SHAPE FROM X

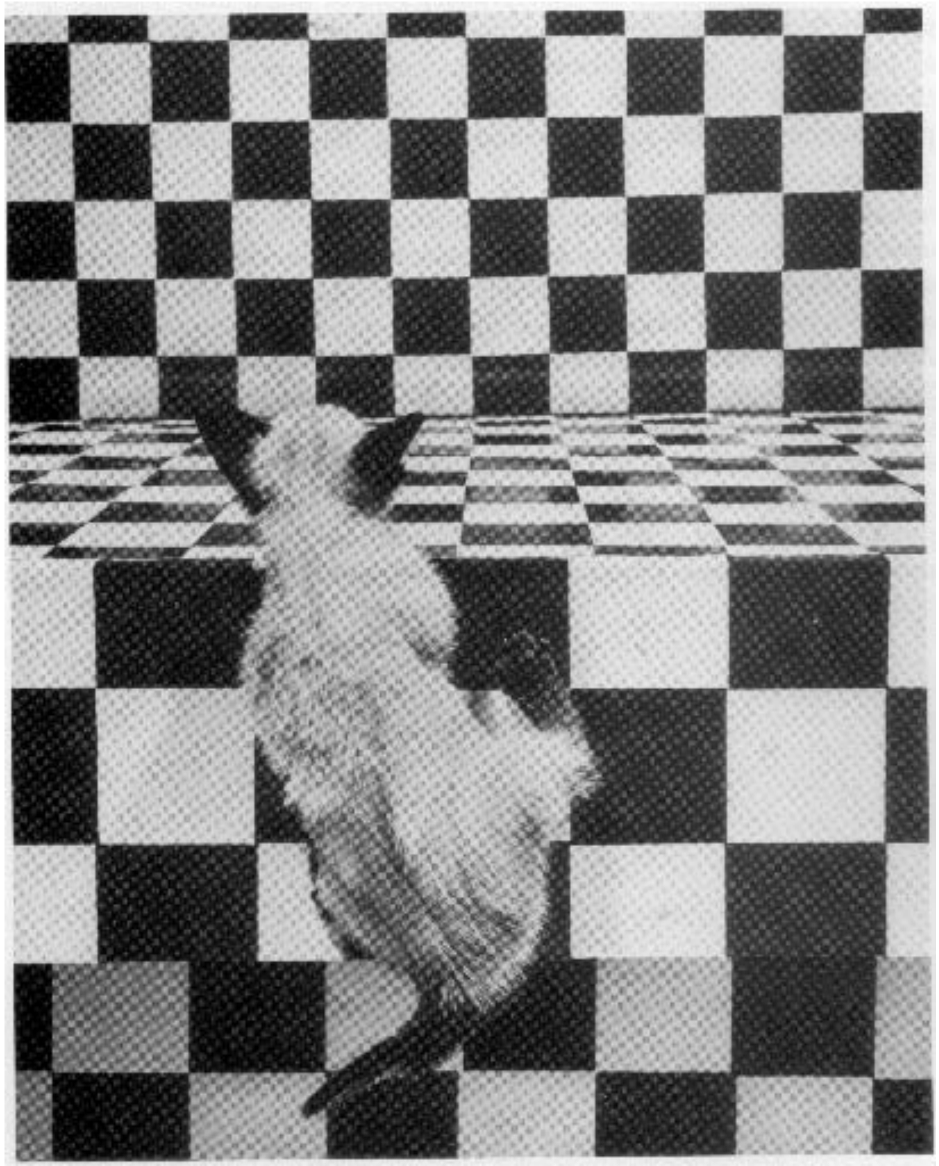
One image:

- Shading
- **Texture**

Two images or more:

- Stereo
- Contours
- Motion

SHAPE FROM TEXTURE



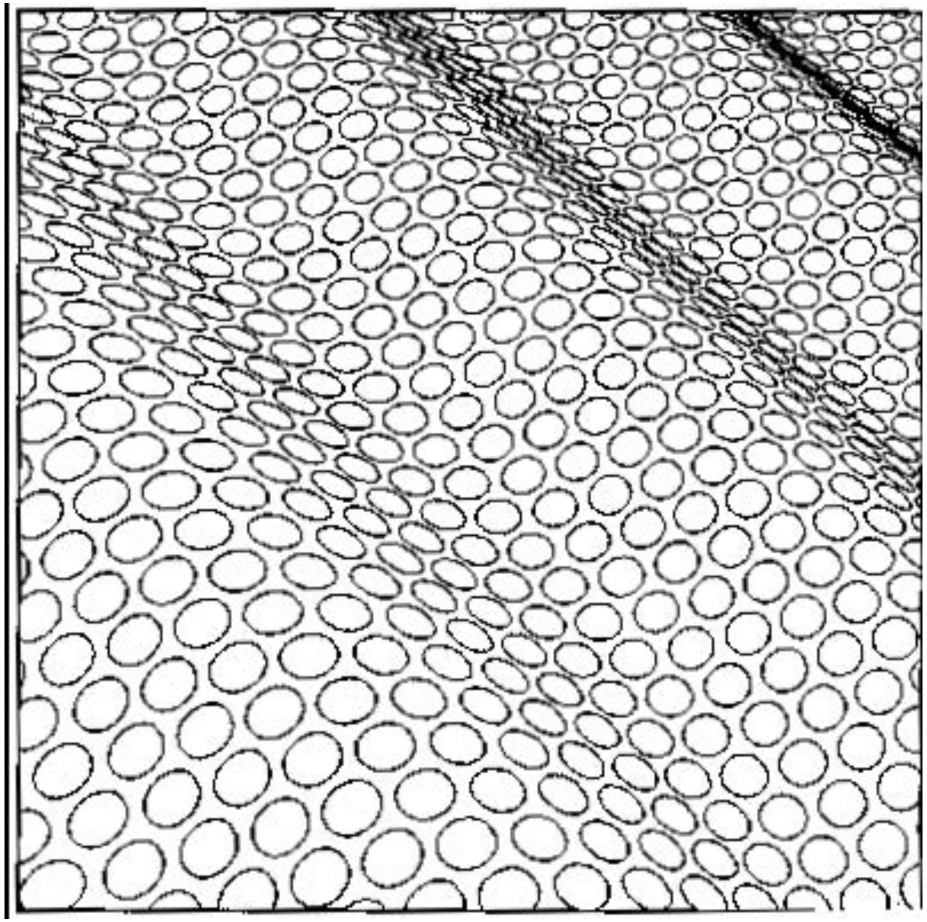
SHAPE FROM TEXTURE

Recover surface orientation or surface shape from image texture.

- Assume texture 'looks the same' at different points on the surface
- This means that the deformation of the texture is due to the surface curvature

and camera orientation

STRUCTURAL SHAPE RECOVERY



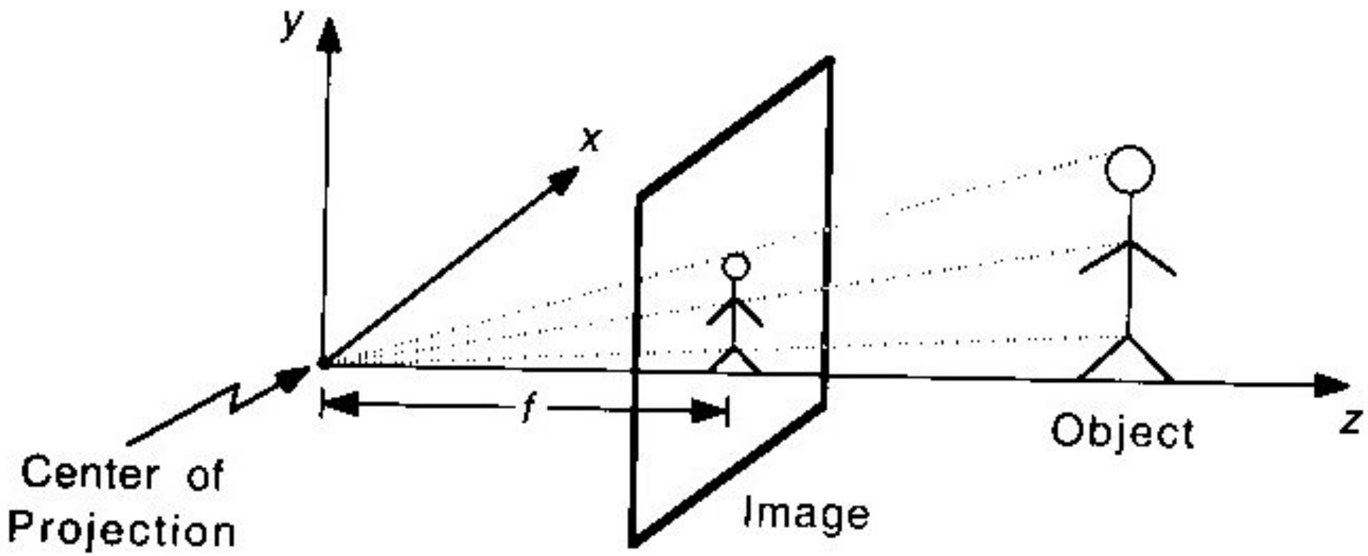
think of them as
patterns painted

Basic hypothesis: Texture resides on the surface and has no thickness.

--> Computation under:

- Perspective projection
- Paraperspective projection
- Orthographic projection

PERSPECTIVE PROJECTION

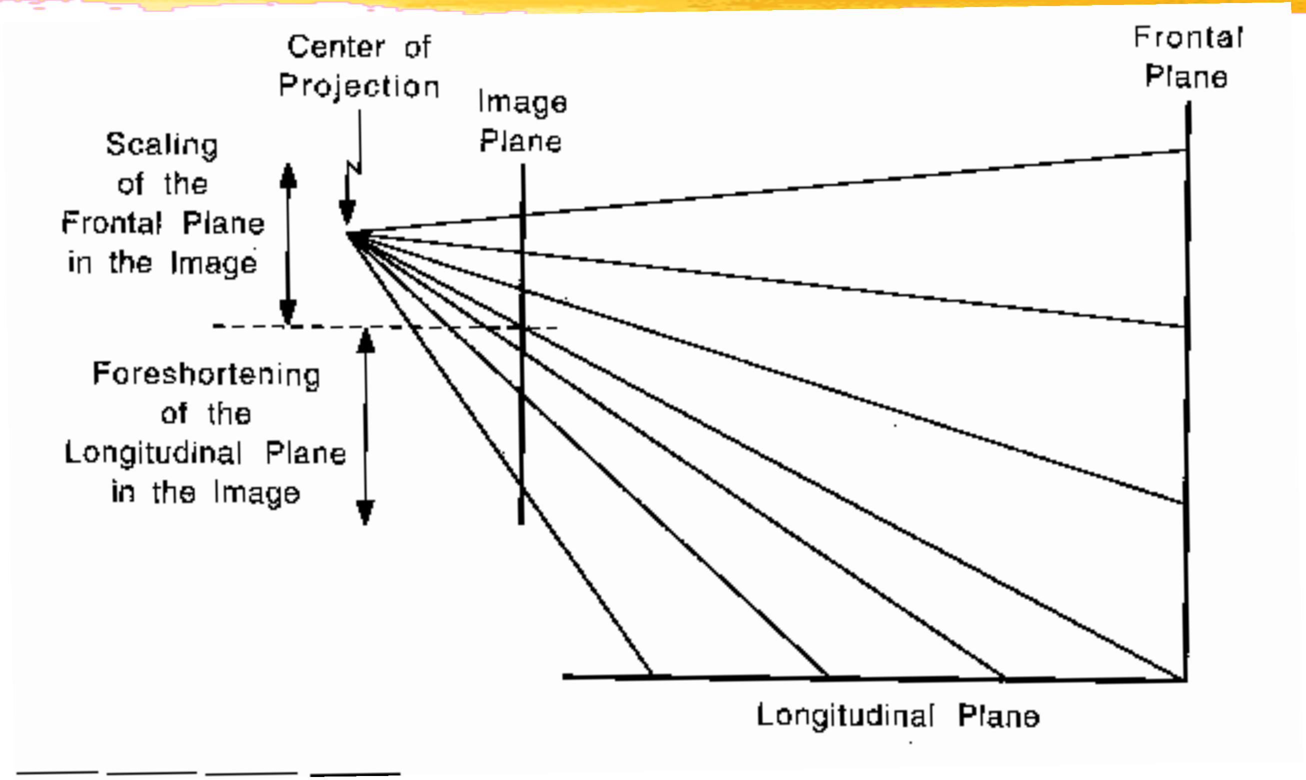


$$u = f\frac{x}{z}$$

$$v = f\frac{y}{z}$$

Pinhole geometry without image reversal

PERSPECTIVE DISTORTION



Perspective projection distortion of the texture

- depends on both depth and surface orientation,
- is anisotropic.

todo: what is anisotropic

FORESHORTENING

Depth vs Orientation:

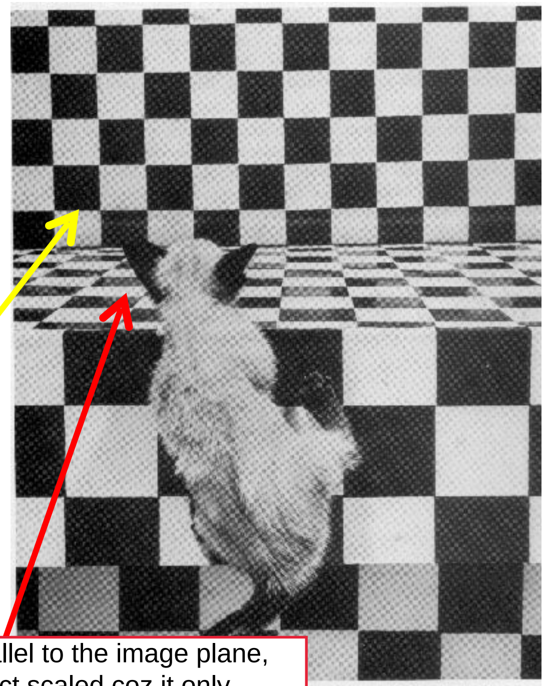
relationship between delta_u and delta_x, delta_y and delta_z

Infinitesimal vector [Δx,Δy,Δz] at location [x,y,z]. The image of this vector is

delta_u , delta_v =

$$\frac{f}{z}\left[\Delta x - \frac{x}{z}\Delta z, \Delta y - \frac{y}{z}\Delta z\right]$$

depends on surface orientation and on distance to camera. which wasnt the case from shape from shading. it all depended on the surface orientation only. assumes light is infinitely far away. which is not the case if the light is close coz the power i receive depends on the distance



o special cases:

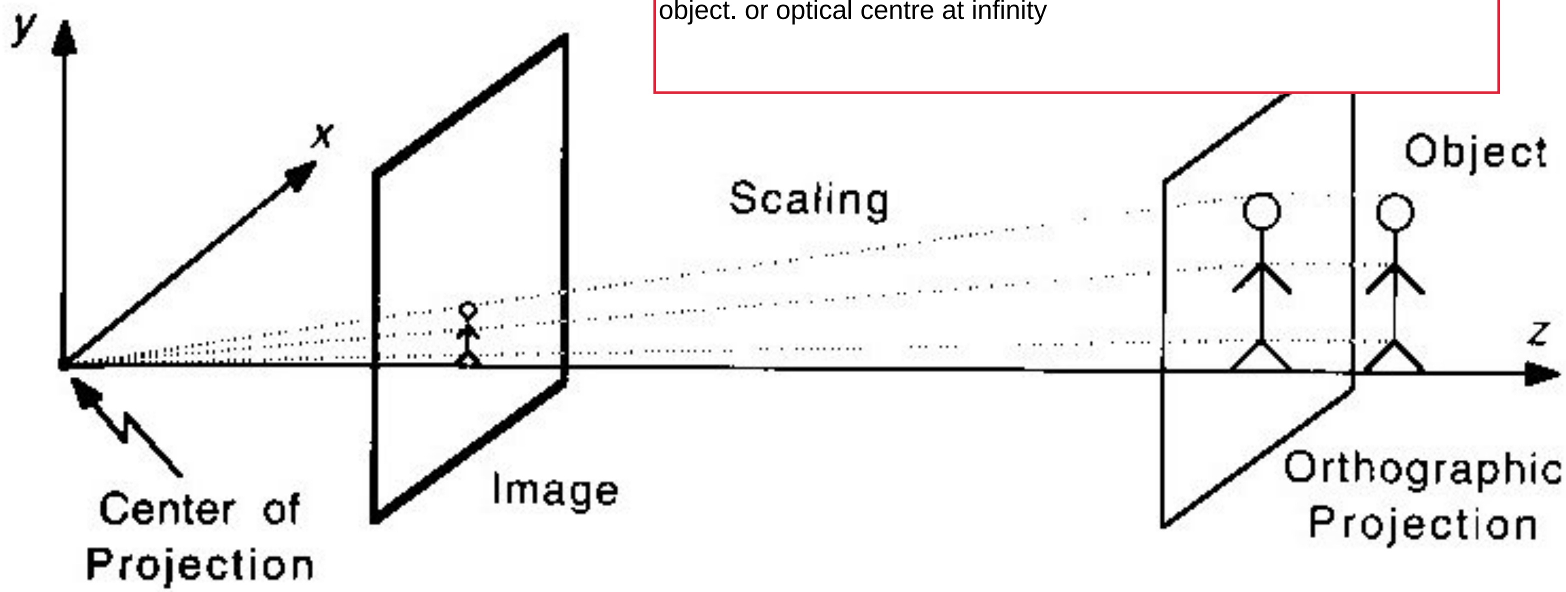
$\Delta z=0$: The object is scaled

parallel to the image plane, object scaled coz it only depends on z

$\Delta x=\Delta y=0$: The object is foreshortened

ORTHOGRAPHIC PROJECTION

no more foreshortening. objects are far or f is large ? and therefore rays to the object are parallel. assume f is extremely close to the object. or optical centre at infinity



$$u = sx$$

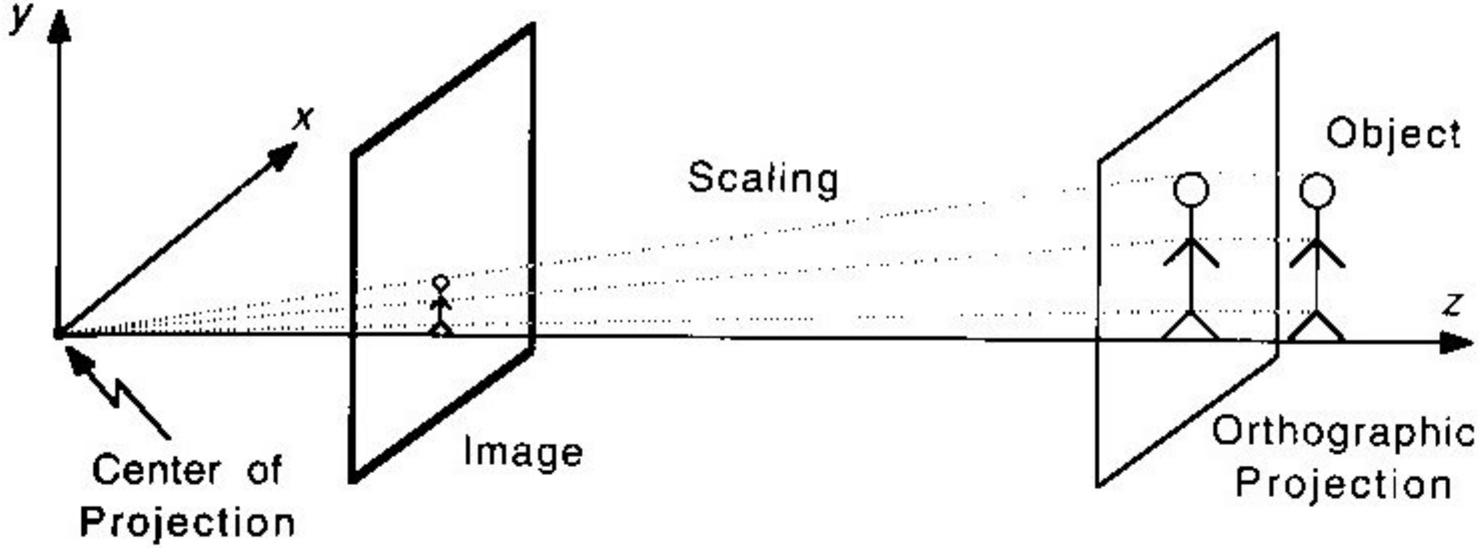
$$v = sy$$

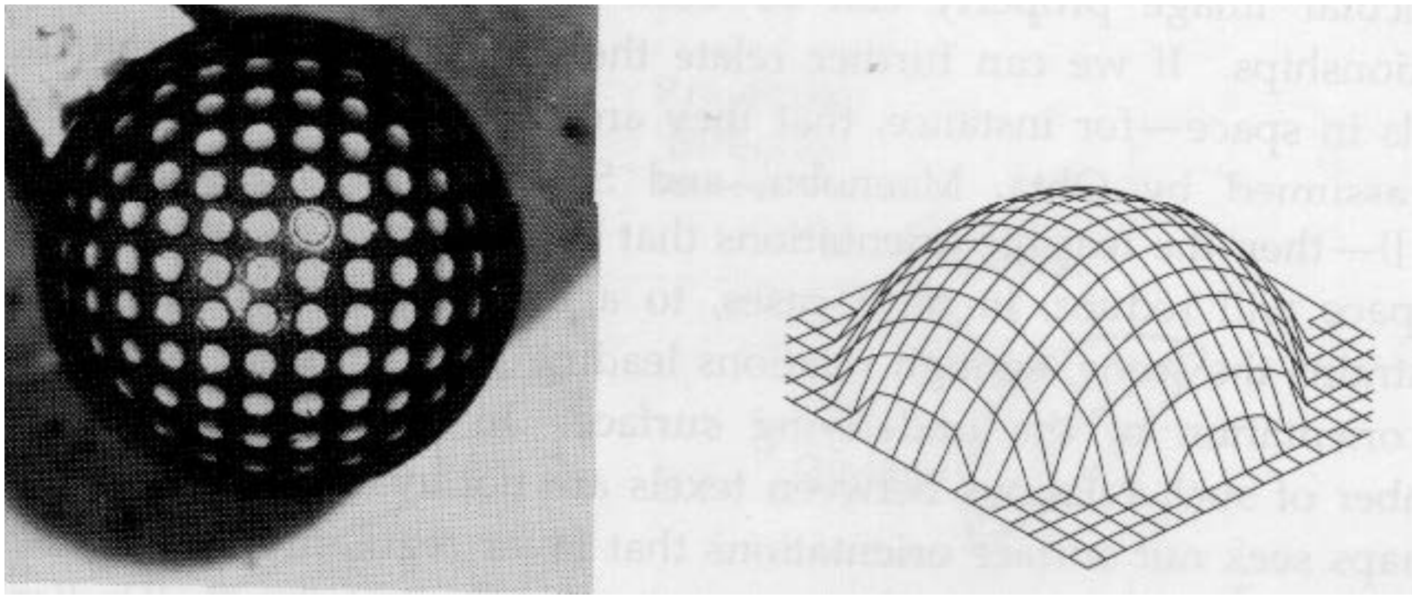
Special case of perspective projection:

- Large f
- Objects close to the optical axis

→Parallel lines mapped into parallel lines.

ORTHOGRAPHIC PROJECTION

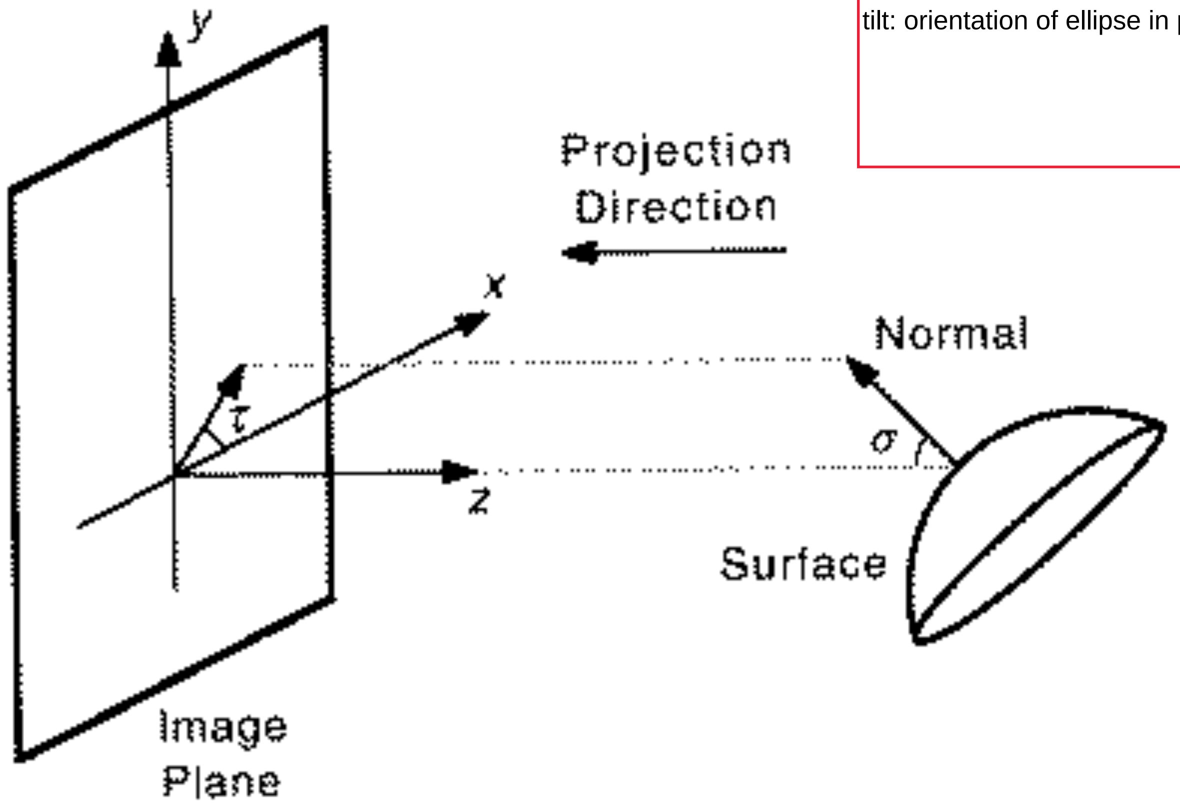




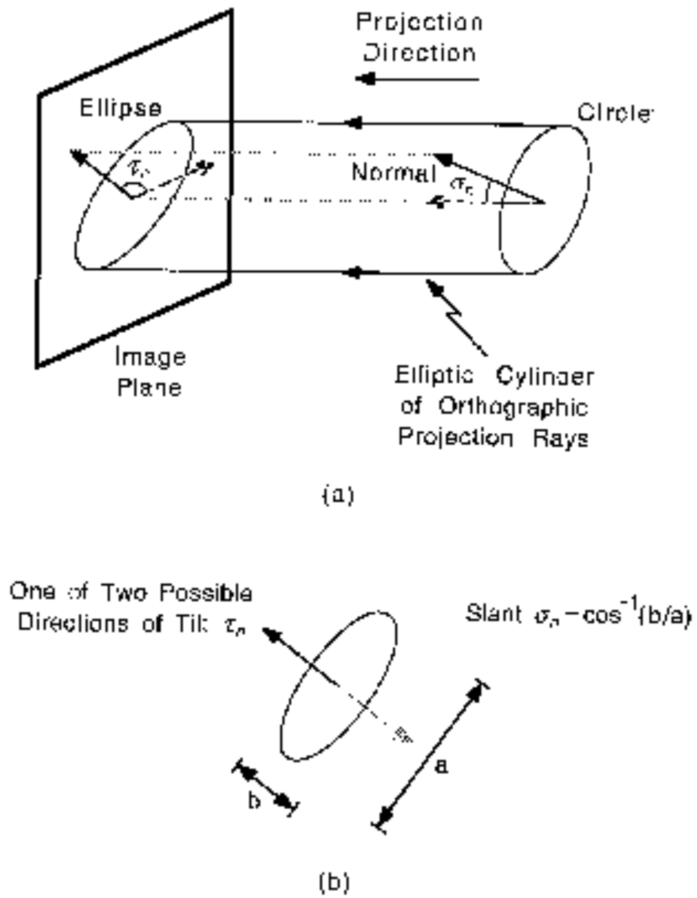
TILT AND SLANT

slant: can be parallel to a plane or slant away. the less parallel it is, the more elongated the projection will be. Think of a circle

tilt: orientation of ellipse in projection



ORTHOGRAPHIC PROJECTION

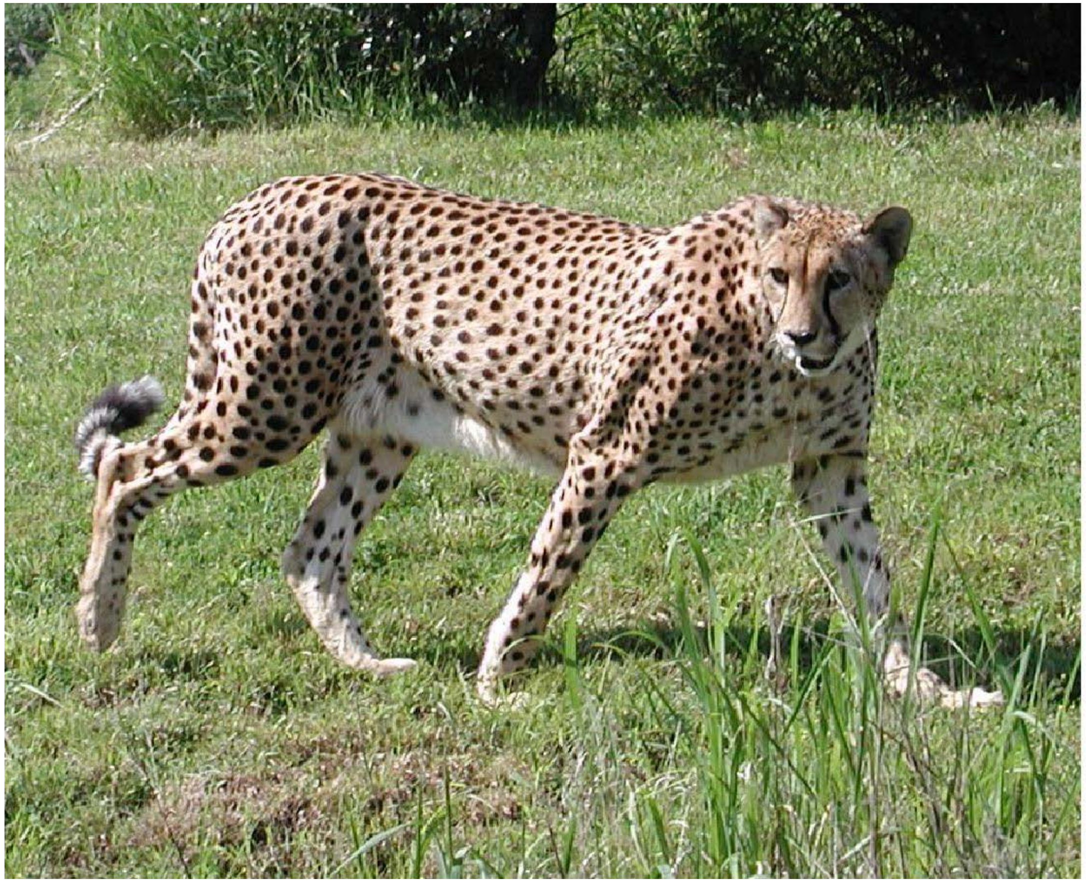


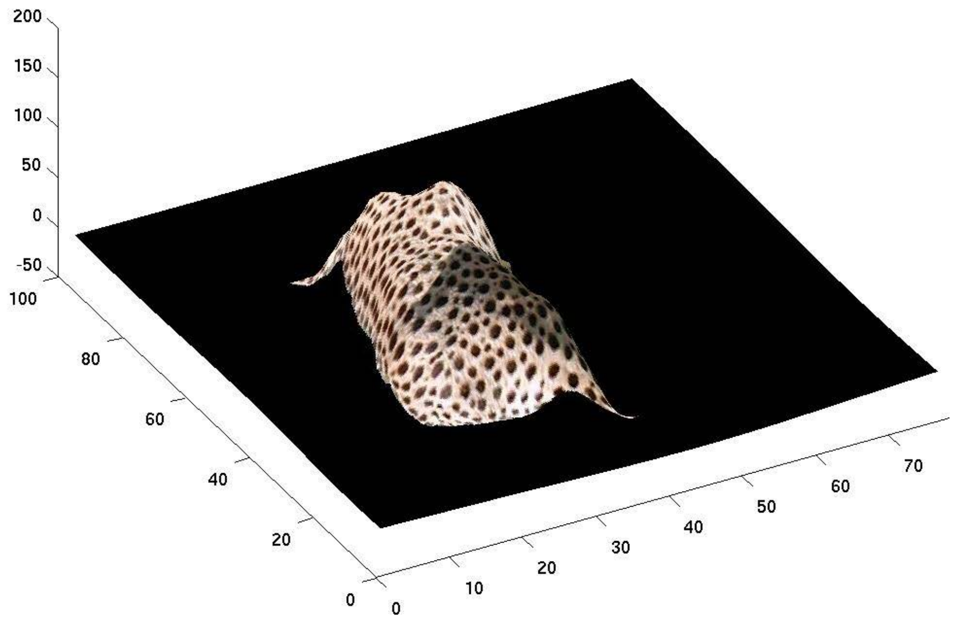
Tilt: Derived from the image direction in which the surface element undergoes maximum compression.

Slant: Derived from the extent of this compression.

ratio of eigenvalues of ellipse gives slant

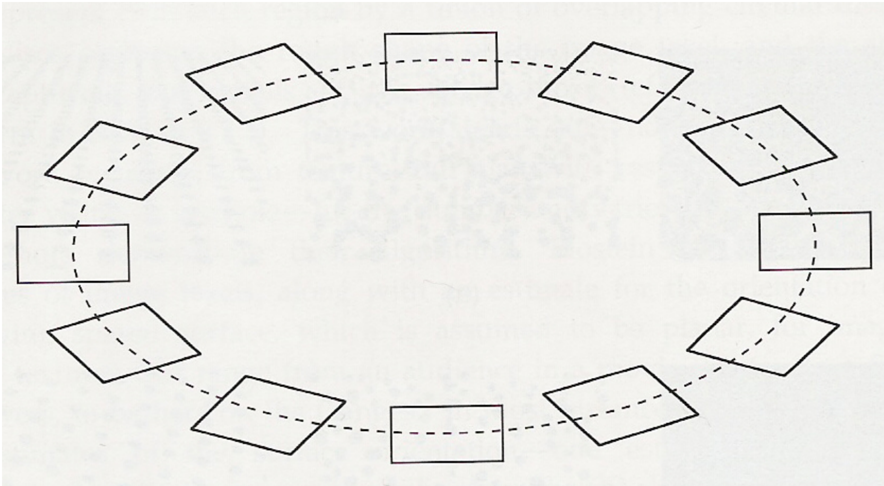
CHEETAH





A.M. Low, Phd Thesis, 2006

PERPENDICULAR LINES

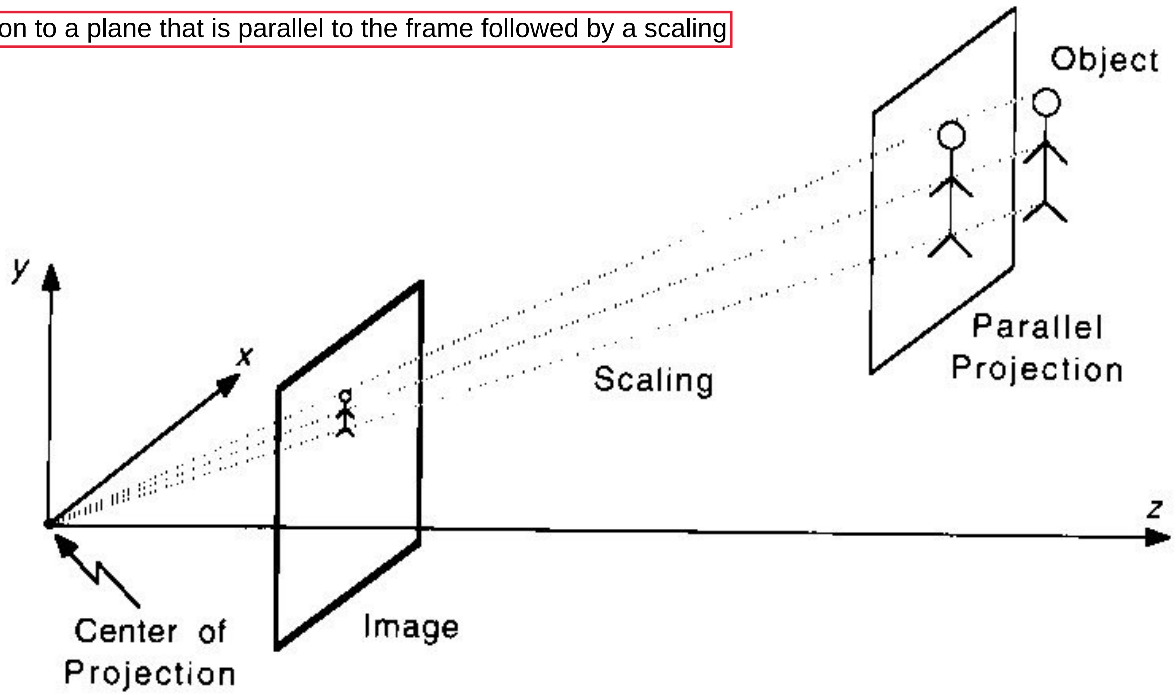


Orthographic projections of squares that are rotated with respect to each other in a plane inclined at $\omega=60°$ to the image plane.

$$\frac{\left\|(\mathbf{p}_1/l_1)\times(\mathbf{p}_2/l_2)\right\|}{\left\|\mathbf{p}_1/l_1\right\|^2+\left\|\mathbf{p}_2/l_2\right\|^2}=\frac{\cos(w)}{1+\cos^2(w)}$$

PARAPESPECTIVE PROJECTION

parallel projection to a plane that is parallel to the frame followed by a scaling



Generalization of the orthographic projection:

- Object dimensions small wrt distance to the center of projection.

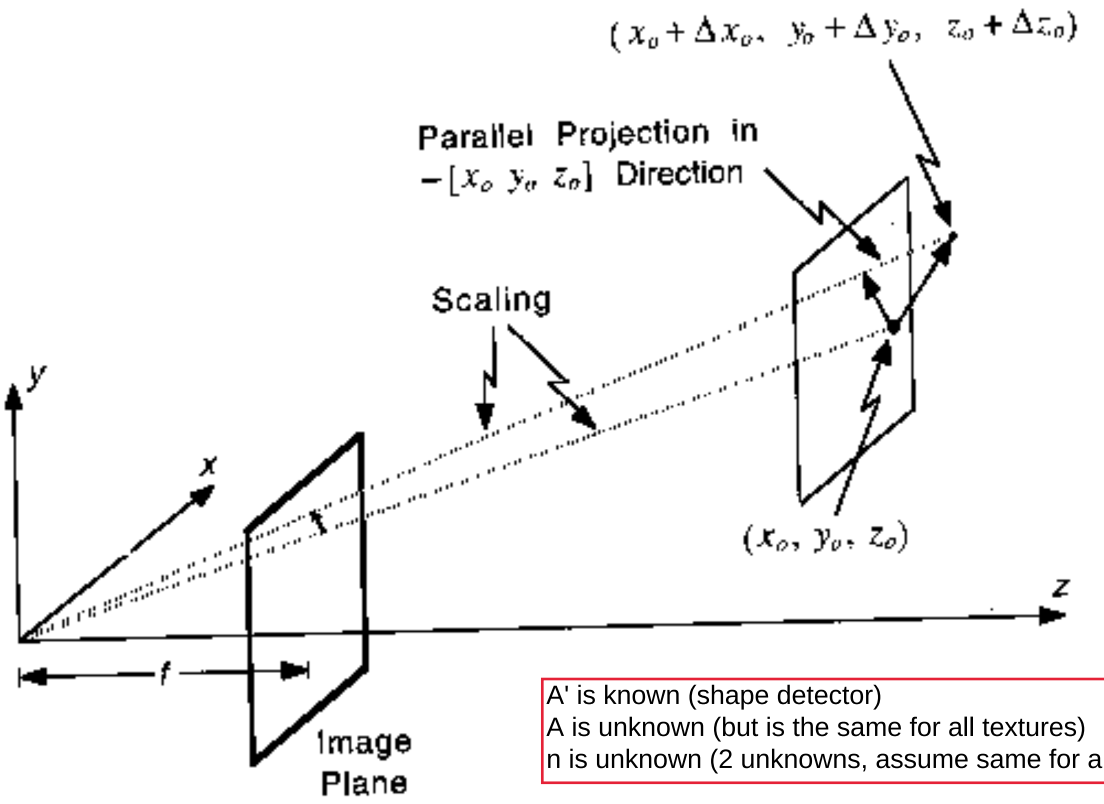
→Parallel projection followed by scaling

PARAPERSPECTIVE PROJECTION

projected area = (normal vector dot position in world) x area in world

if we can assume that the texel is planar, then n is equal throughout. A' and A (?) and xyz (?) are known. if we get enough shapes we can solve for the normal

todo: if parallel area is equal, if slanted area smaller



for structural textures. since Area

A' is known (shape detector)
A is unknown (but is the same for all textures)
n is unknown (2 unknowns, assume same for all textures)

For planar texels:

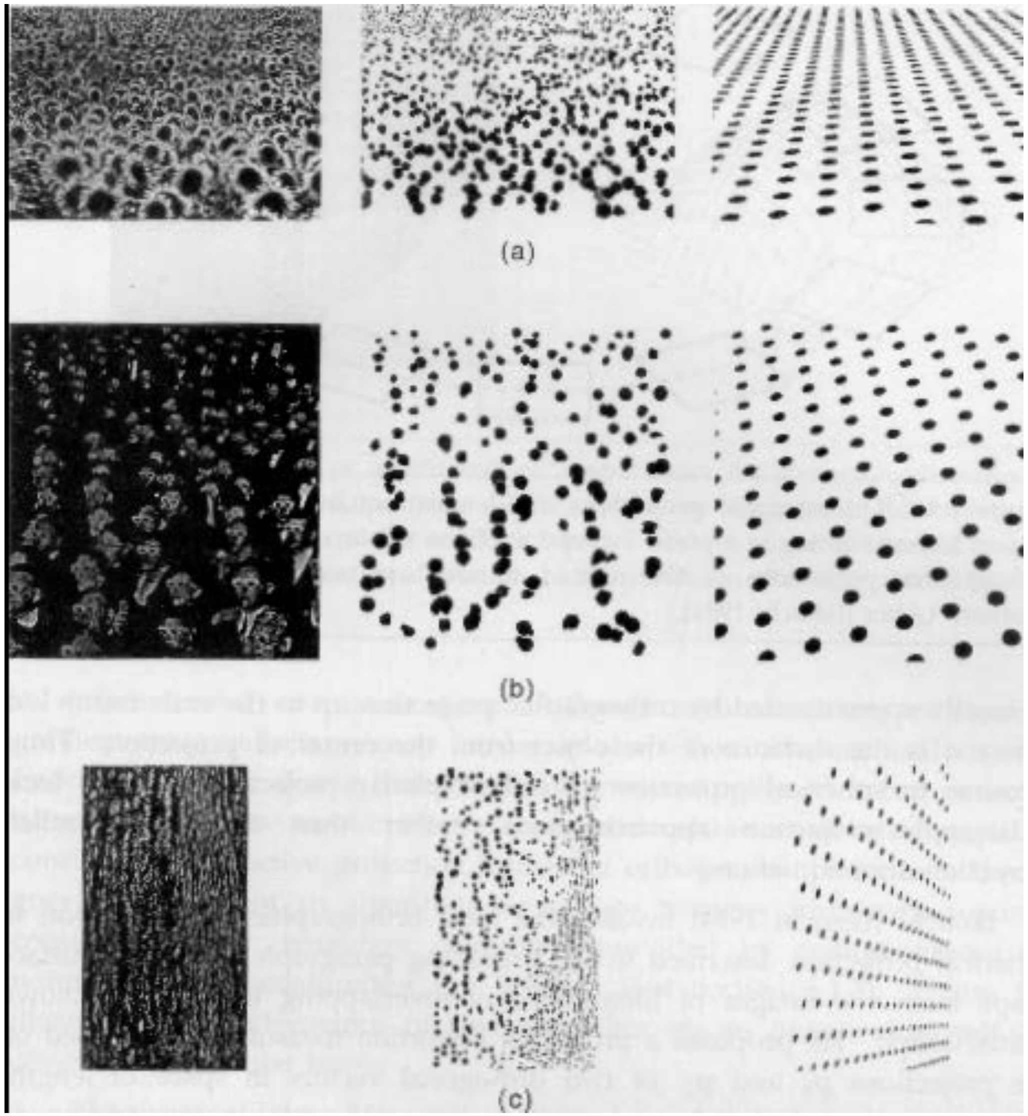
if n is 90 deg away wrt. xyz, then projected area is 0

projected Area

$$A' = -\frac{f^2}{z_0^3}\mathbf{n}\bullet[x_0\,y_0\,z_0]A$$

actual Area

PARAPERSPECTIVE PROJECTION



Texels:

- Image regions that are brighter or darker than their surroundings.
- Assumed to have the same area in space.

→ Given enough texels, it becomes possible to estimate the normal.

TEXTURE GRADIENT

STATISTICAL SHAPE RECOVERY

whats repeating is not the pattern but a specific set of statistical properties: density of white spots, number of white pixels per unit area etc. which changes in projection because of perspective distortion. does not change in the real world

density influenced by surface normals. so we can write the same kinds of equations and compute the normals like previously

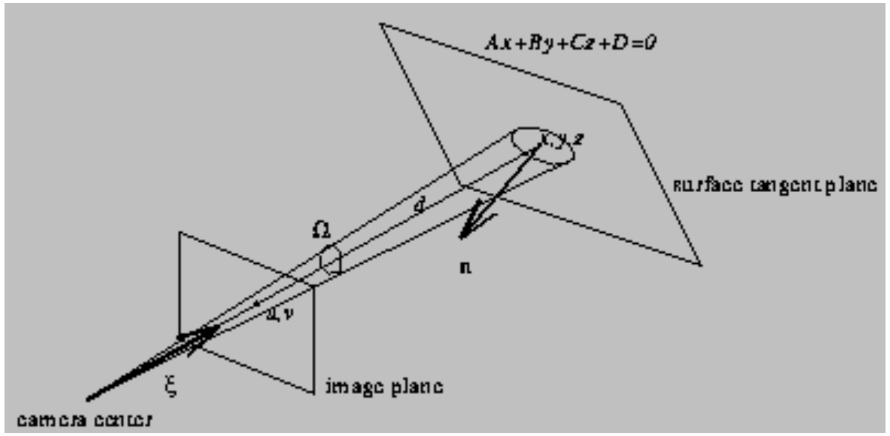
Measure "texture density" as opposed to texel area: number of textural primitives per unit surface

Basic Hypotheses:

- Textural isotropy
- Textural homogeneity

TEXTURE DENSITY

skipped



$$\gamma = k\frac{A_s}{A_i}$$

$$= k\frac{-fD^2}{(Au + Bv + Cf)^3}$$

$$[u, v, f]\mathbf{n} = \lambda\beta$$

$$\text{where } \lambda = (kfD)^2$$

$$\beta = 1\Big/\sqrt[3]{\gamma}$$

TEXTURE DENSITY

For several texture elements:

$$\psi \mathbf{n} = \lambda \mathbf{b}$$

$$\psi = \begin{bmatrix} u_1 & v_1 & f \\ \dots & \dots & \dots \\ u_n & v_n & f \end{bmatrix}$$

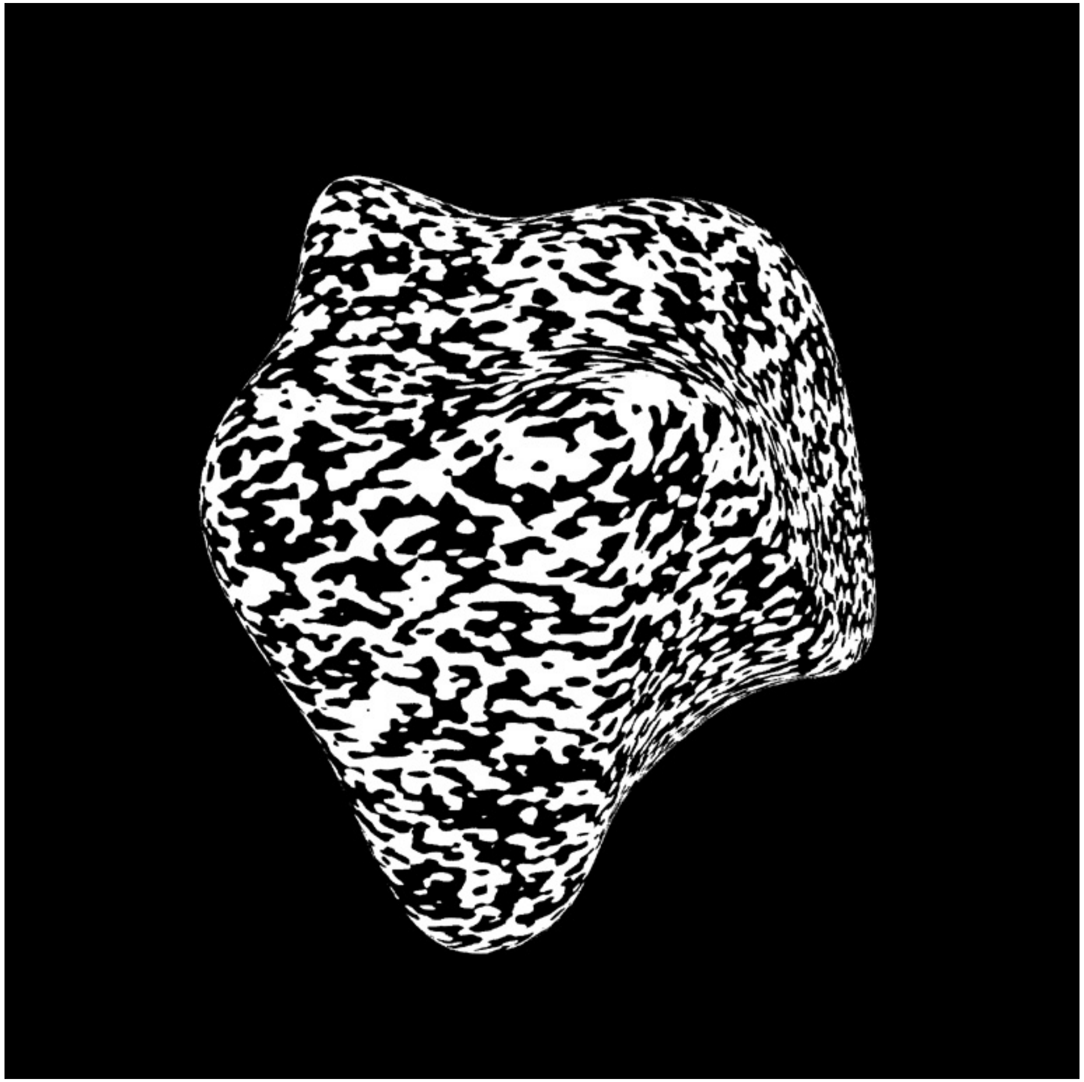
$$b = \begin{bmatrix} \beta_1 \\ \dots \\ \beta_n \end{bmatrix}$$

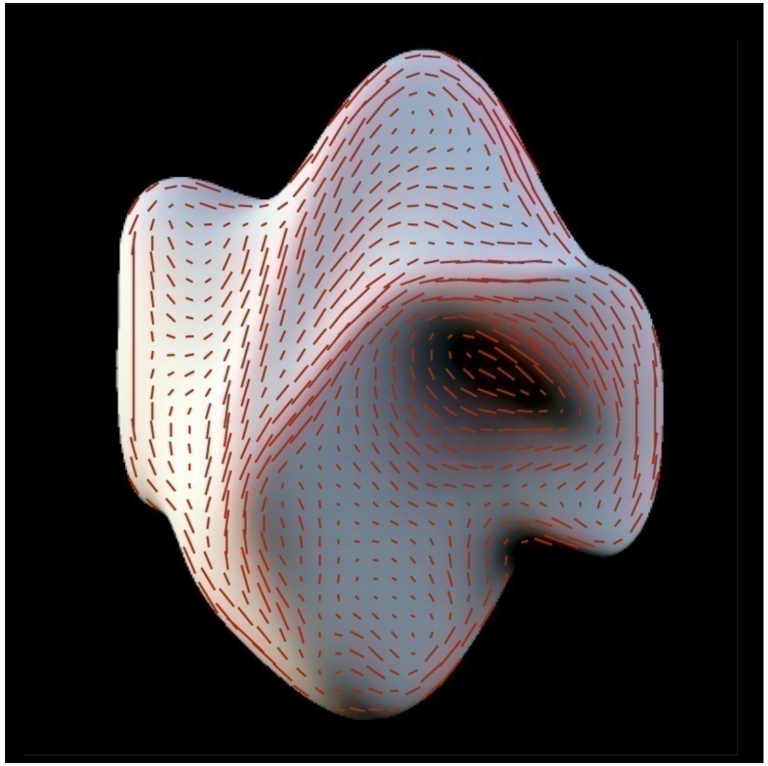
skipped

Therefore:

$$\mathbf{n} = \frac{\psi^t \mathbf{b}}{\left\| \psi^t \mathbf{b} \right\|}$$

ILLUSORY SHAPE DISTORSION





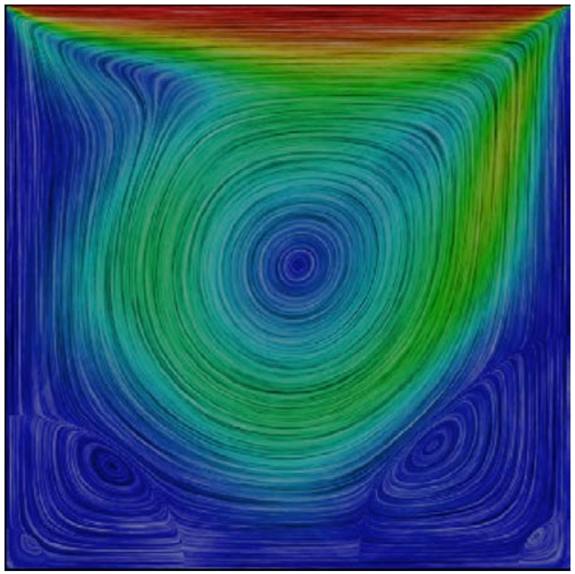
People seem to be sensitive to orientation fields in the cases of both texture and shading.

Flemming et al. PNAS'10

SHAPE FROM SMEAR

Hypothesis: If orientation and scale fields are the key source of information for 3D shape perception, it should be possible to induce a vivid sense of 3D shape by creating 2D patterns with appropriate scale and orientation fields.

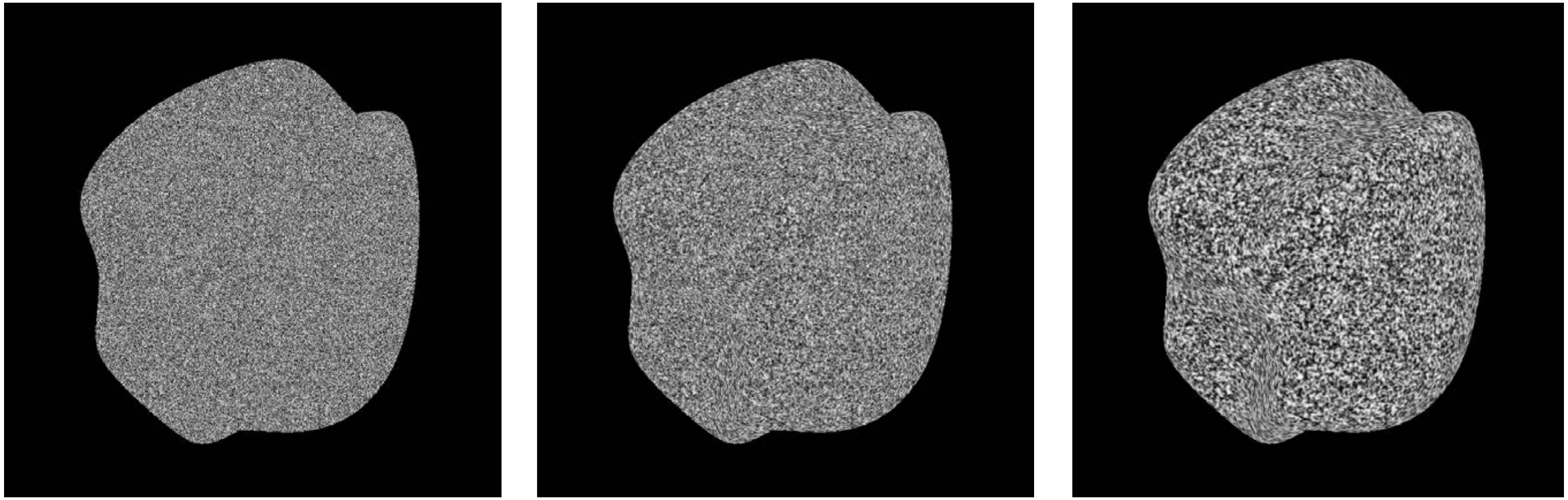
Test: Use a technique known as Line Integral Convolution to smear the texture along specific orientations and scale appropriately.



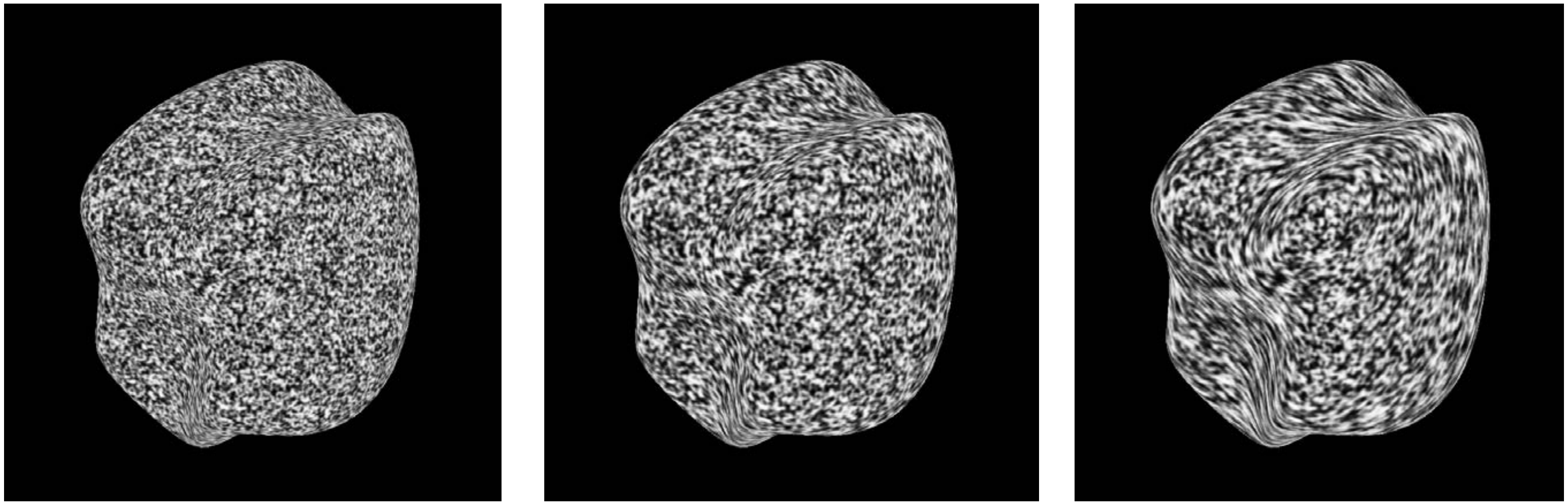
Flemming et al. PNAS'10

SCALING AND SMEARING

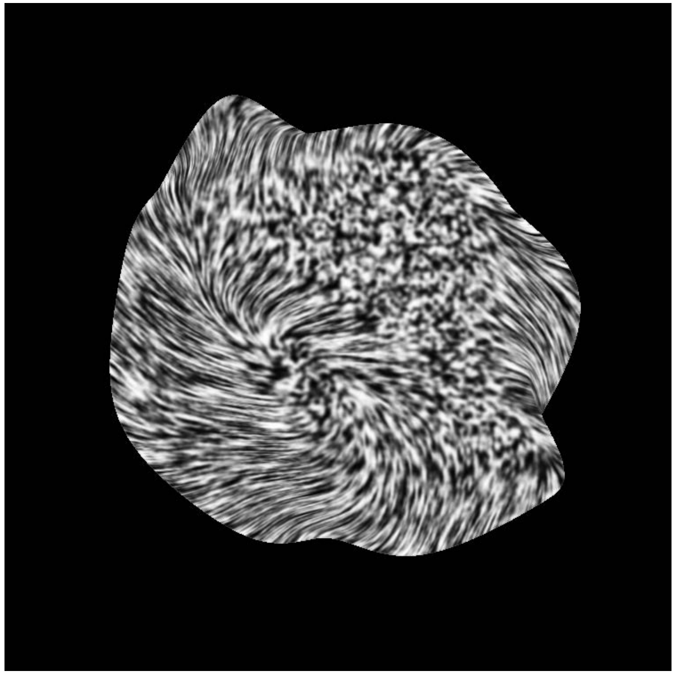
Scaling:

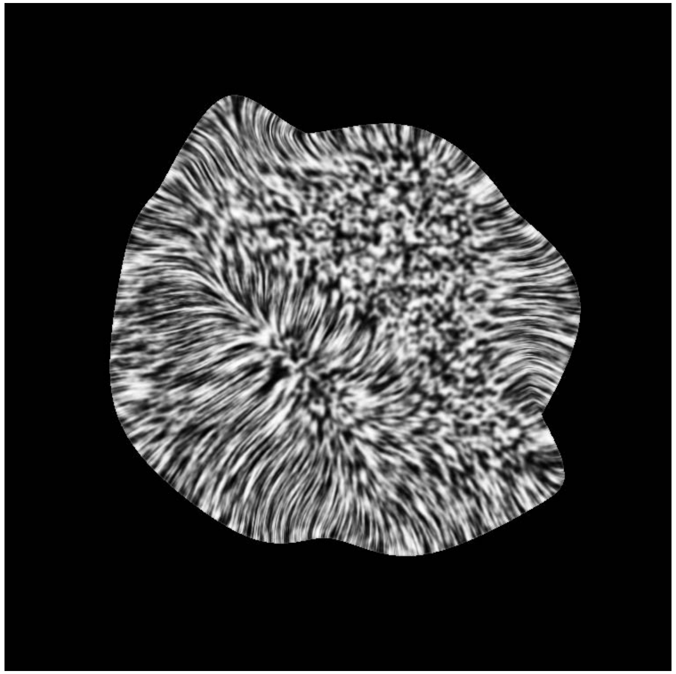


Smearing:



INCONSISTENT STIMULUS





The orientation field cannot be integrated

- ➢No depth perception.
- ➢Do we integrate in our heads?
- ➢Can we design an algorithm that does this?

STRENGTHS AND LIMITATIONS

Strengths:

- Emulates an important human ability.

Limitations:

- Requires regular texture.
- Involves very strong assumptions.