

Fiber Length Measuring System with a Digitizer and a Microcomputer*

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(Accepted November 16, 1985)

Abstract—A fiber length measuring system was constructed and totally examined. The system is consisted of a projecting apparatus and a digitizer connected with a 8-bit microcomputer. They are supported by softwares listed in this paper. Their functions are briefly summarized as follows. Fiber lengths are recorded both on a printer and on a diskette by means of tracing fiber images which projected on the digitizer. The recorded lengths in a sample lot are then processed to a mean, minimum and maximum length, variance, standard deviation, and frequency distribution of the length at 0.3 mm intervals. These statistical values, including a mean of fiber lengths, in respective samples are automatically plotted against tree ages. In addition, the frequency distribution at every annual rings are printed in a three-dimensional manner. This system was effective and accurate enough (resolution ca. 0.2 mm on a sample specimen) for measuring fiber length, and was able to be constructed at a reasonable price.

Introduction

Cell dimensions, especially fiber or tracheid lengths, have often been measured as a factor which evaluates wood and pulp qualities¹⁾. However, the conventional methods are time-consuming and tedious, forcing us to eye-strains, and troublesome data-calculations, etc. Another defect is that the methods are difficult to fit the streight line of a micrometer-scale to the fiber images correctly when they are curved. In other words, experimental errors might be considerably large in the conventional methods²⁾.

Recent development of electronics technology enables us to introduce new instruments for the measurement, and thus the method is gradually improved^{3~8)}. For example, a digitizer was introduced for measuring fiber length^{6,7)}, and a Fiber Size Analyzer was also developed⁸⁾. In the latter case, respective fiber lengths are obtained when the fibers are running through a capillary on which polarized light is illuminated. Although this method achieves rapid measurement

* This system, which tentatively calls FILMS (Fiber Length Measuring System), was used in ref 2) and the user's mannual was presented in ref 13).

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of fiber lengths, it cannot avoid the detrimental counting of overlapped or broken fibers. In addition, an expensive instrument is required for the method. This method, therefore, will be unsuitable for a specific purpose²⁾. In these circumstances, we developed a fiber measuring system with a digitizer and a microcomputer, which was accurate enough, inexpensive and able to be handled by an unexperienced person.

Present paper describes the hardware systems for fiber length measurement, in addition to the softwares which developed for controlling the system. An instruction manual for the system was already presented (in Japanese)¹³⁾.

Sample Preparation for Fiber Length Measurement

Wood pieces (match sized) were treated with equal parts of acetic acid and hydrogen peroxide (30%) at 60°C for 2 to 4 days according to Franklin's method⁹⁾. Two mounting methods were examined after the treated pieces were rinsed with tap-water over night.

First: they stained with a domestic dye (Simplikol; dark blue; Browns Heidtmann Inc.; West Germany) at 60°C for a day. After rinsed them with tapwater, the stained pieces were macerated by a glass rod, then fibers obtained were mounted on a slide glass with Apathy's gum syrup (equal parts of gum arabic, sucrose and water). This dye stained samples better than Safranin did.

Second: macerated fibers were directly spread on a Scotch Book Tape #845 and mounted on a frame for slidemounting after they had been air-dried. The frame was able to carry 25–100 fibers according to their length. The images were clearly recognized on the digitizer plane even if without staining, because of the edge effect caused by different refraction indices between the mercerated fibers and air. This simplified method was highly efficient in order to count normal tracheids of Sugi (*Cryptomeria japonica*). Shrinkage of the tracheids was almost negligible comparing to those in the former mounting method.

Image Projection Systems

The prepared specimen described above was put on a projecting system as shown in Figure 1. Figure 1a shows that the image was projected on a digitizer through a closeup photographing stage and a pair of mirrors set at right angle. This system was appropriate to obtain rather high magnification up to ca. 110 fold, while the projection-image obtained were rather dark.

On the other hand, Figure 1b shows that a slideprojector was fixed in downward direction on the top of a frame and the fiber images were directly projected on a digitizer. The projector was correctly adjusted its position by using a slide

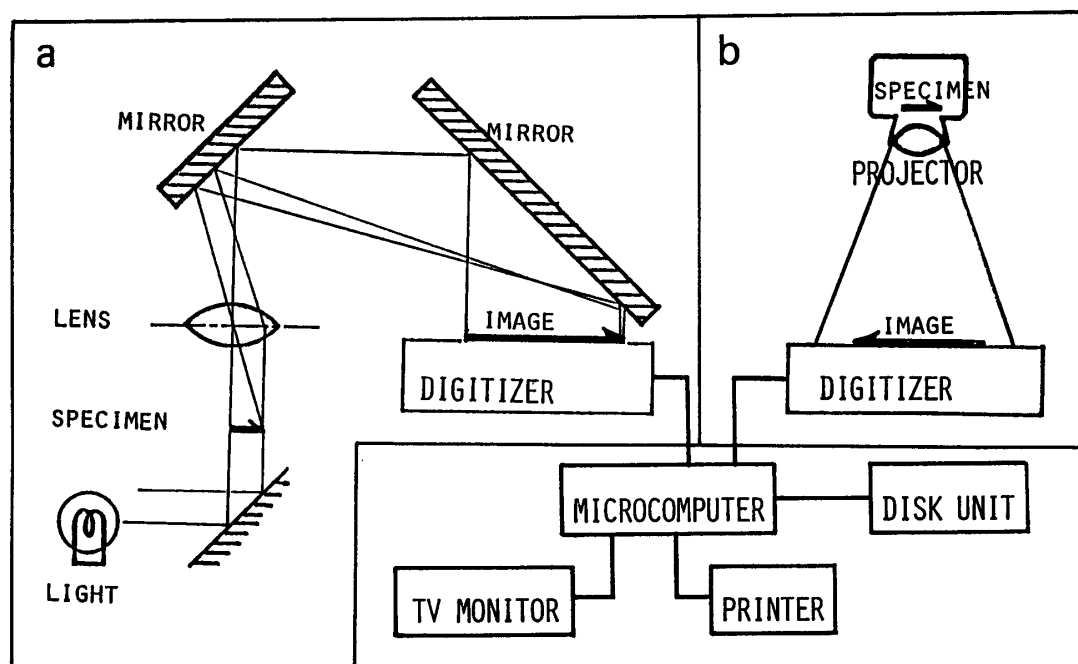


Fig. 1. Projection systems for the fiber images.

Left system (a) is suitable for large magnification, while right system (b) fits the projection of fiber images. Details see in the text.

Table 1. Optical characters of the lenses examined

Lens	f mm	N.A.	F	δ^*
Splan 10X	18.98	0.30		1.12
Zuiko Macro	20		3.5	2.30
Splan 4X	36.16	0.13		2.58
Zuiko Macro	38		3.5	2.30
Cabin III	60		2.8	1.84
Splan 2X	73.42	0.08		4.19
Zuiko Macro	80		4.0	2.63

* $\delta = 0.61\lambda / \text{N.A.} = 1.22\lambda F$ ($\mu\text{m/slit}$), where δ =resolving power, λ =wave length (540 nm), N.A.=numerical aperture, and F = F number. The optical characters of Cabin III (projector lens) show high resolution and brightness.

which ruled into regular squares. Thus, negligible optical distortion was confirmed on the digitizer plane and the image projected were fixed to ca. 17 fold. The lens also has reasonable performance as shown in Table 1, where several lenses examined were summarized. Furthermore, the projector was equipped with bright light source (150W) and was available at low price. Therefore, we concluded that the projector system was superior to the other for projecting fiber images.

Although we set the projector downward in this paper, the horizontal settle-

ment is desirable for that if following apparatuses are available: a translucent digitizer, as reported⁶⁾, on which the fiber images are directly projected, or a popular digitizer, such one as examined here, with a mirror system which is possible to project fiber images on the digitizer at a suitable magnification.

All of the instruments examined here were made in Japan and their performances were briefly summarized as follows: a slide projector (Color CabinIII; lamp 100V, 150W; Cabin Inc.), a close-up photographing stage (Macrophotographing table PMT-35; lamp 100V, 40W; Olympus Inc.), a digitizer (Mitablet DT-1000; effective area 380×260 cm²; resolution 0.1 mm; Graph-tek Inc.), a microcomputer (NEC PC8001MKII; CPU 8-bit, μ PD780), a monitor (NEC PC8050K; 12 inch CRT; 640×200 pixels), a disk unit (Epson TF-20; 5-inch, 2-drive), a printer (Epson RP80; 9×9 dot matrix for a character).

Fiber Length Digitizing System

A few different manners may be available for digitizing a fiber length in the system. Popular one is to count the numbers of crossing-points of the fiber images with gridlines set in a definite area, and is applied to morphometric cytology¹⁰⁾. By means of this manner, a fiber length is obtainable as a mean of a sample lot, while a frequency distribution of the lengths is not directly derived. In order to obtain a frequency distribution of the length, we employed an alternative manner to digitize fiber images as mentioned in a following paragraph.

A fiber image on a digitizer was converted to a series of digital point-coordinates along the image by tracing it. The signals were transmitted to a 8-bit microcomputer as ASCII codes via RS232C cable. The coordinates digitized (X_i, Y_i) were processed to a length by an equation $\sum_i^n \sqrt{(X_i - X_{i-1})^2 + (Y_i - Y_{i-1})^2}$. This equation tells us that the image resolution depends on numbers of the digital coordinates converted on the digitizer.

In order to survey an optimal condition for the conversion rate, several rates were tested by means of tracing 10 cm of a line (repeated five times) on the digitizer. A series of coordinates thus digitized were shown as five dotted-lines in Figure 2. As expected, the numbers of converted points increased when the setting rate was increased. However, processings by a microcomputer (conversion of digital points to a length) took rather long time, if the many points were converted at the same time. In addition, this situation may bring inaccurate length, because, in addition to reading errors, it counts a lot of protruded points along an image traced.

In these contexts, well-balanced dottedlines were in the combination of 9600 baud rates/second for the transmission rate and 4–10 data/second with width mode (see foot-note of Figure 2) for the conversion rate. This combination showed that 14–28

CONVERSION RATE: 2 data/sec				
1	L =	99.20 mm	8 points	.....
2	L =	99.50 mm	10 points	.....
3	L =	98.01 mm	10 points	.....
4	L =	98.91 mm	10 points	.....
5	L =	99.21 mm	12 points	.....
CONVERSION RATE: 4 data/sec				
1	L =	98.94 mm	17 points	.....
2	L =	99.61 mm	22 points	.....
3	L =	99.00 mm	18 points	.....
4	L =	99.31 mm	19 points	.....
5	L =	99.50 mm	17 points	.....
CONVERSION RATE: 10 data/sec				
1	L =	98.32 mm	38 points	.....
2	L =	99.29 mm	50 points	.....
3	L =	99.03 mm	34 points	.....
4	L =	98.81 mm	36 points	.....
5	L =	98.92 mm	40 points	.....
CONVERSION RATE: 35 data/sec				
1	L =	97.72 mm	56 points	.....
2	L =	99.23 mm	62 points	.....
3	L =	99.63 mm	59 points	.....
4	L =	99.32 mm	62 points	.....
5	L =	100.14 mm	60 points	.....

CONVERSION RATE: 2 data/sec*				
1	L =	100.21 mm	10 points	.....
2	L =	99.00 mm	9 points	.....
3	L =	99.11 mm	11 points	.....
4	L =	99.51 mm	9 points	.....
5	L =	99.40 mm	8 points	.....
CONVERSION RATE: 4 data/sec*				
1	L =	99.50 mm	16 points	.....
2	L =	100.20 mm	14 points	.....
3	L =	98.31 mm	13 points	.....
4	L =	98.31 mm	14 points	.....
5	L =	99.21 mm	15 points	.....
CONVERSION RATE: 10 data/sec*				
1	L =	97.41 mm	23 points	.....
2	L =	99.31 mm	24 points	.....
3	L =	99.71 mm	27 points	.....
4	L =	98.50 mm	33 points	.....
5	L =	99.82 mm	33 points	.....
CONVERSION RATE: 35 data/sec*				
1	L =	99.81 mm	41 points	.....
2	L =	99.61 mm	45 points	.....
3	L =	98.62 mm	43 points	.....
4	L =	100.01 mm	44 points	.....
5	L =	99.13 mm	40 points	.....

Fig. 2. Points read by a digitizer in the different conversion rates.

A line from left to right shows: tracing numbers (1-5), lengths found (L), digitized points per 10 cm, the digitized points printed. Details see in the text. * the conversion rates with width mode (the conversion starts only if the cursor moves more than 0.1 mm on the digitizer).

dots/10 cm were digitized by the system. In other words, the data were processed at 0.2-0.4 mm intervals along a fiber on a sample specimen because magnification was 17 fold. The resolution is enough to trace strongly curved fiber images.

Respective lengths were then modified to a real length according to the magnification fold. The lengths thus obtained were recorded both on the diskette and printer, with the date and time under working. An example is shown in Figure 3a. All of the processes mentioned above is controlled by a software presented in PROGRAM LIST 1.

The memorized data were then processed in order to obtain a mean, minimum

```

a
sample.name(magnification): 16a19( 17.05 )      83/09/13  14:52:28
2.54 2.78 2.97 2.57 2.70 2.74 2.45 2.21 2.68 2.49 2.45 2.31 2.85 2.59 2.50 2.74
2.46 2.39 2.69 2.46 2.73 2.86 2.66 2.31 2.97 2.27 2.94 2.38 2.43 2.56 2.54 2.21
2.83 2.52 2.42 2.97 2.90 2.42 2.55 2.78 2.29 2.51 2.43 2.67 2.75 2.63 2.64 2.64
2.62 2.77 2.81 3.15 2.99 2.38 2.34 2.96 2.68 2.70 2.82 2.41 2.37 2.81 2.76 2.60
2.38 2.32 2.97 2.74 2.33 2.46 2.30 2.48 2.40 2.46 2.99 2.53 2.85 2.12 2.31 2.37
2.38 2.36 2.69 2.39 2.52 2.57 3.04 2.31 2.43 2.51 2.70 2.61 2.51 2.47 2.17 2.30
2.75 2.60 2.46 2.72

sample.name(magnification): 16a20( 17.05 )      83/09/13  15:09:55
2.47 2.47 2.43 2.35 2.72 2.24 2.59 2.48 2.48 2.45 2.34 2.52 2.39 2.31 2.75 2.73
2.75 2.38 2.41 2.86 2.14 2.44 2.63 2.45 2.34 2.08 2.40 2.79 2.90 2.58 2.58 3.01
2.76 2.18 2.46 2.49 2.50 2.80 2.90 2.78 2.71 2.58 2.59 2.64 2.87 2.93 2.32 2.52
2.80 2.53 2.38 2.37 2.36 2.87 2.75 2.79 2.82 2.76 2.71 2.88 2.95 2.62 2.77 2.63
2.73 3.07 2.64 2.34 2.49 2.53 2.78 2.45 2.46 2.55 2.70 2.61 2.84 2.62 2.58 2.31
2.94 2.73 2.82 2.39 2.39 2.60 2.41 2.72 2.83 2.53 2.78 2.48 2.47 2.66 2.94 2.64
2.65 2.76 2.70 3.13

b
file.name(magnification): 16a19(17.05)
2.54 2.78 2.97 2.57 2.70 2.74 2.45 2.21 2.68 2.49 2.45 2.31 2.85 2.59 2.50 2.74
2.46 2.39 2.69 2.46 2.73 2.86 2.66 2.31 2.97 2.27 2.94 2.38 2.43 2.56 2.54 2.21
2.83 2.52 2.42 2.97 2.90 2.42 2.55 2.78 2.29 2.51 2.43 2.67 2.75 2.63 2.64 2.64
2.62 2.77 2.81 3.15 2.99 2.38 2.34 2.96 2.68 2.70 2.82 2.41 2.37 2.81 2.76 2.60
2.38 2.32 2.97 2.74 2.33 2.46 2.30 2.48 2.40 2.46 2.99 2.53 2.85 2.12 2.31 2.37
2.38 2.36 2.69 2.39 2.52 2.57 3.04 2.31 2.43 2.51 2.70 2.61 2.51 2.47 2.17 2.30
2.75 2.60 2.46 2.72
frequency      : 0 0 0 0 0 0 0 0 24 46 28 2 0 0 0 0
sample number  :100
average length : 2.5805
minimum length : 2.1216
maximum length : 3.1488
variance       : 0.0498
standard deviation: 0.2232

file.name(magnification): 16a20(17.05)
2.47 2.47 2.43 2.35 2.72 2.24 2.59 2.48 2.48 2.45 2.34 2.52 2.39 2.31 2.75 2.73
2.75 2.38 2.41 2.86 2.14 2.44 2.63 2.45 2.34 2.08 2.40 2.79 2.90 2.58 2.58 3.01
2.76 2.18 2.46 2.49 2.50 2.80 2.90 2.78 2.71 2.58 2.59 2.64 2.87 2.93 2.32 2.52
2.80 2.53 2.38 2.37 2.36 2.87 2.75 2.79 2.82 2.76 2.71 2.88 2.95 2.62 2.77 2.63
2.73 3.07 2.64 2.34 2.49 2.53 2.78 2.45 2.46 2.55 2.70 2.61 2.84 2.62 2.58 2.31
2.94 2.73 2.82 2.39 2.39 2.60 2.41 2.72 2.83 2.53 2.78 2.48 2.47 2.66 2.94 2.64
2.65 2.76 2.70 3.13
frequency      : 0 0 0 0 0 0 0 1 18 42 36 3 0 0 0 0
sample number  :100
average length : 2.6073
minimum length : 2.0752
maximum length : 3.1312
variance       : 0.0449
standard deviation: 0.2119

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Fig. 3. An example of the data printed out.

In the upper part (a), sample name, date, time, and the 100 of fiber lengths (unit: mm) measured are memorized on a sheet of printer paper. In addition to the sample name and lengths, their processed data are also printed in the lower part (b). Details see the text.

and maximum values, variance, standard deviation and frequency distribution of the respective populations. These statistical data were memorized on a diskette and printed as shown in Figure 3b. This process is controlled by a software presented in PROGRAM LIST 2.

The statistical values of fiber length above mentioned were automatically plotted against tree ages by PROGRAM LIST 3. The software also printed the frequency distribution at every annual rings in a three-dimensional manner. An

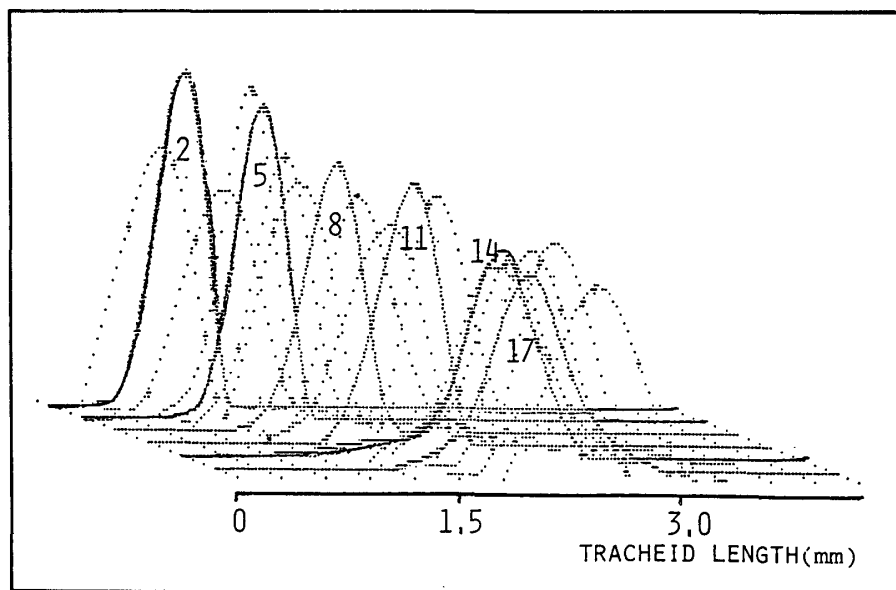


Fig. 4. Frequency distribution of fiber lengths against tree ages. The frequency distribution of fiber (tracheid) lengths is drawn against a series of the annual rings as a three dimensional manner. The figures in the curves show the ring numbers. The distribution became wide from the pith to outer rings.

example of the graphics is shown in Figure 4.

Remarks in The Program Lists

N₈₀ BASIC was used as the programing language¹¹⁾, which is based on the BASIC of the Microsoft family. The programing aimed at the sentences that were as easy to understand as possible rather than high processing-speed.

PROGRAM LIST 1, named "filmsmemory", is developed for controlling digital conversion of the point-coordinates which located on the digitizer, for calculating a lenght from the coordinates, and for saving the lengths in a sample lot. Maximum sampling numbers are able to be set by changing a figure of L and S in the list numbers 120 and 290. In this case, it is 100 at maximum. The figure of MG in the list number 290 can be resetted according to the magnification of the projection image. When fiber images are necessary to be presented on a CRT, rem (') should be removed from the list numbers 420 and 425. The image-presentation, however, resulted in the slowdown of processing speed, and the operator had to wait for a while for counting a next fiber.

Concerning to RS-232C port in list numbers 520-660, a vector for the interruption is set in list number 530. The sentense in the list number enabes interruption and interrupts current register. The port is intialized by the command

“init% 1,-” in the number 540. Four cursor buttons on the digitizer are recognized by the flag F in the subroutine: cancellation of a fiber length after digital conversion (F=8), counting a next sample lot (F=4), memorization of a fiber length (F=2) etc.

PROGRAM LIST 2, named “filmsprint”, is developed for summarizing fiber lengths in each sample lot as mentioned before. After running this program, the diskette, which memorized data files of the lengths by the PROGRAM LIST 1, have to insert in the drive number 2 of a disk unit. The summarized data will be memorized on the diskette in drive number 1. The numbers of sample lots (J) and annual rings (R) are set in the list number 70 and in the corresponding program sentences. Although they are J=150 and R=21 at maximum in this program, more larger-numbers may be set according to the memory size. When a series of sample lots, e.g. ring numbers of a tree, are partly discontinued, the list numbers 3060–3100 will be available with changing file name.

PROGRAM LIST 3, named “filmsgraph”, is developed for drawing graphs based on the data in the diskette which is memorized by PROGRAM LIST 2. The program consists of two parts. First one is able to plot the statistical data in the diskette against tree ages so that variation patterns of the fiber lengths may be observed from pith to outer part of the xylem in a two dimensional presentation. The second subroutine is originated from the published one, which is adapted to our hardware system with modification¹²⁾. Because the spline curves did not completely fit to the three dimensional plots, if-statements were added to the subroutine in order to delete undesirable curve.

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PROGRAM LIST 1

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10  '*****
20  '◆◆◆ Fiber Length Measuring System for ◆◆◆
30  '◆◆◆ Employees: Digitizer+CPU+Disk Unit ◆◆◆
40  '◆◆◆ file name:filmsmemory 1984.08.28 ◆◆◆
50  '*****
60  CMD CLS 3
70  PRINT ' CHECK PILOT LAMPS OF THE PRINTER AND '
80  PRINT ' DIGITIZER, THEN PRESS ***y*** KEY'
90  GOSUB 2230
100 CLEAR 1000:WIDTH 40,25:CONSOLE ,,0,:CMD SCREEN 1,0,3
110 DEFINT F,I,J,K,N,O,P,S,X,Y,W
120 DIM L(210),O(110),P(110),X(110),Y(110)
130 '◆◆◆key selection◆◆◆
140 DEFINT G,H
150 PRINT:PRINT
160 PRINT '***Select one of the heading numbers***'
170 PRINT '***1-4) listed below if you want to***'
180 PRINT ' 1. make a new or another file'
190 PRINT ' 2. add further data in a file'
200 PRINT ' 3. break operation'
210 PRINT ' 4. delete a datum memorized'
220 PRINT:PRINT
230 PRINT ' ■■■ SAVE:1 ADD:2 END:3 DELETE:4 ■■■'
240 PRINT:PRINT
250 INPUT 'heading number';G:CMD CLS
260 IF G<1 OR G>4 THEN PRINT:GOTO 230
270 ON G GOTO 280,280,670,2000
280 '◆◆◆DATA save/add◆◆◆
290 MG=17.05:S=100
300 INPUT 'sample name ';NM$
310 PRINT:LPRINT
320 LPRINT 'sample name(magnification): ';NM$;'(';MG;') ';
330 LPRINT 'DATE$';DATE$;'TIME$';TIME$
340 IF G=1 THEN OPEN '2:'+NM$ FOR OUTPUT AS #1:K=1
350 IF G=2 THEN GOSUB 1000:OPEN '2:'+NM$ FOR APPEND AS #1
360 CMD CLS 3:PRINT 'READY!!':PRINT 'file name: ';NM$
370 FOR J=K TO S
380 GOSUB 520
390 F=0:PRINT%1,'S':BEEP 0
400 FOR I=1 TO N
410 L(I)=SQR((X(I)-X(I-1))^2+(Y(I)-Y(I-1))^2)+L(I-1):L(1)=0
420 O(I)=X(I)*.1682:P(I)=199-Y(I)*.0765
425 CMD PSET (O(I),P(I))
430 NEXT I
440 IF L(N)<.1 THEN J=J-1:I=1:NEXT J
450 L(N)=.1*L(N)/MG
460 LPRINT USING ' #.###';L(N);
470 PRINT USING '### L=####.####mm ###';J;L(N);N
480 PRINT #1,L(N);',':I=1
490 NEXT J
500 CLOSE:BEEP
505 PRINT%1,'Z':PRINT%1,'Z':PRINT%1,'Z':PRINT%1,'Z':PRINT%1,'Z'
510 CMD CLS 3:BEEP:GOTO 100
520 '◆◆◆length reading◆◆◆
530 POKE&H8001,&H23:POKE&H8000,&H7F
540 OUT &HE6,4:OUT &HE4,&HFF:INIT% 1,&HCA,&H37
550 IF F=8 THEN N=1:BEEP 1:CMD CLS 2:RETURN
560 IF F=4 THEN CLOSE:PRINT% 1,'S':CMD CLS3:GOTO 100
570 IF F=2 THEN N=I-1:BEEP 1:RETURN
580 IF F<2 AND I<2 THEN PRINT%1,'B'+Wd'
590 IF F>1 OR I>1 THEN INPUT%1,X,Y,F:GOTO 520
600 FOR I=1 TO 100
610 INPUT%1,X,Y,F
620 IF F=1 THEN X(I)=X:Y(I)=Y ELSE 520
630 IF X(I)>3750 OR Y(I)>2550 THEN N=1:BEEP 1:RETURN
635 IF X(I)<50 OR Y(I)<50 THEN N=1:BEEP 1:RETURN
640 IF I=1 THEN BEEP1:BEEP0

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90 PRINT ' DRIVE#1: Wright(Processed-Data)'
100 PRINT ' DRIVE#2: Read(Found-Data)'
110 PRINT
120 PRINT 'Turn on the Printer Switch'
130 PRINT:PRINT:PRINT
140 INPUT 'sample name (exp:33a)';A$
150 '*****data menu*****
160 FOR R=1 TO 21
170 B$=STR$(R)
180 IF R<10 THEN B$=RIGHT$(B$,1)
190 IF R>=10 THEN B$=RIGHT$(B$,2)
200 NM$=A$+B$
210 GOSUB 3000
220 NEXT R
230 BEEP:END
240 '*****line feed*****
250 FOR K=1 TO 16
260 LPRINT
270 NEXT K
280 RETURN
3000 '*****initialization*****
3010 LO=0:HI=0:TL=0:TV=0
3020 FOR K=1 TO 15
3030 FQ(K)=0
3040 NEXT K
3050 PRINT:PRINT:PRINT NM$
3060 IF NM$='33a1' THEN 240
3080 IF NM$='44a18' THEN 230
3090 IF NM$=A$+'5' OR NM$=A$+'9' THEN LPRINT:LPRINT
3100 IF NM$=A$+'13' OR NM$=A$+'17' THEN LPRINT:LPRINT
3110 '*****DATA load*****
3120 LPRINT:LPRINT 'file name(magnification): ';NM$;'(17.05) '
3130 OPEN '2:'+NM$ FOR INPUT AS #1
3140 FOR J=1 TO 150
3150 IF EOF(1) THEN 3230
3160 INPUT #1, L(J)
3170 PRINT J; ' ';L(J)
3180 IF J=1 THEN LO=L(1):HI=L(1)
3190 IF LO>L(J) AND L(J)>0 THEN LO=L(J)
3200 IF HI<L(J) THEN HI=L(J)
3210 TL=TL+L(J)
3220 NEXT J
3230 CLOSE:N=J-1:AV=TL/N:PRINT
3240 PRINT USING 'sample numbers: ###';N
3250 PRINT USING 'average length: ###.###mm';AV
3260 PRINT USING 'minimum length: ###.###mm';LO
3270 PRINT USING 'maximum length: ###.###mm';HI
3280 PRINT:PRINT '*****UNDER PROCESSING*****
3290 '*****frequency*****
3300 MAX=FQ(1)
3310 LL=CINT(LO/.3)+1:LH=CINT(HI/.3)+1
3320 FOR J=1 TO N
3330 FOR K=LL TO LH
3340 IF L(J)>=(.3*K-.3) AND L(J)<.3*K THEN FQ(K)=FQ(K)+1
3350 IF MAX<FQ(K) THEN MAX=FQ(K)
3360 NEXT K
3370 NEXT J
3380 '*****data summary*****
3390 CMD CLS 3
3400 PRINT 'sample name';NM$
3410 PRINT 'frequency:'
3420 FOR K=1 TO LH
3430 PRINT FQ(K);
3440 NEXT K
3450 FOR J=1 TO N
3460 TV=TV+(L(J)-AV)^2
3470 NEXT J
3480 VR=TV/(N-1)
3490 SD=SQR(VR)

```



```

317 IF NM$="sam33c10" THEN 640
318 IF NM$="sam44c6" THEN 640
319 IF NM$="sam45c9" THEN 640
320 IF NM$="sam51c8" THEN 640
321 IF NM$="sam29c10" THEN 640
322 IF NM$="sam16c8" THEN 640
325 *****DATA load*****
330 OPEN "2:" + NM$ FOR INPUT AS #1
340 FOR K=1 TO 24
350 IF EOF(1) THEN 400
360 INPUT #1,F(K)
370 IF K=6 THEN GOSUB 410
380 IF K>6 THEN PRINT F(K);
390 NEXT K
400 CLOSE:GOTO 500
410 *****
420 PRINT USING "sample number      :###";F(1)
430 PRINT USING "average length      :###.###";F(2)
440 PRINT USING "minimum length      :###.###";F(3)
450 PRINT USING "maximum length      :###.###";F(4)
460 PRINT USING "variance            :###.###";F(5)
470 PRINT USING "standard deviation:###.###";F(6)
480 PRINT "frequency:"
490 RETURN
500 *****
510 N=F(1):AV=F(2):LO=F(3):HI=F(4):VR=F(5):SD=F(6)
520 *****
530 X1=24+14*(R-1):X2=344+14*(R-1)
540 CMD CIRCLE (X1,176-AV*40),2
550 CMD CIRCLE (X1,176-LO*40),1
560 CMD CIRCLE (X1,176-HI*40),1
570 CMD CIRCLE (X1,176-AV*40+SD*40),1
580 CMD CIRCLE (X1,176-AV*40-SD*40),1
590 CMD CIRCLE (X2,176-VR*4000/3),2
600 CMD LINE (X1,176-AV*40+SD*40)-(X1,176-AV*40-SD*40)
610 IF R=21 THEN 640
620 TL=0:TV=0
630 RETURN
640 *****unit marks*****
650 CMD LINE (10,176)-(310,16),,B
660 CMD LINE (330,176)-(630,16),,B
670 X1=0:X2=0:Y1=0:Y2=0
680 FOR R=1 TO 21
690 X1=24+14*(R-1):X2=344+14*(R-1)
700 Y1=176-20*R:Y2=(176-R*40/3)
710 IF X1<310 THEN CMD LINE (X1,16)-(X1,18)
720 IF X1<310 THEN CMD LINE (X1,174)-(X1,176)
730 IF X2<630 THEN CMD LINE (X2,16)-(X2,18)
740 IF X2<630 THEN CMD LINE (X2,174)-(X2,176)
750 CMD LINE (10,Y1)-(12,Y1)
760 CMD LINE (308,Y1)-(310,Y1)
770 IF Y2>16 THEN CMD LINE (330,Y2)-(332,Y2)
780 IF Y2>16 THEN CMD LINE (628,Y2)-(630,Y2)
790 NEXT R
800 CMD COPY2:BEEP
1000 *****three dimensional display*****
1010 CLEAR 1000:DEFINT K,X,Y,R
1020 CMD CLS 3:CONSOLE,,0,:CMD SCREEN 1,0,3
1030 DIM FQ(25),B(15),C(15),D(15),R(30),X(15),Y(15)
1040 INPUT "sample name (exp:33a)";A$
1050 *****file name*****
1060 FOR R=1 TO 19
1070 B$=STR$(R)
1080 IF R<10 THEN B$=RIGHT$(B$,1)
1090 IF R>9 THEN B$=RIGHT$(B$,2)
1100 NM$="sam"+A$+B$
1110 GOSUB 1140
1120 NEXT R
1130 CMD COPY2:BEEP:END

```

```

1140 '♦♦♦♦♦read data♦♦♦♦♦
1150   FOR K=1 TO 15
1160     FQ(K)=0
1170   NEXT K
1180   PRINT:PRINT:PRINT NM$
1190 'IF NM$='sam33a1' THEN RETURN
1200 'IF NM$='sam44b5' THEN RETURN
1210 'IF NM$='sam44a18' THEN 1130
1211 'IF NM$='sam33b13' THEN 1130
1212 'IF NM$='sam44b9' THEN 1130
1213 'IF NM$='sam45b13' THEN 1130
1214 'IF NM$='sam51b11' THEN 1130
1215 'IF NM$='sam29b11' THEN 1130
1216 'IF NM$='sam16b12' THEN 1130
1217 'IF NM$='sam33c10' THEN 1130
1218 'IF NM$='sam44c6' THEN 1130
1219 'IF NM$='sam45c9' THEN 1130
1220 'IF NM$='sam51c8' THEN 1130
1221 'IF NM$='sam29c10' THEN 1130
1222 'IF NM$='sam16c8' THEN 1130
1225 '♦♦♦♦♦DATA load♦♦♦♦♦
1230   OPEN '2:'+NM$ FOR INPUT AS #1
1240   FOR K=1 TO 21
1250     IF EOF(1) THEN 1280
1260     INPUT #1,FQ(K)
1270   NEXT K
1280     CLOSE
1290   FOR K=7 TO 21
1300     FQ(K-6)=FQ(K)
1310     PRINT FQ(K)
1320   NEXT K
1330 '♦♦♦♦♦graphic pattern♦♦♦♦♦
1340   PRINT
1350   FOR K=1 TO 15
1360     X(K)=36+24*(K-1)+6*(R-1)
1370     Y(K)=104-FQ(K)+R-1
1380     IF Y(K)<104+R-1 THEN CMD CIRCLE (X(K),Y(K)),1
1390     IF Y(K)=104+R-1 THEN CMD PSET (X(K),Y(K))
1400   NEXT K
1410 '♦♦♦♦♦spline coefficient♦♦♦♦♦
1420   D(1)=X(2)-X(1)
1430   C(2)=(Y(2)-Y(1))/D(1)
1440   FOR K=2 TO 14
1450     D(K)=X(K+1)-X(K)
1460     B(K)=2*(D(K-1)+D(K))
1470     C(K+1)=(Y(K+1)-Y(K))/D(K)
1480     C(K)=C(K+1)-C(K)
1490     IF FQ(K)=0 AND FQ(K+1)=0 THEN C(K)=0
1500   NEXT K
1510   B(1)=-D(1):B(15)=-D(14):C(1)=0:C(15)=0
1520   C(1)=C(3)/(X(4)-X(2))-C(2)/(X(3)-X(1))
1530   C(15)=C(14)/(X(15)-X(13))-C(13)/(X(14)-X(12))
1540   C(1)=C(1)*D(1)*D(1)/(X(4)-X(1))
1550   C(15)=-C(15)*D(14)*D(14)/(X(15)-X(12))
1560   FOR K=2 TO 15
1570     T=D(K-1)/B(K-1)
1580     B(K)=B(K)-T*D(K-1)
1590     C(K)=C(K)-T*C(K-1)
1600     IF FQ(K)=0 AND FQ(K-1)=0 THEN C(K)=0
1610   NEXT K
1620   C(15)=C(15)/B(15)
1630   FOR IB=1 TO 14
1640     K=15-IB
1650     C(K)=(C(K)-D(K)*C(K+1))/B(K)
1660     IF FQ(K)=0 AND FQ(K+1)=0 THEN C(K)=0
1670   NEXT IB
1680   B(15)=(Y(15)-Y(14))/D(14)+D(14)*(C(14)+2*C(15))
1690   FOR K=1 TO 14
1700     B(K)=(Y(K+1)-Y(K))/D(K)-D(K)*(C(K+1)+2*C(K))

```

```

1710 D(K)=(C(K+1)-C(K))/D(K)
1720 C(K)=3*C(K)
1730 IF FQ(K)=0 AND FQ(K+1)=0 THEN B(K)=0:C(K)=0:D(K)=0
1740 NEXT K
1750 C(15)=3*C(15):D(15)=D(14)
1760 '♦♦♦♦drawing graph♦♦♦♦♦
1770 FOR K=1 TO 14
1780 PRINT Y
1790 FOR X=X(K) TO X(K+1) STEP 2
1800 Y=Y(K)+B(K)*(X-X(K))+C(K)*(X-X(K))^2+D(K)*(X-X(K))^3
1810 IF R=2 OR R=5 OR R=8 THEN GOSUB 1880:GOTO 1850
1815 IF R=11 OR R=14 OR R=17 THEN GOSUB 1880:GOTO 1850
1820 IF Y>103+R THEN NEXT X:GOTO 1860
1830 IF Y(K)=103+R AND Y(K+1)=103+R THEN 1860
1840 CMD PSET (X,Y)
1850 NEXT X
1860 NEXT K
1870 RETURN
1880 '♦♦♦♦♦
1890 IF X=X(1) THEN 1920
1900 IF Y>103+R THEN Y=103+R
1910 IF Y1<103+R THEN CMD LINE (X1,Y1)-(X,Y)
1915 IF Y<103+R THEN CMD LINE (X1,Y1)-(X,Y) ELSE CMD PSET (X1,Y1)
1920 X1=X:Y1=Y
1930 RETURN

```

After the present paper was accepted, bags on the basic system concerning with the numerical calculations of square root were pointed (Interface No. 105, 280-289, 1986; in Japanese). The variance as shown in Fig. 4 will be increased by the bag (in addition to the reading errors derived from the digitizer) when the digital conversions are repeated. Therefore, the net (or naturally occurred) distribution in Fig. 4 should be carefully examined (see also ref 2).