An Efficient Authorship Protection Scheme for Shared Multimedia Content

Mohamed El-Hadedy, Georgios Pitsilis and Svein J. Knapskog

The Norwegian Center of Excellence for Quantifiable Quality of Service in Communication Systems

(Q2S)

Norwegian University of Science and Technology (NTNU) O.S.Bragstads plass 2E, N-7491 Trondheim, Norway

E-mail: hadedy@alumni.ntnu.no,georgios.pitsilis@gmail.com

Abstract

Many electronic content providers today like Flickr and Google, offer space to users to publish their electronic media (e.g. photos and videos) in their cloud infrastructures, so that they can be publicly accessed. Features like including other information, such as keywords or owner information into the digital material is already offered by existing providers. Despite the useful features made available to users by such infrastructures, the authorship of the published content is not protected against various attacks such as compression. In this paper we propose a robust scheme that uses digital invisible watermarking and hashing to protect the authorship of the digital content and provide resistance against malicious manipulation of multimedia content. The scheme is enhanced by an algorithm called MM-BEC, that is an extension of an established scheme MBEC, towards higher resistance.

1 Introduction

Public services, like Flickr [10], Google [11] and Instagram [15], which offer space to users to publish their electronic media and making them accessible to other people, have achieved high popularity today.

Information such as the owner of the photo as well as other information related to technical characteristics can already be captured and saved along with the media to help indexing and searching. Keywords that describe the content of photos submitted by users can yet be attached as metadata, adding in this way semantic meaning to the content. In current implementations of such services (e.g Flickr, Google) such functionality is already offered, but with all meta-data been stored separately from the content. Even though such solutions provide good functionality, they do not offer any added security, since no protection of authorship is provided. This comes from the fact that, for public content anyone is given the reading permission and hence the opportunity to copy, republish and claim the authorship of it. In the same way, owner information or annotations that had been originally associated to the media by its owner also become vulnerable, as they can be replaced either mistakenly or maliciously. Applying ordinary digital watermarking onto the content would not provide sufficient protection against the above threat. *lossy compression, geometric distortion* and *addition of noise* or *filtering* are ways to remove the watermarking and hence making unable to uniquely state the authorship. On the other hand, *visible watermarking*, while it is easy to apply, it requires significant intervention on the aesthetic view of the image.

We propose a new robust scheme which combines hash function and watermarking to protect the authorship of the content against various attacks. Compared to existing robust solutions [1] against manipulation of digital multimedia material, ours has the advantage of not requiring public key encryption and therefore it is neither CPU intensive, nor does it produce large volumes of data. It also uses blind verification, making the provision of the original object in the verification unnecessary, and therefore it is faster, easier and more secure. In addition, in our proposed scheme, hashing is applied onto the whole content thus being more reliable in the verification, as opposed to hashing only part of the content.

The contribution of this paper is twofold. First, we introduce a novel watermarking algorithm called MMBEC which is resistant to various attacks, and second, we propose a scheme which implements this algorithm and can be used for protecting the authorship of shared media content on the web. The rest of the paper is organized as follows: In section 2 we state the problem and we present existing knowledge and related work in the field of watermarking. In section 3 we provide detailed description of the proposed scheme, while in section 4 we present a short description of the proposed watermarking algorithm. Experimental results which demonstrate the ability of our watermarking algorithm to resist compression attacks against other alternative solutions are shown in section 5. Finally our conclusions and discussion follows in section 6.

2 Problem statement and Related Work

The great ease in which digital images and data in general can be edited or duplicated has led to the need for effective tools for protecting their authorship. Digital Watermarking [12] is known as one of the best solutions to prevent illegal duplication, redistribution and modification of digital multimedia. The process of watermarking regards the embedding of additional data along with the digital content prior to publishing the material to a Content Provider.

We consider *Content Provider* as to be a service, mostly cloud-based, which provides public access to various types of material uploaded by the users. The aforementioned Flickr and Instagram, are two of the best known and most featured services of that kind. The practice used today is that, the user who has performed the uploading of the digital material to the Content Provider is assumed to be the author of that material. Nevertheless, for the reason that the content itself does not carry any evidence that could prove the identity of the real author, it makes easy to anyone to claim the authorship after the content has become publically available. We challenge the idea of the authorship being embedded into the material itself for the reason that in this way such evidence could be preserved over the lifetime of the object. That requires from the evidence to be embedded in a form that is resistant to manipulation.

Our idea for protecting the authorship of digital material is based on a simple principle: Original multimedia content (e.g a digital photo) should contain watermarks only by the real author, which would be preserved over any subsequent attempts for re-watermarking.

The existence of an instance of the digital content carrying the identity of a single author would suffice to prove that this author is the real owner of the media. For the case that a user claims the authorship of the watermarked image, a protection scheme should provide a means of resolution carried out by a Trusted Third Party (TTP), which can verify the existence of the identity of the real author in the media. In a real system such task can certainly be carried out by the Content Provider itself.

We should note that, it is most likely that the potential attackers would not be aware of the existence of watermarks in the media they attempt to attack. That is because, in the way watermarking is carried out, there is no way to confirm the existence of watermarks, if not knowing the secret keys used.

Next we describe two likely scenarios, depicted in fig.1 of the authorship been attacked, and we show how the attempt should be overcome by the use of our proposed architecture.

Scenario 1: The image is 'Re-published' by the attacker in its retrieved form

First, user A wishes to publish a digital image to a public Content Provider service of his liking. The user, in order to protect his authorship, would watermark the object prior to uploading it, using a secret key which has the form of text string. The watermarking process can be carried out either locally at the user's end, or by using a trusted public watermarking service. For the latter case we assume the existence of secure communication channel between the service and the user. Once the content has been watermarked, user A proceeds to publishing the watermarked image to the Content Provider service. Later, a malicious user B retrieves from the Content Provider the published image A onto which he attempts modifications. Finally he republishes the modified content at a Content Provider (either the same or a different from the one used by A). From then on, any conflicting claims of authorship on this object should made possible to resolve via a verification process. Verification regards the checking of the existence of the embedded watermark into the published object. For example, if the material is found to be published elsewhere, it should be verifiable whether that was done without the permission of the real author.

Scenario 2: The image is 'Re-watermarked' before it is 'Re-published' by the attacker

In a more complex scenario, the attacker B might also use the watermarking service to re-watermark the stolen image, for embedding his own secret text string in it, either knowing whether the original image is watermarked or not. In the case of dispute, either by the original user A, or by the attacker B claiming the authorship of the image, the verification service should be able to distinguish the real author by verifying and confirming the existence of the hidden watermarks. In the above example it would not be possible for the attacker B to prove that he is the author of the original image, since the existence of his watermark can not be confirmed in the watermarked copy published by the original author. Meanwhile both watermarks (the real author's and the attacker's) would appear to have been embedded into the image published by the attacker. The existence of a copy of the image not containing the attacker's identity should be regarded as sufficient evidence to prove that he/she is not the real owner of the resource.

We summarize our assumptions into the following:

 A potential attacker is most likely not aware of the existence of watermarks in the digital media that he at-

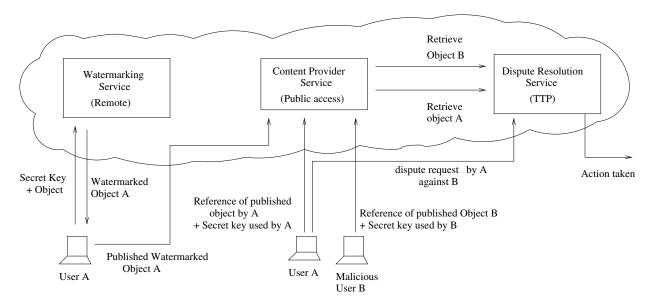


Figure 1. System Architecture

tempts to attack.

- Re-watermarking on the same digital media can be attempted more than once. Each attempt does not remove the likely existing watermarks from the media.
- 3. Any attempt to attack an invisibly watermarked image by removing the hidden identity from it would severely degrade the underlying data, rendering the resulting image useless.
- 4. There exists a Trusted Third Party (TTP) acting as *Dispute Resolution Service* which, with the provision of the appropriate evidence, can confirm the existence of a watermark on an image.

Using watermarks for protecting the copyright in various forms of digital media has been the subject of the research community for long time. We can distinguish two possible approaches in the use of watermarks, *a*) the *asymmetric watermarking schemes*, which require a pair of secret/public keys, and *b*) the use of *zero-knowledge proof protocols*.

The work by Herrigel et at. in [13] is a characteristic example of watemarking technique for images, which belongs to the first category of approaches. Their technique provides robustness against various attacks with the advantage of not needing the original cover-image for the watermark detection. Contrary to our scheme, their method uses public-key cryptography and requires PKI infrastructure for supporting the distribution of public keys between the involved parties for mutual authentication. PKI infrastructure has also been found necessary to other solutions [1], used for video watermarking. Our approach has the advantage of neither needing the cover image to be provided in the verification, avoiding any exposure to other parties, nor does it need a PKI to be set up.

It is known that watermarking-based approaches that make use of *Zero knowledge protocols* must involve a TTP that take part in the embedding phase. Such solution has been reported to have potential drawbacks [16]. In [14], Adelsbach et al. propose an approach based on the use of *Zero Knowledge Proof*. Their protocol allows a prover to convince a verifier of the presence of a watermark without revealing any information that the verifier could use to remove the watermark, something known as *blind watermark detection*. Nevertheless, their protocols still require the existence of another arbitrary Third party along with a Registration Center entity. On the contrary, our approach, having the advantages of *blind detection*, it uses a much simpler but efficient protocol that employs one-way functions for achieving the same result.

In this work we focus on the protocols used for embedding the watermarks into images and for verifying their existence.

3 Proposed Scheme

Our proposed scheme uses hash functions and it comprises two phases: *Embedding* and *Verification*. We present a high level view which describes our previous scenario of uploading a multimedia object (e.g a photo) to a content provider and verifying its authorship. Furthermore, attacks based on modifying already watermarked images (e.g jpeg compression) and re-watermarking them can be overcome by the use of a compression-resistant algorithm such as the one we introduce in this paper.

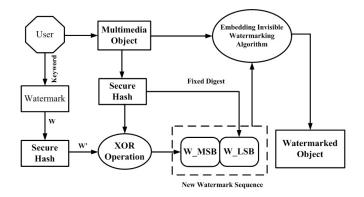


Figure 2. Embedding Architecture scheme

3.1 Embedding

The process of embedding is shown in Fig. 2 and it consists of four main steps:

1. The user chooses its own secret keyword which is hashed. The reason for hashing is to produce a digest which is a unique fixed length sequence to be used as the watermark. That gives the advantage of using secret keywords of any length. There are several hash functions which can be used. We refer to SHA-1 and SHA-2 [2] as the simplest and best known.

2. Along with step 1, the multimedia object (e.g a JPEG,BMP,GIF image) is also hashed producing a fixed length digest of the object. The main reason for doing this is to create a unique sequence for that object. Hash functions used in the previous step can also be used here.

3. The hashed watermark value is XOR-ed with the hashed object digest to produce the most significant part (*W-MSB*) in the new watermark sequence as shown in Fig. 2. On the other hand, the hashed object digest make up the least significant part (*W-LSB*) of the watermark sequence. That part is used as decryption key in the verification phase.

4. The new watermark sequence is then hidden inside the multimedia object using a blind invisible watermarking technique such as MMBEC (Modified Mid-band Exchange Coefficient) we are proposing. This algorithm is described in the following section and it is shown that it has a high level of robustness against normal attacks, such as compression.

The plain object along with the secret keyword can be uploaded to a trusted watermarking service provider for being watermarked. Alternatively, the *Embedding* can be carried out at the user's end before the uploading of the material, using trusted software provided by the Content provider.

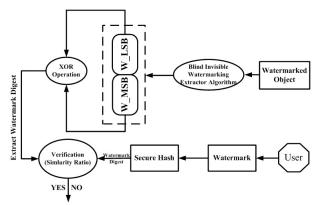


Figure 3. Verification Architecture scheme

3.2 Verification

This phase is used for verifying the authorship of the content and it is shown in Fig. 3. In our design the verification can be carried out by the content provider itself, by whom the identity of the real author can be distinguished without knowing the original content. The verification requires as input the watermarked image along with the hidden keyword which is claimed having been embedded by its creator. As noted, we make the assumption that the hidden keyword is send through a secure communication channel to the content provider during the verification. Using a Secure Sockets Layer (SSL) protocol would suffice. The verification process is as follows:

1. The watermarked secret keyword is hashed producing a hashed watermark digest. Beside this, by applying blind invisible watermarking extraction onto the watermarked object both the *W*-*MSB* and *W*-*LSB* digests can be retrieved.

2. The *Extracted Watermark Digest* of the object is obtained by XOR-ing the *W-MSB* and *W-LSB*.

3. Finally, the watermark digest is checked with respect to similarity to the extracted watermarked digest.

In a real use case, a user who claims the authorship of an object which has been modified and republished by an attacker (in some form we call a Fake object), can raise a dispute with the Content provider. The Content provider in response, acting as TTP would verify both the claimant's and the attacker's hidden keywords against the Original and Fake objects. The Fake object is detected in the verification since the presence of both watermarks (original users' and attacker's) may be confirmed in the attacker's object, while the attacker's watermark is not confirmed in the original user's object. A high similarity value between the extracted watermark digest and the watermark digest of the secret keyword should be enough to confirm the existence of a watermark into the verified object. It should be noted that the original object should be kept secret by the original author, who should publish to the Content provider the

watermarked version only. In this way the original image is not exposed to the attackers. The idea for the Content provider to be acting as TTP and carry out the verification process was made for the reason to protect the secrecy of the watermarking keywords from the potential attackers.

4 The MMBEC watermarking algorithm

Watermarking algorithms are classified in various ways. With regard to the transformation they do on the original image they are divided into *Spatial Domain* and *Frequency Domain* algorithms. The former entail transformation of image pixels and is easy to apply to any image. The later perform transformation in the frequency domain and are more robust [3]. Whether the watermark information can be directly perceived by humans or not, watermarking is classified into: *Visible* and *Invisible*. In the latter category the best known transformations used for hiding the watermark are *Discrete Wavelet Transform* (DWT) and *Discrete Cosine Transform* (DCT).

MBEC is a known technique which utilizes the values of the mid-band DCT coefficients to encode a single watermark bit into a DCT 8×8 block [5]. Our proposed algorithm MMBEC, is an extension of the classical MBEC algorithm. The purpose of creating a new algorithm is to achieve the increased robustness required by the verification process. With robustness we mean the sensitivity of the algorithm in identifying the watermarks claimed to have been embedded into a digital object.

MMBEC introduces two additional steps over the existing MBEC as shown in Fig.4 surrounded by dotted line, and which are described as follows:

- 1. Choosing the exchange coefficients in Mid-band region according to the Quantization factors - shown in the top of Fig. 4
- 2. Increasing the difference between the selected coefficients to increase the robustness against several attacks by using strength factor B.

4.1 The embedding operation in MMBEC algorithm

The watermark can be considered as a two-dimensional vector of binary digits. The aforementioned step 1 can further be divided into the following two operations:

- 1. The host image is divided into 8×8 blocks, on which DCT transformation is applied afterwards.
- 2. The watermark is converted from a two-dimensional vector into a one-dimensional sequence vector W_i , where $i = 1, 2, ..., N \times M$. N, M denote as the length and width of the watermark.

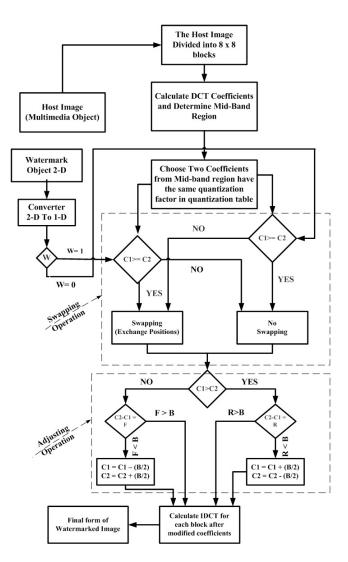


Figure 4. Embedding operation in MMBEC

Two coefficients $C1_b(x, y)$, $C2_b(x, y)$ in each 8×8 block from the middle-band are chosen from the quantization 8×8 table for *jpeg* in Table 1. The use of quantization tables is introduced in [9]. The watermark will be divided into smaller parts in the compression operation for being inserted into the mid-band region. The perfect locations for insertion are those which the quantization factor in the table has the values as follows:

- The coefficients $C1_b(x, y)$ and $C2_b(x, y)$ are located in positions (4, 1) and (2, 3) and quantized by a factor equal to 14.
- The coefficients $C1_b(x, y)$ and $C2_b(x, y)$ are located in positions (3, 3) and (1, 4) and quantized by a factor equal to 16.
- The coefficients $C1_b(x, y)$ and $C2_b(x, y)$ are located in positions (5, 2) and (4, 3) and quantized by a factor equal to 22.

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Table 1. Quantization values used in JPEGcompression scheme

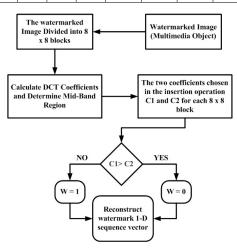


Figure 5. Extraction operation in MMBEC

- The coefficients $C1_b(x, y)$ and $C2_b(x, y)$ are located in positions (3, 4) and (1, 5) and quantized by a factor equal to 24.
- The coefficients $C1_b(x, y)$ and $C2_b(x, y)$ are located in positions (3, 5) and (1, 6) and quantized by a factor equal to 40.

Next, step 2 of the MMBEC algorithm includes *Swapping* and *Adjusting* which are described as follows:

Swapping is done similarly as in the original MBEC with the purpose of hiding the watermark. It requires the selection of two suitable coefficients $C1_b$ and $C2_b$ to be swapped when either of the following two conditions is met:

- $(W_i = 1)$ and $(C1_b(x, y) < C2_b(x, y))$.
- $(W_i = 0)$ and $(C1_b(x, y) < C2_b(x, y))$.

 W_i denotes one bit of the binary sequence.

Adjusting regards the process of increasing the robustness of the watermark and it is done by adding a strength factor B. Increasing B reduces the chance of the watermark being extracted wrongly at the expense of additional image degradation. The method of Adjusting is shown below:

- If $(C1_b(x,y) > C2_b(x,y))$ and $(C1_b(x,y) C2_b(x,y) < B)$ Then $\begin{cases} C1_b(x,y) \leftarrow C1_b(x,y) + \frac{B}{2} \\ C2_b(x,y) \leftarrow C2_b(x,y) - \frac{B}{2} \end{cases}$
- If $(C1_b(x,y) < C2_b(x,y))$ and $(C2_b(x,y) C1_b(x,y) < B)$ Then $\begin{cases} C2_b(x,y) \leftarrow C2_b(x,y) + \frac{B}{2} \\ C1_b(x,y) \leftarrow C1_b(x,y) - \frac{B}{2} \end{cases}$

Finally, the watermarked image is reconstructed by applying the Inverse Discrete Cosine Transform (IDCT)[4] to the output of *Adjusting*.

4.2 The watermark extraction in MMBEC algorithm

For the watermark extraction the original image is not needed as shown in Fig.5. Similarly as in embedding, for each block the values of $C1_b(x, y)$ and $C2_b(x, y)$ are compared with each other giving back the binary sequence of the watermark as follows:

• If $C1_b(x, y) \ge C2_b(x, y)$ Then $W_i \leftarrow 0$ Else $W_i \leftarrow 1$

5 Experimental Results

We present the results of performance tests and comparison of strength of our algorithm against compression attacks.

For the evaluation we used a gray-level image of 256×256 resolution shown in Fig. 6(a) in which we tried to embed the watermark object shown in Fig. 6(b).

The level of JPEG compression applied to the image is expressed by the Quality Factor (QF). The optimal value is dependent on both the level of detail contained in the image and the already applied compression ratio. In our evaluation, the QF ranged from 5 to 100. In practice, values of QF between 0 and 24 correspond to the extreme case of applying high compression to the image. Since the details of the picture as well as the hidden watermark are severely distorted when applying such levels of compression, we consider such cases to be unrealistic. We used a metric we called Similarity Ratio (SR) to demonstrate the effect of compression to the retrieval of the watermark during the verification. This relates to the similarity between the elements of the binary sequence vector of the Extracted Watermark Digest and the digest of the secret word provided as input to the verification. SR is given in formula 1, where S denote as the number of matching pixel values between the pictures of the two digests mentioned above, and D the number of different pixels they have.

$$SR = S \cdot (S+D)^{-1} \tag{1}$$

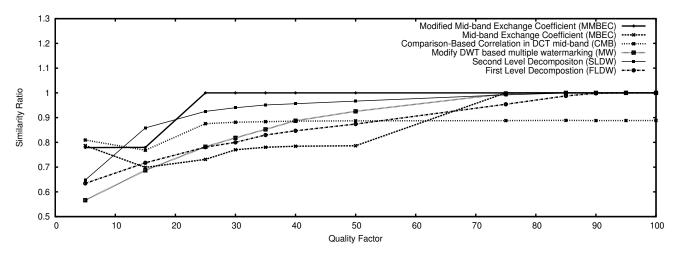


Figure 7. The relationship between SR and QF



Figure 6. The test images

In Fig.7 is shown the comparison diagram between the MMBEC algorithm and five other algorithms used for embedding and extracting the watermark from the same original test image. In table 2 we present the numerical values of this comparison. The symbols used for each technique are: SR1:(MMBEC) for our proposed technique, SR4:Modified DWT based multiple watermarking (MW)[6], SR5:Second Level Decomposition Wavelet (SLDW)[7], SR6:First Level Decomposition Wavelet (FLDW)[7], SR3:Comparison-based correlation in DCT mid-band (CMB)[8] and SR2:Mid-band Exchange Coefficient (MBEC)[5]. The diagram demonstrates how the effect of compression develops over various values of QF. Very interestingly, as can be seen in the figure, both MMBEC and CMB algorithms behave very steadily when QF remains within the range of 25 and 100, with MMBEC achieving higher Similarity Ratios. Meanwhile for MBEC, MW, FLDW and SLDW there is an increasing trend for the same range of QF. In addition, with MMBEC the highest possible resistance against compression (SR = 1) can be achieved for images not compressed very much (QF > 25).

Moreover, no other algorithm could reach such good performance for such a wide range of compression (QF) in the way MMBEC does.

We can attribute the reason for the high performance achieved by MMBEC to the way that the two coefficients $C1_b(x, y)$, $C2_b(x, y)$ are chosen from the quantization table for hiding the image in the mid-band region.

6 Conclusion

Authorship protection of multimedia material has always been a concern of the scientific community as well as of the simple users. We believe a proper solution to this problem would encourage more the online distribution of multimedia material within user communities.

In this paper we proposed a scheme that can be applied on existing and future cloud infrastructures for protecting the authorship of digital multimedia material. The employment of invisible watermarking algorithms for hiding the user's identity in the watermarked image is one of the strong points of our scheme. A Trusted Third Party is involved in the task of resolving the identity of the real author of a multimedia object, a role that the Content provider can certainly serve. A simple to deploy and thus suitable for our use-case attack-resistant watermarking algorithm called MMBEC has also been introduced in this paper. The requirements we have originally set for such an algorithm of being resistant against malicious modifications performed on images, such as compression, are actually fulfilled, as shown in our evaluation results. Further testing its resistance against other types of attacks is left for future work.

QF	SR1	SR2	SR3	SR4	SR5	SR6
5	0.7790	0.7871	0.8094	0.5662	0.6479	0.6343
15	0.7797	0.6987	0.7681	0.6868	0.8583	0.7175
25	1.0000	0.7313	0.8754	0.7823	0.9252	0.7807
30	1.0000	0.7700	0.8814	0.8181	0.9399	0.8001
35	1.0000	0.7802	0.8835	0.8524	0.9511	0.8297
40	1.0000	0.7844	0.8859	0.8873	0.9562	0.8468
50	1.0000	0.7863	0.8870	0.9255	0.9668	0.8740
75	1.0000	1.0000	0.8879	0.9968	0.9919	0.9539
85	1.0000	1.0000	0.8889	1.0000	0.9995	0.9877
90	1.0000	1.0000	0.8879	1.0000	1.0000	0.9982
95	1.0000	1.0000	0.8882	1.0000	1.0000	1.0000
100	1.0000	1.0000	0.8883	1.0000	1.0000	1.0000

Table 2. The relationship between SR (Similarity Ratio) and QF (Quality Factor) (Numerical values)

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