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RONI Size and another Attributes of Representative Sample of Medical Images in Common Hospital Operation, Related to Securing by Watermarking Methods

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***Abstract*:** *Medical institutions adapt digital based archiving of patients records images to fulfil its advantages like availability, easy sharing, high resolution etc. Digital form of records brings apart from advantages also disadvantages at security risks. It is easier attacking, stealing, using without authorization etc. This article deals with this security issue. It names methods of medical image watermarking and compares their plus and cons. Concept of Zero-reversible watermarking, that combine advantages of described methods, is proposed. Four purpose of this concept, there are examined and statistically compared attributes of medical images in a huge database (60 000 images) of medical records from various field and modalities like resolution, bit depth, coloring. This database could be considered as a representative sample of medical images in common hospital operation. Method for finding of minimum size of Region of Non-Interest (RONI) in the images from different types is presented. Results for whole database and certain modalities are depicted.*

Keywords: *Communication, database, DICOM, education, medical images, ROI, RONI, security, watermarking*

1. Introduction

Last two decades bring to medical imaging particularly digitalization. This is associated with a lot of benefits for a medical staff, like: rapid availability of images, easy searching the database by a number of parameters, higher resolution of images, ability to edit and add comments, link with hospital information systems, possibility of remote consultations, simple transfer of information between health facilities, easier application of the image data for educational purposes [1, 2, 3]. Of course, all these advantages carry their own risks, which needs to be coped with. It is especially the security of such stored and transferred data. Due to its digital nature, it is easier to be attacked, stolen, altered, or used without authorization, in comparison to the archives of tangible images in secured hospital premises. In addition, it is necessary to deal with data backup and high availability of the entire system. It is accompanied by additional security risk.

We are facing this problem in the project MeDiMed, where we almost for two decades build Picture Archiving and Communication System (PACS) with large databases of DICOM (Digital Imaging and Communications in Medicine) images from different areas. For example databases with patient images from normal hospitals operations with high availability and archiving requirements, data sharing database, teaching databases which are supplemented with a structured report with the case history and diagnosis. We want this database to be available to medical students as well as doctors. So, we need to ensure the authors that their work of described images will not be misused. Data have to be accessible and easy to use. Equally data have to be secured from unauthorized use.

Watermarking methods that allow prove the origin of the data seems the most suitable for this purpose. For selecting the most appropriate method we performed analysis of medical images attributes like modalities, resolution, bit depth, coloring and RONI on a large number of samples, so we have an idea about their properties.

2. Zero – Reversible Watermarking Concept Proposal

Common methods of medical images watermarking implies some follow-up problems, complicating or completely excluding from their practical mass implementation and everyday use in medical facilities [2]:

- Watermarking in RONI – protects only an insignificant parts of the image. The most valuable part of the image, due to the fear of distortion, is not protected at all [4,5,6].
- Reversible watermarking - requires creation of an additional secure information channel for transmission of data needed for removing the watermark and an access to the original unmodified data [8-11].
- Zero watermarking - requires to build a complex system for storing and comparing watermarks. Moreover, it is especially suitable for copyright protection [16,21].
- Watermarking with no effect on medical information of image - suitable only for certain types of images and hardly predictable impact on the real final diagnosis [19].

Watermarking has a number of positives for the security of image data. However each of the methods used for watermarking of medical data have, besides a number of positive characteristics, also significant negative aspects.

If zero watermarking is used for the region of interest ROI and watermarking in the rest of the image RONI is used for hiding differential data, needed to restore the original data in this region, a number of negative effects of both types of watermarking in medical images would be resolved.

When inserting a watermark, original data are divided into two parts. The first part RONI does not contain information where a slight change could affect the patient's diagnosis, while the second part contains this type of information. The watermark is inserted into the ROI using the zero watermarking method. Information necessary for correct extracting of this watermark is stored in RONI. Both watermarking regions are then joined into one secure whole. At watermark extracting, the image is again split in two parts. ROI and RONI. With the reversible watermarking are extracted information needed for extracting watermark from ROI with zero watermarking. After joining the two parts of the image together, original data are obtained.

The main benefit is the security not only of RONI but especially of the most valuable part of the image - ROI. This substantial part of the image was additionally protected with zero watermarking. This means that without extraction of the watermark, diagnostics process is possible. Furthermore, this solves the problem with creating a special secure information channel, necessary for reversible watermarking. That is essentially created by hiding of information needed to return to the original information in RONI.

One can also assume that the larger the area RONI, the greater will be its capacity in terms of number of hidden information, thus enabling utilization of more robust method for reversible watermarking and data protection at more secure level.

We did not found survey of minimum size of RONI in images of different medical modalities, but only finding of ROI or RONI in images of particular modality in accessible literature [22]. RONI examination of medical image data from different types of modalities is described in next chapter.

3. Examination of Representative Sample of Medical Images in Common Hospital Operation

For our examination purposes we chose one of our medical image database, which is used for educational activities at Masaryk University, Faculty of Medicine and could be considered as a representative sample of medical images in common hospital operation. This database was prepared by large team of medical specialists during several years lasting project. In this project specialists from very various medical disciplines prepared large amount of in detail described educational images. It ensures large diversity of images across different types of medical institutions and due to it, it is suitable for our purpose. This database contains 60093 images. In Table 1 is enumeration of included medical images modalities.

The tables should also be numbered like Table 1, 2, 3…etc. The font size of the table caption should be 10 and the data size inside the table cells should be 9 pt. in times new roman. The caption of the table should be written as shown below:

TABLE I: Enumeration of included medical images modalities

percent in total	number of images	modality
42,77%	25703	MR
24,38%	14653	CT
17,02%	10228	PT
8,48%	5094	ES
1,78%	1070	SR
1,43%	861	XA
1,20%	723	DX
0,98%	590	CR
0,86%	514	US
1,09%	656	other

Product models of the most common modalities:

MR (Magnetic Resonance)- Avanto, Symphony, MAGNETOM OPEN viva, Achieva, MAGNETOM IMPACT, NUMARIS/4 3D

CT (Computed Tomography) - TomoCon Workstation, HiSpeed NX/I, Mx8000, MxView, Brilliance 64

PT (Positron Emission Tomography PET) - Siemens 923

ES (Endoscopy) - TomoCon Workstation, Centricity RA 600

There is another 9 types of modalities included in row “other” with 1,09% in total images, which are not so common and frequently used, so it is not necessary to pay attention to them.

Another important parameter of images is their size, either of amount of pixels or of space needed to storage. The most common resolution of images, modality type, bit depth and color are in the Table 2. The smallest image is 64x64 pixels 12bit grayscale CT and the largest are 3480x3480 pixels 12 bit grayscale CRs.

TABLE II: Resolution of images, modality type, bit depth and color

percent	resolution	modality	bit depth	color
33,10%	512x512	CT, MR	12	grayscale
13,93%	128x128	MR,PT	12 or 16	grayscale
9,56%	256x256	MR	12	grayscale
4,92%	768x576	US,ES	8	grayscale
3,23%	448x512	MR	12	grayscale
2,90%	764x572	ES	8	true color

Resolution distribution across images shows Fig. 1.

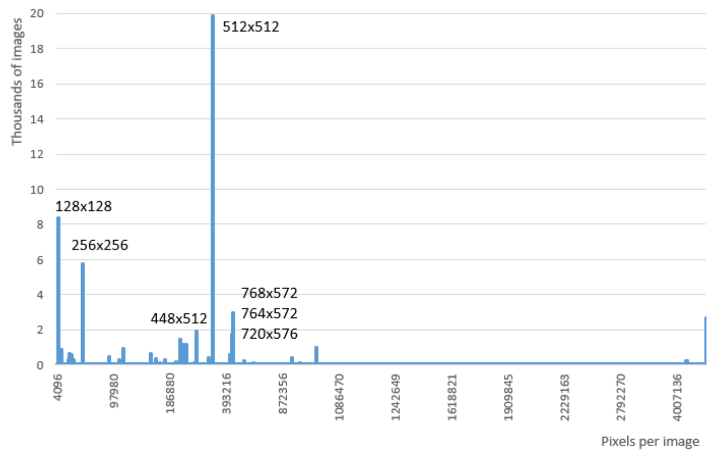

Fig. 1: Resolution distribution across images

In the Table 3, there are the other interesting parameters of images in educational database.

TABLE III: Parameters of images in educational database

		amount	percent
total amount		60093	100,00%
color	grayscale	51628	85,91%
	true color	5790	9,64%
bit depth	n/a	2678	4,46%
	8b	6593	10,97%
	12b	40146	66,81%
	14b	363	0,60%
	16b	10316	17,17%

4. RONI in Medical Images

Typical medical image has image data surrounded by black border that could be included into RONI. RONI is the area of image, where we consider information that is of no pertinent context for further analysis. This region is from the aspect of the security purposes very important area. There is possible to hide watermark with such features that allow little change of spatial pixels. We tried to estimate the size of this area in the images of our database.

4.1. RONI Detection Method

For an overview of RONI size, we used a simple method based on comparing nearby vectors of pixels. In horizontal direction rows from top and bottom, in vertical direction column from left and right of the image. The degree of similarity of each vector was given by coefficient, which we changed from one to fifty percent.

For a better scale we found out highest and lowest value of pixels in image and between these values, we performed comparisons of individual vectors. This scaling is showed in Fig. 2:

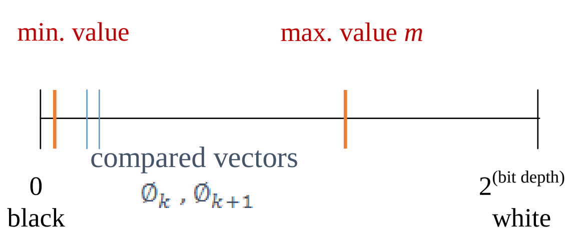

Fig. 2: Scaling pixel vectors value

Inequation for finding border edge in horizontal direction from top:

$$\emptyset_k = \sum_{i=1}^{x} \frac{p_{k,i}}{x}, \emptyset_{k+1} = \sum_{i=1}^{x} \frac{p_{k+1,i}}{x} \tag{4}$$

$$\emptyset_{k+1}\frac{100}{m} - \emptyset_k\frac{100}{m} > c \tag{5}$$

where x is number of rows in image, $\emptyset$ is average of pixels value, p is pixel value, k is index of row, m is maximum value of pixel in image and c is coefficient of similarity in percent.

Until inequation (5) is valid we increase index k as long as (5) is invalid. Then k is number of rows from top of image, where is border. Similar procedure is applied to the other three directions where we get number of rows from bottom l, number of rows from left m and number of rows from right n.

Size of RONI in pixels R is then simply:

$$R = (k + l)x + (m + n)y - (m + n)(k + l) \tag{6}$$

As we found out, that similarity coefficient change had no significant impact on detected RONI size, what assured us that our method is suitable for our purpose and detects correctly border area. Fig. 3 shows automatic detection of ROI (area in red square) and RONI (rest of square). White lines shows searching borders from each side of picture.

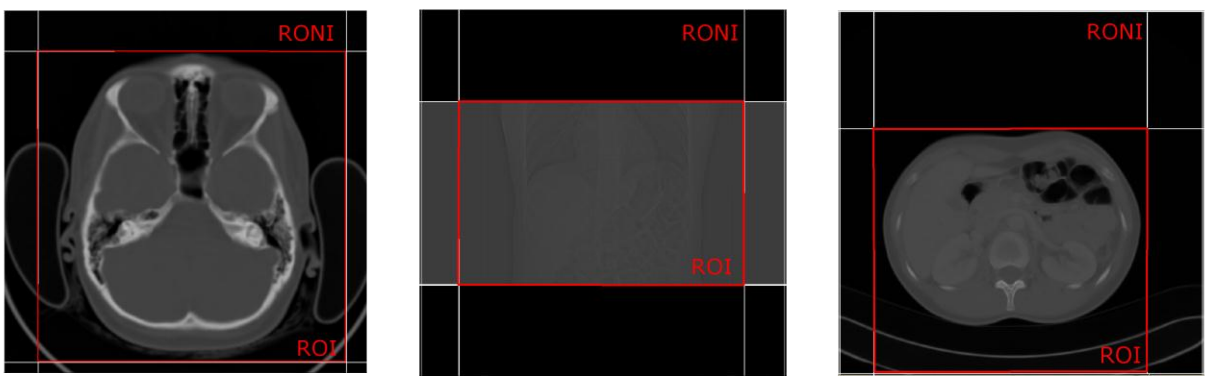

Fig. 3: Automatically detected ROIs in different types of anonymized medical images

Graph showing detected RONI size as a percentage of the total number of pixels in images with similarity coefficient 10% is shown at Fig. 4.

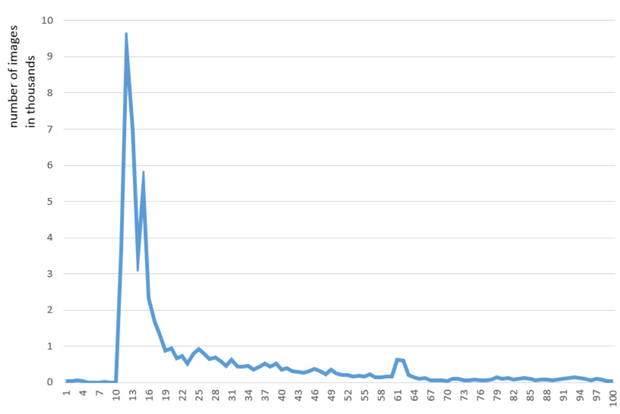

Fig. 4: Detected RONI size as a percentage of the total number of pixels in images with similarity coefficient 10%

As we can see, we can calculate with more than 11% of image pixels within each medical image as RONI. This is a first peak with 9253 images. Second peak is in 15% with 5433 images. Interesting is last peak with 56-58% or RONI pixels with 1450 images.

We can see on next graph which modalities takes part on each peak and what are their characteristics.

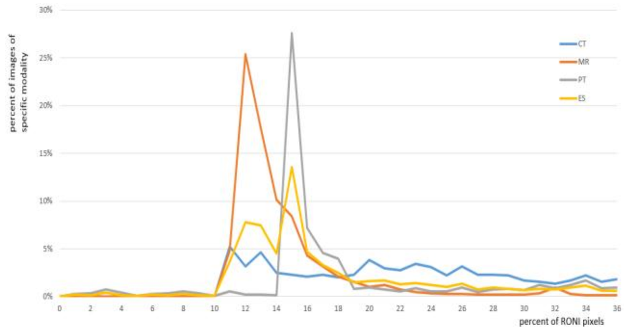

Fig. 5: Detected RONI size of certain modality as a percentage of pixels in images with similarity coefficient 10%

Fig. 5 shows detected RONI divided by certain medical modalities with relative, not absolute distribution. Shown modalities are four most frequent in educational database - CT, MR, PT and ES.

TABLE IV: Size of RONI in percent of medical images divided according certain modalities

% of RONI	CT	MR	PT	ES
5	0,01%	0,00%	0,05%	0,04%
6	0,12%	0,00%	0,27%	0,20%
7	0,05%	0,00%	0,31%	0,12%
8	0,07%	0,00%	0,56%	0,27%
9	0,09%	0,00%	0,30%	0,13%
10	0,01%	0,00%	0,08%	0,04%
11	5,24%	4,76%	0,54%	3,64%
12	3,14%	25,40%	0,21%	7,77%
13	4,64%	17,65%	0,18%	7,47%
14	2,45%	10,11%	0,13%	4,51%
15	2,26%	8,37%	27,61%	13,59%

We can see in Fig. 1 and Table 4 that most frequent MR images have in 95% of cases RONI bigger than 10% and in 100% of cases bigger than 11%. It has major peak in about 12% or RONI with 25% of images. The second most common CT images has no major peak. We can see that vast majority has 11 and more percent of RONI pixels. PT images peak is in 15% of RONI pixels and we can see, that 95,7% of images have 15 or more percent of RONI pixels. And finally ES images have in 98,4% cases more than 11% of RONI. The results indicate, that we can calculate with 6 and more percent of RONI pixels of medical images.

5. Conclusion

This article describes the problem with the protection of the database of medical images and its solution by using watermarking. Direct diagnostics on this way secured images is possible. The most commonly used methods of watermarking, as well as, their positives and negatives are described. By appropriate combination of two described methods negative characteristics are eliminated and positive ones are accentuated. Novel Zero – reversible watermarking concept is proposed. For it's propose a huge database of medical images is examined, because we did not found survey of minimum size of RONI in images of different medical modalities in accessible literature. Most often used modalities are MR, CT, PT and ES. Most often resolutions are 512x512

128x128 and 256x256 with bit depth 12. The smallest image is 64x64 pixels 12bit grayscale CT and the largest are 3480x3480 pixels 12 bit grayscale CRs. Method for finding of RONI, necessary for proposed watermarking method is described. MR modalities have in 95% of cases RONI bigger than 10%, CT images have 11 and more percent of RONI pixels, PT's RONI peak is in 15%. For whole database we can say, that we can recon 11 and more percent of RONI pixels in vast majority of images. This results enables choice of appropriate methods of zero and reversible watermarking for securing medical images.

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