Comparative Study of Negative Aspects Elimination of Medical Image Watermarking Methods

Aleš Roček and Vladimír Zatloukal

***Abstract*—This article provides a comprehensive overview of the most common methods of medical images watermarking. It describes the watermarking of RONI (Region of Non Interest), Reversible watermarking and Zero watermarking. Main advantages and disadvantages of each method are mentioned and the causes of small watermarking methods deployments in securing medical image data are discussed. Based on this analysis, paper proposes a method for appropriate combining of two existing methods by making use of positive and eliminating negative properties of both methods.**

***Index Terms*—Communication, DICOM, medical images, security, watermarking.**

I. Introduction

In contemporary medicine, traditional 'wet' processing of patient medical images is increasingly abandoned and instead, for many years, it turns to technology of digital processing. So the way of patient images storing, accessing and distributing has fundamentally changed. This development brings a number of benefits to doctors. In particular, 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 images data for educational purposes [1]-[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. Principles of medical image data management are defined by strict ethical and legislative rules, which relevant subjects are required to respect. A number of widely used standards and procedures for the security of personal health information has been created.

Czech Republic has its own legislation ordering the security of medical data. In particular, Personal Data Protection Act (No. 101/2000 Coll.) on the protection of personal data. Since 2000, it has 23 edits, the last of which is the Act No. 375/2011 Coll. coming into force from December 8, 2011 and taking effect from 1 April 2012 [4]. It is obvious that this issue received considerable attention in legislative field.

At European level, the safety and security of sensitive personal data is dealt by Convention for the Protection of Individuals with regard to Automatic Processing of Personal Data - for the Czech Republic it came into effect on 1 November 2001. And in particular, Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data [5], [6].

The basic international standard created for the handling of health information is ISO27799: 2008 (Health informatics -- Information security management in health using ISO/IEC 27002) [7]. The Standard addresses the security issues of the personal health information of patients for the healthcare organizations. Another standard dealing with medical data and their security is the well-known standard Digital Imaging and Communication in Medicine (DICOM) [8]. It was introduced in 1983 by the association American College of Radiology (ACR) and by National Electrical Manufacturers Association (NEMA). In its early days, however, did not gain general acceptance. It succeeded in 1993, when its version 3.0 was published. This version became the standard in radiology and has been adapted into other medical areas, such as dentistry, pathology or cardiology [9]. Nowadays it is known as DICOM standard and consists of 18 parts. It focuses on the definition of the technical framework for equipment's providing digital medical image data interchange. This standard includes a set of security profiles and implements digital signature to ensure data integrity.

Security of medical image information is necessary to be implemented on several levels. It is necessary to take care of the physical and electronic access to all parts of the system. From the scanning modalities, data storage, servers, communications and media, up to the diagnostic workstations of doctors. This can be done by standard and proven methods used in the field of information technology. Moreover, it is necessary to ensure medical image data itself. Depending on the use, it is necessary to ensure data authenticity. This means that the data really concerns particular patient and has not been changed, or we need to ensure it against stealing, i.e. securing the study authorship.

The following chapters describe four main procedures for watermarking of medical images and appropriate areas of

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A. Roček is with the Faculty of Electrical Engineering and Communication, Brno University of Technology, Technická 3082/12, Královo Pole, 61600, Brno, Czech Republic (e-mail: rocek@ics.muni.cz).

V. Zatloukal is with the Institute of Computer Science, Masaryk University Botanická 68, 60200, Brno, Czech Republic (e-mail: zatlouk@ics.muni.cz).

their use, particularly with regard to their pros and cons. In the fourth chapter we present a method of elimination of major drawbacks of two of these methods by their appropriate combination as well as next steps to design a custom method for medical image data security with better properties than show the methods published so far.

II. Watermarking in Region of Non-Interest

Any bit change in medical image data could be a problem for correct diagnosis. In this method, watermark is stored only in parts that don't care important information for diagnosis. Choosing the RONI (Region of Non-Interest) can be either automatic or manual. Reliability of automatic detection of important areas depends on the chosen method. It depends mainly on whether to be more versatile for scanning modalities, or whether to be used for a special device. CT scans of patients use rather elliptical, X-rays rather rectangular area of the RONI. Selecting the shape of the ROI for manual labeling depends on the laboratory that performs examination. Most often rectangular, elliptical and polygonal shapes are used. An example of polygonal ROI is shown in Fig. 1. If manual ROI labelling is done carefully it allows the insertion of watermarks with greater robustness and capacity. With a large amount of watermarked images, manual labeling becomes inefficient, time consuming, leading to errors caused by the routine of constantly repeated activities. In practice, different methods of automatic RONI selection are mostly used [10]-[12].

Its advantages and disadvantages arise from principles of this method. Among the advantages there is great similarity to already known watermarking methods applied to RONI area. Big disadvantage is in a lack of protection in part of medical image that is most important. The need to search RONI makes watermarking more difficult and can bring errors with the automatic and manual ROI labeling process.

Fig. 1. Manual polygonal ROI in MR image of pelvis minor.

III. Reversible Watermarking

Reversible watermarking is based on the process of watermark insertion into a medical image, transmission of watermarked image and complete removal of watermark from image on the recipient side. After watermark removal, original image is completely restored and unchanged. Once the watermark is removed from the image, the image is no longer protected. In this similarity with data encryption systems can be seen. There are two kinds of inserting - additive and substitutive. In additive method watermark value is added to or subtract from original image, in substitutive method watermark value is inserted directly into original image. It is evident that there is a need to transmit those differential values by secure way. These differences are used at recipient's side to remove the watermark and reconstruct the original image [13]-[17].

As an advantage of this method, we can mention possibility of securing the whole image by robust watermarking methods and higher capacity than RONI watermarking. The major disadvantage is the need to create another channel to secure transport of differential information.

IV. Zero Watermarking

In zero watermarking, watermark is not inserted directly into watermarked data, but it is kept away for later comparison. As a result it can be considered as a lossless since no data are modified. It is primarily used to ensure copyrights protection. It is based on a CA (Certification Authority) and PKI (Public Key Infrastructure). As an example, procedure in wavelet domain could be mentioned. The digital signature is generated by comparing image coefficients in low frequency sub band. Then XOR function is applied to the signature and the signature of the owner. Result is stored for later verification in PKI [12], [17].

Main advantage is high robustness and zero distortion of watermarked image. Big disadvantage is the need to build fairly complex PKI system for watermark store and comparison.

V. Watermarking with Image Change Not Affecting Diagnosis

Methods changing values of some bits in the resulting image can also be used for watermarking of medical images. But the change has to be so insignificant that it cannot in any way affect the final diagnosis, the study was intended for. In general, this method can be used with images taken on the scanning modalities with a higher resolution than needed for accurate diagnosis. This type of watermarking is typically suitable for X-ray images such as fractures, where important information is seen from surrounding pixels, regardless of the exact shade grayscale in the given bit depth. This method is unsuitable for images intended for the diagnosis of metastasis for which accurate bit pixel value as well as its surroundings is critical [18].

Invisibility of watermark is for the hidden watermark fundamental attribute, especially with use of medical image data. Invisibility is measured by some exact parameters with only a mathematical approach (PSNR (1), MSE (2)), or with consideration to the properties of the human eye (SSIM (3))

[19], [20].

PSNR- Peak Signal to Noise Ratio:

$$PSNR = 10 \log \frac{X^2}{\frac{1}{N_1 N_2} \sum_{i=1}^{N_1} \sum_{j=1}^{N_2} (C_O(i,j) - C_W(i,j))^2} \quad (1)$$

MSE- Mean Squared Error:

$$MSE = \frac{1}{N_1 N_2} \sum_{i=1}^{N_1} \sum_{j=1}^{N_2} (C_O(i,j) - C_W(i,j))^2 \quad (2)$$

SSIM- Structural Similarity Metric Index:

$$SSIM(x,y) = \frac{(2\mu_x \mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (3)$$

where N_1 a N_2 are horizontal and vertical dimensions of the image, X is the maximum pixel value (in 16-bit images it is 65536).

The advantage of this type of watermarking is great similarity to conventional watermarking of common types of image data, the disadvantages are the use only with certain types of images and the unpredictable real impact on the final diagnosis.

VI. Assessment of the Problems of Medical Image Watermarking

The above list of available methods of medical images watermarking implies some follow-up problems, complicating or completely excluding from their practical mass implementation in normal everyday use in medical facilities:

- Watermarking in RONI - only protection of insignificant parts of an image. The most valuable information, due to the fear of distortion, is not protected at all.
- 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.
- Zero watermarking - the need to build a complex system for storing and comparing watermarks. Moreover, it is especially suitable for copyright protection.

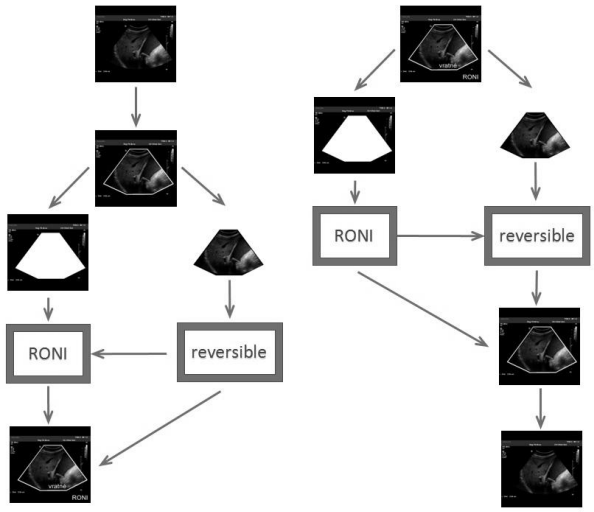
Watermarking not affecting diagnosis - suitable only for certain types of images and hard predictable impact on the real final diagnosis.

VII. Reversible-RONI Watermarking

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

But what if the positive characteristics of each method are combined and serve to eliminate the negative characteristics? If reversible watermarking were used for the region of interest ROI and watermarking in the rest of the image RONI were 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.

We will try to confirm this hypothesis supported by previous study.



a) b)

Fig. 2. Watermarking of medical images using new method a) insertion of the watermark into original data b) removing the watermark and restoring the original data

Scheme of the new watermarking method is illustrated in Fig. 2. When inserting (Fig. 2a) a watermark original data are divided into two parts. The first part RONI (Region of Non-Interest) does not contain information a slight change of which could affect the patient's diagnosis, while the second part contains this type of information. The watermark is inserted into the second part using the reversible watermarking method. Information necessary for correct reversible extracting of this watermark is stored in RONI. Both watermarking regions are then joined into one secure whole. At watermark extracting Fig. 2b), the image is again split in two parts. The watermark, information from which is used for reversible watermark removal from critical data, is removed from RONI. After joining the two parts of the image original data are obtained.

The main benefit is the security of not only RONI but of the most valuable part of the image - ROI. This substantial part of the image was additionally protected with reversible watermarking. This means that after extraction of the watermark, restoring of original information takes place. Furthermore, this solves the problem with creating a special secure information channel, necessary for reversible watermarking. That is essentially created by hiding 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.

VIII. Conclusion

In this article, we review four approaches to watermarking

in the area of medical image data. We point out the problems with the real deployment of these methods and propose solutions to these problems by combining the positive properties of two methods. Appropriate combination of watermarking in RONI and reversible watermarking should allow, according to our hypothesis, the security of medical image data with better parameters than other methods published so far.

The principle of the proposed method consists in splitting medical image data into two parts. First part of data, in which a minor change results in affecting the patient diagnosis, and the other, a minor change in which does not affect the final diagnosis. The first part of the image is secured by reversible watermarking method. Information needed for extracting the watermark and hundred per cent restoration of original data are used for watermarking the second part. Both parts are then joined in one secure whole. Similar process is applied when extracting the watermark from an image. The image is split into two parts, the data from extracted watermark from the first part - RONI are used for reversible data restoration and for extracting the watermark from the second part. This will lead to restoring original data without any effect on the patient's diagnosis. Simultaneously this procedure solves the problem of creating another secure communication channel, necessary for the reversible watermarking.

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Aleš Roček was born in Vyškov, Czech Republic, in 1978. He received his master's degree in electrical engineering from the Brno University of Technology in 2002. At present, he is a PhD student at the Department of Telecommunications, Brno University of Technology.

He works as an ICT specialist at the Institute of Computer Science at Masaryk University. His latest publications: Influence of the TCP packet setting and encryption for data transfer in medical applications (Paris, France: WSEAS Press, 2013), The possibilities of using single-board computers for medical data transmission security (Warszawa, Poland: Wydawnictwo Czasopism i Ksiażek Technicznych Sigma-NOT, 2013), and Medical image data security based on principles of digital watermarking methods (Siena, Malta: WAEAS Press, 2012). His research interest is focused on medical image security, especially watermarking.

Vladimír Zatloukal was born in Brno, Czech Republic, in 1953. He received his master's degree in electrical engineering from the Brno University of Technology in 1977.

He is a system analyst with the Institute of Computer Science, Masaryk University. His main publications: Secure medical multimedia DICOM data transfers over Internet (Siena, Malta: WAEAS Press, 2012), Environment for effective training in medical image diagnostics (Lisabon, Portugal: Formatex, 2009). His main interests include medical image processing and medical data transferring and sharing.