SIMPLE PROCEDURE TO REFINE ULTRASONIC IMAGERIES
OBTAINED BY AN OSCILLOSCOPE CAMERA

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Abstract

The ultrasonic equipments permit to obtain a two dimensional display of the body's cross section through which the ultrasonic waves are propagated. This analogue appears on a screen and then photographed by an oscilloscope camera.

The photograph is an image gray-scaled of the internal bodies existing on that section.

The ultrasonic photographs are subjected to a variety of distortions resulted from the combined effect of many factors including :ultrasound properties electronics, display process and mechanical system.....;in addition to the deformations produced by the film and the camera's lens.

This paper searches the distortion's pattern of the ultrasonic equipment. It states a general procedure of system calibration of the ultrasonography under the actual operational conditions. A final mathematical model which describes the performance of the intire ultrasonic system only ,after discarding the effect of the camera and film,is derived.

Close Range Photogrammetric techniques are applied to attain the right size and shape of the invisible photographed bodies.

Introduction

Close Range Photogrammetry may have a considerable role in a new field of application ; that's of Ultrasound. The majority of ultrasonic equipments are used for medical purposes, but they also have several applications in civil engineering ,as detecting and measuring of thin internal cracks inside the materials to predict any destructive failures .

The fidelity of the ultrasonography has not been examined before and the dimensions are extracted directly without any refinment or evaluation of their accuracies .

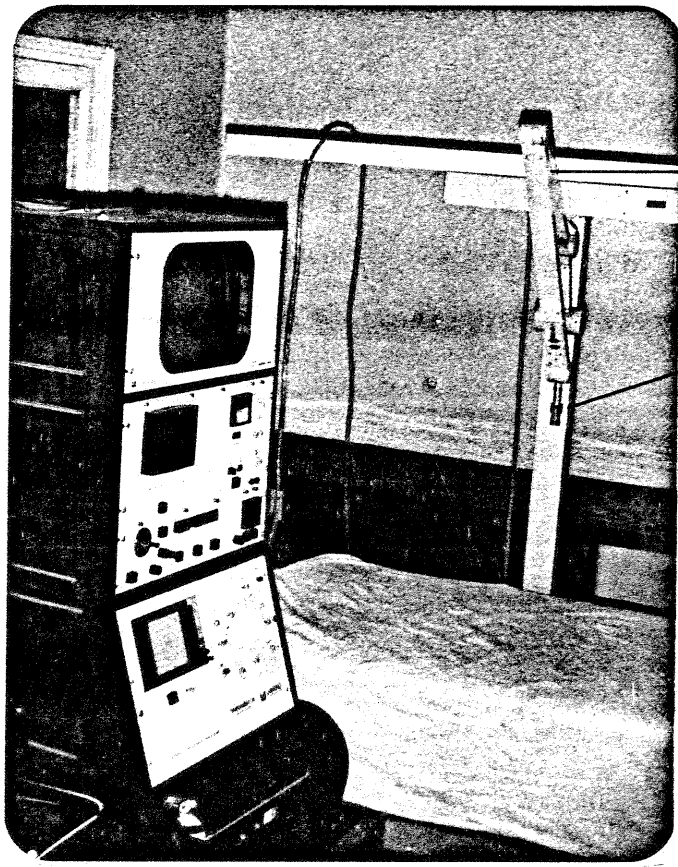
This paper is a part of the author's PH.D (still under preparation) , in which she suggestes a simple procedure to refine the ultrasonic imageries and to overcome the difficulties of non metric camera . Although this research was developed for an ultrasonic instrument used for medical purposes (gray-scale sonograph ,the Greatone III),fig (.1.) ,but it may be applicable for similar equipments of other applications, as well as photographs obtained from Cathode Ray Tubes .

Ultrasonic waves have the ability of penetration through different materials or tissues , and be reflected at their boundaries. The reflection depends on the difference in densities and acoustic impedances between the two internal bodies and upon the orientation of the reflected surfaces.They are emitted in very short pulses by a transducer ,fig (.1.),able to receive the reflected echoes between pulses and transformes them into electrical energy.

The voltage generated is proportional to the intensity of each returning wave. Echoes are then detected and analysed before being displayed on a screen as different degrees of gray, relative to their amplitudes. Thus a two dimensional display of the cross section is obtained .

In addition , these apparatues have the ability of giving images of successive parallel sections at constant intervals (0.5- I cm),which can be considered as contours, perpendicular to the transducer's face.

This analogue is then photographed by an oscilloscope camera (HP model I97 A),using either Polaroid or X-Ray films. The camera fit all oscilloscopes having the standard II x I4 cm rectangular bezel. The mounting frame is designed for 2 cm (3/4 in)bezel depth ,permitting direct attachement to the oscilloscope as showing in fig 2 .



Mechanical transducer's arms.

The transducer

Fig -I-
The ultrasonic Greatone III

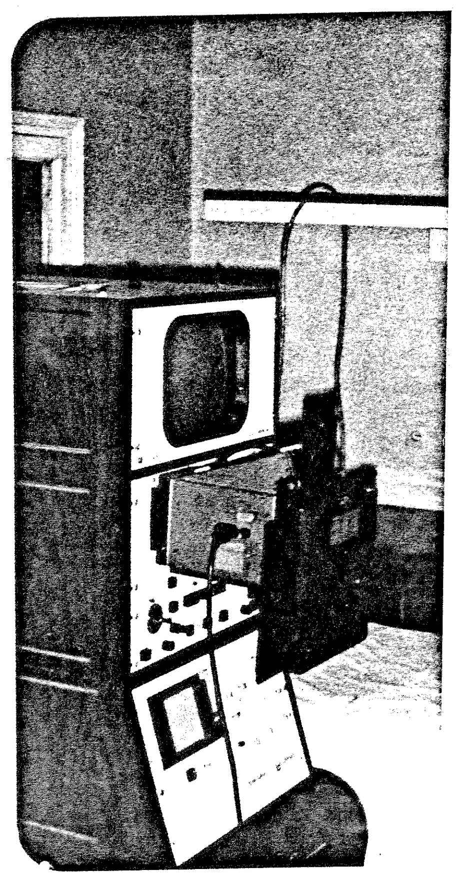


Fig -2-
The HP camera fitting the oscilloscope of the ultrasonic equipment.

The resulted image is subjected to the effect of the following sources of errors :

- unstability of Polaroid films
- use of non metric camera of unknown interior orientation
- properties of propagation and reflection of the ultrasonic waves
- the scanning process obtained by the motion of the transducer over the body
- distortions at the Cathode Ray Tube
- other factors concerning the electrical and mechanical systems .

Compensation of systematic errors has been carried out by dividing the previous factors into two main groups :

- Group A is consisting of the combined effect of the lens and film deformation
- Group B is the ultrasonic instrument as a whole ,including the transducer ,wave's properties ,C R T's distortions, electronics.......

The effect of each individual source of errors has been analysed and a mathematical model with correction parameters has been developed for each group .

To eliminate the distortions resulting from group A, a standard Reseau , fig 3 , having the same dimensions of the oscilloscope (7.5×9.8 cm^2) , consisting of thin wires of aluminium (0.3 mm),has been fixed in front of the screen (i.e between the camera and the CRT)and then photographed.
This type of photographs where the camera and film are the only sources of errors , are called PHOTO I .

The mathematical model describing the relationship between the set of observations $\bar{X}$,$\bar{Y}$ of the Reseau's points measured by a mono comparator and the coordinates $\bar{x}$, $\bar{y}$ of their corresponding images on PHOTO I was found to be of the form :

$$\bar{X} = \frac{a_1\bar{x} + b_1\bar{y} + c_1}{a_o\bar{x} + b_o\bar{y} + 1} + k\,(\bar{x}^3 + \bar{x}\,\bar{y}^2) + e_1\bar{x}\,\bar{y} + d_1\bar{x}^4$$
$$\bar{Y} = \frac{a_2\bar{x} + b_2\bar{y} + c_2}{a_o\bar{x} + b_o\bar{y} + 1} + k\,(\bar{y}^3 + \bar{y}\,\bar{x}^2) + e_2\bar{x}\,\bar{y} + d_2\bar{y}^4 \qquad (..I..)$$

Where :

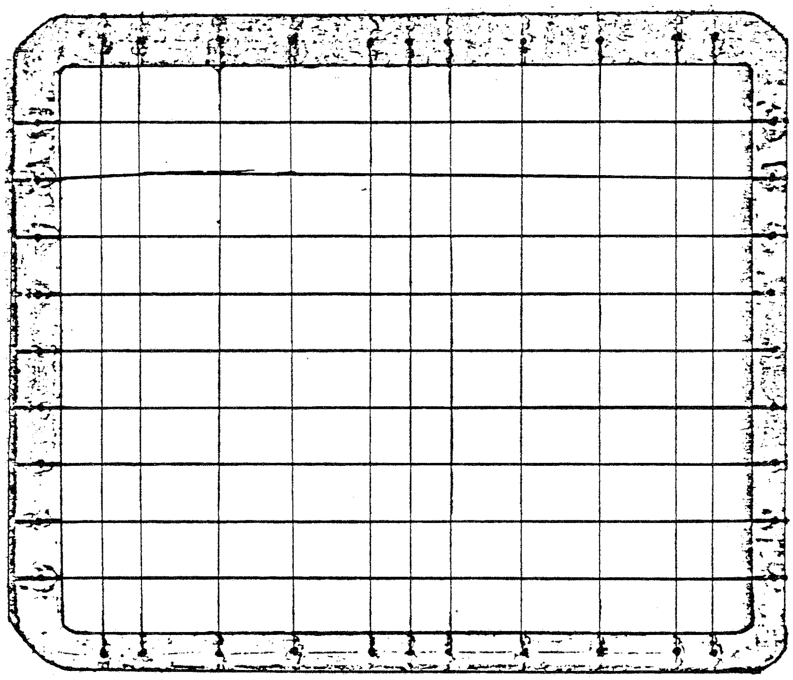
- a_i , b_i , c_i are the parameters for the projectivity relationship between the plans of the film and the Reseau.
- k is the coefficient of symmetrical lens distortion.
- e_i ,d_i are parameters to account the non linearity and curvelinear Polaroid film deformations .

The general form of least squares adjustment

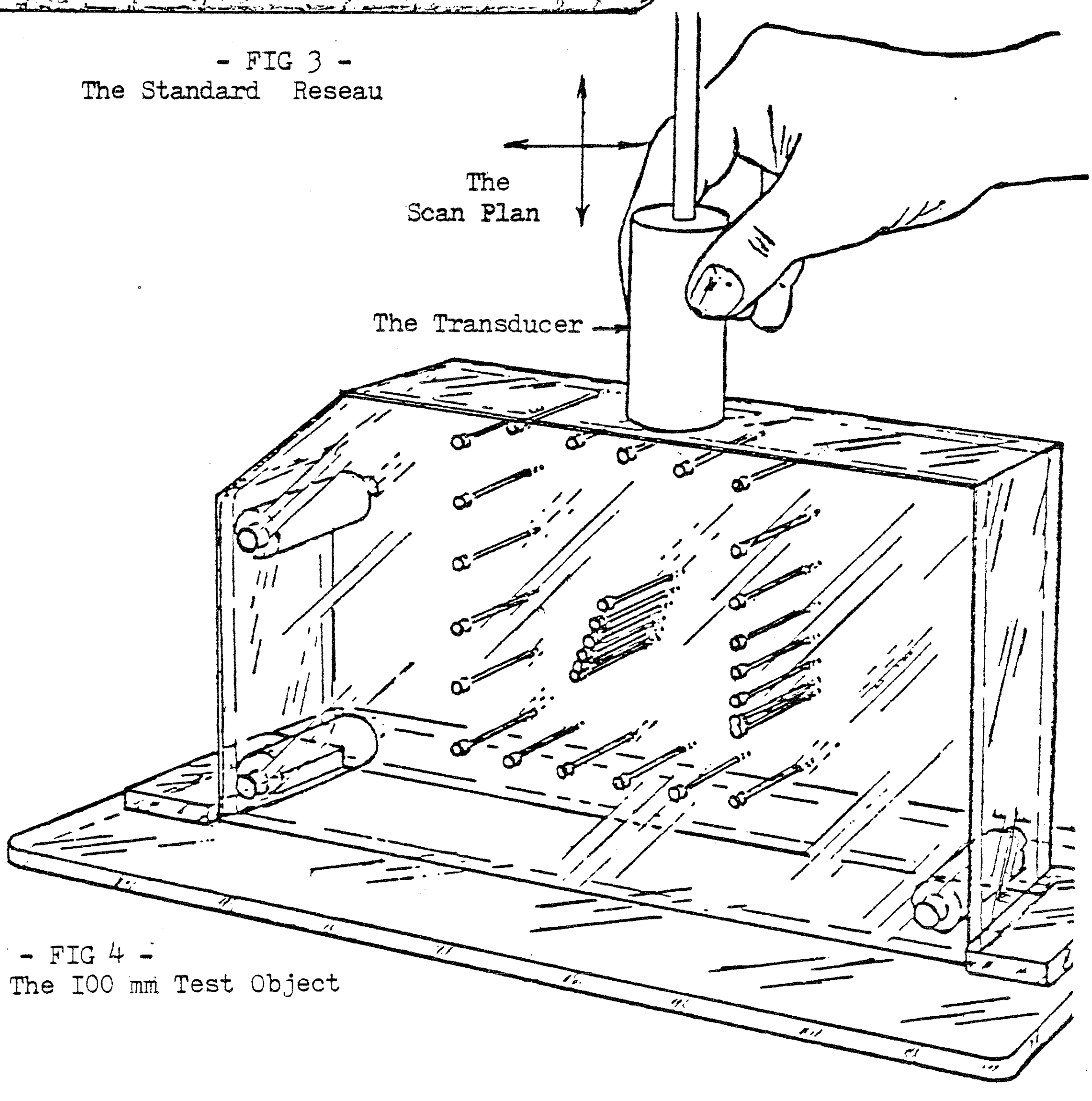
$$A\,V + B\,\Delta = F$$

was applied to find the values of the previous parameters.
The validity of the adjustment procedure was statistically tested; it was accepted at 0.05 significance level,and all parameters were found to be significant.

To derive the mathematical model describing the performance of the intire instrument , an ultrasonic image of an I00 mm Test Object, fig 4 ,was developed . It is consisting of a series of 0.75 mm (0.3 in) diameter stainless



- FIG 3 -
The Standard Reseau



- FIG 4 -
The 100 mm Test Object

steel rods (pins) arranged in a standard IOO mm x IOO mm square pattern full of special liquid . This type of photographs ,where the distortions are function of the all factors of both Group A and Group B are called PHOTO II .

The x',y',the pin's coordinates on PHOTO II,are first refined from the effect of the camera and film according to equations (1) as follows :

$$x = \frac{a_1x' + b_1y' + c_1}{a_ox' + b_oy' + 1} + k\,(x'^3 + x'y'^2) + e_1x'y' + d_1x'^4$$
$$y = \frac{a_2x' + b_2y' + c_2}{a_ox' + b_oy' + 1} + k\,(y'^3 + y'x'^2) + e_2x'y' + d_2y'^4 \qquad (..2..)$$

Where :

- a_i ,b_i ,c_i ,e_i ,d_i and k are KNOWN parameters
- x , y are the coordinates of PHOTO II refined from the effect of the Group A factors .

The relationship between X ,Y the object coordinates and x , y the new photo coordinates was derived as :

$$X = A_o + A_1x + A_2y + A_3x\,y + A_4x^2 + A_5y^2 + A_6(x^3 + x\,y^2) + A_7(x^2 + y^2)^2..$$

$$Y = B_o + B_1x + B_2y + B_3x\,y + B_4x^2 + B_5y^2 + B_6(y^3 + y\,x^2) + B_7(x^2 + y^2)^2.. \qquad (..3..)$$

Where :

A_i ,B_i are the correction parameters for the effect of Group B factors ONLY .

Fig 5 is a schematic graph summerising the procedure .

These two non conformal polynomials (.3.) were accepted at 0.05 significance level ,after applying the least squares adjustment to obtain the values of coefficients A_i and B_i .

Thus equations (3), now with KNOWN parameters , may be used DIRECTLY to obtain the true coordinates X and Y of any invisible body photographed by that ultrasonic instrument.

The Reseau is considered as a CONSTANT system of coordinates for both PHOTO I and PHOTO II to overcome the missing of fiducial marks : all the coordinates are first referred to it .

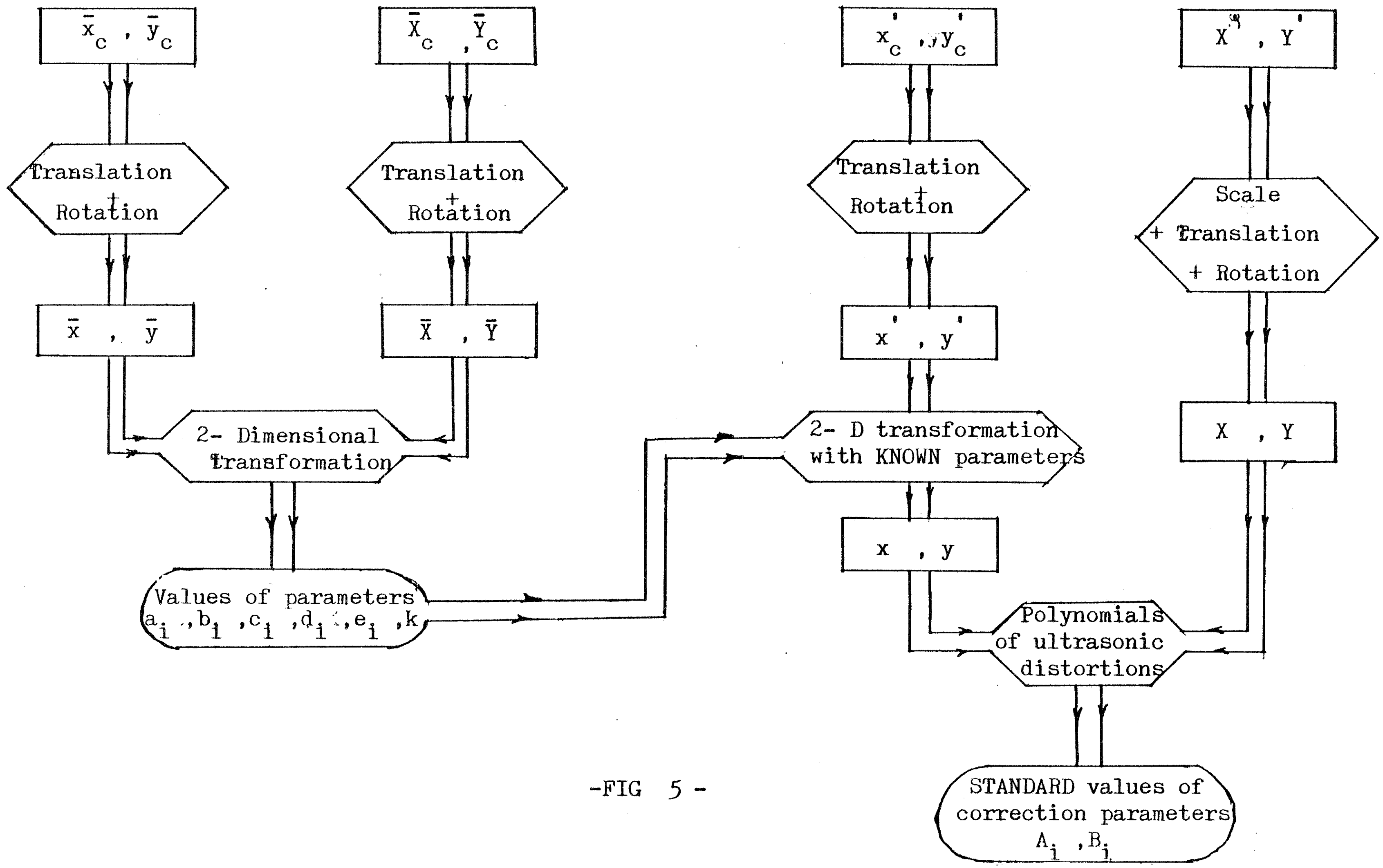
Application Techniques :

Whatever the object to be photographed (materials,bodies or internal organs ..), many advanced techniques may be used to enlarge the field of the ultrasonic photogrammetric applications .

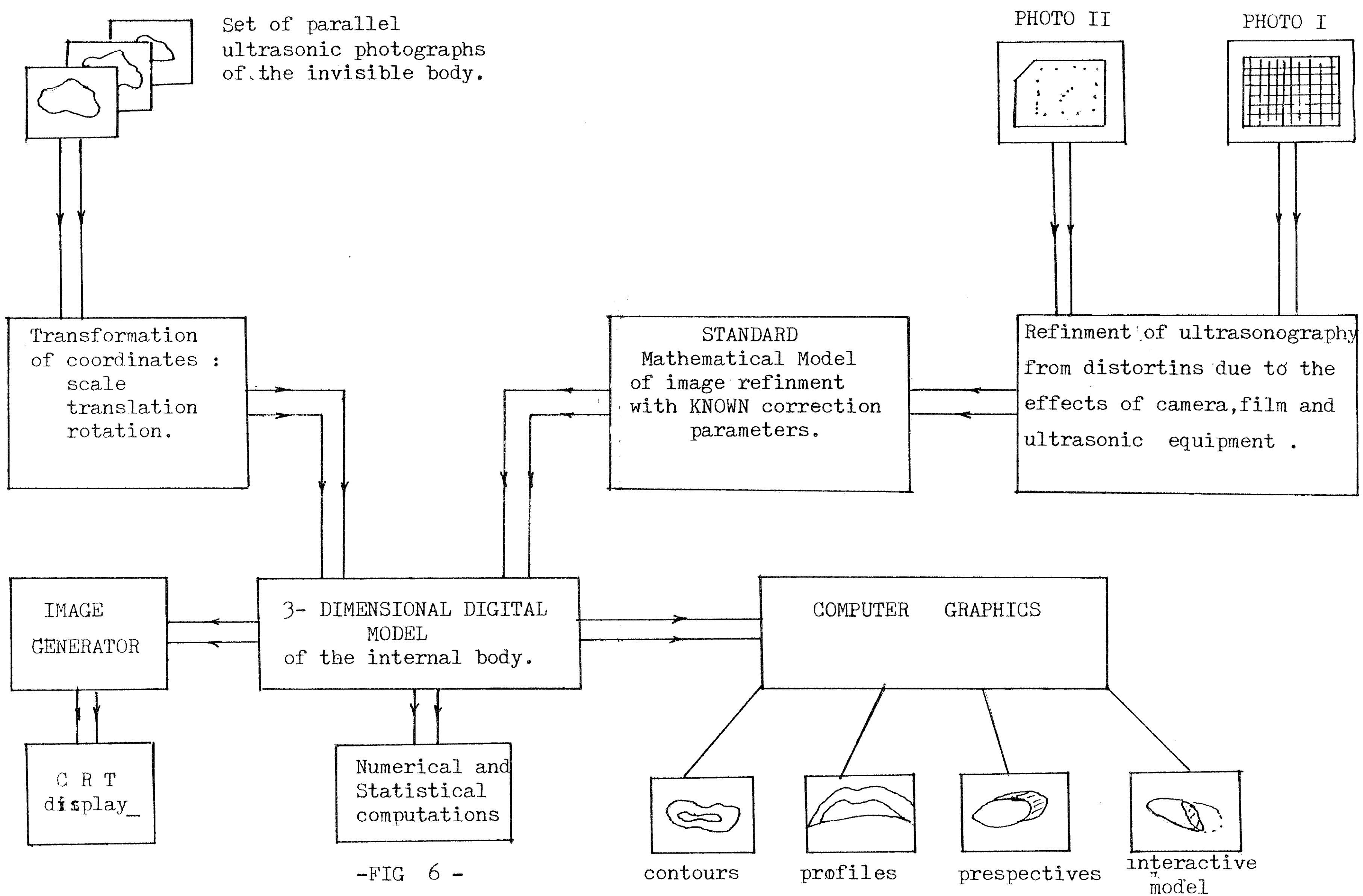
After the measurment and refinment of photographs of parallel cross sections taken at constant intervals ,one will obtain a Three Dimensional Digital Model of the internal object . This may be introduced in a Computer Graphic to deduce as much information as needed :

- numerical parameters can be easily derived ,as areas ,volumes,curvatures mass distributions, center of gravity ....
- illustration of required graphics as contours ,profiles , 3 - D models, prespective drawings .....

If an Image Generator is connected,and codes of reflectivity and colour


$\bar{x}_c$, $\bar{y}_c$
Translation + Rotation
$\bar{x}$, $\bar{y}$
$\bar{X}_c$, $\bar{Y}_c$
Translation + Rotation
$\bar{X}$, $\bar{Y}$
2- Dimensional Transformation
Values of parameters a_i , b_i , c_i , d_i , e_i , k
x_c' , y_c'
Translation + Rotation
x' , y'
2- D transformation with KNOWN parameters
x , y
X' , Y'
Scale + Translation + Rotation
X , Y
Polynomials of ultrasonic distortions
STANDARD values of correction parameters A_i , B_i

-FIG 5 -


Set of parallel
ultrasonic photographs
of the invisible body.
PHOTO II
PHOTO I
Transformation
of coordinates :
scale
translation
rotation.
STANDARD
Mathematical Model
of image refinment
with KNOWN correction
parameters.
Refinment of ultrasonography
from distortins due to the
effects of camera, film and
ultrasonic equipment .
IMAGE
GENERATOR
3- DIMENSIONAL DIGITAL
MODEL
of the internal body.
COMPUTER GRAPHICS
C R T
display_
Numerical and
Statistical
computations
contours
profiles
prespectives
interactive
model

-FIG 6 -

are added to the computer input , a 3- D Real Time Display of the internal bodies may be processed on a cathode ray tube screen ,fig 6 .

CONCLUSIONS

- This procedure is an external refinment of the photographs obtained by scanning on a CRT,as the ultrasonic equipments ,under the actual operational conditions . It does not require any modification in the design of the internal parts of either the instrument or the camera .
- Refinment of distortions resulting from the camera and film is occured by introducing a standard Reseau having the same dimensions as the CRT between the camera and the screen , and referring all the object and the photo coordinates to it .
- This procedure will be applied ONCE for a selected ultrasonic instrument and its camera to deduce the values of their correction parameters. The mathematical model with KNOWN coefficients will be STANDARD for all the following photographs .
- The true coordinates of the invisible objects are then DIRECTLY obtained by resolving the STANDARD mathematical model having as input : the photo coordinates of the object 's image(s) and the parameters's values .

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