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Integrity and Authenticity of Digital Images by Digital Forensic Analysis of Metadata

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***Abstract*—During various court hearings, the thesis that every authentic digital file has precise metadata of its creation date was questioned.In this way, the problem was raised which indicates, if the metadata of a digital file (Image) whose label records the date of creation by the recording device of a digital image file are accurate and reliable.For this reason, during the forensic analysis carried out in this work, a record of the metadata of five (05) digital image files from known sources is shown and where their characteristics have been detailed, in addition a record of the metadata of the images used that were later manipulated with image editing software with which metadata comparisons were made to show the labels that suffered modifications in their content.Finally, the obtaining of HASH code with the SHA - 256 algorithm is shown, for digital assurance, of the edited and original files whose comparison allows observing the changes in the content at a binary level.**

***Keywords*—Crime; Cybercrime; Digital Image; HASH; Metadata.**

I. Introduction

Today there are different types of crimes and cybercrimes, where part of the expert work is the forensic analysis of digital evidence.This type of evidence can be data, videos, images, audios, among others.The present experimental investigation focused on the forensic digital analysis of the metadata of five images, knowing the recording device.It is based on the thesis that the expert work of cases in which the validity as proof of digital evidence is discussed is made up of several specialized examinations.Thus, on the one hand, we have the expert work of forensic digital analysis of integrity and authenticity of images, where the first part of the analysis consists of obtaining the metadata and the hash code.On the other hand, the expert work of editing and manipulating digital images requires establishing the conditions of the equipment with which they were captured, so that the expert analysis carried out to date by the present members of the study shows, empirically, the following ways of recording such information:

- *Factory mode:* The configuration date is registered in the memory of the camera recorded during the factory process.
- *User configuration:* The user of the recording equipment configures the date and time according to the corresponding region and time zone; this is exclusive competence of the user.
- By updating or formatting the device's software, certain recording devices suffer alteration of the device's date and time.
- Internal battery change or deterioration of the battery, some image and video capture devices present the factory or user-set date stored in memory during power interruptions caused by internal or interchangeable battery change or when the battery is completely discharged.

The research approach is quantitative, descriptive in scope and experimental in design.

II. Background

In the context of a fiscal investigation, the analysis of the integrity and authenticity of an image is part of the expert work of digital forensic analysis. There are many research works related to this type of analysis and, in particular, to the analysis of metadata.

On the one hand, we find research in which protocols are disclosed to determine whether a digital image is intact and authentic. An example of this type of research is the one developed by Rodríguez-Santos, Delgado-Gutierréz, Palacios-Luengas and Vasquéz-Medina (2015), who present a methodology for detecting modifications in JPEG image files that includes, among other tests, digital assurance and metadata analysis [1]. Another example is the research by Zeng, Shi, Li, and Lu (2016), who present a methodology for image file authentication consisting of techniques based on the analysis of encoding metadata [2].

On the other hand, we find more specialized studies in which the focus is on metadata analysis. A case of this kind of studies is the one developed by Sandoval, Arenas, García and Hernández-Castro (2015), who show anomalies in the EXIF metadata of images created by mobile devices [3]. Another case is the study by Gangwar and Pathania (2018), who used metadata analysis with free computational tools to detect alterations by editing images [4].

The background information reviewed describes important concepts such as metadata, HASH code, modification date and others. It is vital that this terminology has no ambiguity or subjective connotation. With this in mind, forensic research circles, such as the Scientific Working Group on Digital Evidence (SWGDE), propose glossaries of these key concepts.

A. Metadata

Data, frequently embedded within a file, that describes a specific file or directory, which may include the locations where content is stored, dates and times, and application-specific information as well as permissions [5].

B. HASH code

An established mathematical calculation that generates a numerical value based on input data. This numerical value is called HASH or HASH value [5].

C. The date of the recording devices:

- File creation date: this is the date the file was "created". This date does not change whenever the file is opened, closed, saved or modified.
- File access date: this is the date on which the file was last accessed. An access can be a move, an open access or any other simple access.
- File modification date: this is the date on which there has been a change in the file content. For example, if the original content of a text file is modified, the file modification date will be updated.

D. The date of the recording devices:

The application of image science and domain expertise to discern whether a challenged image or video is an accurate representation of the original data according to some defined criteria and/or the determination of the original source of the image [6].

E. The date of the recording devices:

The process of altering the visual appearance of an image or specific features within an image that results in misrepresentation or misinterpretation [6].

F. Image content

Visual information within an image, such as subjects/objects, artifacts (due to compression and/or capture) and physical aspects of the image scene [6].

G. Image structure

Non-visual information about the image itself, such as the file type, file compression, metadata, or image source [6].

III. METHODOLOGY

The methodology used is ISO 27037, which corresponds to the management of digital evidence related to the identification, collection and acquisition of digital evidence.

A. Recording Devices Used

On October 25, 2020, 5 images were captured with 5 different recording devices, one (01) video camera, one (01) digital camera, two (02) mobile phones and one (01) tables; 3 of which had their internal date in factory mode. Table I shows the characteristics of the devices used while Figure 1 shows the recording devices.

TABLE I
Equipment Feactures Regarding Recording Devices Used

Item	**Appearance (in Time New Roman or Times)**			
	Equipment	**Brand**	**Model**	**Internal Date**
1	Filmmaker	Sony	HDR-CX240	11/05/2037
2	Photographic Camera	Panasonic	DMC-FH5	01/01/2011
3	Cellphone	Alcatel	5059A	25/10/2020
4	Cellphone	Huawei	MED-LX9	25/10/2020
5	Tablet	Advance	RK30 SDK	01/01/2011

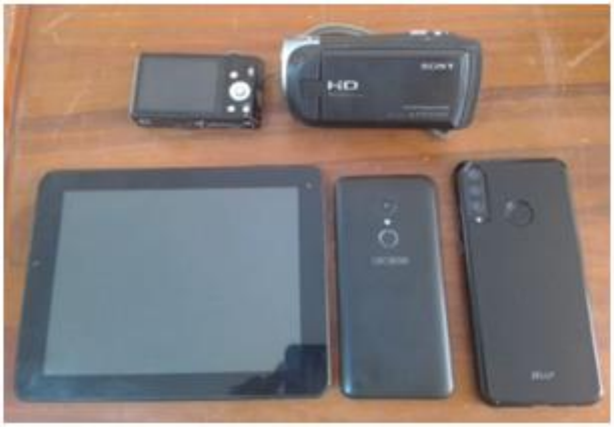


Figure 1 The architecture of the software framework

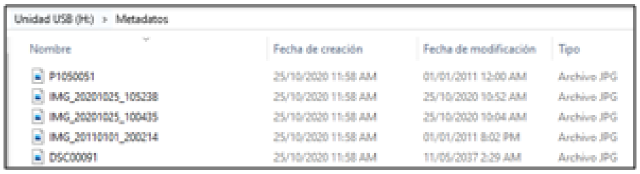
B. *Collection and Extraction*

The extraction method was Level 1 [12], which corresponds to manual procedures and photographic captures for the extraction of information, which included connection via computer equipment.

The files were extracted from each recording device as shown in Table II and verifying their creation date (see Figure 2).

TABLE II
FEATURES OF THE COLLECTION AND EXTRACTION EQUIPMENT

Item	**Equipment Employed**		
	Equipment	**Brand**	**Name of Captured Image**
1	Filmmaker	Sony	DSC00091.JPG
2	Photographic Camera	Panasonic	P1020021.JPG
3	Cellphone	Alcatel	IMG_20201025_105238
4	Cellphone	Huawei	IMG_20201025_100435
5	Tablet	Advance	IMG_20110101_200214



Unidad USB (H:) › Metadatos

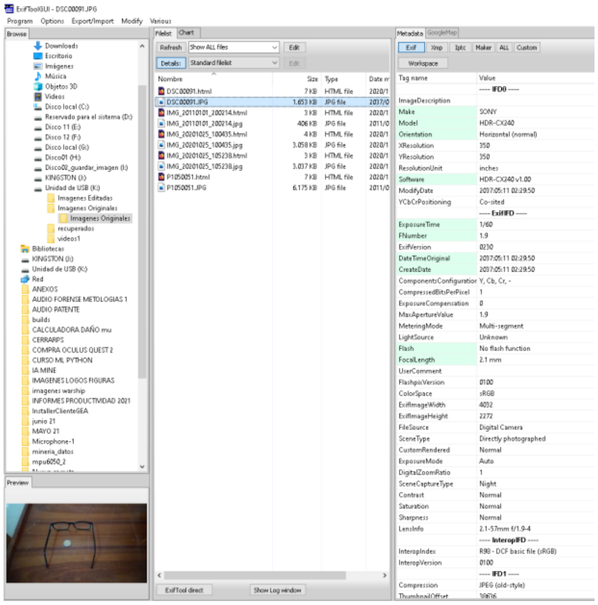
Nombre	Fecha de creación	Fecha de modificación	Tipo
P1050051	25/10/2020 11:58 AM	01/01/2011 12:00 AM	Archivo JPG
IMG_20201025_105238	25/10/2020 11:58 AM	25/10/2020 10:52 AM	Archivo JPG
IMG_20201025_100435	25/10/2020 11:58 AM	25/10/2020 10:04 AM	Archivo JPG
IMG_20110101_200214	25/10/2020 11:58 AM	01/01/2011 8:02 PM	Archivo JPG
DSC00091	25/10/2020 11:58 AM	11/05/2037 2:29 AM	Archivo JPG

Figure 2Digital image properties analyzed

C. *Metadata Collection*

As part of the experiment to be carried out in the process of image authentication [7], metadata examination is described exposing the main parameters obtained from the metadata of digital images with the aim of exposing the importance of this information and as an assistance to the research [8].

We proceeded to use the GUI-Exiftool software [7], [9], which is detailed in Figure 3 and Figure 4.

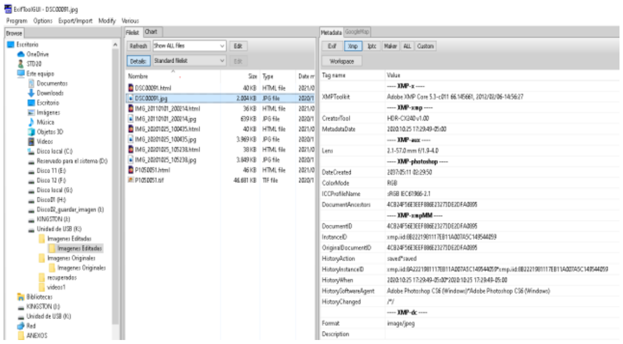


ExifToolGUI - DSC00091.JPG
Program Options Export/Import Modify Various
Browse
Filelist Chart
Refresh Show ALL files Edit
Details: Standard filelist Edit
Metadata GoogleMap
Exif Xmp Iptc Maker ALL Custom
Workspace
Preview
ExifTool direct
Show Log window

Nombre	Size	Type	Date m
DSC00091.html	7 KB	HTML file	2020/1
DSC00091.JPG	1.653 KB	JPG file	2037/0
IMG_20110101_200214.html	3 KB	HTML file	2020/1
IMG_20110101_200214.jpg	406 KB	JPG file	2011/0
IMG_20201025_100435.html	4 KB	HTML file	2020/1
IMG_20201025_100435.jpg	3.058 KB	JPG file	2020/1
IMG_20201025_105238.html	3 KB	HTML file	2020/1
IMG_20201025_105238.jpg	3.037 KB	JPG file	2020/1
P1050051.html	7 KB	HTML file	2020/1
P1050051.JPG	6.175 KB	JPG file	2011/0

Tag name	Value
	---- IFD0 ----
ImageDescription	
Make	SONY
Model	HDR-CX240
Orientation	Horizontal (normal)
XResolution	350
YResolution	350
ResolutionUnit	inches
Software	HDR-CX240 v1.00
ModifyDate	2037:05:11 02:29:50
YCbCrPositioning	Co-sited
	---- ExifIFD ----
ExposureTime	1/60
FNumber	1.9
ExifVersion	0230
DateTimeOriginal	2037:05:11 02:29:50
CreateDate	2037:05:11 02:29:50
ComponentsConfiguratior	Y, Cb, Cr, -
CompressedBitsPerPixel	1
ExposureCompensation	0
MaxApertureValue	1.9
MeteringMode	Multi-segment
LightSource	Unknown
Flash	No flash function
FocalLength	2.1 mm
UserComment	
FlashpixVersion	0100
ColorSpace	sRGB
ExifImageWidth	4032
ExifImageHeight	2272
FileSource	Digital Camera
SceneType	Directly photographed
CustomRendered	Normal
ExposureMode	Auto
DigitalZoomRatio	1
SceneCaptureType	Night
Contrast	Normal
Saturation	Normal
Sharpness	Normal
LensInfo	2.1-57mm f/1.9-4
	---- InteropIFD ----
InteropIndex	R98 - DCF basic file (sRGB)
InteropVersion	0100
	---- IFD1 ----
Compression	JPEG (old-style)
ThumbnailOffset	18636

Figure 3 GUI – Exiftool with Original Image EXIF Metadata



ExifToolGUI - DSC00091.jpg
Program Options Export/Import Modify Various
Browse
Filelist Chart
Refresh Show ALL files Edit
Details: Standard filelist Edit
Metadata GoogleMap
Exif Xmp Iptc Maker ALL Custom
Workspace

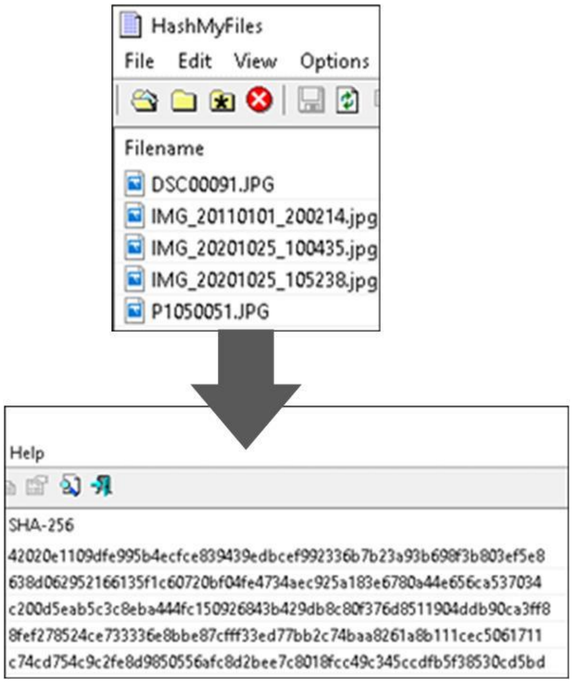
Nombre	Size	Type	Date m
DSC00091.html	40 KB	HTML file	2021/0
DSC00091.jpg	2.004 KB	JPG file	2020/1
IMG_20110101_200214.html	36 KB	HTML file	2021/0
IMG_20110101_200214.jpg	639 KB	JPG file	2020/1
IMG_20201025_100435.html	40 KB	HTML file	2021/0
IMG_20201025_100435.jpg	3.969 KB	JPG file	2020/1
IMG_20201025_105238.html	38 KB	HTML file	2021/0
IMG_20201025_105238.jpg	3.849 KB	JPG file	2020/1
P1050051.html	46 KB	HTML file	2021/0
P1050051.tif	46.681 KB	TIF file	2020/1

Tag name	Value
	---- XMP-x ----
XMPToolkit	Adobe XMP Core 5.3-c011 66.145661, 2012/02/06-14:56:27
	---- XMP-xmp ----
CreatorTool	HDR-CX240 v1.00
MetadataDate	2020:10:25 17:29:49-05:00
	---- XMP-aux ----
Lens	2.1-57.0 mm f/1.9-4.0
	---- XMP-photoshop ----
DateCreated	2037:05:11 02:29:50
ColorMode	RGB
ICCProfileName	sRGB IEC61966-2.1
DocumentAncestors	4CB24F56E3EEF886E23273DE2DFA0895
	---- XMP-xmpMM ----
DocumentID	4CB24F56E3EEF886E23273DE2DFA0895
InstanceID	xmp.iid:8B222198111 7EB11A007A5C149544059
OriginalDocumentID	4CB24F56E3EEF886E23273DE2DFA0895
HistoryAction	saved*saved
HistoryInstanceID	xmp.iid:8A222198111 7EB11A007A5C149544059*xmp.iid:8B222198111 7EB11A007A5C149544059
HistoryWhen	2020:10:25 17:29:49-05:00*2020:10:25 17:29:49-05:00
HistorySoftwareAgent	Adobe Photoshop CS6 (Windows)*Adobe Photoshop CS6 (Windows)
HistoryChanged	/*/
	---- XMP-dc ----
Format	image/jpeg
Description	

Figure 4 GUI – Exiftool with Edited Image XMP profile metadata

D. Securing

The HashMyFile program is used to extract the HASH code that guarantees the integrity of the information Figure 5.



```
Filename
DSC00091.JPG
IMG_20110101_200214.jpg
IMG_20201025_100435.jpg
IMG_20201025_105238.jpg
P1050051.JPG
```

```
SHA-256
42020e1109dfe995b4ecfce839439edbcef992336b7b23a93b698f3b803ef5e8
638d062952166135f1c60720bf04fe4734aec925a183e6780a44e656ca537034
c200d5eab5c3c8eba444fc150926843b429db8c80f376d8511904ddb90ca3ff8
8fef278524ce733336e8bbe87cfff33ed77bb2c74baa8261a8b111cec5061711
c74cd754c9c2fe8d9850556afc8d2bee7c8018fcc49c345ccdfb5f38530cd5bd
```

Figure 5 Securing with code HASH SHA-256

E. Metadata Analysis

The methodology used is based on the recommendations of the SWGDE (2018) for the analysis of image structure in the authentication process [6].This methodology consists of the Image File Format Examination, Image Metadata Examination, Image File Packaging Examination, and Image Noise Examination. The image metadata examination consists in turn of the camera brand, model and serial number examination, the examination of the creation and modification date and time, the camera configuration examination, the image resolution and size examination. , Image Processing and History Examination, Original Filename Examination, and other.

Next, metadata were obtained in the form of tags and values which describe technical characteristics of the image capture device, characteristics of the photograph taken, and of the software used for its coding at the time it was generated. The comparison and analysis performed on the tags are presented below.

The metadata obtained referring to the brand, model, and software version of the capture equipment are detailed in the Table III.

TABLE III
TAGS AND CHARACTERISTIC VALUES OF ORIGINAL IMAGES 1

Image Name	Equipment Employed			
	Brand	Model	Orientation	Software
1	Sony	HDR-CX240	Horizontal (normal)	HDR-CX240 v1.00
2	Panasonic	DMC-FH5	Horizontal (normal)	Ver.1.0
3	Alcatel	5059A	Horizontal	Mediatek Camera Application
4	Huawei	MED-LX9	Horizontal (normal)	MED-L09 10.1.0.134(C25E8R2P2)
5	Advance	rk30sdk	Horizontal (normal)	-

Metadata referring to camera characteristics and date of creation can be found in Table IV.

TABLE IV
TAGS AND CHARACTERISTIC VALUES OF ORIGINAL IMAGES 1

Font Size	Metadata tags 2						
Image Name	Number	Date Time Original	Date of Creation	ISO	Flash	FocalLength	Time
DSC00091.JPG	1.9	2037:05:11 02:29:50	2037:05:11 02:29:50	-	No flash function	2.1 mm	1/60
P1050051.JPG	3.1	0000:00:00 00:00:00	0000:00:00 00:00:00	160	Auto, Fired	5.0 mm	1/60
IMG_20201025_105238	2.0	2020:10:25 10:52:39	2020:10:25 10:52:39	337	No Flash	3.5 mm	1/20
IMG_20201025_100435	1.8	2020:10:25 10:04:37	2020:10:25 10:04:37	809	No Flash	0.0 mm	1/25

Metadata referring to resolution and XMP profile in specific XMP Toolkit [11] tag of the digitized image in Table V.

TABLE V
Tags And Characteristic Values Of Original Images 3

Image Name	Metadata tags 3		
	ExifImageWidth	ExifImageHeight	XMP Toolkit
DSC00091.JPG	Sony	HDR-CX240	Horizontal (normal)
P1050051.JPG	Panasonic	DMC-FH5	Horizontal (normal)
IMG_20201025_105238	Alcatel	5059A	Horizontal
IMG_20201025_100435	Huawei	MED-LX9	Horizontal (normal)
IMG_20110101_200214	Advance	rk30sdk	Horizontal (normal)

The information obtained as indicated above corresponds exclusively to non-manipulated digital photographic images, which are verified copies, by SHA 256 hash, obtained from the recording equipment sources.

We have included tags obtained from the metadata that XOMToolkit highlights and that are visible as file system characteristics in Windows systems when observing file properties.

Other tags that refer to the rest of the technical parameters of the captured image and capture camera have not been included in order to limit the analysis to the dates of file creation, resolution, XMP profile that are affected in Adobe Photoshop.

F. Editing and manipulation process

Adobe Photoshop was used to edit and manipulate the files according to the following details:

For the image named "DSC00091.JPG", the first coin from the original image was cloned as shown in Figure 6.

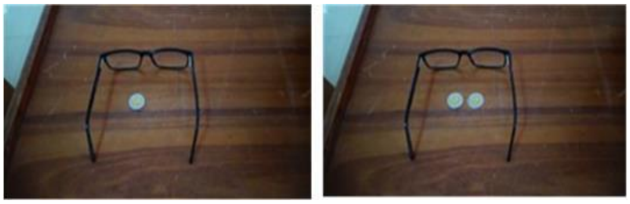


Figure 6 Cloning part of an image (coin)

For the image with the name "IMG_20110101_200214.JPG", the coin was removed from the original image as follows as shown in Figure 7.

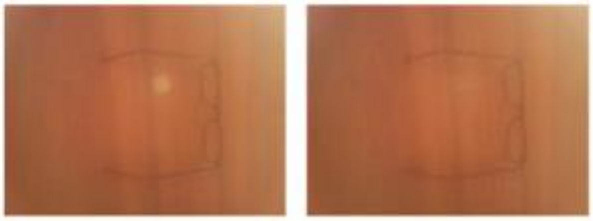


Figure 7 Removing part of an image (Currency)

For the image with the name “IMG_20201025_105238.JPG”, part of the coin of the original image was enhanced as shown in Figure 8.

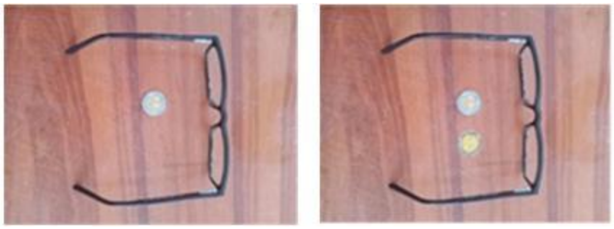


Figure 8 Insertion of part of an image (Currency)

For the image with the name "P1050051.JPG", only the format change was made to "P1050051.TIF" as shown in Figure 9.

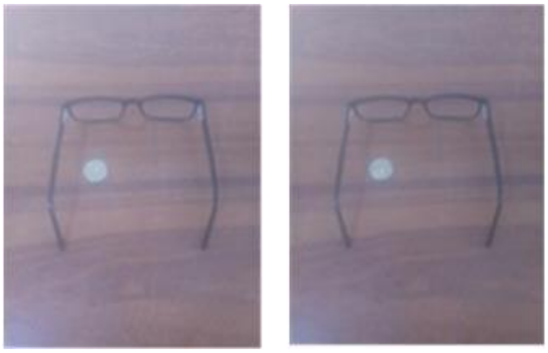


Figure 9 Enhancement of part of an image (Currency)

For the image with the name “P1050051.JPG”, only the format change was made to “P1050051.TIF” as shown in Figure 10.

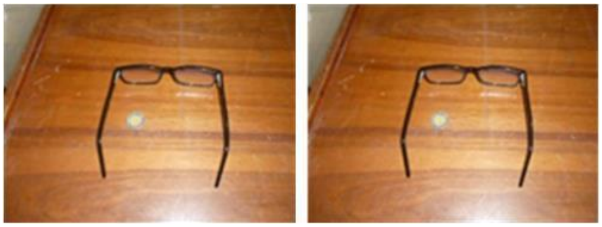


Figure 10 Change from JPG to TIF format

It is noted that the edits applied, did not alter the resolution of the original image, also the Adobe Photoshop software, with default settings, added metadata information in the XMP profile of the GUI-EXIFTool.

IV. Results

The results of the metadata and HASH codes of the edited and manipulated files are detailed:

A. Editing and Manipulation

The 5 images were edited and manipulated with Adobe Photoshop and the edited image metadata tags and values were obtained as shown in Table VI.

TABLE VI
TAGS AND VALUES OF EDITED IMAGE CHARACTERISTICS 1

Image Name	**Metadata tags**				
	Brand	**Model**	**Orientation**	**Software**	**Exposure Time**
DSC00091.JPG	SONY	HDR-CX240	Horizontal (normal)	Adobe Photoshop CS6 (Windows)	1/60
P1050051.JPG	Panasonic	DMC-FH5	Horizontal (normal)	Adobe Photoshop CS6 (Windows)	1/60
IMG_20201025_105238	TCL	5059A	Horizontal	Adobe Photoshop CS6 (Windows)	1/20
IMG_20201025_100435	HUAWEI	MED-LX9	Horizontal (normal)	Adobe Photoshop CS6 (Windows)	1/25
IMG_20110101_200214	rk30sdk	rk30sdk	Horizontal (normal)	Adobe Photoshop CS6 (Windows)CS6 (Windows)	1/100

Metadata referring to resolution and XMP profile [11] of the edited digital image in Table VII.

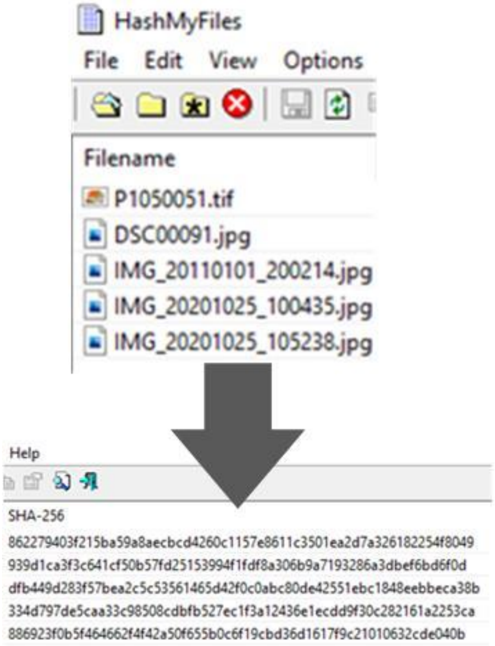
TABLE VII
TAGS AND VALUES OF EDITED IMAGE CHARACTERISTICS 2

Image Name	Metadata tags 2		
	ExifImageWidth	ExifImageHeight	XMP Toolkit
DSC00091.JPG	4032	2272	Adobe XMP 5.0
P1050051.JPG	4608	3456	Adobe XMP 5.0
IMG_20201025_105238	3120	4160	Adobe XMP 5.0
IMG_20201025_100435	4160	3120	Adobe XMP 5.0
IMG_20110101_200214	1600	1200	Adobe XMP 5.0

As observed in Table VI and Table VII, there are variations in two groups of tags.

- *Software:* version of the software used for image processing.
- *XMP Toolkit:* Extended metadata profile used by Adobe Photoshop.

The remaining metadata of the digital images of the five images used, in the other parameters shown in Table VI and Table VII no changes were observed in the information except for the XMP profiles, it is detailed that the default configuration of the Adobe Photoshop software was used since it allows adding metadata to the images processed in its environment. In Figure 11 it is verified that the HASH codes of the edited images correspond to the HASH codes of the extracted and secured original files as detailed in Figure 5.



```
Filename
P1050051.tif
DSC00091.jpg
IMG_20110101_200214.jpg
IMG_20201025_100435.jpg
IMG_20201025_105238.jpg
```

```
SHA-256
862279403f215ba59a8aecbcd4260c1157e8611c3501ea2d7a326182254f8049
939d1ca3f3c641cf50b57fd25153994f1fdf8a306b9a7193286a3dbef6bd6f0d
dfb449d283f57bea2c5c53561465d42f0c0abc80de42551ebc1848eebbeca38b
334d797de5caa33c98508cdbfb527ec1f3a12436e1ecdd9f30c282161a2253ca
886923f0b5f464662f4f42a50f655b0c6f19cbd36d1617f9c21010632cde040b
```

Figure 11 HASH SHA-256 code of the edited and manipulated images

V. CONCLUSIONS

From the five (05) extracted images it is concluded that the date of capture of the image depends on the date of configuration and/or state of the battery or internal battery that stores the configured information among which are the date and time, verifying that some recording devices of the present experiment had factory dates due to the discharge of the internal power supply.

Every device with digital image capture capability has as a property the assignment of a specific alphanumeric format for the assignment of the name of the recorded digital image file, concluding that it depends on the brand and model of the recording device.

The HASH codes and metadata will be affected depending on the editing or manipulation process they undergo, preserving in the metadata in some cases certain characteristics of the original file and certain characteristics of the editing or manipulation software among other data.

In the original digital image P1050051.JPG changed its HASH code when the format was changed to P1050051.TIF, which does not alter the context of the image, which could be part of a future research Figure 12.

Figure 12 Original image and image with format change

Likewise, it is important to emphasize that the original digital image IMG_20201025_105235.jpg was enhanced generating a new image with the same name Figure 13, verifying the variation of the HASH code, which could be part of a future investigation for image enhancement with the use of forensic or commercial software.

Figure 13 Original image and enhanced image

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