SHAPE FROM X

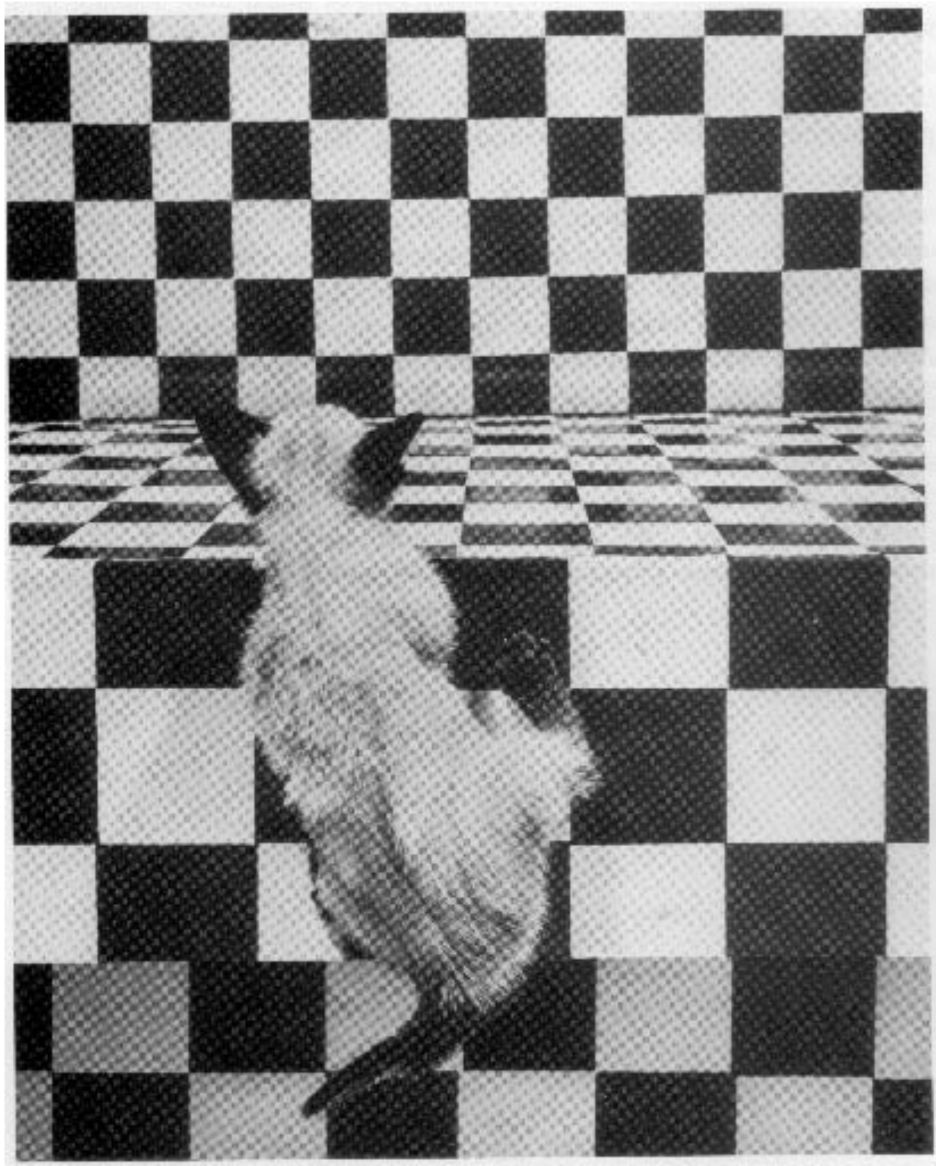
One image:

- Shading
- **Texture**

Two images or more:

- Stereo
- Contours
- Motion

SHAPE FROM TEXTURE

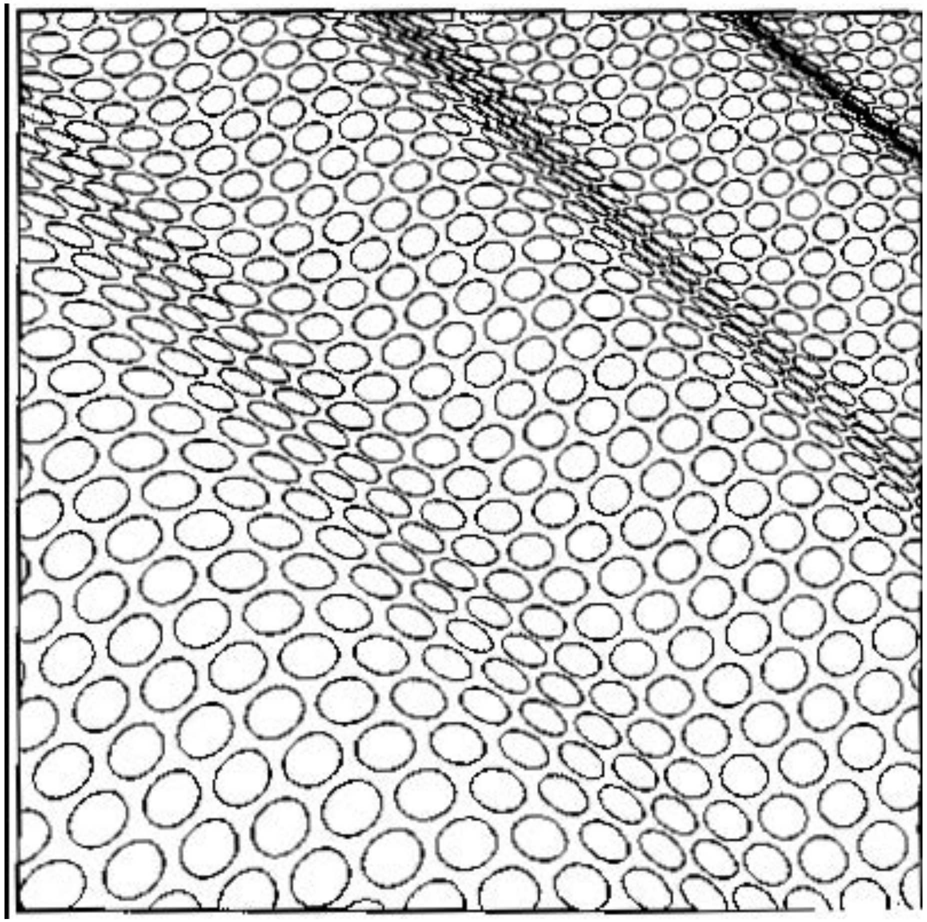


SHAPE FROM TEXTURE

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

STRUCTURAL SHAPE RECOVERY

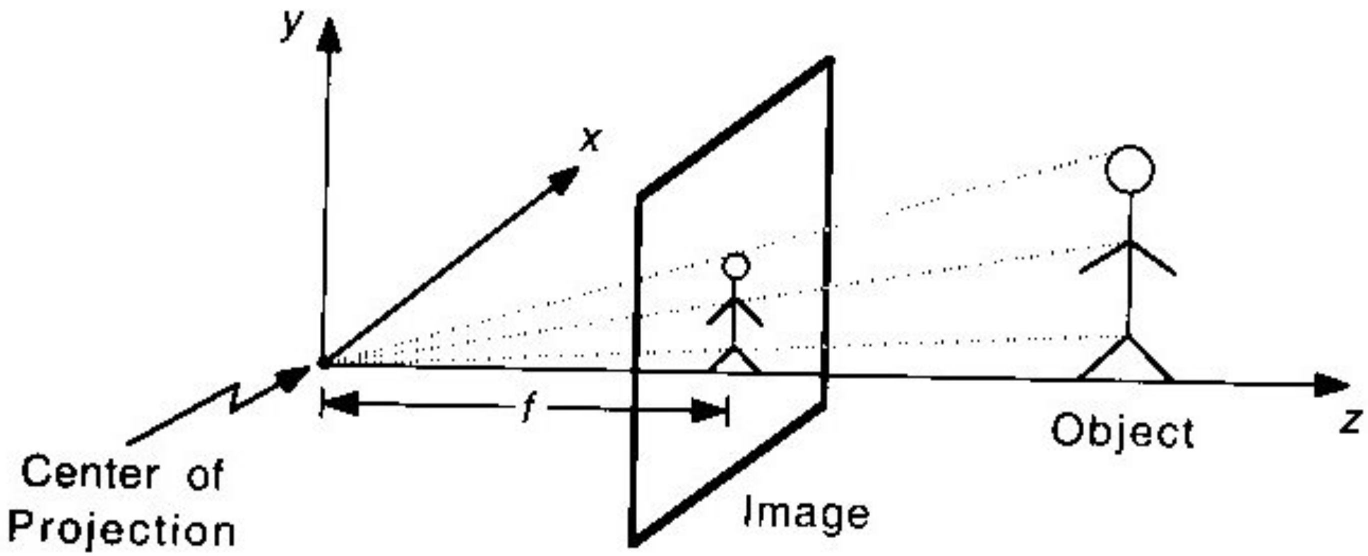


Basic hypothesis: Texture resides on the surface and has no thickness.

--> Computation under:

- Perspective projection
- Paraperspective projection
- Orthographic projection

PERSPECTIVE PROJECTION

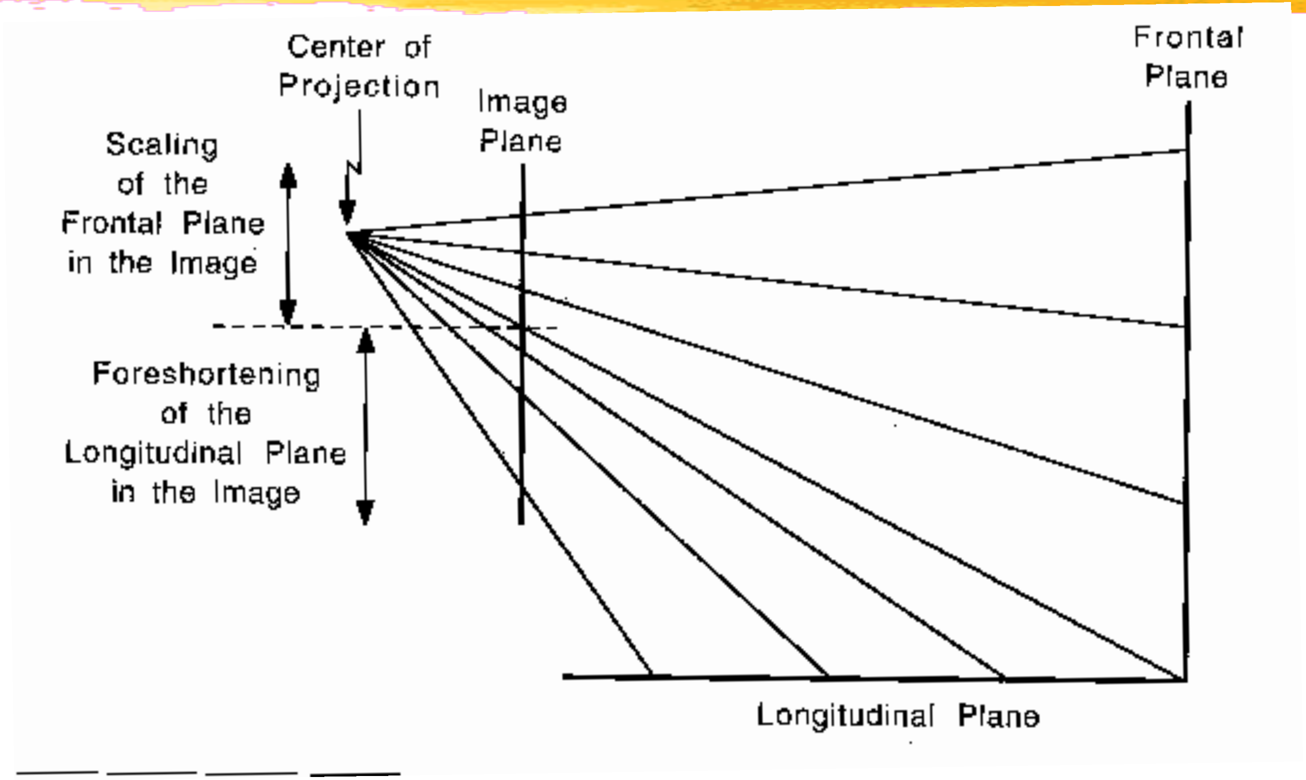


$$u = f\frac{x}{z}$$

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

Pinhole geometry without image reversal

PERSPECTIVE DISTORTION



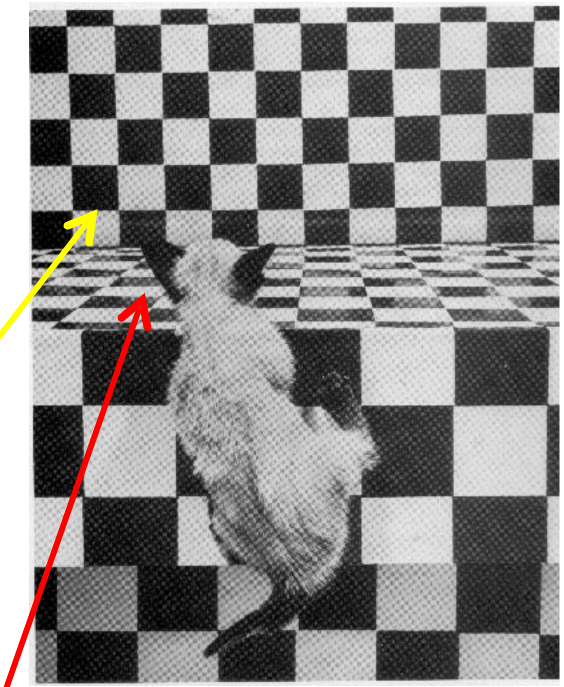
Perspective projection distortion of the texture

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

FORESHORTENING

Depth vs Orientation:

Infinitesimal vector $[\Delta x, \Delta y, \Delta z]$ at location $[x,y,z]$. The image of this vector is



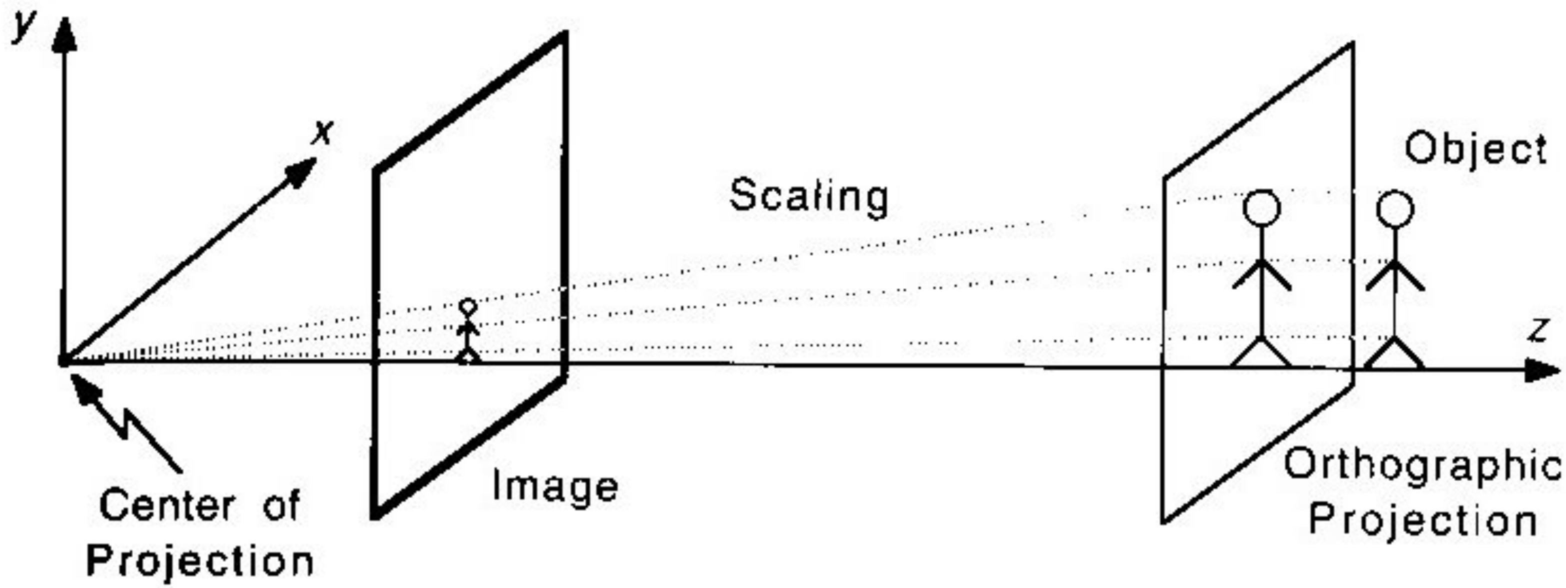
$$\frac{f}{z}[\Delta x - \frac{x}{z}\Delta z, \Delta y - \frac{y}{z}\Delta z]$$

Two special cases:

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

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

ORTHOGRAPHIC PROJECTION



$$u = sx$$

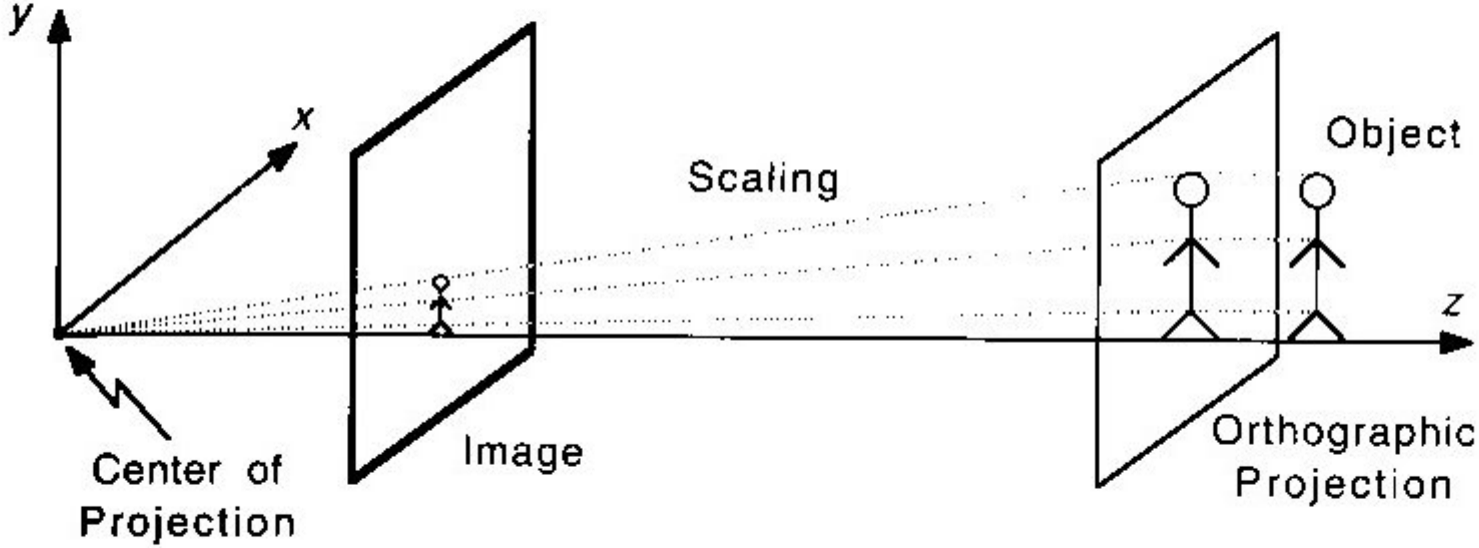
$$v = sy$$

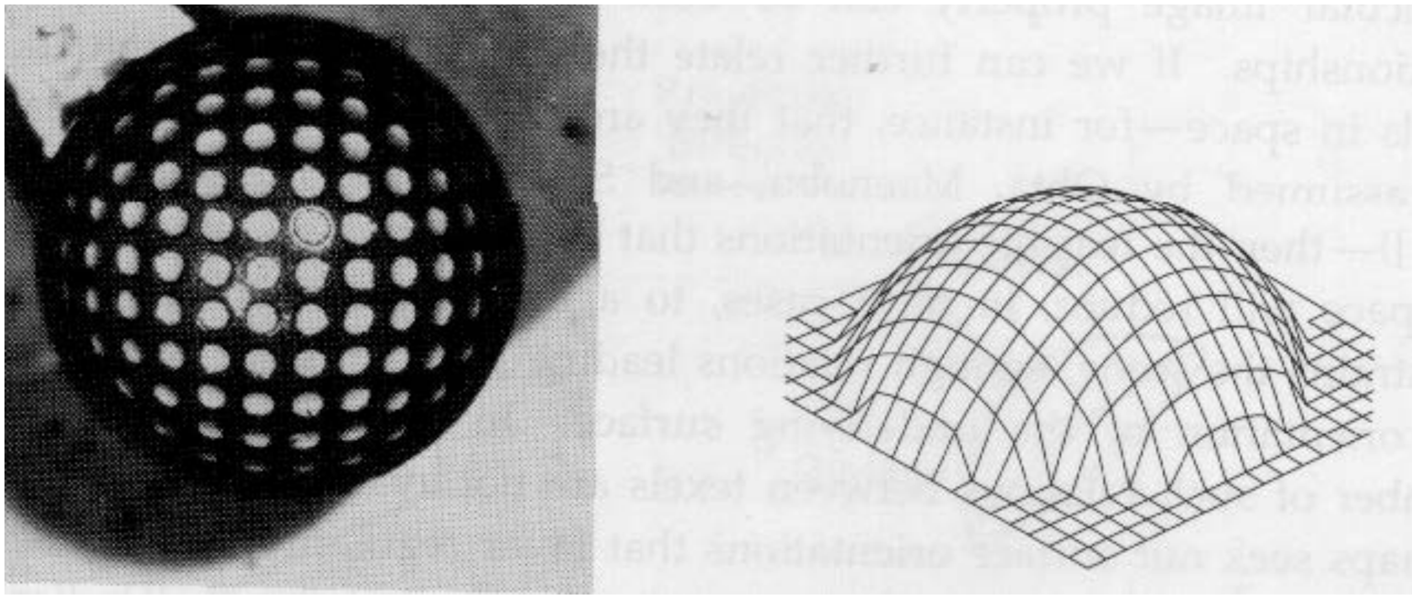
Special case of perspective projection:

- Large f
- Objects close to the optical axis

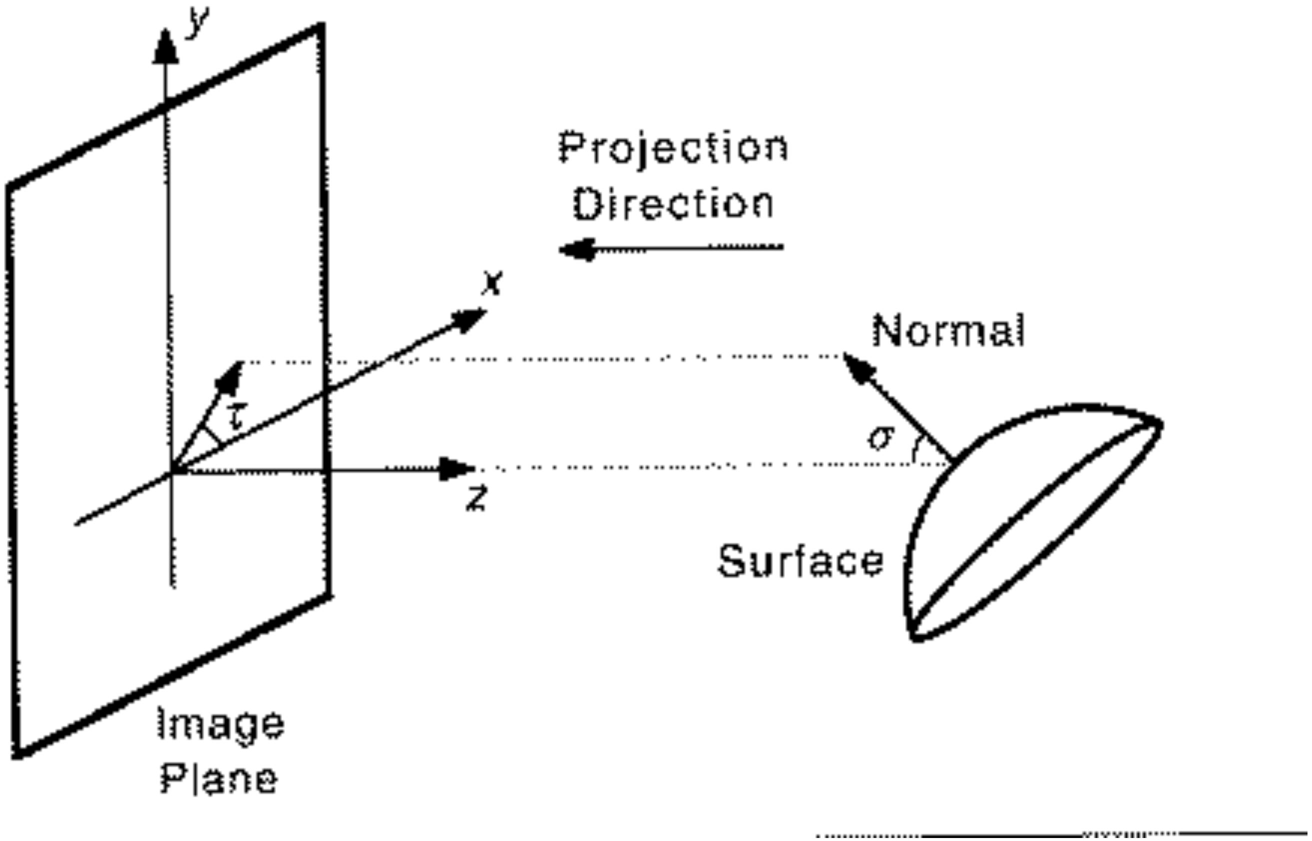
→Parallel lines mapped into parallel lines.

ORTHOGRAPHIC PROJECTION

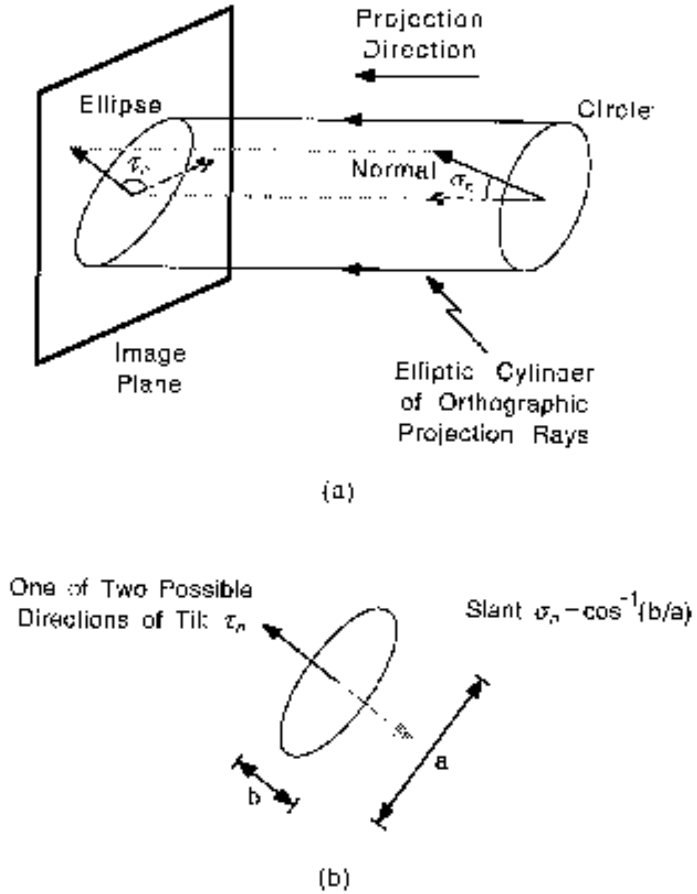




TILT AND SLANT



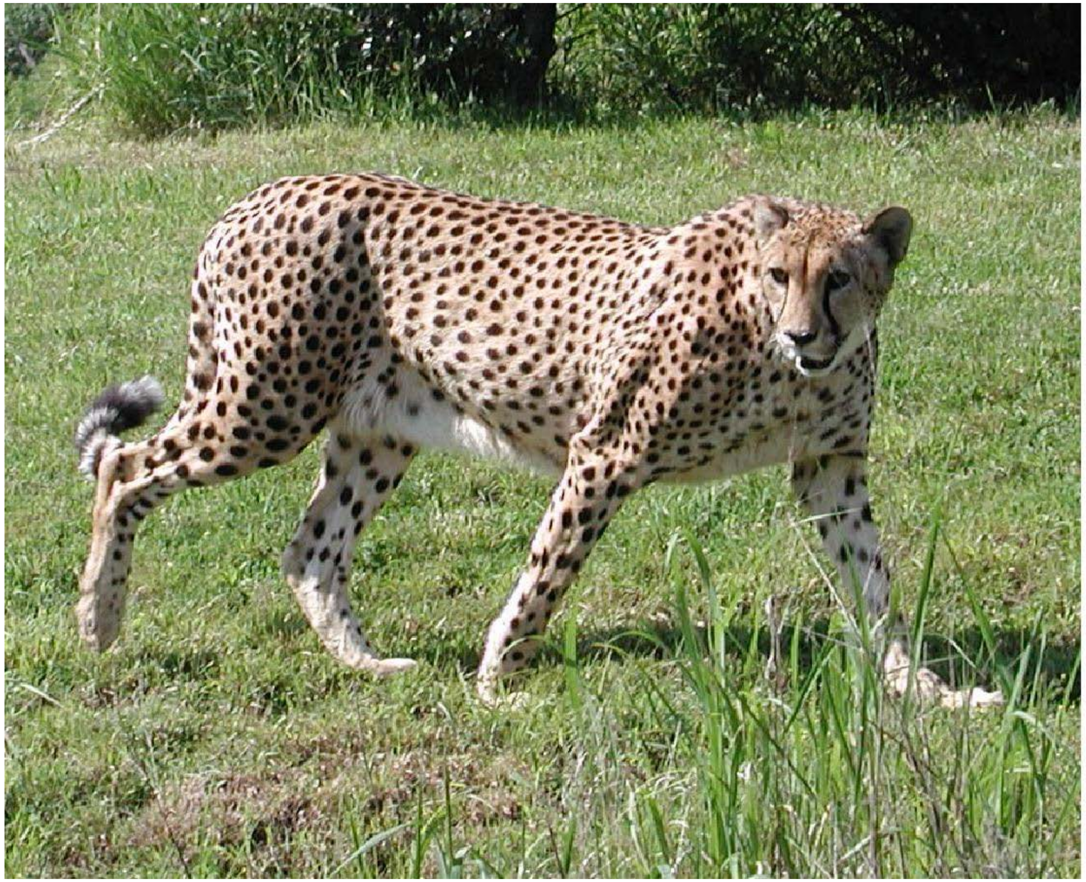
ORTHOGRAPHIC PROJECTION

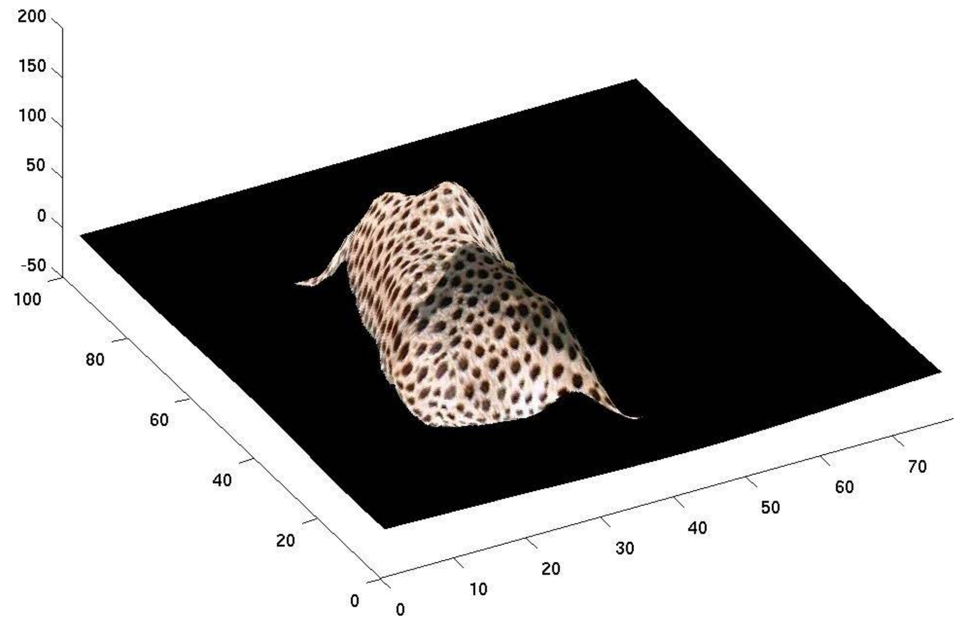


Tilt: Derived from the image direction in which the surface element undergoes maximum compression.

Slant: Derived from the extent of this compression.

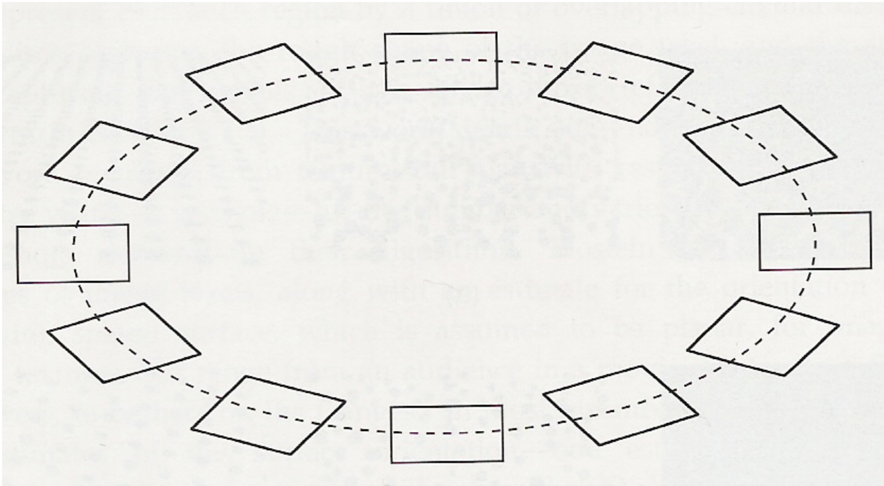
CHEETAH





A.M. Low, Phd Thesis, 2006

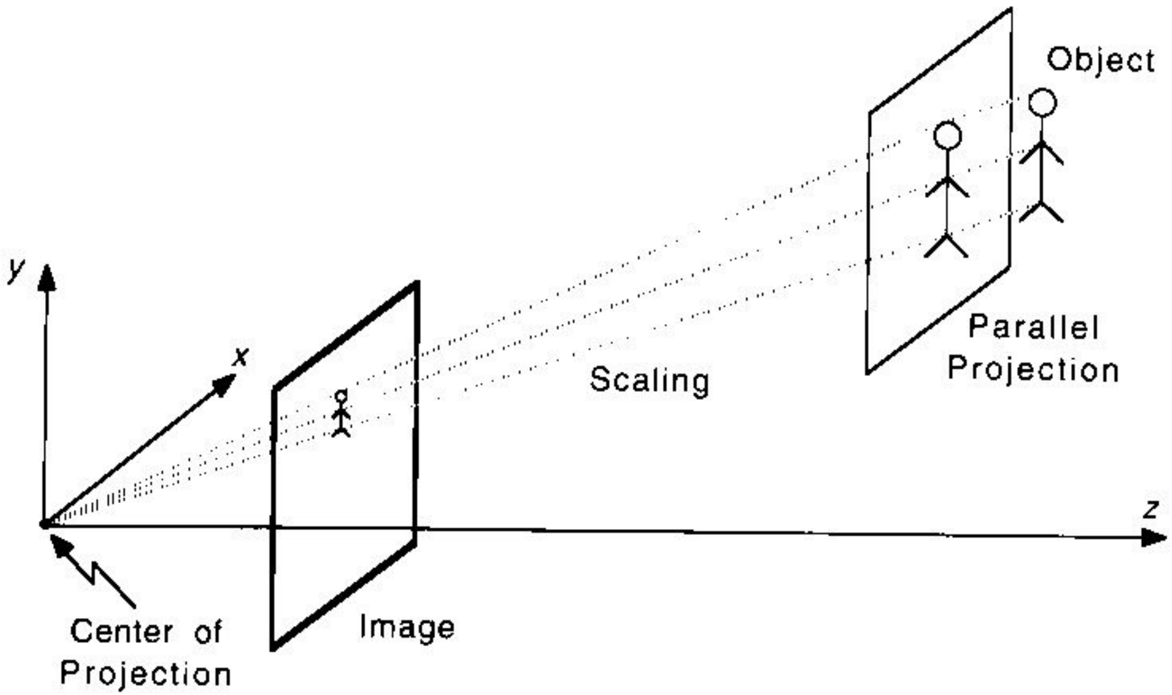
PERPENDICULAR LINES



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

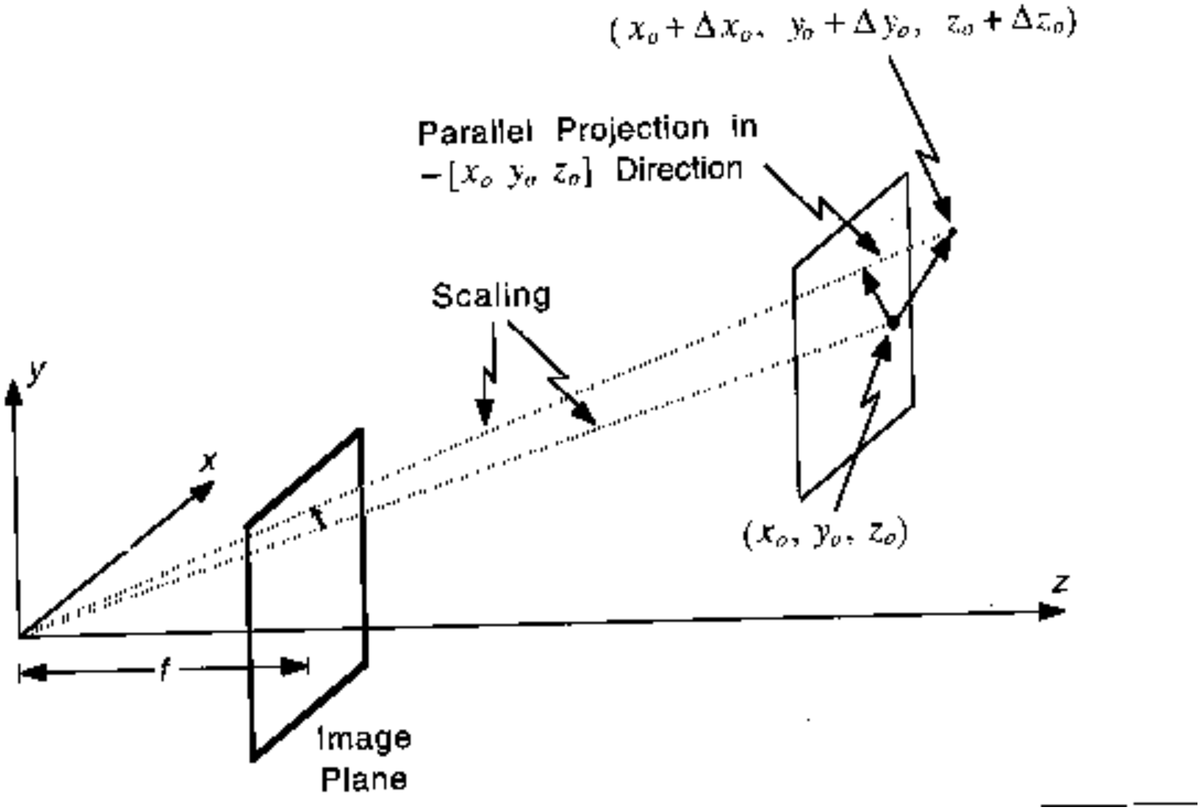


Generalization of the orthographic projection:

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

→Parallel projection followed by scaling

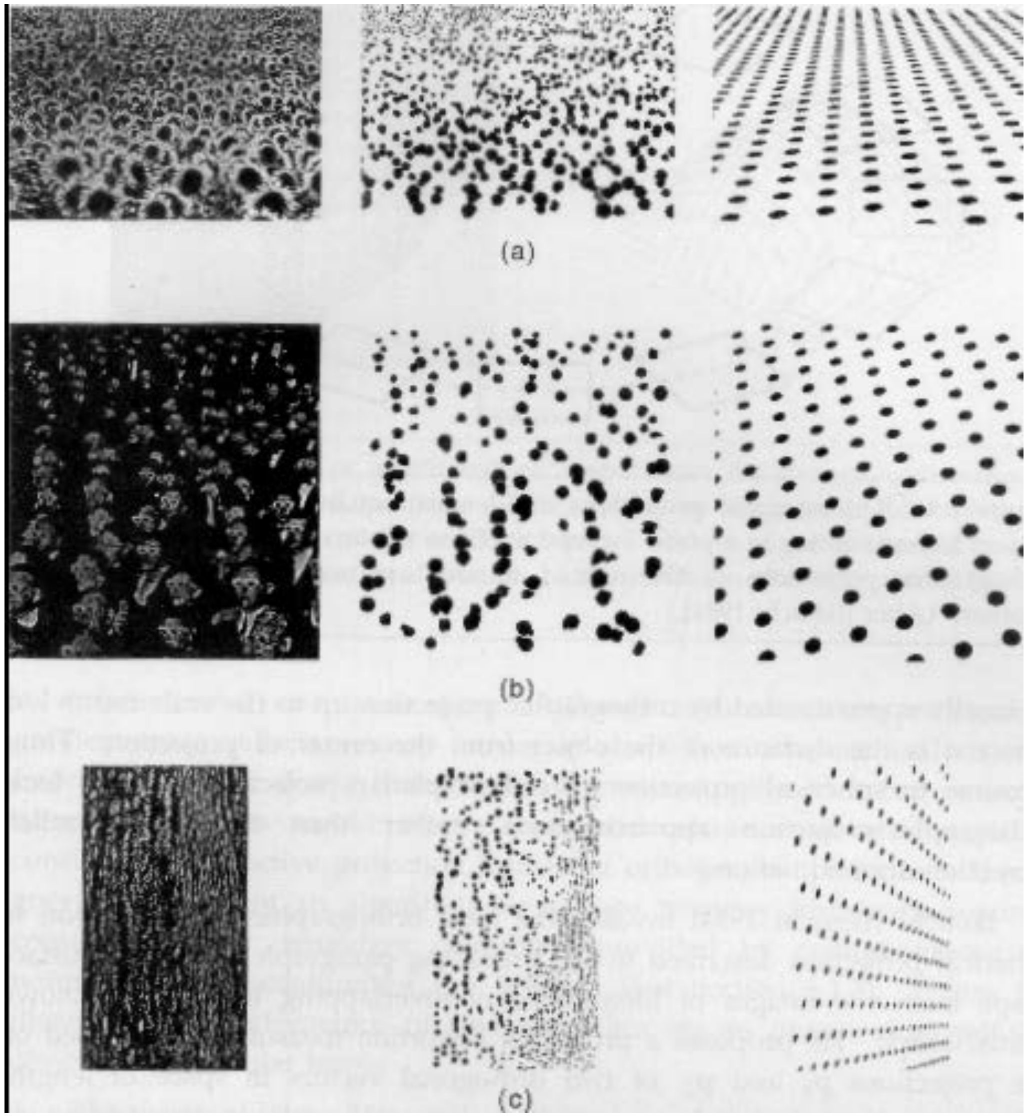
PARAPERSPECTIVE PROJECTION



For planar texels:

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

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

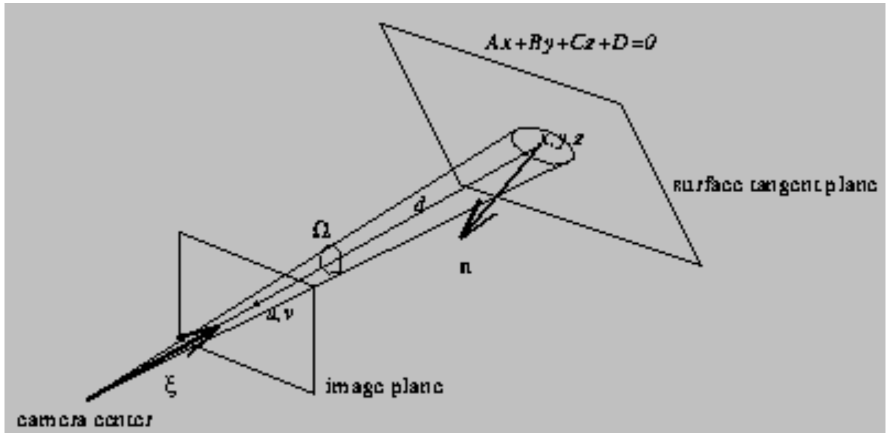
STATISTICAL SHAPE RECOVERY

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

Basic Hypotheses:

- Textural isotropy
- Textural homogeneity

TEXTURE DENSITY



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

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

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

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

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

TEXTURE DENSITY

For several texture elements:

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

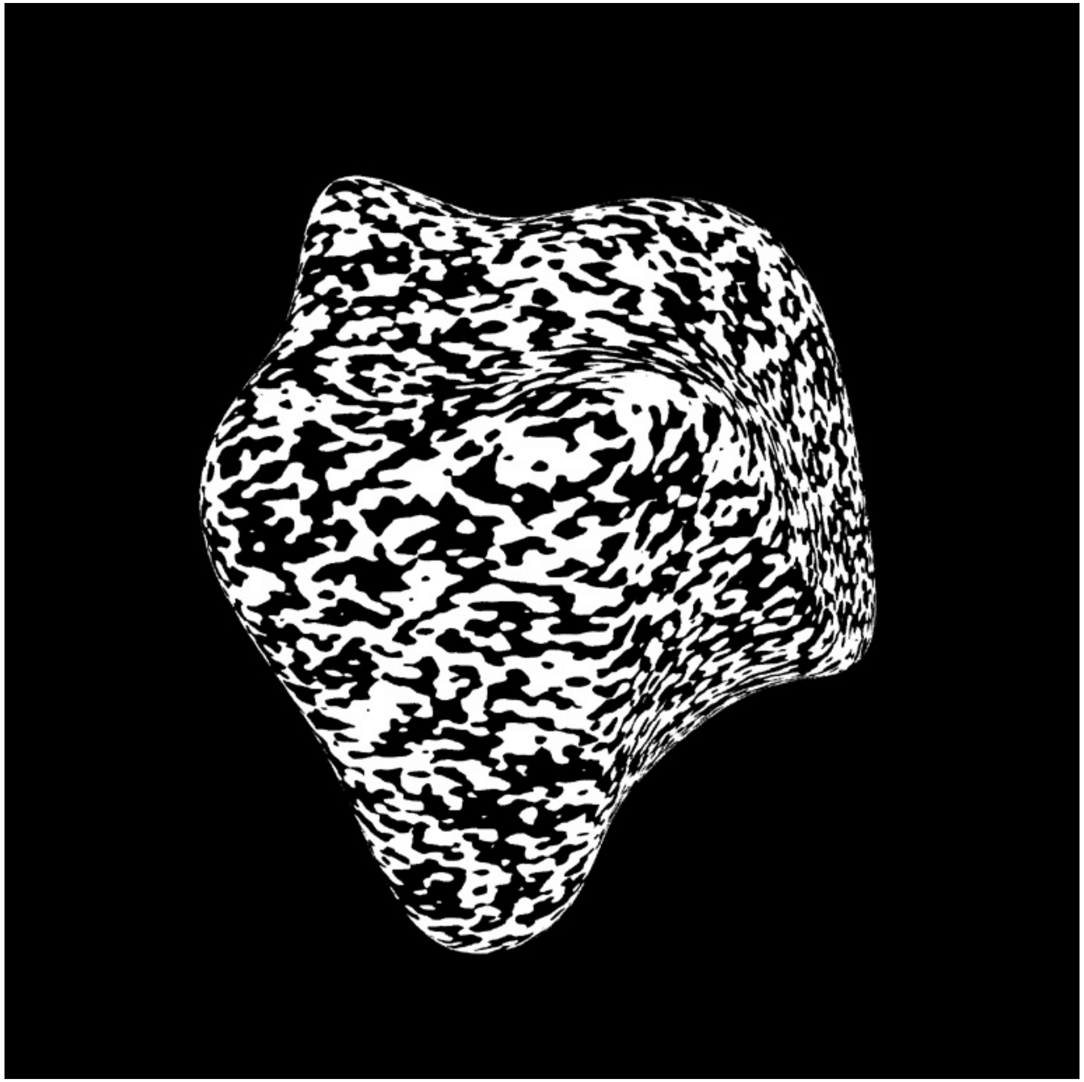
$$\psi = \begin{bmatrix} u_1 & v_1 & f \\ \dots & \dots & \dots \\ u_n & v_n & f \end{bmatrix}$$

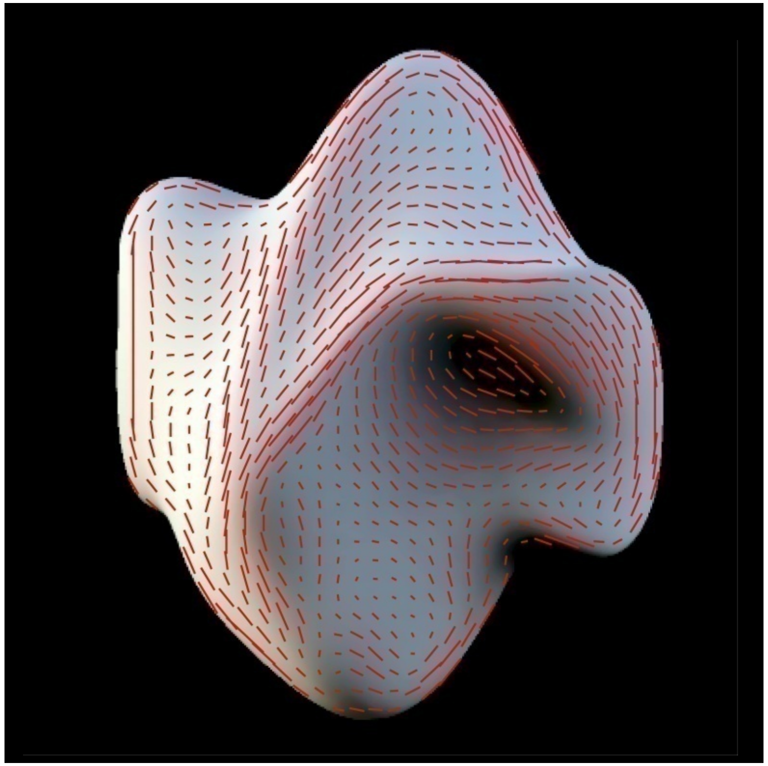
$$b = \begin{bmatrix} \beta_1 \\ \dots \\ \beta_n \end{bmatrix}$$

Therefore:

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

ILLUSORY SHAPE DISTORSION





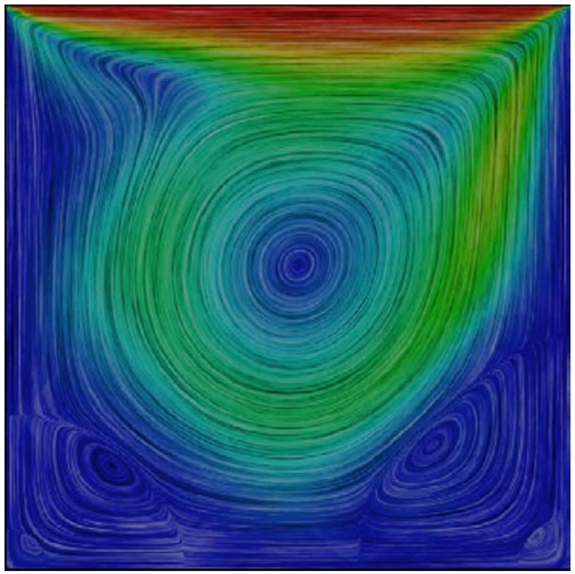
People seem to be sensitive to orientation fields in the cases of both texture and shading.

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.

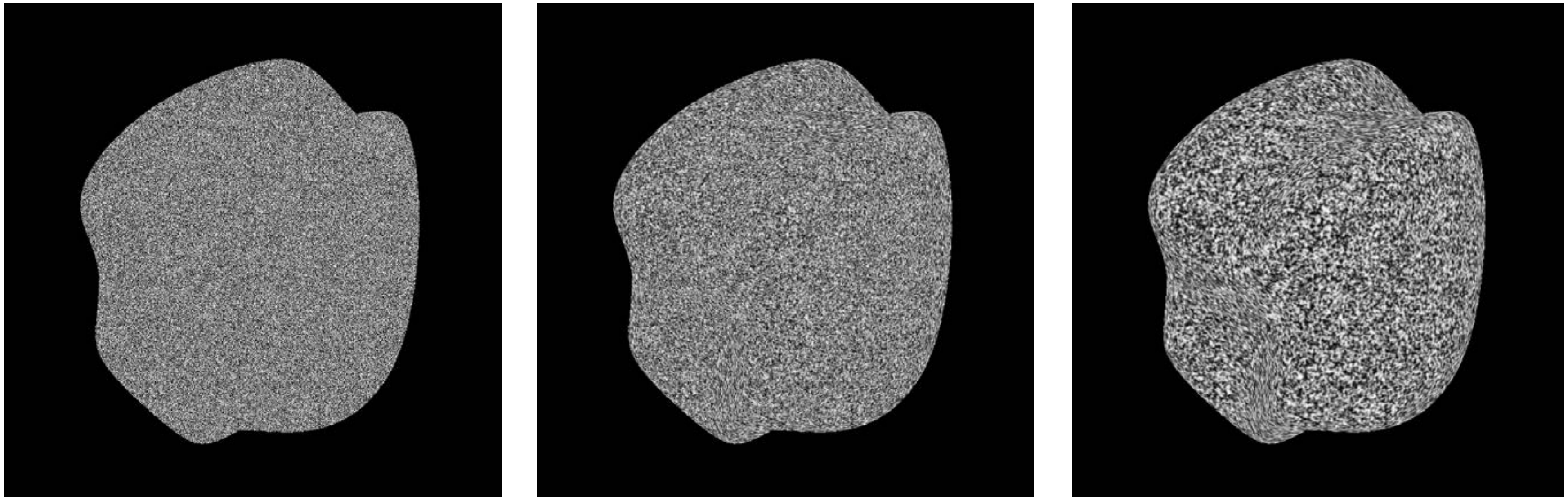
Test: Use a technique known as Line Integral Convolution to smear the texture along specific orientations and scale appropriately.



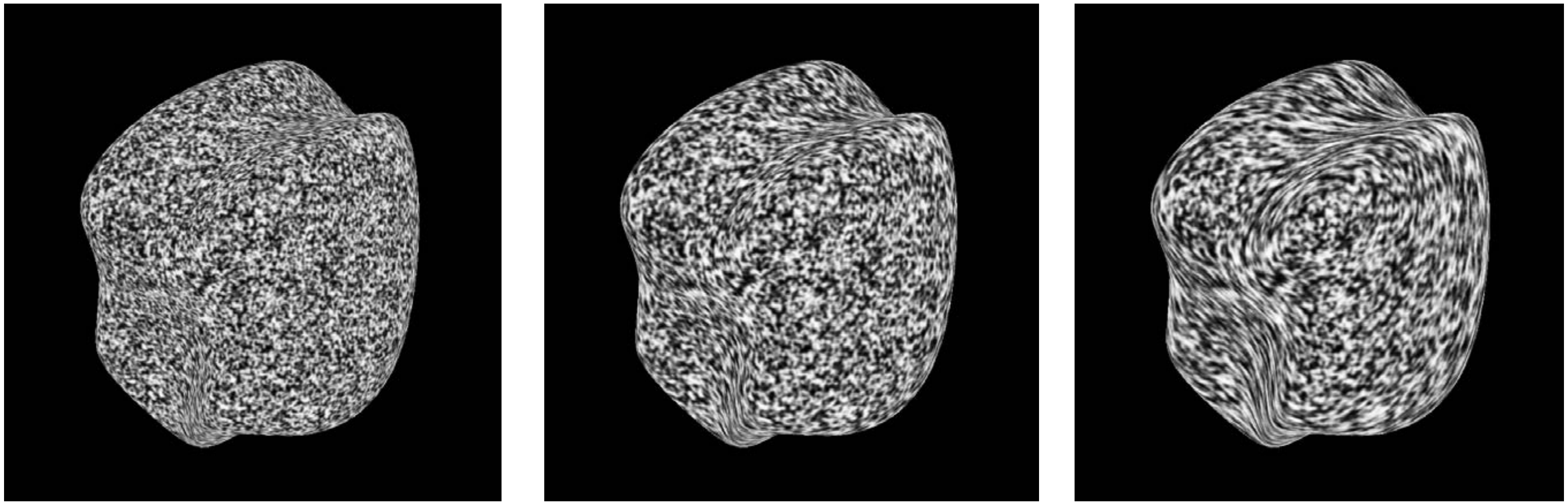
Flemming et al. PNAS'10

SCALING AND SMEARING

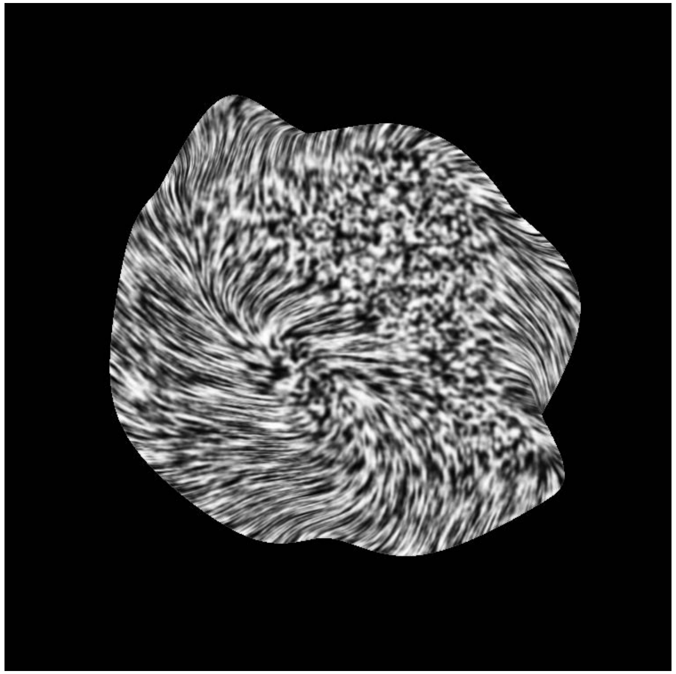
Scaling:

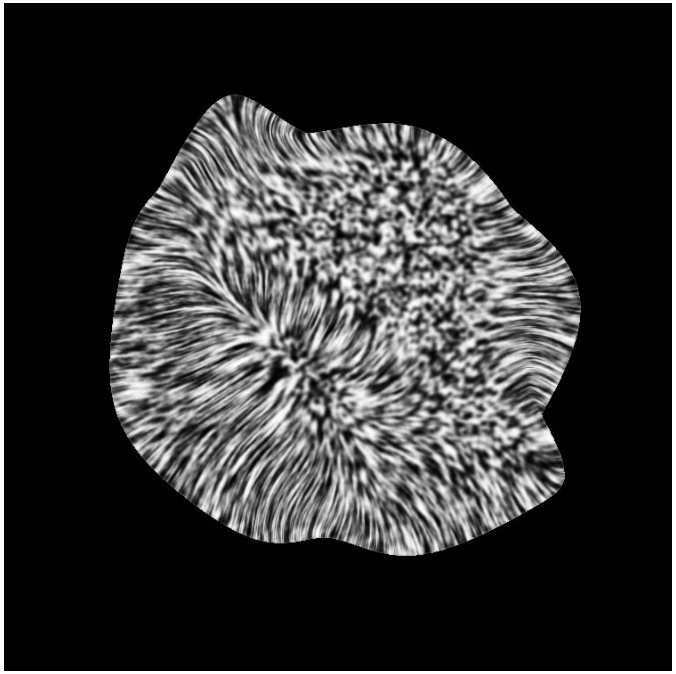


Smearing:



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.