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Measuring the size of objects by X-ray stereoscopy in nondestructive testing and medical use

The synthesis of 3D and 4D (moving) X-ray images and measuring of investigated organs or parts of machines and mechanisms in the aerospace industry of the world's leading countries determines today's face of medical diagnosis and non-destructive testing. The experimental results of such measuring stereoscopy X-ray system are provided.

X-ray stereoscopy system for objects size measuring.

X-Ray stereo method is based on two roentgenograms of the observed organ that done from different points. Such shifted images constituted stereopair. When stereopair viewed with special stereoglasses perception of depth is formed, in contrast to the tomographic methods when volumetric model is calculating from set of crosssections of observable object. The use of this stereo mode allows analyzing the state and pathological changes of movable organs, such as heart, lungs, diaphragm and the like. Best result achieved in the case, when three-dimensional images obtaining by tomographic reconstruction is labored or impossible, because of significant organ displacement. Such organ displacement leads to artifacts or failure to comply the tomographic reconstruction of cross-sections from the set of obtained projections, because points of organ will occupy new positions on every next projection. It is necessary to measure the accuracy of the such measuring procedure.

In general stereo X-ray measurement can be realized with the help of synthesized stereo cursor [1]. Position of cursor between viewer and monitor's screen will correspond to certain coordinates of the space between X-ray tube and digital receptor. When viewer will combine stereo cursor on the 3D X-ray image with object details, the real coordinates of such details will be found. Cursor is synthesized with the same technology, which used for X-ray stereo image. Based on such several obtained coordinates the geometrical measurement of the object is performed.

As investigated objects were used geometrical (Fig. 1) and anatomical (Fig. 2) test objects. For geometrical test we used rectangular parallelepiped. The distance between test object and digital receptor is 130 mm. And the depth of this test object is 238 mm.

Anatomical test object is simulating to patient's thorax. It placed at the same distance from X-ray tube as the geometrical test object. The anatomical test object consists of ribs, bones and X-ray test pattern that is cover with paraffin. Anatomical test differs from geometrical with rounded lines without sharp edges. At the same time, there are more details and various values of contrast on image of such test object compared to the image of rectangular parallelepiped. For such viewed distance and 100% image scale parallax of the geometrical test object's foreground is equaled to 13 mm. Also was created stereo images with 50 and 33 % image scale.

Fig. 1. Geometrical test object for experimental measuring

In the sum there were realized eighteen measurements by each trainee. Fifteen trainees in all were involved in the experiment. So it was obtained 270 measurements for each test object.

For measured result ratio error for geometrical object is calculated as 1,81%.

Anatomic test object is made from bones, ribs and X-ray test pattern that are covered in container with paraffin (Fig. 2). Compared to geometrical test object anatomical test have more details and distinguished by rounded lines without sharp edges. At the same time in anatomic test object there are various values of contrast on obtained image compared to geometrical test object image.

For measured result ratio error for anatomical object is calculated as 1,81%.

Fig. 2. Anatomical test object for experimental measuring

Ratio error for anatomic test object is higher compared to geometrical test object. Because it's more complicated to correlate stereo cursor with rounded edge of anatomic structures. But such geometrical measurements are more accurate than in common

radiography and can be realized for medical observation of treatment dynamics.

Since we are talking about a moving body, we are faced with an effect when there is an error in measuring this organ. Although, artifacts on the generated stereo images are not observed by the doctor. The nature of these errors is that, in addition to the movement of the tube itself, the movement of the organ itself also occurs. Thus, the sought point on the image is additionally shifted.

For our experiment a sequence of images of a breathing cat during a veterinary examination was obtained (Fig. 3). The most moving organs are the lungs and the diaphragm. In our case, they are best suited for evaluating the errors in determining the depth coordinate. Since the main direction of the movement of the lungs and diaphragms coincides with the direction of movement of the tube-detector system. At the same time, to estimate the error, it is necessary to determine the reference value of the measured coordinate. To determine the reference value of the coordinate, it is necessary that the organs do not move. With a heart this cannot be done. However, breathing pauses may occur in the circulatory cycle. The resulting series of X-ray projections of the cat consists of 84 projections in 8.5 s. The angle between neighbor projections is 0.5°. There are only five projections with two breathing pause. From these breathing pauses three stereo images can be obtained.

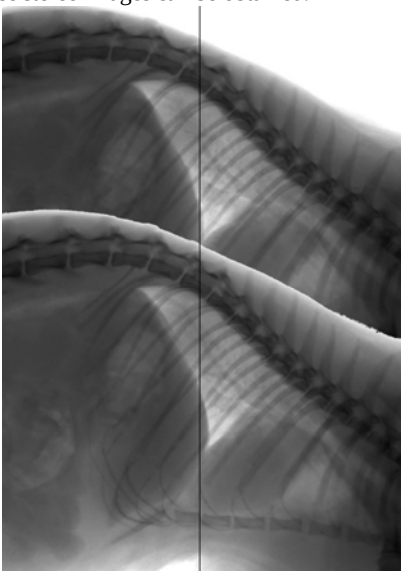

Fig. 3. Cat's lungs and diaphragm during linear tomography study

Distance BE between X-Ray tube and digital receptor is 1 m. We choose a point on the X-ray stereoimage, which corresponds to the surface of the diaphragm of the cat. On the basis of three stereo images of the respiratory pause, the coordinate along the depth of the sought-for point is 462 mm.

Then two movements were singled out: inhalation and exhalation. They were considered separately. On exhalation the diaphragm of the cat moved in the same direction

in which the X-ray tube moved. On exhalation, on the contrary in the opposite direction from the direction of movement of the X-ray tube. For each inhalation and exhalation where analyzed ten X-ray stereo images in which the organ displacement is maximally.

For measured result ratio error for anatomical object is calculated as 3,8 and 4,8%. As seen for exhalation when sought point of the moving organ moves in the same direction as the X-Ray tube moves absolute error is less than in situation when sought point moves in the opposite direction than X-Ray tube moves.

It should be noted that the errors in the measurement of linear dimensions by existing modern cone beam computed tomography units can be higher than in the above experiment: Galileos (Sirona Dental Systems, GmdH, Bensheim, Germany): 0,57 - 8,57%, Promax 3D (Planmeca Oy, Helsinki, Finland) 3,29 - 5,23% [2].

Conclusions

Patient's X-ray dose can be decreased in dozen times with stereo X-ray imaging. But the main disadvantage that need determination is the possibilities of object's size measurements based on obtained stereo model.

Proposed common stereo cursor forming model allows to solve measurement sum in imaginary 3D volume, which determinates necessity of experimental researches. The proposed method makes it possible to objectively evaluate the possibility and accuracy of measured by operators sizes of investigated objects.

Geometrical and anatomical test objects were measured. Rectangular parallelepiped geometrical measurements of imagined stereo model is 66,16 ± 1,2 mm, measured ratio error – 1,8%. Measured depth distance for imagined anatomic stereo model is equal to 50,31 ± 7,3 mm. Measured depth distance for anatomic test object is 185,6 ± 27 mm, ratio error – 14,5 %. Obtained higher ratio error for anatomic test structures explained by roundness and smoothness of anatomical organs and structures compared to geometrical test objects.

With the use of the proposed method, the errors in determining the depth coordinate of the sougth point of the mobile organ are experimentally measured. The proposed method can be used for the geometric measurement of mobile organs, in order to provide the physician with additional diagnostic information Errors in linear dimensions measurements in stereo X-Ray imaging arise as a result of non-simultaneous acquisition of stereopair images. For a frame rate of 10 Hz or more, on which modern cone beam and linear tomography units operate, and the frequency of organ contractions of 1 Hz, errors in measurements of dimensions do not exceed 5%, which in most cases is acceptable in practice.

The measurement errors in the current study are comparable to cone beam computed tomography [2] that is satisfactory for most medical diagnostics tasks.

References

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