UDC 681.327.12

Mobile Image Scanner

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(Manuscript received July 7,1998)

The progressive downsizing of notebook personal computers and the spread of communication tools such as portable phones, electronic mail, and the Internet have accelerated the mobile use of notebook personal computers. To meet the demand for clipping articles from newspapers and magazines outside the home and office and for collecting information from a library, Fujitsu has developed a high-performance mobile image scanner, named "Pen Scanner," which is small, lightweight, and portable.

1. Introduction

The progressive downsizing of notebook personal computers and spread of communication tools such as portable phones, electronic mail, and the Internet have accelerated the mobile use of notebook personal computers.

An increasing number of people carry notebook personal computers and use them to read electronic mail, collect information via the Internet, and send reports.

Digital cameras have recently become popular as a portable means of collecting information. However, although they are suitable for shooting objects and landscapes in three dimensions, they are not suitable for collecting character information from documents.

To meet the demand for clipping articles from newspapers and magazines outside the home and office and for collecting information from a library, Fujitsu has developed a mobile image scanner, named "Pen Scanner," which is small, lightweight, and portable.

2. Requirements for Mobile Scanner

Palm-sized handy image scanners have been the smallest among conventional scanners. **Figure 1** shows a handy image scanner, and **Table 1** lists its general specifications. The specifications show that the handy image scanner is not sufficiently compact and light to be carried conveniently.

The handy image scanner has the disadvantage of a slow scanning speed and must be operated slowly and carefully in order to capture images accurately. Furthermore, the handy image scanner cannot be used easily to scan a business card or photograph that is smaller than the scanner itself.

Fujitsu therefore decided to develop a new mobile image scanner that would be as small and light as a fountain pen. Power would be supplied to the Pen Scanner from the PC card slot of the notebook personal computer, thus eliminating the need for a dedicated power supply. To reduce the consumption of the internal battery of the computer, the power consumption of the Pen Scanner had to be minimized.

The following targets were set for the Pen

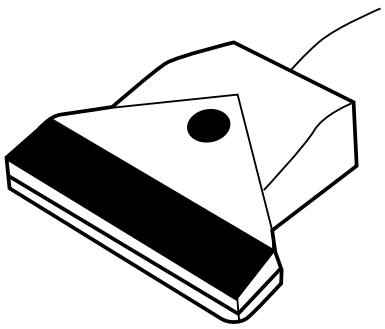

Figure1.
Handy image scanner.

Table 1. Specifications of handy image scanner.

	Target specifications	Handy image scanner specifications
Size	140 X 10 X 10	140 X 140 X 41
Weight	100 g	410 g
Scanning speed	3 seconds/A6 size	10 seconds/A6 size
Power consumption	1 W	2.5 W
Input power supply	Dedicated power supply not necessary	Dedicated power supply not necessary (power supply from PC card slot)

Table 2. Specifications of Pen Scanner.

Scanning method	Hand-held type
Resolution	Maximum of 400 x 400 dpi
Scanning device	Contact image sensor
Scanning speed	Maximum of 1.1 ms/line (2.6 seconds per vertically oriented A6-size document)
Interface	Special PC card (accessory) (Type II conforming to PCMCIA)
Document size	26 x 26 mm (minimum) to 105 x 356 mm (maximum)
Specified document size	A6,A6 (vertical) x 2, business card, postcard, photogragh, free size, and custom size
Image type	Halftone (dither matrix), black and white (binary image)
Drop-out color	Red (red LED used as light source)
Dimensions	183 (W) x 17.6 (D) x 14.7 (H) mm (scanner unit only)
Weight	80 g (scanner unit), 30 g (PC card)
Input power supply	Power supply via PC card (Maximum power consumption: 1W)
Personal computer	AT-compatible models (PCMCIA Type II slot required)
Scanner driver	Comforming to TWAIN
Operating system	Microsoft® Windows® 95/Windows® 98

Scanner, and technologies were developed to attain them.

– Size: Must be as small as a fountain pen.
– Power supply and power consumption: The power must be supplied from the PC card slot of the notebook personal computer, and the power drain on the computer's battery must be minimal.
– Scanning speed: The scanning speed must be fast enough to make the scanner convenient to use.
– Operation: The scanning operation must be simple to perform.

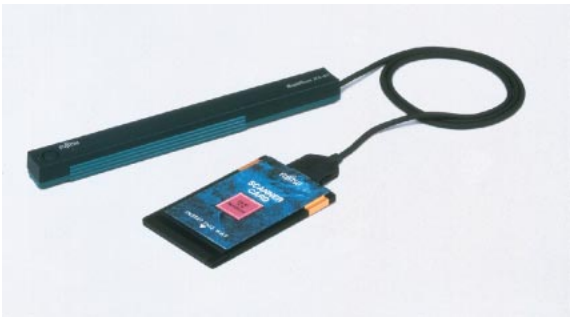

Figure 2.
Pen Scanner.

Figure 2 shows the Pen Scanner, and **Table 2** lists its specifications.

3. Technological Development

The technological issues for the Pen Scanner were as follows:

– How to miniaturize the optical system
– How to miniaturize the rollers that smoothen manual scanning and the encoder that detects the moving distance

– Where to mount the control circuit system
– How to supply power and reduce power consumption

Optical system

Like other image scanners, conventional handy image scanners use a zooming optical system that has a minimum light-path length of about 100 mm, so such scanners cannot be made as small as a fountain pen. To solve this size problem, we developed a new optical system which incorporates a short-focus lens, a contact-type image sensor, and an LED light source. If the parts of the conventional zooming optical system were replaced with contact-type parts, the assembling accuracy necessary for the short-focus structure could not be maintained. For the Pen Scanner, we therefore incorporated an image sensor, LED light source, short-focus lens, rollers, and encoder into a pen-sized unit, then separated the optical system from the roller system while maintaining the assembling accuracy. By this method, the light-path length was reduced to one-tenth of the length in conventional handy image scanners. **Figure 3** shows the structural differences between the zooming optical system of conventional scanners and the contact-type optical system developed for the Pen Scanner.

Rollers and encoder

Because the Pen Scanner is operated manually, the rollers measure the scanned distance, the encoder detects the number of roller rotations, and the gear mechanism assures the accuracy of rotation detection. To contain these parts in a pen-sized body, we developed an optical incremental encoder that has a diameter of 8 mm and uses a very small rotary disk. **Figure 4** shows the encoder.

To realize smooth scanning, the rollers were designed to have a dual configuration as shown in **Figure 5**.

Image processing system

The image scanner must be able to convert the analog signals output by the image sensor into digital signals, process image data for displaying on a display unit, and transfer the image data to the personal computer. To minimize the size of the scanner unit, these functions were assigned to the PC card. The scanned analog signals are sent to the PC card by cable, and all the image processing is executed in the PC card. The transmission of analog signals by cable could cause waveform distortion and cross-talk noise, so we

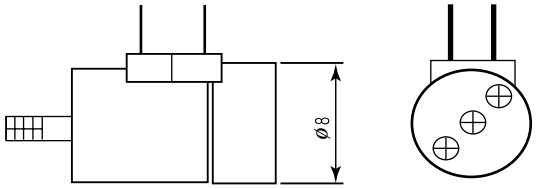

Figure 4.
Encoder.

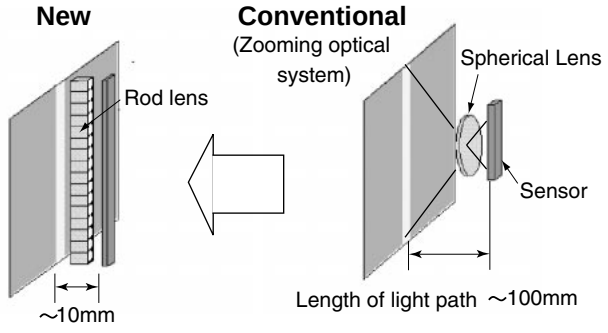

Figure 3.
Optical system.

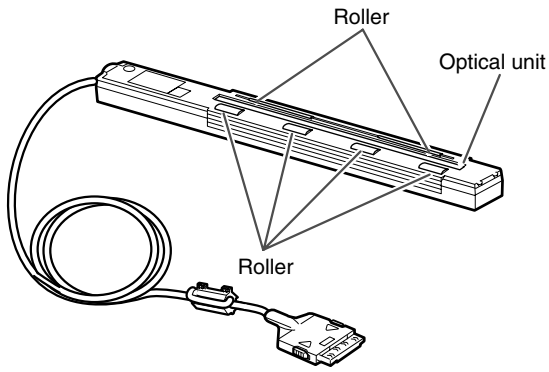

Figure 5.
Dual-roller configuration.

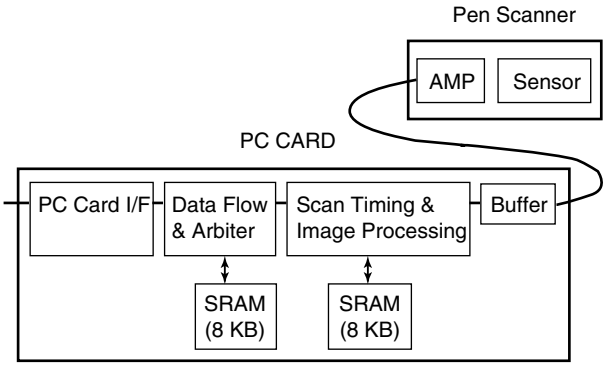

Figure 6.
Overall block diagram of the Pen Scanner.

eliminated the adverse effects of noise by optimizing the thickness and length of the cable, buffering the analog waveform to be transmitted, and terminating the received signals. **Figure 6** shows the overall block diagram of the Pen Scanner.

We designed the power for the Pen Scanner to be supplied from the personal computer via the PC card, thus eliminating the need for a dedicated power supply for the Pen Scanner.

Scanning speed

Conventional handy image scanners can scan images correctly only when operated very slowly, because the performance of conventional image sensors is low and image processing by software is time-consuming. For the Pen Scanner, we used a new image sensor operating at 1.1 ms per line, which is five to ten times as fast as the conventional image sensor. Also, we developed an LSI that executes all the image processing in hardware at high speed. As a result, the Pen Scanner has a high scanning speed, for example, it can scan an A6-size document in 2.6 seconds. **Figure 7** shows the block diagram of the image processing system.

The flow of image processing is as follows.

– The scanner unit transmits an analog image signal to the PC card according to the timing signal generated by the image processing LSI.
– The analog signal is converted to an 8-bit digital signal by the internal analog-to-digi-

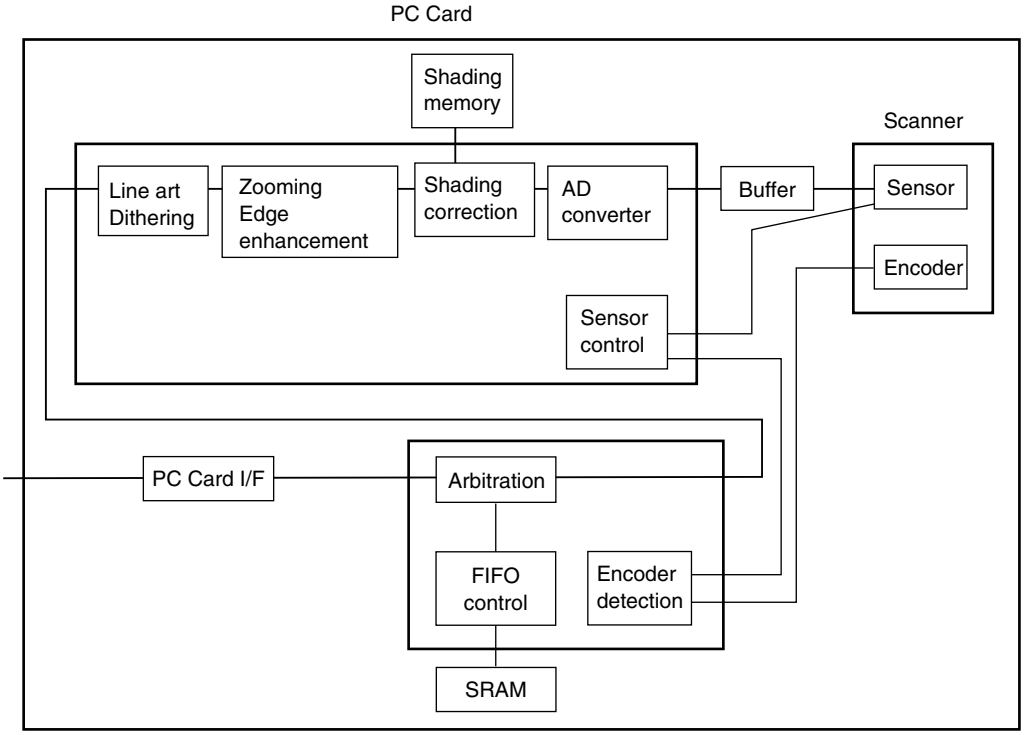

Figure 7.
Block diagram of the image processing system .

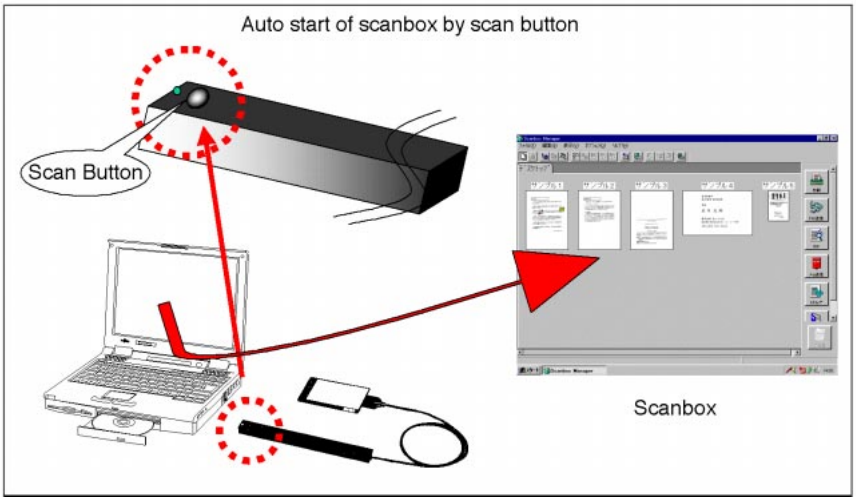

Figure 8.
Concept of quick startup using the scan button.

tal converter of the image processing LSI. The digital signal is processed by shading correction, converted to binary data, then transferred to the internal buffer memory. Before transfer to the internal buffer memory, thinning and edge enhancement are applied to the signal as required.

– The binary image data is read by the program, displayed on the preview screen sequentially, and transferred to the application program.

All the above processes, from the processing of the analog signal to the processing of 1-bit binary data, are executed at high speed by the LSI.

Scan button

The mobile image scanner must be able to be used quickly without keyboard operation, simply by connecting it to a notebook personal computer. We therefore included a scan button and developed a program that always monitors the scan button to determine whether it is pressed and a monitoring application program that activates a specified application program and starts input from the scanner as soon as the scan button is pressed. These programs are started automatically at system startup, and the specified application program is started automatically when the scan button is pressed to start accepting input from the scanner. **Figure 8** shows the concept of processing.

Automatic correction of slant, rotation, and mirroring

It is difficult to operate the scanner precisely in the vertical or horizontal direction, and images are unavoidably scanned at a slant. In addition, because the Pen Scanner allows the user to scan images in various directions, e.g., from top to bottom or left to right, the scanned image may be rotated 90 degrees or mirrored horizontally. In these cases, in conventional handy image scanners an editor function of the application program executes slant correction, rotation, or direction/mirroring correction for the image data input to the personal computer. For the Pen Scanner, we developed new algorithms for slant correction and orientation/mirroring detection so that the correction operations can be done automatically. **Figures 9** and **10** show the slant correction algorithm, and **Figures 11** and **12** show the orientation/mirroring detection algorithm.

Slant correction algorithm:

As shown in Figure 9, the document image is divided into portions by the lines running across the character lines at right angles, divided parts

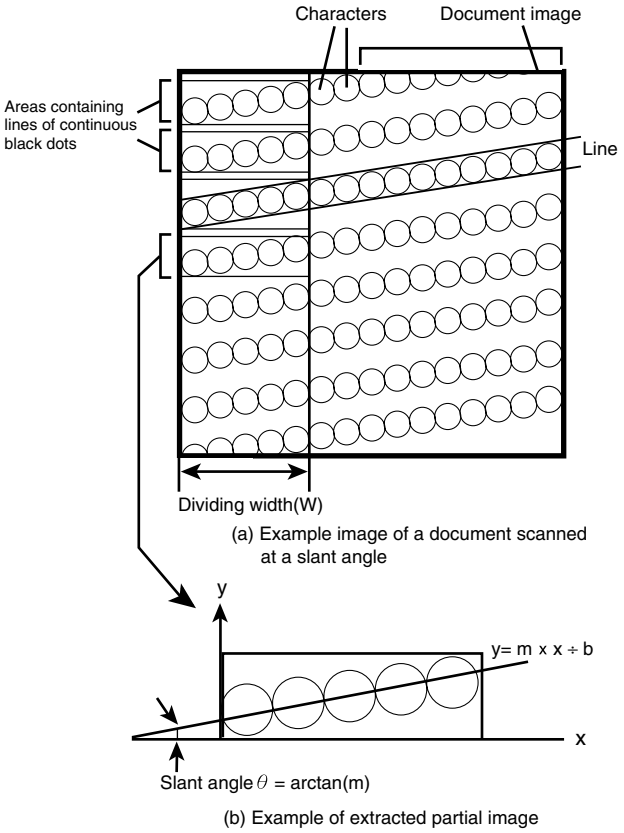

Figure 9.
Slant correction algorithm.

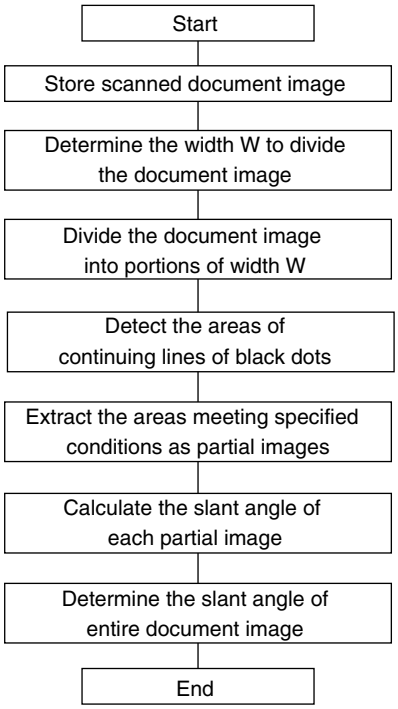

Figure 10.
Flow of slant correction processing.

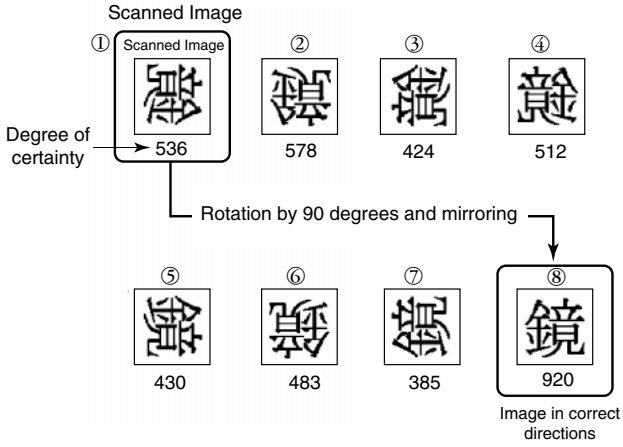

Figure 11.
Direction/mirroring detection algorithm.

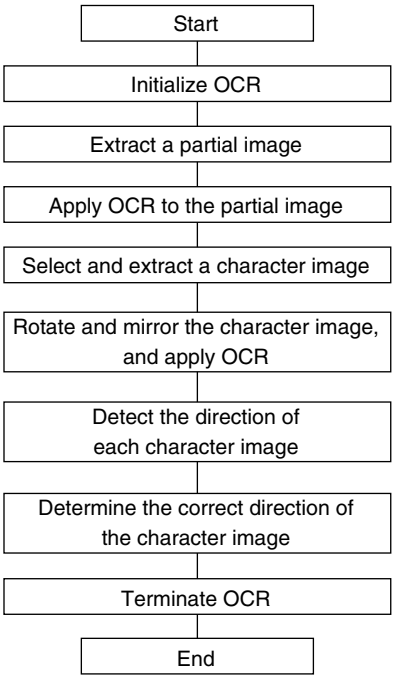

Figure 12.
Flow of document direction/mirroring detection.

Table 3. Outline of Scanbox functions.

Function Items	Remarks
Scanning function	Applicable to TWAIN
Filing function	
Filing	
Image edit function	
Annotation function	
Application linkage function	Electronic mail, fax transmission, etc.
Search function	
Business card management function	
Japanese character recognition function	
Scrap function	Cuts only required parts and pastes them onto the clipboard.
Fax function	
Copy function	

of character lines are selected, and the average of the slant angles of the selected character lines is then calculated. The slant angle of the whole document image is determined from the average. The flow of processing is shown in Figure 10 and is explained below.

– Determining the width of division of a document image:
  The width of division is determined based on the fact that the white section between slanted character lines has a certain horizontal length.
– Selecting and extracting portions containing scanned characters:
  The document image is divided into vertical rows having the above width (a certain number of dots), and each row is scanned to extract the portion that includes characters.
– Calculating the slant angle of extracted images:
  Linear approximation is applied to the black dots in the extracted images, and the slant angles of the images are calculated.
  The average of the slant angles is calculated and taken as the slant angle of the document image.

Detection of document orientation and charactermirroring :

As shown in Figure 12, OCR processing is executed for the partial images extracted by the above procedure to detect a character image. The detected image is rotated by 90, 180, and 270 degrees, and the original image and three rotated images are mirrored. OCR recognition processing is executed for those images to obtain the degree of recognition certainty of each image. The orientation of the image with the highest degree of recognition certainty is taken as the correct orientation, then, converting the image by this orientation the image data of the correct entire document is obtained.

Application of the above algorithms to sample documents resulted in a slant correction error within 0.3 degree and a 100% accuracy for correction of character orientation. The correction processing took about 1.8 seconds on a 486DX-100 MHz CPU.

4. Application

The Pen Scanner can be used to collect document information from a library, sort business cards and information collected during a business trip, and transmit conference materials by elec-

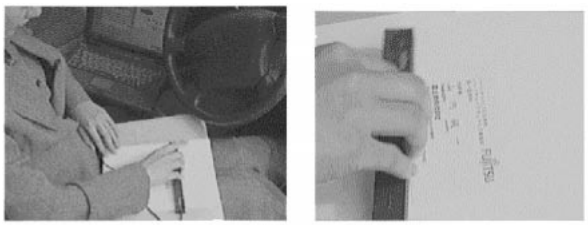

Figure 13.
Example of using the Pen Scanner.

tronic mail or facsimile. For these applications, we have developed an application program that has functions for tasks such as filing, business card recognition, business card management, OCR, scrapbook creation, electronic mail linkage, and facsimile linkage. **Table 3** shows an outline of the functions, and **Figure 13** shows an example of using the Pen Scanner.

5. Conclusion

We have developed the world's first pen-sized lightweight scanner, called "Pen Scanner," that is suitable for mobile use. The new scanner has a short-focus optical system, very small rollers, a very small encoder, and a custom image processing LSI. These features make this the smallest scanner in the world that is capable of high-speed scanning. Newly developed features for the Pen Scanner include a scan button to start scanning by one-touch operation, character orientation correction by image processing, and application for mobile use. We will extend the capabilities of mobile scanners by making the following enhancements:

– Connection to interfaces such as USB
– Color capability
– Extension of scanning size to A4.

Fumitaka Abe received the B.S. and M.S. degrees in Electrical Engineering from Osaka University in 1972 and 1974, respectively. He joined Fujitsu Laboratories Ltd., Kawasaki in 1974 and has been engaged in research and development of advanced peripheral systems such as laser-beam printers, optical disk drives, image scanners, and input devices. He is a member of the Institute of Electronics, Information, and Communication Engineers (IEICE) of Japan and the Optical Society of Japan.

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