Digitization of Documented Signals using Vertical Scanning

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***Abstract*—The document digitization is one of the emerging trends of digitization. The digitization of documents allows retrieving of information from paper document. This information can be ECG, EEG, humidity etc. The document digitization process involves conversion of paper document into image and processing of obtained image to extract information. The digitized signals can be directly applied to present prediction algorithms. As the digitization literature is surveyed, the process of extraction of digital signal from scanned paper document plays very important role in document digitization process. Generally this is done using horizontal scanning. This paper emphasize on use of vertical scanning for extraction of signal trace from paper documents in contrast to horizontal scanning. The vertical scanning method reduces complexity of the digitization process as well as gives accurate digitization.**

Keywords— paper documents; digitization; digital signal

I. INTRODUCTION

For medical and metrological applications it is necessary to observe pervious history for future analysis, in such cases, the documented paper records are analyzed manually. Generally, signals acquired by the clinical and metrological systems are documented by plotting on graph papers. These graphical representations are observed manually for predication rather than the digital signals. Today various standard instruments are available for prediction but these available systems are not able to analyze the previous documented records. For some critical analysis it is required to predict on the basis of previous history. Generally these previous history records are in paper documented format. In addition, most of the documented graphs are got torn or in position of blurred. So, it is necessary to preserve them by converting to equivalent digital signals through tracing and reconstruction processes. This process of digitizing documents in digital signal offers several advantages such as when this digitized signal is fed to today's advanced software/techniques, previous symptoms can be analyzed. This also helps to create the database of previous observed cases, which may be used for further analysis. It will be easy to transmit the digital signals rather than sending scanned documented images. Digitized signals can be easily converted to today's various usable formats. This reconstruction will be definitely helpful to medical practitioners and metrological department. Another requirement of this work is that, in biomedical applications, digitizing paper records permits the integration of patient's medical (electrocardiography (ECG)) data with the patient's Electronic Medical Record (EMR) [1]. With the government mandated push for Electronic Health Records to be implemented nationally, such tools will be needed for routine clinical use. Furthermore, such tools would allow for comparison of a patient's current ECG with a baseline ECG, enhancing confidence in the diagnosis of acute changes.

Standard documented paper has a graphical grid upon which any physical quantity (voltage, temperature, humidity etc) is printed as a function of time. Majority of signal's information is said to be found in the intervals and amplitudes defined by its features (characteristic wave peaks and time durations).The documented paper records are scanned and converted into 2-D image. The extraction of information from this two-dimensional (2-D) image and conversion to a one-dimensional (1-D) signal is referred to as digitization of documented signal. Thus, digitization of a signal printout is the process of assigning discrete time-voltage values to the pixels of an image corresponding to a signal from the printout. The document digitization process involves steps like scanning of paper documents, grid removal from scanned image, extraction of signal trace through scanning, scaling of pixels for real view of the signal. For extraction of signal trace from this 2-D image into 1-D signal is generally performed using horizontal scanning. A distinguishing feature of this paper is that we have used vertical scanning for extraction of signal trace from scanned paper image which gives more accurate and fast digitization results than horizontal scanning. The rest of the paper is organized as follows. Section II describes the literature survey. In Section III, methodology for document digitization is discussed. Results are discussed in section IV. Section V presents conclusion of this paper.

II. LITERATURE SURVEY

Digitization of document is step by step method to convert signal printout into digital signal. Majority of signals are printed on graphical grid. Thus it is necessary, to first remove background grid from scanned signal printout. The background gridlines are removed using color filter in the color image [2]. The signal trace is separated [3] from the background grids using histogram. The missing pixels are replenished by checking the value of the pixel in the original image. This is a tedious process. A scanning resolution of 200

dpi [4] is used for scanning signal printouts and used gray scale thresholds to separate the ECG trace from the background grid lines.

After removing the grid in order to convert the extracted data into its final form horizontal scanning is used. During scanning, it is observed that at any single time in x-axis, corresponds many voltage levels in y-axis. One of the methods to select y-axis pixel is median or average operator [5].The method to select y-axis pixel for every x-axis pixel needs to address for faithful extraction of digital signal. This is one of the major problems in documented signal digitization. The work proposed in [6] developed an application for extraction of the ECG trace from the image. The ECG waveform extraction is obtained using active contour method. A line function is used to attach the active contour to the waveform in the scanned image. A smoothness function is used so that the digitized waveform does not exhibit large discontinuities. But the method requires the user to fix anchor points for missing peaks and thus the accuracy comes down. The ECG signal digitization literature discusses various methods at different stages. One of the approaches for ECG waveform extraction and parameters retrieval is using K-means method [7].The Radon transform [8] is used for de-skewing the scanned images for accurate extraction. However, all the above work addresses the issue of retrieval of one-dimensional time series signal from documented paper records alone.

III. METODOLOGY

Digitization of a signal printout refers to the process of assigning discrete time-voltage values to the pixels of an image corresponding to a signal from the printout. The following sections explains in detail the various stages involved in capturing the signal trace, signal extraction and digital signal generation as shown in Fig. 1.

A. Scanning of signal printout

First, the signal paper is scanned and a digital image is converted to 8-bit gray scale. The paper records are scanned at different resolutions for accurate trace extraction depending on the required accuracy of the digitized signal. The scanning resolution plays a major role in the conversion of the ECG trace into digital time series signal [8]. For example let us assume that the signal printout is scanned at resolution of 300 dpi(dots per inch), it implies, there are 300 pixels in an inch. As the thermal record has the grid dimensions specified in mm, number of pixels in mm is derived using the equation (1). The amplitude and time scaling of a pixel in terms of mV and ms is calculated as shown in (2) and (3).

$$1 \text{ mm} = 300/25.4 \text{ pixels} = 11.81 \text{ pixels} \quad (1)$$

$$\text{Amplitude scale: } 10 \text{ mm} = 1 \text{ mV} = 118.1 \text{ pixels.} \quad (2)$$

$$\text{Time scale: } 25 \text{ mm} = 1 \text{ second} = 295.25 \text{ pixels} \quad (3)$$

$$1 \text{ pixel} = 8.467 \text{ mV}$$

$$1 \text{ pixel} = 3.387 \text{ ms}$$

This procedure will be different for different signals depending on paper speed and scanning resolutions.

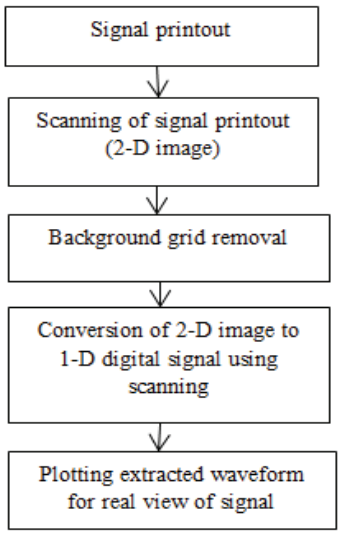


Fig. 1 Digitization process of signal paper records

B. Background grid removal

The next step is to remove the graphical grid and convert the gray scale image to a binary image. Global threshold technique is used to separate signal trace from background graphical. Since the pixel intensity value of the graphical grid is usually greater than that of the printed signal, the threshold is determined using the histogram of the image. By considering the pixel intensity of the graphical grid region alone (black = 0 and white = 255), the threshold for the grid removal process is determined automatically. In this example, the range 150−160 was contributed by the grid lines alone. In Global thresholding, threshold T is selected such that it separates object from the background. If f (x, y) > T then f (x, y) = 0 else f (x, y) = 255 where x, y are pixel locations and f(x, y) is the pixel intensity.

In general, good threshold can be selected if the histogram peaks are tall, narrow, symmetric, and separated by deep valleys. However, binary thresholding may introduce ``salt and pepper'' noise in the background, which often occurs as a result of the scanning process. In addition, there may be discontinuities or gaps in the signal from removal of major grid lines due to reduced printer ink retention on the major grid lines. Performing median filtering and interpolation after the thresholding process eliminates these artifacts.

C. Digitization of signal using vertical scanning

After removing the background grid using global thresholding the resultant image is the binary image. This binary image is then scanned vertically for identification of raised components. This step is used for extraction of locations of raised pixels by scanning line by line vertically.

For tracing of signal which is traversing horizontally, horizontal scanning is not suitable as it is difficult to localize the equal-valued (equal gray valued) pixels. It requires iterative process for exact localization of such pixels. To reduce this iterative process, vertical scanning process is used instead of horizontal scanning. In single scan trace (with no iterative process), it can identify the high intensity pixels as

there is only one high valued pixel in vertical trace of signal. The concept can be explained with the diagram as shown in Fig. 2.

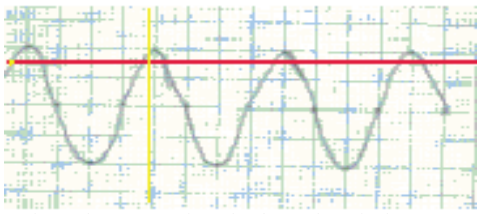


Fig.2. Horizontal scan trace in red color and vertical scan trace in yellow color

In red horizontal trace, sine wave cuts at eight locations and pixels values are also different so it requires identifying the high value pixels as POI. Their location identification also requires iterative process. But in case of yellow vertical scan, it is very easy to identify the pixel of maximum value and its location identification with non-iterative process. The use of vertical scan instead of horizontal scan reduces the complexity depending on the trace cutting points which is found to be generally 20 cuts averagely for standard size image of ECG paper. Thus complexity is reduced approximately by 20 times. High intensity pixel's scanning involves the conversion of digital image into the array of high valued pixel's locations. These high intensity pixels' locations are used to extract signal trace and plotted as 1-D signal.

IV. RESULTS

The sinusoidal signal drawn on plain paper is scanned for different resolutions. Scanning with high resolution scanner is desirable for exact results. But algorithm should work on any type of images like blurred image or darken image. It is important to note that the graph grid and plotted waveform may be of any color but pixels of waveform must be darker than grid. Scanning resolution can be 600/300/200 dpi. Preferred algorithm for the image compression is JPEG. For example, a resolution of 600 dpi implies 600 pixels in an inch (25.4 mm). Thus the number of pixels per mm can be calculated. These values are used during the digital signal generation. The gray scale image is then scanned horizontally to retrieve signal trace from an image. The results obtained in Fig. 3 shows that the digitization is better at higher resolution compared to low resolution. In horizontal scanning, we may get multiple maximum intensity pixels which are difficult in reorganization as a waveform. This problem is solved using vertical scanning. Generally scanning is performed in horizontal direction in all the cases, whether it is for signal digitization or other application. For signal digitization, where signal trace traverse horizontally, vertical scanning is used as maximum intensity pixel can be considered as a pixel on curve of signal. In horizontal scanning, there are multiple maximum intensity pixels which are difficult in reorganization as a waveform. In vertical scanning only one maximum intensity pixel is possible.

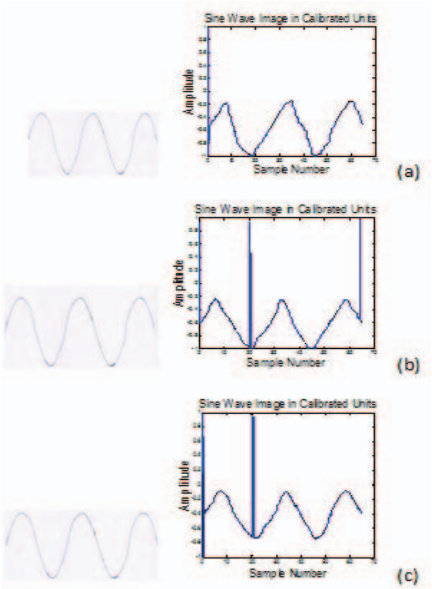


Fig. 3 Horizontal pixels scan of sinusoidal signal at different (a) 200dpi (b) 300dpi (c) 600 dpi

Vertical scanning is used for identification of raised components. This step is used for extraction of locations of raised pixels by scanning line by line vertically. The results obtained in Fig. 4 shows that the given algorithm is able to remove the background grid and can accurately convert the documented signal into digital signal. The following results shows that vertical scanning gives much better results in digitization of biomedical paper records.

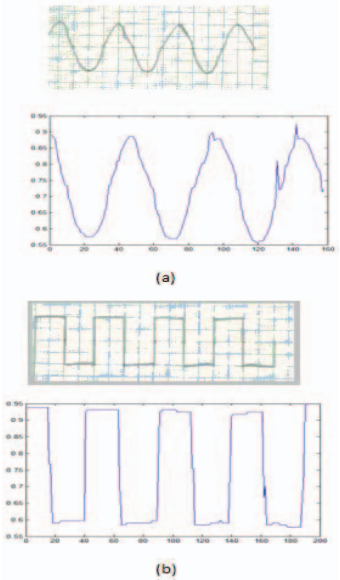
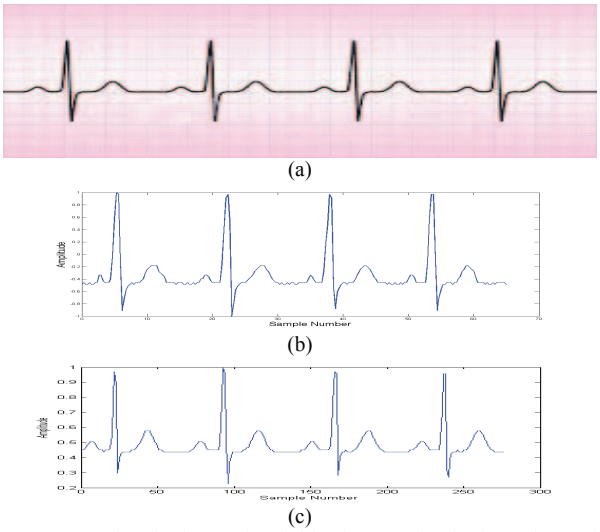


Fig. 4 Signal printout and its digitized signal by vertical scanning (a) sinusoidal signal (b) square wave signal

Recently, the Food and Drug Administration has launched an initiative intended to recommend to the pharmaceutical industry the use of digital annotated ECGs for the submission of new drug applications [3]. More importantly, the new regulatory guidelines will magnify the need for efficient and

widely applicable tools for the conversion of paper ECGs to digital ECGs, particularly for retrospective studies. Academic research will also indirectly benefit from these efforts; indeed, there still exist today, many large databases collected on paper ECGs that must be converted to digital format. Fig. 5 and 6 show comparison of horizontal and vertical scan for ECG and EEG signal digitization. The result shows that the digitization using vertical scanning is more accurate than horizontal scanning.

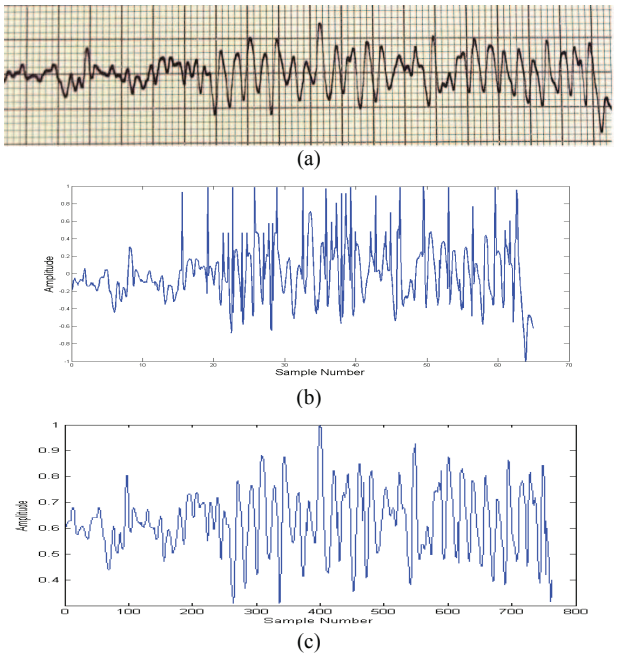


(a)

(b)

(c)

Fig.5 (a) ECG signal printout (b) Digitized ECG using horizontal scanning (c) Digitized ECG using vertical scanning



(a)

(b)

(c)

Fig.6 (a) EEG signal printout (b) Digitized EEG using horizontal scanning (c) Digitized EEG using vertical scanning

The documented paper or paper image storage is the major problem many educational and Research organizations are facing. After digitization of these documented records, the storage space reduces greatly. The digitized data again can be used for prediction and analysis.

V. CONCLUSION

Document digitization is emerging field from various perspectives. The document digitization can be used for conversion of historical text records to equivalent sound signals, which is useful for blind people. The application of digitization of documented records can be extended to signature analysis to study psychological characteristics of a person from HR point of view. The digitized signals can be directly used for large retrospective studies or for patient's future diagnosis on the basis of old records. The documented signals such as deterministic as well as random signals like ECG and EEG are efficiently digitized using vertical scanning method. The results show that scanned images of documented records are accurately converted into digital signal using vertical scanning compared to horizontal scanning. After digitization the digital signals requires less space to store or transmit as compared to documented printouts or scanned images. The digitized signals are visualized on their own scale and not on the original scale. Visualization in original scale and extraction of required parameters is a very challenging task and very much necessary for medical diagnosis.

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