นิพนธ์ต้นฉบับ • Original Article

ต้นแบบระบบที่ง่ายและแม่นยำสำหรับการวัดขนาดที่แท้จริงของวัตถุจากภาพฟิล์มเอกซเรย์

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A Prototype of an Accurate and Simple System for the Measurement of Actual Object Size from Roentgenographic Images

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หลักการและวัตถุประสงค์: การวัดขนาดที่แท้จริงของวัตถุจากภาพฟิล์มเอกซเรย์เป็นสิ่งที่ทำได้ยาก เนื่องจากกำลังขยายของภาพ (magnification) ที่ไม่คงที่ คณะผู้วิจัยจึงได้พัฒนาต้นแบบระบบที่ง่ายและแม่นยำสำหรับการวัดขนาดที่แท้จริงของวัตถุบนภาพฟิล์มเอกซเรย์

วิธีการศึกษา: คณะผู้วิจัยได้ออกแบบและพัฒนาต้นแบบฯ ที่ประกอบไปด้วยไม้บรรทัดอ้างอิงที่สะดวกต่อการใช้งาน มีต้นทุนต่ำ และซอฟต์แวร์ที่สามารถวัดขนาดของวัตถุบนภาพฟิล์มเอกซเรย์ได้ถูกต้องแม่นยำ การศึกษาได้ทำการทดลองต้นแบบฯทั้งในกรณีที่กำหนดระยะห่างระหว่างวัตถุ-ฟิล์มคงที่ และกำหนดระยะห่างระหว่าง x-ray tube – ฟิล์ม คงที่ จากนั้นทำการเปรียบเทียบผลที่ได้จากการวัดขนาดวัตถุบนฟิล์มเอกซเรย์ด้วยซอฟต์แวร์ และการวัดขนาดของวัตถุจริง

ผลการศึกษา: ผลจากการทดลองพบว่า ต้นแบบฯสามารถวัดขนาดวัตถุได้ถูกต้องแม่นยำมากกว่าร้อยละ 90 โดยไม่มีความแตกต่างกันระหว่าง intraobserver และ interobserver

สรุป: ต้นแบบนี้มีประสิทธิภาพให้ความถูกต้องแม่นยำ ง่ายต่อการใช้งาน และเสียค่าใช้จ่ายน้อย ทำให้มีความเหมาะสมในการนำต้นแบบนี้ไปใช้งานในโรงพยาบาลทั่วไป

คำสำคัญ: การวิเคราะห์รูปภาพทางการแพทย์ 2 มิติ, การประมวลผลรูปภาพทางการแพทย์, กำลังขยายของภาพทางการแพทย์, การคำนวณขนาดที่แท้จริง

Background and objective: The magnification in an x-ray image is generally accepted; however, the finding of an actual size of an object from the x-ray image is often difficult. Using the prototype of an accurate and simple system for finding an actual object size in x-ray images can ease the difficulties. Thus, the researchers created the prototype of an accurate and simple system for finding an actual object size in x-ray images.

Methods: The researchers have developed a reference ruler and software. The two methods of taking X-ray images are as follow; fixed object-film distance and fixed x-ray tube-film distance. Then, the results from the prototype were compared to the actual size of the objects.

Results: The experimental results were more than 99 percent accurate. There were no differences between intraobserver and interobserver.

Conclusion: This prototype is very efficient, accurate, simple and cost effective. It should be suitable for all hospitals.

Keywords: 2D Medical image analysis, Medical image processing, Magnification of medical image, Computerized actual size

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Introduction

Conventional roentgenography, or x-ray image is normally used as a routine and standard investigation to diagnose diseases in most of medical specialty; nevertheless, in some medical specialty, especially in orthopaedics, the surgeons need more accuracy in measuring for osteosynthesis and prosthesis implantation.

Images from the x-ray are usually accepted to be 10-20% in magnification[1-5]; however, there are two main factors which impact the magnification. (Figure 1)[6-8]

1. Variation of the distance from the object to the film.
2. Variation of the distance from the x-ray tube to the film.

The variation of the distance from the object to the film is caused by the size and position of the patient's body which causes the bone to appear on the film at a certain distance for each patient; on the other hand, the variety of the distance from the x-ray tube to the film is usually caused by human errors.

We developed the accurate and simple technique for measuring the actual object size from roentgenographic images.

Materials and Methods

There are two main parts of the materials;

1. Reference ruler: The reference ruler is made from a radio-opaque metal rod. The rod is 5 centimeters long, segmental marked, and equipped with a height and incline adjustable stand. (Figure 2)
2. Software: The software is originally developed by the researchers to operate under Microsoft Windows XP Professional and Microsoft Visual Basic. NET, MATLAB 7.0 to connect to Microsoft Access 2003.

The reference ruler is placed at the same level of the object while the roentgenography is being taken. Then, the image was transferred to the software by all kinds of digital cameras. The software will automatically identify each segment of the reference ruler from the image to calibrate for an actual image size of each area[9-11].When the observer marks two points on the object image; the software will report an accurate result promptly. This measuring can be repeated and recorded multiple times. The results recorded previously can also be shown at the same time. (Figure 3)

A.

B.

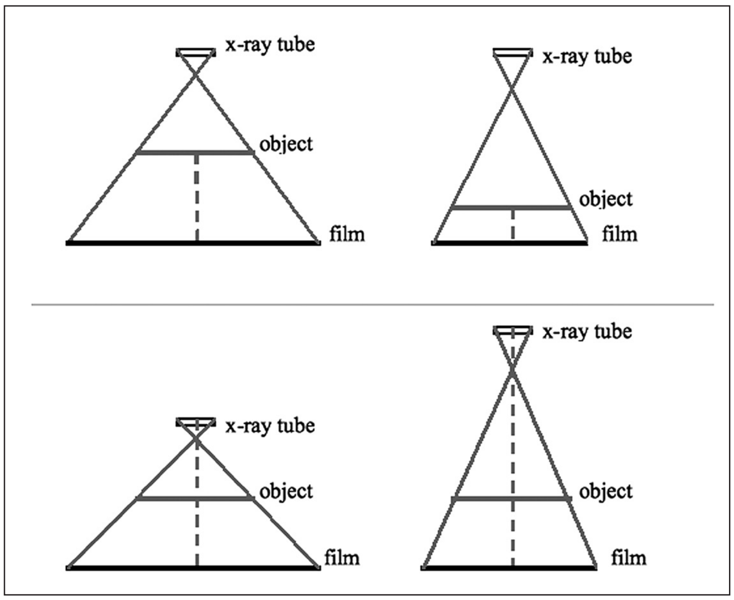


Figure 1 Two factors which influence the magnification
A. The variation of the distance from the object to the film
B. The variation of the distance from the x-ray tube to the film

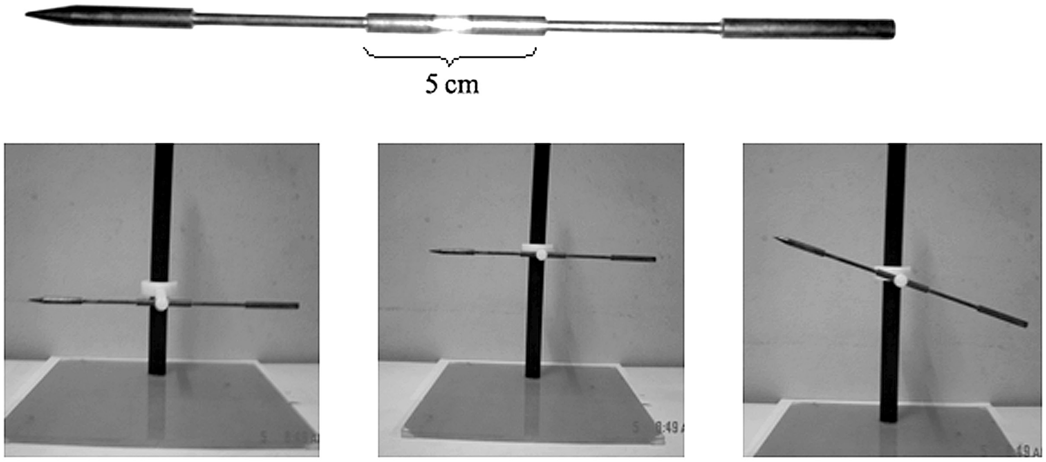


Figure 2 Reference ruler, height and incline adjustable stand

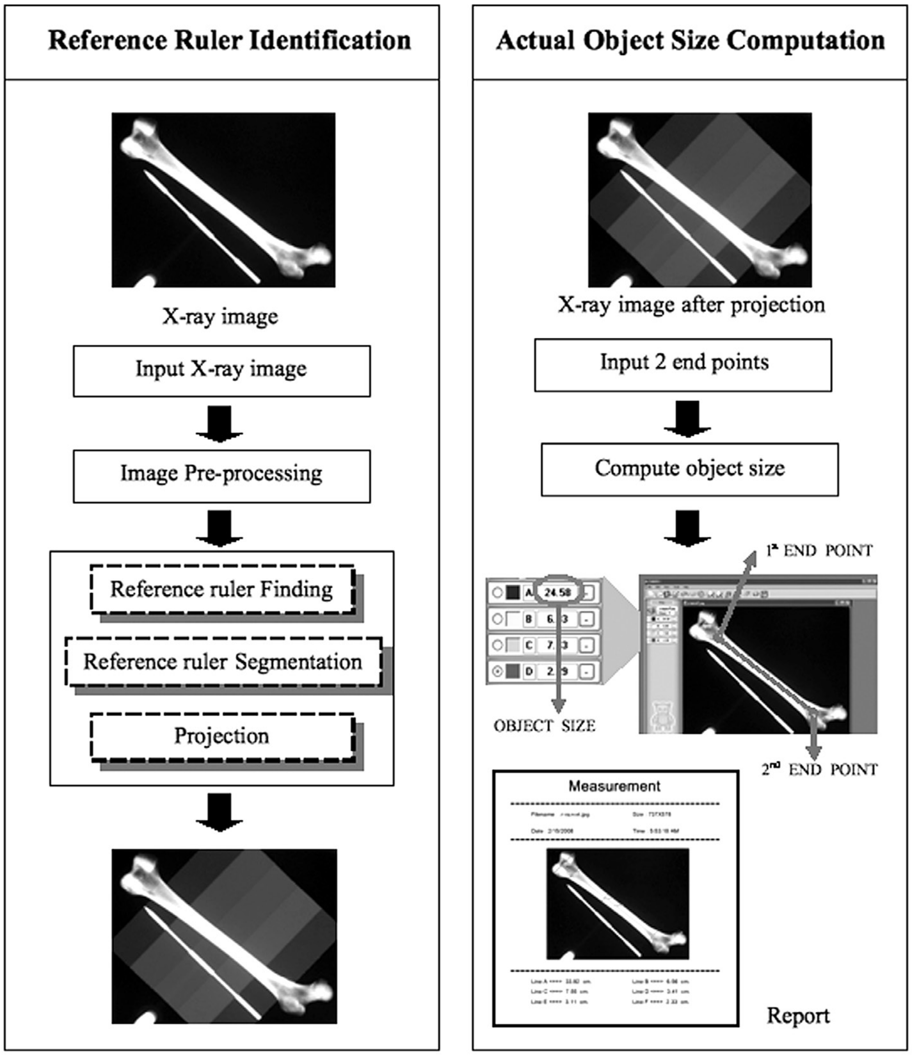
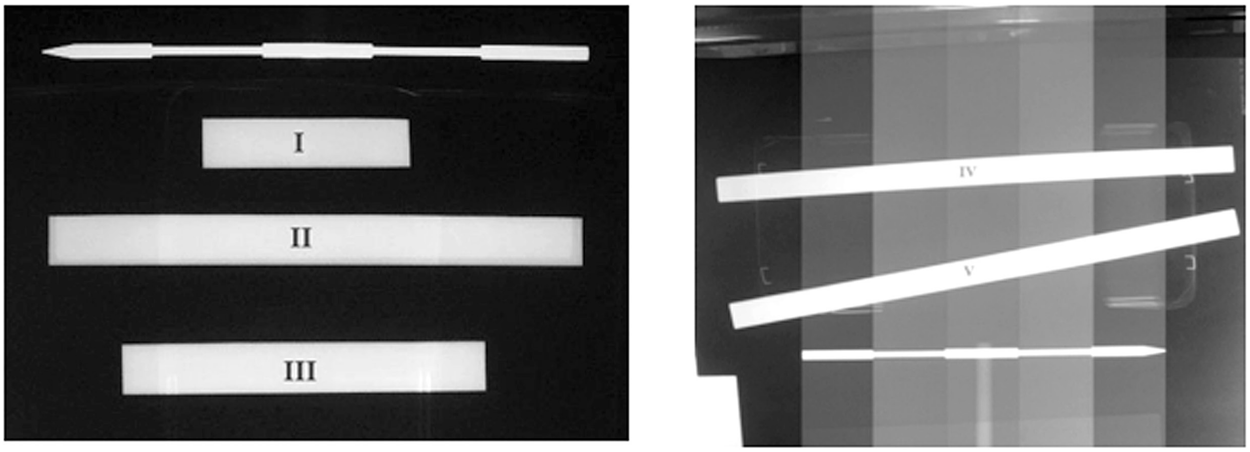


Figure 3 The processing steps of the software



A B

Figure 4 Some of experimental x-ray pictures containing multiple known sized objects with the same width but different in lengths and are placed in various directions. The width of the rectangular images in figure A and B are different which correspond to the schematic effect as shown in figure 1.

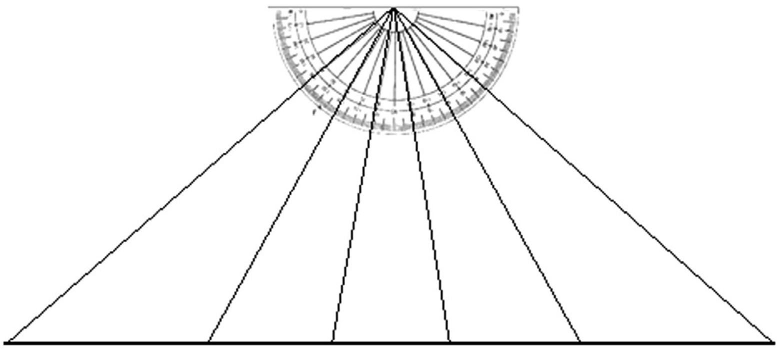


Figure 5 The magnification on x-ray film

Methods

Thirty X-ray images of multiple rectangular metal plates were taken. All plates had the same width but differ in lengths. The lengths of the plates were both shorter and longer than the reference ruler rod and were taken in various directions. Two experiments were taken; first, fifteen images were taken with a variation of distances between the object and the X-ray film, whilst the distance between the X-ray tube and the film was fixed. Another fifteen were taken with a variation of distances between the x-ray tube and the film, whilst the distance between the object and the film was fixed. (Figure 4)

The objects in each image were measured by 3 observers 3 times each. Each measurement required each observer to measure the objects in 3 different dimensions; parallel, perpendicular and oblique to the reference ruler. The results were compared to the size of the real object and reported by percentage of the actual size. All of the data were analyzed by using one-way ANOVA (p-value < 0.05).

Results

The accuracy of comparisons between computerized object image and the real object were shown in table 1 and 2.

There were no statistically differences between data that obtained from direct measurements and computerized measurements in all directions. The reliability of the intraobserver and interobserver from the 3 observers showed excellent correlation ($r \geq 0.99$).

Table 1 Experiment I : Fixed object-film distanace

Direction of measuring	Percent of the actual size of the defect									Overall average
	First observer			Second observer			Third observer			
Parallel	99.80	99.81	99.80	99.82	99.81	99.80	99.80	99.81	99.81	99.81
Perpendicular	99.50	99.52	99.51	99.53	99.51	99.50	99.50	99.52	99.51	99.51
Oblique	99.15	99.16	99.14	99.17	99.16	99.11	99.16	99.17	99.15	99.16

Table 2 Experiment II : Fixed x-ray tube-film distance

Direction of measuring	Percent of the actual size of the defect									Overall average
	First observer			Second observer			Third observer			
parallel	99.78	99.76	99.75	99.77	99.76	99.75	99.75	99.77	99.75	99.76
Perpendicular	99.52	99.54	99.53	99.55	99.53	99.55	99.56	99.54	99.55	99.54
Oblique	99.26	99.25	99.23	99.27	99.26	99.26	99.25	99.24	99.25	99.25

Discussion

The magnification on the x-ray film increased continually from center to periphery (Figure 5). This prototype concentrated on this intensification and detected the magnification of each area on the film and also calculated the magnification power of the area beyond the reference ruler. Thus, the object image size from this prototype is very accurate and reproducible. There were no differences between intraobserver and interobserver and nor to the factors which impact the magnification. Consequently, the problems mentioned above can be easily resolved. Clark et al[1] mentioned about problems with x-ray reference rod; the practical limitations were that an extra step was added to the radiographic procedures, the rod was sometimes poorly delineated on hip radiographs, and with the more obese patient there was not always room on the radiograph to depict the lateral aspects of the thigh and the reference rod. Avoiding the problem mentioned above, the reference ruler developed here is very thin, compared to regular rulers in the market[12], and even though for the patient with larger body figure, the adjustable stand can be placed outside of the film cassette and can be easily adjusted to parallel with the object, while the ruler will still be shown on the x-ray film. In spite of that, the body figures of Asian people are usually smaller and slimmer than Caucasians or Hispanics. In this manner, there is plenty of room for both the reference ruler and the patients' body to present on the film even when taking an x-ray of the chest or pelvis.

This prototype is very cost effective and simple; ordinary offices can by no means afford this program and apply it to use effectively. The reference ruler rod can also be made by a regular casting machine which can tremendously reduce the cost compared to buying an expensive x-ray ruler in the market[12]. Before the final reference ruler was made, we have made a reference ruler by placing an opaque marker on the ordinary ruler which seemed to reduce the cost, but the marker usually caused an opaque area and often didn't pinpoint on the x-ray film which led to inaccuracies and the ordinary ruler usually large. This prototype will be suitable for every hospitals and clinics with very low budget especially in Asia. The next step to improve this prototype is to develop it to be able to measure curve and round objects and to convert the images from two plain conventional images into 3 dimensions.

Conclusion

This prototype is very effective and user friendly. It is very simple, cost effective, and accurate in measuring the size of the objects from x-ray images.

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