A Scale and Pointer for Observation of the Stereoscopic Magnification Image

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立体拡大像観察のためのスケールとポインター

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立体拡大撮影においては，ある点のフィルム面からの距離と，その点が二枚のフィルム上に撮影される点間の距離との間には一定の関係が成立する．この現象を応用すると，ある一定の間隔をもつ二点，ないし矢印をステレオ像中に一点として観察することが可能である．二点の距離が大きくなればその点はステレオ中で観察者に近づき，小さくなれば遠くなる．異なった間隔をもつ二点の組を多数，上下に排列し立体画像中に観察すると，立体画像のスケールとして用いることができる．二本の矢印を用いると，これを左右に動かすことにより二人が同時に立体像を観察する場合のポインターとすることができる．

In stereoscopic magnification radiography, depths can be calculated using films on the basis of geometric arrangements[5]; however, depth perception is considered relative and measurements have not been attempted within the stereoscopic image[1]. On the basis of the geometry involved in stereoscopic magnification radiography, a pair of rulers was viewed stereoscopically as a scale for measuring the depths of the stereoscopic image.

On the same basis a pair of arrows placed within the stereoscopic image instead of the rulers can function as a pointer for another observer viewing the stereoscopic image simultaneously.

This is a report of the theory and its practical application using a scale and pointer within the stereoscopic image.

Theory

The basic geometry for stereoscopic magnification radiography is shown in Figure 1. Point A within the object is exposed using two focal spots, F_L and F_R, separated by the distance S. Point A

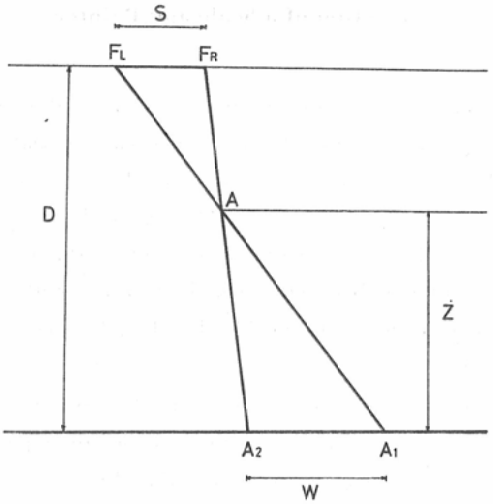

Fig. 1 Geometric arrangements for stereoscopic magnification radiography

FL,FR: Focal spots S: Focal spot separation
A: A point in the object D: Focal-film distance
Z: Distance of point A from the film plane
A_1,A_2: 2 different images of point A on stereoscopic film
W: The discrepancy

is visualized as 2 images on a stereoscopic film pair; A_1 and A_2. The distance between A_1 and A_2 is called the "discrepancy" and is expressed as W. D is the focal-film distance, and Z is the distance between point A and the film plane.

Since the triangles AF_LF_R and AA_1A_2 are similar, we can obtain the following relationship;

$$\frac{W}{Z} = \frac{S}{D-Z}$$

$$W(D-Z) = SZ$$

$$Z = \frac{WD}{S+W} \qquad (1)$$

$$W = \frac{SZ}{D-Z} \qquad (2)$$

From equations (1) and (2), each point within the object has two images on the stereoscopic films, depending on the depth or distance of that point from the film plane. Each point on a plane parallel to the film plane reveals the same discrepancy or W, which is independent of the distance of the point from the center of the X-ray beam.

When the discrepancy is known, the depth of the point from the film plane is determined from equation(1). When the distance of the point from the film plane is known, the discrepancy is calculated using equation(2).

Two points with a given discrepancy can be viewed as a single point in the stereoscopic image. When the discrepancy is relatively large, the point in the stereoscopic image is closer to the observer. When the discrepancy is relatively small, it appears farther away.

Construction of a Scale and Pointer

1) Scale

A pair of rulers were marked according to the differences in the discrepancy. The marks on the rulers were arranged in a stepladder fashion and placed symmetrically so that they were not superimposed in the stereoscopic image. The interval between marks was 2 cm, in depth, and the corresponding discrepancy for the 2 cm was calculated using equation (2). S and D are 3.5 cm and 90 cm, respectively, on our unit[3)4)5)] (Table 1). The magnification factor and the difference in the discrepancy is also shown in Table 1. The 2 cm interval between marks indicating depths (2) reflected the difference between the corresponding discrepancies, multiplied by 1/2 (Fig. 2). The factor 1/2 corresponds to the difference shared by the two rulers.

When these rulers were observed in the stereoviewer, the dots with greater discrepancy were visualized closer to the observer, whereas the dots with a smaller discrepancy were visualized farther away (Fig. 3). The image which corresponded to the dots Z at 45 cm or W at 3.5 cm, is in the middle plane of our radiographic system[3)4)5)]. The rulers were placed on the films and viewed stereoscopically with the films. The actual separation of the dots in this instance was a summation of the film size, the space between the films, and the discrepancy (3.5 cm) (Fig. 2). The remaining dots had a similar relationship except for the discrepancy.

The rulers were moved on the film maintaining this distance (Fig. 4), that is, they were moved on the films with reciprocal relationship to the fixed dots. They were placed on the lesion or site where a

Table 1. Relationship of depth from film plane (Z), magnification factor (M) and discrepancy (W).

Z (cm)	M	W (cm)	Difference of W (cm)
25	1.39	1.35	
			0.15
27	1.43	1.50	
			0.16
29	1.47	1.66	
			0.18
31	1.52	1.84	
			0.19
33	1.58	2.03	
			0.20
35	1.64	2.23	
			0.21
37	1.70	2.44	
			0.24
39	1.77	2.68	
			0.25
41	1.84	2.93	
			0.27
43	1.91	3.20	
			0.30
45	2.00	3.50	
			0.33
47	2.09	3.83	
			0.35
49	2.19	4.18	
			0.40
51	2.31	4.58	
			0.43
53	2.43	5.01	
			0.49
55	2.57	5.50	
			0.55
57	2.73	6.05	
			0.61
59	2.90	6.66	
			0.70
61	3.10	7.36	
			0.81
63	3.33	8.17	
			0.93
65	3.60	9.10	

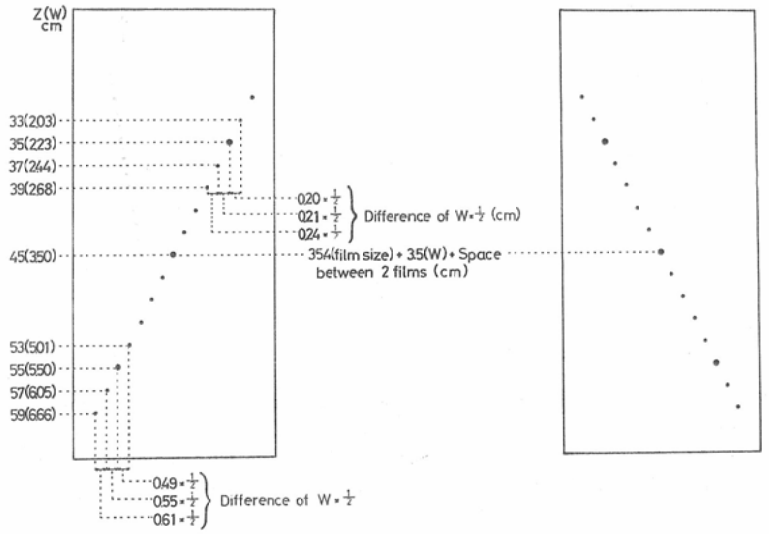

Fig. 2 Arrangements of dots and arrows for the scale and the pointer. The method of marking the dots on the ruler is shown

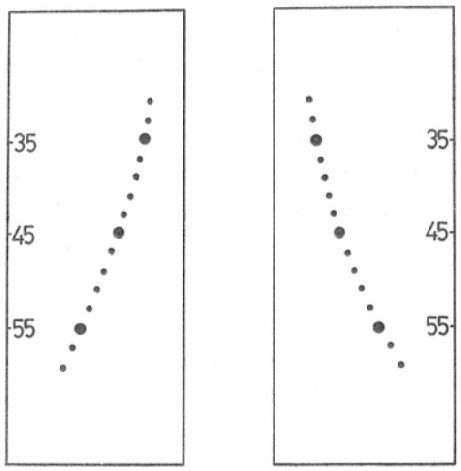

Fig. 3 A pair of rulers with dots arranged in a stepladder fashion. The rulers are viewed as a scale in the stereoscopic image. Each interval between the dots is 2cm in depth. The number indicates Z

measurement was to be made. The approximate size was ascertained by reading the values on the scale.

2) Pointer

One each of pair of small arrows was placed on each stereoscopic radiograph. They were first placed pointing to an anatomical structure or a lesion. The arrows were visualized within the stereoscopic image, pointing to the structure or lesion. When arrows were moved apart on the abscissa, the pointer in the stereoscopic image apparently moved closer to the observer; when the arrows were

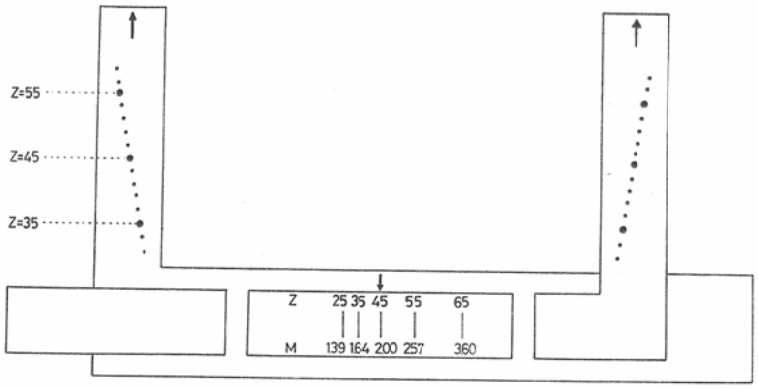

Fig. 4　An instrument with rulers and arrows. The numbers for Z and M are related only to the upper arrows. The structure to which the twc upper arrows point, is present at Z from the film plane with magnification factor of M, as indicated by the lower arrow. The length of the lower arrow is 2 cm

more closely approximated, the pointer apparently moved farther away (Fig. 4).

When, in addition to the film size and the space between the films, there was a separation of 3.5 cm in the size of the discrepancy, the pointer pointed to the midline of the radiographic system, and any structure in this plane was in the midline of the system[3)4)5)]. It was possible to ascertain the approximate depth and magnification factor by placing the arrows on the corresponding lesion or anatomical structure (Fig. 4). This was possible because there was one to one relationship between the size of separation of arrows (that is, the discrepancy), and the magnification factor and the depth.

Therefore, the arrows in the stereoscopic image could be moved in any direction desired. Two or more observers could follow this movement, providing the stereoviewer accommodated more than one observer.

3)　Instrument with a scale and a pointer

A system consisting of a scale and a pointer was constructed, having the above geometric features (Fig. 4). However, the arrangement of the dots was reversed in a mirror image, since our viewing system had a mirror on each side. This unit was easy to operate and was very useful in discussions and in teaching stereoscopic radiography.

4)　Theoretical estimation of error

When there is a small error, ΔW, in the measurement of W, small errors, ΔZ and ΔM, are introduced in calculation of the depth from the film plane, Z, and the magnification factor, M. The following 2 equations have already been established[5)];

$$Z = \frac{DW}{S+W} \tag{1}$$

$$M = 1 + \frac{W}{S} \tag{3}$$

Therefore, we obtain;

$$Z + \Delta Z = \frac{D\,(W+\Delta W)}{S+W+\Delta W} \tag{4}$$

$$M + \Delta M = 1 + \frac{W+\Delta W}{S} \tag{5}$$

By subtracting (4) and (5) from (1) and (3), respectively,

$$\Delta Z = \frac{DS\Delta W}{(S+W+\Delta W)(S+W)} \tag{6}$$

$$\Delta M = \frac{\Delta W}{S} \tag{7}$$

In our radiographic system, S=35, W=40 at 2 times magnification, and D=900 can be substituted and the following equations can be obtained,

$$\Delta Z = \frac{420\Delta W}{75+\Delta W} \simeq \frac{420}{75}\Delta W = 5.6\Delta W \tag{8}$$

$$\Delta M = \frac{1}{35}\Delta W \tag{9}$$

From equation (8), we can conclude that the ΔW, if less than 0.15 mm, can produce an error of less than 1 mm in depth. The equation (9) indicates that the error in W does not give significant error in mangnification factor.

Discussion

In stereoscopic radiography, numerous factors relate closely to the stereoscopic image and can be classified in two groups. One related to the geometry of the radiographic system, includes focal spot separation, focal-film distance, and the position of an anatomical structure or lesion within the body. The other, related to viewing, consists of the viewing distance, interpupillary distance, and the observer's ability to accommodate and converge. The latter varies by observer.

Since the precise geometry of stereoscopic radiography cannot be achieved in contact stereoscopic radiography, stereoscopic depth perception has been termed "relative" in that it merely determines which of two objects is closer to the observer[1]. However, with stereoscopic magnification radiography, the geometric arrangements are advantageous and precisely known for accurate calculation of various factors. If these factors remain constant, a pair of rulers and arrows, calculated from basic arrangements, may be viewed stereoscopically using the pertinent stereoscopic films, providing a scale or a pointer within the stereoscopic image.

The most important theory behind this report relates to the relationship of the discrepancy of a point and its depth from the film plane[5]. This relationship is independent of the distance from the center of the radiation exposure field. Using this theory, the depth can be graduated in 2 cm increments according to the discrepancy of the point on 2 stereoscopic films. On this basis, a pair of rulers was used to measure approximate depths. Since a 2 cm depth corresponds to a smaller discrepancy on the films, the scale is not highly accurate, but this method can be used as a standard for approximate measurements.

In viewing the stereoscopic image, a pointer is an important tool for discussions and teaching. A pointer was designed for these purposes, using the above theory of stereoscopic magnification radiography. It is possible to point out a lesion or an anatomical structure quite efficiently within the stereoscopic image.

In stereoscopic magnification radiography, it has been found that the magnification factor at various points in an object can simply be determined by measuring the discrepancy of the point[5]. Sizes of small lesions or structures can be calculated. In this study, the depth and magnification factor of a given point or a lesion was calculated by introducing the discrepancy on 2 stereoscopic films.

On stereoscopic magnification radiography, the precision of the measurements may be influenced by the focal spot size, focal spot separation, focal-film distance, tube positions and measurements on films[5]. These factors except measurements on films, however, can be completely fixed and constant when the radiographic geometry is precisely obtained.

The influence of the focal spot size is not great since the focal spot is small compared with the focal spot separation. Physical estimation of error in measurement on our system has been determined and has been found to be considerably small. Therefore, measurements on films may introduce major inaccuracies. In our previous report[5], the overall measurement error on our system was found to be within ± 1 mm when a small metallic object was radiographed with 0.1 mm focus at FFD of 90 cm and 2 times magnification.

The scale and pointer has been very useful in the interpretation of stereoscopic radiographs, especially in education and discussions. With increasing use of stereoscopic magnification angiography[2)3)], the system described in this report will have important significance in the future.

We are now developing equipment capable of automatically interpreting the position, size and length of a lesion on two stereoscopic radiographs[5]. This unit is equipped with the scale and pointer described in this report.

Summary

In stereoscopic magnification radiography, an equation has been advanced concerning the distance of a given point from the film plane and the distance between two images of the point on the stereoscopic film pair. According to this relationship, a pair of rulers marked at 2 cm intervals for depths were developed to measure the stereoscopic image. This scale provided estimates of the size of a lesion visualized stereoscopically. Based on the same theory, a pair of arrows has been viewed stereoscopically as a pointer, and has proved useful in teaching and discussions.

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