A SIMPLE ALGORITHM FOR EDGE DETECTION

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Abstract

This paper describes a very simple algorithm for edge detection from images, which can be divided into 1-D and 2-D versions. The former one can be applied to epipolar line correlation, and the latter can be used for different purposes. Examples of this approach using some images are shown.

1. Introduction

Edge detection is a basic problem with numerous applications in digital image processing and machine perception. Good feature extraction including edge detection is a reliable step for good image matching in digital photogrammetry and computer vision. However, there may not exist an universal interest operator available to any purpose and any matching method, or intended application. For example, although features like points can generally get good matching accuracy /Förstner 1986, Hannah 1974, Lü 1988, Moravec 1979/, they might give rise to many ambiguous matches too. And they are insufficient to the case, in which a lot of line structures are existing, and epipolar constraints can be introduced, as edges perpendicular to the epipolar lines can achieve very high matching accuracy. For this reason different algorithms should be developed for different tasks. A very simple algorithm for edge detection is presented in this paper, the 1-D version of which can be used in epipolar line correlation, while the 2-D version, directly derived from the 1-D version, can be applied to other purposes such as pattern recognition, robot scene analysis, edge-preserving smoothing, and image coding.

2. Discription of the Algorithm

It is well known, that the given camera model can be used to constrain the search for matches of corresponding points to one dimension, i. e. the search for a match of a point in the left image may be limited to an one-dimensional neighborhood in the right image (called epipolar line), which leads to an enormous reduction in computational complexity /Lü et al. 1988/. In view of this fact, selection of features used for epipolar lines correlation should also be taken into account, e. g. selecting features along epipolar lines (in the following called EpL for short) rather than in two-dimensional manner, in order to simplify successive EpL correlation, and save computation time. For this purpose a very simple version is explained as follows.

2.1 Am Operator for EpL Correlation

Actually this operator is derived from the version I of the Ly interest operator /refer to Lü 1988/. The only difference to the Ly operator is, that this is used for 1-D EpL correlation, in which edges perpendicular to the EpL are selected, while the other is used for 2-D cases, in which features like points are selected /Lü 1988/.

Assuming, that EpL images are available, running the operator consists of two parts : first lots of pixels with little information are cut off by a ground operator, then local non-maxima are suppressed to select interest points.

2. 1. 1 The Ground Operator

At each point on each EpL the two gradients to the neighboring pixels are calculated (Fig.1). A point is kept only for the following, if one of the absolutes of these two gradients is larger than a threshold dg. The range of the threshold dg is rather small. It can be determined manually to achieve visually acceptable results, before one finds a way to define the optimal threshold automatically. Empirically the lower bound of dg for natural images lies between 5~10, if a simple filter such as the local average of 3 by 3 pixels is used before resampling along the EpL; it lies between 8~15 without any filtering. For artificial images such as SIMENS Star (Fig.5) the threshold should be taken a little higher.

2. 1. 2 Selection of Interest Points

This part includes two steps :

1) Calculation of interest values (IV) for points selected by the ground operator by formula (1) :

$$IV = \sum_{i=1}^{2} abs\,(dg_i) \tag{1}$$

where dg_i is the difference of gray levels between two adjacent pixels.

2) Suppression of local non-maxima of the interest values. The size of the 1-D window used for comparison is progressively enlarged (Fig.2). The idea of this step is to avoid clustering of relative maxima. The suppression window size of 1x5 or 1x7 pixels is appropriate, as the number of selected interest points does not change significantly by further enlarging the size, as shown in Tab.1 and Tab.2.

Thus selecting features on EpL images EpL by EpL results in a series of edges orthogonal or nearly orthogonal to EpLs instead of feature points (Fig.3 and Fig.4). From this one can imagine, that

selecting features on general images along two orthogonal directions line by line delivers lines rather than feature points.

Fig.1
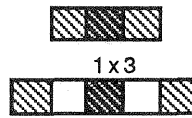
1x3

1x5

Fig.2

Tab.1 numbers of selected points on normal images by the 1-D operator without filtering

threshold	window size	PHOTO (240x240 pixels)							
d g	for suppr.	ISP 1	ISP 2	ISP 7	ISP 8	ISP 13	ISP 14	ISP 19	ISP 20
10	(Ground Op.)	28775	40358	9456	11105	23101	30393	12778	11686
	1x3	10738	14599	4126	4761	8252	10704	4736	4236
	1x5	8937	11561	3584	4129	6563	8329	3478	2995
	1x7	8887	11514	3571	4113	6533	8295	3475	2990
	1x9	8855	11458	3561	4099	6525	8261	3470	2983
	1x11	8829	11422	3547	4083	6484	8211	3448	2975
8	(Ground Op.)	35832	45505	15465	17713	27787	34998	16836	15169
	1x3	12803	15732	6421	7203	9637	11970	6056	5363
	1x5	10314	12142	5498	6182	7495	9144	4393	3785
	1x7	10258	12094	5479	6160	7455	9110	4385	3780
	1x9	10222	12037	5461	6139	7446	9075	4379	3772
	1x11	10190	11996	5437	6111	7402	9022	4355	3762

Tab.2 numbers of selected points on normal images by the 1-D operator with filtering

threshold	window size	PHOTO (240x240 pixels)							
d g	for suppr.	ISP 1	ISP 2	ISP 7	ISP 8	ISP 13	ISP 14	ISP 19	ISP 20
8	(Ground Op.)	20350	25423	2753	3862	20095	26044	13078	12089
	1x3	7369	9078	1168	1579	7039	9122	4601	4182
	1x5	5699	7112	831	1149	4994	6563	2891	2625
	1x7	5675	7088	829	1146	4981	6543	2888	2623
	1x9	5651	7056	829	1141	4973	6513	2883	2619
	1x11	5631	7023	825	1140	4948	6457	2866	2607
5	(Ground Op.)	34792	38931	9749	12446	30078	36302	22016	19322
	1x3	11719	12954	3692	4642	10028	12021	7326	6343
	1x5	8615	9728	2963	3697	6987	8452	4721	4057
	1x7	8583	9700	2952	3682	6966	8431	4715	4053
	1x9	8548	9660	2935	3662	6955	8400	4708	4047
	1x11	8521	9616	2928	3650	6910	8336	4684	4028

2. 2 An Operator for Line Detection

Enspired by the above mentioned 1-D operator, we applied formula (1) in horizontal and vertical directions respectively, which resulted in a quite good line extraction (Fig.5 and Fig.6). In other words, except that calculation is performed in two directions successively, all other operations are the same as in the 1-D case. Of course the suppression avoiding clusters of relative maxima should also be carried out in the two directions individually, and mutual influence between the two directions should be taken into consideration. From Tab.1 and Tab.2 it can also be seen, that for lines detection the suppression window size of 1x5 or 1x7 pixels in each direction is appropriate.

Although this operator is derived from version I of the Ly operator and used in 2-D cases, too, algorithms and results are completely different from each other. The former runs in two orthogonal directions respectively in 1-D manner, while the latter runs in 2-D manner. The results of the former are lines, while those of the latter are features, like points /Lü 1988/. Additionally, it is necessary to run a simple filtering like the local average before applying this operator (either 1-D or 2-D) to get clearer lines without noise.

3. Experimental Results

Fig.3 ~ Fig.6 illustrate some results acquired by this operator with the data distributed by WG III/4 of ISPRS and other images, where Fig.3 and Fig.4 are examples for 1-D cases, Fig.5 and Fig.6 for 2-D cases. The originals in Fig.3 are normal images, thus the selected edges can be directly used in EpL correlation. The originals in Fig.4 have been changed to normal images first /Lü et al. 1988/, then calculated using the 1-D operator. The left original in Fig.5 is SIMENS Star, the right is the portrait of a little girl. Fig.6 shows the results of using three simple filters before running the operator, in which one can find the function of filtering. Fig.7 and Fig.8 indicate some grayvalue curves of the corresponding EpLs on the left and right images, and interest points selected by the 1-D operator. From these figures it is apparent, that searching corresponding points along the two EpLs in such a manner can be far easier than searching in 2-D images. Furthermore, it is also possible that two adjacent interest points are simultaneously treated in one correlation window, in order to correct geometric deformation by resampling before correlation /Zhang 1988/.

The applied suppression sizes for all listed images in this paper are 1x5 pixels. Tab.3 shows the CPU time which the two methods depicted above consumed on a SUN 3/280. Both methods are programmed in Language C.

From Fig.6 it can be seen, that filtering before running the operator is necessary, and that using a more complicated filter such as a *weighted local average* instead of a *local average* can improve the result.

Tab.3   CPU time consumed by the operator on a SUN 3/280

case	1 - D		2 directions in 1 - D				
photo size	ISP 5 240x240	ISP 19 240x240	SIMENS 512x512	Girl 512x512	ISP 5 240x240	ISP 11 240x240	ISP 23 240x240
dg	8	6	15	5	8	8	5
CPU time (seconds)	1.1	1.4	13.84	12.71	2.96	2.86	2.73

4. Conclusions

The boundless universe changes boundless. Of course, images taken from the boundless universe are full of changing pattern. Attempting to develop a certain interest operator for feature extraction suitable to the boundless universe is impossible. Therefore, different methods and ways for different cases should be developed. The simple operator presented in this short paper is especially designed for 1-D epipolar line correlation or for 2-D line detection. Experimental results show, that the operator is both simple and effective.

This paper is a continuity of the preceding research /Lü 1988/. Some problems to be further investigated, such as automatically selecting the optimal threshold dg, are still unsolved. Furthermore, additional study should be directed to choose a proper filter.

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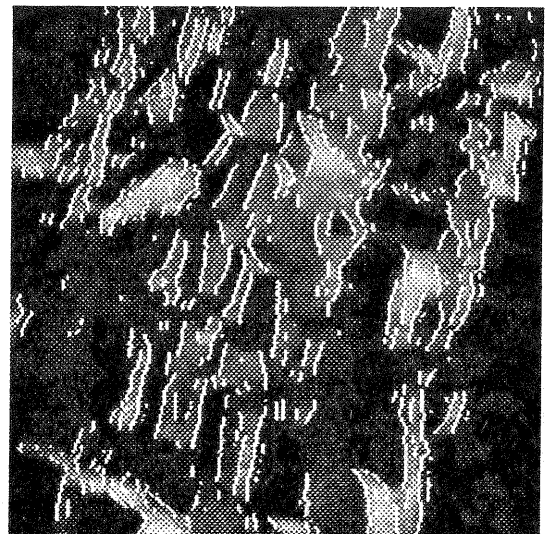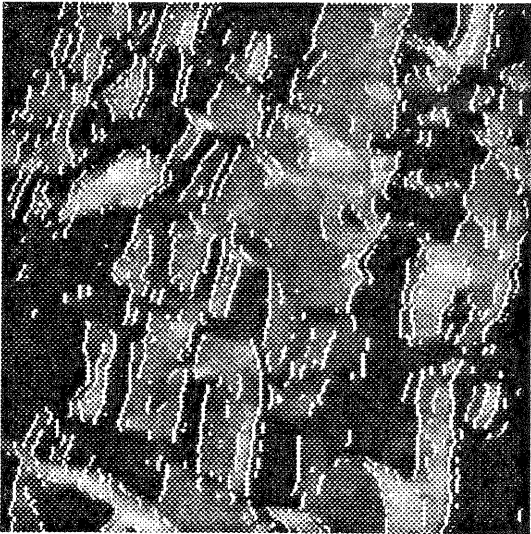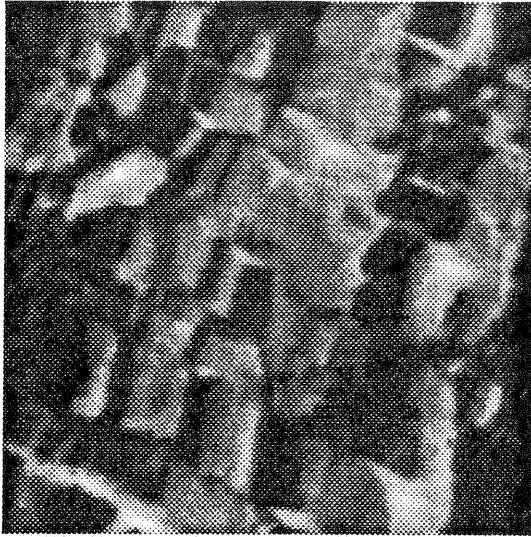
Fig.3   upper :   ISP photo 19, 20 - wall in quarry

below :   edges selected by 1-D operator with dg=6, with 3x3 local average filtering

Fig.4   (see next page)

upper :   ISP photo 5, 6 - plexiglas roof of Olympia tent in Munich

middle :   normal images acquired by resampling the original images

below :   edges selected by 1-D operator with dg=6, with 3x3 local average filtering

Fig.5   (see after)

upper :   SIMENS Star and Portrait of a little girl

middle :   lines selected by 2-D operator with dg=15 and dg=6, without filtering

below :   lines selected by 2-D operator with dg=15 and dg=5, with 3x3 local

average filtering

Fig.6   (see after)

with different filtering as shown in matrices (left: with dg=15 ; right : with dg=5)
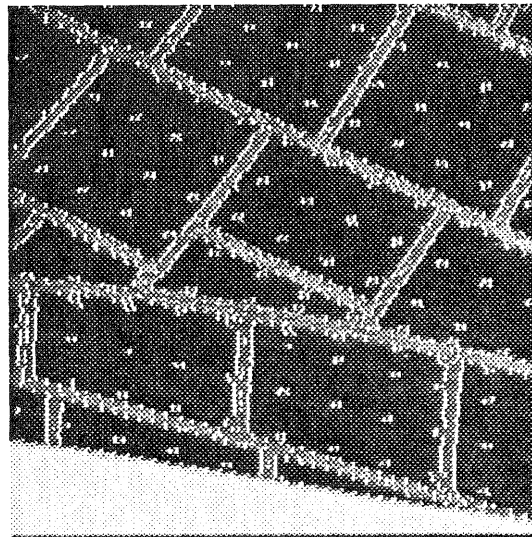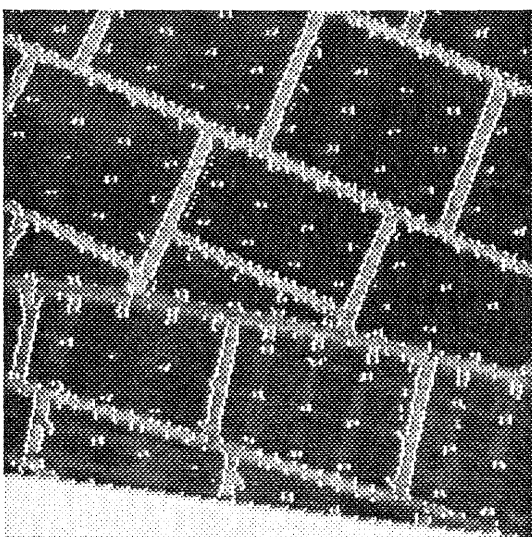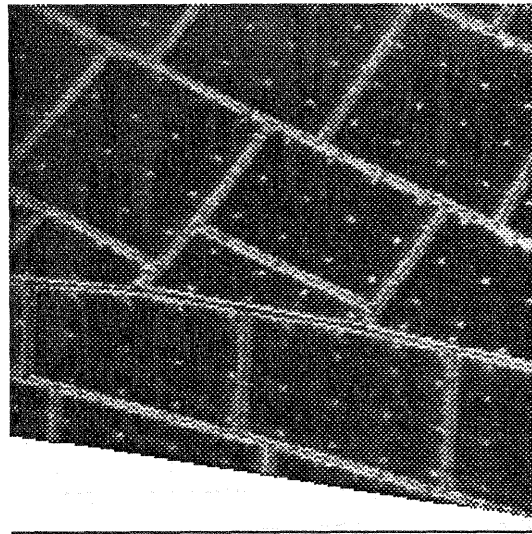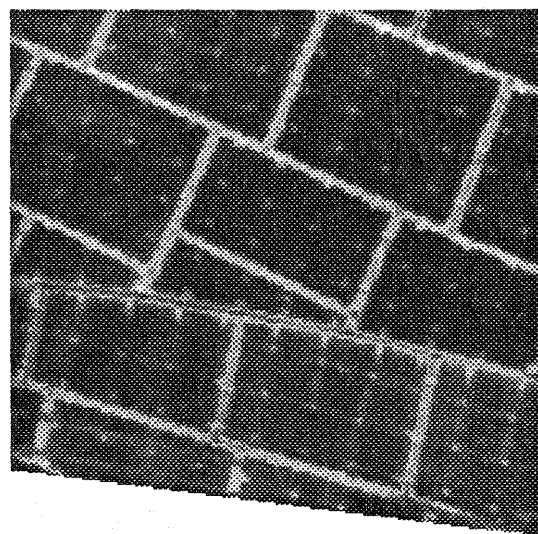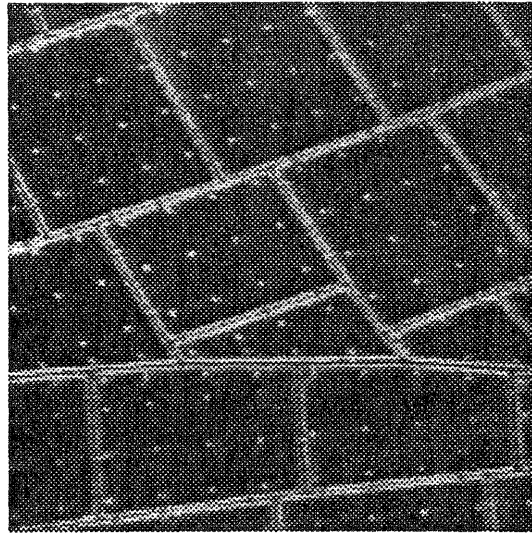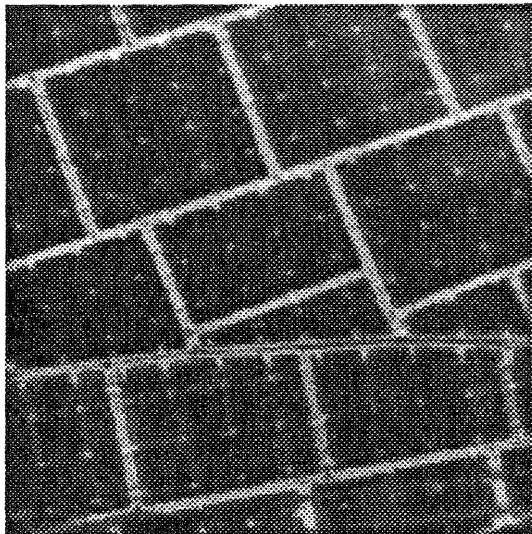
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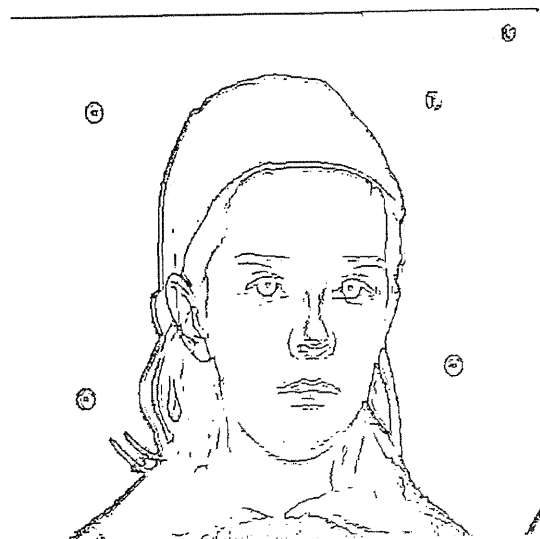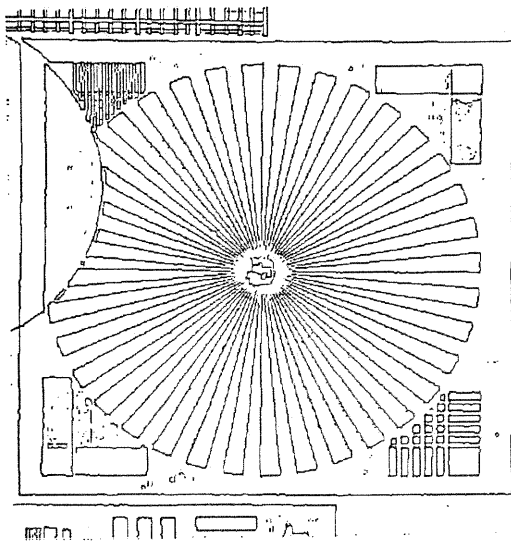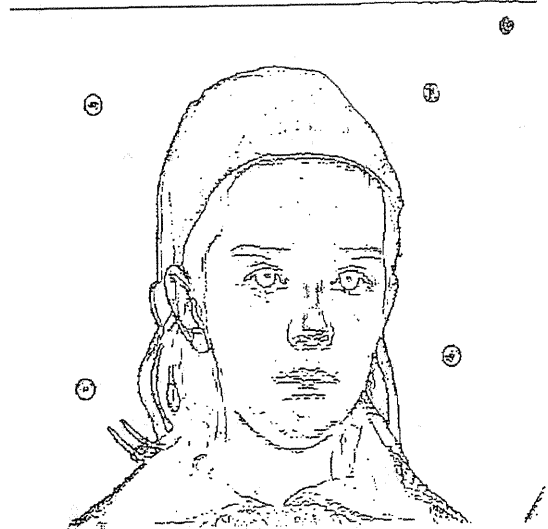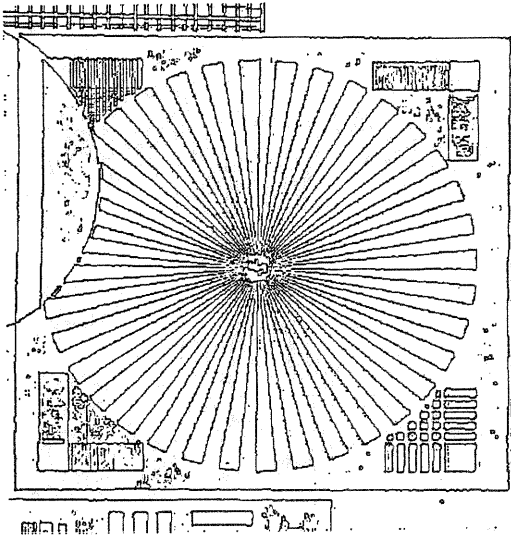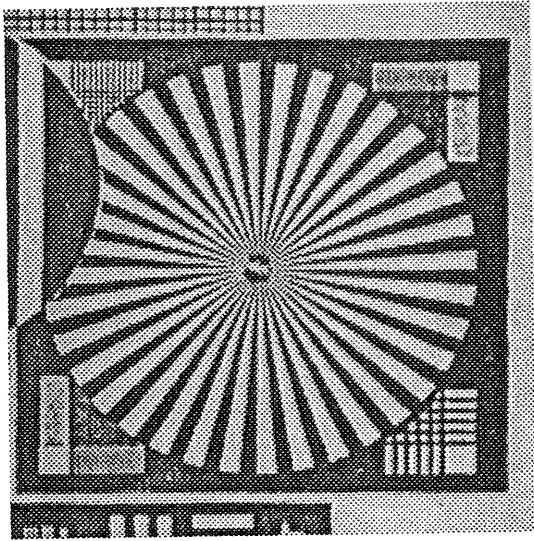
Fig.5
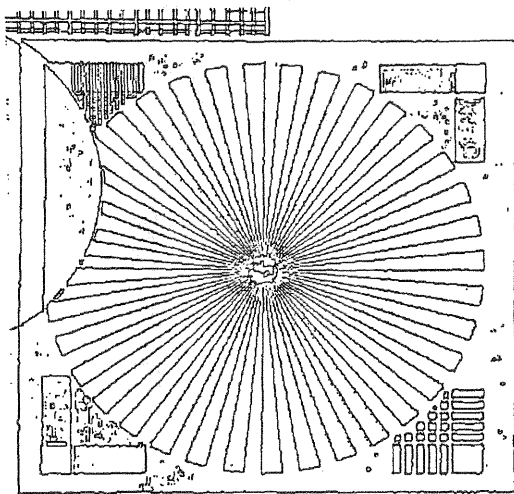
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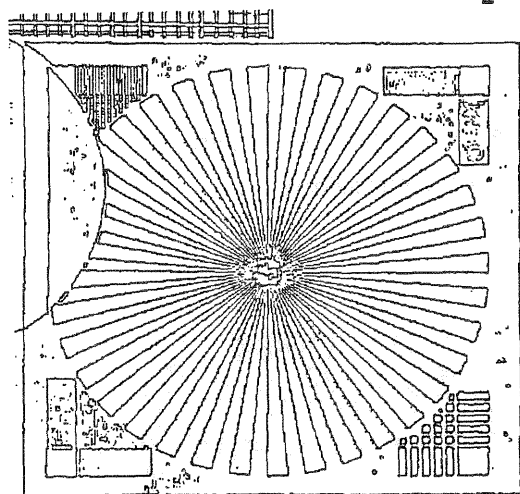
$$\begin{bmatrix} 0.08 & 0.08 & 0.08 \\ 0.08 & 0.36 & 0.08 \\ 0.08 & 0.08 & 0.08 \end{bmatrix}$$
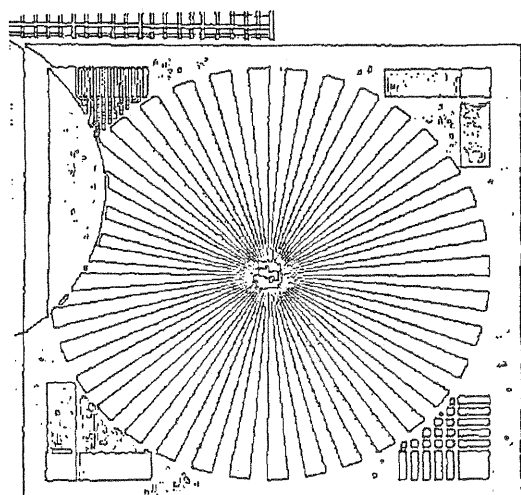
$$\begin{bmatrix} 0.06 & 0.06 & 0.06 \\ 0.06 & 0.52 & 0.06 \\ 0.06 & 0.06 & 0.06 \end{bmatrix}$$
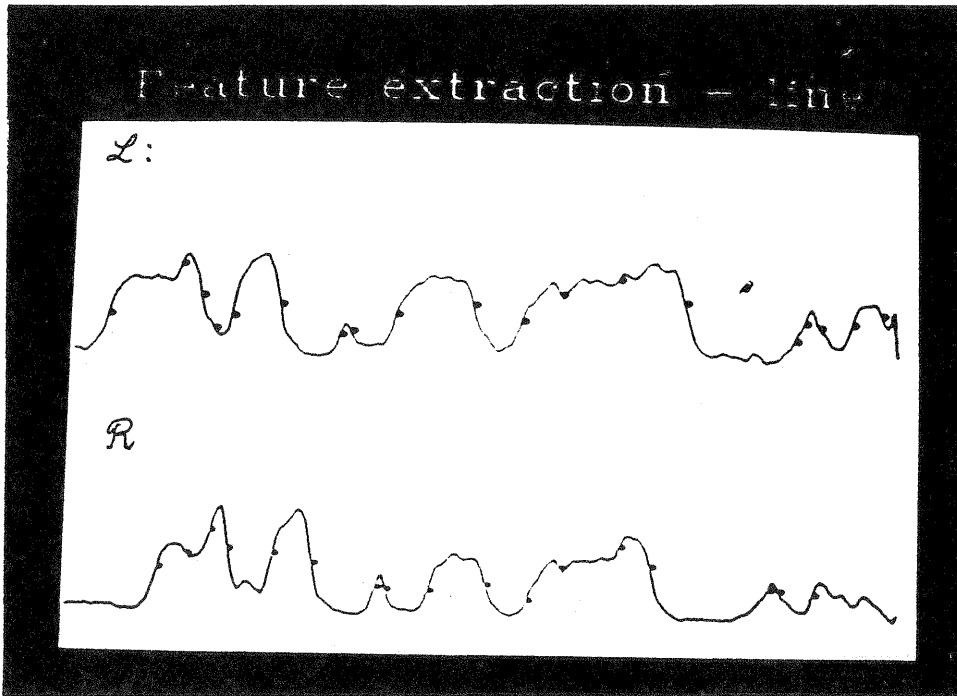
Fig.6

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Fig.7   Graylevel curves along a corresponding epipolar lines on left (upper)
         and right (below) of ISP Model 10 with interest points selected by
         the 1-D operator
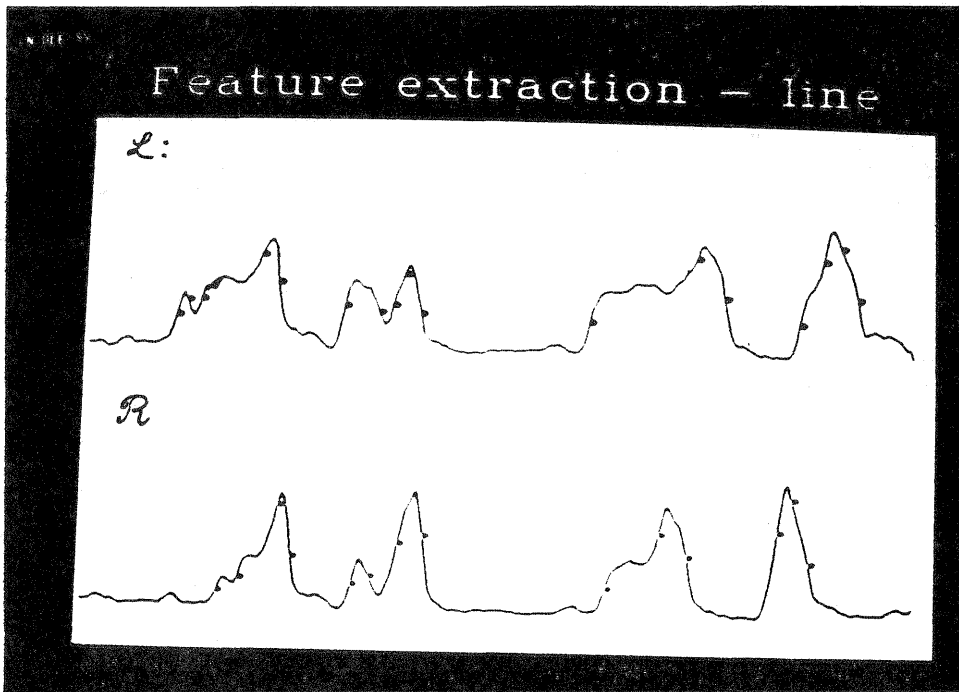

Fig.8   Graylevel curves along a corresponding epipolar lines on left (upper)
         and right (below) of ISP Model 10 with interest points selected by
         the 1-D operator