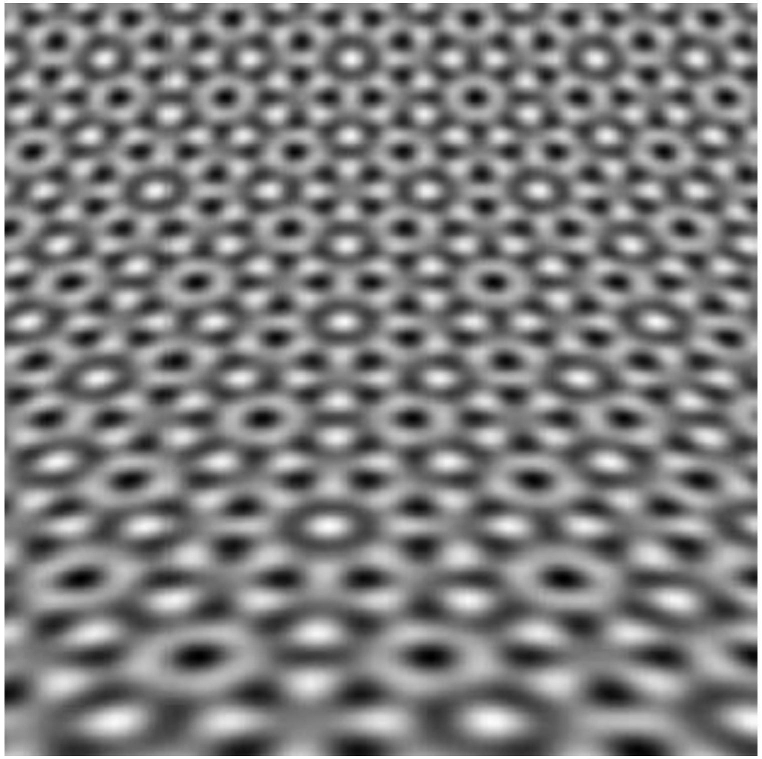
↳ can be many things

- One image:
  - **Shading**
  - Texture

- Two images or more:
  - Stereo
  - Contours
  - Motion

Shape From X

- One image:
  - Shading
  - **Texture**
- Two images or more:
  - Stereo
  - Contours
  - Motion



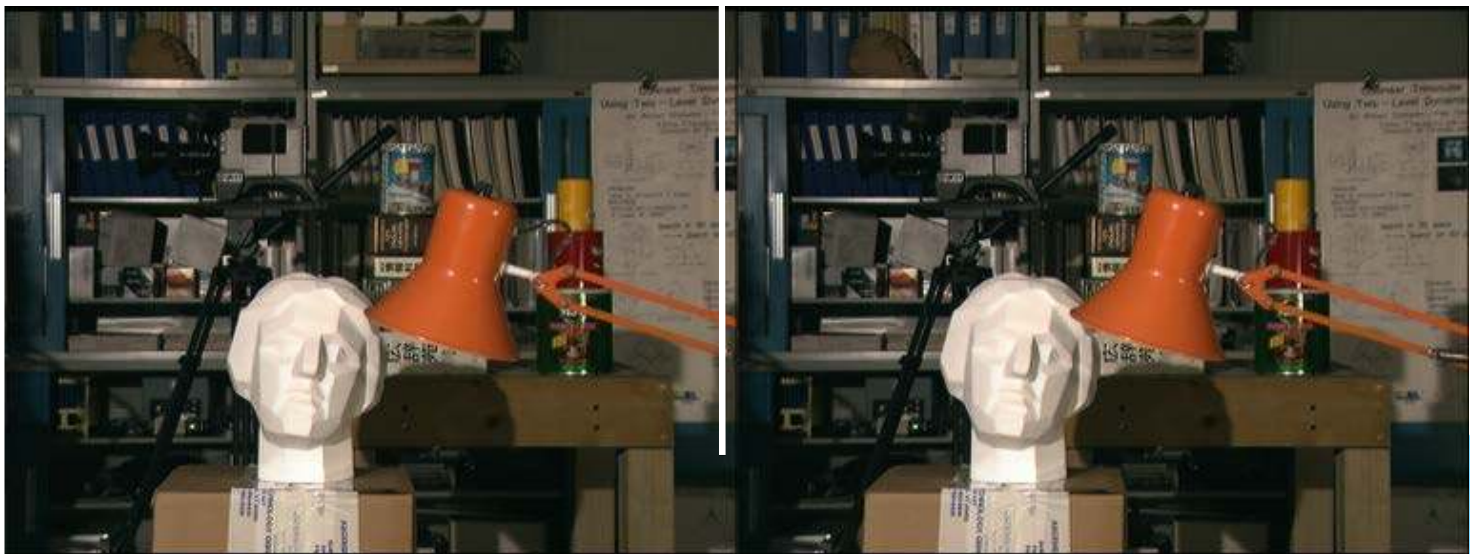
tells us sth about shape

Shape From X

- One image:
  - Shading
  - Texture

- Two images or more:
  - **Stereo**
  - Contours
  - Motion

Video sequences



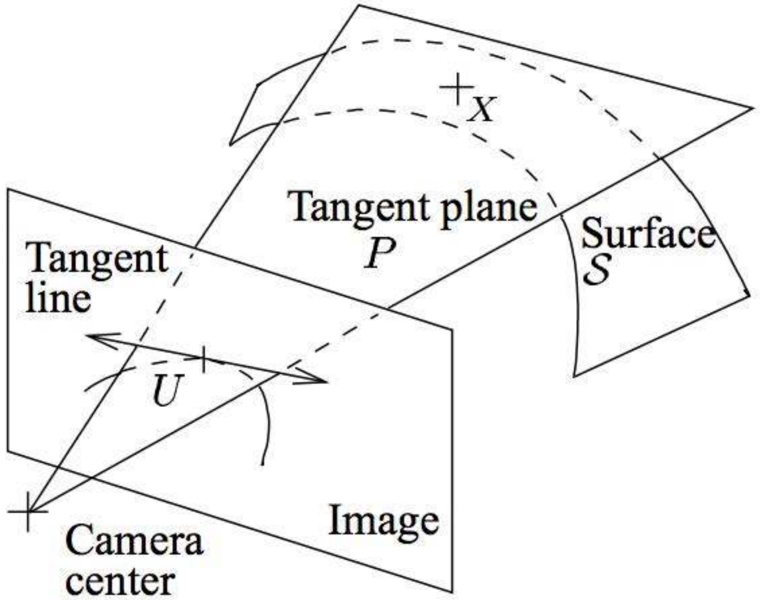
recover depth
(e.g. color img)

EPFL

Shape From X

- One image:
  - Shading
  - Texture

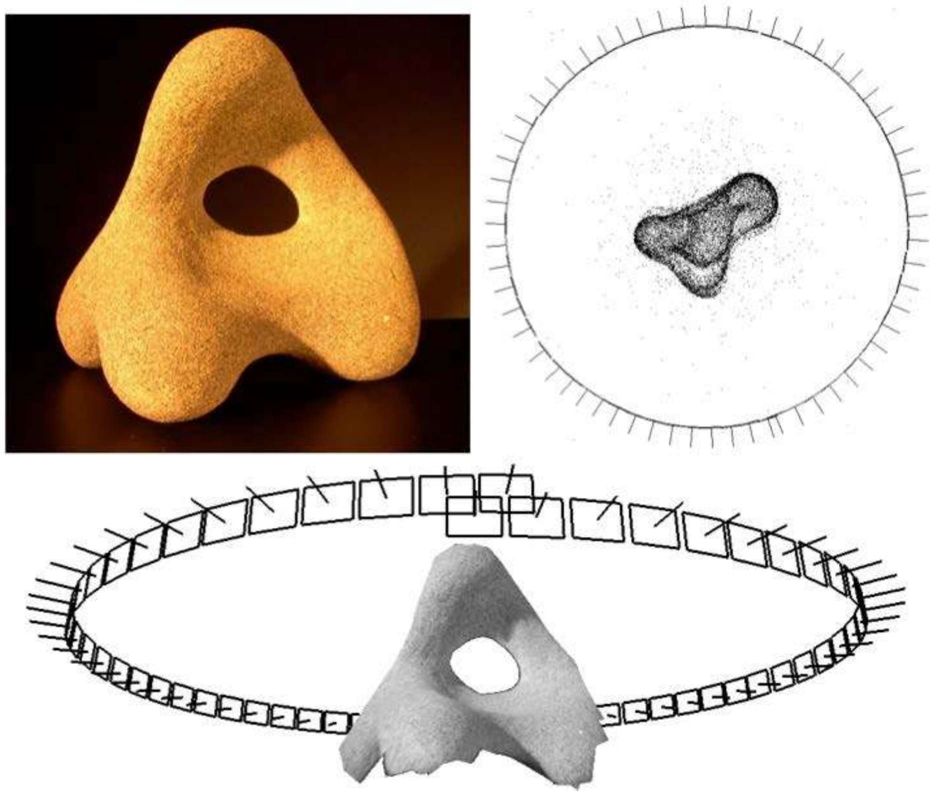
- Two images or more:
  - Stereo
  - **Contours**
  - Motion



Shape From X

- One image:
  - Shading
  - Texture

- Two images or more:
  - Stereo
  - Contours
  - **Motion** ↳ whole video of sequence



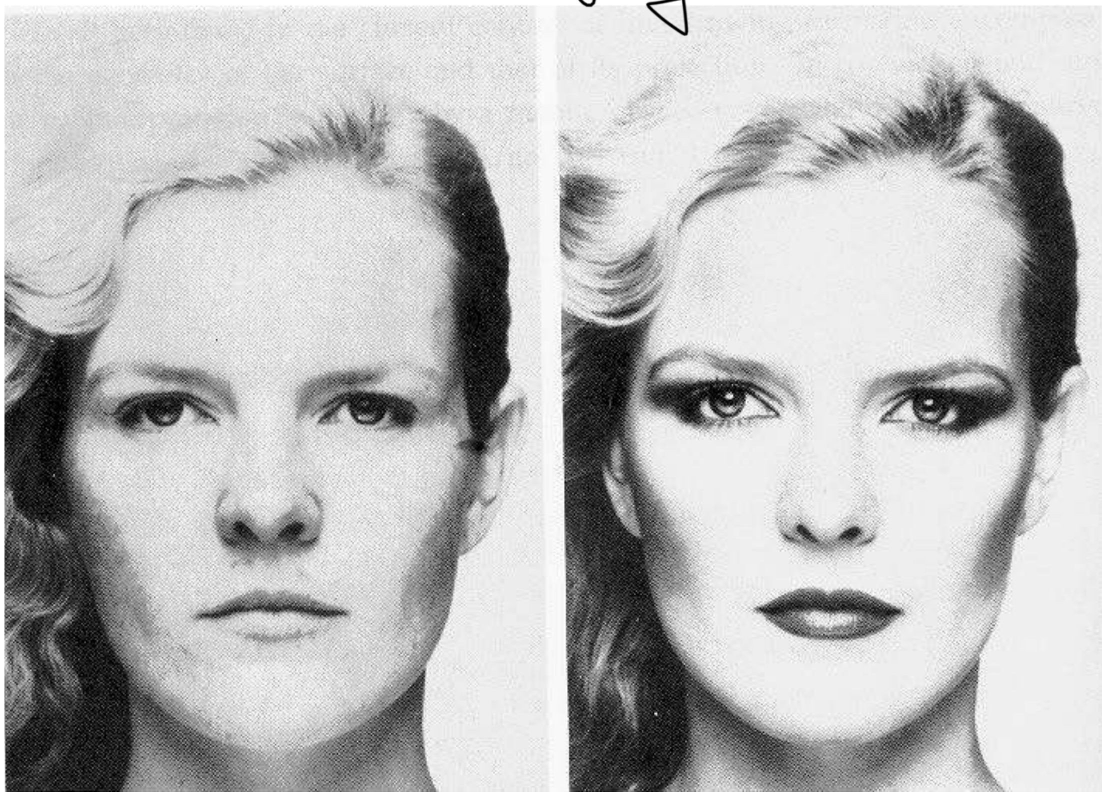
Shading

Shape-from-shading

No surgery

illumination

- Shading models
- Shape from shading
  - Variational Methods
  - Photometric Stereo

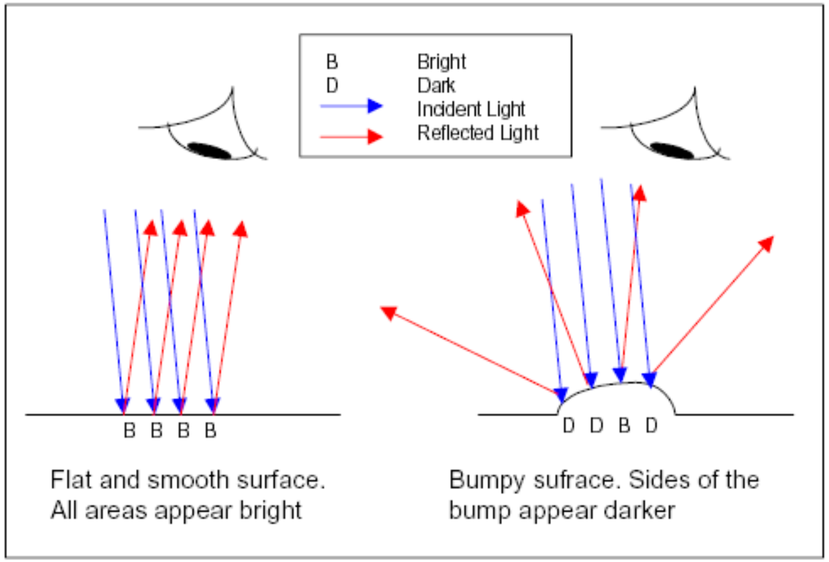


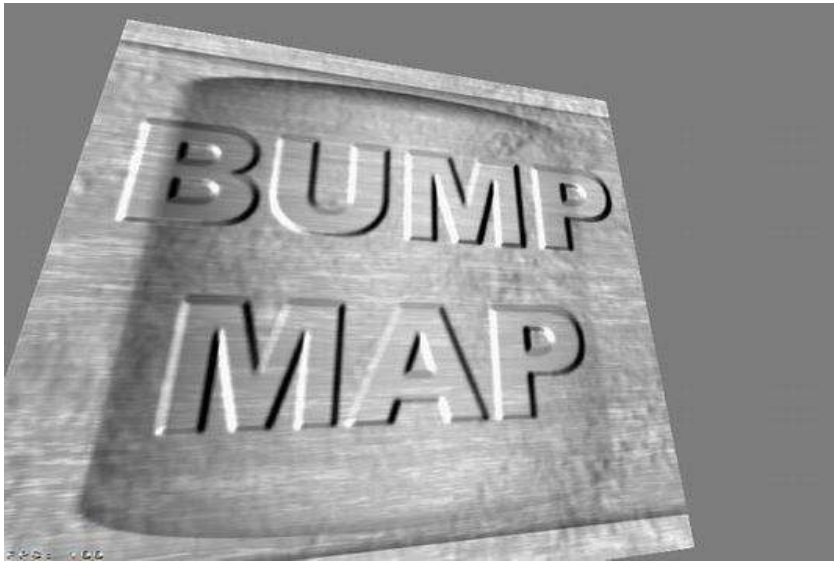
no makeup

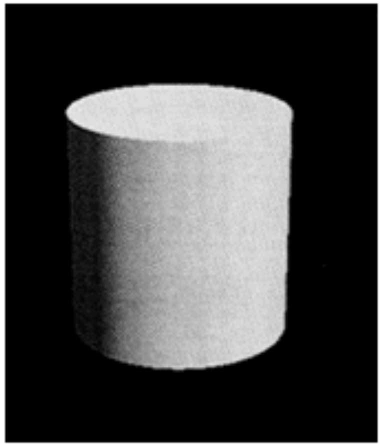
makeup ✓

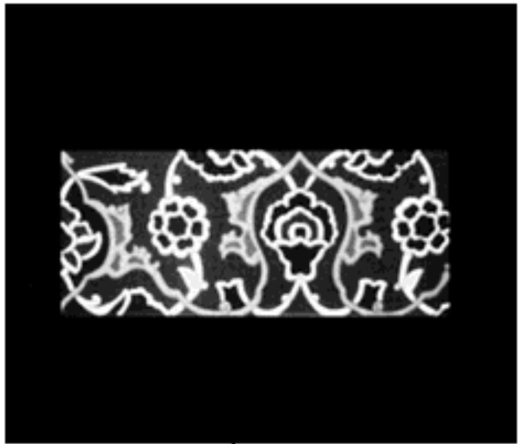
↳ change gray levels of the image

Bump Mapping









visually looks 3D

paint on the cup

bump map

↳ appropriate patterns of light and gray

Simple mesh + 2D bump map = Complex looking object

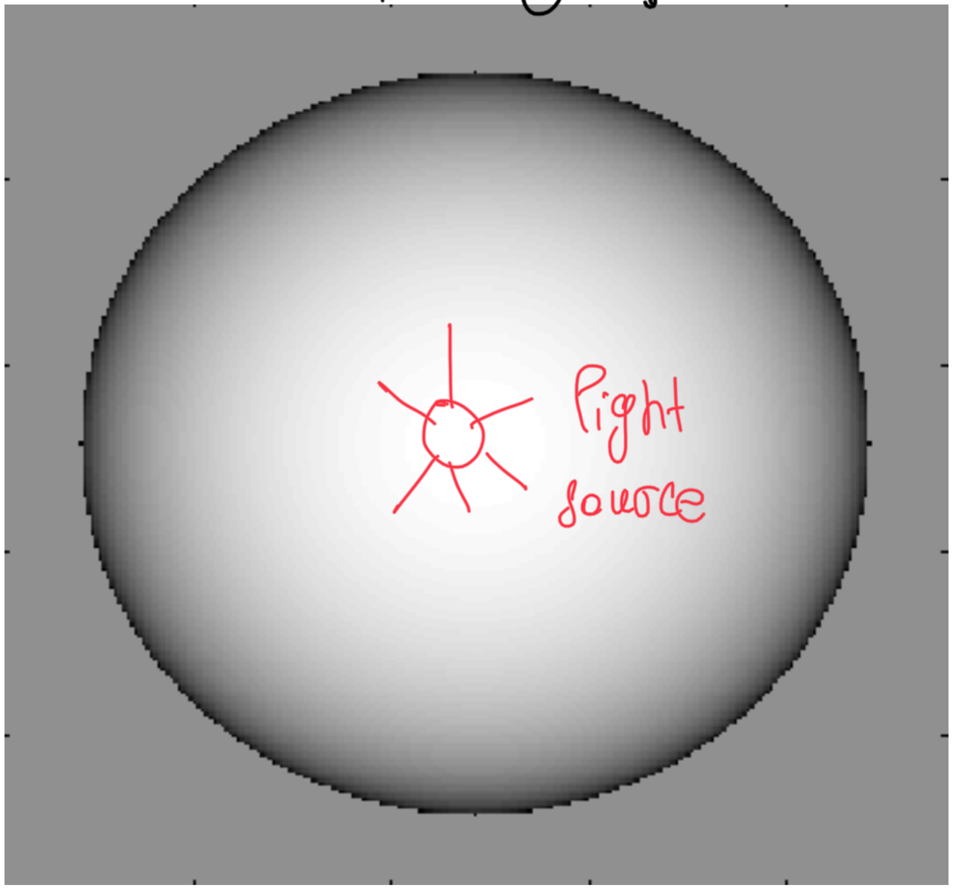
Lambertian Half-Sphere

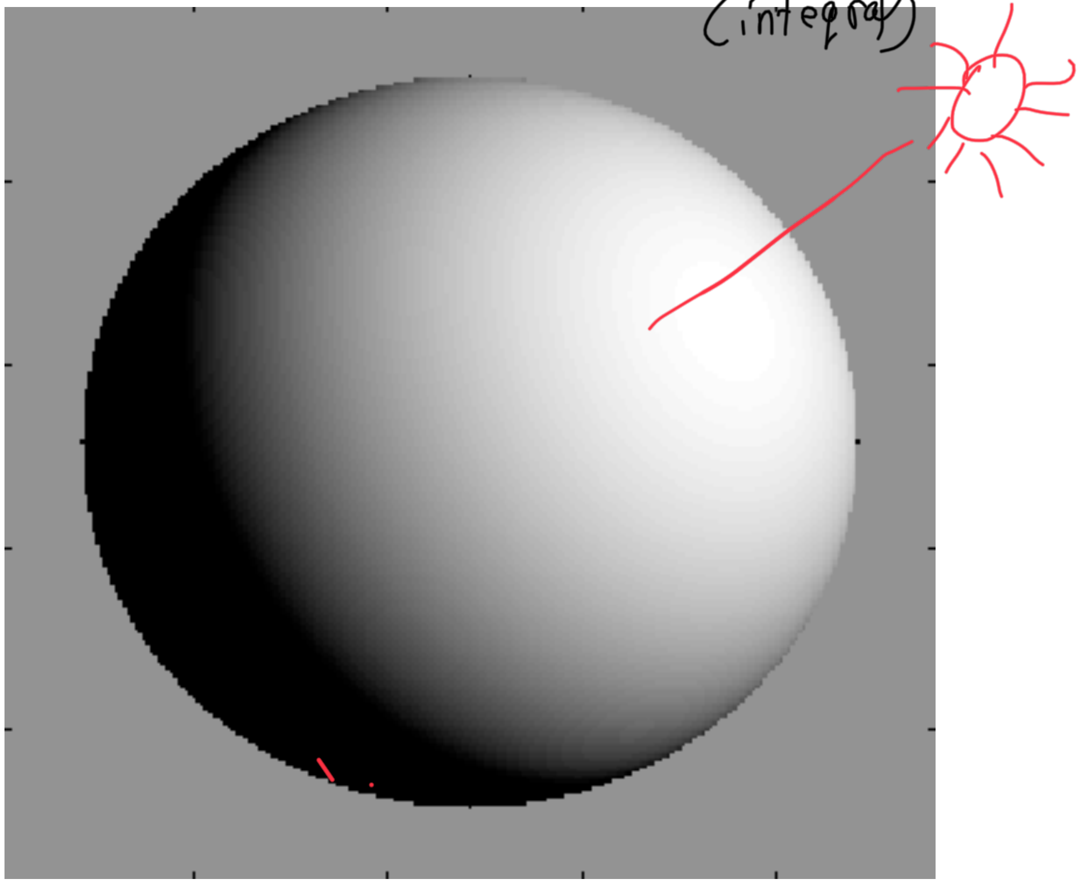
Screen is flat, yet!

those normals

Somehow, we integrate

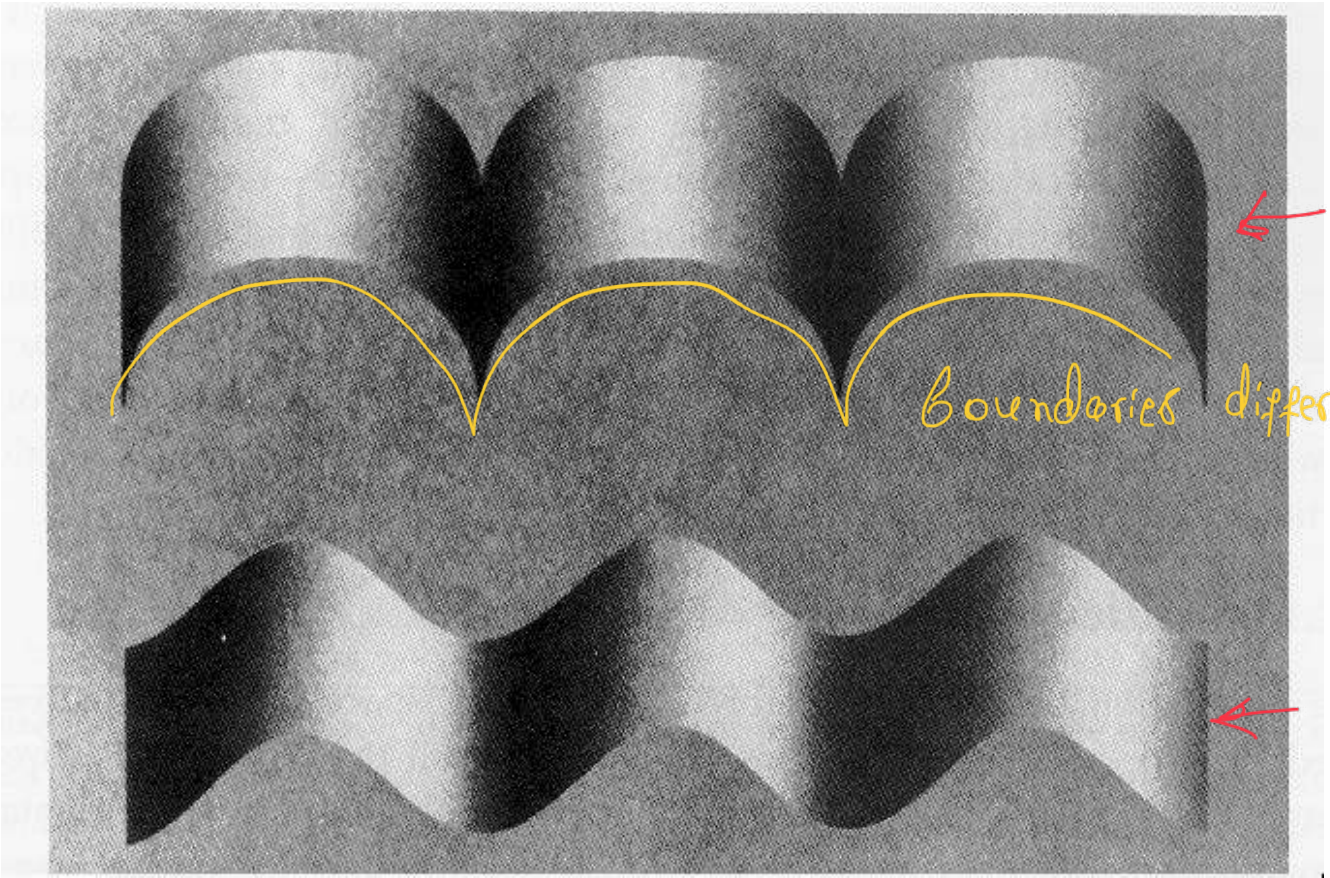
(integral)





Gray level changes are interpreted as changes in the direction of the surface normal.

Solving an Inverse Problem



boundaries different

pattern of light and dark is the same as top and bottom

gray level changes based on

- Shading gives information about surface normals.
- Recovering the 3D surfaces amounts to solving a differential equation.

We use them to integrate those "ribbon" images

→Boundary conditions are required to do so.

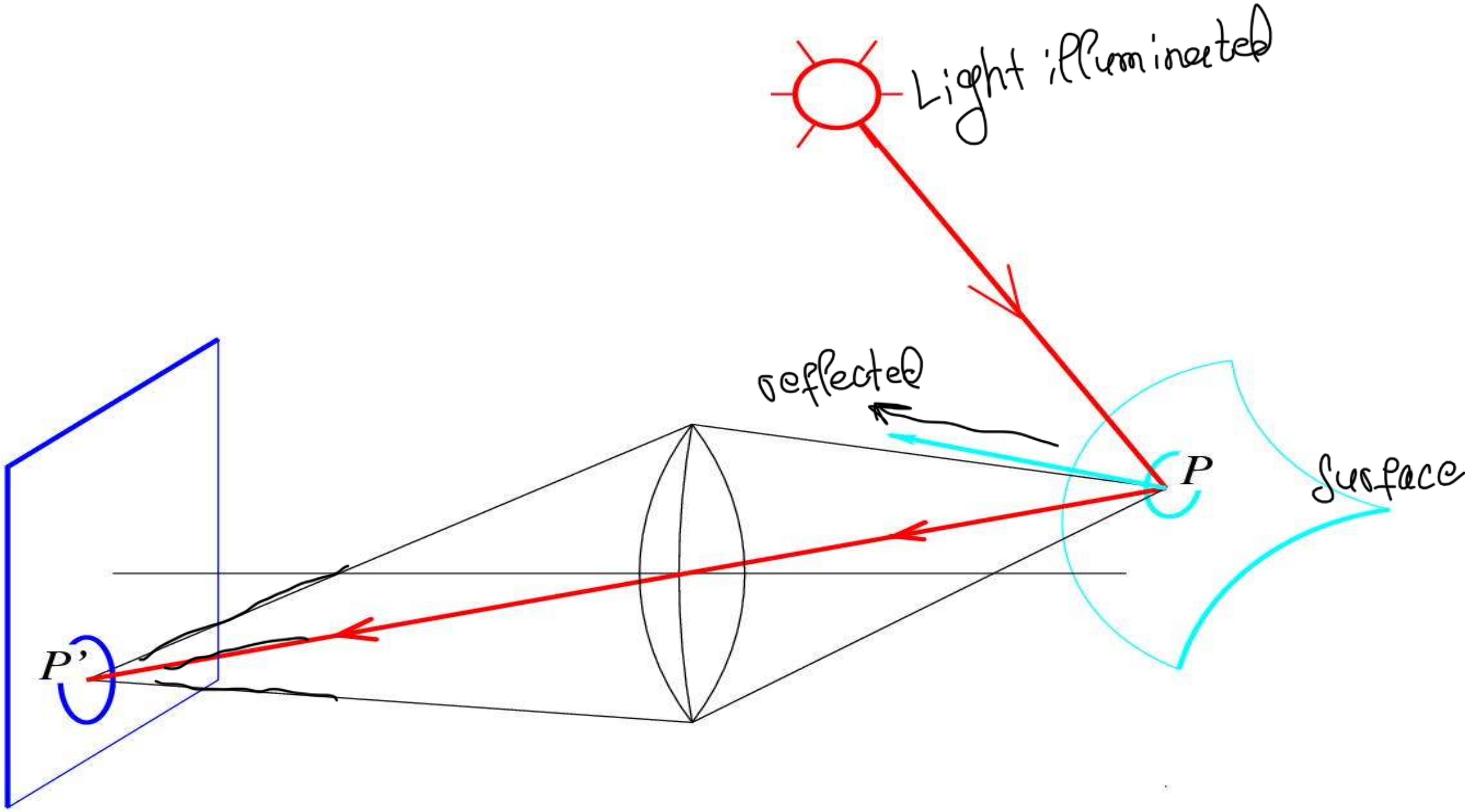
Boundary Conditions

Right and color

appropriate boundary conditions

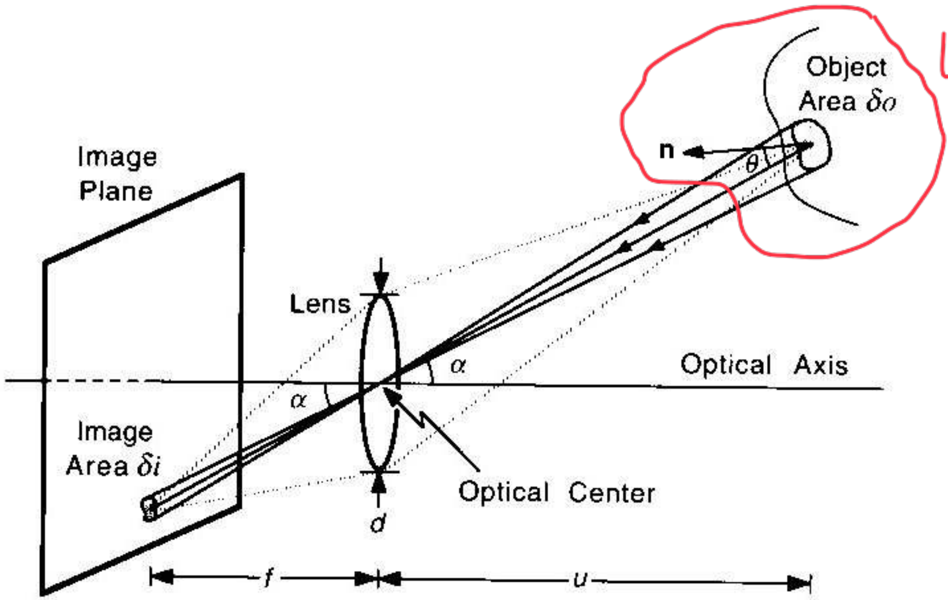
—> The carefully designed contour gives us an erroneous perception!

Reminder: Image Formation



- The light source illuminates a 3D surface.
- The 3D surface reemits some the light.
- It goes through a lens and forms an image on the image plane.

Reminder: Fundamental Radiometric Equation



Light emitted from surface

Scene Radiance (Rad): Amount of light radiation emitted from a surface point (Watt / m2 / Steradian)

Image Irradiance (Irr): Amount of light incident at the image of the surface point. (Watt / m2)

Radiometric eq'n

$$\text{Irr} = \frac{\pi}{4}\left(\frac{d}{f}\right)^2 \cos^4(\alpha)\text{Rad} \,,$$

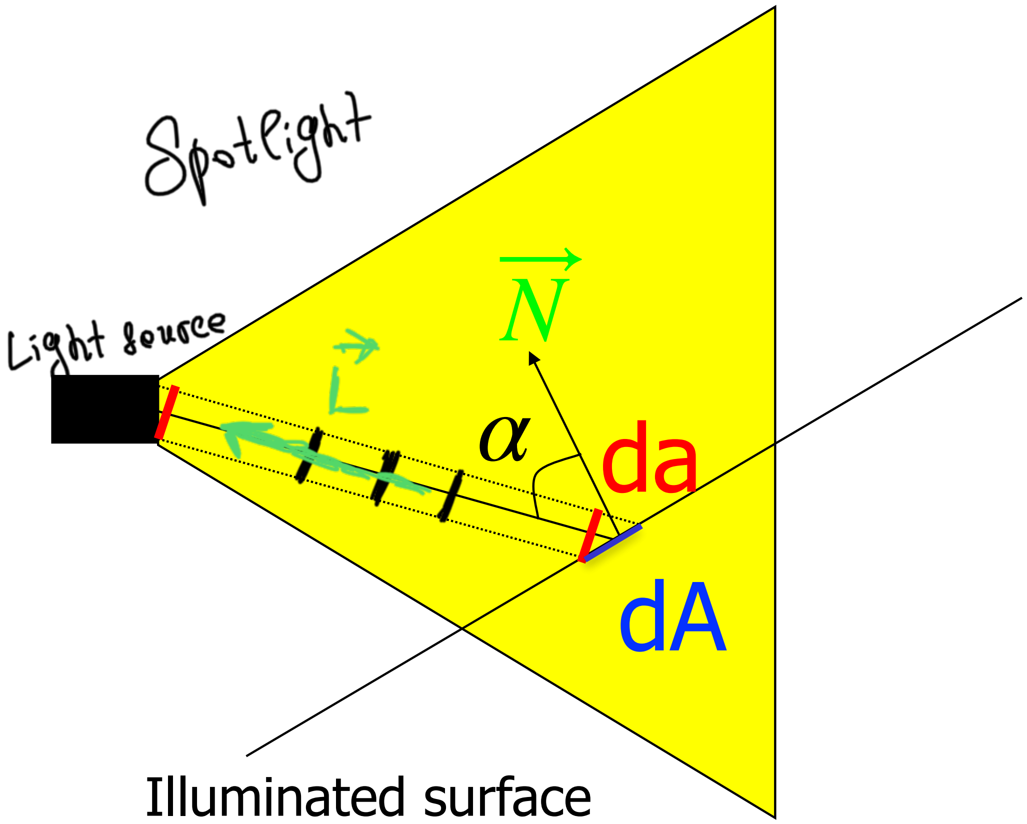
$$\Rightarrow I \propto \text{Rad} \,,$$

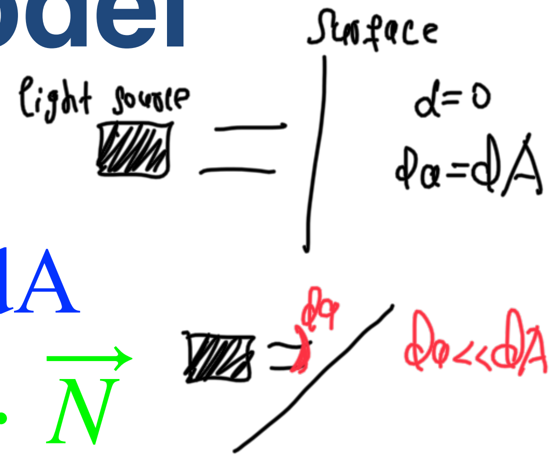
Image intensity

can be eliminated by having a lens that's not strictly transparent (darker in the middle) to compensate for that

when the camera is photometrically calibrated.

Lambertian Shading Model





Foreshortening:

$$da = \cos(\alpha) dA$$

$$\cos(\alpha) = \vec{L} \cdot \vec{N}$$

↳ direction of light source

Radiance:

$$\text{Rad} \propto \text{albedo } \mathbf{P}/dA$$

$$\mathbf{P} \propto da$$

$$\Rightarrow \boxed{\underbrace{\text{Rad}}_{\text{on } dA} \propto \text{albedo } \underbrace{\vec{L} \cdot \vec{N}}_{\cos\alpha}}$$

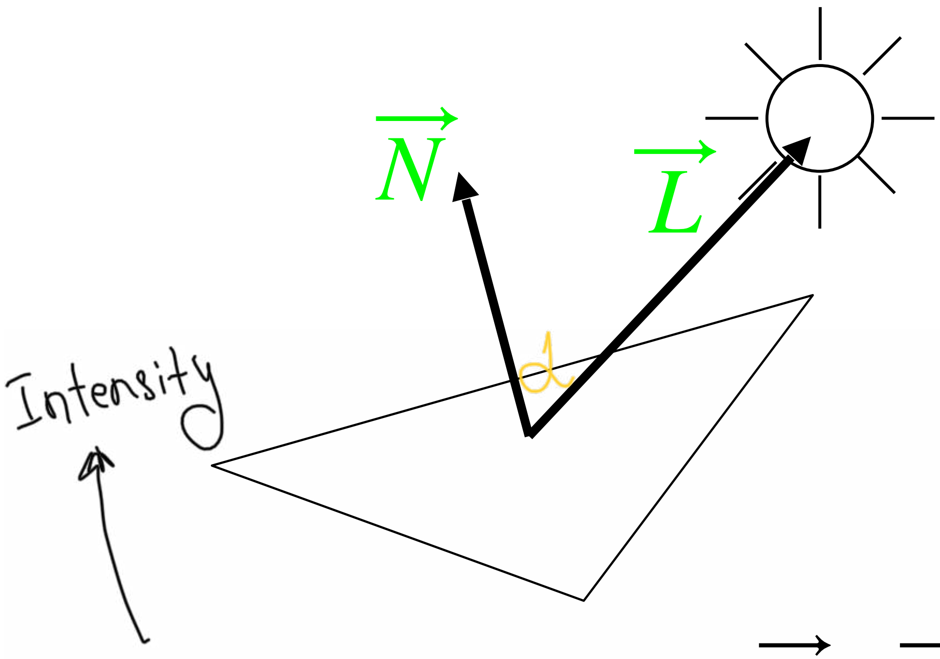
- The amount of light radiation **P** in the cylinder of section da in direction $\vec{L}$ is spread over the surface area dA.

White surface → albedo = 1 (reflects everything)
Black // → albedo = 0 (absorb everything)

When you shine light on surface, gets reflected

- Some light is absorbed (0 < albedo < 1).

Ideal Lambertian Surface



$$I = \max(0, \text{albedo}\ \vec{L} \cdot \vec{N})$$

No negative light!

Brightest

darker

$\vec{L} \cdot \vec{N} = 0$

$\vec{L} \cdot \vec{N} < 0$

Perfectly matte surface: The radiance depends only on angle of incidence and not on viewing direction. This is known as **diffuse** reflection.

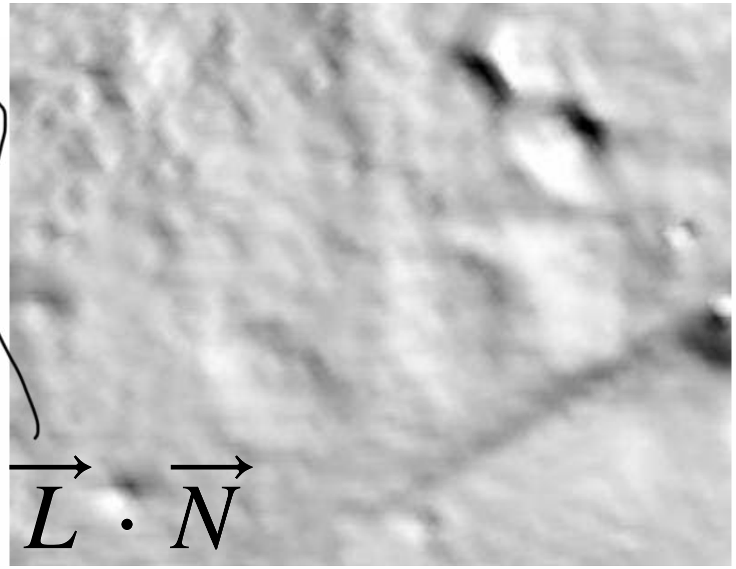
→ I also on albedo

Estimated Albedo

sun is (we know where) light source

Original image.

$=$



$*$

Most bumps are gone

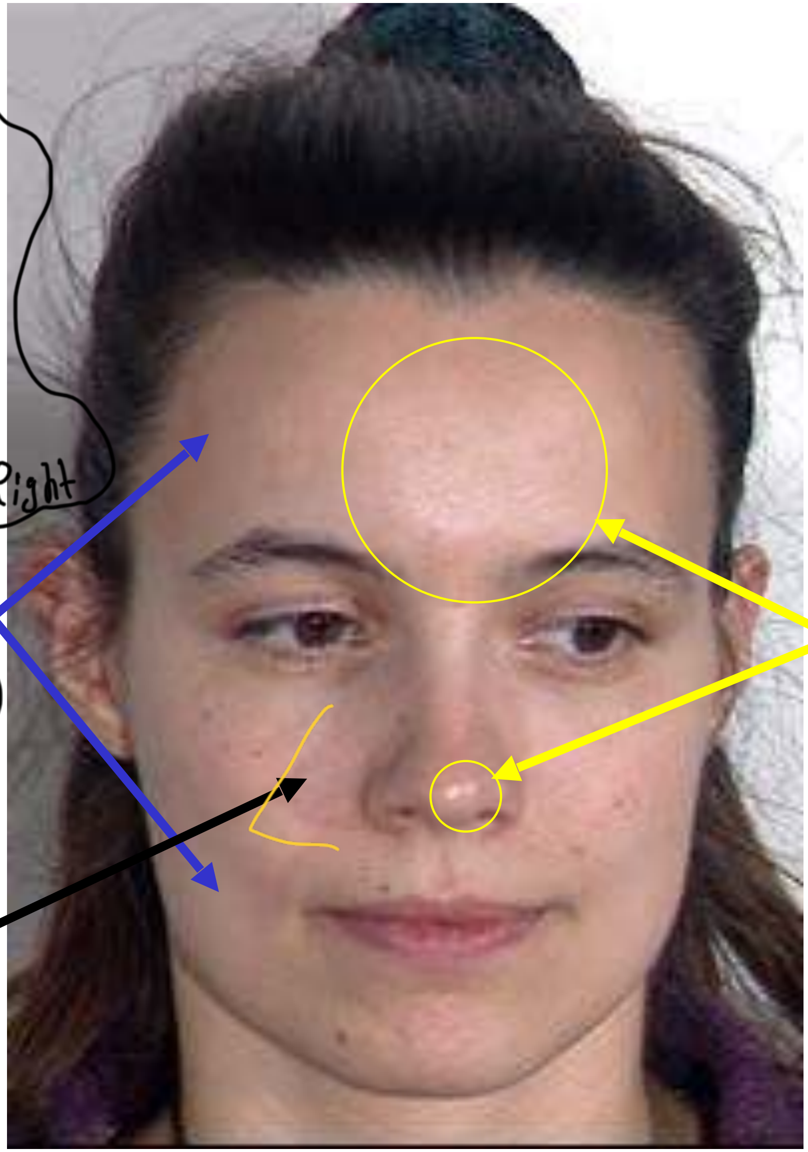
has to do with physical properties of the surface

If ideal Lambertian $\rightarrow \left\{ \underline{I} / (\vec{L} \cdot \vec{N}) \right)$ $\xrightarrow{\text{of terrain}}$ ≠ shape but physical properties

—> The "albedo" image looks much flatter than the original one.

Diffuse vs Specular

albedo ⊥ (physical properties
no geometry
~~shape of terrain~~
what surface is made of and how it interacts with light



Diffuse reflection
(Lambertian behaviour)

(behaves like mirror)
Specularities
⊥ direction you are looking at img from

Shadow
of nose

(oversimplification)
Real-world surfaces are not strictly Lambertian!

Radiance under Indirect Lighting

- The light source is not visible. Yet there still is light.
- The light enters through the windows and bounces of the walls.

Visualizing Secondary Illumination

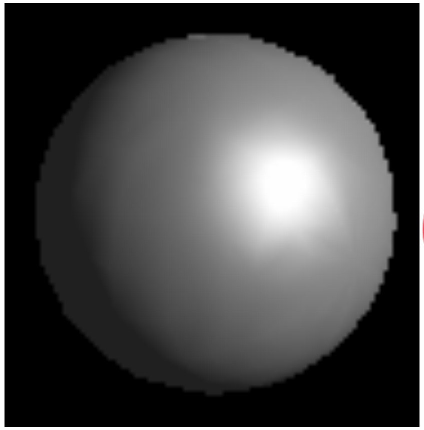
Indirect illumination

Reflections produce indirect lighting.

Unique light source assumption doe not allow correct albedo recovery.

I

$(\vec{L}\cdot\vec{N})$



Lambertian shading

Ideal

pretty constant

light albedo

Lambertian albedoes

$I/\vec{L}\cdot\vec{N}$

Because of indirect lighting

Because table is white, light bounces off the table and lights up ball

why?

This is not right!

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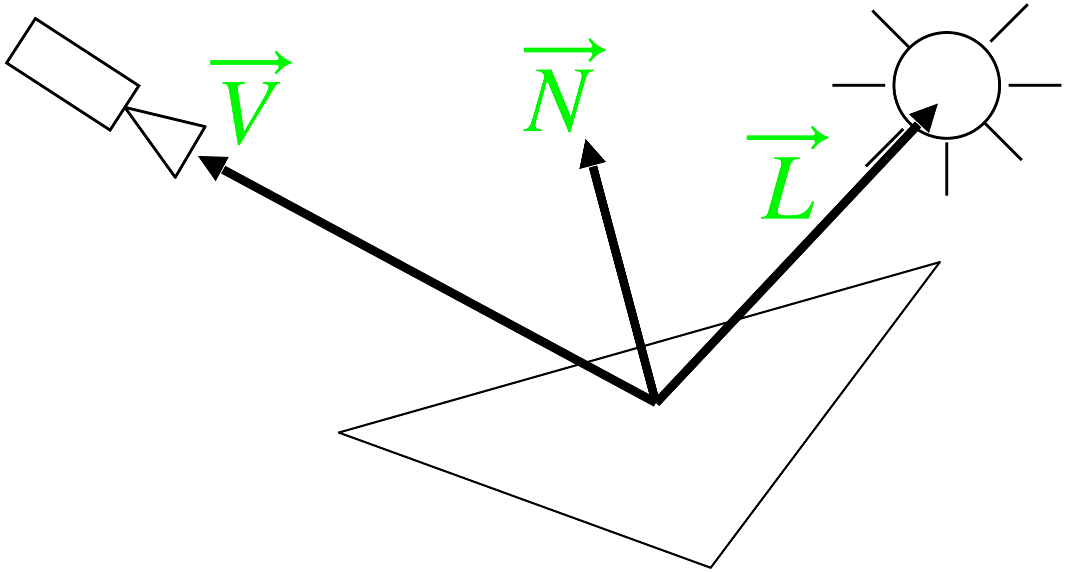
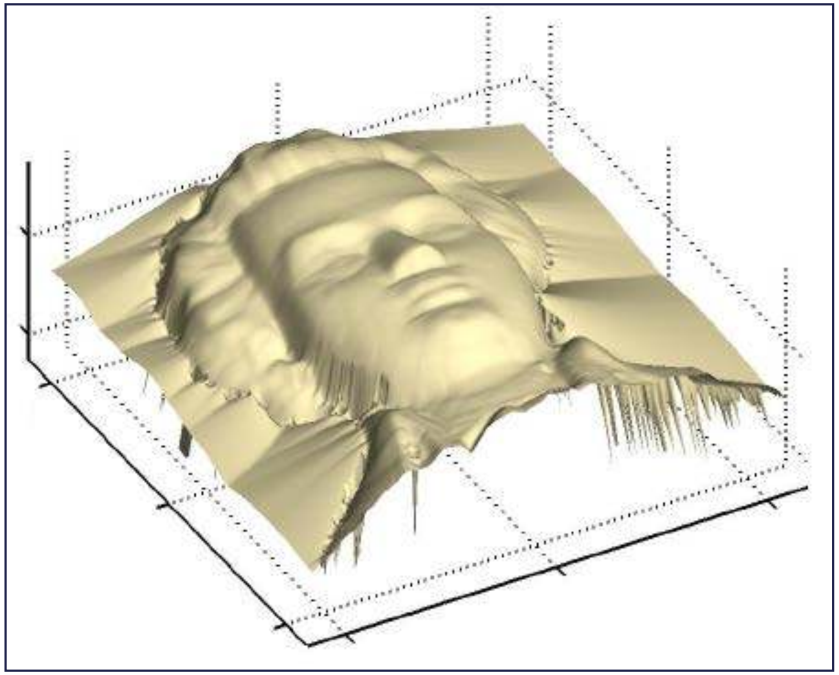
Simplifying Assumptions



- Accounting for secondary illumination in the computer vision context remains an open research problem.
- We will mostly ignore it in this class and make the following assumptions.
  - The illumination sources are distant from the imaged surfaces.
  - Secondary illumination is not significant.
  - There are no cast shadows.

Ideal Synthetic Case



Goal:

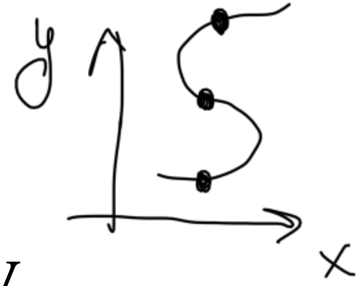
- Recover the 3D shape of the head from the 2D image.

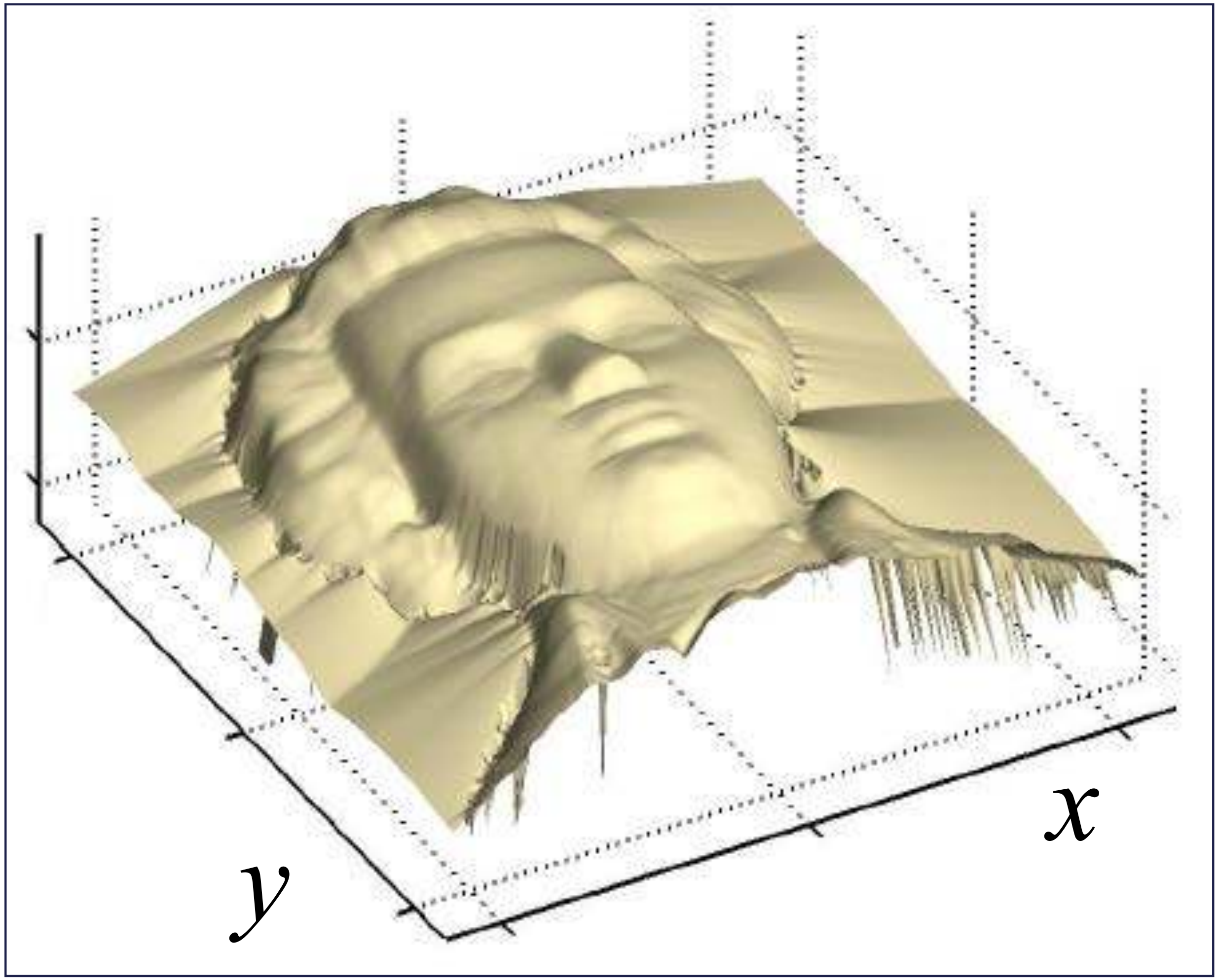
Questions:

1. Given the surface normals, can we recover the surface? Yes
2. Can we recover the normals?

Monge Surface

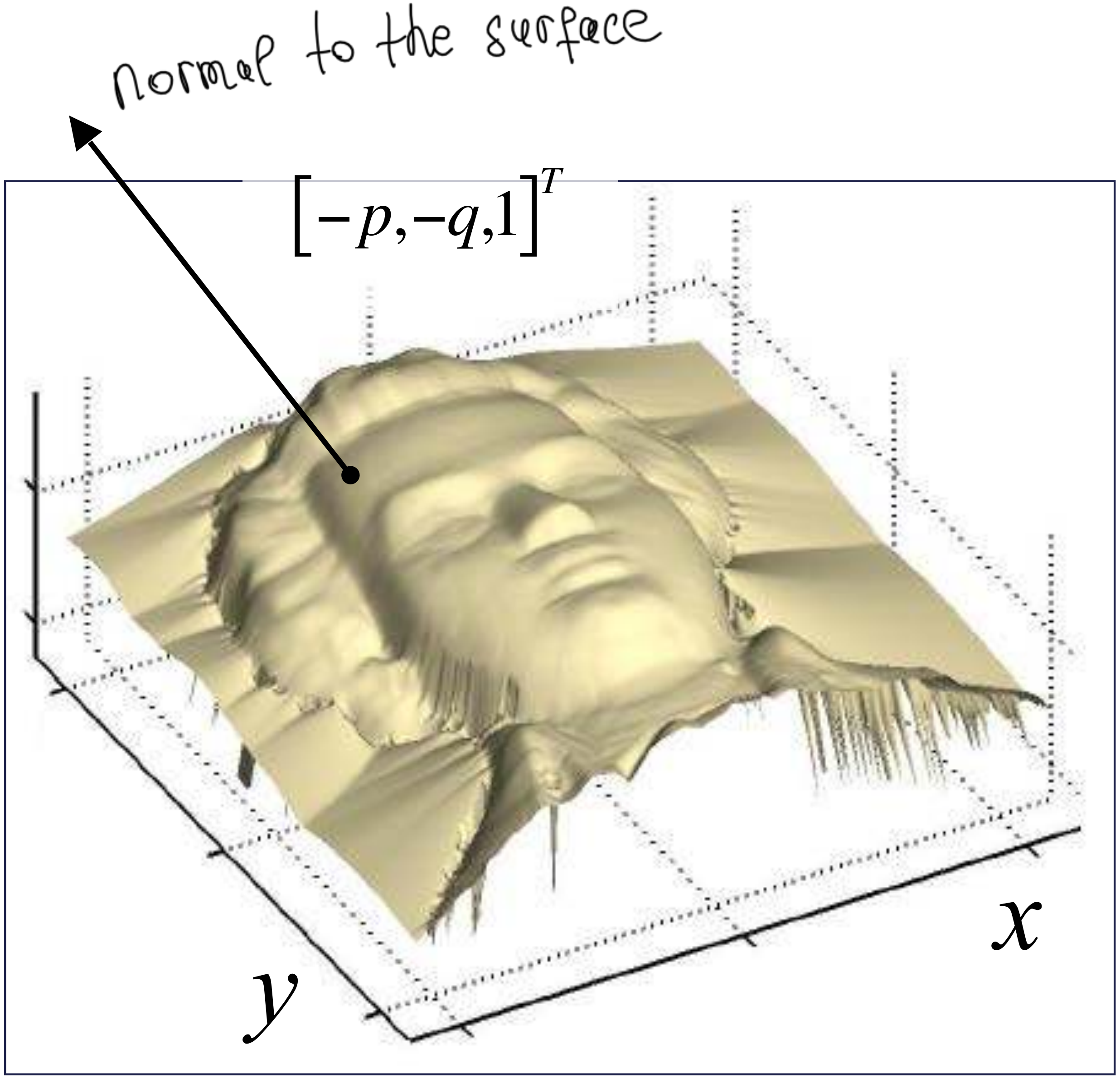
- A Monge surface is defined by z = f(x,y).
- Not all surfaces can be represented this way.





Surface Normals

$$z = f(x, y)$$
$$p = \frac{\delta z}{\delta x}$$
$$q = \frac{\delta z}{\delta y}$$



Tangent Vectors

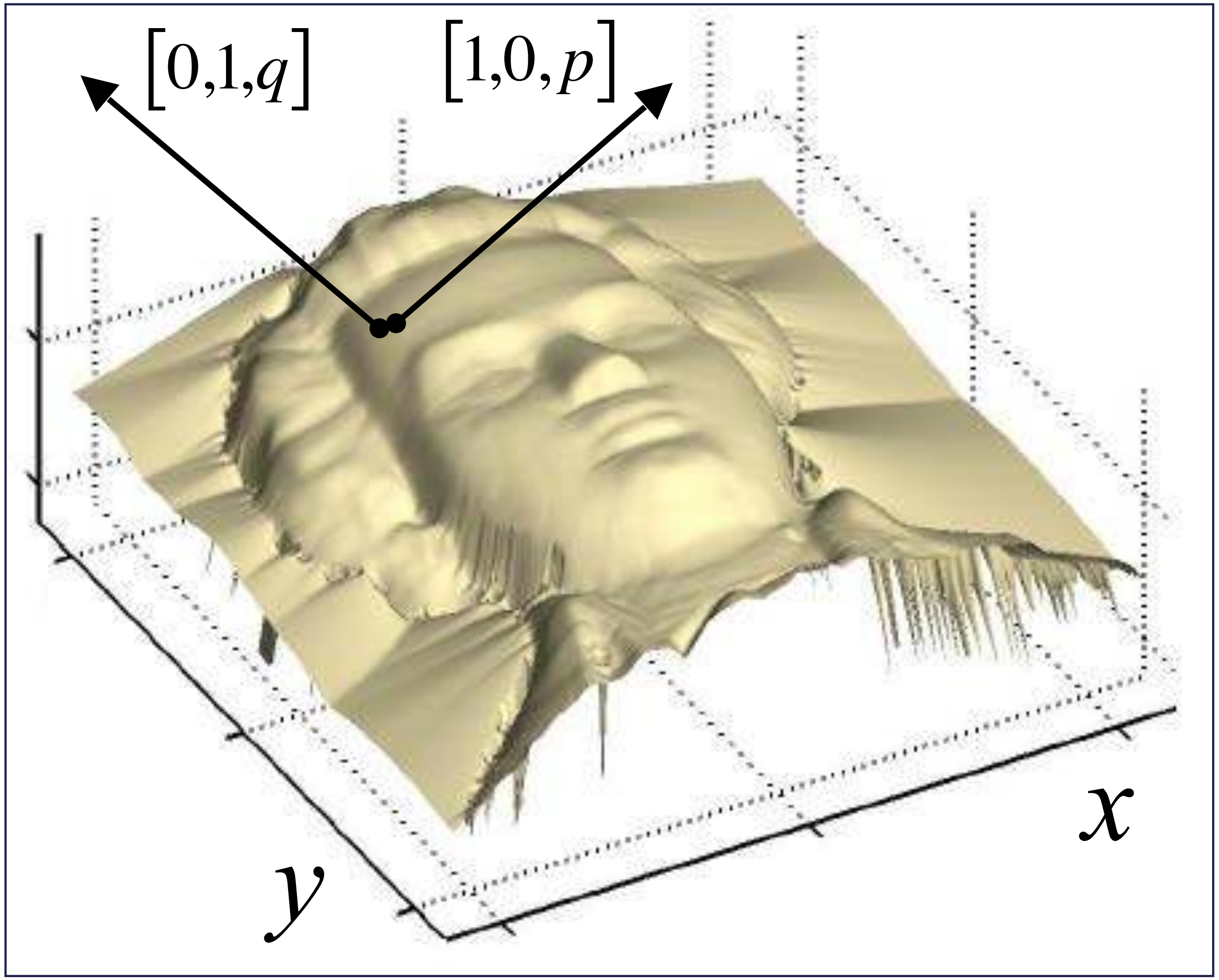
· not normalized

tangent to the surface

$$z = f(x, y)$$

$$p = \frac{\delta z}{\delta x}$$

$$q = \frac{\delta z}{\delta y}$$



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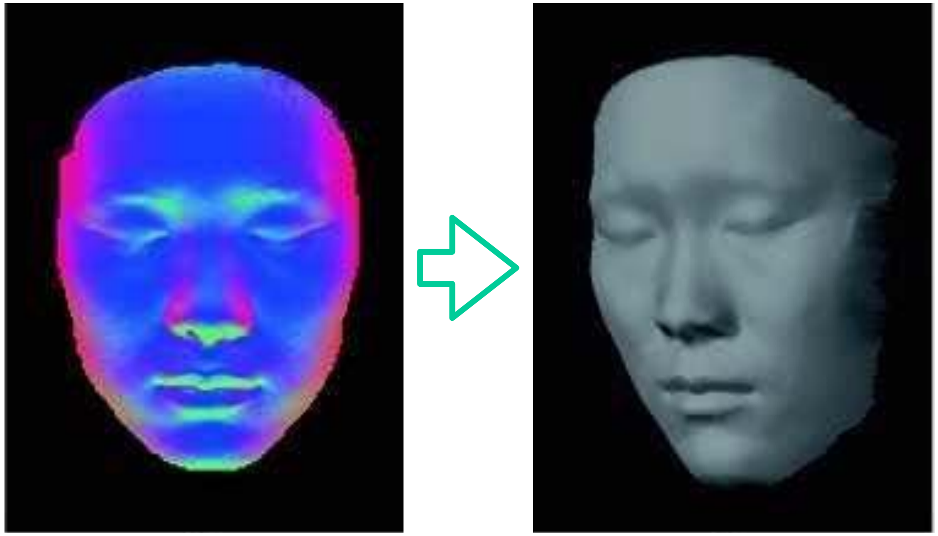
Shape from Normals



Normals 3D shape

Elevation and normal:

$$z = f(x, y)$$

$$\mathbf{N} = \frac{1}{\sqrt{1 + p^2 + q^2}} \begin{bmatrix} -p \\ -q \\ 1 \end{bmatrix} \quad \begin{bmatrix} -f_x \\ -f_y \\ 1 \end{bmatrix}$$

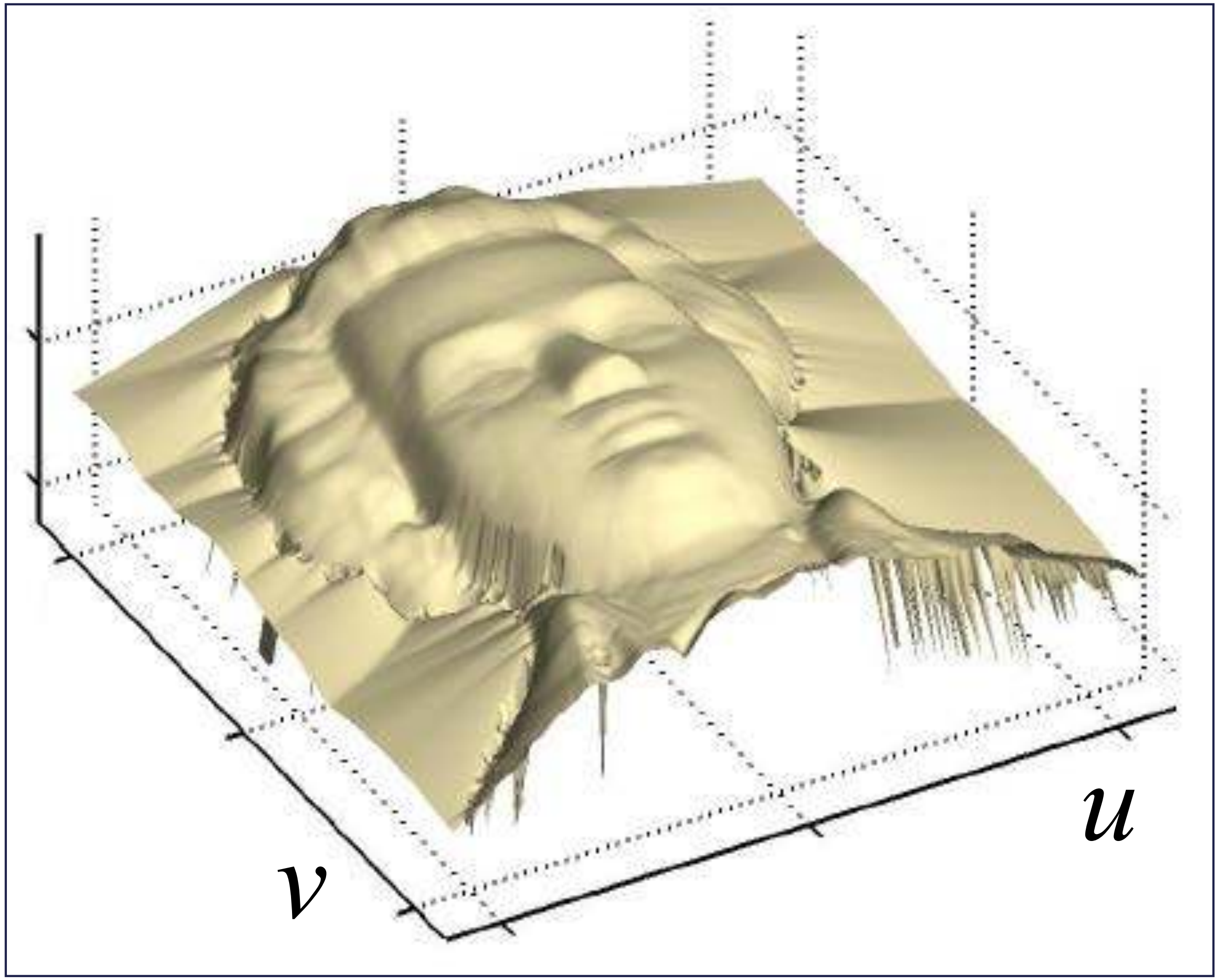
Orthographic projection:

$$u = sx$$
$$v = sy$$

camera with long focal length so that 2D-coordinates (u,v) are simply scaled version of (x,y)

Re-Parametrization

Perform a change of variables z = f(u,v) where u and v are image coordinates.



Shape From Normals (1)

Since u = sx and v = sy, the normal vector **N** is

$$\begin{bmatrix} n_x \\ n_y \\ n_z \end{bmatrix} = \frac{1}{\sqrt{1 + \frac{\delta z}{\delta x}^2 + \frac{\delta z}{\delta y}^2}} \begin{bmatrix} -\frac{\delta z}{\delta x} \\ -\frac{\delta z}{\delta y} \\ 1 \end{bmatrix} ,$$

$$\Rightarrow \frac{\delta z}{\delta x} = -\frac{n_x}{n_z} \text{ and } \frac{\delta z}{\delta y} = -\frac{n_y}{n_z} ,$$

$$\Rightarrow \frac{\delta z}{\delta u} = -\frac{1}{s}\frac{n_x}{n_z} \text{ and } \frac{\delta z}{\delta v} = -\frac{1}{s}\frac{n_y}{n_z} ,$$

$$\Rightarrow \frac{\delta \bar{z}}{\delta u} = -\frac{n_x}{n_z} = n_1 \text{ and } \frac{\delta \bar{z}}{\delta v} = -\frac{n_y}{n_z} = n_2 ,$$

these are known

where $\bar{z} = sz$ is the scaled distance.

depends on camera

Shape From Normals (2)

- Let us assume we are given the normal at each pixel (u,v).
- Let $n_1(u,v) = -n_x(u,v)/n_z(u,v)$ and $n_2(u,v) = -n_y(u,v)/n_z(u,v)$.
- From the previous slide, we have

Finite difference between neighbours

$$\forall u,v \quad \begin{cases} n_1(u,v) = \dfrac{\delta \bar{z}}{\delta u} \approx \bar{z}(u+1,v) - \bar{z}(u,v) \\ n_2(u,v) = \dfrac{\delta \bar{z}}{\delta v} \approx \bar{z}(u,v+1) - \bar{z}(u,v) \end{cases}$$

we know them

We are trying to compute $\bar{z}$

- We therefore have roughly twice as many equations as we have unknowns, the scaled distances $\bar{z}(u,v)$.
- This can be solved in the least squares sense.

equations >> unknown

solve with over-constrained system

—> Given the normals at every pixel we can recover the distances up to a scale factor.

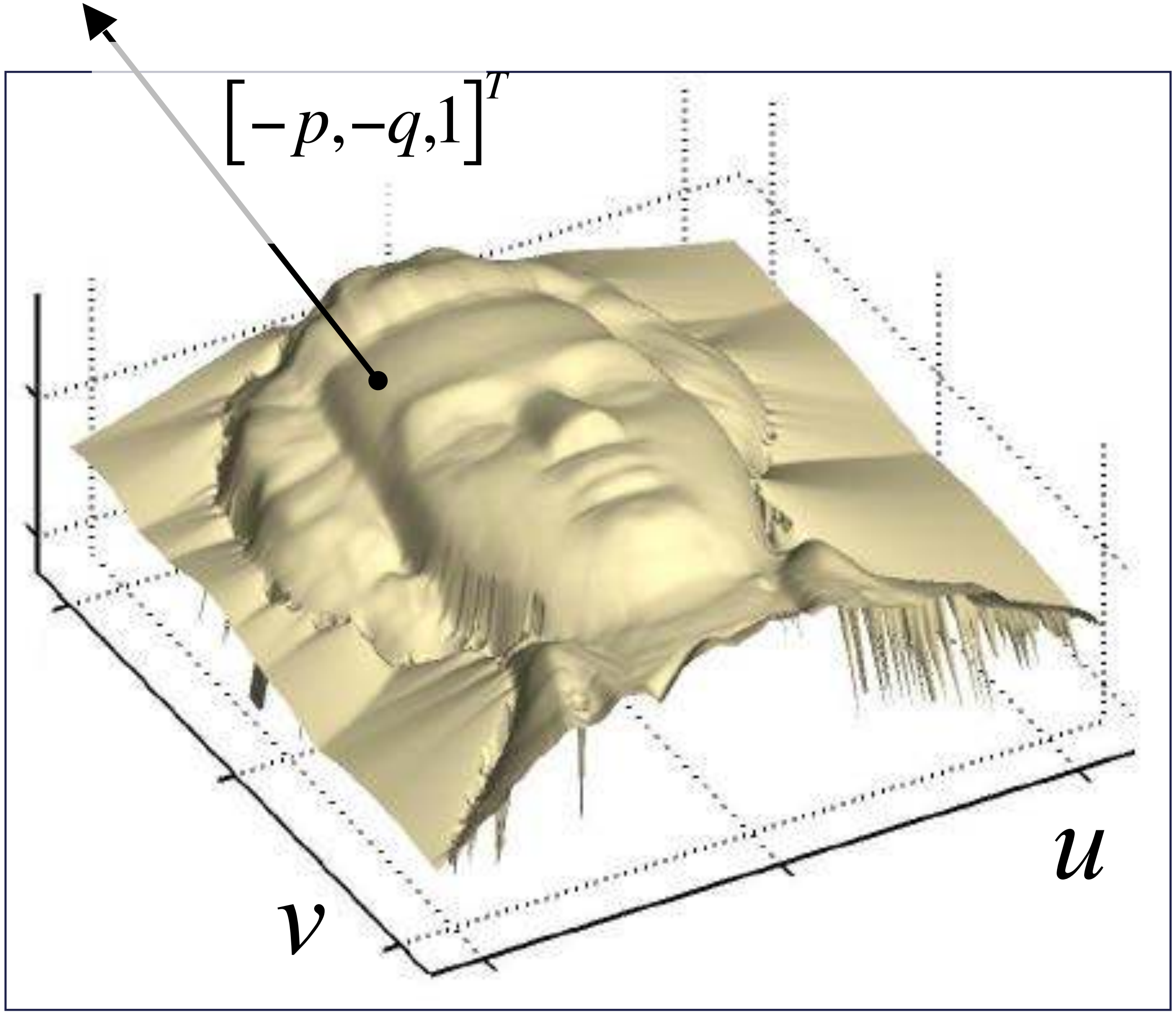
$\bar{z} = \delta z$

↳ we can compute the 3D-shape ($\bar{z}$'s)

But how do we get the normals?

Back to Estimating the Normals

$$z = f(u, v)$$
$$p = \frac{\delta z}{\delta u}$$
$$q = \frac{\delta z}{\delta v}$$



What does the image tell us about them?

Reflectance Map

In the Lambertian case and for a constant albedo:

Intensity

$$
\begin{aligned}
I(u,v) &\propto \mathbf{L} \cdot \overrightarrow{\mathbf{N}} \\
&\propto \mathbf{L} \cdot \left[-p(u,v), -q(u,v), 1\right]^T \\
&\propto Ref(p(u,v), q(u,v))
\end{aligned}
$$

(For Lambertian case)

→ Reflectance function

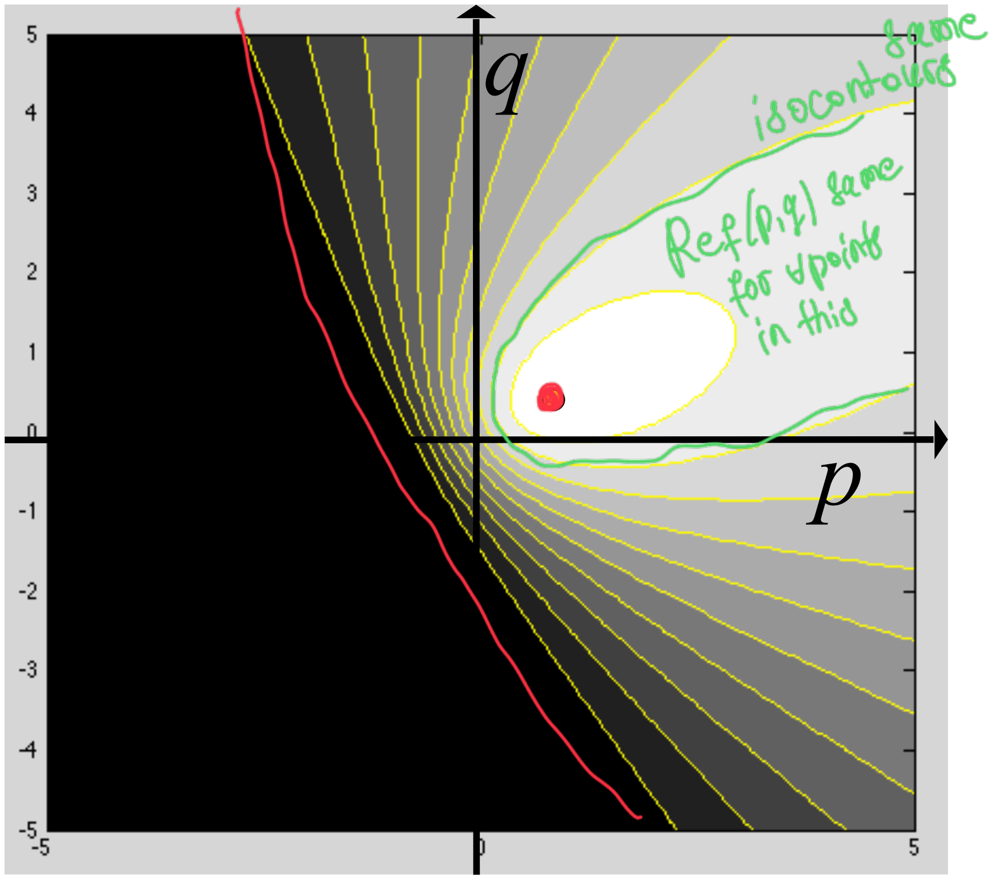
it associates (p, q) normals with intensity observed

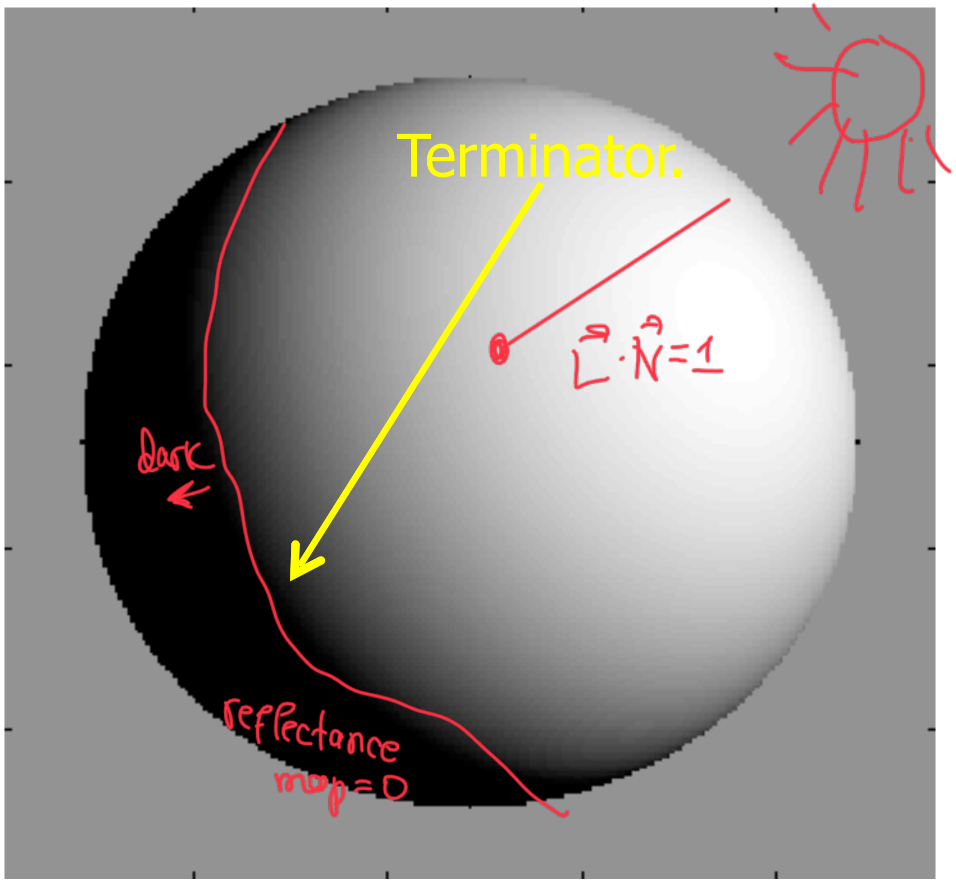
- The function Ref is known as the reflectance map.
- For non-Lambertian surfaces it can be more complex.

≠ shapes you are looking at, but at the materials (even for complex ones)

Lambertian Reflectance Map

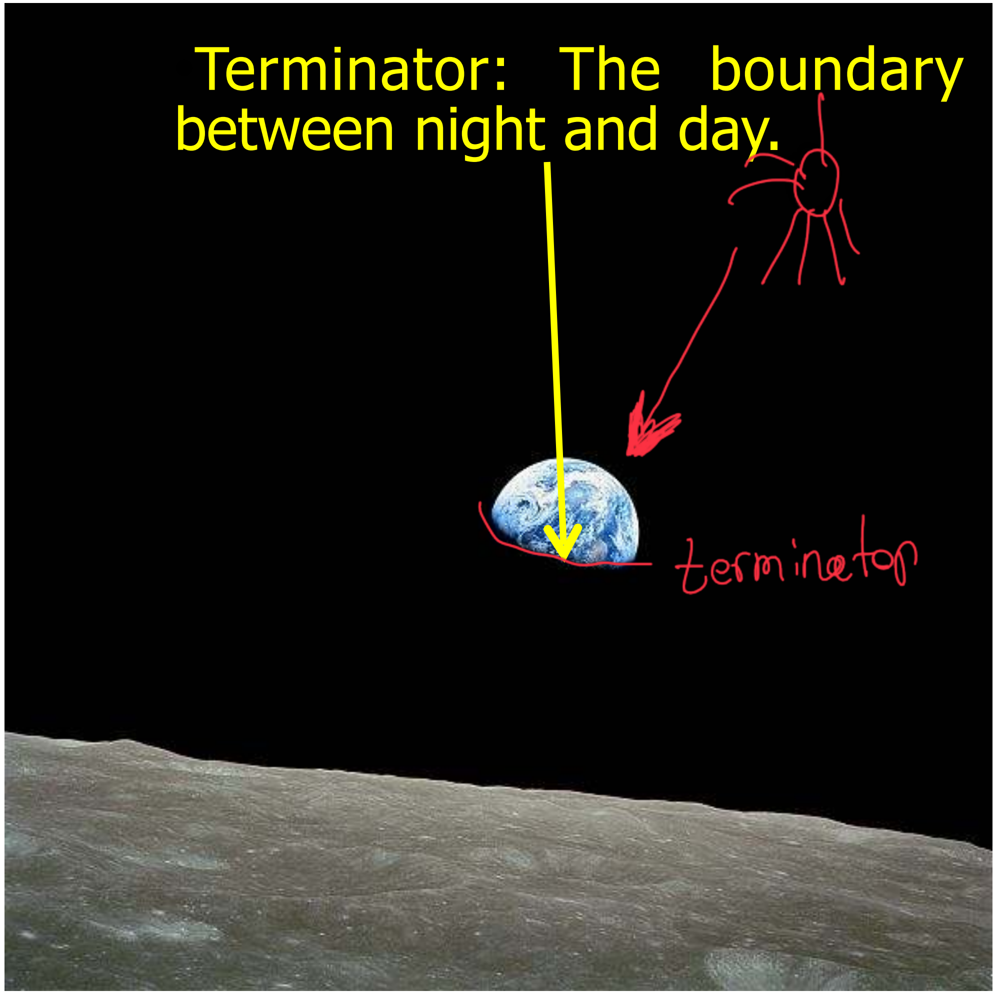
$\vec{L}\cdot\vec{N}=0$ (terminator)





Reflectance map and shaded surface for Lambertian surface illuminated in the direction [-1 -0.5 -1].

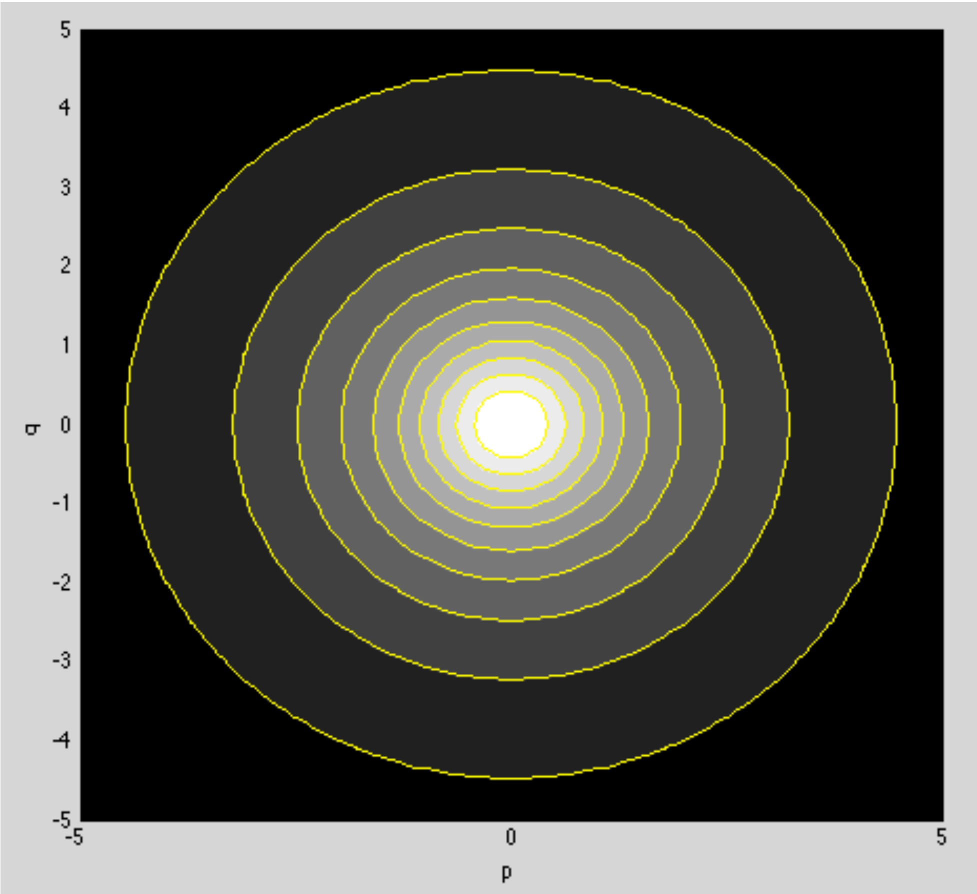
Earth Seem from the Moon

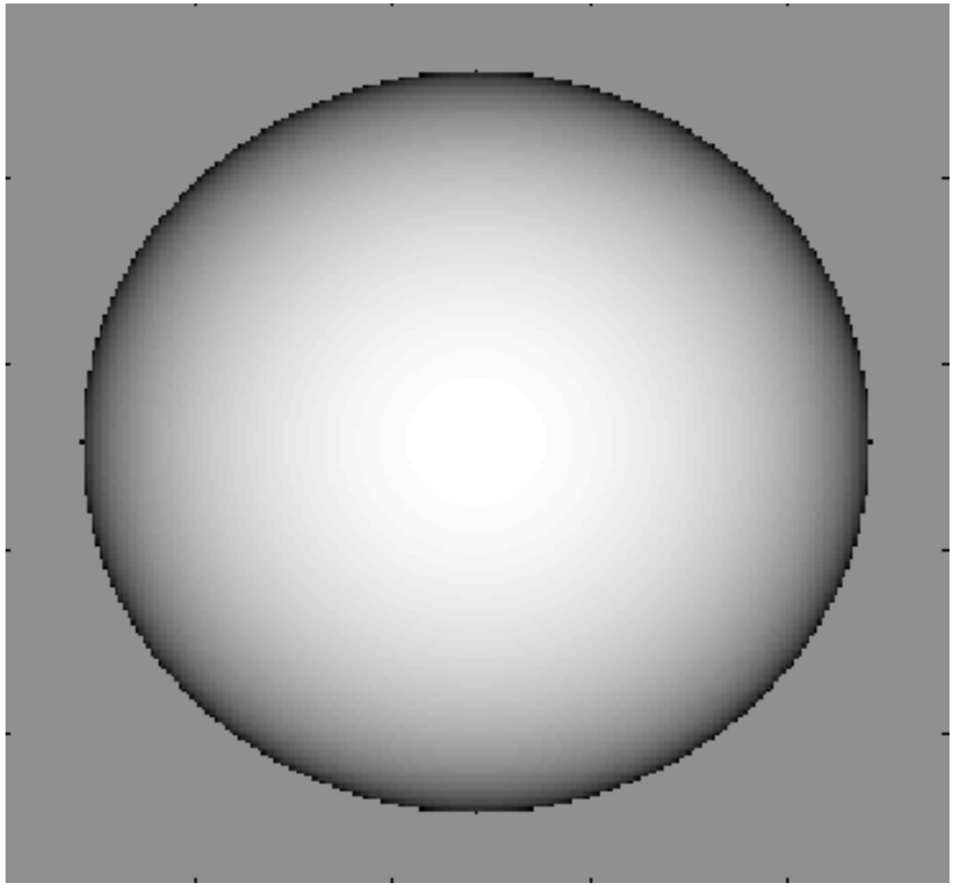


Apollo 8, 1968.

Close to Lambertian model

Lambertian Reflectance Map

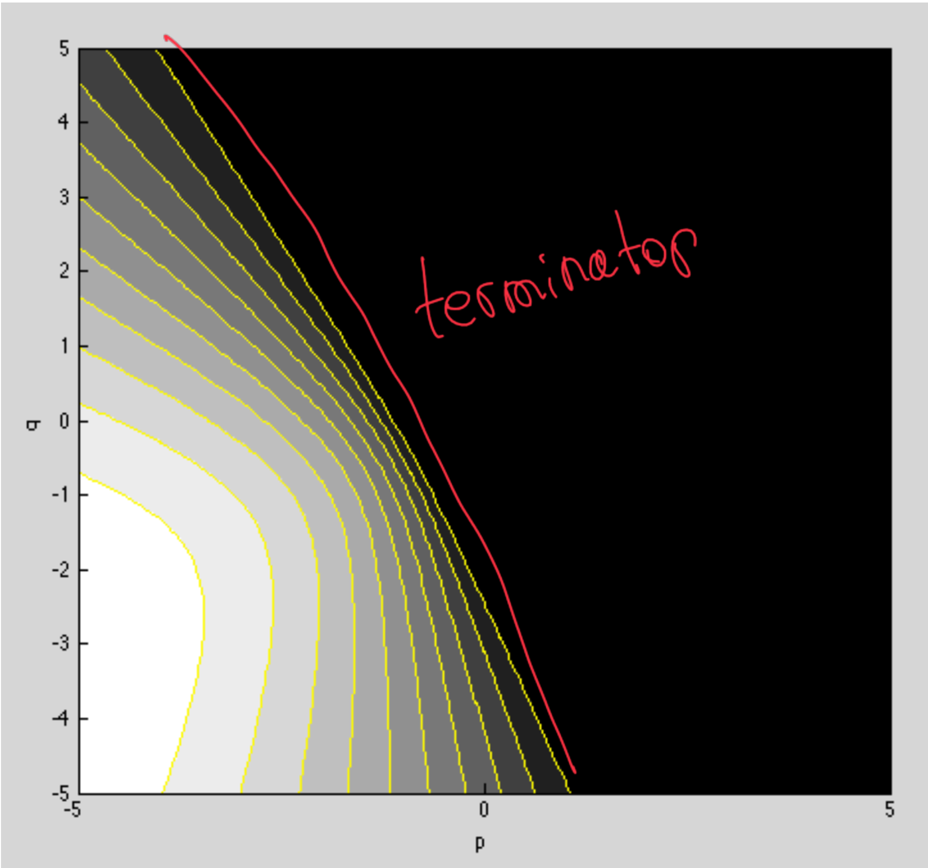


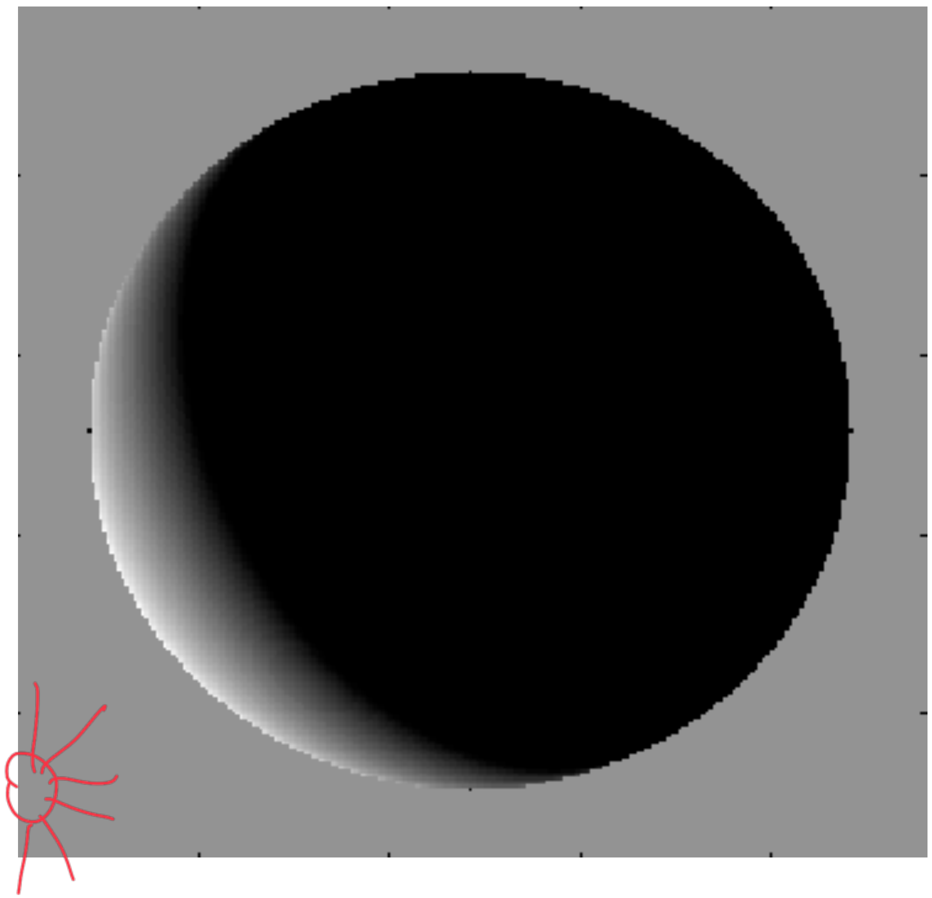


Reflectance map and shaded surface for Lambertian surface illuminated in the direction [0 0 -1].

EPFL

Lambertian Reflectance Map



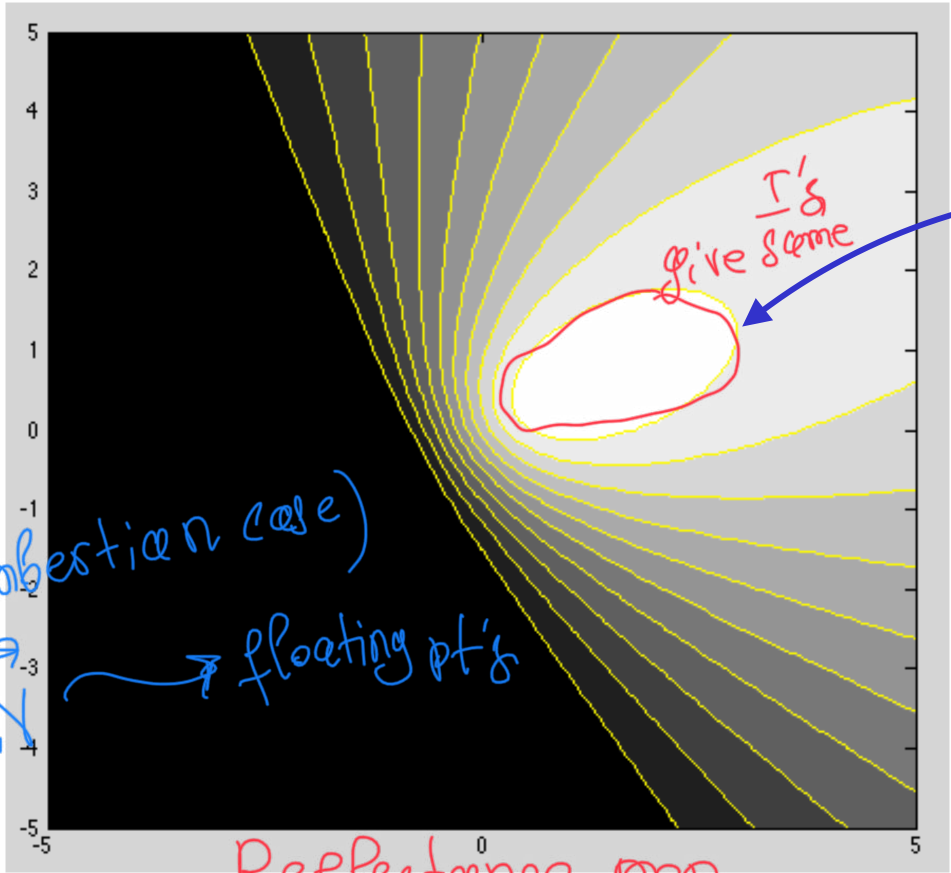


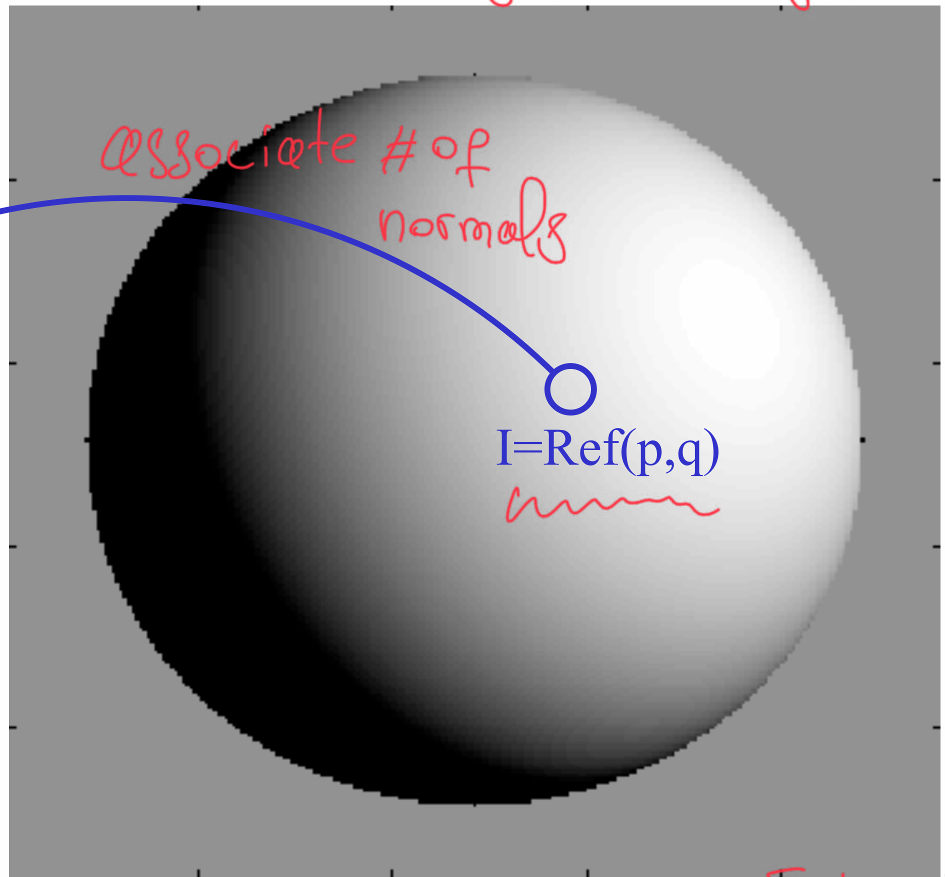
Reflectance map and shaded surface for Lambertian surface illuminated in the direction [1 0.5 -1].

Inverse Problem (Shape from Shading)

Can we determine (p,q) uniquely for each image point independently?

Gray-level image



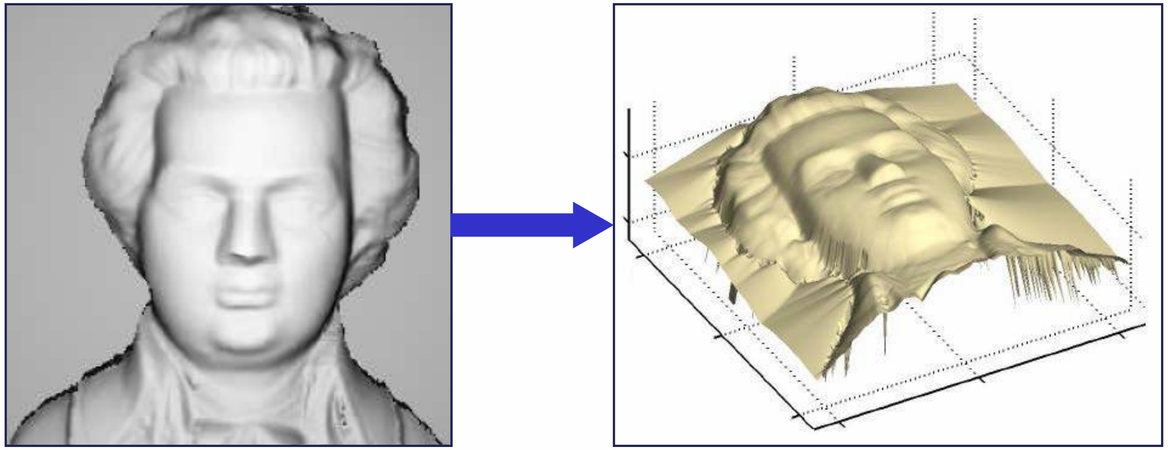


No because many p and q yield the same Ref(p,q).

—> Global optimization required.

Variational Method (1)

for all your points



Minimize:

similar

similar to snakes

If they're derivative ⇒ it becomes v

$$\int\int\left([I(u,v)-Ref(p,q)]^2+\lambda\left[\left(\frac{\delta p}{\delta u}\right)^2+\left(\frac{\delta p}{\delta v}\right)^2+\left(\frac{\delta q}{\delta u}\right)^2+\left(\frac{\delta q}{\delta v}\right)^2\right]+\mu\left[\frac{\delta p}{\delta v}-\frac{\delta q}{\delta u}\right]^2\right)dudv$$

normals at neighboring pts (not indep.) should be similar

$p = \frac{\partial f}{\partial v}$

Data term

Smoothness term

(regularization)

Integrability term

$$\frac{\frac{\delta z}{\delta u}}{\delta v}=\frac{\frac{\delta z}{\delta v}}{\delta u}=\frac{\delta^2 z}{\delta u \delta v}$$

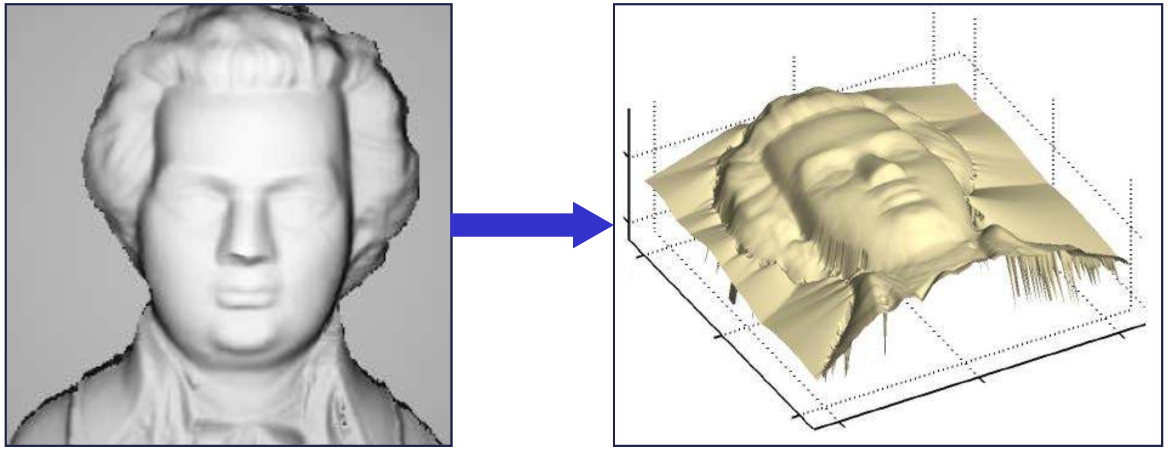
Set of

Get (p,q)'s

1. Recover the normals and make them integrable.
2. Integrate to recover the 3D surface. RHS

(p,q)

Variational Method (2)



Minimize:

$$\int\int\left(\left[I(u,v) - Ref\left(\underbrace{\frac{\delta z}{\delta u}}_{p}, \underbrace{\frac{\delta z}{\delta v}}_{q}\right)\right]^2 + \lambda\left[\left(\frac{\delta^2 z}{\delta u^2}\right)^2 + \left(\frac{\delta^2 z}{\delta u \delta v}\right)^2 + \left(\frac{\delta^2 z}{\delta v^2}\right)^2\right]\right) dudv$$

Second derivatives of z

Data term

Smoothness term

Introduce z

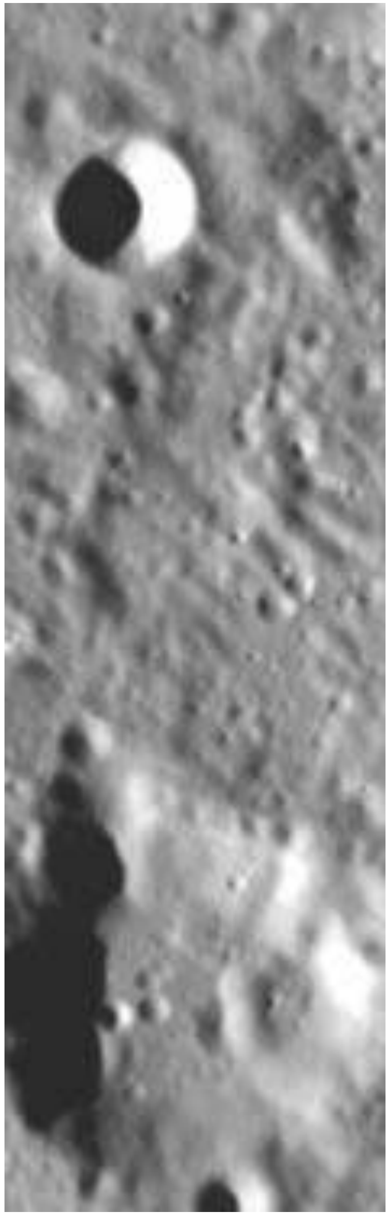
- Recover the surface directly, which means solving a second order differential equation instead of a first order one.
- Both approaches are valid and require boundary conditions.

for DEs

Moonscape

(albedo ~ constant)

same physical properties over the extensive areas



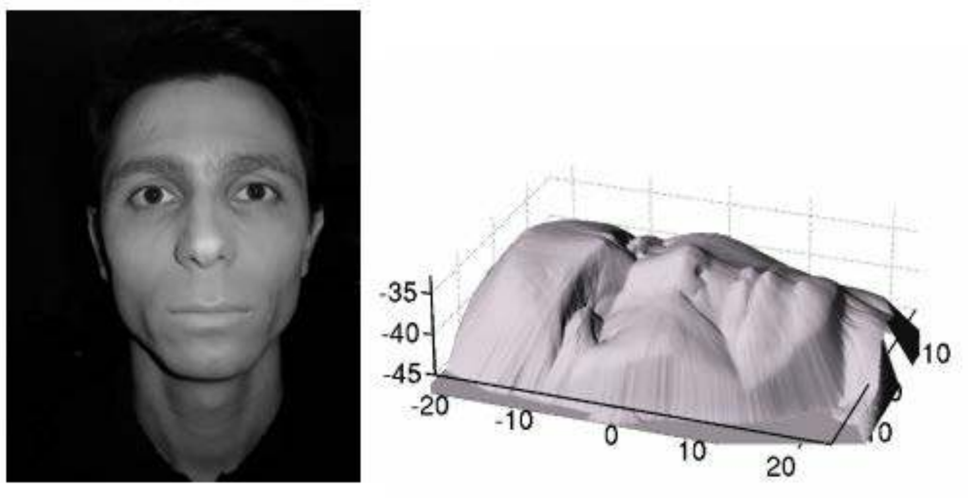
Moon image

Depth map

(what has been coded is the altitude)

EPFL

Faces from Shading



A djust not only z's but also model params

- Generic Monge surface
- Low resolution images

Prados and Faugeras, CVPR'05.

- Deep face model
- High resolution images

Bagautdinov et al. , CVPR'18.

Combination of shape-from-shading and powerful face models (VAEs)

T-Shirt

old approach

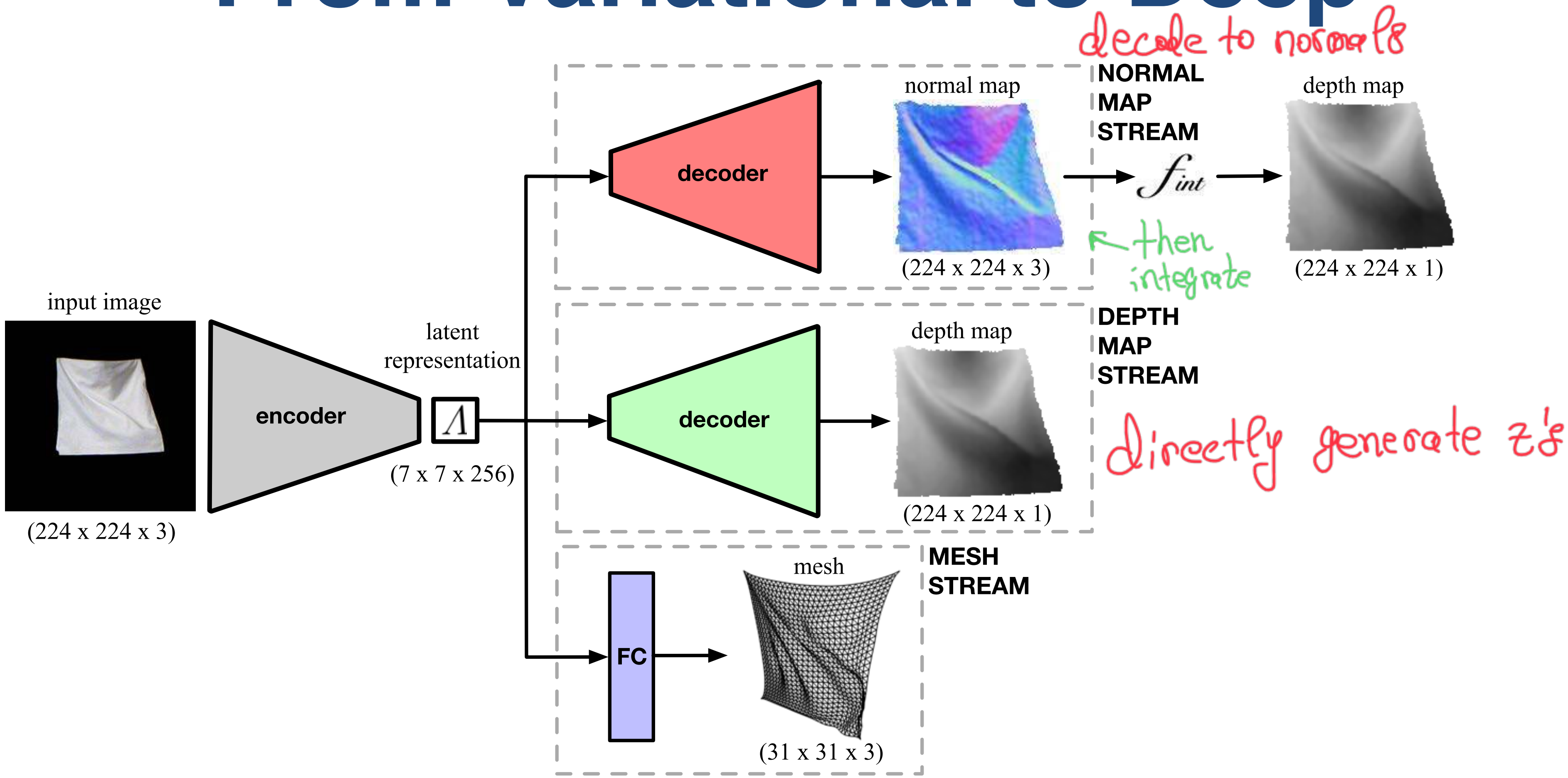
smoothness too much

T-shirt which has patterns => bad

Works because the albedo is constant!

Barron & Malik, PAMI'15

From Variational to Deep



The deep net is trained to:

- produce both a depth map and a map of normals,
- ensure they are consistent with each other.

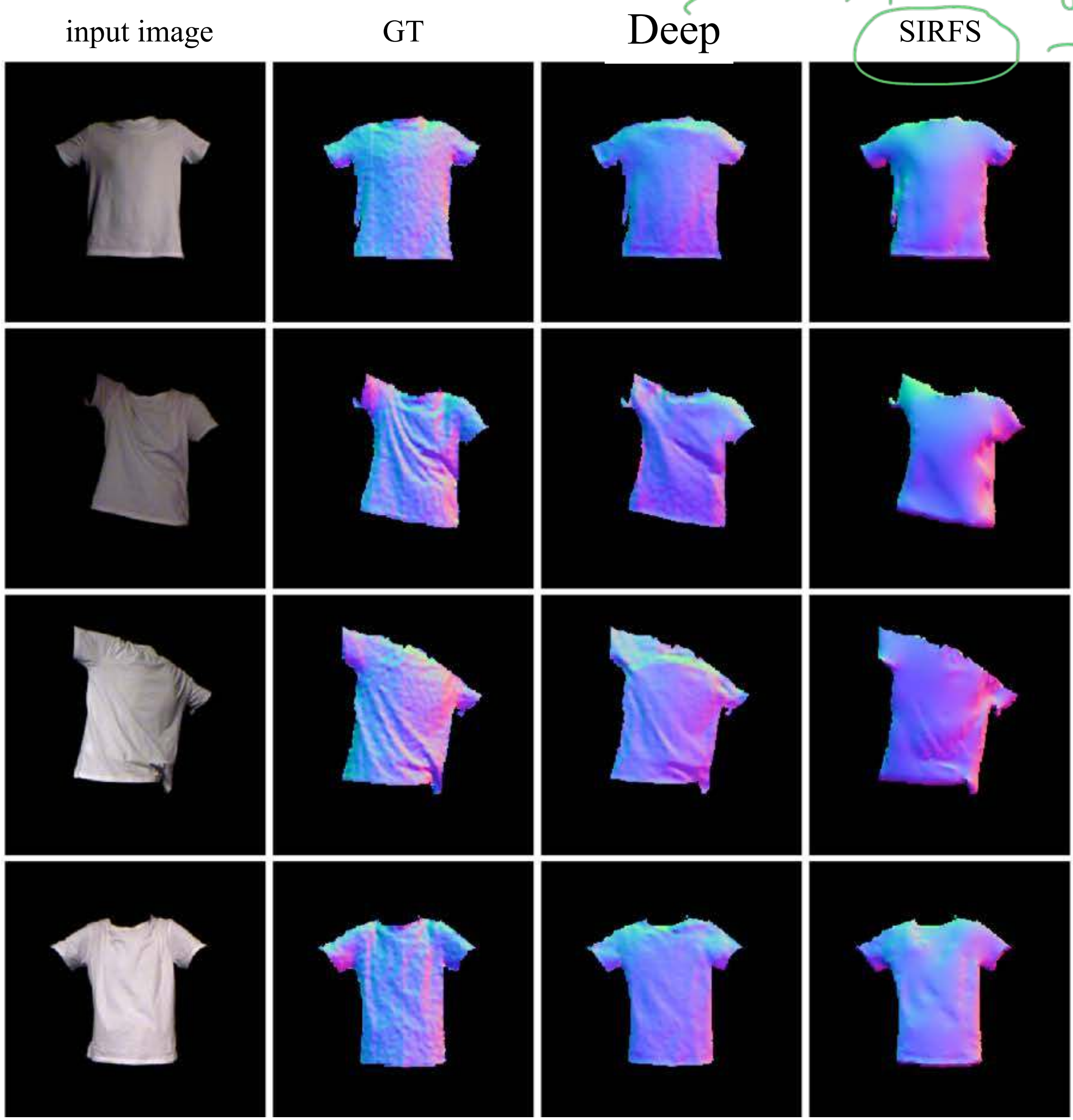
in different way

—> Can be understood as another way to solve the variational problem.

Bednarik et al. , ECCV'18

Improved Results

fewer regularization constraints

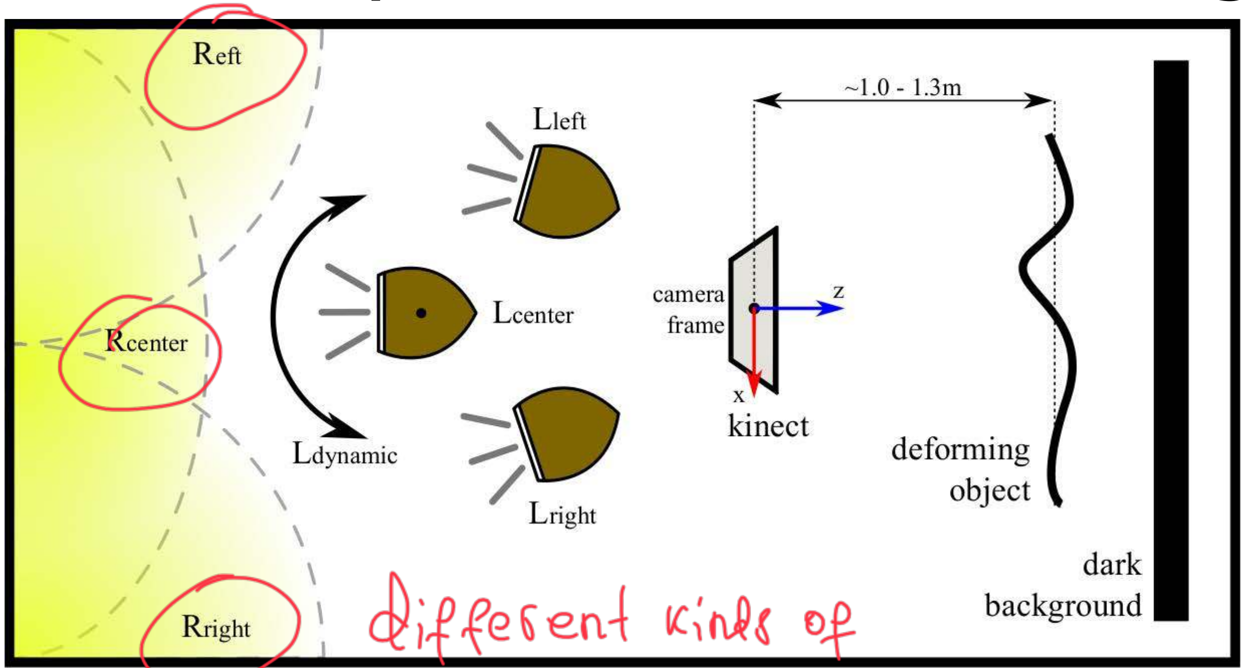


variational algorithm

The deep net recovers more details ......

Training Data

... but required serious training.



different kinds of lighting

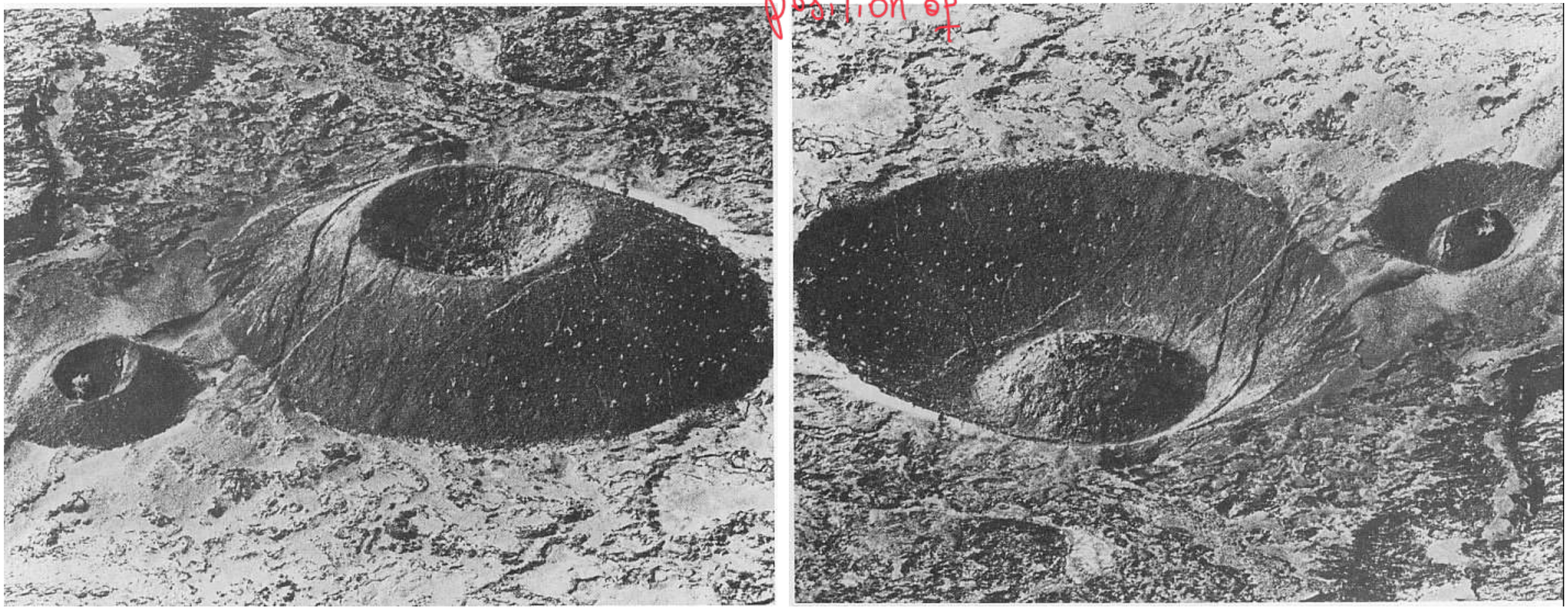
- 3 fixed light sources.
- 1 mobile one.

—> Not a yet a generally applicable solution.

But getting closer. We'll talk about it again next week .....

Reminder: Ambiguities

We flipped the images
but light source → still same
position of



- Back where we started.
- Let us look at them more closely.

Bas-Relief Ambiguity

Looks like a normal human head …

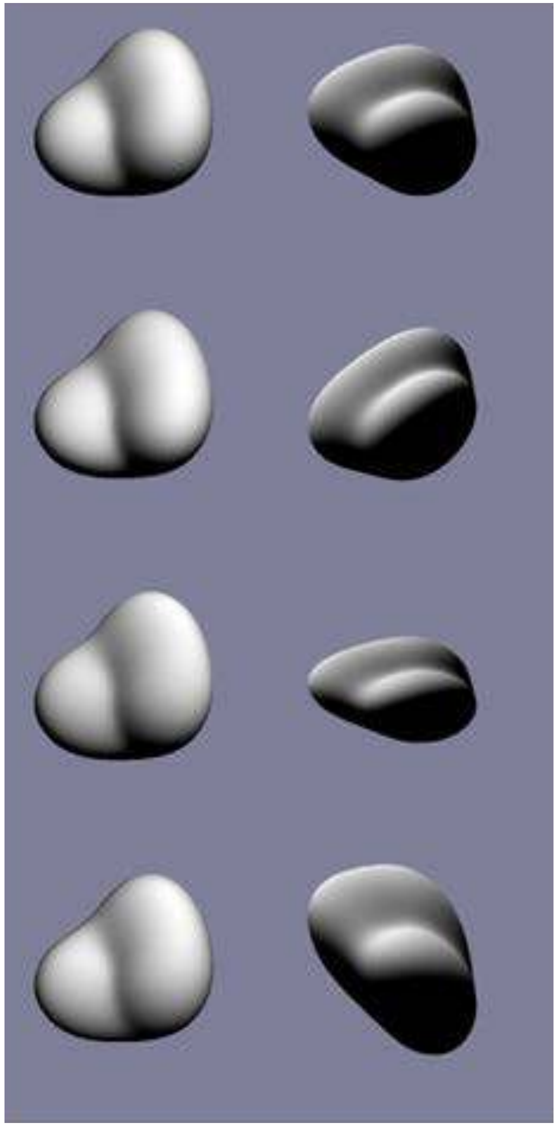
Head is squashed

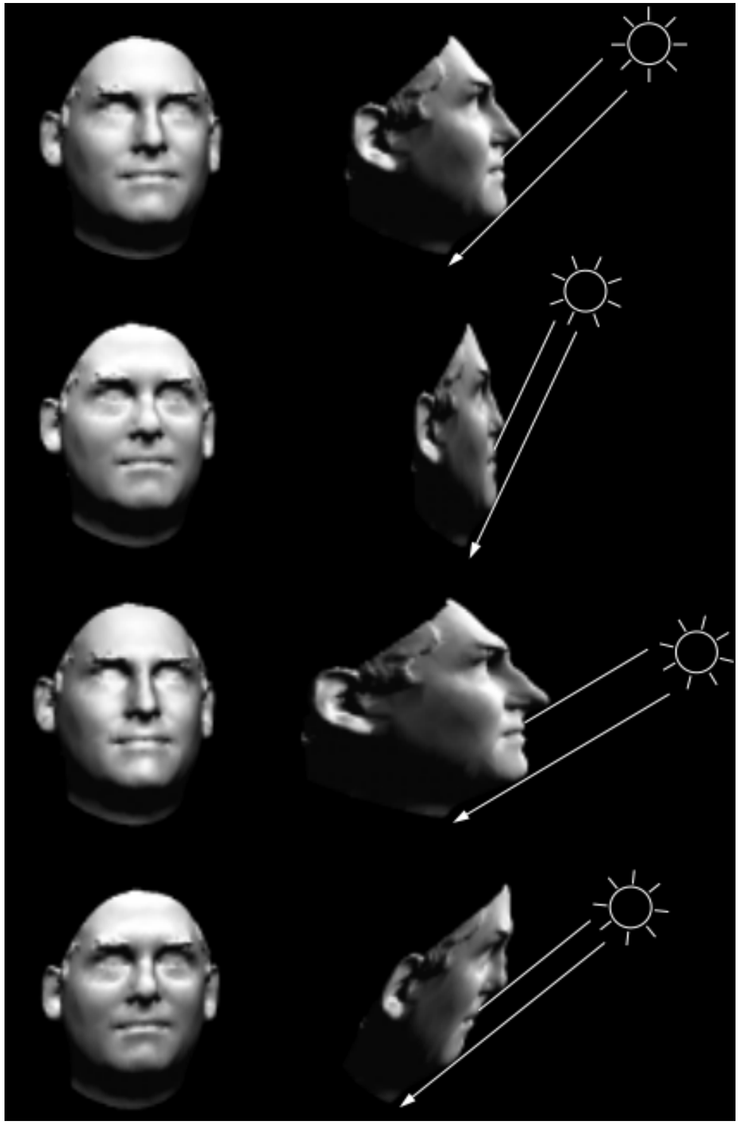
narrow in this direction

… but not when seen from the side.

Why is that?

Bas-Relief Ambiguity





rendered as a Lambertian surface with const albedo (equal grey values for all surface pts)

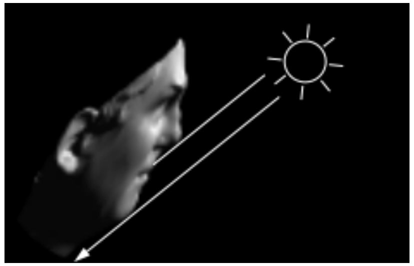
By moving the light source, it is possible to produce the same image for different 3D shapes.

Bas-Relief Ambiguity Explained (1)

$$Ref = \mathbf{N} \cdot \mathbf{L}$$

3x1 vector

↳ Reflectance function



For any invertible 3x3 linear transformation A:

similar intensities

$$\begin{aligned}(\mathbf{AN}) \cdot (\mathbf{A}^{-T}\mathbf{L}) &= (\mathbf{AN})^T(\mathbf{A}^{-T}\mathbf{L}) \\ &= \mathbf{N}^T\mathbf{A}^T\mathbf{A}^{-T}\mathbf{L} \\ &= \mathbf{N}^T\mathbf{L} \\ &= \mathbf{N} \cdot \mathbf{L}\end{aligned}$$

$(A^{-1})^T$

move the light source and get ~same result

- In theory, applying **A** to the normals and $\mathbf{A}^{-1}$ to the light source would not change the image.
- However, the normals must remain integrable, which means that not all transformations of the normals are valid.

AN →

- In particular, for a Monge surface z = f(u,v), we must have

$$\frac{\frac{\delta z}{\delta u}}{\delta v} = \frac{\frac{\delta z}{\delta v}}{\delta u} = \frac{\delta^2 z}{\delta u \delta v}$$

Bas-Relief Ambiguity Explained (2)

Let us write the integrability constraint in our specific case:

$$\left.\begin{aligned} \frac{\delta z}{\delta u} &= -\frac{n_x^*}{n_z^*} \\ \frac{\delta z}{\delta v} &= -\frac{n_y^*}{n_z^*} \end{aligned}\right\} \Rightarrow \frac{\delta \frac{n_x^*}{n_z^*}}{\delta v} = \frac{\delta \frac{n_y^*}{n_z^*}}{\delta u} \text{ with } \begin{bmatrix} n_x^* \\ n_y^* \\ n_z^* \end{bmatrix} = \mathbf{A}^{-T} \begin{bmatrix} n_x \\ n_y \\ n_z \end{bmatrix}$$

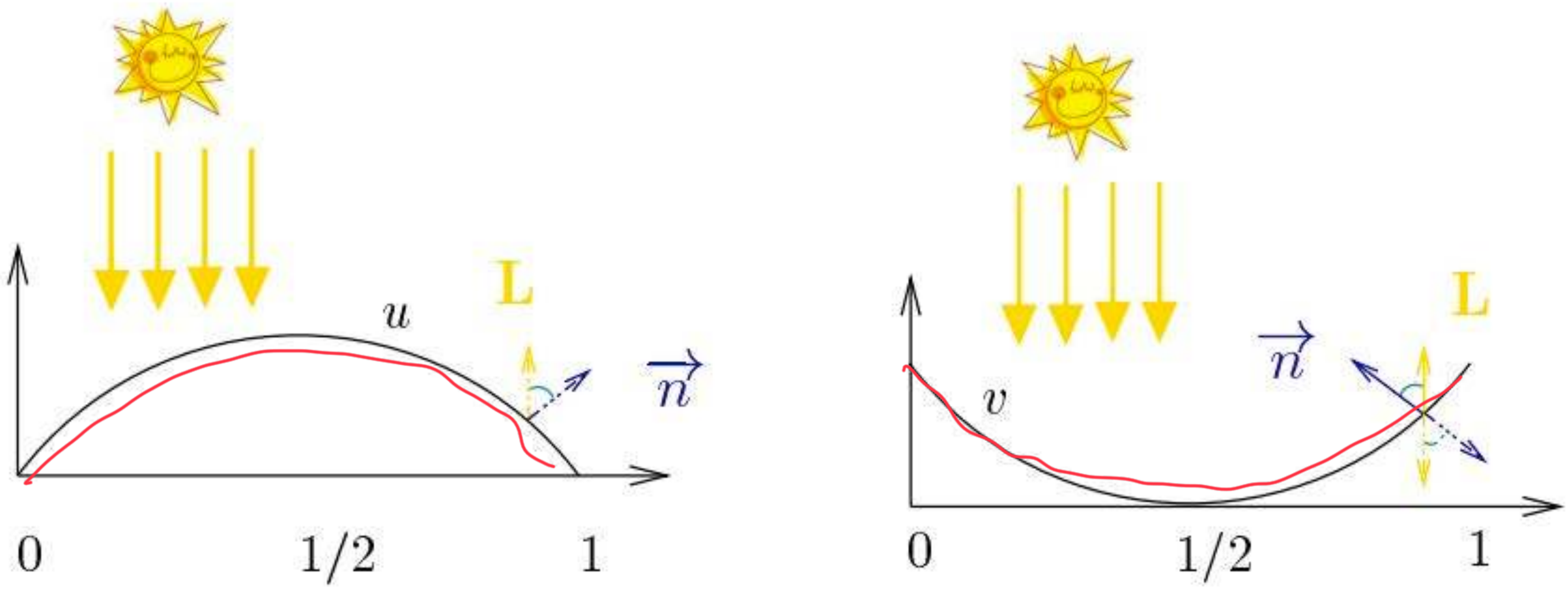
$$\Rightarrow \mathbf{A} \text{ restricted to } \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ \underset{\in \mathbb{R}}{\mu} & \underset{\in \mathbb{R}}{\nu} & \lambda \end{bmatrix}$$

—> The surface f(u, v) can be changed into λf(u,v) + μu + νv and still produce the same image.

By simply moving the light source in a correct way

Convex/Concave Ambiguity

in shape from shading



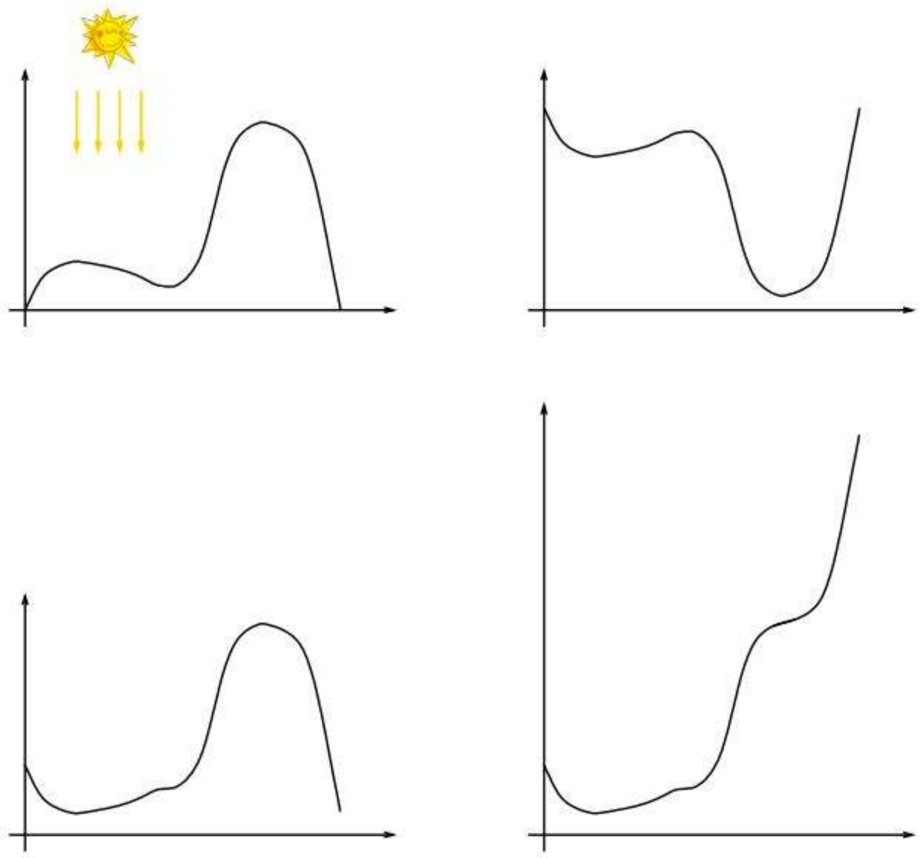
It can happen even when the light source is known!

you can't differentiate them just on the basis of their shading

convex/concave surface is same

light from → even light source is far

Convex/Concave Ambiguity



- All four profiles will produce the same image under the illumination shown here.
- The SfS (variational) problem under orthographic projection with a distant light-source is ill-posed. → no unique sol'n (one of them ⊥ starting pt)

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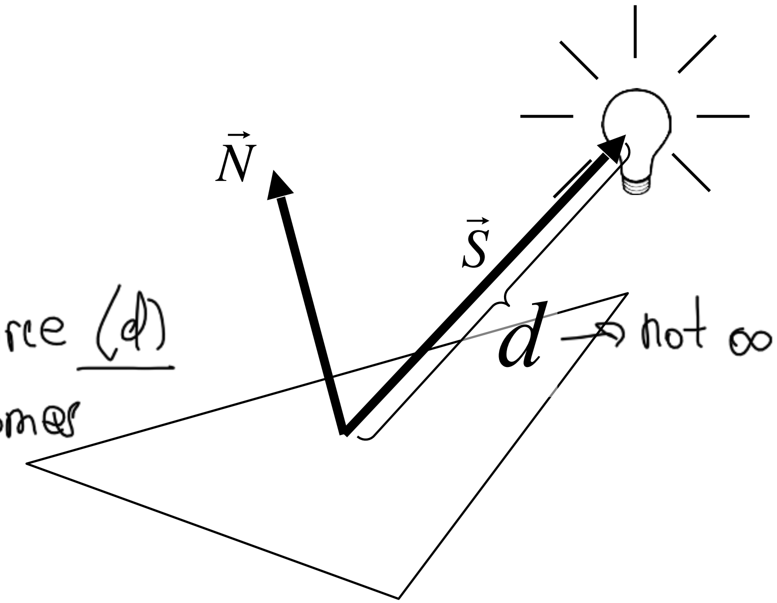
Making the SfS Problem Well-Posed

- Use perspective projection model;
- Radiance depends on distance to light source:

$$I = \frac{Albedo \cdot (\mathbf{N} \bullet \mathbf{S})}{d^2}$$



instead of

further away from light source (d)
→ the dimmer image becomes

$$I = Albedo \cdot (\mathbf{N} \bullet \mathbf{S})$$

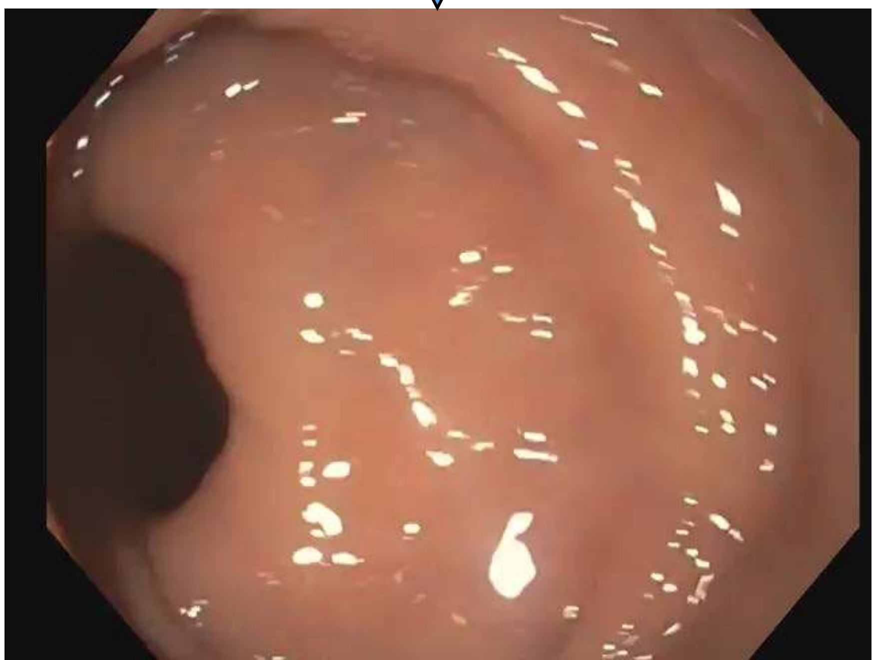
- Light source located at the optical center.

camera and light source at same place

-> Unique solution but more complex computations.

Prados and Faugeras, CVPR'05.

Endoscopy



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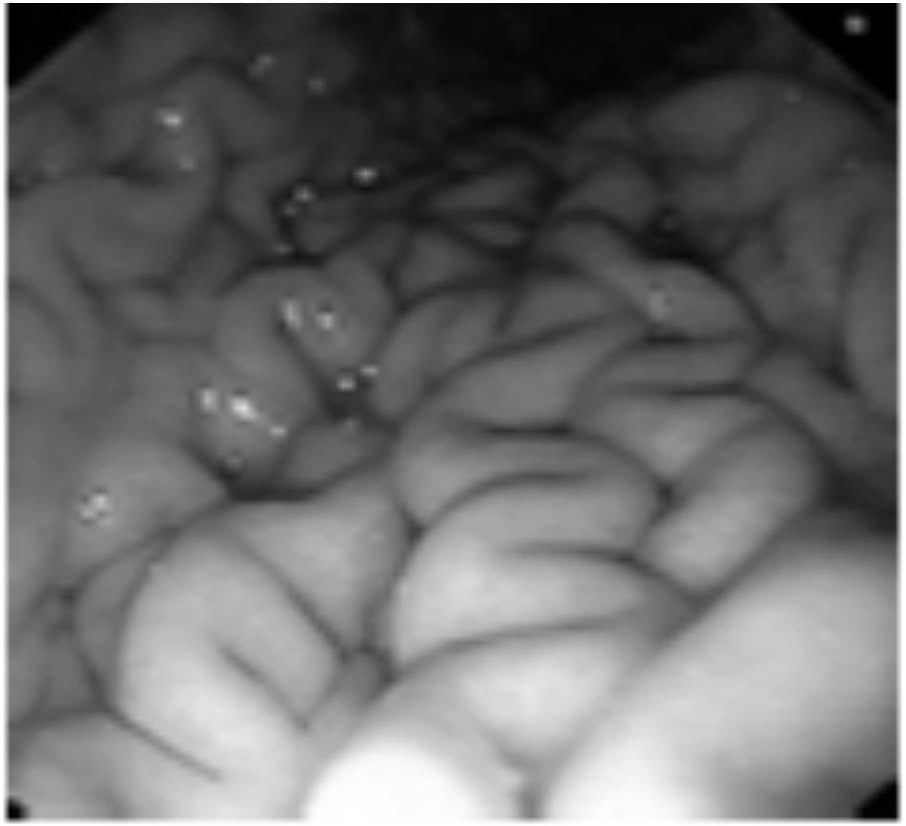
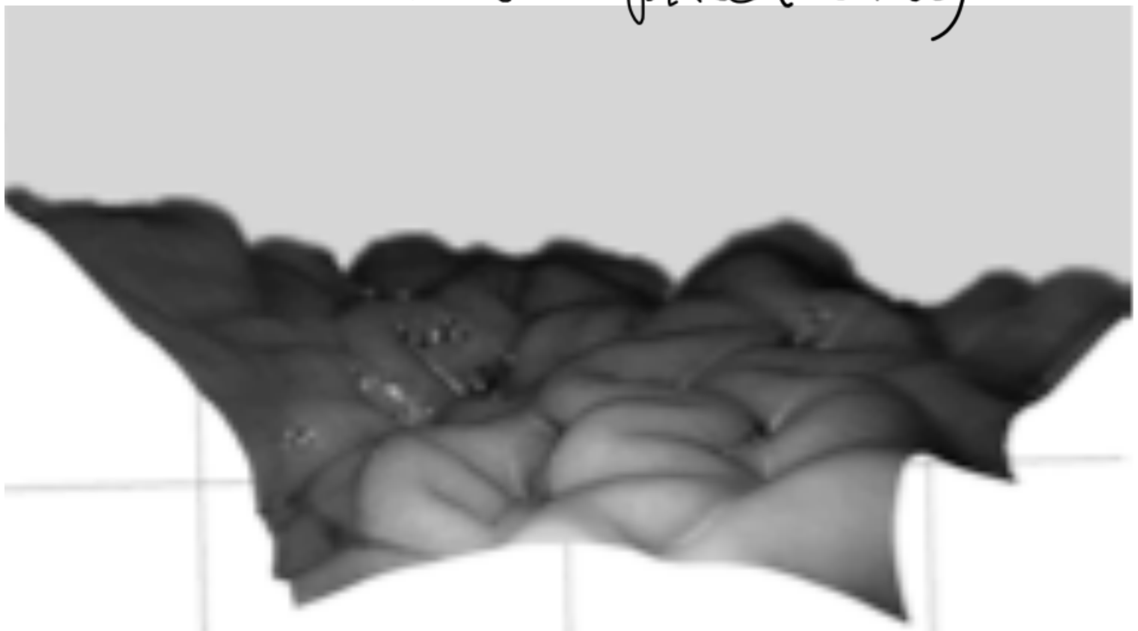
Endoscopy 2005



Light source and camera
→ at the same place (almost)



- The problem becomes well-posed but the variational approach assumes constant albedo, which is limiting.
- Can we take advantage of deep learning to overcome this problem?

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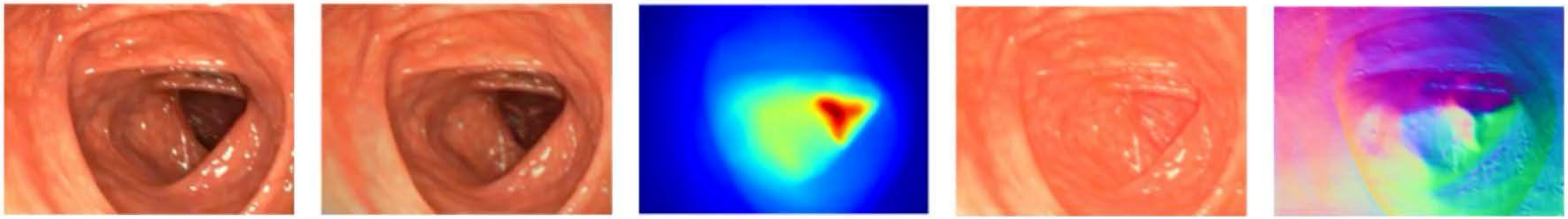
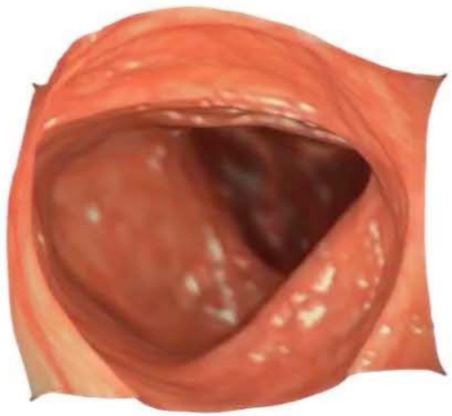
Prados and Faugeras, CVPR'05.

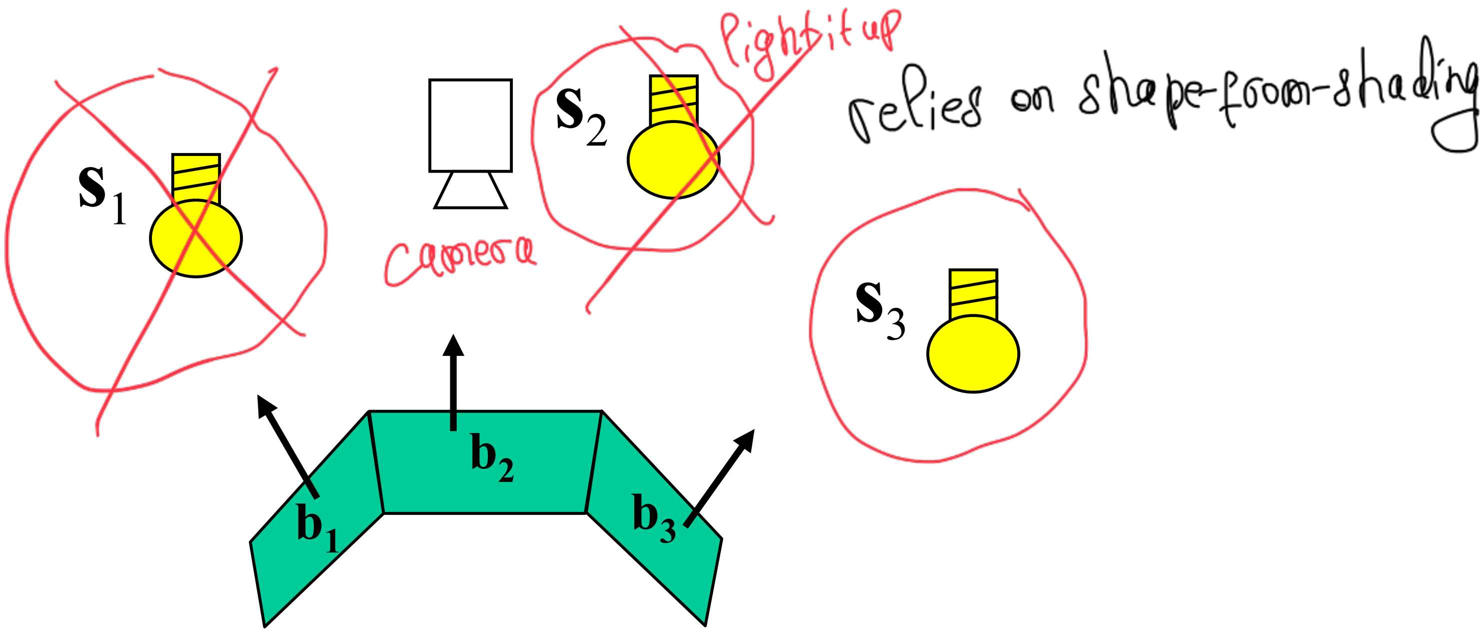
Endoscopy 2023

Image | Synthesized | Depth | Albedo | Normals





Photometric Stereo

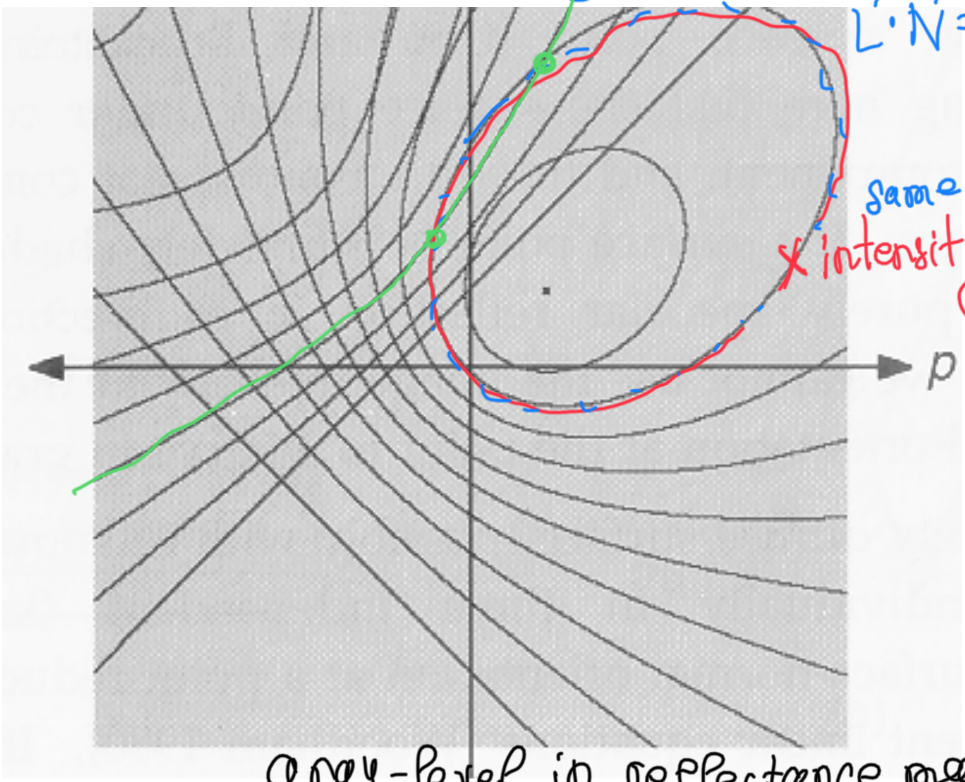


Given multiple images of the same surface under different known lighting conditions, can we recover the surface shape?

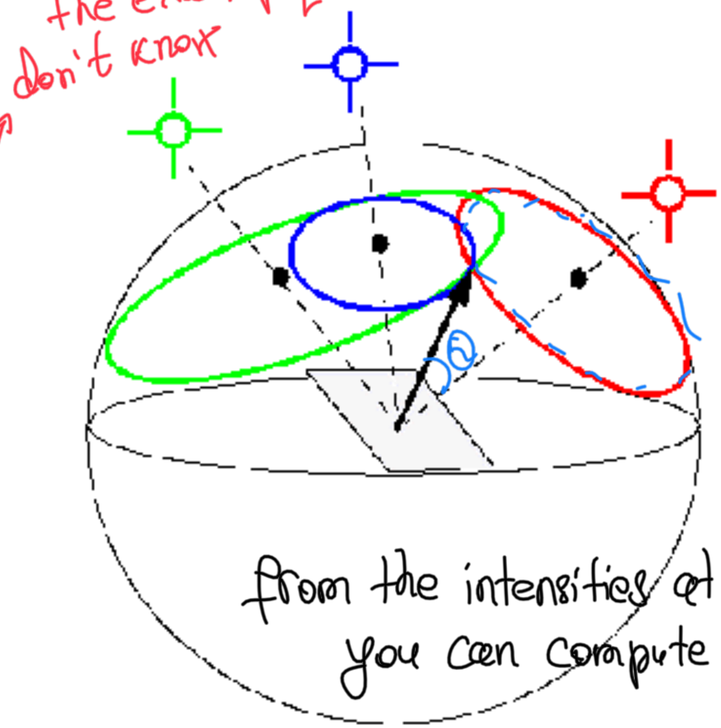
- **Yes!** (Woodham, 1978).
- This gave rise to an early and still practical application of computer vision.

have the same angle θ with the direction of light source
go through this circle
all normals that

Basic Idea



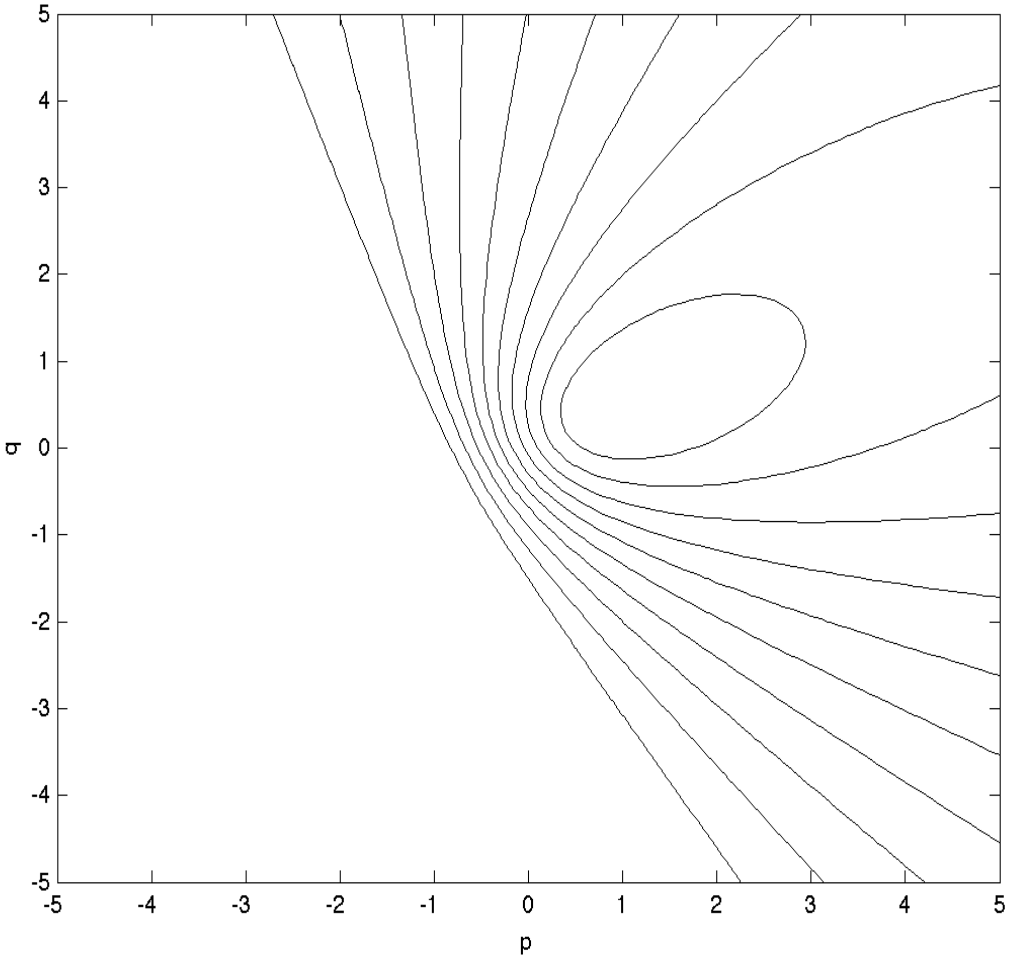
gray-level in reflectance map

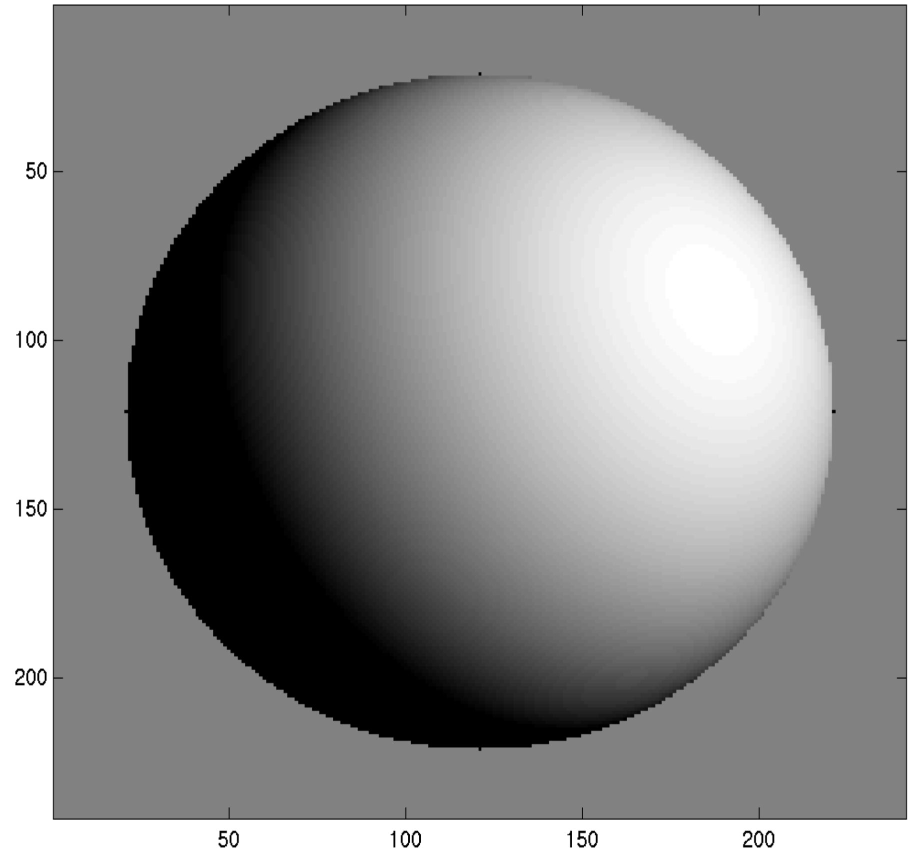


from the intensities at a single pt, you can compute normals

- Take several images under different lighting conditions.
- Infer the normals from the changes in illumination.
- Given at least three different lights, there are no more ambiguities.

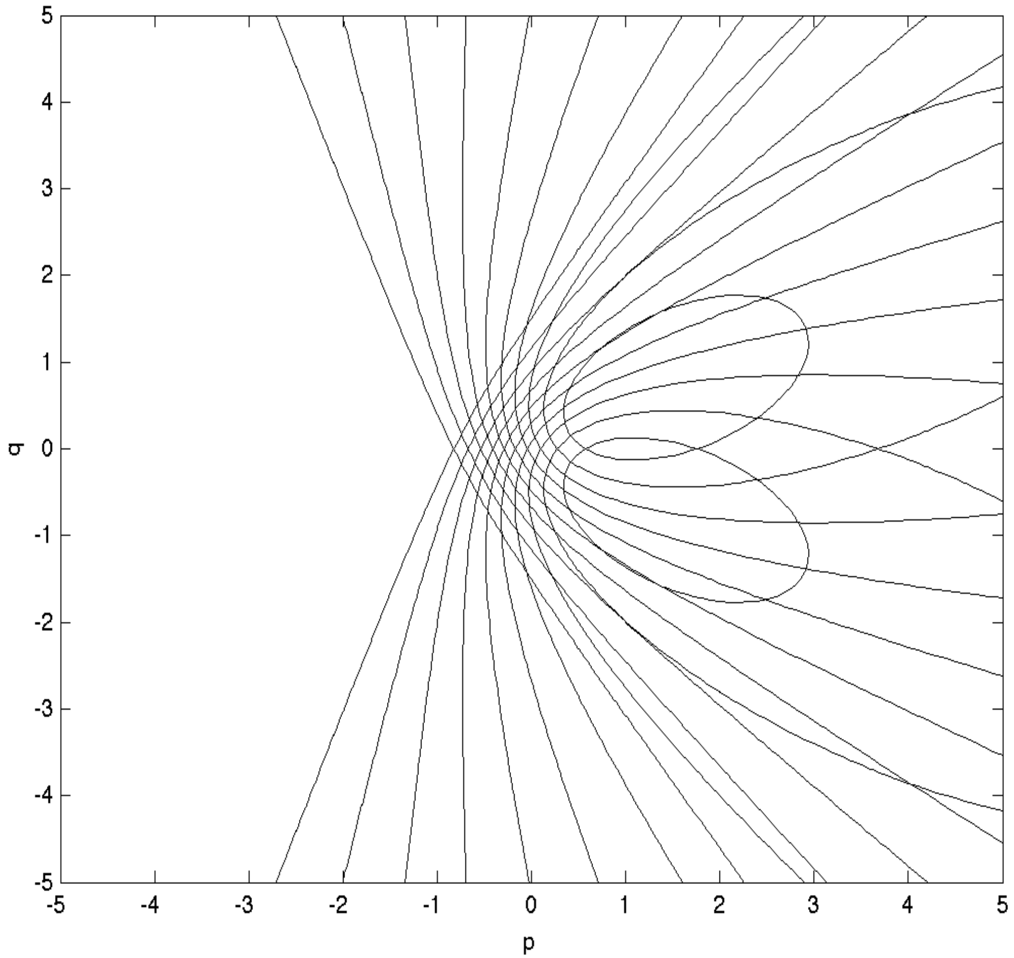
One Single Light Source

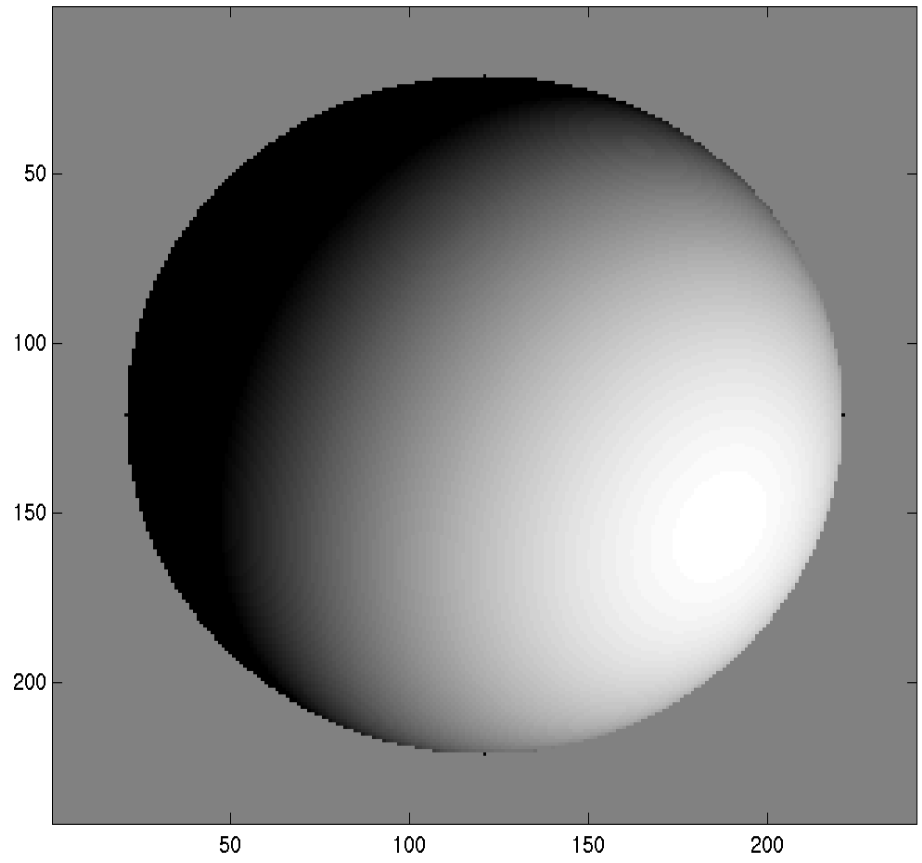




Many potential normals for each image point.

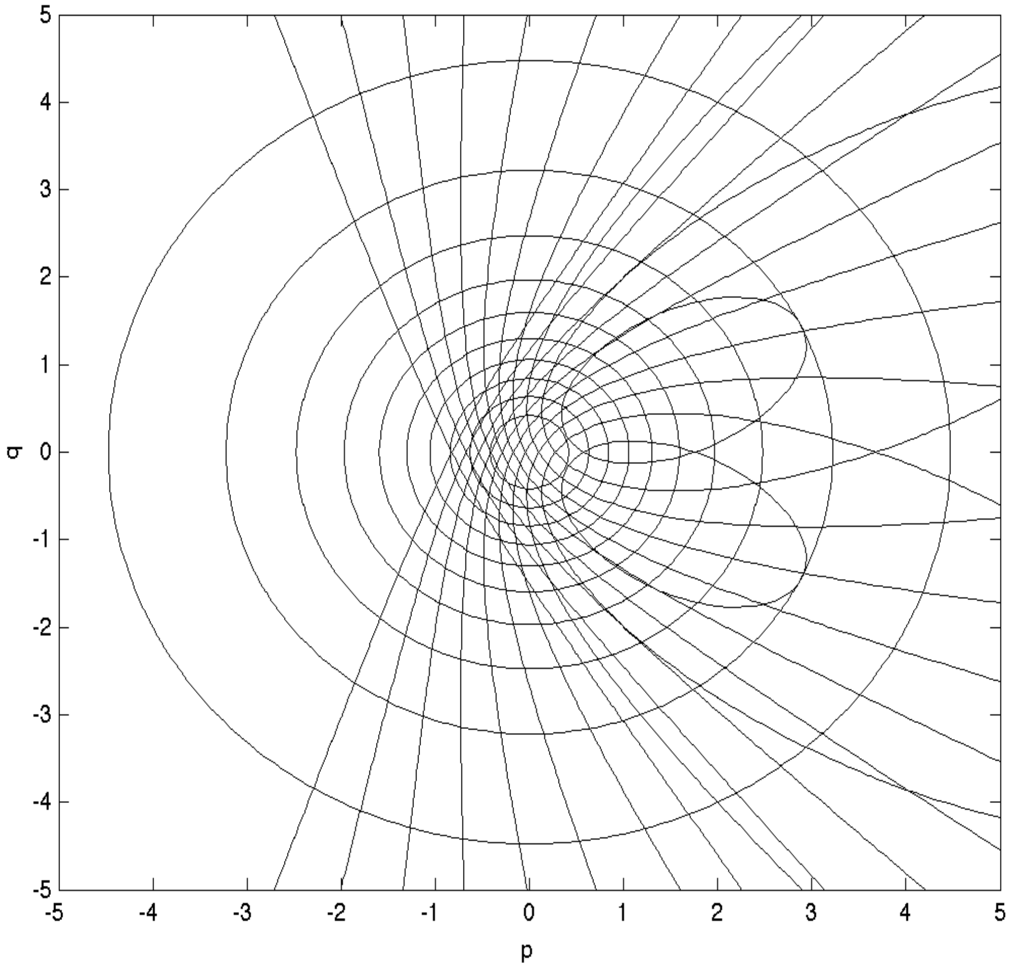
Two Light Sources

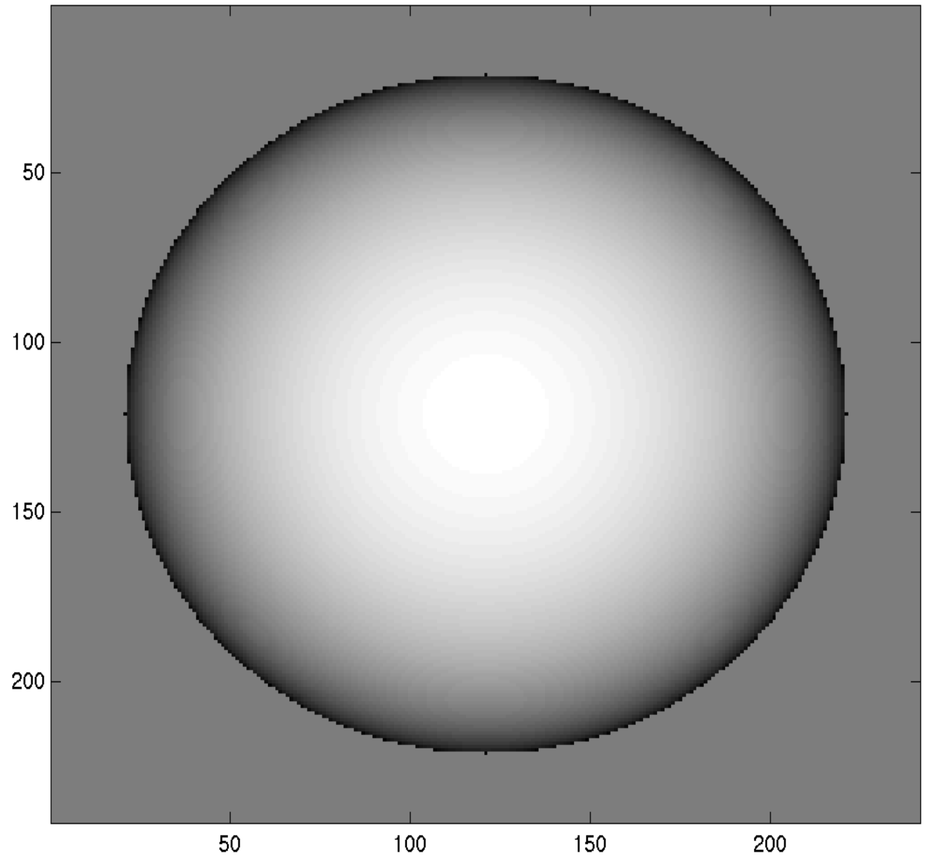




Still some ambiguities.

Three Light Sources





No more ambiguities even if the albedo is unknown.

Algebraic Formulation

Recover shape: estimate α, N with known L

Lambertian model:

Intensity

$$I = \alpha(\mathbf{L} \cdot \mathbf{N}) = (\mathbf{L} \cdot \mathbf{M})$$

albedo: unknown

estimate

unknown → normal vector

Light source: ✓ direction

Three light sources:

Unknown 3 vector that can be estimated by solving a 3x3 linear system.

vector of intensities: ✓

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} \mathbf{L}_1 \\ \mathbf{L}_2 \\ \mathbf{L}_3 \end{bmatrix} \mathbf{M}$$

Light source: ✓

Normals

$$\mathbf{N} = \frac{\mathbf{M}}{||\mathbf{M}||}$$

N and a can then be inferred from **M**.

$$\alpha = ||\mathbf{M}||$$

Using More Lights (≥ 3)

Photometric stereo

One can use as many lights as one wants:

$$\mathbf{I} = \mathbf{LM}, \text{ with } \mathbf{I} = \begin{bmatrix} I_1 \\ \vdots \\ I_n \end{bmatrix} \text{ and } \mathbf{L} = \begin{bmatrix} \mathbf{L}_1 \\ \vdots \\ \mathbf{L}_n \end{bmatrix}$$

$$\Rightarrow \mathbf{L}^t\mathbf{LM} = \mathbf{L}^t\mathbf{I} \text{ (Least - squares solution)}$$

more equations $n >>$ unknowns $(=3)$

—> This is known as an over-constraint problem and, the more camera, the more robust to noise the solution is.

→ finding solution for M using ≥ 3 imgs

EPFL

Discounting Shadows

In Reflectance maps, we didn't consider
Some pixels might shadows, thus appearing darker
be in

- Shadowed pixels for a given light source position do not conform to the model.
- Premultiplying by the intensities reduces their contributions because their intensities tend be lower.

minimize $\sum_j I_j (I_j - L_j M)^2$

Intensities on the diagonal

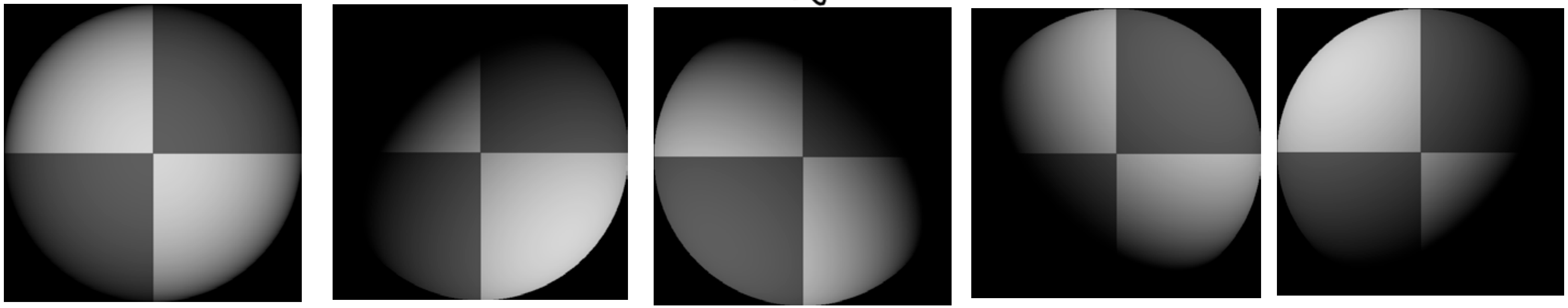
$$\begin{bmatrix} I_1 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & I_n \end{bmatrix} \boldsymbol{I} = \begin{bmatrix} I_1 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & I_n \end{bmatrix} \boldsymbol{LM}$$

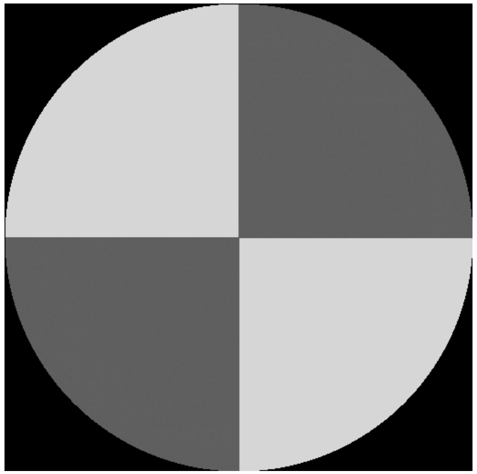
→ weights ∝ intensities
→ pixels having low intensities have less influence on others (those on shadows ⇒ ↓)

Synthetic Sphere Images

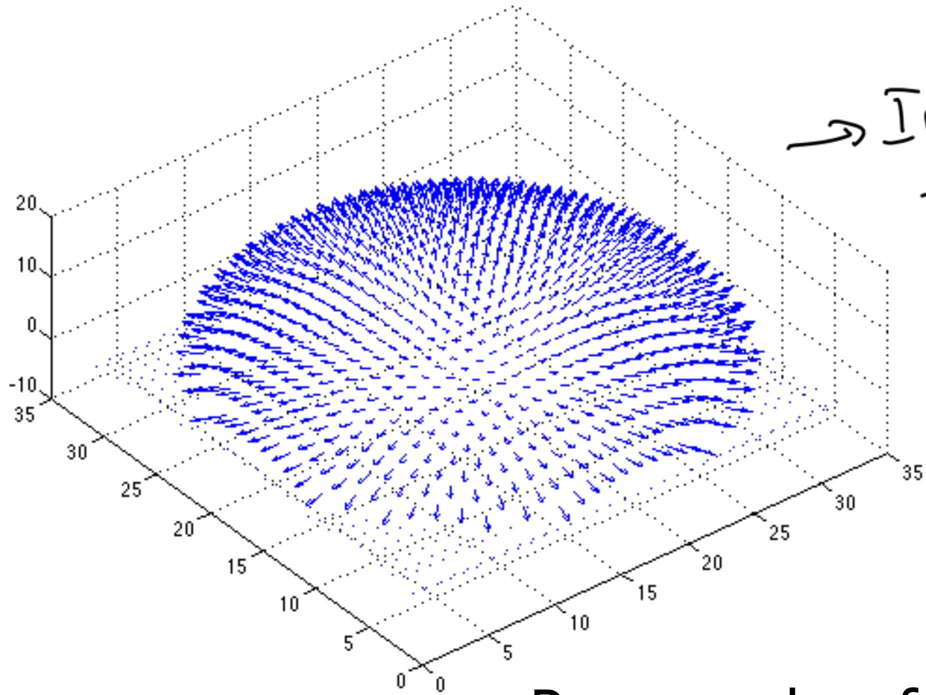
Five different light sources:

Synthetic img's





Recovered albedo



→ Integrate back to get the sphere

normal

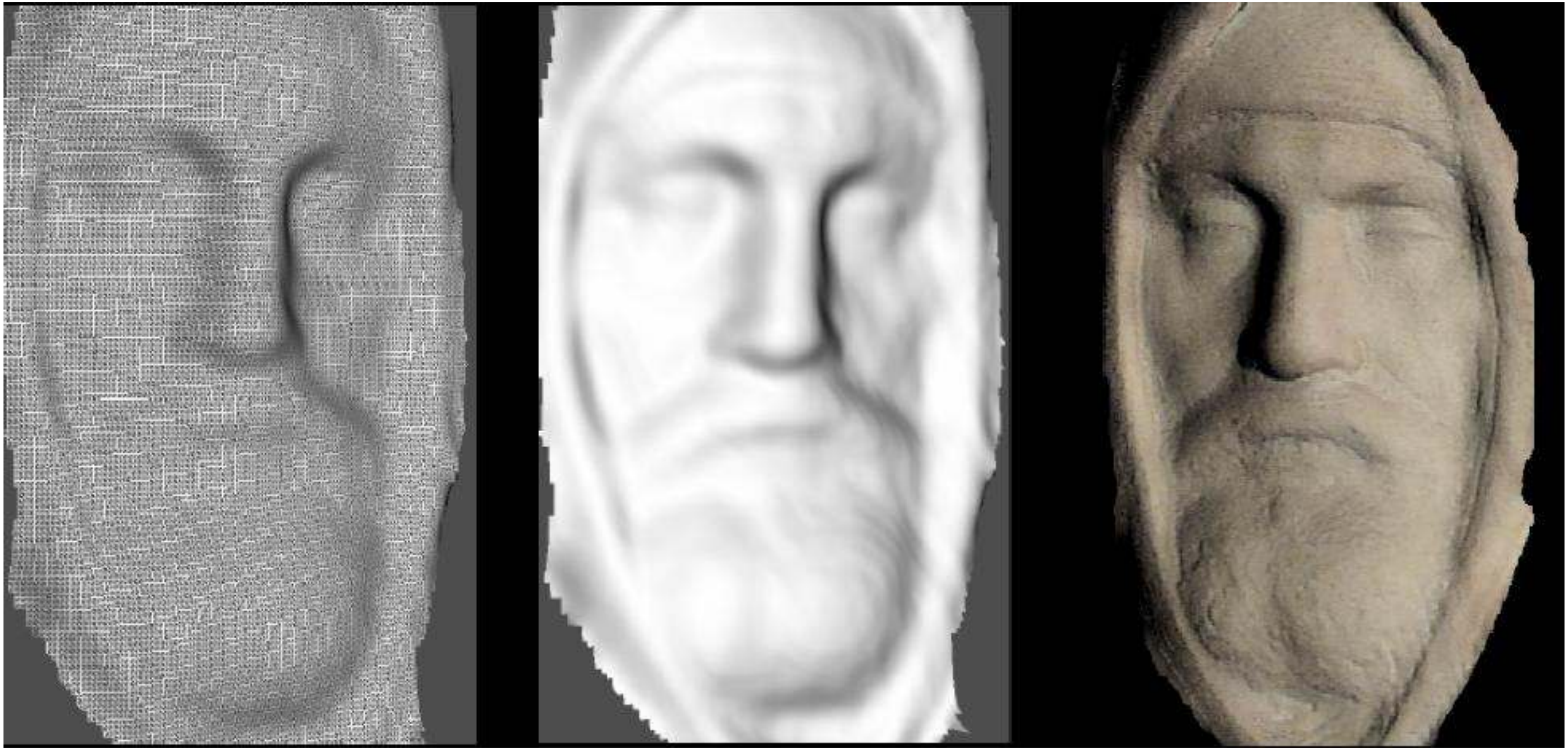
Recovered surface normals

map

Scanning Michel Angelo's Pieta

- One camera and five light sources. They know $L_1, \ldots, L_5$
- The positions of the light sources w.r.t. the camera are exactly known.

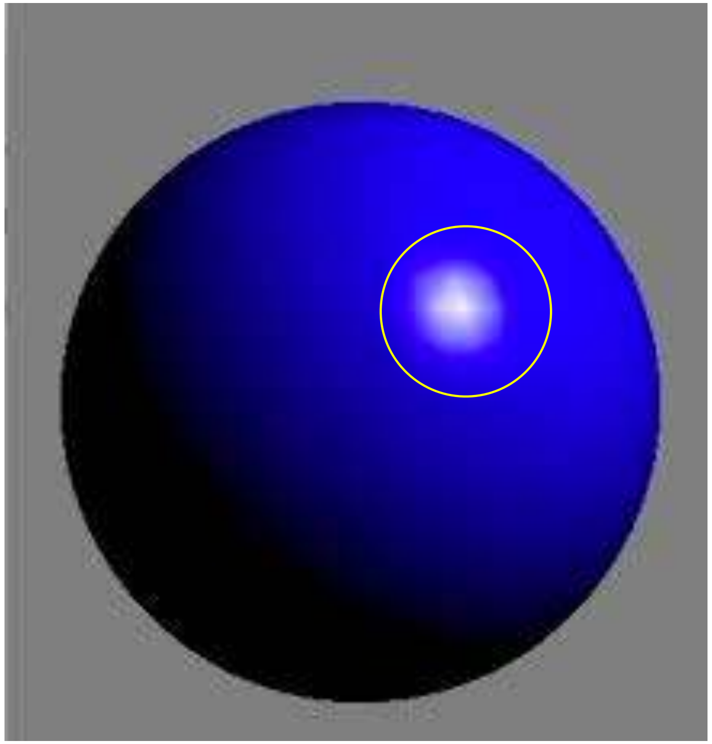
Full 3D Model



- This was done for the whole statue.
- All the fragments were then "glued" together.

—> A full 3D model that can be visualized from any viewpoint and under any illumination conditions. (even animated)

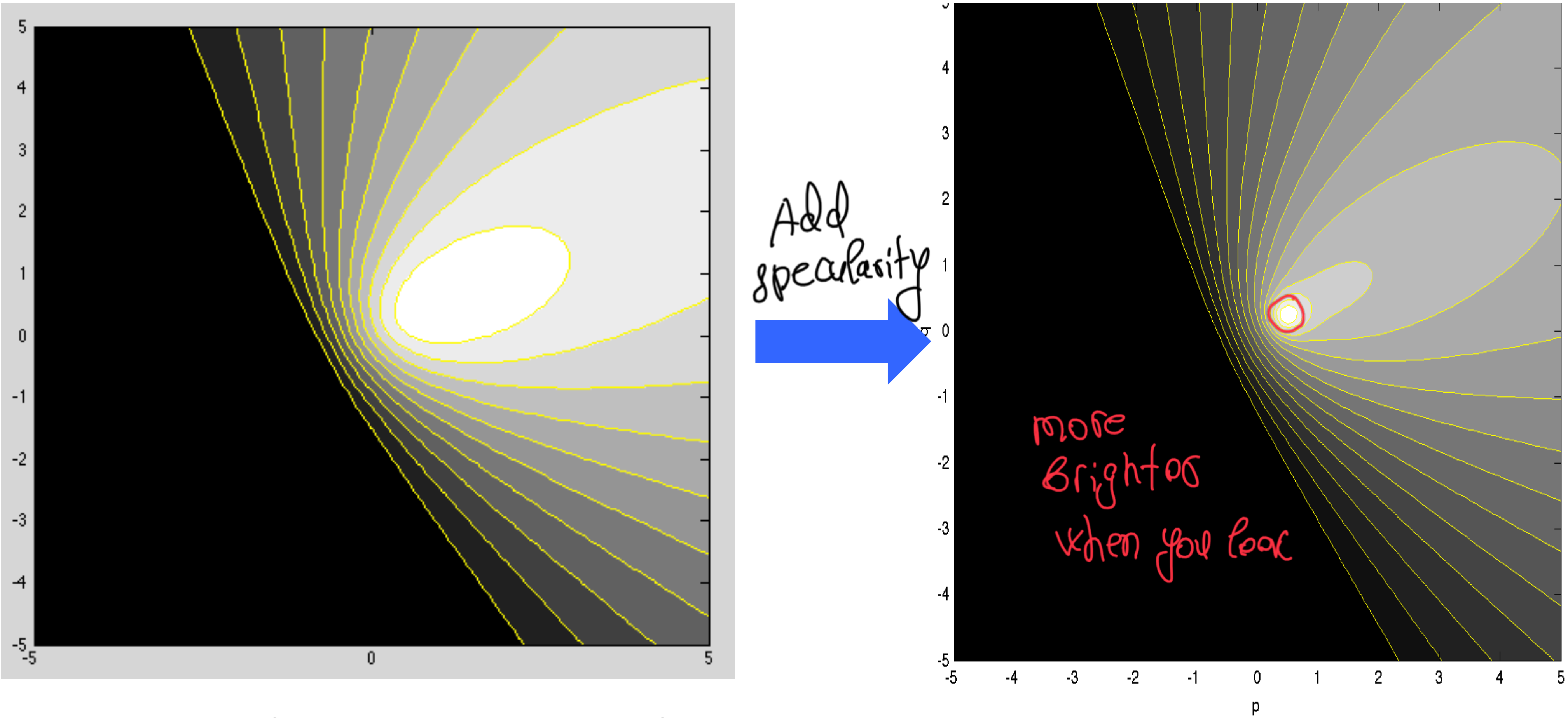
Specularities



- At specular points Lambertian assumptions are violated.
- The surface behaves like a mirror. (brighter than it should be)
- This is known as specular reflection.
- Most surfaces are a combination of diffuse and specular reflectors.

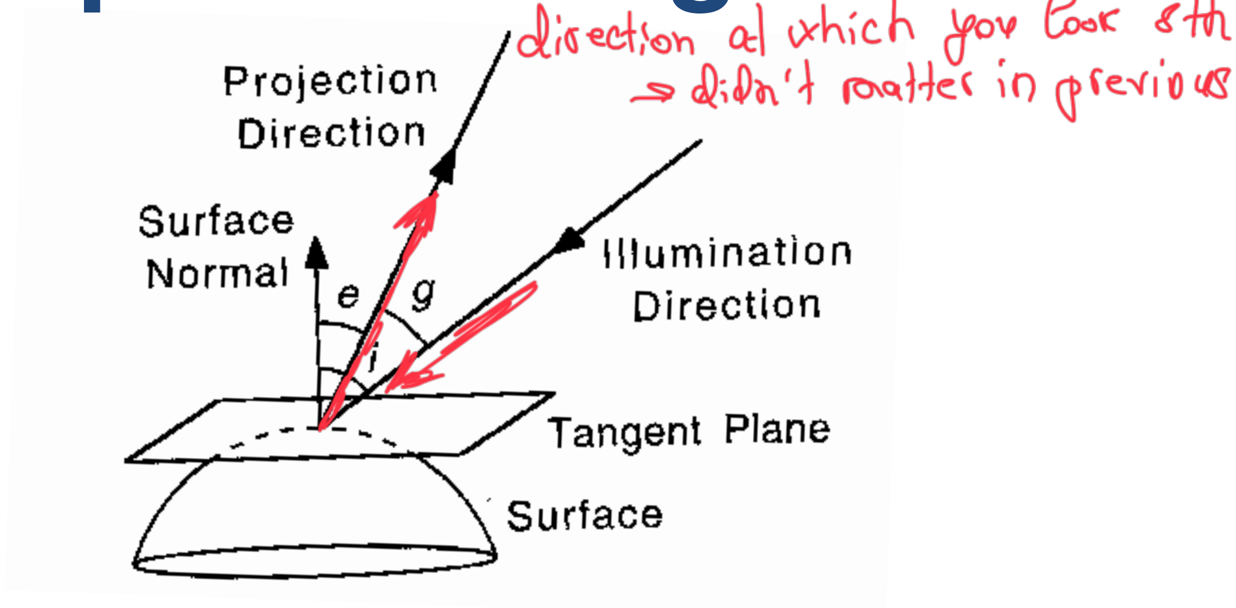
Lambertian + Specular Reflectance Map

The notion of reflectance map still applies but the function Ref becomes more complex than in the diffuse case:



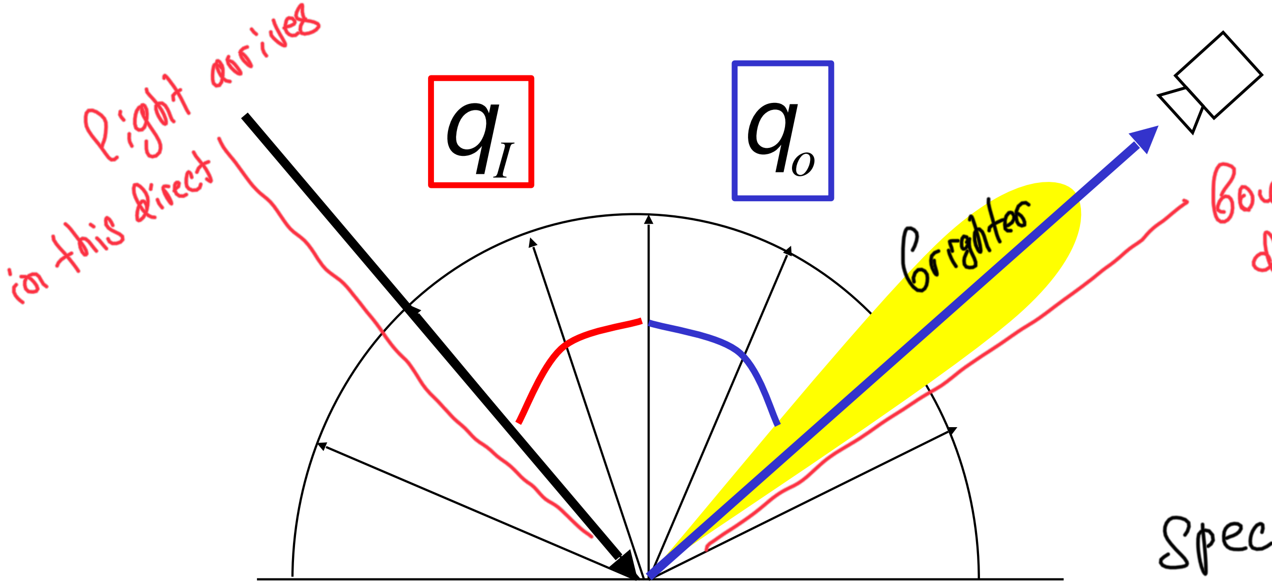
Reflectance map for glossy white paint: It is the weighted sum of a diffuse and a specular component.

Important Angles



- **Angle of incidence (i):** Angle between the surface normal and the direction of the incident light ray. $\vec{L} \cdot \vec{N}$
- **Angle of emittance (e):** Angle between emitted light ray and surface normal.
- **Phase angle (g):** Angle between incident and emitted light ray.

Mirror-Like Behavior



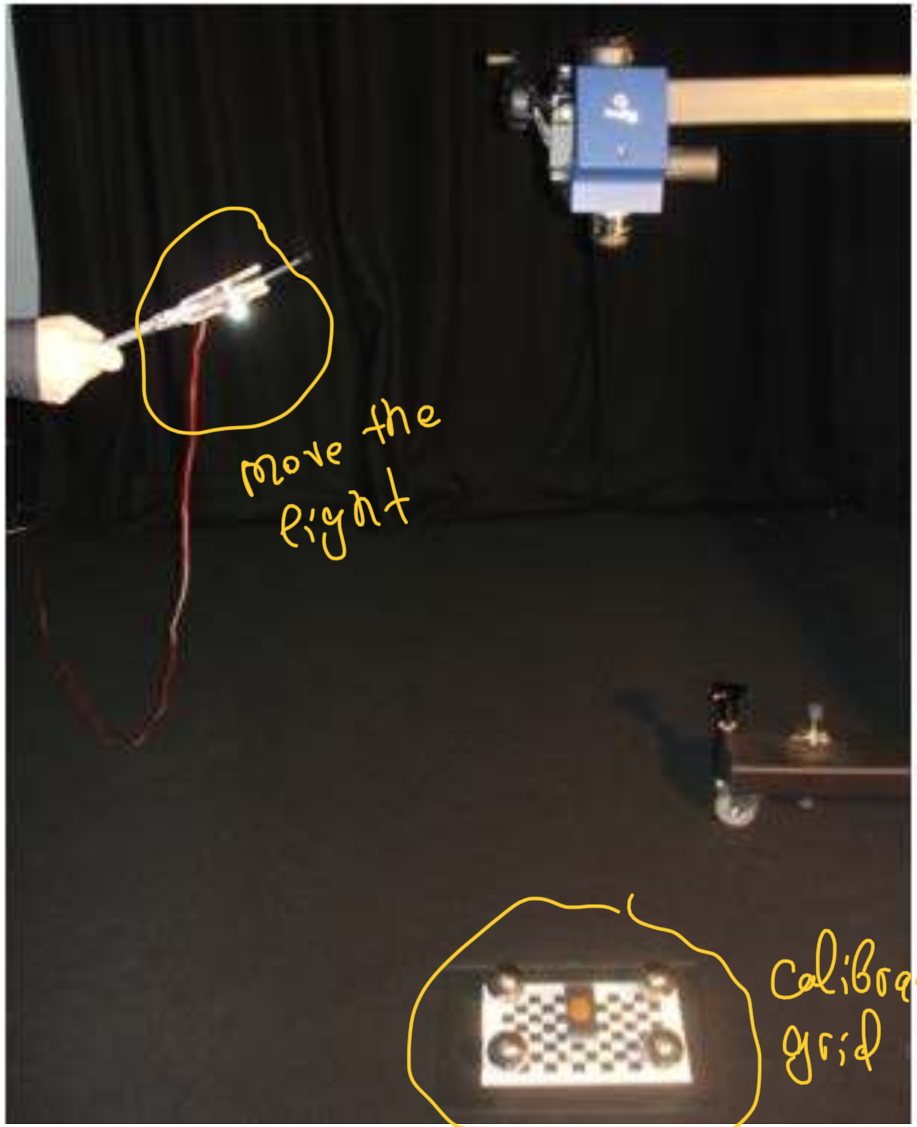
Specularity → removing noises in shape from shading (do not obey Lambertian laws)

- Specularities occur when i=e and i+e=g.
- In other words, when the two directions are symmetric with respect to the normal.

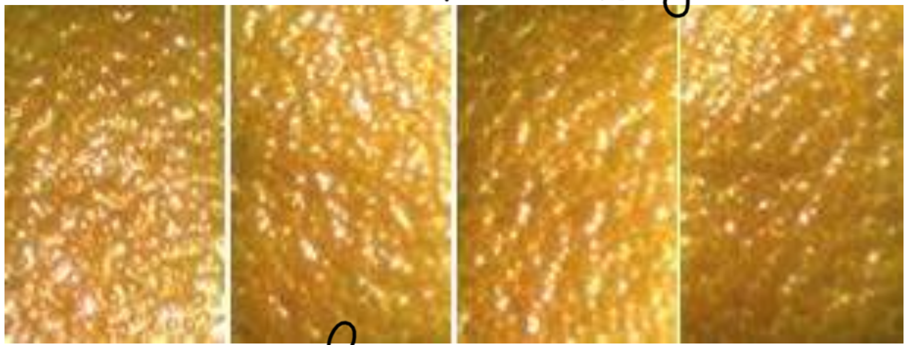
solving LS in robust way

—> They can also be used to infer the normals.

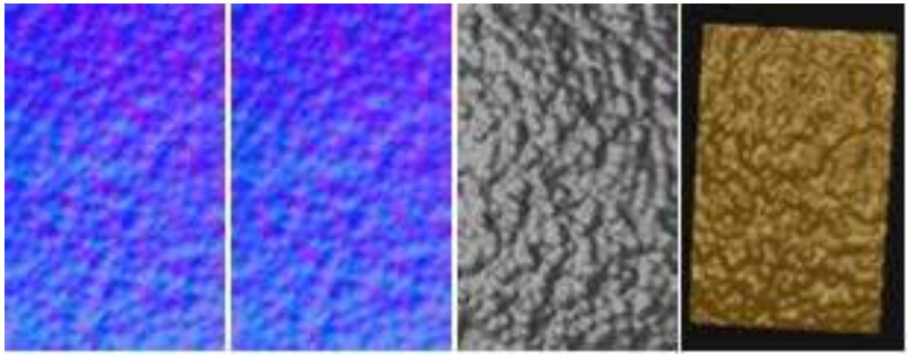
Shape from Specularities



Normals you recover



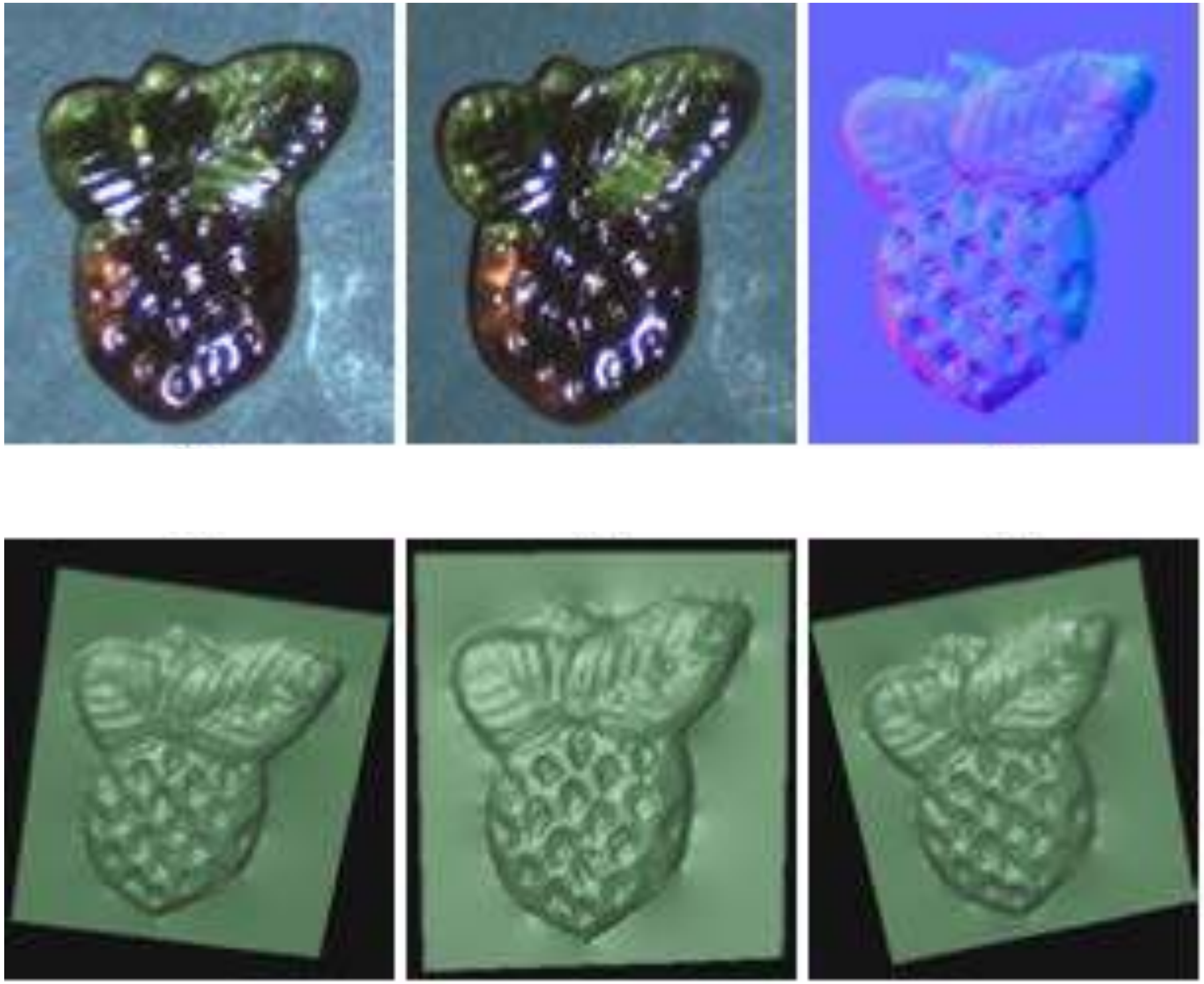
light source
normal
where you look



- Move the light around and compute its position each time.
- Find the bright spots and the image and assume they are secularities.
- Infer the normals at those points.

Chen et al., CVPR 2006

Shape from Specularities



Shiny images

- Excellent precision can be achieved because the secularities are very sensitive to the exact normal direction.
- However, this only works well for shiny, that is, highly specular, objects.

Chen et al., CVPR 2006

Specularities in Short

- Most materials are both diffuse and specular.
- Specularities are very sensitive to motion. → they can provide additional info Besides shape-from-shading
- Specularities do not constrain all the degrees of freedom.

➡They can either be discarded as noise or used to get additional information.

Shape-from-Shading in Short

Traditional Shape-from-Shading requires strong assumptions:

- Constant or piece-wise constant albedo
- No interreflections
- No shadows
- No specularities

Photometric stereo → useful ✓

ignore

→ In a single image context, it is most useful in conjunction with other information sources.