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Quality Conservation of Ultrasonography (US) Images in Mobile Devices

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Abstract:

Medical ultrasonography (US) is based on the correct evaluation of images. To guarantee the maintenance of consistent image quality over the lifetime of the device it is necessary to conduct periodic quality controls, consisting in image processing of images acquired from dedicated phantoms. At the present time mobile devices (e.g., iPad, Windows RT tablets, Android-based systems) are increasingly used for visualization of diagnostic images acquired by US machines, so images processing on this kind of hardware plays a crucial role in diagnostic imaging. In this paper we report an overview on the conservation of quality of the images transferred from the US consoles to remote electronic devices, in order to detect possible differences between homologous images. Moreover, always related to image quality controls, the Authors report about the development of an alternative procedure to quantitatively evaluate the US Functional Resolution (FR) parameter. To perform image conservation, image quality controls were conducted on eighteen different US systems and several parameters were evaluated by using a dedicated phantom, according to international and national technical protocols. The obtained images were analysed qualitatively and, if possible, quantitatively both on the US device (live analysis) and on a PC by using a dedicated LabView-based software (post processing). An iOS device was used for qualitative evaluations on the same images. The developed LabView-based application aims at measuring both directly and univocally the FR parameter, unlike the usual qualitative procedure that highly depends on medical staff capability. This alternative procedure allows to represent the anechoic structures as minima in the intensity vs. pixel graph. Thus, the measurement of the FR does not depend on the operator's eye response.

Keywords: US quality Controls; US Devices; Mobile Devices; US Functional Resolution; LabView Application

1. Introduction

Biomedical technological development is experiencing a rapid advancement, although it could be discussed if this advancement is driven by clinical needs or commercial interests. This situation depends on the different disciplines and application fields. Today a large diffusion of ultrasound (US) scanners, not requiring ionising radiation, is encountered as a diagnostic technique. The increase in use of the US equipment is mainly related to the non invasive technique and almost total absence of health risks. In addition, biomedical technological development has made the US devices more transportable and more accessible, also in a context different from the hospital one at lower expense. In US diagnostics this development carries large clinical benefits, regarding both the use of US systems in remote and awkward areas [1,2], and to workers other than the hospital staff [3,4]. Often, bedridden or not easily moving patients are not obliged to reach health care facilities. Now the more recent "mini" and "pocket" US scanners, that sometimes provide for wireless probes, are now in development with the advantage of an early diagnosis.

These new portable devices, for private practice, clinic, hospital or business, must display the acquired images on a small screen, usually a LCD one. However, the operator usually needs to view the stored images on a larger screen, so these devices are

equipped with tools (USB or network interface) to export the stored images. This is a great innovation because in the past, US diagnostic systems were considered as standalone systems without any possibility to communicate with other devices.

During the years, many manufacturers have provided new US system models with a set of interfaces to set up a connection between US systems and computers.

Connecting (directly or indirectly) US systems and computers is a fundamental step because nowadays any operator or researcher can use various and powerful software to carry out post-processing tasks over diagnostic images and extend the image analysis made during the exam on the US system.

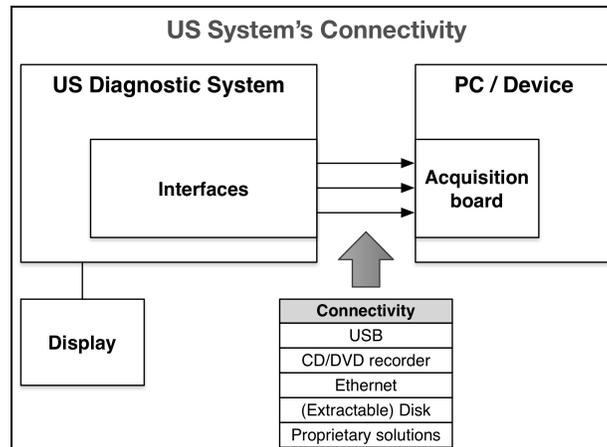


Figure 1: US system's Connectivity

At the present time some US system manufacturers provide devices with many ways to connect system and computer varying from proprietary hardware solutions to wireless interfaces. Figure 1 is a simplified scheme that shows the most common interfaces used for the transfer of images or videos from US system to computer.

In this context an important issue consists of verifying that the quality of the images achieved with mobile devices (i.e. Android tablet, iPad, Windows tablet) is comparable to that obtained using traditional US scanners. In fact, Image Processing plays a crucial role in the biomedical field, because both immediate and after post-processing evaluation are essential for a correct diagnosis.

The aim of this paper is to study the aspect of the conservation of the quality of the images transferred from the US console to remote devices. A dedicated quality controls phantom was used to perform image evaluations. The obtained images were qualitatively analysed by radiologists and, where possible, measurements were conducted using rulers and owner US (native) software; then, the same images were analysed on a PC, after transferring data using a USB interface, on a mobile device, i.e. an iPad, and finally the images were stored on the PC after transferring them from the iPad. In addition, homologous images (before and after iPad view) were analysed in order to evaluate the occurrence of alterations related to the copy/sync operation.

Moreover, always related to QCs and, in particular image conservation, during the post-processing analysis an alternative LabView based procedure was developed to univocally evaluate, in a quantitative manner, the Functional Resolution (FR) parameter, defined as “the imaging system’s ability to detect and display the size, shape and depth of an anechoic structure within the test phantom” [5].

FR represents an important parameter that a Medical Physicist must check during his periodic tests, focused on the evaluation of system status and image quality. These tests permit the identification of both image quality degradation, before it affects patient scans, and the source of an equipment malfunction. Until today, FR evaluation has been univocally based on qualitative methods, relying on the capability of medical staff to distinguish targets at a given depth.

The advantage of the developed alternative method consists of quantitatively determining the FR parameter by measuring the last identifiable target at a given depth. In practice, the obtained data using the developed LabView software gives us a direct indication of the minimum size structure the system is capable of resolving.

2. Materials and Methods

US diagnostic techniques are based on the correct evaluation of images that are able to point out any alteration on the human body. In this context, to guarantee the maintenance of consistent image quality over the lifetime of the US device and to ensure safe and accurate operation of the process as a whole, it is necessary to establish and actively maintain regular and adequate Quality Assurance (QA) procedures. The QA program should include periodic tests to ensure accurate target and critical structure localization [6]. Such tests are referred to as Quality Controls (QCs). They hold a key role within the QA procedure by enabling complete evaluation of system status and image quality [7,8].

Image QCs were performed using a Multipurpose Phantom model 539 PTW – Freiburg [5] dedicated to the US equipment. Image Quality Controls were conducted on eighteen different US systems. For each of them, the following imaging parameters were evaluated, according to national and international technical protocols [9,10]:

- dead zone
- vertical and horizontal calibration

- axial and lateral resolution
- functional resolution
- focal zone
- sensitivity (maximum depth of visualization)
- gray scale

The procedure used during the image evaluation is summarized in a three staged scenario shown in Figure 2.

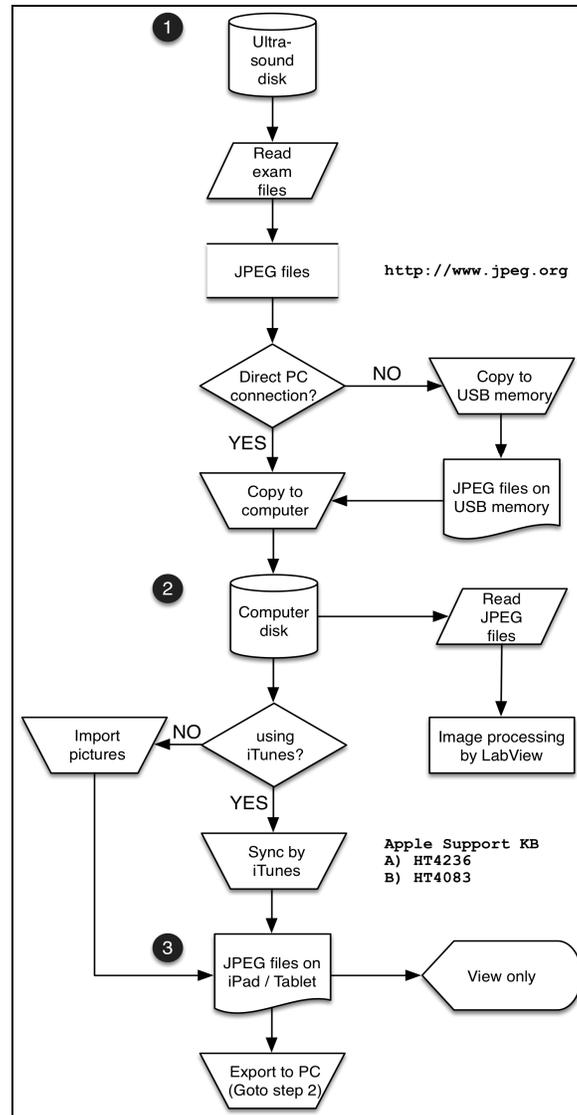


Figura 2: the three staged scenario describing the procedure used during images evaluation

The first stage is the file transfer. Two common approaches were employed to copy exam files. As indicated in Fig. 2, the exam files could be moved to the computer through a direct connection between the US device and computer, usually with Ethernet interface, or by making a copy on a USB drive. All US systems provide a console to evaluate image quality. The second stage of the procedure is the post-processing, representing a very important stage in order to obtain more information about diagnostic images.

The third stage is the transfer of the acquired JPEG file onto the mobile device, considering the wide diffusion of mobile devices as new possibilities arisen for viewing diagnostic images beyond the traditional PC-based viewing [11, 12]. For this study an iPad 2 with 64 Gbytes of memory was used.

There are many practical approaches for copy/sync of images from computer disk to iOS storage memory [13, 14]. A simple analysis has been carried out in order to provide an overview of changes on images while copying them from/to iOS devices. The software utilities used for this purpose are Exiv2 and hexdump.

Exiv2¹ is a C++ library and a command line utility to manage image metadata. It provides fast and easy read and write access to the Exif, IPTC and XMP metadata of images in various formats. The term metadata refers to descriptive data possibly related to

¹ <http://www.exiv2.org/>

the structure and/or content of digital data (“*data about data*” is an informal definition of metadata). In the biomedical field, the definition of specific standard metadata models (patient data, technical information, notes, etc.) for diagnostic images [15-19] may be extremely useful in highly heterogeneous environments.

The most important tasks provided by exiv2 as command-line utility are:

- print Exif, IPTC and XMP image metadata in different formats: Exif summary info, interpreted values, or the plain data for each tag,
- extract, insert and delete Exif, IPTC and XMP metadata and JPEG comments,
- extract previews from RAW images and thumbnails from the Exif metadata,
- insert and delete the thumbnail image embedded in the Exif metadata,
- print, set and delete the JPEG comment of JPEG images,

The *hexdump*² command-line tool [14] is a powerful utility mainly used for reverse engineering purposes³. This tool has been used against diagnostic images in order to carry out a low-level inspection on changes occurred after file copy from US systems and computers/devices.

The most important command-line options of hexdump are:

- C: Canonical hex+ASCII display. Displaying the input offset in hexadecimal, followed by sixteen space-separated, two column, hexadecimal bytes, followed by the same sixteen bytes in %_p format enclosed in “|” characters.
- s offset: Skip offset bytes from the beginning of the input. By default, offset is interpreted as a decimal number. With a leading 0x or 0X, offset is interpreted as a hexadecimal number, otherwise, with a leading 0, offset is interpreted as an octal number. Appending the character b, k, or m to offset causes it to be interpreted as a multiple of 512, 1024, or 1048576, respectively.

Finally, once the image has been copied on PC, we developed an alternative LabView based procedure to analyse the FR in the post processing step. The developed software is compatible with non standard and standard image formats (BMP, TIFF, JPEG, JPEG2000, PNG and AIPD). In order to evaluate FR, the procedure began by opening the image under investigation and, utilizing the “Line Profile” tool, by drawing a line on the opened image we were able to get the pixel values of the image along this line (line profile). So we used the “Line Profile” command in inspection and gauging tasks to find the edges of an object or a part being inspected.

To measure the FR, a vertical line was traced in correspondence to targets, which had a different echogenic characteristics of a structure. The “Line Profile” tool showed all the observable circular anechoic structures inside the phantom as minima in an intensity vs. pixel number plot.

3. Results

In Fig. 3 the comparison between the phantom image, stored during the conduction of quality controls on an US system (Fig. 3a), and the same image (Fig. 3b) analysed on PC after the cycle (PC - iPad - PC) was shown in order to evaluate the quality conservation.

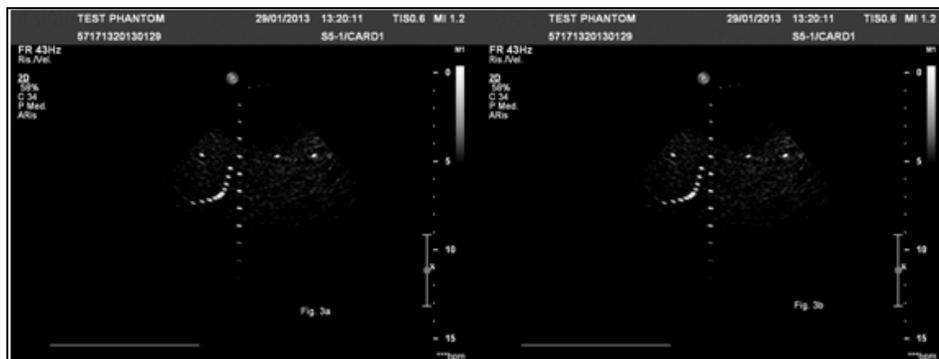


Figure 3: comparison between homologous images of the US QC dedicated phantom. Fig. 3a represents the image stored on the console of the US system; Fig. 3b shows the same image analyzed to the PC after the cycle (PC – iPad – PC)

Running exiv2 pr /path/to/image over figures 3a and 3b we can observe the differences showed in Table I:

Image file	Ultrasound	iPad	Ipad without Exif
test_phantom_1.jpg	83542 B	88517 B	83524 B

Table 1: results output from running exiv2 pr/path/to/image over both image version (pre and post iPad)

² http://en.wikipedia.org/wiki/Hex_dump

³ On Unix/POSIX/GNU systems: The utilities od and hexdump output octal, hex, or otherwise encoded bytes from a file or stream. These are useful for access to or visual examination of characters in a file that is not viewable on terminal.

The iPad version of diagnostic image, Fig. 3b, has about 5 KB more than the original ultrasound version. This difference is related to Exif metadata (header and thumbnail) added to images by iPad software. Removing the *Exif* data by `exiv2 rm`, we can easily compare the hexadecimal dump of files using `hexdump` (figure 4):

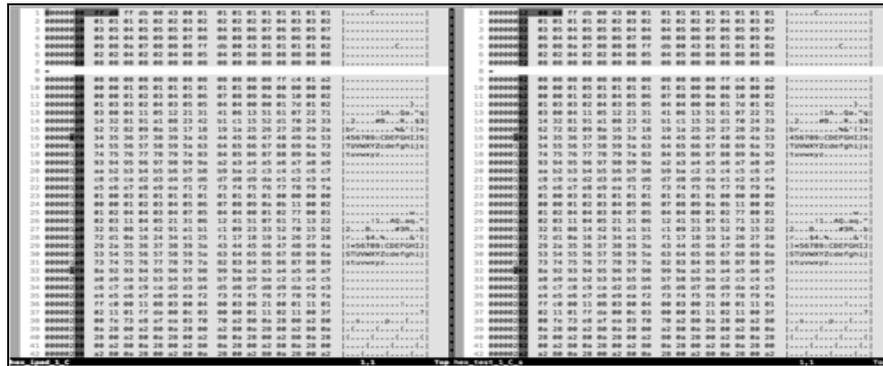


Figure 4: Hexadecimal comparison (vimdiff output) of image versions.

The screenshot showed in Figure 4 demonstrated the differences of the hexadecimal dump of iPad-without-Exif (left side) and original (right side) versions. After inspecting and comparing the hexdump results, we observed that both versions are the same except for the header. The right side is obtained by using the following command:

```
hexdump -C -s 0x12 test_phantom_1.jpg > hex_test_1_C_s
```

The same images were also analyzed qualitatively and, where possible, quantitatively first on the US device, then on iPad (only qualitative evaluations), and finally on a PC using a dedicated software. The obtained results are shown in Table II.

Parameter	US Console	PC before the cycle	iPad view	PC after the cycle
Vertical Calibration	0.96	0.94	Only qualitative evaluation	0.94
Horizontal Calibration	2.07	2.1	Only qualitative evaluation	2.02
Lateral Resolution	6 Targets	6 Targets	6 Targets	6 Targets
Axial Resolution	6 Targets	6 Targets	6 Targets	6 Targets
Functional Resolution	Targets correctly visualized	Targets correctly visualized	Targets correctly visualized	Targets correctly visualized
Gray Scale	6 Targets	6 Targets	6 Targets	6 Targets
Dead Zone	9 Targets	9Targets	9 Targets	9 Targets
Sensitivity	152 mm	151 mm	Only qualitative evaluation	151 mm
Focal Zone	41 mm	41 mm	Only qualitative evaluation	40 mm

Table 2: comparison between the results of the images quality measurements conducted on US console, on PC before and after the cycle (PC – iPad – PC) and on the mobile device (iPad)

We observe that the qualitative measurements were comparable each other and quantitative results were also within experimental error. Finally, in Figure 5 we report the developed software mask which was used to measure the FR. In particular in Figure 5a we show an example of a measurement conducted on an image stored on the PC compared with the same image after the cycle (PC - iPad - PC), Fig. 5b. In both cases, the anechoic structures inside the phantom were correctly indicated, using the “Line Profile” tool, as minima on the intensity vs. pixel number plot, reported at the left side of the mask.

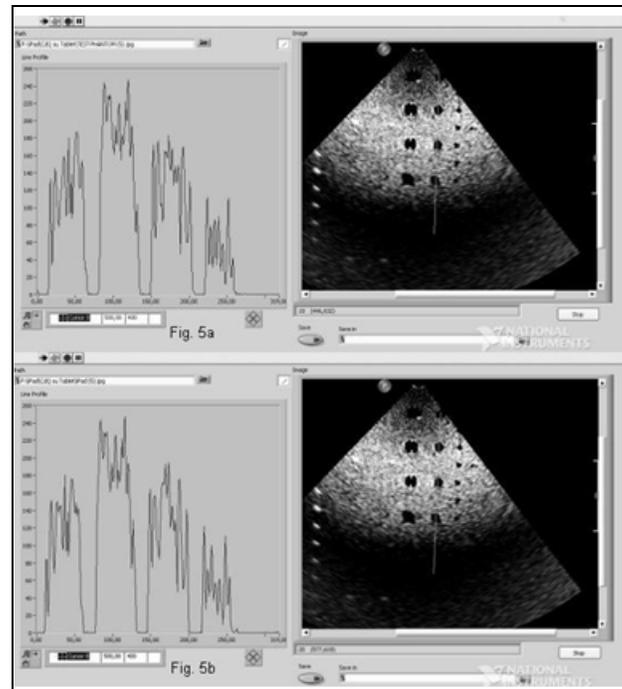


Figure 5: Functional Resolution evaluation using the alternative LabView based procedure: before (Fig. 5a) and after (Fig. 5b) the cycle (PC – iPad – PC)

This alternative procedure enables us to derive unambiguously the FR parameter, that, using the usual qualitative method, would be determined by the operator's ability to interpret the US acquired image.

4. Conclusion

The latest mobile devices, such as the iPad and smartphone, allow us to consult books and papers and, even, they are able to display medical images, such as anatomic tables and radiological atlas, but only for study purposes. However, when acquired images are transferred to mobile devices to compute diagnosis, it is important that these images do not lose quality after copy/sync on the iPad or smartphone, because even a small alteration may cause a non correct diagnosis. This paper handled the aspect of preservation of US image quality, when images were transferred from US scanners to displaying devices.

In order to detect if alterations occurred in pixel sizes during the data transfer, the acquired images were processed using two different iTunes software. Moreover, in order to guarantee the maintenance of consistent image quality performing QCs procedures, in post processing the same images were quantitatively - and when no measurements were possible, also qualitatively - processed by a dedicated software, LabView based, before and after the cycle (PC-iPad-PC).

By choosing *exiv2* and *hexdump* for image (and related data) processing, we used powerful command-line tools that allow us to carry out an accurate inspection of images' properties without any complicated, cumbersome and commercial software. The images copied on computer disk after evaluation on iPad present a little different file size compared with those evaluated before iPad synchronization. The file size of image copied on iPad is slightly greater than the same image stored on PC. This "scenario" represents a cause for reflection about an innovative way to conceive mobile devices for reading and/or processing diagnostic images, because the standardized use of the metadata in diagnostic images is extremely useful for the sharing and the automatic processing of information in highly heterogeneous environments.

In the second case, a good agreement between all the measurements carried out on stored images was obtained from both quantitative and qualitative results.

Finally, the developed software, LabView based, dedicated to measure FR, and also used for image evaluation, resulted useful and manageable. In addition the developed procedure, unlike the usual qualitative procedure that highly depends on medical staff capability, permitted determining directly and univocally the FR. In fact, whereas during the usual procedure the operator set the US system as a function of his own eye response, the alternative procedure allowed the anechoic structures to be represented as minima in the intensity vs. pixel graph: in this manner the measurements of the FR results were independent from the operator's eye response. The encouraging results of this study indicate the possibility to extend the developed procedure to other diagnostic equipment. Indeed, more manufactures utilize mobile devices to display diagnostic images, such as in Cone Beam Computed Tomography (CBCT) of latest generation.

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