ScanRX: Software for Low-Cost Digitization of Chest X-Rays Films Using a Flatbed Scanner

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Abstract. *This paper describes the software named scanRX, which was developed to digitize x-rays films at low cost using a conventional flatbed scanner, capable of scanning up to A4-sized media, equipped with a transparency media adaptor (TMA). Since chest x-rays films are available in five distinct sizes, and only one fits the scanner window, the films must be digitized in 1, 2 or 4 parts, depending on the film size, and then stitched together. ScanRX guides the user step-by-step through the whole process and stitches the images together seamlessly, providing a digital image of the whole x-ray film.*

Resumo. *Este artigo descreve o software scanRX, desenvolvido para digitalizar radiografias a baixo custo usando um scanner de mesa convencional de tamanho A4 e equipado com um adaptador de transparências (TMA- transparency media adaptor). Como os filmes de raio-X de torax são fornecidos em 5 tamanhos distintos e apenas um cabe na janela do scanner, os filmes tem que ser digitalizados em 1, 2 ou 4 partes, dependendo do tamanho do filme e posteriormente "costuradas". O scanRX guia, passo a passo todo o processo de digitalização e costura as imagens parciais, obtendo uma imagem digital do filme inteiro.*

1. Introduction

ScanRX is a software developed to digitize chest x-rays at low cost. It was developed at the High Performance Computing Center (NACAD) at COPPE/Federal University of Rio de Janeiro and is free software, written with open source tools and libraries.

The software was developed for the project *Tele-Integration for X-Ray Images* (TIPIRX), funded by the agency *Research and Projects Financing* (FINEP), and is a partnership of COPPE/Federal University of Rio de Janeiro with the university hospitals of the Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro State University (UERJ) and Fluminense Federal University (UFF).

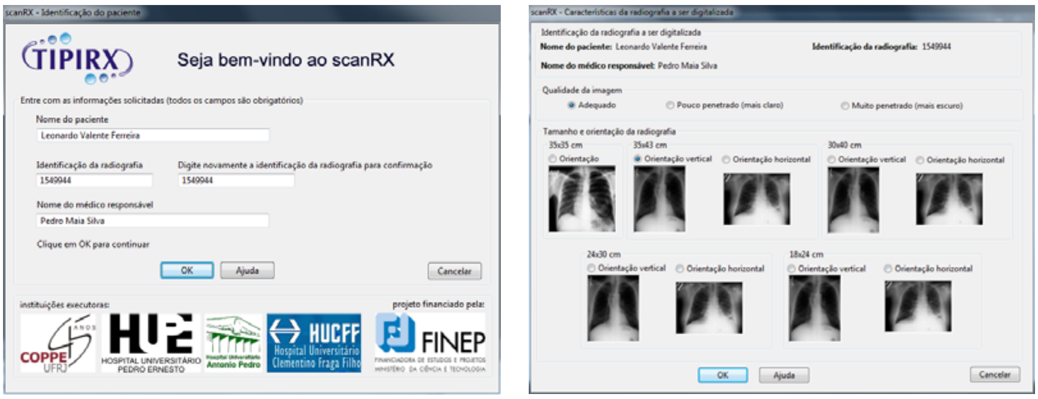
The TIPIRX project aims at providing a low-cost integrated solution for telemedicine. The main objective of the scanRX software within the TIPIRX project is to allow remote locations in Brazil, which lack human resources and equipment, to use telemedicine facilities by digitizing x-ray films acquired in those locations and transmitting the digital images to locations where radiologists are available to provide a second opinion.

The scanner used is a Microtek ScanMaker i800 equipped with a transparency media adapter (TMA) for A4 size (21cm×29.7 cm) transparent media, which provides the necessary lighting to scan transparent media. This scanner costs about R$2500 (= US$1,250) in Brazil and was chosen after extensive tests with several models sold in the Brazilian market. The Microtek ScanMaker i800 is the model that best fits the needs of the TIPIRX project, considering the tradeoff between scan quality and cost.

2. How ScanRX Works

Chest radiographs come in five different sizes, of which only one fits the A4 scanner window used by scanRX. The solution adopted is to digitize the film in 1, 2 or 4 parts, depending on the film size, and then to stitch together the partial images to obtain a digital image of the whole film. This technique is known as *image stitching* [Gramer et.al 2007] and a specific template matching-based image stitching algorithm was developed to this end. This algorithm is described in detail in the companion paper [Vela et al. 2010].

In order to stitch the images correctly, it is necessary that each part of the film to be digitized be positioned correctly in the scanner window. When scanRX is started, it display a form that the user must fill with the identification of the patient and of the physician who is requesting the digitization of the radiograph; screen shots shown in Figure 1(a).



(a) **(b)**

Figure 1: Screen shots showing information that must be supplied by the user: (a) Identification of the patient; (b) Physical properties of the x-ray film

In the next stage, the user has to inform the physical properties of the film that will be digitized. In the screen shot shown in Figure 1(b), the user must inform the software about the quality of the X-ray film: this information is used by the image stitching algorithm that drives scanRX, in order to try and improve the image quality by adjusting brightness and contrast. In the same window, the user will also informs the software about the size and orientation (portrait or landscape) of the film; once again, this information is crucial for the success of the stitching algorithm. With this information in hand, the software scanRX will guide the user through a step-by-step process of digitization of the film, which is crucial to obtain a correctly stitched digital image of the whole film.

After this stage, scanRX has all the necessary data to digitize the x-ray film. In the example shown in Figure 2 a 35x43cm-film, with portrait orientation will be digitized. This is a large film and it has to be scanned in for parts, the whole process lasts about 5 minutes and the illustration in the scanRX screenshot shown in Figure 2 tells the user how the film must be positioned in the first stage.

Figure 2: scanRX screenshot guiding the user in the digitization of the first part of a x-ray film

The position of the X-ray film on the scanner glass plate (shown in Figure 2 for the first stage) changes at each stage and after the fourth stage, the images are stitched together and saved in a DICOM dataset. The image is compressed with lossy JPEG with quality 85. The largest images given by scanRX are not larger than 700KB and can be easily transmitted using Internet connections from locations in which broadband links are not available. All the information provided in the identification form shown in Figure 1(a) is included in the DICOM header that is also created by scanRX. Finally, after digitizing the four parts of the film, scanRX displays the stitched image, shown in Figure 3, and waits for the user's approval in order to store the image in a folder with a name automatically created in a prescribed fashion from the DICOM header data.

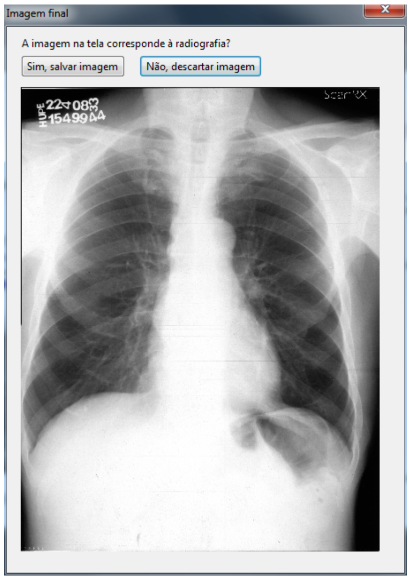


Figure 3: Image digitized in four parts and stitched using scanRX

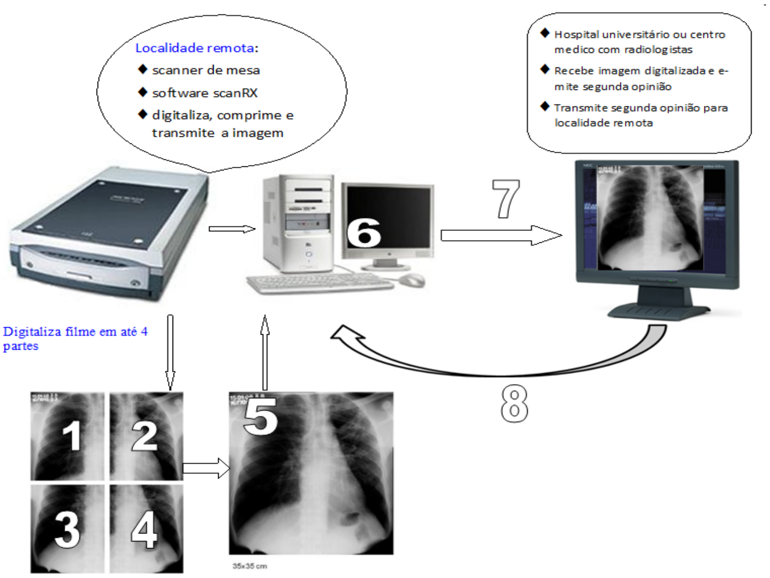


Figure 4: The process of digitization and transmission an x-ray film

The complete process of digitization (in four steps) and transmission of the digital image of an x-ray film is shown in Figure 4. The complete cycle of a teleradiology consultation consists of the following stages:

1. Digitization of the upper left corner of the film
2. Digitization of the upper right corner of the film
3. Digitization of the lower left corner of the film
4. Digitization of the lower right corner of the film

5. ScanRX stitches the four parts together and provides a digital image of the whole film
6. The image is compressed using lossy JPEG encoding
7. The remote location transmits the image using an Internet connection to an university hospital
8. The institution that received the image gives a second opinion and sends it back to the institution that requested it

The transmission of the digital image is performed by means of an upload using a web-based form, that can be accessed using any web browser.

3. Technical Aspects of ScanRX

ScanRX is free software developed exclusively with free tools and open source libraries. It has an intuitive and easy to use interface and can be used by anyone with basic computer skills and no knowledge of radiology is necessary, since all the technicalities of the image processing are dealt with by scanRX in a manner that is completely transparent to the user.

3.1 The Development of ScanRX

The main objective was to write an easy-to-use free software using standards and APIs that are widely used in the market. ScanRX was written in C++ and the image stitching algorithm was implemented using the C programming language. The whole package was compiled with the MinGW compiler, which is a Windows implementation of the well-known (in the Linux world) GCC compiler.

The graphical user interface was written using the wxWidgets library (formerly called wxWindow) [www.wxwidgets.org], which is a free API for writing cross-platform applications; the supported platforms are Windows, MacIntosh and Linux, which means that scanRX can also be compiled successfully in MacIntoshes. It cannot be compiled in Linux, because the scanner chosen is not supported by such systems, imposing a limitation for the use of scanRX in Linux operating systems.

ScanRX is modularized. The main module is the executable file, there is also a help file and the stitching algorithm and the DCMTK library are implemented as dynamic link libraries (DLLs). The modularization makes the scanRX code easier to maintain.

3.2 Communication with the Scanner

ScanRX is a TWAIN (Technology without an Interesting Name) compliant software that performs the digitization as well as the registration of the image acquired.

TWAIN is a standard protocol and an application programming interface for Windows and MacIntosh, maintained by the TWAIN Group since 1992, which regulates the communication between application and image devices, such as scanners and webcams. It can be used freely in applications and data sources and is supported by all major imaging device manufacturers and software vendors.

In order to make scanRX as easy to use as possible, all the necessary configuration of the scanner is performed by the software itself and this operation is transparent to the user.

First of all, the software interface of the image source (in our case the scanner), is hidden from the user. Then, when the user clicks the button that calls the scanner, it is activated immediately. Additionally, the transparency media adapter is automatically activated and the scanning resolution is also set to 185dpi, which ensures that the quality of the images obtained is sufficient for diagnosis, while keeping them sufficiently small to be transmitted without the need of a broadband Internet connection, since this is a requirement of the TIPIRX project. The dimensions of the scanning area are also set by scanRX, which ensures that all the digitized parts have the appropriate dimensions so that the stitching algorithm operates correctly.

3.3 Creation of DICOM Datasets

The DICOM datasets are created by scanRX using the DICOM Toolkit (DCMTK) 3.5.4 library, developed and maintained by Offis. This library is open source and can be used free of charge.

The image produced by the scanner is a uncompressed bitmap. When the scanning process ends and the image is stitched, the image created is also an uncompressed bitmap; scanRX then opens this image, gets all its pixels and, using DCMTK, creates a DICOM dataset and encloses the pixels in this dataset. The DCMTK library then compresses the image using lossy JPEG compression, based on the Independent JPEG Group library (www.ijg.org), the compression level used, according to the scale of IJG, is 85. The information provided in the scanRX identification screen (see Figure 1(a)) is also included in the appropriate dataset fields. When the digitization process ends, the output is a DICOM file, with a compressed image enclosed and all the identification data informed by the user available in the DICOM header (see Figure 1).

The level of image compression has to be chosen very carefully in this application, since important structures may be lost if the level is too high. However, according to Slone et.al (2003), the JPEG compression at a ratio of 10:1 is visually lossless at close inspection, that is, the degradation caused in the image by the compression can be considered negligible and the image can be used safely for diagnostic purposes. In the JPEG image quality scale, the level 85, used in scanRX to compress the digitized images, corresponds to a compression of about 10:1, which according to Slone et.al (2003), is a visually lossless compression.

4. Results and Discussion

The scanRX software has been tested for over one year and hundreds of x-ray films of several sizes have been scanned, by users ranging from family health workers to doctors and residents. The scanned images have been examined by radiologists of the university hospitals of UERJ, UFF and UFRJ, who approved their quality. Additionally, a pilot unit was implemented in the state of Rio de Janeiro, under the auspices of the project TeleSSaúde Brasil.

The main advantages of the solution using scanRX and the ScanMaker i800 scanner are portability and ease of use. ScanRX can be used by anyone without any knowledge of radiology; only basic skills on personal computers use are needed. Thelow cost of the solution is also a great advantage. Large scanners and digital x-ray machines (CR) are so expensive that the majority of the public health unities located in remote areas in Brazil, which constitute the target public of the TIPIRX project, cannot afford to purchase them. Table 1 shows the cost of several solutions to implement digital radiology.

Table 1: Price comparison of different technologies to obtain digital X-ray images

Equipment	Price
Digital x-ray machine (CR)	R$100,000 (about US$50,000)
Scanner A3	R$15,000 (about US$7,500)
Scanner Microtek MED 6000 (designed for medical image digitization)	R$20,000 (about US$10,000)
Scanner Microtek ScanMaker i800	**R$2,500 (about US$1,250)**

Another popular solution for digitization of x-ray films is the use of digital still cameras, where the user takes a digital photograph of the film. However, this solution demands specific illumination conditions, requires additional photography skills and, in addition, the resulting image has still to be subjected to some processing before it can be used: at the very least to be put into DICOM format. None of this is necessary with scanRX, since it passes the entire configuration to the scanner, allowing practically anyone who has only very basic computer skills to digitize an x-ray film successfully.

Finally, scanRX is currently formatted to digitize chest x-ray films, but it can also be used to digitize other types of medical image, like mammograms. Currently the solution consisting of scanRX and the ScanMaker i800 scanner is being implemented in seven locations in the state of Rio de Janeiro, that will serve as pilot locations for testing the system.

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