INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
34100 TRIESTE (ITALY) - P.O.B. 586 - MIRAMARE - STRADA COSTIERA 11 - TELEPHONE: 2240-1
CABLE: CENTRATOM - TELEX 460392 - I

SMR/302-28

COLLEGE ON NEUROPHYSICS:
"DEVELOPMENT AND ORGANIZATION OF THE BRAIN"
7 November - 2 December 1988

"Visual Reconstruction: Stereo Vision"

Andrew BLAKE
Department of Engineering Science
University of Oxford
Oxford, U.K.

David Marr's 3 levels of information processing in the brain.

1. Computational theory
2. Algorithm
3. Hardware implementation (silicon!)

At these levels there can be fruitful cooperation between Robot engineering and studies of biological vision.

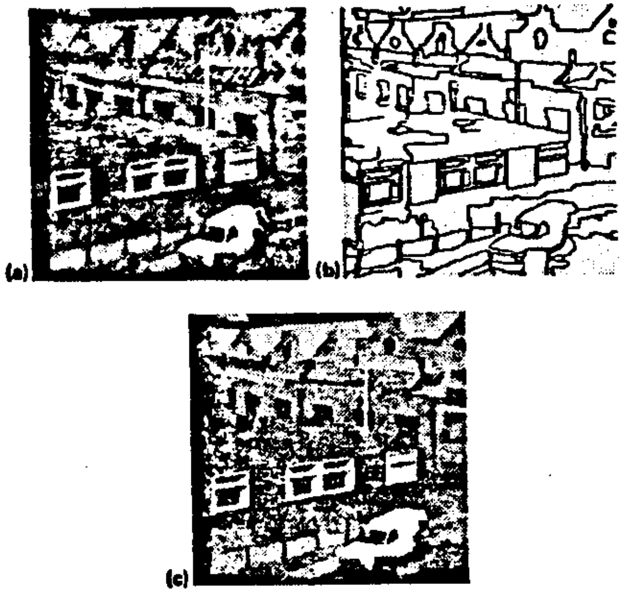
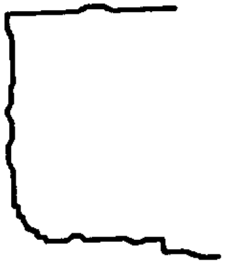
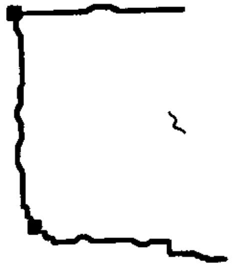


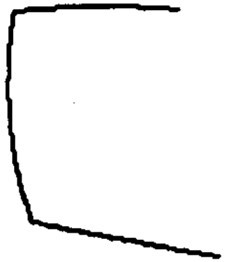
Figure 2.4: The weak membrane as an edge detector. The image in (a) and its discontinuities (b). Reconstructed intensity (c) is the filtered version of (a), preserving the discontinuities marked in (b). Both (b) and (c) are produced simultaneously by the weak membrane.

Edges + reconstruction simultaneously

Describing curves


a


b


c

a) The curve

b) Find discontinuities

c) Approximate curve by straight lines and circular arcs.

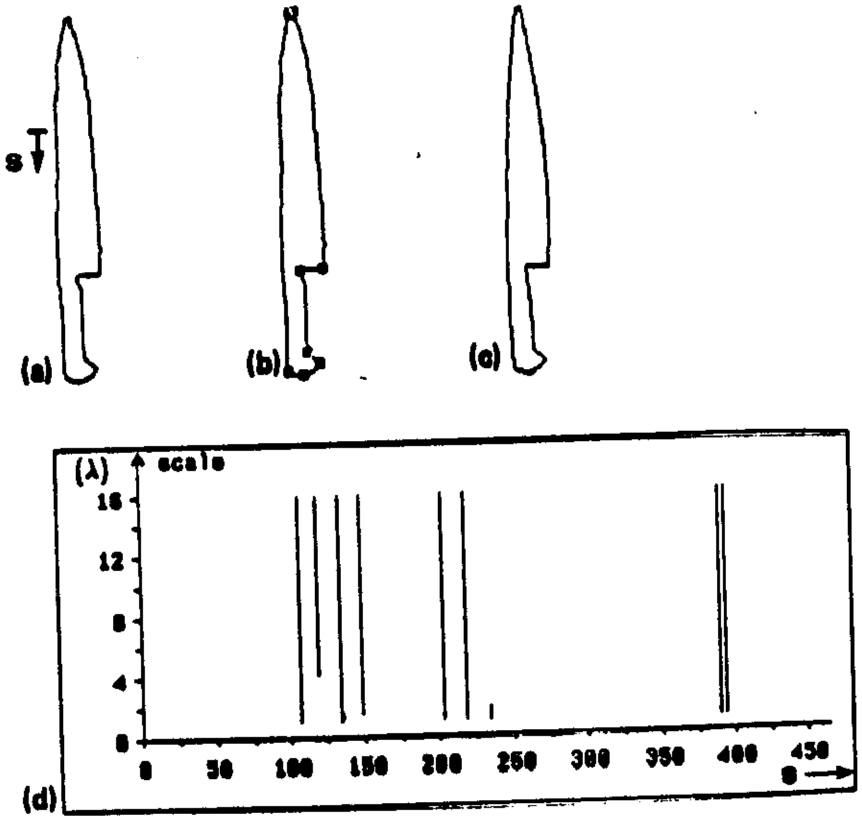


Figure 2.15: Weak string scale-space applied to a real image. Sillhouette (a) segmented at coarse scale (b) and reconstructed by fitting arcs between discontinuities (c). It is apparent that discontinuities and arcs together constitute a compact but accurate representation of the silhouette. (d) Scale-space. Most features, in this case, are visible at both coarse and fine scale, except for the curved base of the handle, visible at coarse scale only. (Data after Asada and Brady (1986).)

Localisation!

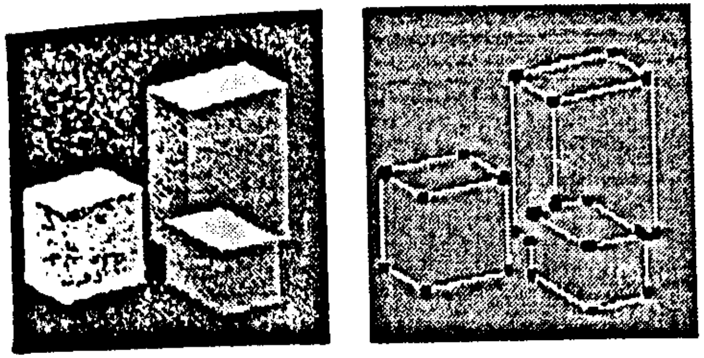


Figure 2.16: Corner and junction detection: synthesised image. Dark blobs mark discontinuities in tangent angle, obtained from fitting weak strings to the entire "graph" of edges.

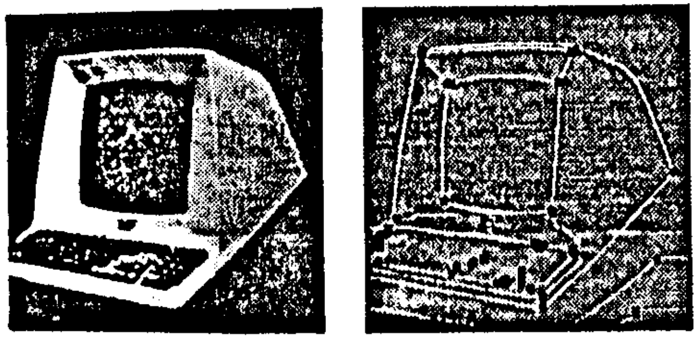


Figure 2.17: Corner and junction detection: real image.

Stereoscopic images

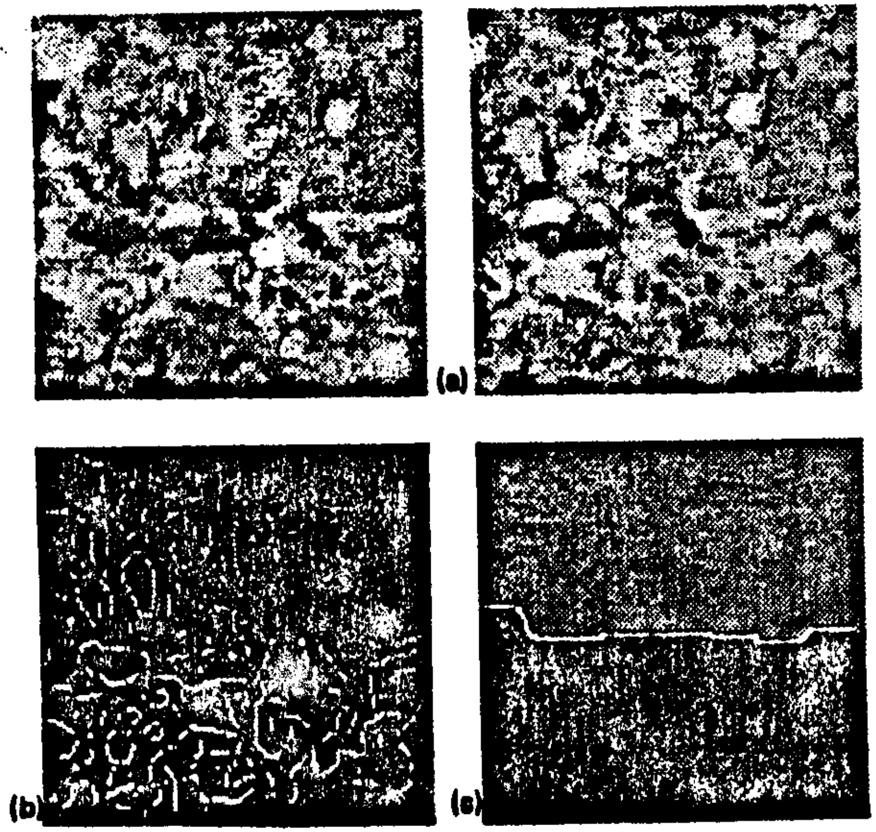


Figure 2.10: **Weak membrane reconstruction of real stereo data.** A stereo pair (a) of a foam block, with a step discontinuity across the middle, that is all but invisible monocularly. Stereo correspondence using a state-of-the-art matching algorithm (Pollard et al. 1985) produces depths along sparse contours (b). The reconstructed surface is shown with its contour of discontinuity (c).

correspondence

surface reconstruction

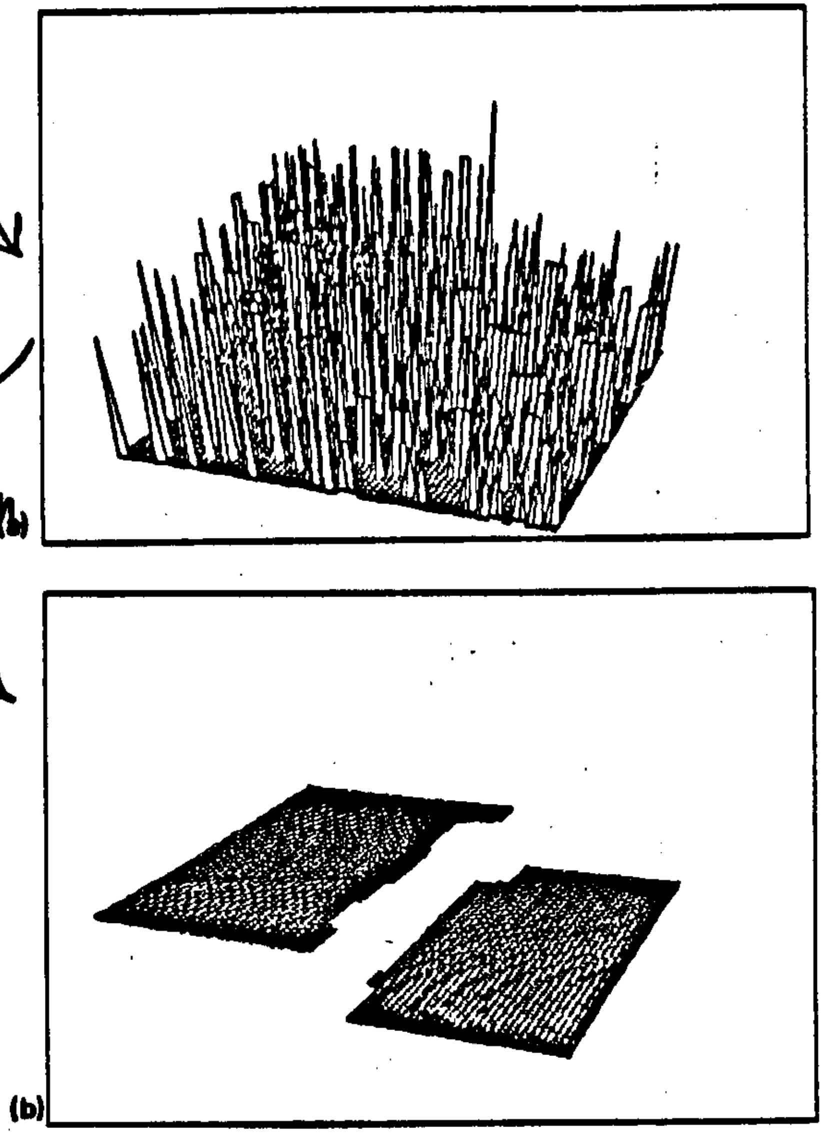


Figure 2.11: Isometric plots of the stereoscopic data from figure 2.10b and the reconstructed surface in figure 2.10c.

Elastic Model.

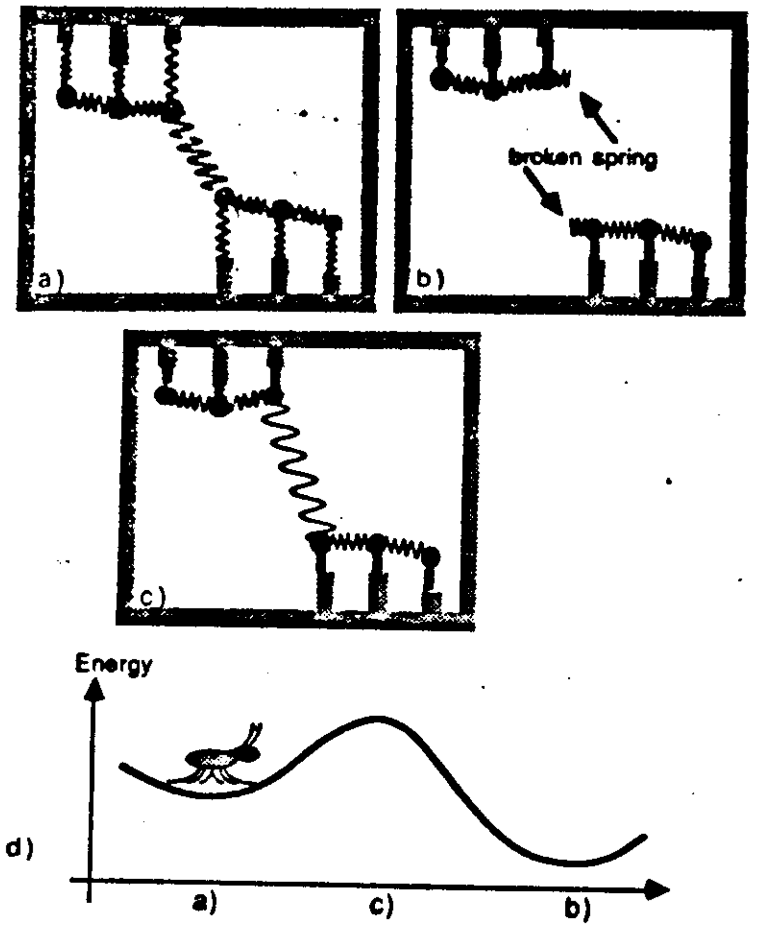


Figure 3.4: Non-convexity: the weak string is like a system of conventional vertical springs with "breakable" horizontal springs as shown. The states (a) and (b) are both stable, but the intermediate state (c) has higher energy than either (a) or (b). Suppose the lowest energy state is (b). A myopic fly with vertigo, crawling along the energy transition diagram (d) thinks state (a) is best - he has no way of seeing that, over the hump, he could get to a lower state (b).

Weak elastic models.

Simplest model: "weak string" reconstructn

given $d(x), x \in [a.b]$ ← data

Minimise w.r.t. $u(x), x \in [a.b]$

and $B = \{b_0, b_1, \ldots b_{n-1}, b_n\}$ $b_0 = a$, $b_n = b$

breakpoints

$$E = \sum_{i=0}^{n-1} \int_{b_i}^{b_{i+1}} \{ (u(x) - d(x))^2 + \underline{\underline{\lambda}}^2 u'(x)^2 \} dx + \underline{\underline{\alpha}} n$$

parameters

regulariser

'non-classical' term.

Discretise via finite elements → NON-CONVEX

2D: "weak membrane" reconstruction.

given $d(x,y)$, $(x,y) \in D$

<u>minimise</u> w.r.t $u(x,y)$, $(x,y) \in D$

& set of curves $C \subset D$

$$E = \int_{D \setminus C} \left\{ (u-d)^2 + \underline{\underline{\lambda}^2 (\nabla u)^2} \right\} dx\, dy$$

$$+ \underline{\underline{\alpha} |C|}$$

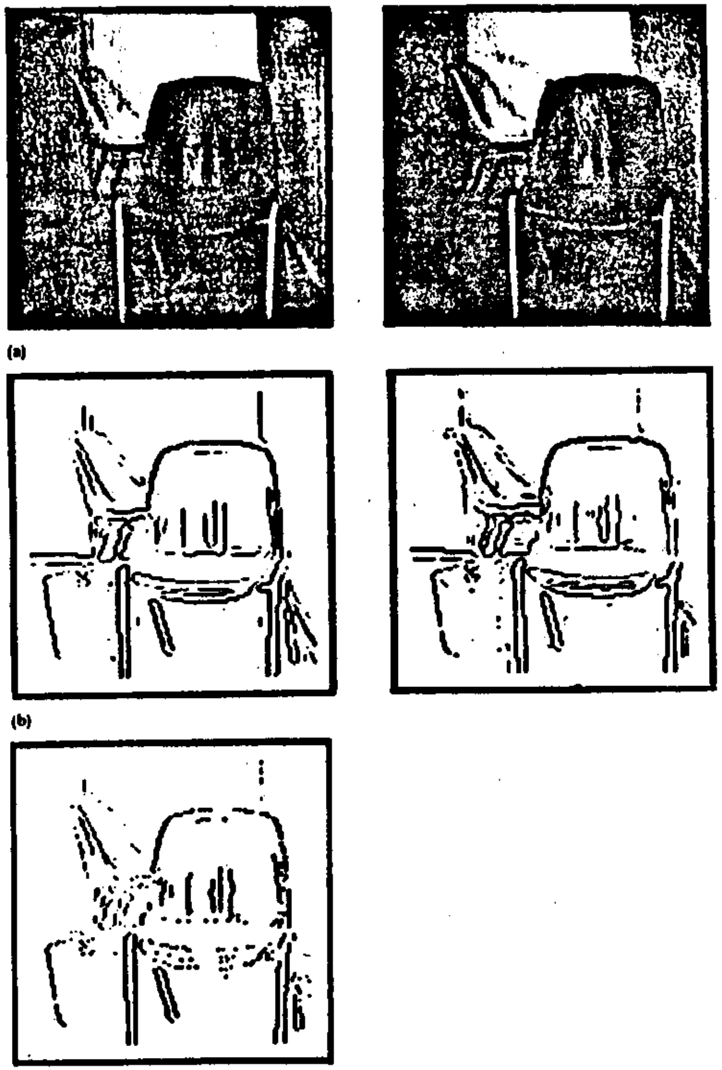
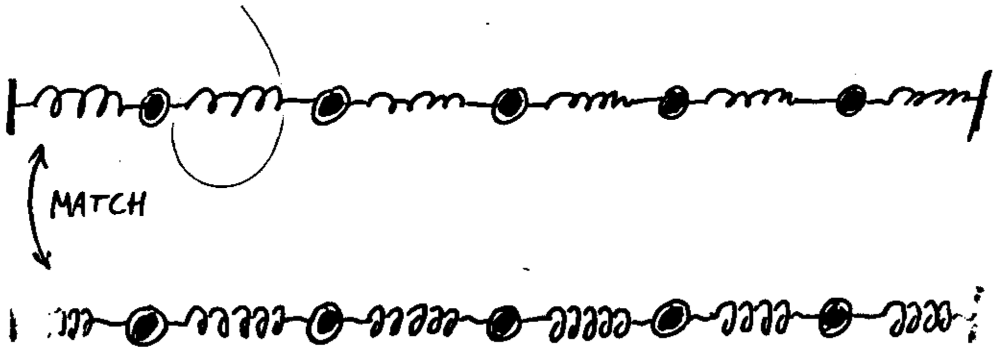


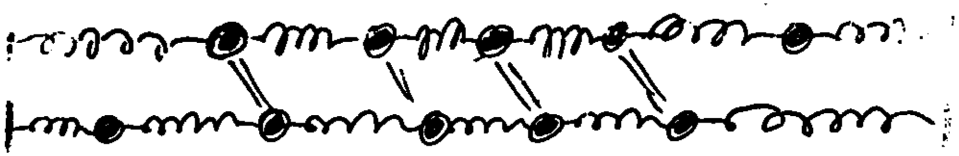
Figure 7. The performance of PMF on a stereo pair comprised of natural images of an office scene. (a) Stereo pair arranged suitably for crossed-eye fusion. (b) Edge-like primitives extracted with the use of a Marr–Hildreth operator. (c) Matches found by PMF, with intensity used to code relative disparities (dark = near, faint = far). See text for further details.

JULESZ - GLOBAL STEREOPSIS

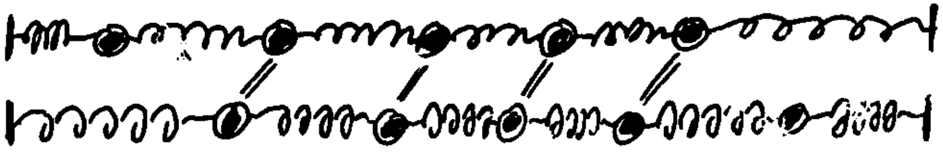
Cooperative processes:



MATCH A//



MATCH B//



e.g. Stereoscopic Matching:

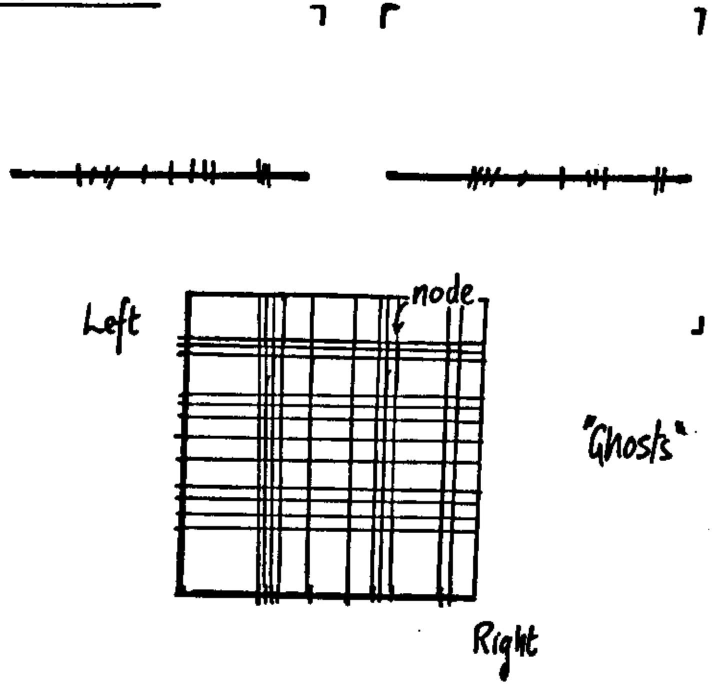
(Julesz, 1971; Marr + Poggio 1976)

III Stereoscopic correspondence problem

A number of solutions have been proposed that are computationally effective:

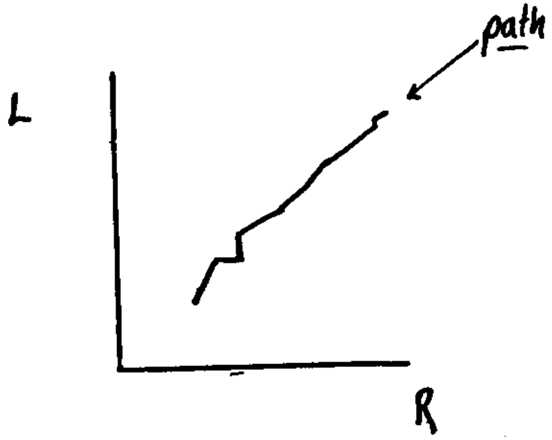
Marr + Poggio; Mayhew, Frisby, Pollard; Baker + Binford; Ohta + Kanade; Kass Terzopoulos + Witkin.

Epipolar constraint:



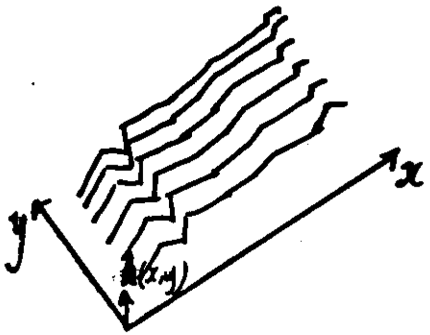
through the nodes,

	CONSTRAINT
* whose gradient is positive	ordering
* gradient rarely vertical or horizontal	uniqueness (disparity gradient)
* visits as many L/R features as possible	"completeness"
* fits paths on neighbouring epipolar line-pairs as closely as possible	figural continuity



Kass - Terzopoulos - Within

– 'scale space matching':



e.g

$$\min_{h(x,y)} \left\{ \iint \left(f_L(x+h(x,y),y) - f_R(x,y)\right)^2 dx\,dy + \lambda \iint (\nabla h)^2\, dx\,dy \right\}$$

(solved using a continuation method with variable image blur - c.f. Marr & Poggio Witkin)

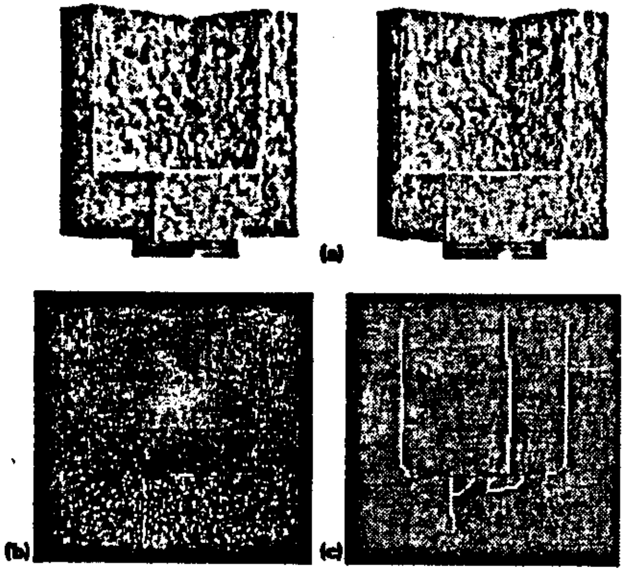


Figure 2.12: Applying a weak plate to sparse, stereoscopic depths. (a) Stereo image-pair. (b) Stereoscopically matched features. Both steps and creases are recovered by the plate (c), shown superimposed on the reconstructed, dense depth-map. Creases are marked as thin white lines, whilst steps are marked as thick, black lines. A few spurious creases have been generated as a result of "ghost" matches in the stereoscopically viewed texture.