A Novel Framework for Multiple Creatorship Protection of Digital Movies

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Abstract. A digital movie can be created jointly under the cooperation of many creators. It is then necessary to provide protection to the creatorship of each participating creator. In this paper, we propose a framework for providing the creatorship protection of multiple creators involved in creating the object-based digital movie. The proposed framework makes use of digital watermarking techniques and cryptographic protocols to achieve the creatorship protection purpose. Object-based movie may consist of several audio and video objects, which may be created by different creators. The proposed framework embeds different watermarks in different video/audio objects in such a way that each creator can show the joint-creatorship of the movie; as well as each creator can prove his/her creatorship of video/audio object he/she created.

1 Introduction

Nowadays, digital rights management (DRM) issue is discussed more and more since a large amount of digital assets involving media such as text, audio, video etc. are being created. The parties involved in the digital asset creation and transaction are creators, owners, distributors and consumers. Creators have creator rights, owners have owner rights, distributors have distributor rights and consumers have consumer rights. DRM refers to a set of technologies and approaches that establish a trust relationship among the parties involved in a digital asset creation and transaction [16]. Cryptographic techniques and watermarking techniques are important tools in DRM. Cryptographic techniques provide confidentiality, authentication, data integrity, and non-repudiation functions. Watermarking techniques are usually preferred for copyright ownership declaration, creator/authorship declaration, copyright violation detection, copyright violation deterrence, copy control, media authentication, and media data integrity functions. Our proposed framework employs both cryptographic and watermarking techniques to protect the creatorship of multiple creators involved in the creation of object-based digital movie.

The creator has creatorship of digital assets. Many digital media are very complex and almost impossible to be created by single creator. For example, in an image creation, some creators may be good at drawing the plants; some may be good at drawing animals and some may be good at drawing human beings; or in another way, some may do well in sketching the skeleton of the images and others may be good at coloring. Therefore, to create a good complex image, which contains lots of contents

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inside, the whole creation process needs the cooperation of many creators. Another example, in a cartoon movie, different cartoon characters may be created by different video creators and the associated audio dialogues may be dubbed by many audio dubbers. In addition the background music including special effects and foreground music may be created by many creators. Therefore creating a complex cartoon movie may involve many creators from video and audio domains.

In the case of joint creation of digital media by multiple creators, there are some concerns for each of the participating creators. Firstly, it is possible that a creator disowns his/her object at a later stage due to the malpractices (copying from someone else's work etc.) he/she has done during the creation. This disowning may cause unnecessary hardships for the good creators. Secondly, a creator may pose as the sole creator and sell the product to a buyer. These concerns arise mainly due to the mistrust among the creators. Our proposed framework intends to build the trust relationship among the creators involved in joint creations.

There are different kinds of digital media such as image, video, movie etc. In this paper, we focus on the creatorship protection of multiple creators of object-based digital movies. The digital graphics (cartoon) movies may be an example. The creation process of an object-based movie consists of video creation process and audio creation/dubbing process. In the video creation process, each video creator works on one or more video objects and then they refine their creations through several iterations. Usually the audio dubbing is carried out after the video creation process. The background and foreground musics are created by audio creators and are then dubbed along with the dialogs of characters into the movie. The audio dubbing also employs iterative procedures to refine the audio part of the movie.

We in this paper propose a novel framework to address the creatorship concerns of multiple creators of object-based movies (such as digital graphics/cartoon movies). We make use of watermarking techniques and cryptographic protocols for the framework. The watermarking scheme that the framework employs has certain requirements such as robustness, imperceptibility, asymmetric and non-invertibility. So that it can perform well under the complex joint creation situation to achieve the creatorship protection purpose. Cryptographic protocols require the use of digital signature algorithms.

The remainder of the paper is structured as follows: Section 2 discusses related watermarking and cryptographic schemes. Our proposed framework is presented in Section 3. Section 4 lists some application of our framework. Section 5 presents discussion and Section 6 concludes the paper.

2 Related Watermarking and Cryptographic Schemes

So far, there are quite few watermarking schemes considering the joint-creatorship protection problem. Guo and Georganas [8] introduce a digital image watermarking scheme for joint-ownership verification. The scheme that they used embeds a combined watermark of the creators' individual watermarks and a jointly created watermark, and then verifies the partial ownership and full ownership by setting different levels of thresholds in the detector. This scheme is not suitable for protecting the creatorship of multiple creators in a joint creation environment. It does not provide

the protection during the creation process, and each creator cannot specify which video/audio object is created by him/her. For joint-creatorship protection, the scheme needs to provide the protection during the creation process, so it can take care of the two concerns we mentioned in the introduction, which may occur in the creation process. At the same time, single creator should have the ability to show which video/audio object was created by him/her. Our framework gives a solution to this type of problem for object-based movie creation.

Our framework employs both watermarking scheme and cryptographic protocol. The watermarking scheme is mainly used for creatorship protection and the cryptographic protocol is mainly used for digital signature purpose. Some research work on watermarking and digital signature scheme are reviewed below.

There have been many researches done in watermarking area [1][2]. The work by Cox et. al. [3] is spread spectrum based watermark, which is robust and invisible. Being robust watermark, it would be hard for the attackers to make undetectable or remove the watermark. The watermarking techniques proposed in [4] and [5] are asymmetric. The asymmetric watermarks make use of another key for embedding other than the detection key. Thus it would be hard for the watermark verifier to perform watermarking but can detect the watermark. Craver et.al. [6], Qiao and Nahrstedt [7], give a non-invertible watermarking scheme. In order to prove the rightful owner unambiguously, the watermarking scheme should be non-invertible.

Many audio and speech watermarking schemes have been proposed. The dialog in the movie can be seen as speech; the background music and foreground music can be seen as audio. Bassia et. al. [9] applies a straightforward time-domain spread-spectrum watermarking method to audio signals. An audio watermarking technique based on correlation detection is introduced in [13], where high-frequency chaotic watermarks are multiplicatively embedded in the low frequencies of the DFT domain.Wu et.al. [10] propose a low complexity speech-Watermarking scheme as an effective way to detect malicious content alterations while tolerating content preserving operations. The proposed scheme is based on the modified odd/even modulation scheme with exponential scale quantization and a localized frequency-masking model while assuring no mismatch between quantization steps used in watermark embedding and detection. Cheng et. al. [12] propose a speech watermarking technique in which maximum possible watermark signal energy is added to the speech signal satisfying the constraint that the added signal is not audible. Additional watermark energy is embedded into the portions of the speech that have white spectrum, fricative sounds and rapidly changing plosives sounds.

There are many digital signature schemes available such as RSA [14], Digital Signature Algorithm (DSA) and Elliptic Curve Digital Signature Algorithm (ECDSA). Recent years, some new schemes have been proposed. Elkamchouchi et. al. [11] have developed a digital signature scheme with appendix and message recovery in the real and Gaussian integers' domains. The proposed scheme employs the idea of combining the integer factorization, and the Generalized Discrete Logarithm problems. Chang et. al. [15] have proposed a secure digital signature scheme, where neither one-way hash functions nor message redundancy schemes are employed. We can apply any digital signature scheme in our framework as far as it can perform the digital signature safely.

3 Our Proposed Framework

In our proposed framework, a digital movie creation has two stages: video creation process and audio creation/dubbing process. Fig. 1 gives the flowchart of the whole digital movie creation process.

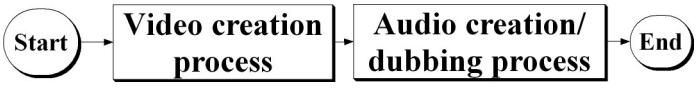

Fig. 1. The digital movie creation process

***Brief Description*:** In the proposed framework the movie creation begins with a video creation process. First, each video creator creates his/her video object. The created video object is then watermarked and signed by the creator and transmitted over the network to other participating video creators. On receiving every others signed watermarked video objects, each video creator then assembles a local video part of the movie by combining every others watermarked video objects and own watermarked video object. The video creators then carry out refinement iterations on their video objects until all the video creators are satisfied with the video part of the movie. The video creators can create their video objects in their own local machine as shown in Fig. 2 and they exchange their creations through the network to every other creators.

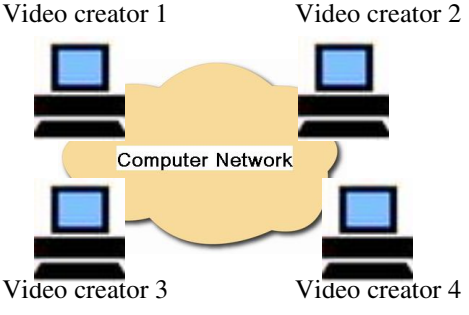

Fig. 2. Hardware infrastructure of the video creation process

Once the video part of the movie is completed, the audio creation/dubbing process begins. Some audio components such as background and foreground music may be created beforehand by some audio creators. Dubbing of all the audio components such as background music, foreground music and the dialogs of characters on to the movie usually will be done in real time while the video is playing. Different audio components can be recorded on different tracks and can be treated as different audio objects. For example, the background music can be one audio object, the dialogs of each character can be considered as individual audio objects. Each audio creator also gets a signed watermarked copy of every audio object. The audio dubbing is also done in

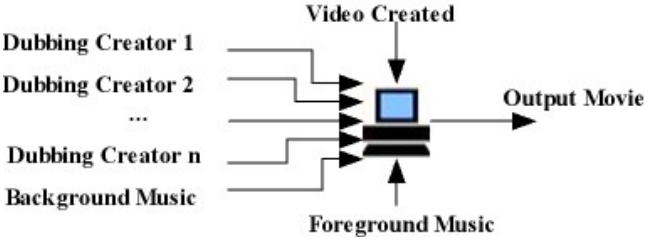

Fig. 3. Hardware infrastructure of audio creation process

iterative manner until all the creators are satisfied with the audio part. And the dubbing is usually done in single computer as shown in Fig 3.

Let N_v be the number of video creators, N_a be the number of audio creators and $N = N_v + N_a$ be the total number of creators jointly creating an object-based movie. Let there be J iterations to complete the video creation process and J_a iterations to complete the audio creation process.

Notation: The notation $Sign_i\{m\}$ denotes the digitally signed message m signed by the i^{th} creator using his/her private key. This signed message can be verified by everyone using the corresponding public key. The verification of signed message will result in message m, thus anyone can obtain the message from $Sign_i\{m\}$.

The video creation process and audio creation process are discussed in detail below.

3.1 The Video Creation Process

The video is created in an iterative manner. The iteration steps focus on the video objects (VOs) created by the video creators. Let VO_{ij} be the video object created or modified by the i^{th} creator in the j^{th} iteration and VO_{ij}^{w} be the watermarked VO_{ij} using W_i. Each VO is made up of several consecutive video object planes (VOPs). Let VOP_{ijn} be the n^{th} VOP of VO_{ij} and VOP_{ijn}^{w} be the watermarked VOP_{ijn} using W_i.

First iteration

Let there be N_v video creators and each video creator creates one VO each.

Step 1: Each video creator creates his/her own VO. For example, the i^{th} creator creates VO_{i1} in the first iteration. Then embeds his/ her watermark W_i using his/her watermark embedding key Kw_{iv} into his/her creation VO_{i1} to obtain VO_{i1}^{w}. The watermarking technique employed is asymmetric and hence the corresponding asymmetric detection key is Kw_{iv}^{*}. The watermarking is carried out VOP wise, i.e. the watermark W_i is embedded into each VOP using the watermark embedding key Kw_i. Thus watermarked n^{th} VOP of VO_{i1} would be denoted as VOP_{i1n}^{w}.

Each video creator then makes a digitally signed version (using the private key of the creator) of their watermarked creation and transmits them to all other video creators. For example, the i^{th} creator transmits $Sign_i\{VO_{i1}^{w}\}$ to all other creators. The creator then stores his/her video object VO_{i1}, watermark W_i, embedding key Kw_{iv} and

detection key Kw_{iv}^{*} in a database DB_i. These information are needed to be presented to a judge in case of a creatorship dispute which is discussed in Section 4.1.

Discussion: We use different watermarks w_i for different creators and hence help to declare the full creatorship of their video objects. The watermarking scheme should be robust since others (including other creators) should not be able to remove the embedded watermark. In addition, the watermark should be invisible in such a way that the high visual quality of the watermarked video object is preserved. In order for the buyer to buy a particular video object, the buyer should be able to verify the existence of the watermark in that object without the capability to remove or embed the watermark, which requires the watermarking technique to be asymmetric as well. The transmitted digitally signed watermarked video objects prevent the creators from disowning their own video objects at a later stage. In the case that certain creator tries to disown the creatorship, the rest creators can show the signed version of the person's video object to prove the person's creatorship.

Step 2: On receiving the signed watermarked objects from other creators, the video creator first stores them locally. The creator then verifies all the signed watermarked objects from all other creators, using the public keys of the corresponding signatures and obtains the respective watermarked objects. If there is no signature detected, the video creator will ask for the retransmission of that particular video object. After the successful signature verification, every creator possesses his/her original video object and the watermarked video objects of all creators (vo_{i1}^{w} for all i's). All creators then assemble the watermarked objects individually, and then discuss on how the video objects should be modified. Fig. 4 gives the flowchart of first iteration. Fig. 5 illustrates the n^{th} frame of the video after the first iteration.

Discussion: The received signed watermarked objects, own object vo_{i1}, own watermark w_i, embedding key Kw_{iv} and detection key Kw_{iv}^{*} are stored locally for checking-malpractices by other creators during later iterations and also for reference in dispute resolution which is discussed in Section 4.1.

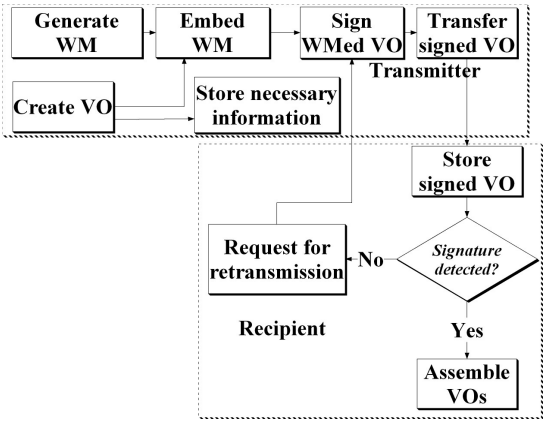

Fig. 4. First Iteration of video creation process

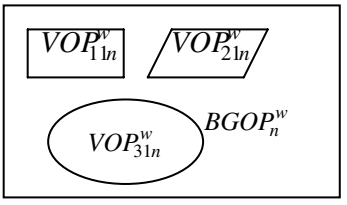

Fig. 5. The n^{th} frame after first iteration

Refinement iterations

Step 3: After all the video creators agree on how to modify the video objects, the original creator will only modify the VOPs that need to be modified, and just rewatermark those modified VOPs. Each creator then makes a digitally signed version (using the private key of the creator) of their modified watermarked VOPs and then transmits them to all other video creators. For example the i^{th} creator transmits $Sign_i$ {all watermarked modified VOPs} to all other video creators. The video creator then stores his/her modified VOPs into database DB_i for solving the creatorship dispute.

Discussion: Normally, the creator does not need to modify all the VOPs of the video object in the second iteration and following iterations. So, they will also transmit only the watermarked modified VOPs of the video object to the rest of the creators. This will reduce the size of data transmission and storage requirement in the database.

Step 4: On receiving the signed watermarked modified VOPs from other video creators, the creator first stores them locally. The creator then verifies all the signed watermarked VOPs from all other video creators using the public keys of the corresponding signatures and obtains the respective watermarked VOPs. If no correct signature is detected, the creator will ask for the retransmission of that object. Every video creator after the successful signature verification possesses the watermarked modifications of all creators. Then, each creator uses all the modified VOPs to replace the corresponding VOPs in the corresponding stored watermarked video object. After that, all video creators assemble the watermarked objects and again discuss how to modify the video objects. The iteration is shown in Fig 6.

Step 5: Iterations (step 3 and 4) are carried out until J^{th} iteration, i.e. the final video is obtained. Fig. 7 describes the n^{th} frame of the final video.

Discussion: Since all the creators have the watermarked video objects of the whole video, sometimes it is possible that a single creator or a group of creators may cheat another creator by putting a second watermark on the person's video object. This action would cause both watermark to be detected from the same video object. In order to defeat this kind of attack, the watermarking technique should be non-invertible which would identify the original creator unambiguously even though two watermarks are detected from the same video object, which is illustrated in Section 4.1.

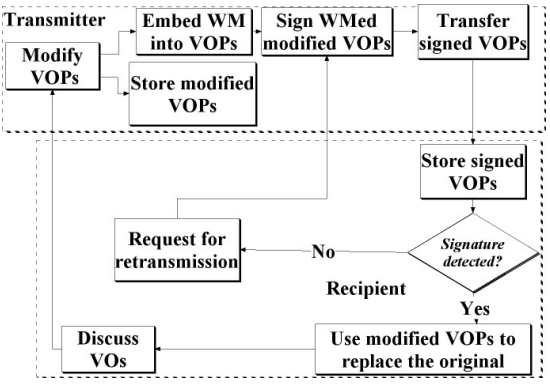

Fig. 6. Refinement iterations of video creation process

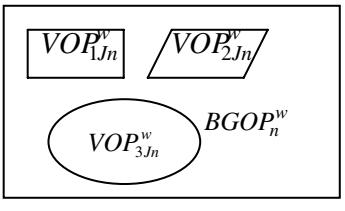

Fig. 7. The n^{th} frame of the final video after J^{th} iteration

3.2 The Audio Creation/Dubbing Process

After the video creation process, a complete video with all the watermarks and without any audio is produced. The subsequent audio dubbing process will add all the audio tracks to the video to complete the whole movie. The audio tracks can be dialogs of characters, background music (including special effects such as thunder, car engine sounds etc.) and foreground music. The background and foreground music tracks may be created beforehand but dubbed along with the dialogs on to the movie. In audio creation process, different audio tracks will be considered as different audio objects. For easiness of discussion, we consider only one background music object (BO) created by one creator, one foreground music object (FO) created by another creator and several audio dubbers dubbing the dialog objects (DOs) of characters in the movie.

The audio creation/dubbing process is also conducted in an iterative manner. But for the easiness of explanation, we assume that the background and foreground music are perfect so they will not be modified during the iteration process. The audio creation/dubbing is usually carried out in one single computer.

First iteration

Let there be N_a audio creators and each audio creator creates one Audio Object (AO) each. For dialog of characters, each character's voice will be treated as one dialog object DO_{i1}, which is dubbed by i^{th} creator in the 1st iteration. Then, the audio object

created by the i^{th} creator will be watermarked with a watermark embedding key Kw_{ia} which is only known to him/her (the corresponding detection key is Kw_{ia}^{*}). Let FO_i be the foreground music object created by i^{th} creator and BO_i be the background music object created by i^{th} creator. FO_i and BO_i are also watermarked with watermark embedding key Kw_{ia} to obtain FO_i^w and BO_i^w. The watermarking scheme employed here needs to be asymmetric.

Then, the watermarked audio objects will be signed by their respective audio creators. Each audio creator then make copies of their signed watermarked audio object which are then passed to all the other creators. All the audio creators store the received audio objects and multiplex the watermarked audio objects together with the watermarked video objects. At this stage, the first draft of audio dubbing is produced. The first iteration is illustrated in Fig. 8.

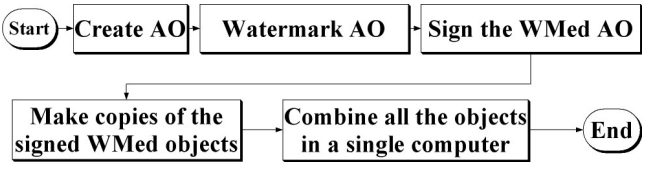

Fig. 8. The first iteration in the audio creation process

Discussion: The watermarking scheme used here must be robust, imperceptible, asymmetric and non-invertible. First, to protect the audio creator's creatorship, the watermarking scheme must be robust so the attackers cannot remove the watermark easily. Second, the human audible system is quite sensitive to the audio, so the watermarking scheme must be imperceptible to keep a good quality of audio. Third, the buyer of the movie may use the watermark to identify the creator of certain audio object, so the watermarking scheme is required to be asymmetric. Fourth, sometimes, attackers may put another watermark on a watermarked audio object. In the detection process, usually two watermarks will be detected; the non-invertibility will help to resolve this problem. For any audio object, if it is found to be illegal in a later time, the creator cannot disown his/her creatorship since all the other creators have his/her signed object.

Refinement iterations

The first draft of the audio dubbing may not satisfy all the people. This requires the audio creators to do some modification on the audio objects. So, the audio creators will modify the parts which are not good enough and rewatermark that part. After the watermarking, the modified parts will be signed by the audio creators and passed to all the audio creators. Then again all the audio creators multiplex the audio and video objects for further evaluation. This process may repeat several times until all the creators (video creators and audio creators) are satisfied with the audio objects. The process is shown in Fig. 9.

Until now, the movie creation process is completed.

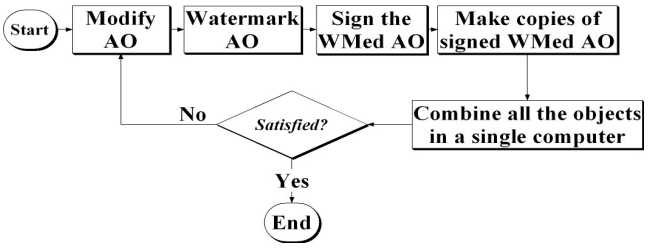

Fig. 9. Refinement iterations of audio creation process

4 Applications of the Proposed Framework

In this section, we will give some applications of the proposed framework. Section 4.1 tells how our framework works for creatorship dispute resolution, and Section 4.2 is for movie purchasing situation under the framework. These situations are discussed in detail below and our framework can successfully handle the two situations.

4.1 Rightful Creatorship Dispute Resolution

In the event of creatorship dispute among creators, the judge asks for the watermarks W_i, watermark detection key Kw_i^* and the video/audio object of dispute in the final watermarked movie from the disputing creators. The judge then verifies the existence of watermarks in the disputed video/audio object of the watermarked movie. If there is more than one watermark found in the same video/audio object, the judge uses non-invertible property (which needs to use the embedding key Kw_i) of the watermark to prove the rightful creator. For resolving the rightful creatorship dispute, the asymmetric property of the watermarking technique is not useful, thus the original unwatermarked object is necessary for using the non-invertibility property to prove the rightful creator. However, for creatorship verification by buyer, the asymmetric property is useful.

4.2 Movie Purchasing Situation

When a buyer wants to buy the entire jointly created movie, the buyer can approach all the creators for purchase of the jointly created movie. In the event that the buyer is interested in only part of the jointly created movie, such as certain video object(s), the buyer can use the watermark detection key to identify the creators of the video objects that he/she is interested in and then contact those creators to purchase their video objects individually.

5 Discussion

The watermarking scheme used in the creatorship protection for multiple creators has the following requirements. First, the watermarking scheme should be robust for the reason that others (including other creators) should not be able to remove the placed

watermark. Second, the watermark should be imperceptible in order to have a high quality of video or audio object. Third, It is possible that a conniving creator(s) can place a second watermark on the creation of the creator whom conniving creator(s) wants to get rid of creatorship and claim for the creatorship of that part. In order to safe guard against such attacks the watermarking scheme used must be non-invertible. Fourth, The buyer of the jointly created movie should be able to verify the existence of the watermark (without the capability to remove it or embed it), which requires the watermarking technique to be asymmetric as well. Each creator should watermark his/her video/audio object completely. This will help to identify the creator of the video/audio object. Thus the watermarking technique employed in the framework should have the following properties: robust, invisible, asymmetric and non-invertible. It is possible that a creator disowns his/her video object at a later stage due to the malpractices (copying from someone else's work etc.) he/she has done during the creation. In order to defeat this problem, the framework employs cryptographic protocols in the video and audio creation process.

6 Conclusion

We proposed a novel watermarking framework that solves the creatorship protection problem in the creation of multiple creators, object-based digital movie. The framework employs the watermarking and digital signature scheme and is applied during the video creation and audio creation/dubbing process. The framework successfully handles the creatorship dispute problem among creators. At the same time, the single creator cannot disown his/her creatorship of the object he created. By applying the framework, the creator also has the capability to prove the creatorship of his/her video/audio object to a buyer.

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