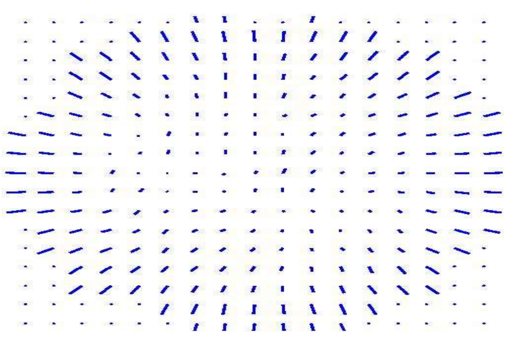

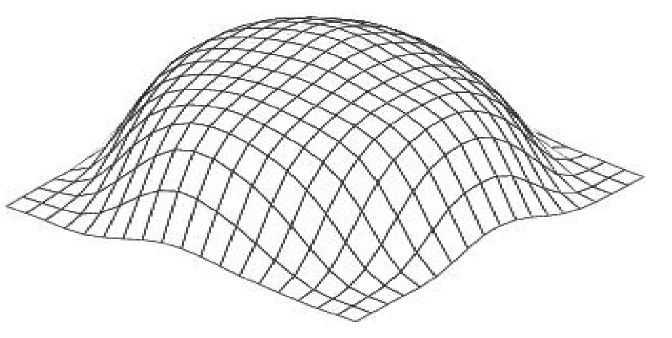

Shape from Texture

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Shape from texture is a computer vision technique where a 3D object is reconstructed from a 2D image. Although human perception is capable to realize patterns, estimate depth and recognize objects in an image by using texture as a cue, the creation of a system able to mimic that behavior is far from trivial.

Although texture as a meaning is difficult to describe in our case we mean the repetition of an element or the appearance of a specific template over a surface. Such element or surface is called texel (TEXture ELement). Various textures can be seen in figure 1.

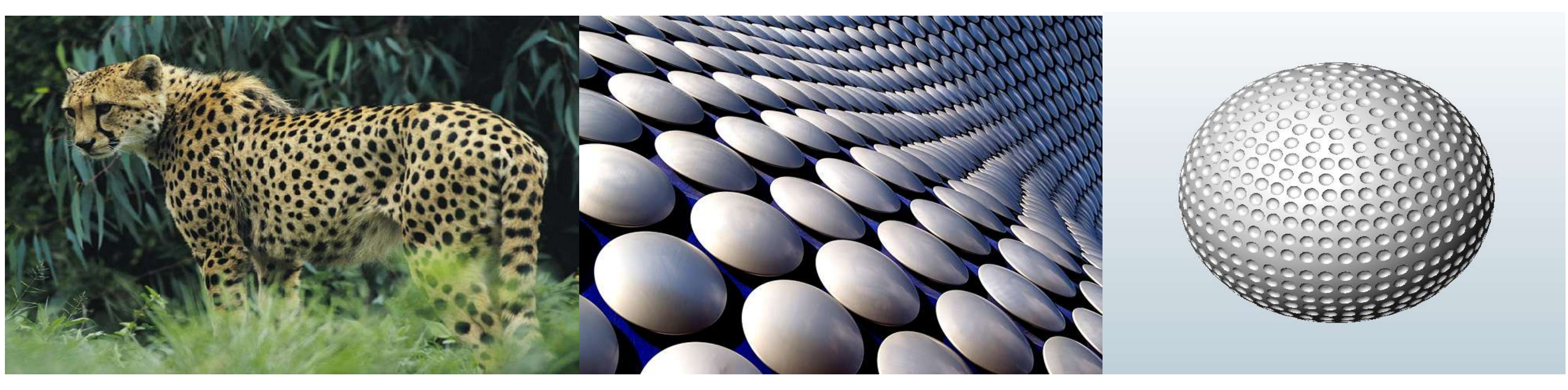

Figure 1: Some examples of textures

The first person who proposed that a shape can be perceived from a texture was Gibson in 1950[2]. Gibson used the term texture gradient in order to denote that areas of a surface that have similar texture, with other neighbor areas, are perceived differently from the observer due to differences in orientation of the surfaces and the distance from the observer.

In order to measure the orientation of the texels in a texture, we need to find the slant and tilt angles. Slant denotes the amount and tilt denotes the direction of the slope of the planar surface projected on the image plane. In figure 2 [3] the angle ρ between z_s and z_i is the slant angle while the angle τ between x_i and the projection of the surface normal z_s onto the image plane is the tilt angle.

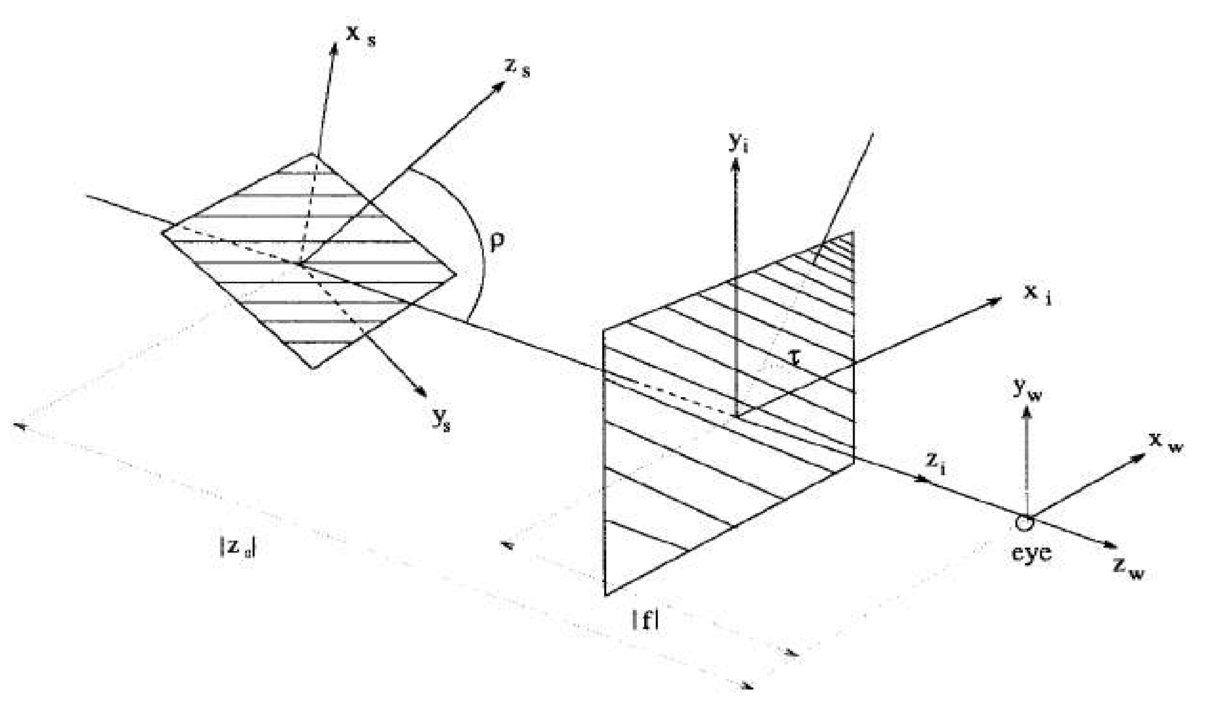

Figure 2 : Coordinate relationship between the image plane and the surface plane , figure from [3]

We will present a shape from texture technique that is based on [4].

In [4] they try first to find the frontal texel that will lead them to identify the surface with the best consistency measure. Their aim is to identify the transformation matrices that lead from that texel to all the other ones. Since in the beginning they don't know the appearance of the frontal texel, they define the transformation matrices as product of a randomly chosen texel to all the other texels multiplied by the transformation matrix from the frontal texel to the randomly selected one.

In order to find the tilt direction and the degree of slant they use formula (1)

$$T_{f->i} = UDU^T(UV^T) \quad (1)$$

where D is a diagonal matrix (where $D_{11} < D_{22}$) and gives the degree of the slant (σ) and U gives the tilt (τ) direction (2) ,(3),(4) and (5). U and V are orthogonal matrixes.

$$cos(\tau) = U_{11} \quad (2)$$

$$sin(\tau) = U_{12} \quad (3)$$

$$cos(\sigma) = D_{11}/D_{22} \quad (4)$$

$$sin(\sigma) = \sqrt{1 - cos^2(\sigma)} \quad (5)$$

since (2) and (3) come from $U = \begin{pmatrix} cos(\tau) & sin(\tau) \\ -sin(\tau) & cos(\tau) \end{pmatrix}$

and (4) and (5) come from $D = \begin{pmatrix} cos(\sigma) r & 0 \\ 0 & r \end{pmatrix}$ where r is the scalling factor.

Having the previous equations it is now possible to calculate the surface normal which is

$$\begin{pmatrix} n_x \\ n_y \\ n_z \end{pmatrix} = \begin{pmatrix} \pm cos(\tau) sin(\sigma) \\ \pm sin(\tau) sin(\sigma) \\ cos(\sigma) \end{pmatrix} \quad (6)$$

and now it is possible to calculate the gradients for patch of the frontal texel. Then by using the Fundamental Theorem of Line Integrals they calculate the cost term and with the Levenberg-Marquardt method [1] they find the most consistent surface. Finally having determined the frontal texel they use it to calculate the surface shape. This is done by solving the transformation:

$$T_{f->i} = T_{j->i} \begin{pmatrix} 1 & 0 \\ c_f & b_f \end{pmatrix} \quad (7)$$ by using equations (2),(3),(4),(5).

Finally the orientation for every texel can be specified and is given by these two equation:

$$\tau = arctan(U_{12}/U_{11}),\ \sigma = arccos(D_{11}/D_{22}) \quad (8)$$

In Figure 3 we can see the result from their algorithm. In the left image we can see the texture and the needles in each texel where they show us their orientation, the second image is the estimated height of the surface of the texture, and finally in the right image the surface as estimated as seen from side view.

(a) Needle diagram also showing detected texels (b) Calculated surface height shown in gray value (c) Mesh surface seen from side view

Figure 3: Shape estimation , figure from [4]

For more details on this algorithm and other projects of the same author you can visit : http://www.csse.uwa.edu.au/~angie/

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