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Corso di Laurea Magistrale in Ingegneria  
Informatica

# Forensic Analysis of Video File Containers

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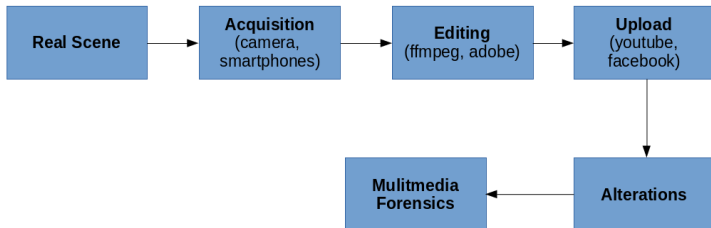
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# Introduction

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In an increasingly digital world, the analysis of the 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

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We have focused our attention on Source Identification and Integrity Verification of digital videos acquired by smartphones and tablets.

Forensic Analysis is based on the research of the so called *fingerprints*, left both by the acquisition device and by the post-processing steps.

In this regard, techniques mainly use two different tools:

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

# Video File Container - What's inside?

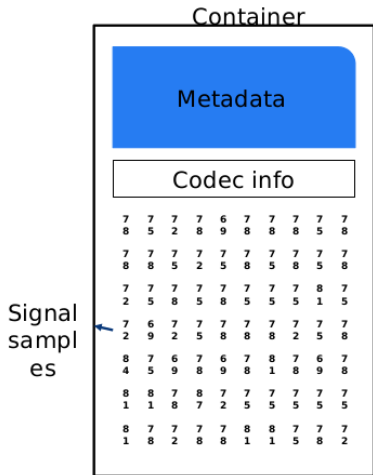
**Contained data**, structured information about the content, like:

- Content-related metadata (acquisition time, place, settings, etc.)
- Number of tracks/signals (e.g. a video container may include several video tracks.)

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

- Quantization tables.
- Information for entropy decoding

**Encoded signal(s)**

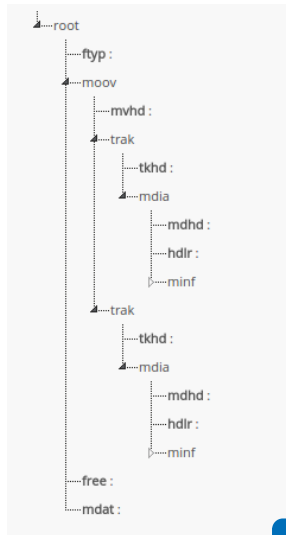


# Video File Container - Structure

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 fields and can contain other boxes.



## Video File Container - Why?

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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.

## Video File Container - Why?

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Low-level information to be exploited by the Forensic Analyst.



## Source Identification

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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, the 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

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

We split the ground-truth in two sets:

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

$\Omega$  contains all the attributes  $\omega$  of the boxes contained in each of the ground-truth media.

We determine the discrimination power of each of the attributes  $\omega$  for the class  $C$  and  $\bar{C}$ .

$$W_C(\omega) = \frac{\sum_{i=1}^{N_C} |X_i \cap \omega|}{N_C}$$

$$W_{\bar{C}}(\omega) = \frac{\sum_{i=1}^{N_{\bar{C}}} |X_i \cap \omega|}{N_{\bar{C}}}$$

## Source Identification - Test

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

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

$$H_1 : X \in C$$

Then we determine the likelihood ratio of observing  $\omega_j, j = 1 \dots t$ .

$$\begin{aligned} P(\omega_j | H_0) &= \Omega_{\overline{C}}(\omega_j) \\ P(\omega_j | H_1) &= \Omega_C(\omega_j) \end{aligned} \qquad L(X) = \prod_{\omega_j} \frac{\Omega_C(\omega_j)}{\Omega_{\overline{C}}(\omega_j)}$$

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

## Source Identification - Correlated Features

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We have supposed that the values of the attributes of a certain box are independently distributed. However, some features might be correlated.

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

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

with

$$\alpha_i = \frac{(n-1)\gamma_i + 1}{n}$$
$$\gamma_i = -\frac{n}{\log n} P(x_i) \log P(x_i)$$

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

## Source Identification - Experiments

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

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

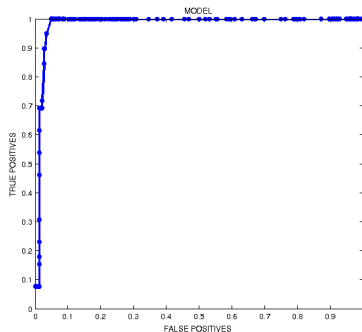
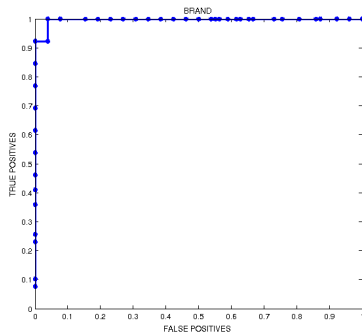
- **Brand:** we try to identify the test videos brand.
- **Model:** we try to identify both brand and model.

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	THRESHOLDS	TH = 0	TOP 1	TOP 3	TOP 5
Brand	98.08%	$[-12, 14]$	98.08%	92%	-	-
Model	97.54%	$[3, 4]$	96.79%	84.62%	100%	100%



## Integrity Verification

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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

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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 change 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.  $(x_1, \dots, x_n) \in C_i, (x_i, x_j) \rightarrow d_{ij}$
2.  $(\overline{x_1}, \dots, \overline{x_n}) \in \overline{C_i}, (x_i, \overline{x_j}) \rightarrow \overline{d_{ij}}$

## Integrity Verification - Results

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N.	Tool	ACC	THRESHOLD
1	Ffmpeg	100%	[0.11, 0.66]
2	Exiftool	100%	0.001
3	YouTube	100%	[0.39, 0.55]

Using the file containers, we were always able to correctly separate the original videos from the modified ones.

For the *Exiftool* case, we did not consider the differences caused by attributes whose values are unique to each video (acquisition time, modification time, duration, size, etc.).

## Integrity Verification - Results

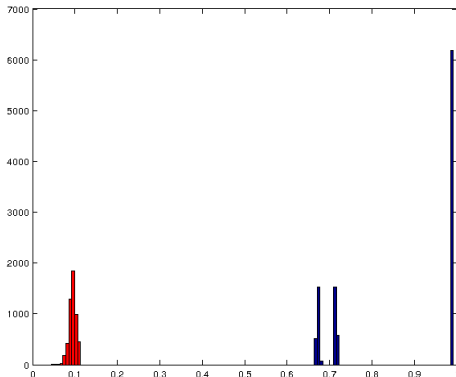


Figura : Differences distribution for the Ffmpeg case. Red for original videos; blue for modified videos.

## Conclusions

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- Using the video file containers, we implement 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).
  - For Source Identification, it is critical how the reference population is built.

## References

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- [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.