Multimedia Content Protection of Videos and Images in Cloud

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ABSTRACT:

We propose a new design for large-scale multimedia content protection systems. Our design leverages cloud infrastructures to provide cost efficiency, rapid deployment, scalability, and elasticity to accommodate varying workloads. The proposed system can be used to protect different multimedia content types, including 2-D videos, 3-D videos, images, audio clips, songs, and music clips. The system can be deployed on private and/or public clouds. Our system has two novel components: (i) method to create signatures of 3-D videos, and (ii) distributed matching engine for multimedia objects. The signature method creates robust and representative signatures of 3-D videos that capture the depth signals in these videos and it is computationally efficient to compute and compare as well as it requires small storage. The distributed matching engine achieves high scalability and it is designed to support different multimedia objects. We implemented the proposed system and deployed it on two clouds: Amazon cloud and our private cloud. Our experiments with more than 11,000 3-D videos and 1 million images show the high accuracy and scalability of the proposed system. In addition, we compared our system to the protection system used by YouTube and our results show that the YouTube protection system fails to detect most copies of 3-D videos, while our system detects more than 98% of them. This comparison shows the need for the proposed 3-D signature method, since the state-of-the-art commercial system was not able to handle 3-D videos.

I. INTRODUCTION

ADVANCES in processing and recording equipment of multimedia content as well as the availability of free online hosting sites have made it relatively easy to duplicate copyrighted materials such as videos, images, and music clips. Illegally redistributing multimedia content over the Internet can result in significant loss of revenues for content creators. Finding illegally-made copies over the Internet is a complex and computationally expensive operation, because of the sheer volume of the available multimedia content over the Internet and the complexity of comparing content to identify copies. We present a novel system for multimedia content protection on cloud infrastructures. The system can be used to protect various multimedia content types, including regular 2-D videos, new 3-D videos, images, audio clips, songs, and music clips. The system can run on private clouds, public clouds, or any combination of public-private clouds. Our design achieves rapid deployment of content protection systems, because it is based on cloud infrastructures that can quickly provide computing hardware and software resources. The design is cost effective because it uses the computing resources on demand. The design can be scaled up and down to support varying amounts of multimedia content being protected. The proposed system is fairly complex with multiple components,including: (i) crawler to download thousands of multimedia objects from online hosting sites, (ii) signature method to create representative fingerprints from multimedia objects, and (iii) distributed matching engine to store signatures of original objects and match them against query objects. We propose novel methods for the second and third components, and we utilize off-the-shelf tools for the crawler. We have developed a complete running system of all components and tested it with more than 11,000 3-D videos and 1 million images. We deployed parts of the system on the Amazon cloud with varying number of machines (from eight to 128), and the other parts of the system were deployed on our private cloud. This deployment model was used to show the flexibility of our system, which enables it to efficiently utilize varying computing resources and minimize the cost, since cloud providers offer different pricing models for computing and network resources. Through extensive experiments with real deployment, we show the high accuracy (in terms of precision and recall) as well as the scalability and elasticity of the proposed system.

The contributions of this paper are as follows.

• Complete multi-cloud system for multimedia content protection. The system supports different types of multimedia content and can effectively utilize varying computing resources.

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• Novel method for creating signatures for 3-D videos. This method creates signatures that capture the depth in stereo content without computing the depth signal itself, which is a computationally expensive process.

• New design for a distributed matching engine for high-dimensional multimedia objects. This design provides the primitive function of finding -nearest neighbors for large-scale datasets. The design also offers an auxiliary function for further processing of the neighbors. This two-level design enables the proposed system to easily support different types of multimedia content. For example, in finding video copies, the temporal aspects need to be considered in addition to matching individual frames

II. RELATED WORK

The problem of protecting various types of multimedia content has attracted significant attention from academia and industry.

One approach to this problem is using watermarking [10], in which some distinctive information is embedded in the content itself and a method is used to search for this information in order to verify the authenticity of the content. Watermarking requires inserting watermarks in the multimedia objects *before* releasing them as well as mechanisms/systems to find objects and verify the existence of correct watermarks in them. Thus, this approach may not be suitable for already-released content without watermarks in them.

III. OVERVIEW OF THE PROPOSED SYSTEM

The goal of the proposed system for multimedia content protection is to find illegally made copies of multimedia objects over the Internet. In general, systems for multimedia content protection are large-scale and complex with multiple involved parties. In this section, we start by identifying the design goals for such systems and our approaches to achieve them. Then, we present the high-level architecture and operation of our proposed system.

A. Design Goals and Approaches

A content protection system has three main parties: (i) content owners (e.g., Disney), (ii) hosting sites (e.g., YouTube), and (iii) service providers (e.g., Audible Magic). The first party is interested in protecting the copyright of some of its multimedia objects, by finding whether these objects or parts of them are posted on hosting sites (the second party). The third party is the entity that offers the copy finding service to content owners by checking hosting sites. In some cases the hosting sites offer the copy finding service to content owners. An example of this case is YouTube, which offers content protection services. And in other, less common, cases the content owners develop and operate their own protection systems.

We define and justify the following four goals as the most important ones in multimedia content protection systems.

• *Accuracy:* The system should have high accuracy in terms of finding all copies (high recall) while not reporting false copies (high precision). Achieving high accuracy is challenging, because copied multimedia objects typically undergo various modifications (or transformations). For example, copied videos can be subjected to cropping, embedding in other videos, changing bit rates, scaling, blurring,

• *Computational Efficiency:* The system should have short response time to report copies, especially for timely multimedia objects such as sports videos. In addition, since many multimedia objects are continually added to online hosting sites, which need to be checked against reference objects, the content protection system should be able to process many objects over a short period of time. Our approach to achieve this goal is to make the signatures compact and fast to compute and compare without sacrificing their robustness against transformations.

• *Scalability and Reliability:* The system should scale (up and down) to different number of multimedia objects. Scaling up means adding more objects because of monitoring more online hosting sites, having more content owners using the system, and/or the occurrence of special events such as sports tournaments and release of new movies. Conversely, it is also possible that the set of objects handled by the system shrinks, because, for example, some content owners may terminate their contracts for the protection service. Our approach to handle scalability is to design a distributed system that can utilize varying amounts of computing resources.

With large-scale distributed systems, failures frequently occur, which require the content protection system to be reliable in face of different failures. To address this reliability, we design the core parts of our system on top of the MapReduce programming framework, which offers resiliency against different types of failures.

• *Cost Efficiency:* The system should minimize the cost of the needed computing infrastructure. Our approach to achieve this goal is to design our system to effectively utilize cloud computing infrastructures (public and/or private). Building on a cloud computing infrastructure also achieves the scalability objective discussed above and reduces the upfront cost of the computing infrastructure.

IV **CONCLUSION AND FUTURE WORK**

Distributing copyrighted multimedia objects by uploading them to online hosting sites such as YouTube can result in significant loss of revenues for content creators. Systems needed to find illegal copies of multimedia objects are complex and large scale. In this paper, we presented a new design for multimedia content protection systems using multi-cloud infrastructures.

The proposed system supports different multimedia content types and it can be deployed on private and/or public clouds.

Two key components of the proposed system are presented. The first one is a new method for creating signatures of 3-D videos. Our method constructs coarse-grained disparity maps using stereo correspondence for a sparse set of points in the image. Thus, it captures the depth signal of the 3-D video, without explicitly computing the exact depth map, which is computationally expensive. Our experiments showed that the proposed 3-D signature produces high accuracy in terms of both precision and recall and it is robust to many video transformations including new ones that are specific to 3-D videos such as synthesizing new views. The second key component in our system is the distributed index, which is used to match multimedia objects characterized by high dimensions. The distributed index is implemented using the MapReduce framework and our experiments showed that it can elastically utilize varying amount of computing resources and it produces high accuracy. The experiments also showed that it outperforms the closest system in the literature in terms of accuracy and computational efficiency. In addition, we evaluated the whole content protection system with more than 11,000 3-D videos and the results showed the scalability and accuracy of the proposed system. Finally, we compared our system against the Content

ID system used by YouTube. Our results showed that:
(i) there is a need for designing robust signatures for 3-D videos since the current system used by the leading company in the industry fails to detect most modified 3-D copies, and (ii) our proposed 3-D signature method can fill this gap, because it is robust to many 2-D and 3-D video transformations.
The work in this paper can be extended in multiple directions. For example, our current system is optimized for batch processing. Thus, it may not be suitable for online detection of illegally distributed multimedia streams of live events such as soccer games. In live events, only small segments of the video are available and immediate detection of copyright infringement is crucial to minimize financial losses. To support online detection, the matching engine of our system needs to be implemented using a distributed programming framework that supports online processing, such as Spark. In addition, composite signature schemes that combine multiple modalities may be needed to quickly identify short video segments. Furthermore, the crawler component needs to be customized to find online sites that offer pirated video streams and obtain segments of these streams for checking against reference streams, for which the signatures would also need to be generated online. Another future direction for the work in this paper is to design signatures for recent and complex formats of 3-D videos such as multiview plus depth. A multiview plus depth video has multiple texture and depth components, which allow users to view a scene from different angles. Signatures for such videos would need to capture this complexity, while being efficient to compute, compare, and store.

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