UNIVERSITÀ DEGLI STUDI FIRENZE

Scuola di Ingegneria

Corso di Laurea Magistrale in Ingegneria Informatica

Forensic Analysis of Video File Containers

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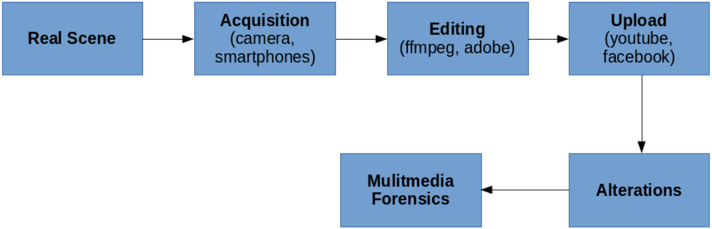
Anno Accademico 2015/2016

Introduction

In an increasingly digital world, the analysis of multimedia objects is rapidly assuming importance in the context of **digital investigation**.

Multimedia Forensics has developed many techniques with the goal of providing aid in making decisions about a digital content **authenticity**, **integrity** and **origin**.



Introduction

In this regard, techniques mainly use two different approaches:

1. **Audio-video signal**: the research of inconsistencies and artefacts in the digital content.
2. **Metadata/Container**: the determination of their compatibility, completeness, and consistency.

Video File Container - What's inside?

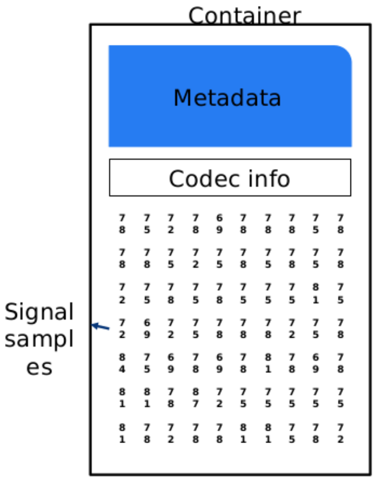
Container data, structured information about the content:

- Content-related metadata
- Number of tracks/signals

Codec data, necessary information to decode and present the signal:

- Quantization tables.
- Information for entropy decoding

Encoded signal(s)

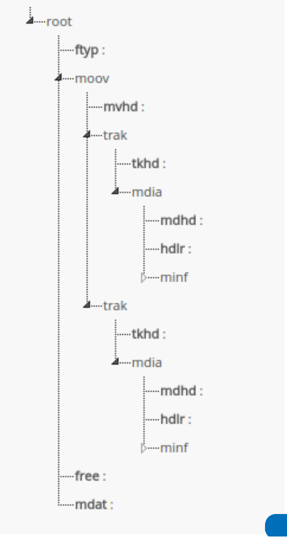


Video File Container - Structure

As defined by the *ISO Base Media File Format Standard* [1], file containers have a object-oriented type structure.

Each object, called **box** or **atom**, includes specifics information about the media and are identified by 4-byte characters (e.g. *ftyp*, *mdat*, *moov*, etc.).

Boxes can have **attributes** and can contain other boxes.



Video File Container - Why?

As noticed by *Gloe et al.* [2], the video format standards (e.g. *ISO Base Media* [1], *MP4* [3], *MOV* [4]) for the file container prescribe only a limited number of features.

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Low-level information that we have exploited with regard to **Source Identification** and **Integrity Verification**.

Source Identification

Given a video, we want to assess its origin based on its file container.

We split the problem in **binary questions**.

Ex. Does the video belongs to Samsung?
... to Samsung Galaxy S3?
... to Huawei G6?
... to Apple?
... to Apple iPhone 5?

Given a question, a training dataset is queried to obtain two classes (videos for which the answer is true, and the complementary).

For each question, we want to define a compatibility score.

Source Identification - Training

Determine whether a video belongs to a class C (e.g. Samsung).

We split the ground-truth in two sets:

$$\Omega = X_C \cup X_{\overline{C}} = x_1, \ldots, x_{N_C} \in C \cup x_1, \ldots, x_{N_{\overline{C}}} \in \overline{C}$$

Ω contains all the attributes ω of the boxes contained in each of the ground-truth media X.

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We determine the **discrimination power** of each of the attributes ω for the class C and $\overline{C}$.

$$W_C(\omega) = \frac{\sum_{i=1}^{N_C} \mid X_i \cap \omega \mid}{N_C} \qquad W_{\overline{C}}(\omega) = \frac{\sum_{i=1}^{N_{\overline{C}}} \mid X_i \cap \omega \mid}{N_{\overline{C}}}$$

Source Identification - Test

Given a media query $X = \omega_1, ...\omega_t$, we solve the two hypothesis test problem:

$$H_0 : X \in \overline{C}$$
$$H_1 : X \in C$$

To do so, we determine the **likelihood** ratio of observing $\omega_j, j = 1 \ldots t$.

$$P(\omega_j | H_0) = W_{\overline{C}}(\omega_j)$$
$$P(\omega_j | H_1) = W_C(\omega_j)$$

$$L(X) = \prod_{\omega_j} \frac{W_C(\omega_j)}{W_{\overline{C}}(\omega_j)}$$

Then, $l(X) = lnL(X)$ can be used to determine whether X belongs to class C.

Source Identification - Correlated Features

Some features might be correlated. For each box, we consider the **entropy** of its attributes in order to remove redundant information.

When considering a box, given a vector of likelihood ratios $\overline{x} = (x_1, \ldots, x_n)$, we compute the likelihood for that box as:

$$L(\overline{x}) = \prod_{i=1}^{n} x_i^{\alpha_i(\gamma_i)}$$

with

$$\gamma_i = -\frac{n}{logn} P(x_i) logP(x_i)$$

and where $P(x_i)$ represents the probability of finding that value of ratio in the vector.

Source Identification - Dataset

The dataset is composed of 260 videos acquired from smartphones and tablets with Android (Samsung, Huawei) and iOS.

OS	BRAND	MODEL	#
Android			150
	Samsung		132
		Galaxy S3	18
		Galaxy S3 mini	36
		Galaxy S4 mini	18
		Galaxy Tab 3	36
		Galaxy Tab A	9
		Galaxy Trend Plus	15
	Huawei		18
		G6	18
iOS			110
	Apple		110
		iPad 2	15
		iPad mini	15
		iPhone 4S	14
		iPhone 5C	18
		iPhone 5	31
		iPhone 6	17
			260

Source Identification - Experiments

The tests are divided in two types, changing the definition of a class of device:

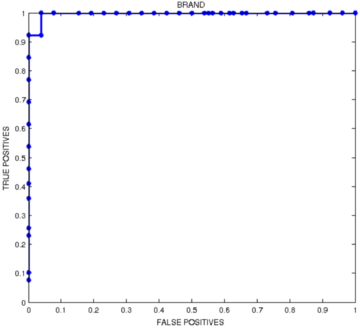
- **Brand**: we try to identify the test videos brand (3 brands).
- **Model**: we try to identify both brand and model (13 models).

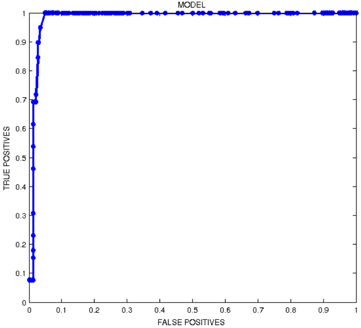
For each of these types, we consider:

- **Binary Classification**: for each class of devices in the dataset, we try to correctly classify the test videos.
- **Retrieval**: how many times the correct classes are in the first position, in the top three position, or in the top five position (ordered by the likelihood ratios).

Source Identification - Results

Type	ACC	THRESHOLD	TOP 1	TOP 3	TOP 5	
Brand	98.08%	0	98.08%	92%	-	-
Model	97.54%	3.5	96.79%	84.62%	100%	100%





Integrity Verification

Given a query video X that supposedly comes from a certain device.

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By comparing the two file containers, we compute the percentage of differences.

Integrity Verification - Experiments

For these experiments, we have altered the videos of the dataset with different tools:

- **Ffmpeg**: we have directly cut the videos, without re-encoding.
- **Exiftool**: we have changed the metadata related to Date and Time.
- **YouTube**: we have uploaded and downloaded the videos from *YouTube*.

Using their file containers, we compute the differences:

1. $(x_1, \ldots, x_n) \in C_i$, $(x_i, xj) \rightarrow d_{ij}$
2. $(\overline{x_1}, \ldots, \overline{x_n}) \in \overline{C_i}$, $(x_i, \overline{x_j}) \rightarrow \overline{d_{ij}}$

Integrity Verification - Results

N.	Tool	ACC	THRESHOLD
1	Ffmpeg	100%	0.385
2	Exiftool	100%	0.001
3	YouTube	100%	0.470

We were always able to correctly separate the original videos from the modified ones.

These tools alter the original file container.

Web Application

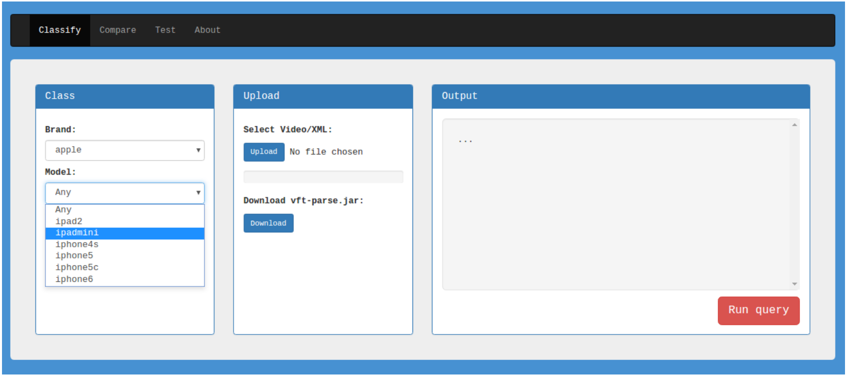

Figura : Interface for the Source Identification feature.

Conclusions

- Using the video file containers, we implemented two approaches for Source Identification and Integrity Verification.
- Video file container turned out to be a powerful tool; both approaches achieved promising results.
- Should be considered preliminary work; further developments:
  - Perform tests with a higher variety of devices.
  - Take into consideration the version of the operating system.
  - Specialize how the attributes are compared (e.g. check for format for Date and Time).

References

[1] I. 14496. *Information Technology. Coding of audio-visual objects, part 12: ISO Base Media File Format*, 3rd ed. 2008.

[2] T. Gloe, A. Fischer, and M. Kirchner. Forensic analysis of video file formats. *Digital Investigation*, 11, Supplement 1:S68-S76, 2014. Proceedings of the First Annual DFRWS Europe.

[3] I. 14496. *Information Technology. Coding of audio-visual objects, part 14: Mp4 File Format*, 2003.

[4] I. Apple Computer. *Quicktime file format*, 2001.