Classification of Digital Angiograms Using Multipulse Excited Linear Prediction Model

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Abstract- A new automated method is presented for the classification of digital angiograms. The technique is based on approximating the given image by a two-dimensional linear prediction (LP) model along with a multipulse excitation sequence. The input to the synthesis filter is a stream of pulses, characterised by their location and amplitudes. The pulse parameters are estimated by minimizing a least squares problem. This results in a pulse pattern which traverses the contour of the dye in the angiogram. Excitation of the model by this multipulse sequence reconstructs the image containing only the dye profile. The correlation between multiple frames can be exploited in tracking the dye movements in time.

I. Introduction

Digital angiography is widely used in the diagnosis and treatment of coronary arterial diseases. Identification of the path traversed by the dye is an important image understanding problem. Gray scale thresholding, knowledge based systems, neural networks [1] and active contours [2] are some of the image processing techniques proposed in this direction. Each of these techniques have a few inherent limitations such as creation of a knowledge base, network training and operator intervention In this paper we propose an automated technique for classification of angiograms into dye (arteries) and background, by using a multipulse excited LP model.

II. Theory

The digital angiographic image s(m,p) is represented as the output of a two-dimensional, quarter plane linear prediction model of order (n,q) excited by a white noise sequence e(m,p), i.e.

$$s(m,p) = e(m,p) + \sum_{k=0}^{n} \sum_{r=0}^{q} a(k,r)\, s(m-k,p-r) \qquad (1)$$

where a(0,0) = 1. The parameters a(k,r) are estimated by the covariance LP method.

The multipulse excitation approximates the residual error signal e(m,p) in (1) by a set of t1*t2 pulses of amplitudes β_{kr} and locations (n_k,n_r) as

$$u(m,p) = \sum_{k=0}^{t1-1} \sum_{r=0}^{t2-1} \beta_{kr}\, \delta(m-n_k,p-n_r) \qquad (2)$$

The output of the all pole synthesis filter can then be written as,

$$\hat{s}(m,p) = \sum_{k=0}^{t1-1} \sum_{r=0}^{t2-1} \beta_{kr}\, h(m-n_k,p-n_r) \qquad (3)$$

where h(m,p) is the impulse response of the LP model. Simultaneous estimation of pulse locations and amplitudes is a very complicated and computationally expensive problem. We overcome this problem by separately estimating the location and amplitude of one pulse at a time [3].

Minimization of the sum of squared error between s(m,p) and $\hat{s}(m,p)$ with respect to the pulse amplitudes β_{kr}, results in the normal equation,

$$a\beta = c \qquad (4)$$

where a is the autocorrelation matrix of the model impulse response, c is the cross correlation vector of s and h while β is a vector made up of unknowns β_{kr}.

The resulting error in the estimation of the pulse amplitude vector is

$$E = \sum_{m=0}^{N-1} \sum_{p=0}^{N-1} s^2(m,p) - \beta^T c \qquad (5)$$

Equation (5) is first used to locate the pulse position by searching for the minima in E for various lags of cross correlation function c and (4) is then used to estimate the pulse amplitude. This algorithm computes one pulse at a time, positioning them at those locations where the cross correlation between the model impulse response and image is maximum.

When the auto and cross correlation functions in the least squares normal equation are mapped into raster sequential form, the two dimensional estimation problem reduces to a single dimensional problem and the optimal amplitude computation algorithm in [3] can be used directly.
Since the maxima in cross correlation are located at lags corresponding to dye position, the pulses are positioned along the contour of the dye. Also excitation of the model with this multipulse sequence results in an image containing only the dye in a clear background.

The proposed method of angiogram classification can be applied to the whole image or on a block by block basis.

Multiframe Analysis:

Both one shot and block by block methods of classifications can be extended for tracking the dye movement in a sequence of angiographic images. The pulses from the previous frame are used in the estimation of pulses in the next frame, and hence the movement of the dye in time can be tracked.

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III. Results and Discussion

Figs. 1a and 2a show the original images of size 128x128 quantized at 8 bits/pixel. A block size of 32x32 and all pole models of order 2 were used in the analysis. Figs. 1b and 2b show the pulse positions as black dots, superimposed on the originals for comparison. Table I gives the number of pulses which are placed outside the dye contour in both the images. As can be seen, barring a few pulses, all are placed along the dye. Figs. 1d and 2d give the number of pulses used in each block for the two pictures. Figs. 1c and 2c show the respective model output responses. These too give a good reconstruction of the dye for both the pictures. While the first image is a simple one the second one is more complicated, containing a large amount of vasculature. The results indicate that the algorithm has performed equally well in both the cases.

The number of pulses required to approximate an image depends upon the density of dye. However the method can be made independent of the number of pulses by thresholding the error E in (5) which would stop the algorithm once a prespecified error power is reached.

IV. Conclusion

A fully automated method based on multi-pulse excited LP model is presented for tracking dye movement in angiograms, with highly satisfactory performance.

Acknowledgment

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References

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Table I. Summary of the results.

Image No.	No. of pulses out of place	Total no. of pulses
1	3	**131**
2	3	**132**

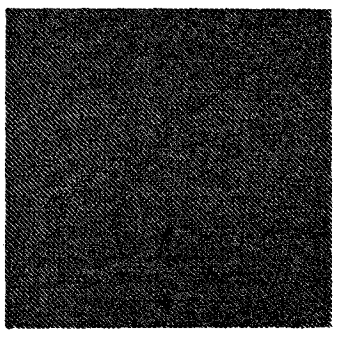

Fig. 1a

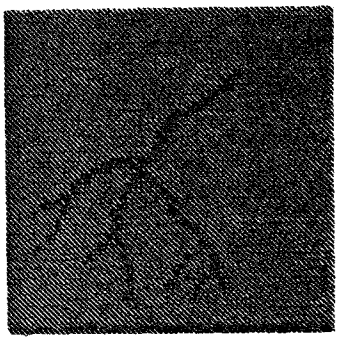

Fig. 1b

Fig. 1c

0	0	8	0
0	25	18	0
18	27	10	0
1	8	16	0

Fig. 1d

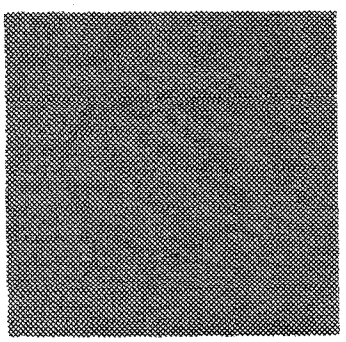

Fig. 2a

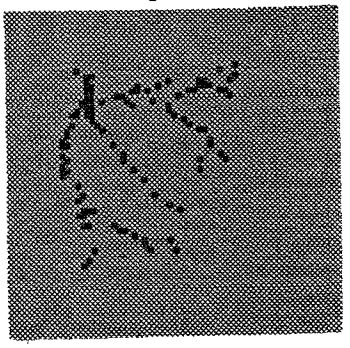

Fig. 2b

Fig. 2c

1	7	13	0
17	38	19	0
13	14	4	0
1	3	2	0

Fig. 2d

Fig. 1a,2a: Original images; 1b,2b: Pulse positions 1c,2c: Model outputs; 1d,2d: Number of pulses/block