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THE USE OF AN IMAGE ANALYSER FOR DIMENSIONAL QUANTIFICATION IN ULTRASONIC IMAGES

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The use of a sophisticated commercially available image analyser is described in the context of obtaining numerical geometrical data from ultrasonic visualization systems. As an example of its value, its application to the ultrasonic foetal monitoring is discussed. The main features are light pen selection, with immediate display and numerical analysis. Whereas the instrument is too sophisticated for routine use it could be invaluable in ascertaining the design specification of a simpler purpose-built system for incorporation into ultrasonic visualization equipment.

Introduction

Interest in the accurate measurement of the linear dimensions, cross-sectional areas, and volumes of discrete structures within optically opaque media has been growing in recent years in the field of ultrasonic diagnostics, particularly in medical applications.

Linear measurements is usually achieved by employing the pulse-echo technique of the *A*-scan used in sonar, non-destructive testing and medical diagnosis. The time interval between echoes returned from known features of the object is converted, assuming that the velocity of sound in the medium is known, into a measurement of their spatial separation. Alternatively it is possible to take a measurement off a two-dimensional visualization produced, for example, by pulse-echo *B*-scanning [1], *C*-scanning [2], or holography [3], etc. This method still assumes a known velocity of sound in the medium but because of the difficulties of defining exactly the correct plane and the degradation of the information in the *B*-scan (i.e. demodulation, filtering) during the visualization process, it is generally considered [1], most accurate for the measurement to be made from an *A*-scan trace. The correct *A*-scan direction is chosen with the aid of an associated two-dimensional *B*-scan display.

This technique is only feasible where the structure whose linear dimension is to be measured has a fairly well defined geometry and has good echo-producing extremities. Examples of situations suitable for this type of measurement are foetal biparietal diameter [4], intra-ocular distances [5], and the depth of cracks in metal components [6].

However, when the structure whose linear dimension is to be assessed does not have well defined boundaries (ultrasonically), e.g. a first trimester foetus or a cloud of inclusions in a metal casting, then it is necessary to take the measurement from the two-dimensional (sectional) pictorial display. In addition, measurements such as the perimeter or area of an internal structure have to be taken by hand from the pictorial display, using a map-measurer or a planimeter.

This communication describes the use of a sophisticated image analyser, generally used for the analysis of microscopic images, in this context. Its potential as a useful research tool for defining optimum procedures is discussed, and the possibility of building a much simpler but more specific instrument for use in ultrasonic diagnostics identified.

In the discussion which follows, the medical problem of the assessment of foetal maturity has been chosen as an example of a fairly complex problem in which the analyser may be of considerable value. It is hoped that the parallels with the other areas of ultrasonic materials investigation will be sufficiently clear that specific mention of them would be superfluous.

Analyser

The analyser used for these trials was a commercially available machine, Quantimet 720 *M*, manufactured by Cambridge Scientific Instruments, Royston, Herts, England. It consists essentially [7] of a closed circuit television camera connected to a 720-line non-interlaced display. The video signal is digitised into 8 bits and fed into a memory column by column, storing a total of 604,000 points for the whole screen, with 6 bits of grey scale on each. The input to the analyser may be any optical image, a positive or negative print or transparency. The image processing that can be achieved is extremely varied and flexible, (largely due to the modular construction of the analyser) and includes compensation for uneven illumination. However for the problems reported here, which are of the simplest in image analysis, the most useful facility is the use of a light pen for editing the image displayed on the TV monitor or for selecting a particular region for analysis.

Figure 1 ($a-e$) indicates a typical analysis procedure that may be used.

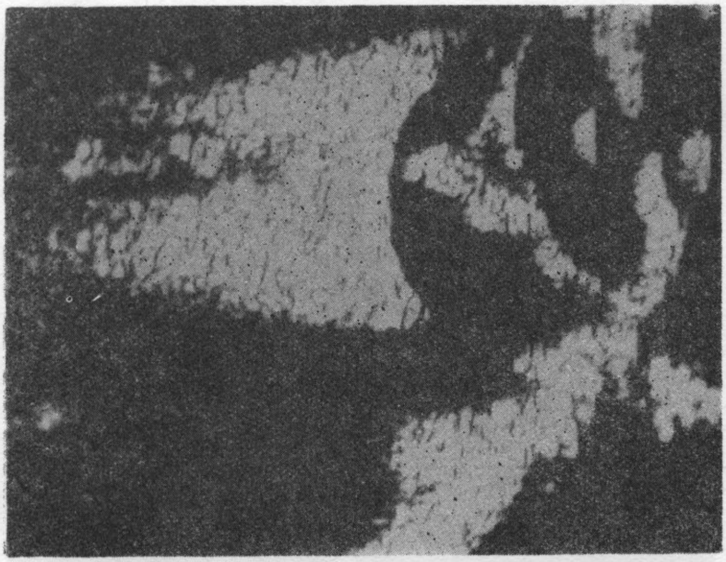

Fig. 1a

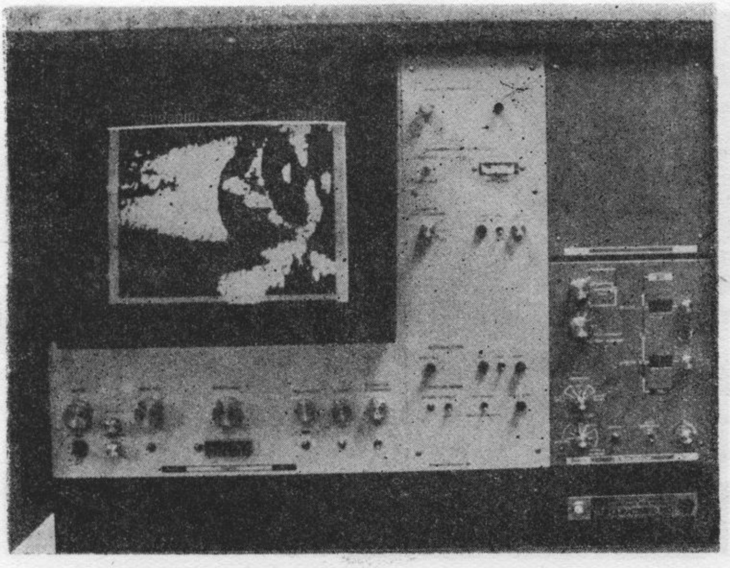

Fig. 1b

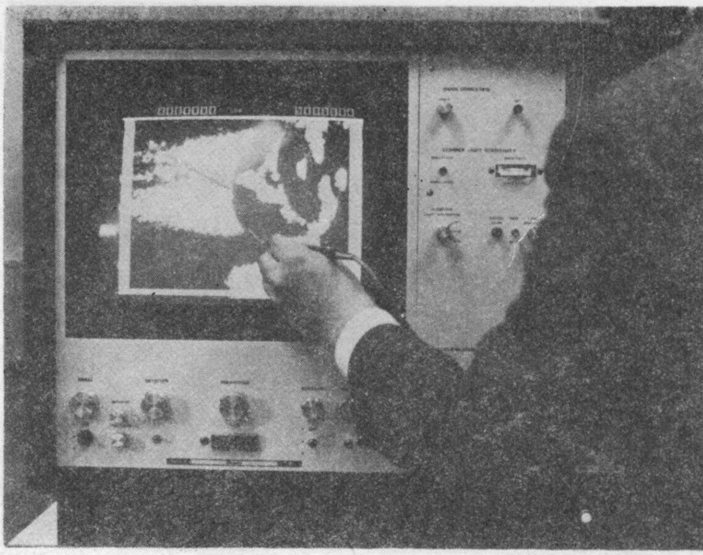

Fig. 1c

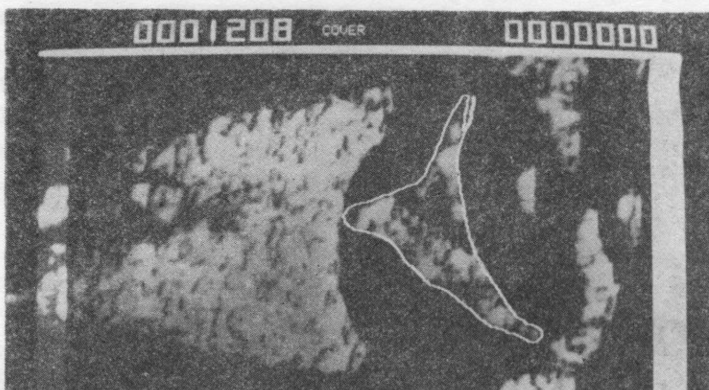

Fig. 1d

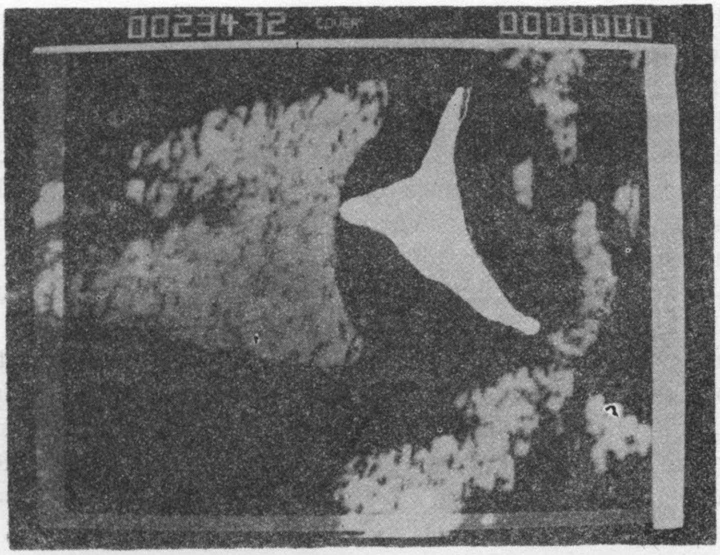

Fig. 1e

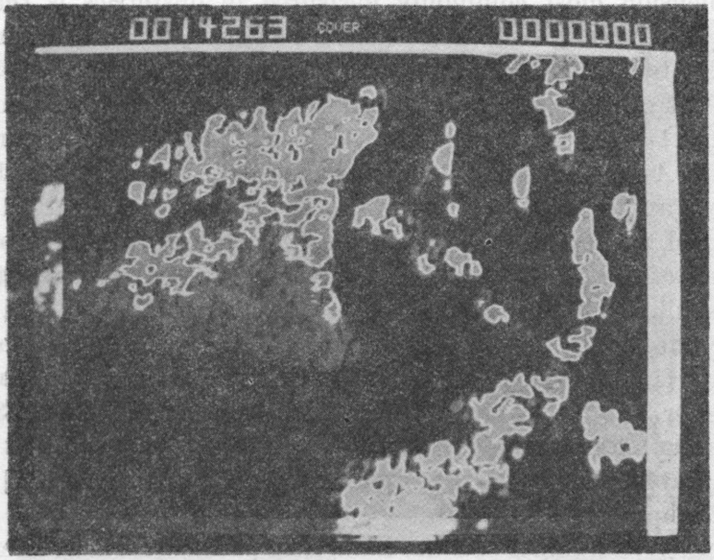

Fig. 1f

Fig. 1. Use of the analyser

a) original image from ultrasonic scanner

b) image displayed on analyser

c) use of the light pen to define an area of interest

d) area displayed and quantified

e) perimeter displayed and quantified

f) typical processed image

Figure 1*a* shows a print from a roll-film negative taken of the display of the ultrasonic scanner. Figure 1*b* shows this picture displayed on the monitor of the analyser. Identification of an area of interest is performed by enscribing it with the light pen (Figure 1*c*). Almost immediately the analyser can display the area enclosed (Figure 1*d*), the perimeter (Figure 1*e*) and in some cases the longest dimension of the area. On the particular simple model available to the present authors, this last measurement was not always easy to achieve although modules are available which would make it comparatively easy. The image processing available may permit the display to be optimised for a particular measurement (Figure 1*f*).

The number at the left at the top of each picture represents the number of picture points. In order to convert it to geometrical area it is necessary to know the scale of the original picture, and to include a scale in the analyser field of view (see Figure 1*d*). The minimum area that may be considered is four picture points.

Application in obstetrics

The dimension most commonly measured in obstetrics is the biparietal diameter of the foetus measured in utero. The usefulness of this measurement was first indicated by Donald and his colleagues [4, 8], was widely accepted [5, 10], and put on a secure basis by Campbell [11, 12]. Although techniques using only the *A*-scan [10, 13] or only the *B*-scan [14, 15] have been described, the combined *A*- and *B*-scan technique mentioned above, which was first developed by Campbell [11] and has been much adapted [16, 17, 18], is generally considered to be the most accurate for measurement of biparietal diameter, because of the good definition of the echo producing extremities on each side of the skull.

This measurement is, however, only useful for foeti of 14 or more week's gestational age [19], and there has been considerable discussion of the precision, sources of error and accuracy of the technique [10, 16, 20 –23, 37] as well of the fundamental methodology employed [24]. It appears that the major sources of variability lie in the definition of the normal curve [24] and in the scanning technique used [25].

More recently, a number of other numerical parameters have been suggested for monitoring foetal well-being. The cephalocaudal dimension of the foetal sac [26], the average diameter of the foetal sac [38], the volume of the foetal sac [27] and the crown-rump length of the foetus [28, 29] have all been suggested as indicators of the gestational age of the foetus during the first 13 weeks. Only the last-named publication gives some indication of the reproducibility of the method.

Garrett and Robinson [15] give curves linking foetal trunk area, occipito-

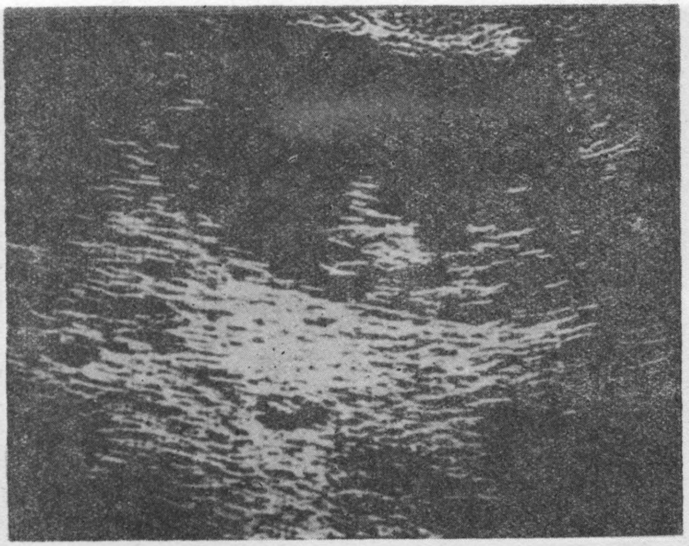

Fig. 2a

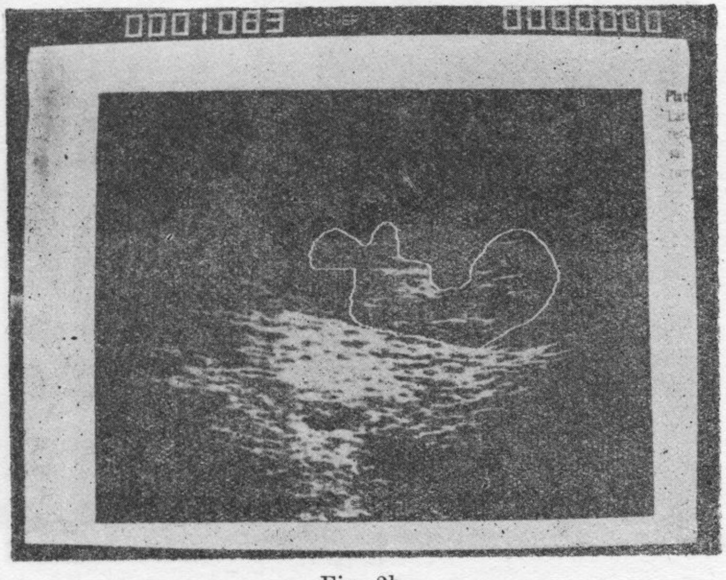

Fig. 2b

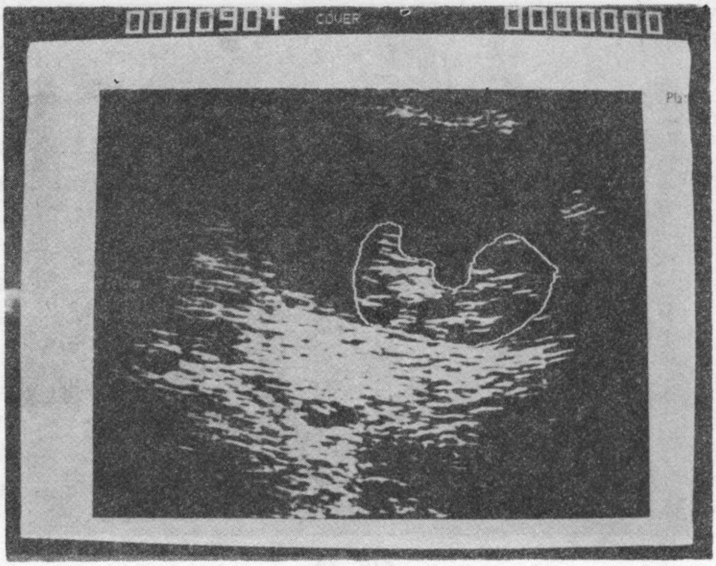

Fig. 2c

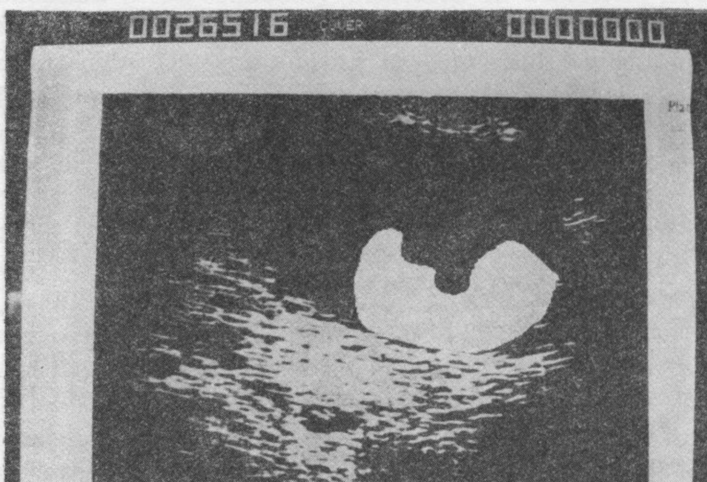

Fig. 2d

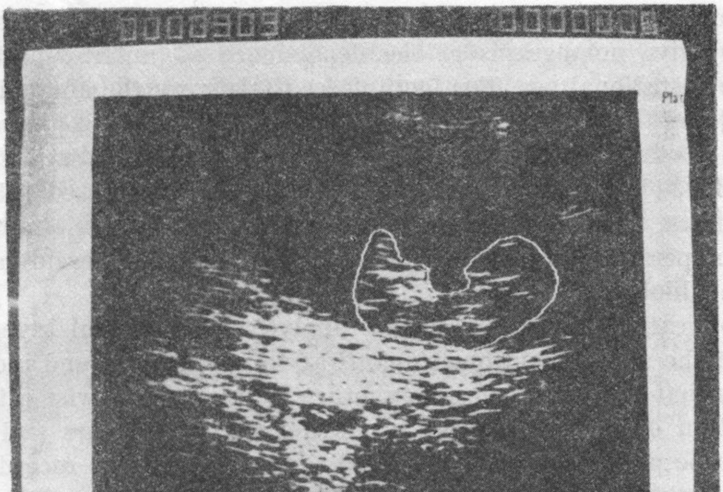

Fig. 2e

Fig. 2f

Fig. 2. Application of the analyser to foetal assessment

a) original from ultrasonic scanner (courtesy Mrs. R. M. Lunt and Cambridge University Press)

b) selectionont area of interest (erroneous)

c) selection of area of iureerest (preferred) and measured perimeter

d) m afment of corresponding area

e) selectiousand perimeter measurement repeated

e)jassociated area measured

frontal diameter and head area to gestational age, while THOMPSON and MAKOWSKI [30] give nomograms of the dependence of anterior-posterior chest diameter on gestational age. For foeti closer to delivery the abdominal circumference [31] and the product of the skull and thorax areas [32] have been used to estimate foetal weight, studies of bladder volume and urine production described [33, 34], and ultrasonic cephalo-pelvimetry proposed [35]. In most of these studies, there is little critical discussion of the variations that may occur due to operator error, the essential limitations of the measurement technique and the biological variations.

The application of the Quantimet analyser to a careful investigation of the value of the above mentioned quantitative parameters (and indeed to any further ones that may be suggested whether foetal or otherwise [19]), is clear. The extraction of numerical data in the form of perimeters and areas, has otherwise to be performed manually, and there is usually no record of the line or area that has actually been considered. The main advantages of the Quantimet are: the speed of selection of the relevant area with the light pen, the identification of the area traced and the speed and accuracy of the analysis. As one of the foremost image analysers available, the quality of the analysis is very high, being much better than it appears from a visual assessment of the image on the display screen.

As a single example, a scan of a young foetus is shown (by courtesy of Mrs. R. M. LUNT [19]) in Figure 2*a*. Outlining the area of the foetus with the light pen can be checked (Figure 2*b*) and may not be considered to be optimum. It may be immediately retraced and checked, the measurements of perimeter (Figure 2*c*) and area (Figure 2*d*) taken, and repeated (Figures 2*e* and 2*f*), with surprisingly good agreement. The crown-rump length was also measured by the analyser as 246 picture points. The whole process, with the machine already set up, including writing down the measurements and photography took only 3–4 minutes. The value of such equipment in the training of operators is considerable, particularly if linked to a realistic tissue model of known dimensions [36].

Conclusion

The application of a commercially available image analyser to the problems of geometrical quantification in ultrasonic visualization in any field has been identified with consideration of the particularly difficult questions raised in medical applications. Particular features of the analyser that are advantageous are the use of a light pen for defining an area of interest, the visualization of the area described and an extremely rapid analysis to give a number of numerical indices, with considerable display flexibility. The quality of the analysis and the flexibility of the analyser in its present form are undoubtedly too sophisticated to be cost-effective in routine use. Nevertheless the analyser may be used to advantage in optimising the procedures that are most useful both in terms of clinical value and operator training in order to define a purpose built system incorporating a light pen and a microprocessor that may be accommodated in commercially available ultrasonic visualization systems where geometrical quantification is important. Detailed studies of specific problems and applications to tissue characterization are in progress and will be discussed in future reports.

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