APPLICATIONS OF SIGNAL PROCESSING TECHNIQUES IN MAN-COMPUTER COMMUNICATIONS

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ABSTRACT

This paper is confined, in its first part, to the discussion of five cases as specific applications of signal processing in man-computer communications taken in its broadest sense. These cases are: 1) representation of planar shapes for comparison, localisation and identification; 2) digital processing of electrocardiograms for arrhythmia monitoring in intensive care units; 3) deconvolution of video-pulse radar images; 4) translations of images into tactile form for the blind; 5) automated schistosome egg counting in microscopic preparation.

In the second part, a synthetic view of "who is doing what" in Europe in applying signal processing techniques in man-computer communications is given. This survey is a result of a questionnaire sent to more than 120 European laboratories involved in signal processing and its applications.

RÉSUMÉ

Dans sa première partie, cet article se limite à la discussion de cinq cas comme applications spédifiques du traitement des signaux aux communications homme-machine, au sens le plus large du terme. Ces cas sont: 1) représentation des formes planes pour comparaison, localisation et identification; 2) traitement numérique des électrocardiogrammes pour la surveillance des arythmies en soins intensifs; 3) déconvolution d'images de radar à impulsion-vidéo; 4) traduction des images en forme tactile pour les aveugles; 5) comptage automatique d'oeufs de schistosomes dans des préparations microscopiques.

Dans la deuxième partie, on présente une vue synthétique de "qui fait quoi" en Europe sur les applications du traitement des signaux dans les communications homme-machine. Cette enquête résulte d'un questionnaire envoyé à plus de 120 laboratories européens s'occupant du traitement des signaux et de ses applications.

1. INTRODUCTION

Because of the difficulties involved in an attempt to cover with a paper like this one the applications of signal processing techniques in man-computer communications, it is preferable to discuss a few of them as case studies. The cases presented below consider man-computer communications in its broadest sens. They are selected in robotics, biomedical signal processing, image processing and pattern recognition. The unique selection criterion is the personal involvement of the author in these specific problems.

In the second part of the paper an overview of the European scene is given. It is definitely not exhaustive. Some current projects of 30 European Laboratories are briefly discussed. References are given to facilitate possible contacts.

2. CASE 1 : LOCALISATION, IDENTIFICATION AND COMPARISON OF PLANAR SHAPES

In this case, the problem is the following: given one or several planar shapes in a field of view, how to locate (position and orientation), to identify and to compare them ? These shapes can be describes either by their outlines (contours) or by their silhouette. Contours will be used in the following.

Let us first consider a single shape in the field of view. Its estimated location can conveniently be obtained with two geometrically independant information : the position of a central point solely determined by the shape and a rotation angle around this point with respect to a reference. An obvious choice for this point is the center of mass whose coordinates m_x and m_y are the mean values of x and y coordinates of all the contour points. When computed on a cartesian digitization grid, serious errors may affect m_x and m_y due to uneven contributions of digital contour points to the real contour. That is why, it is necessary to weight the contour points according to their real contribution before estimating m_x and m_y [1]. Such a weighting reduces the maximum error to one sampling interval. The next step consists in sweeping radially the contour of the shape with constant angular steps from its center of mass. A vector is formed whose components are the distances, on these radial lines, from the center of mass, to the contour. This vector, called the signature of the shape, is periodical with a period 2π. If ever a radial line intercepts the contour at several locations, the corresponding component of the signature can be obtained by combining these segments in a variety of ways. A sum, a weighted sum, the longest, the shortest, the mean length are some examples of this combination.

The orientation of the shape is estimated by comparing cyclically its signature with the reference signature stored during the learning phase. This is equivalent to rotating the observed signature with respect to the reference one untill a maximum match is obtained. Several functional relationships can be used for this comparison such as cross-correlation, binary (sign) correlation, absolute difference or its simplified versions. Another possibility is to extract, from the shape, the direction of a particular symmetry; for example that for which the odd component of the signature is minimum. If the corresponding direction is obtained when the shape is in a reference position, their angle gives the orientation. The ambiguity of π can be solved easily as well as the one on head or tail. This technique is summarized in Fig. 1.

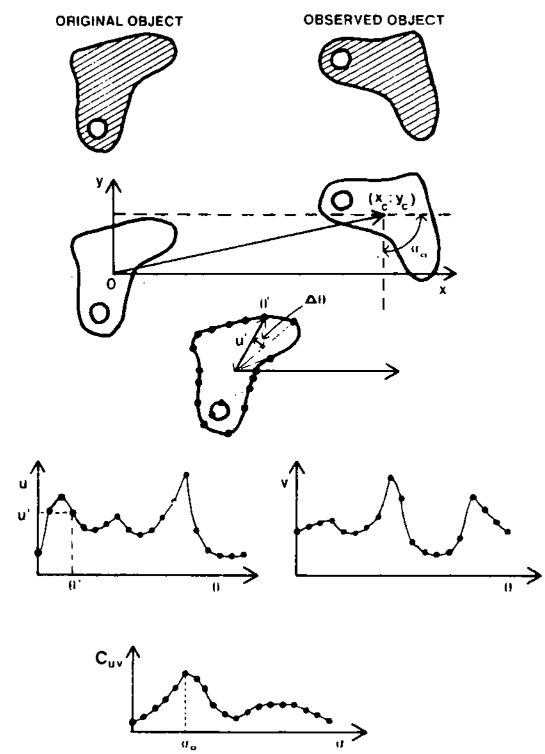

Fig. 1 Illustrating the polar coding

Let us now consider the case where several different shapes are present in the field of view. Clearly, the above described method cannot be used if the image is not previously segmented. In such a case, the implicit segmentation offered by contour following is a precious advantage.

The recognition of a shape must be preceeded by feature extraction. Commonly used features are contour length, area and curvature, because of their invariance under translation and rotation. They all however rely on small increments (differences) on x and y. The well known high-pass nature of differentiation must be compensated before extracting features. An iterative curvilinear filtering is developed to smooth the contour [2]. Its drastic improvement is shown in Fig. 2. The feature space is three-dimensional for contour length L, area S and standard deviation σ of the

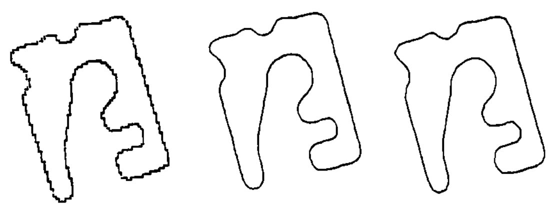

Fig. 2 Iterative curvilinear filtering

curvature function. In the learning phase, each shape is identified with a unique cluster (ideally a point) in the feature space. An observed shape is classified according to

$$C_i = \alpha \frac{|S_j - S_i|}{S_i} + \beta \frac{|L_j - L_i|}{L_i} + \gamma \frac{|\tau_j - \tau_i|}{\tau_i}$$

computed for all j from 1 to N where N is the number of shapes. If C_i is less than any C_k and less than C_{thresh} the shape is recognized as ith shape and rejected otherwise. The parameters α, β and γ are used for weighting each feature according to their dispersions.

When a shape is recognized, its position is given by the coordinates of its center of mass as before. Its orientation is given by comparing the angles of two orientation vectors having the same origin and extremity on the shape. The location of these two particular points can be found by cross-correlating the curvature functions.

This technique can even be used when shapes overlapp, provided that the contour on the overlapping region can be extracted. For further details on this case the reader may refer to [1] and [3]. Although it was developed in the context of robotics, it can also be used in biomedical engineering [4].

3. CASE 2 : ARRHYTMIAS MONITORING IN ELECTROCARDIOGRAMS

The electrocardiographic signal (ECG), observed at some determined points of the human body, is a wave packet composed of five basic waves denoted by P,Q,R,S and T. This packet structure repeats itself quasi-periodically in time. In cardiological intensive care units, trained personnel observe continuously this signal to detect abnormalities in frequency, duration, shape, orientation and amplitude of each wave. The problem, in this case, is to develop signal processing and pattern recognition techniques to automatize, as much as possible, the monitoring. It is necessary, however, before applying any of these techniques, to preprocess the signal.

Indeed, the ECG signal, as recorded by the commonly used sensors, is corrupted mainly by two types of additive noise. These are artefacts and base line variations, resulting respectively from local myographical activities and body motion. Artefacts are around and beyond 50 Hz whereas base line variations are predominently concentrated around the DC components. The filtering problem is to find a so-called band-pass filter with a lower cut-off frequency around f_{c1} = 1.5 Hz to attenuate base line variations and a higher cut-off frequency around f_{c2} = 50 Hz to attenuate artefacts and the harmonics of the power line (fig. 3).

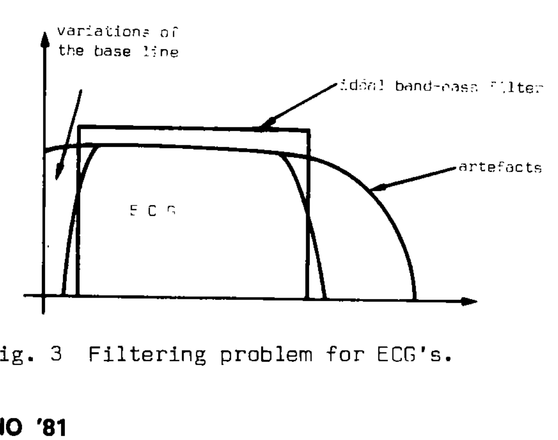

Fig. 3 Filtering problem for ECG's.

Since the exact frequency combination of the original ECG, in terms of noise and useful signal is unknown, the constraints on the attenuation characteristics of the filter are of secondary importance. A simple way of designing a digital band-pass filter is to use two low-pass filters with cut-off frequencies f_{c1} and f_{c2}. The filtered signal is the difference of the outputs of these two filters. The simplest digital low-pass filter is a moving average filter which is characterized with a rectangular impulse response. It can be implemented recursively with only two additions, independently of its length. If two of such filters are cascaded, or, equivalently, if one is used in two passes, the resulting filter has a triangular impulse response. The ripples in the stop-band of this filter are more tolerable than those of the moving average filter. Furthermore, attenuations are very important around frequencies multiple of 1/K where K - the unique parameter - is the length of the moving average. This property is very valuable in eliminating power line's harmonics. The frequency response resulting from the parallel use of two triangular low-pass filters will cut-off frequencies 1.25 Hz and 50 Hz is shown on Fig. 4. The result of this filtering is depicted in Fig. 5.

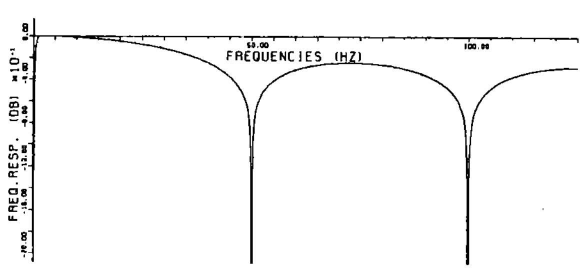

Fig. 4 Frequency response of the band-pass filter

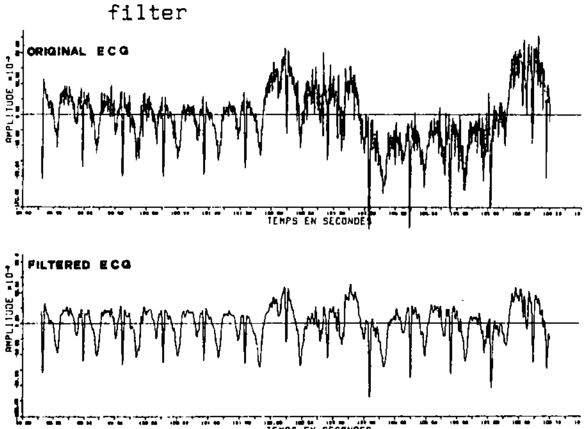

Fig. 5 ECGs before and after filtering

In order to measure the beat frequency and to extract features from the ECG waves, it is necessary to define and detect a particular point in each beat period. The choice, commonly made, is the top of the R wave. A simple and elegant procedure to estimate its abcessa is given by Vary [5]. A more precise procedure would be to observe a peak configuration through a window sliding on the digitized ECG. That is an odd numbered sample set showing a monotonic increase in the first half and a monotinic decrease in the second half with respect to the central sample. Since the amplitude of R waves is generally much higher than that of the other waves, a test on the energy level of its derivative done when a peak is seen through the window gives the abcissa of the highest amplitude of the R wave. Clearly, the monitoring of R-R distances gives the evolution of the beat frequency.

Among several possibilities, two feature extraction methods are currently under investigation. In the first one, each wave of a beat period is approximated by a gaussian curve, in the minimum mean-square error sens. Each gaussian curve is entirely specified with three parameters : the amplitude in the center, the position of the center and the standard deviation. A whole period of about 200 samples is thus reduced to 15 parameters, used as features. Exception made for some pathological cases, the quality of the approximation is generally very good as shown in Fig. 6. The data compression obtained by this technique makes it very attractive for ECG archiving. Results are not yet available to show how successful is this technique in the in the detection and classification of different arrhytmias.

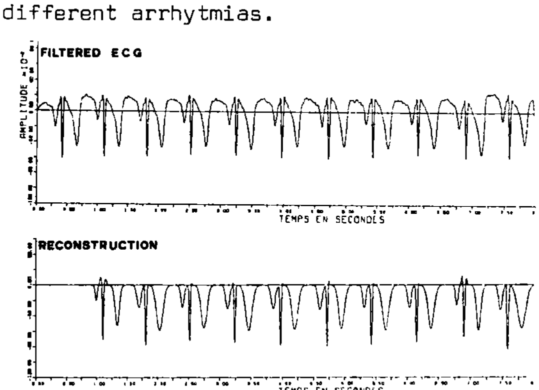

Fig. 6 Approximating filtered ECGs with Gaussian curves.

The second technique, also still under investigation, consists in modelling each beat period with an ARMA (Autoregressive-moving average) model. This can be viewed as approximating the z-transform of a beat period by a quotient of two polynomials of finite degree in z. The coefficients of these polynomials are then used as features. A few classifications made with the particular case of a denominator polynomial are quite promising. This case corresponds to linear prediction, i.e., to the estimation of an ECG sample as a linear combination of a finite number of past samples preceeding it. For more detail, the reader may refer to [6] and [7].

4. CASE 3 : DECONVOLUTION OF VIDEO-PULSE RADAR IMAGES

A video-pulse radar utilizes pulses of very wide bandwidth to penetrate media with high absorption losses such as ground or water. Its purpose is to detect burried objects, holes near mine shafts and so on, which present dielectric discontinuities and thus cause a part of the incident electromagnetic energy to be reflected back to the receiver. Hence the received signal would ideally consist of pulses showing the presence and the range of such discontinuities. In reality however, these returns have the appearance of damped oscillations wich often completely obscure the desired information. Assuming that the media is a linear system, the problem, in this case, is to recover, or more precisely, to estimate the pulses from the received signal. When the returns are recorded as the radar and its antenna move along a straight line, they can be displayed as grey levels in an image showing the underground structure. The problem is then one dimensional deconvolution of a two dimensional information, formulated as follows : given the impulse response g(k) of the system, find a filter whose impulse response is h(k) such that $x(k) = g(k) * h(k)$ be as close as possible to a desired function d(k). Two solutions of this problem will be discussed here.

In the first one, it is necessary to extract the impulse response g(k). This can be done by moving the radar and its antenna, for example over a swimming-pool filled with water. The corresponding image (Fig. 7) represents the water-concrete boundary return. One scan line of this image, as depicted in Fig. 8, shows the ringing impulse response. The impulse

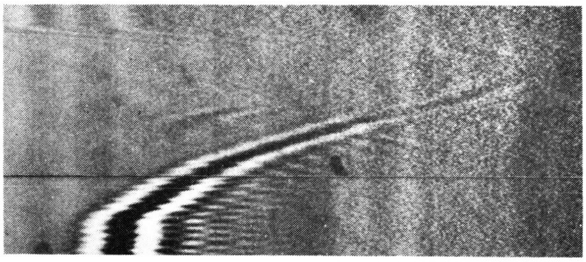

Fig. 7 Video-pulse radar image of a swimming-pool.

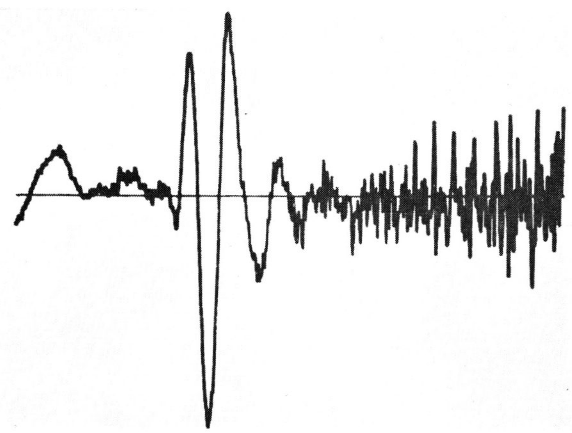

Fig. 8 A scan line of the image shown in Fig.7

response g(k) can easily be extracted from these data. If the least square criterion is used to measure the error between the desired function d(k) and the convolution $x(k) = g(k) * h(k)$, the impulse response of the deconvolution filter is simply given by the matrix-vector product $H = A^{-1}.R$ where H is deconvolution filter vector whose components are h(k), A is symmetric definite positive matrix whose entries are the correlation coefficients of g(k) and R is the autocorrelation vector of g(k). See [8] for more details. The ideal choice for the desired finction d(k) is of course the unit sample (discrete Delta function). It has, however, a limited practical interest because of the finite length data and the noise dominating the high frequency part of the spectrum. Better results can be obtained if d(k) is a Gaussian function with a standard deviation σ. Fig. 9 shows the result obtained by deconvolving the data of Fig. 8 with the above described technique.

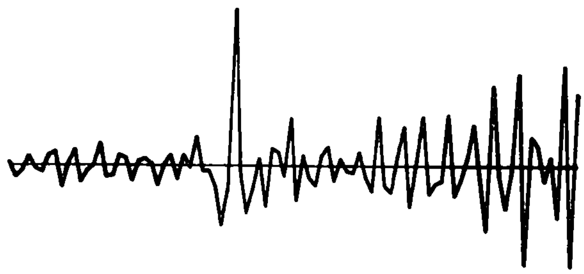

Fig. 9 Algebraicly deconvolved scan line

Even if we assume that the shape of g(k) is not modified from one environment to another but only its ringing frequency is changed, an adjustment is needed to solve $H = A^{-1} R$.

In the second approach, we first observe that the impulse response g(k) (see Fig. 8) can be represented with an analytical model of the form

$$g(k) = k^2 \exp(-\alpha k) \sin(2\pi f_0 k)$$

where f_0 is the ringing frequency, α is a parameter such that the envelope of g(k) can be made as small as desired after 5 lobes. A plot of this model is shown on Fig. 10 along with the data extracted from Fig. 8. The main advantage of such a model is that its Fourier transform can also be expressed analytically.

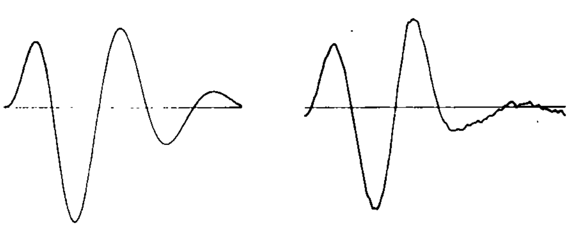

Fig. 10 Model of the impulse response (left) and the real data (right)

In the Fourier domain, the convolution x(k) = g(k) * h(k) = d(k) becomes a simple product D(f) = G(f) . H(f) where D(f), G(f) and H(f) are the Fourier transforms of d(k), g(k) and h(k) respectively. The frequency response of the deconvolution filter is then H(f) = D(f)/G(f), the so-called inverse filter. In order to attenuate the noise in the high frequency part of the spectrum, the desired function d(k) is again a Gaussian function. The deconvolution filter can be implemented either in the frequency domain by FFT or in the image domain by a recursive structure. In the latter case, it is even possible to consider line to line, or environment to environment adaptation of the filter coefficients. The result obtained by this technique on the scan line of Fig. 8 is shown in Fig. 11. It is comparable to that of Fig. 9. Extensive results of these two techniques applied to various video-pulse radar images can be found in [8].

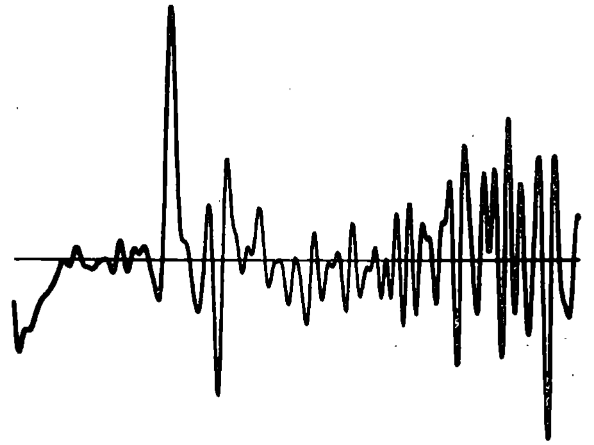

Fig. 11 Scan line after inverse filtering with the modelized filter.

5. CASE 4 : IMAGE PROCESSING FOR VISUAL PROTHESIS

Tactile perception of simple patterns is a well known way of information acquisition for sight handicapped. The Braille alphabet and relief maps of cities are some typical examples. Experiments with the tactile presentation of more complexe scenes have been reported some years ago [9], apparently with a rather mitigated success. One of the reasons for that is probably the lack of real image processing. The picture was sent on a tactile transducer after a single thresholding, yielding a too complex binary scene.

The case studied here, currently under investigation in our laboratory, is the search of image processing techniques available or usable in this context. The underlying philosophy is that successful tactile interpretation of binary images could greatly be enhanced if pictorial information is processed for removing spurious details and stylizing the contour patterns. In order to obtain closed contours of informative areas, segmentation seems to be suitable. The whole process is divided into two stages. First, the original picture is transformed into a binary image containing the most relevant contours. Second, these contours are used to extract statistical parameters characterizing the areas to be segmented. The segmentation is then performed on the original picture. Artificial textures might be introduced to help in the tactile interpretation.

The original picture of Fig. 12 is digitized with a raster of 256x256 picture elements and quantized to 256 grey levels. This image

Fig. 12 An original grey level image

is first preprocessed, using a noise reducing operator and a high-pass filter. Median smoothing is applied for noise elimination. Its basic properties are the preservation of edges and the removal of noise areas, small compared to the size of the operator window. This size has been choosen as 5x5 points. If it is larger, too much details are lost, and deformations in the picture are induced. The edge extraction is performed by the 2x2 high-pass Mero-Vassy operator. Larger filters correspond - implicitely or explicitely- to the convolution of a 2x2 high-pass operator by a wider low-pass one. Since median smoothing still present a low-pass effect, a 2x2 high pass filter is sufficient.

After the preprocessing operation, the picture can be viewed as a surface in a three dimensional space. The contours are the mountains. The ridges of these mountains are extracted by the so-called ridge riding algorithm [10] which directly leads to one pixel wide segments. This algorithm scans the picture until reaching a point whose grey-level is higher than a Contour Start Threshold (CST). A local maxima is searched in the neighbourhood of this point, giving then the starting point of a ridge. Successive connected points of this ridge are extracted, as local grey level extremas, as long as they exceed a Contour Continuation Threshold (CCT). Since the contour may go both ways from the starting point, the second possible part of the same contour is also searched and traced. The total length of the contour is examined, in order to eliminate too short segments. The CST is relatively high, so that the background noise is ignored. The CCT is quite low, which allows to track contours of very uneven contrast without breaks. These two thresholds are computed from the grey-level histogram of the preprocessed picture by the entropic thresholding method [11]. The result obtained with this technique, after omitting contours shorter than 30 points, is shown in Fig. 13. Clearly, main outlines are successfully extracted. It should also be noted that this

Fig. 13 Result of contour extraction

picture is certainly too complex for tactile interpretation. But the performances of differents processing algorithms are best determined in such a scene. When mapping Fig. 13 on Fig. 12, one observes that the contours are shifted with respect to their original location due to successive filtering operations. Histograms computed on the original image along these contours provide a simple mean for the segmentation. Thus the final result is uniform regions surrounded by closed contours. Displaying each of these region with a different tactile texture improves the interpretation of contours. The complete processing can be displayed step by step allowing the handicapped to interact with the system. During the interaction, it is possible to go back and forth in the process to facilitate the extraction of the semantic invariants (the contours of the scene.

6. CASE 5 : AUTOMATED SCHISTOSOME EGG COUNTING

Schistosomiasis is a parasitic infection prevalent in many developping countries with an estimated 180-200 million people affected worldwide. Although direct mortality is low, the high prevalence of infection and the multiplicity of chronic pathological sequels has been recognized as a profound burden on public health and therapeutic services in countries where transmission is endemic. In recognition of this, the World Health Organization (WHO) has led for many years the promotion, coordination and evaluation of research aimed at controlling this disease, under its special program for research and training in tropical diseases. The recommendation has been made to develop automated schistosome egg counting systems, in order to improve and facilitate parasitological mass screening and diagnosis procedure. The ultimate goal is to make rugged, lightweight and inexpensive equipment for large scale screening in remote areas by minimally trained personnel. Such a system is schematized in Fig. 14. The problem in this case is to develop digital image analysis techniques for recognizing and counting schistosome eggs in microscopic preparations. Three different techniques, developped during a feasibility study [10], [12], will be discussed here.

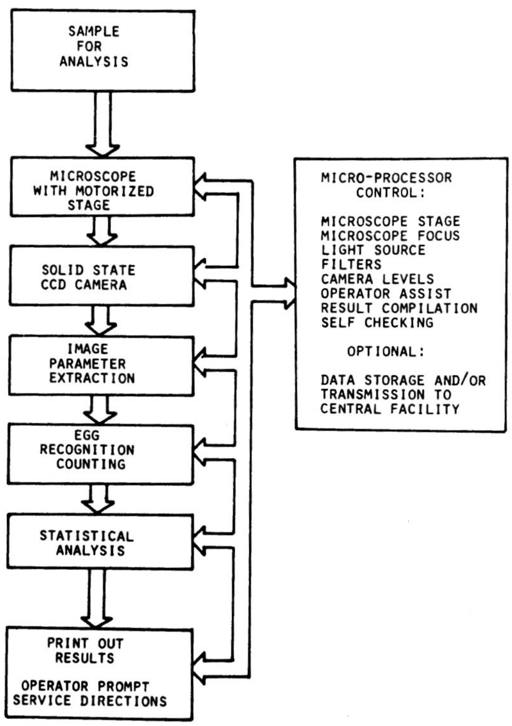

Fig. 14 Automated schistosome egg counting system

The first method is, in fact, described in the previous case on image processing for visual prothesis as ridge riding algorithm. Edges are enhanced first using the Sobel mask functions for computational simplicity. Once the starting point of a ridge and its highest neighbour are found, the search is restricted to the direction pointed by these points plus or minus fortyfive degrees. The motivation behind this restriction is to eliminate spurious objects with high curvatures because the egg contours are very smooth. Also eliminated are short contours segments. An example of this algorithm is shown in Fig. 15. The remaining contour points in the image are counted and divided by the average number of contour points per egg, giving thus the number of eggs.

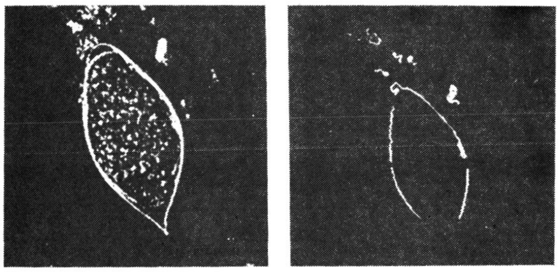

Fig. 15 An original egg image (left) and the result of ridge riding (right)

The second approach relies upon the presence of expected features within a simple Gestalt template. The schistosome image is scanned with a ring shaped mask. The ring is bounded by the length and the width of an average egg so that an egg contour can fully be intercepted (Fig. 16). For each position of the template, edge values of permitted direction are accumulated in the ring and the pixel values are accumulated in the center. When the scanning is completed, the accumulated values are tested against a discriminant function. Positive test results give the number of eggs. Clearly, this operation is rotation invariant and relies only approximately upon the general shape of the egg.

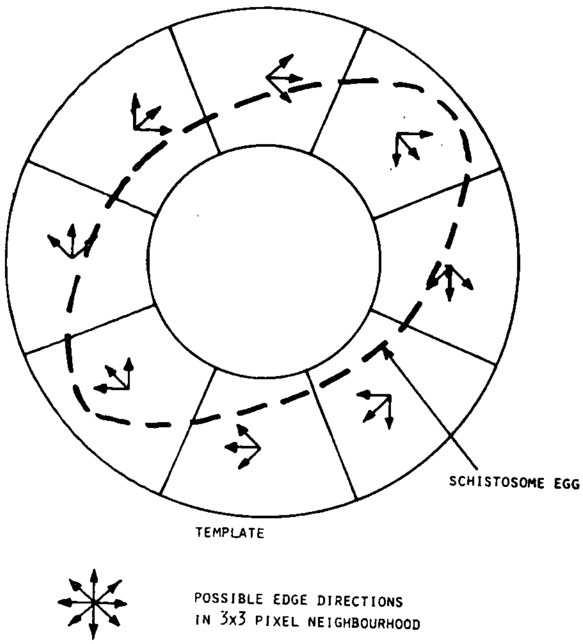

Fig. 16 Template with permissible edge directions

This algorithm can be implemented recursively by adding new contributions at right and substracting old ones at left while scanning the image. This characteristic is particularly suitable for hardware implementation at video rates, using pipe-line architecture.

In contrast with these first two methods, the third one is developed for absorbance images, that is images where the biomedical stain has caused the object of interest to be stained darker than its surround. In principle, a simple threshold on the image will cause all points on the image darker than the level to be black and all points in the image brighter than the level to be white. The black points will correspond to the eggs. Due to non-uniform staining, stain debris, non-uniform illumination and artefacts in the background, many of the points that should be black will be white and many that should be white will be black. For this reason, a variety of iterative neighborhood transformations and binary operators are applied on order to end up with a picture in which the final estimate of the object contours is as accurate as possible. Two operators were used : shrink and expend. Where a white object touches a black background, the shrink operator removes a white point and the expend operator adds a white point. Thus shrinking causes the object to become smaller as if a layer of "onion skin" had been peeled off. The expend operator works in the opposite way. By combining these operators, objects other than eggs which are smaller or greater can be eliminated to avoid false positives. Contours can then be extracted easily by one shrink exclusively ored with the original image. The total number of Contour points divided by the average number of contour points per egg gives the result.

7. OVERVIEW OF THE EUROPEAN SCENE

7.1 Preliminary remarks

A survey of different projects, investigated at 30 European Laboratories will be given. This survey is definitely not exhaustive. Groups who were not contacted are asked to forgive author's ignorence. The activities reported by the selected group leaders are classified into robotics, speech processing, image processing, pattern recognition, biomedical signal processing and acoustic and optical signal processing. The author is the only one to blaim for any misclassification or misinterpretation. In addition to the references, addresses will also be given to facilite possible contacts.

7.2 Robotics

A sensorsystem for automation and measurement (SAM) is developed in West Germany [L1] Its hardware performs real-time analysis of binary images like blob labeling, area perimeter and number of holes computation, centroid coordinates for every blob. Its software runs on a microprocessor (Z 80) and performs data collection and analysis, inspection tasks and model driven workpiece recognition. It has a modular structure. Several vision systems for industrial applications can be configurated [13]-[14].

A similar system is developed in France [L2] for recognizing and counting simple shapes. The video signal generated by a standard TV camera is processed in real-time to extract contours and contour points having horizontal tangent. The sorting is performed by a microprocessor (Motorola 6800) on the basis of perimeter, area, externally bordering rectangle. Envisaged applications are simple industrial part sorting and cell classification [15][16].

An artificial vision project is currently under investigation in Italy [L3] using digital processing techniques on special purpose image acquisition and processing systems. Linear space variant filtering and non uniform frequency resolution filtering algorithms are developed. They are based on features of the human visual system [17]-[19]. The same group is also investigating three dimensional movements using linguistic pattern recognition and scene interpretation [20].

A microprocessor controlled and ultrasonic guided maze solver has been developed in England [L4]. The system is mounted on a small four wheel chassis containing 2K ROM, 1K RAM and 8085 CPU. It is programmed in Pascal and guided by pulse-echo sonar operating at 40 kHz [21]. A new chassis is beeing designed for greater manoeuvreability.

7.3 <u>Speech processing</u>

Several projects are studied at CNET (France) [L5] in three different departments. Hutin, in the LAA/TSS department is developing a phone book inquiry system accessed by the dial and answered by synthetic speech. The synthesis is done by diphones preceeded by an orthographic-phonetic translation [22]. The prototype will be operational in 1981. Rejand and his colleagues in the TSS/ATP department are working on spoken word recognition. Their technique is a simplified recognition algorithm obtained by dynamic programming on a microprocessor. The error rate is less than 5 % with a vocabulary of 50 words, each recognized in 500 ms. Ten units are operational. Envisaged applications are in cars, robotics, data acquisition and automatic phone dialing. Courbon and Roumiguière, in the same department, are working on text to speech conversation. The text is translated into phonemes which are then processed prosodically. The synthesis is done by linear prediction (LPC) using a diphone dictionary. The LPC chip designed at CNET will soon be commercially available. Finally, Emerard, in the TSS/RCP department, uses speech synthesis for handicapped. A correctly constructed sentence is pronounced from selected words [23].

A fairly large group, in Toulouse, France [L6] headed by Perennou, is working on the following projects : Acoustical analysis including models of ear, pitch detection, and temporal identification; speaker dientification; isolated word recognition by global method; lexicon and text treatment; multiprocessor system for speech recognition; and speech recognition by analytical method at phonetical, lexical and syntactical levels. The long list of their publications can be obtained upon request addressed to [L6].

In Grenoble, France [L7], Groc and Tuffelli have developed a versatile speech recognition system working under various conditions : isolated words, continuous speech with or without syntactic rules. The system is based on ARMA models, dynamic programming and linguistic rules [24]. For isolated words without syntax and for one speaker, the error rate is 3 % in a 65 word vocabulary.

A group headed by Simon in Paris [L8] is working on speech coding and recognition, and speech and singing voice analysis and synthesis. The first problem is analysed in the time domain at the acoustic-phonetic level using various pattern recognition techniques with semantic information [25]. It is implemented in a low cost microprocessor based system. In the second problem, speech is synthesized by rules, by linear prediction and formant waveform. The voiced sounds have high fidelity quality and the work is in progress for consonants [26]. The method is implemented on a mini computer.

A group led by Niemann in West Germany [L9] is working on the understanding of connected German speech. The system is developed in a dialog environment. It is made of largely independant modules coupled through a common data base and initiated by a separate control module [27], [28].

Bolc and Kielczewski are developing in Poland [L10] a telephone information system. The analysis is done through PCM using the Fast Fourier Transfrom and linear prediction. The synthesis uses a microphonemic method [29]. A prototype of an automated information office is operational.

A speech synthesis and recognition project using short-time spectre and linear prediction is studied by Geçkinli in Turkey [L11] and a speech synthesis by rule for German, from written text, is investigated by Kaeslin in Switzerland [L12]. Kaeslin is using linear prediction and threaded concatenation of diphones.

7.4 Image Processing

A general operator concept (GOP) for image processing and analysis has been developed by Granlund in Sweden [L13]. This operator describes image information as hierarchical structural relationship [30]-[32]. A special purpose processor for its implementation has been built. It speeds up the computation of most image processing algorithms by a factor of 1000. This operator has proved very useful for detection of lines and edges, description of texture, implementation of relaxation operations, content-dependent filtering and coding. Two versions of a picture array processor (PICAP) have been developed in the same group [33].

Image processing, analysis, understanding, pattern recognition, robotics and visual psychophysics are the areas of activities of a group in France headed by Faugeras [L14].Their main projects are portable image processing and analysis software package, 3-D laser range finder, fast 2-D convolutions [34], theory and applications of relaxation labeling [35] and texture perception [36].

Real-time color TV picture enhancement is studied in Toulouse, France [L2], by Bajon and Cattoën. It is based on histogram modification [37]. An efficient image restoration technique by recursive filtering is developed by Demoment and his colleagues in another french laboratory [L15]. The technique is implemented with an 8-bit microprocessor [38] [39].

A group headed by Levialdi, is developing in Italy [L16] a high level language for image manipulation and processing. The compiler will be operational by the end of 1981 [40], [41]. Another group [L3], is working on 2-D spatial affine transformations on images and interactive image registration and mosaicing [42] , [43]. Algorithms for 2-D digital filtering, data compression, edge extraction and pattern recognition are studied by a group led by Cappellini [L17]. They are implemented by a modular software on a minicomputer [44] , [45]

A new algorithm for edge detection, based on a model of human edge perception is developed by Liedtke and Geuen in West Germany [L18] The model has three components : frequency, response, adaptation and noise reduction. Considerable improvements over other methods are obtained with subjective assessment [46] , [47]. In another group [L18], Zamperoni is investigating shape oriented digital image processing for storage and retrieval. The analysis generates a set of hierarchically structured data, which allows a stepwise reconstruction of the original image by successive approximations.

In England [L20], Ullmann completed a very interesting review of various video-rate image processing techniques [48] and proposed a new microprocessor technique for video-rate connectivity based analysis.

A study on image synthesis applied to digital terrain models have been completed by Hugli in Zürich [L12]. Synthesized shaded pictures of digital reliefs show sufficient realism and three-dimensional rendering to simulate reality [49]. Orum, in another group [L21], transforms large data bases in a graphical form to facilitate the extraction of essential information, at a glance, without concentration. Information extraction from satellite imagery in land classification, mineral exploration, coastal planning, crop yield estimation, city planning, detection of water pollution are actively carried out in Turkey [L11] using Landsat imagery [50], [51].

7.5 Pattern Recognition

A project analysing circuit diagram drawings is in progress in West Germany [L9]. The image is first proprocessed to obtain a picture graph. Then lines and characters are separated by connected components. The allowable sequence of alpha-numerical characters is freely defined by a finite automata. A user defined set of circuit elements is represented by a search tree [52], [53]. Another West German Group [L18] is interested in developing new algorithms for texture discrimination, using a model of the human texture perception. The model consists of s nonlinear filter which simulates the processing capabilities of the human visual system and a multidimensional threshold detector derived from subjective tests. Schürmann, in Ulm [L22] is working on text and character recognition using digital image processing. Line finding, segmentation, normalization, multi-channel, multi-choice approach for single character recognition by polynomial classifiers and contextual post processing are the main techniques used.

Scene mathing with translation independent transforms (R-transform) is studied in Friedrichshafen [L23]. A coarse location is computed first followed by a fine tuning [54]. The system working at video-rate will be used for terminal guidance and midcourse navigation for airplanes.

The problem of matching two patterns, such that one may be a distorded image of the other is investigated by Ullmann [55] in England [L20]. The central idea is to approximate the set of admissible distorsions by a set of relational projections of it.

A handwritten signature verification system is under investigation in Zürich, Switzerland [L21] by de Bruyne. The position of a stylus is followed dynamically with a graphic tablet. Extremities and slope changes are detected and used to define different types of segments. Verification is done by correlating the sequence of segments with previously stored reference.

In Marseille, France [L24], Sessarego is working on acoustical target imaging. From the projections of spatial distribution of bright spots the target is reconstructed by image sommation.

7.6 Biomedical Signal Processing

Liedtke and Haussmann, in a previously mentioned group [L18], are working on segmentation and classification of cell images. Blobs are constructed by split and merge procedure then assembled using features like colour, texture, size, shape and neighborhood relations. Successful results are obtained for leucocyte segmentation. The technique will now be used for a large set of urothelial cells [56]. Single cell classification by polynomial classifier is studied by Schürmann in Ulm [L22].

Kulpa and his colleagues developed a fairly large image processing minicomputer in Warsaw [L25]. In addition to a basic picture operation software package, several application programs are designed for the analysis of leukemia cells, chromosomes, eye-fundus images, animal and human locomotion [57].

A new ultrasonic technique, called ultrasonic impediography, used for biological tissue characterozation is developed by Lefebre in Marseille, France [L24]. It is based on the use of broad-band pulses and allows quantitative investigation taking into account multiple reflexions and absorptions [58], [59].

A new project is started in Erlangen, West Germany [L9] by Niemann and his colleagues to analyse image sequences from nuclear medecine (heart). The envisaged system will use an explicit model of the heart from two views.

A model of the basilar membrane is developed in Grenoble, France [L7] as well as a model of the inner and outer cells. They are based on digital filtering techniques and system modeling [60], [61]. In another french laboratory [L15], Lumeau and Clergeot are investigating the spatial localization of cerebral activities. Their goal is to obtain maximum information on it, prior to the explicit use of any propagation model. The method is based on the cross correlation matrix at the outputs of sensors [62].

Two projects on blood flow-rate measurement are actively carried out in Toulouse, France [26] by a group headed by Castanie in collaboration with a medical group. The first one is on aortic flow-rate measurement by non invasive electromagnetic methods in order to built a heart performance index. The method is based on the potential generated by the blood motion in a magnetic field, and uses ARMA modeling. It will be implemented with a microprocessor for real-time exploitation [63]. In the second project, an algorithm is developed to obtain from the instantaneous pressure a set of coefficients which in turn can reconstruct the flow-rate. A microprocessor based prototype is in its last phase of implementation.

A biomedical ultrasonic imaging system is beeing developed in England [L27] by Kennair and his colleagues. Their technique is a combination of phased array transmission and holographic reception using CCD FFT beamformer. The overall control and signal processing is done by microprocessors.

7.7 Acoustical and optical signal processing

Escudié and his colleagues are working in Lyon, France [L28] on interferometric imaging of noise acoustic sources. They developed methods to locate and describe acoustical noise sources in industrial units or in vehicules. The methods are based on multipath correlation, two dimensional Fourier transform and the so-called positive deconvolution [64], [65]. Their system is built and systematically tested in true atmosphere. Their next step is to investigate moving multisource problems with super-resolution.

Electronically scanned and focused receiving arrays are studied by Salvini, Calaora and Gazanhes in Marseille, France [L24]. Real time beam forming and focusing is possible with the use of hybride elements. A ten elements antenna including electronic circuitry to obtain five simultaneous Fourier transforms in real time for beamforming has been constructed and experimented.

A group in Grenoble [L29], headed by Lacoume is working on high resolution goniometry in collaboration with Laval University, Quebec. The technique used is based on model fitting (Maximum entropy spectral analysis) and cross spectral analysis. Two targets or sources whose directions are very close can be detected with a resolution much higher than that of a classical antenna. Currently, digital methods are developed for optimum processing of the cross spectra matrix. The system is beeing tested in submarine acoustics [66], [67].

Optical processing in this film waveguides is investigated in Firenze, Italy [L30]. The system built for computing the Fourier transform or other imaging operations is made of geodesic components. These components were introduced in integrated optics by this group [68], [69].

8. CONCLUSION

Five cases were discussed as applications of signal processing techniques in man-computer communications in its broadest sens. Far from illustrating all the possible applications in a large variety of disciplines, they show how, simple notions like filtering, correlation, convolution, etc.. can be used in different areas. One of the most important uses of signal processing in any information processing system is at the level of preprocessing. The aim here is to clean up the rough data, be it one-dimensional or two-dimensional, so that subsequent processing is alleviated, becomes more robust and more reliable. Filtering and modeling are typical preprocessing examples. Another important use of signal processing is in the analysis phase where one might be interested in estimating a parameter or extracting features. Spectral analysis, correlation convolution, linear or non linear transformations are some of the most commonly used techniques for these purposes. Detection, identification, pattern recognition, interpretation and interaction may be the ultimate goals after preprocessing and analysis. Data reduction and retrieval is also increasingly welcoming signal processing. Widespread use of electronic files and archives will reenforce this interaction. Last but not least, communication, in general, is the favorite ground of signal processing, as shown by the brief survey of some European activities and by the other papers of this conference.

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