International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
IJARST
ISSN: 2457-0362

Cloud-Based Multimedia Content Protection System

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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.

Keywords:

1. 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.

2. Literature Survey

1) Dimo: Distributed index for matching multimedia objects using MapReduce

This paper presents the design and evaluation of DIMO, a distributed system for matching high-dimensional multimedia objects. DIMO provides multimedia applications with the basic function of computing the *K* nearest neighbors on large-scale datasets. It also allows multimedia applications to define application-specific functions to further process the computed nearest neighbors. DIMO presents a novel method for partitioning, searching, and storing high-dimensional datasets on distributed infrastructures that support the MapReduce programming model. We have implemented DIMO and extensively evaluated it on Amazon clusters with number of machines ranging from 8 to 128. We have experimented with large datasets of sizes up to 160 million data points extracted from images, and each point has 128 dimensions. Our experimental results show that DIMO: (i) results in high precision when compared against the ground-truth nearest neighbors, (ii) can elastically utilize varying amounts of computing resources, (iii) does not impose high network overheads, (iv) does not require large main memory even for processing large datasets, and (v) balances the load across the used computing machines. In addition, DIMO outperforms the closest system in the literature by a large margin (up to 20%) in terms of the achieved average precision of the computed nearest neighbors. Furthermore, DIMO requires at least three orders of magnitudes less storage than the other system, and it is more computationally efficient.

1) Cannot achieve better index generation.

2) Distributed Kd-Trees for retrieval from very large image collections

Distributed Kd-Trees is a method for building image retrieval systems that can handle hundreds of millions of images. It is based on dividing the Kd-Tree into a "root subtree" that resides on a root machine, and several "leaf subtrees", each residing on a leaf machine. The root machine handles incoming queries and farms out feature matching to an appropriate small subset of the leaf machines. Our implementation employs the MapReduce architecture to efficiently build and distribute the Kd-Tree for millions of images. It can run on thousands of machines, and provides orders of magnitude more throughput than the state-of-the-art, with better recognition performance. We show experiments with up to 100 million images running on 2048 machines, with run time of a fraction of a second for each query image.

Spatial signatures weakness is the lack of resilience against large geometric transformations.

3) Spider: A system for finding 3D video copies

This article presents a novel content-based copy detection system for 3D videos. The system creates compact and robust depth and visual signatures from the 3D videos. Then, signature of a query video is compared against an indexed database of reference videos' signatures. The system returns a score, using both spatial and temporal characteristics of videos, indicating whether the query video matches any video in the reference video database, and in case of matching, which portion of the reference video matches the query video. Analysis shows that the system is efficient, both computationally and storage-wise. The system can be used, for example, by video content owners, video hosting sites, and third-party companies to find illegally copied 3D videos. We implemented Spider, a complete realization of the proposed system, and conducted rigorous experiments on it. Our experimental results show that the proposed system can achieve high accuracy in terms of precision and recall even if the 3D videos are subjected to several transformations at the same time. For example, the proposed system yields 100% precision and recall when copied videos are parts of original videos, and more than 90% precision and recall when copied videos are subjected to different individual transformations.

It may not be effective for the rapidly increasing online videos, especially those uploaded to sites such as YouTube and played back by any video player.

4) Efficient processing of k nearest neighbor joins using MapReduce

k nearest neighbor join (kNN join), designed to find k nearest neighbors from a dataset S for every object in another dataset R, is a primitive operation widely adopted by many data mining applications. As a combination of the k nearest neighbor query and the join operation, kNN join is an expensive operation. Given the increasing volume of data, it is difficult to perform a kNN join on a centralized machine efficiently. In this paper, we investigate how to perform kNN join using MapReduce which is a well-accepted framework for data-intensive applications over clusters of computers. In brief, the mappers cluster objects into groups; the reducers perform the kNN join on each group of objects separately. We design an effective mapping mechanism that exploits pruning rules for distance filtering, and hence reduces both the shuffling and computational costs. To reduce the shuffling cost, we propose two approximate algorithms to minimize the number of replicas. Extensive experiments on our in-house cluster demonstrate that our proposed methods are efficient, robust and scalable.

The implementation is too complex

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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, 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.Many previous works proposed different methods for creating and matching signatures. These methods can be classified into four categories: spatial, temporal, color, and transform-domain. Spatial signatures (particularly the block-based) are the most widely used.Youtube Content ID, Vobile VDNA, and MarkMonitor are some of the industrial examples which use fingerprinting for media protection, while methods such as can be referred to as the academic state-of-the-art.

1) Watermarking approach may not be suitable for already-released content without watermarks in them. Watermarking may not be effective for the rapidly increasing online videos, especially those uploaded to sites such as YouTube and played back by any video player.

2) Spatial signatures weakness is the lack of resilience against large geometric transformations.

Temporal and color signatures are less robust and can be used to enhance spatial signatures. Transform-domain signatures are computationally intensive and not widely used in practice.

3. Proposed System

We present a novel system for multimedia content protection on cloud infrastructures. The system can be used to protect various multimedia content types.In our proposed system we present complete multi-cloud system for multimedia content protection. The system supports different types of multimedia content and can effectively utilize varying computing resources.Novel method for creating signatures for 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.The focus of this paper is on the other approach for protecting multimedia content, which is content-based copy detection (CBCD). In this approach, signatures are extracted from original objects. Signatures are also created from query (suspected) objects downloaded from online sites. Then, the similarity is computed between original and suspected objects to find potential copies.

1. Accuracy.
2. Computational Efficiency.
3. Scalability and Reliability.
4. Cost Efficiency.
5. The system can run on private clouds, public clouds, or any combination of public-private clouds.
6. 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.
7. The design is cost effective because it uses the computing resources on demand.
8. The design can be scaled up and down to support varying amounts of multimedia content being protected.

4. Results and Implementation

Distributed Matching Engine

This module describes the designing of matching engine suitable for different types of multimedia objects that is scalable and elastic .It can support different types of multimedia objects, including images, 2-D videos, and 3-D videos. To achieve this generality, we divide the engine into two main stages. The first stage computes nearest neighbors for a given data point, and the second stage post-processes the computed neighbors based on the object type. In addition, our design supports high-dimensionality which is needed for multimedia objects that are rich in features.

Signature Creation

The system abstracts the details of different media objects into multi-dimensional signatures. The signature creation and comparison component is media specific,while other parts of the system do not depend on the media type.

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ISSN: 2457-0362

Our proposed design supports creating composite signatures that consist of one or more of the following elements:

• Visual signature: Created based on the visual parts in multimedia objects and how they change with time;

• Audio signature: Created based on the audio signals in multimedia objects;

• Depth signature: If multimedia objects are 3-D videos, signatures from their depth signals are created;

• Meta data: Created from information associated with multimedia objects such as their names, tags, descriptions, format types, and IP addresses of their uploaders or downloader's.

Crawl component

Crawl component downloads all objects and the signatures are created, the signatures are uploaded to the matching engine to perform the comparison. Compression of signatures can be performed before the upload to save bandwidth. Once all signatures are uploaded to the matching engine, a distributed operation is performed to compare all query signatures versus the reference signatures in the distributed index.

Performance Evaluation

We have implemented and integrated all parts of the proposed content protection system: from a web user interface to control various parts of the system and its configurations, to tools to allocate, release, and manage cloud resources, to all algorithms for creating and matching signatures, as well as all distributed Map Reduce algorithms for processing thousands of multimedia objects. This is a fairly complex system with tens of thousands of lines of code in different programming and scripting languages. We validated our proposed multi-cloud architecture by deploying part of our system on the Amazon cloud and the other part on our local 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.

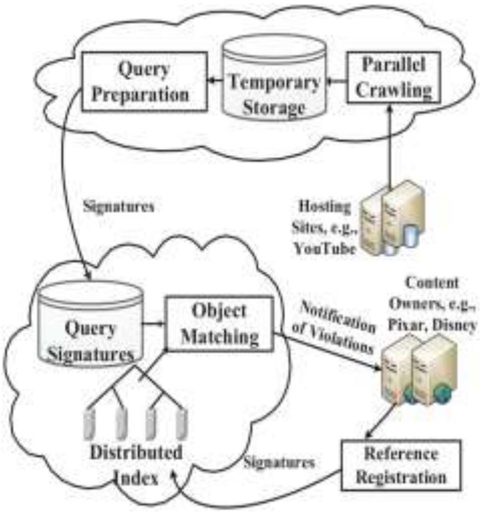

Fig.1. System Architecture

5. Conclusion

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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