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IDENTIFYING PAEDOPHILES BY THEIR KNUCKLES

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Resumen: La biometría ha experimentado un crecimiento exponencial en las últimas décadas debido a la necesidad de seguridad y autenticación de la sociedad. Este aumento ha abarcado diversos campos, incluyendo el ámbito policial, donde se emplea en la identificación de víctimas y perpetradores de multitud de delitos, entre ellos la pornografía infantil.

Este delito consiste en un tipo excepcional puesto que supone la prueba de otro delito intrínseco: el abuso sexual del menor. A diferencia de otros delincuentes, numerosos pederastas optan por documentar la comisión del delito mediante fotografías o vídeos.

La complejidad en la identificación de estos individuos radica en su tendencia a ocultar su rostro detrás de la cámara. No obstante, en ocasiones, las manos sí que son visibles en las imágenes y vídeos que toman. Pero, ¿es suficiente la foto de una mano para identificar a una persona?

Abstract: Biometrics has experienced exponential growth in recent decades due to society's need for security and authentication. This growth has encompassed various fields, including law enforcement, where it is used in the identification of victims and perpetrators of a multitude of crimes, including child pornography.

This crime is an exceptional type since it is evidence of another intrinsic crime: the sexual abuse of a minor. Unlike other offenders, many pedophiles choose to document the commission of the crime by means of photographs or videos.

The complexity in identifying these individuals lies in their tendency to hide their faces behind the camera. Sometimes, however, their hands are visible in the images and videos they take. But, is a photo of a hand enough to identify a person?

Palabras clave: Pornografía infantil, pederasta, biometría, rasgo biométrico, nudillo.

Keywords: Child pornography, pederast, biometrics, biometric trait, knuckle.

ABBREVIATIONS

CIESI: Classification of Child Sexual Exploitation Images

Etc..: Et cetera

FKP: Finger Knuckle Print

ICSE: International Child Sexual Exploitation

INTERPOL: International Criminal Police Organization

SAP: Sentencing Advisory Panel

SEC: Crime Statistical System

SIGO: Integrated Operational Management System

1. INTRODUCTION

Sexual abuse of children represents one of the most serious forms of child maltreatment, transgressing their fundamental rights and posing substantial threats to their well-being and development. This crime, on numerous occasions, manifests in the production of child pornography, where perpetrators, unlike other crimes, often record or photograph themselves carrying out illicit actions for the purpose of later reliving or disseminating them via the Internet (Langran and Stewart, 2018).

Child pornography is established as one of the most disturbing crimes for society as a whole, not only because of the repulsive nature of its content but also because of the devastating consequences for the victims. This reality is reflected in the continuous revision of the legislative framework and the increase in punishable conduct related to this type of crime.

Although it is a priority for society to eradicate this type of criminal behaviour, police forces face considerable difficulties in combating it. One of the greatest complexities in pursuing and apprehending perpetrators is that, despite recording themselves committing the crime, they often hide their identity behind the camera, making it difficult to identify and prosecute them. (Guay, 2017).

A priori, it is reasonable to assume that the identification of an individual is limited to images that reveal his or her face. However, in such images, the perpetrator's visible body part is often the hand. Some questions then arise about the feasibility of identifying a person from their hand: Is it possible? Does the hand have unique characteristics that distinguish one individual from another? And if some time has passed since the images or videos were taken, haven't these characteristics changed?

One of the features of the hands common in child pornography images is the back of the hand and, within the back of the hand, the knuckles. The aim of this work is to analyse the possibility of identifying an individual through the FKP technique[1] in the police field, evaluating its viability as expert evidence.

2. CHILD PORNOGRAPHY

2.1. CONCEPTUALISATION OF CHILD PORNOGRAPHY

One of the most worrying problems today is related to the sexual abuse or assault of children. In the past, this subject used to be taboo, with a tendency to hide and cover up such crimes and their perpetrators. However, as a result of developments and increased awareness, police and judicial investigations into this type of crime have increased. Due to the previous concealment of this type of crime, there is a notable lack of information in society and, therefore, it is necessary to establish a series of definitions to clarify concepts.

The Royal Spanish Academy (n.d.) defines paedophilia as "the erotic or sexual attraction that an adult person feels towards children or adolescents", while pederasty is

[1] Finger Knuckle Print.

defined as "sexual abuse committed with children" (Real Academia Española, n.d., definition 2).

Therefore, the primary difference between paedophilia and pederasty lies in the existence (or absence) of sexual assault or abuse of minors. Sexual assault is the involvement of children in non-consensual sexual activity by adults in an abusive and superior position. It should be noted that physical contact between the child and the adult, whether anal, oral or genital, is necessary. (Aydillo Pérez, 2019).

It is not uncommon for such actions, which violate the sexual integrity of minors, to be captured in some form of visual representation, commonly referred to as child pornography. However, it is not only paedophiles who can commit a child pornography offence since, even if the consumption of such files does not involve contact with a child, the material exists because a real child has been sexually assaulted or abused somewhere in the world, and seeking out such content contributes to the continuation of the abuse. (Interpol, 2003)and the search for this kind of content contributes to the continuation of the abuse.

Defining the scope of this concept is a challenging task, as it is subject to a number of variables as diverse as culture, moral beliefs, patterns of social behaviour and religious ideas in each community. (Sanz Mulas, 2009). These conceptual discrepancies are reflected in the legal terms used in each country's penal code. However, the Protocol on the Sale of Children, Child Prostitution and Child Pornography to the UN Convention on the Rights of the Child[2], in its second article, paragraph c, defined child pornography as "[...] any representation, by whatever means, of children engaged in real or simulated explicit sexual activities or any representation of the genital parts of a child with a primarily sexual focus".

One might think that child pornography emerged with the advent of the Internet, but the truth is that the dissemination of child pornography was observed long before that through a variety of media. However, it is true that the emergence of the Internet and new technologies has revolutionised the speed of information exchange and the generation of various types of content. (Morillas, 2005).

With the Internet, child pornography is accessible to anyone quickly and anonymously. The images can be viewed, stored or recreated and, in addition, many of these images are free and easily accessible in the privacy of one's own home. (Webb et al., 2007). Consequently, despite the fact that new technologies did not bring about their emergence, it is not surprising that the frequency of sexual crimes against children has risen sharply in recent years.

[2] Resolution A/RES/54/263 [General Assembly], Optional Protocol to the Convention on the Rights of the Child on the sale of children, child prostitution and child pornography. 25 May 2000.

2.2. THE REGULATION OF CHILD PORNOGRAPHY IN SPAIN

Currently, Directive 2011/93/EU[3] sets the framework for actions in this field at the European level. This directive, together with the Budapest Convention[4] and the Lanzarote Convention[5], have served as the basis for the amendments made to Spanish criminal legislation in the fight against this type of crime.

In Spanish legislation, several reforms of the Penal Code define and criminalise offences related to child pornography. The first intervention was Organic Law 11/1999[6], which criminalised the possession of child pornographic material with the intention to produce, sell, distribute, exhibit or facilitate these activities. The 2003 reform represented a step forward by criminalising the simple possession of child pornography material. In 2010, the range of punishable conduct was broadened from possession to production and distribution of such material.

However, it was not until Organic Law 1/2015[7], that a complete definition of child pornography, in line with international standards, was incorporated. Thus, according to Article 189, it is considered child pornography:

> (a) Any material that visually depicts a minor or person with a disability [...] engaging in sexually explicit conduct [...].
>
> (b) Any depiction of the sexual organs of a minor or person with a disability [...] for primarily sexual purposes.

Therefore, for a file (excluding audio files) to be considered child pornography it must contain visual depictions showing minors or persons with disabilities engaged in sexually explicit activities. “Sexually explicit activities", according to the Proposal for a Council Framework Decision on combating the sexual exploitation of children and child pornography[8], includes at least one of the following behaviours: "carnal access, by genital-genital, oral-genital, genital-anal or oral-anal contact; bestiality; masturbation; sadomasochistic violence, or obscene exhibition of the genitals or pubic region".

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[3] Directive 2011/93/EU of the European Parliament and of the Council of 13 December 2011 on combating the sexual abuse and exploitation of children and child pornography and replacing Council Framework Decision 2004/68/JHA. (BOE, no. 335, of 17 December 2011).

[4] Council of Europe Convention on Cybercrime, signed in Budapest on 23 November 2001. (BOE, no. 226, of 17 September 2010).

[5] Council of Europe Convention on the Protection of Children against Sexual Exploitation and Sexual Abuse, signed in Lanzarote on 25 October 2007. (BOE, no. 274, of 12 November 2010).

[6] Organic Law 11/1999, of 30 April, amending Title VIII of Book II of the Criminal Code. (Official State Gazette (BOE), No. 104 of 1 May 1999).

[7] Organic Law 1/2015, of 30 March, which amends Organic Law 10/1995, of 23 November, on the Criminal Code (BOE, no. 77, of 31 March 2015).

[8] Proposal for a Council Framework Decision 2001/0025 (CNS) of 27 February 2001 on combating the sexual exploitation of children and child pornography. Official Journal of the European Union, 62, 327-330.

Nudity of minors will also be considered an offence only if it focuses on the genital areas with lewd intent. Images of minors in neutral contexts, such as on beaches, although they may be used for sexual purposes, would not constitute an offence as they are not classified as child pornography. (Lanning, 2010)would not constitute a criminal offence, as they are not classified as child pornography.

Child pseudopornography refers to pornographic material in which minors or persons with disabilities have not been used directly, but their voice or image has been used in an altered or modified form. This material is currently prosecuted as virtual or technical child pornography, as highlighted in Circular 2/2015[9] of the State Prosecutor's Office.

Technical pornography refers to material that depicts people who appear to be minors in a sexual context, due to their clothing or youthful appearance, even if the minority has not been confirmed. Where there are doubts in this respect, such files should be considered as criminal unless it can be proved that the victim was at least 18 years old at the time of the production of the images.

On the other hand, the concept of "realistic images" has been incorporated, which includes content such as comics or *hentai* or manga-type cartoons, where sexual relations between adults and children are depicted (virtual pornography). However, only images in which it is difficult to distinguish whether they are real or not (such as those produced in three dimensions) shall be considered as criminal offences.

Another significant change in the current Penal Code is the increase in the number of punishable conducts related to child pornography, incorporating: the acquisition of child pornography, knowingly accessing child pornographic material and attending exhibitionist or pornographic performances involving minors. Particularly noteworthy is the incorporation of deliberate access to child pornography, which punishes the simple viewing of such material, through *streaming* or direct reproduction of the video, as well as access without downloading photographs on websites. This conduct falls under the same article that criminalises acquisition and possession, with the same criminal response applying to all three conducts.

2.3. CLASSIFICATION OF CHILD SEXUAL EXPLOITATION IMAGES (CIESI)

In Spain, Guardia Civil has carried out a study in collaboration with the Institute of Forensic and Security Sciences of the Autonomous University of Madrid, which was based on previously established international scales.

In order to carry out this classification, a sample of photographs and videos obtained in police investigations between 2008 and 2013 related to child pornography was examined. This classification was later validated by an agreement between judges specialised in the field.

[9] Circular 2/2015, of 19 June, on child pornography offences following the reform introduced by Organic Law 1/2015. (FIS-C-2015-00002).

It should be noted that the proposed national classification is based on the SAP Scale[10], a classification tool proposed in 2002 by the Sentencing Advisory Committee of England and Wales to the Court of Appeal, to assist judges in determining sentences for child pornography offences. (Quayle, 2008).

The levels are detailed in the table below:

Table 1

Classification by levels of child pornography in Spain.

Nivel 0: otro material relevante
Imágenes que no se engloban dentro de la categoría de pornografía infantil: imágenes no eróticas y no sexualizadas de niños total o parcialmente vestidos o desnudos, provenientes de fuentes comerciales, álbumes familiares o fuentes legítimas, así como imágenes que no se pueden incluir en ninguno de los niveles superiores.
Nivel 1: desnudos o poses eróticas
Imágenes de niños total o parcialmente vestidos o desnudos, en poses provocativas o sexualizadas, o que hagan hincapié en las zonas genitales.
Nivel 2: Actividad sexual entre niños
Imágenes de actividad sexual[21] realizada entre niños o masturbación propia.
Nivel 3: Actividad sexual entre niños y adultos excluyendo la penetración de adulto a niño
Imágenes de actividad sexual con la participación de un adulto[22]. Se incluye la penetración producida de niño a adulto pero se excluye la penetración (de cualquier tipo) de adulto a niño.
Nivel 4: Actividad sexual con penetración de adulto a niño
Imágenes de actividad sexual entre niños y adultos que incluyan penetración de adulto a niño.
Nivel 5: Actividad sexual sádica y bestialismo
Imágenes de actividades sexuales que aumenten el dolor físico o humillación de manera innecesaria, así como actividad sexual entre niños y animales.

Note: Taken from Pascual et al. (2017).

As shown in the table, the classification comprises six levels, with level 0 representing the lowest severity and level 5 representing the highest severity.

A major difference with respect to the SAP Scale is the distinction made at level 3 with respect to child to adult penetration and adult to child penetration, excluding the latter behaviour. Despite the debate that ensued, it was concluded that there were considerable differences in severity depending on who was the active subject, as the position of authority and superiority exercised by an adult is less if he or she is the passive subject.

Another remarkable aspect with respect to other classification scales is the incorporation of a level 0, which is not included in other classifications because it represents the absence of severity or risk. However, it was suggested that it should be added to cover images that do not fit the concept of child pornography, but which could

[10] Sentencing Advisory Panel.

be archived for other purposes, such as photographs of naked children that do not focus on the genitalia. (Pascual et al., 2017).

Another important feature is that, as mentioned above, the classification was carried out on the basis of a sample of photographs and videos. Although we began by classifying only images, it was found that no adaptation was necessary for the incorporation of videos, so the classification includes both contents.

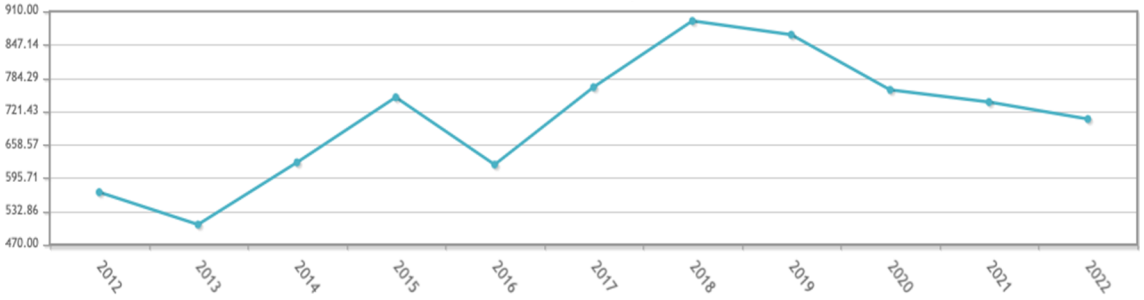
2.4. INCIDENCE OF CHILD PORNOGRAPHYL IN SPAIN

Broadly speaking, the main countries where child pornography is produced coincide with the countries of origin of trafficking in human beings: Eastern Europe, South East Asia, Central and South America. (Pérez Ramírez et al., 2017).

However, domestic production of this material, i.e. by individuals who are not part of organised crime, can occur in any country in the world, including Spain. These individuals often have access to victims because they are part of their environment. (Pérez Ramírez et al., 2017).

According to information compiled by the Crime Statistics System (SEC), an irregular pattern has been observed in the incidence of child pornography offences collected by the State Security Forces and Corps in recent years. Below is a graph showing the number of cases per year of this crime between 2012 and 2022.

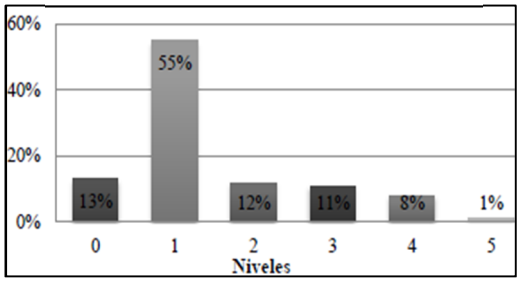
Figure 1.
Evolution of child pornography in Spain.



On the other hand, it is also important to know the incidence taking into account the nature and content of the photographs and videos seized. For this purpose, the severity levels set out in the CIESI, explained above, will be used.

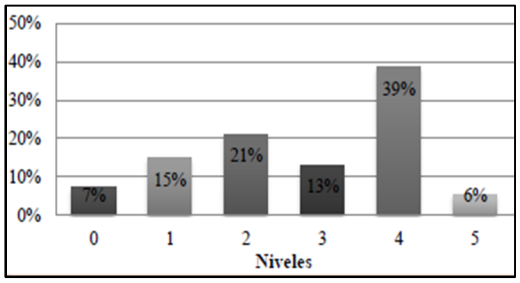
The following two graphs represent the distribution of the sample of photographs (figure 2) and the distribution of the videos (figure 3). Both samples are the same as those used to create the classification.

Figure 2.
Distribution of images.



Note: Taken from Pascual et al. (2017).

Figure 3.
Distribution of the videos.



Note: Taken from Pascual et al. (2017).

As shown in the graph on the left, most photographic content downloaded by users falls within level 1, which comprises nudity and erotic poses (55%). It is significant to note that 80% of the photographs are classified at less severe levels (0 to 2). In contrast, Figure 3 shows the distribution of the video sample across the different levels. In this case, most videos are classified in the most severe levels, with the highest percentage (39%) in level 4.

This difference between photographs and videos can be interpreted by considering the inherent characteristics of both formats. While the video offers a visual dynamic that allows for classification at various levels of severity, the photographs capture static instants and individual sexual behaviours.

On the other hand, in this case, the age of the victim being the statistical factor, the most common category (61%) is that of pre-pubescent minors, i.e. those between 2 and 10 years of age. It is worth noting that this figure coincides with the data provided by INTERPOL's International Child Sexual Exploitation Video and Image Database (ICSE[11])[12], which shows that 60% of unidentified victims were pre-pubescent.

In relation to age, there is a clear preference for the female sex, accounting for 77.3%. Again, this agrees with the ICSE database, which shows 64.8% of girls among unidentified victims.

3. BIOMETRY

3.1. CONCEPT OF BIOMETRICS

The term "biometrics" is derived from the Greek roots bios (life) and metron (to measure), suggesting that this discipline is dedicated to the measurement and identification of characteristics inherent to each individual (Escajeado, 2015). Humans possess unique morphological characteristics that distinguish them from one another. These identifying

[11] International Child Sexual Exploitation.
[12] International Criminal Police Organisation.

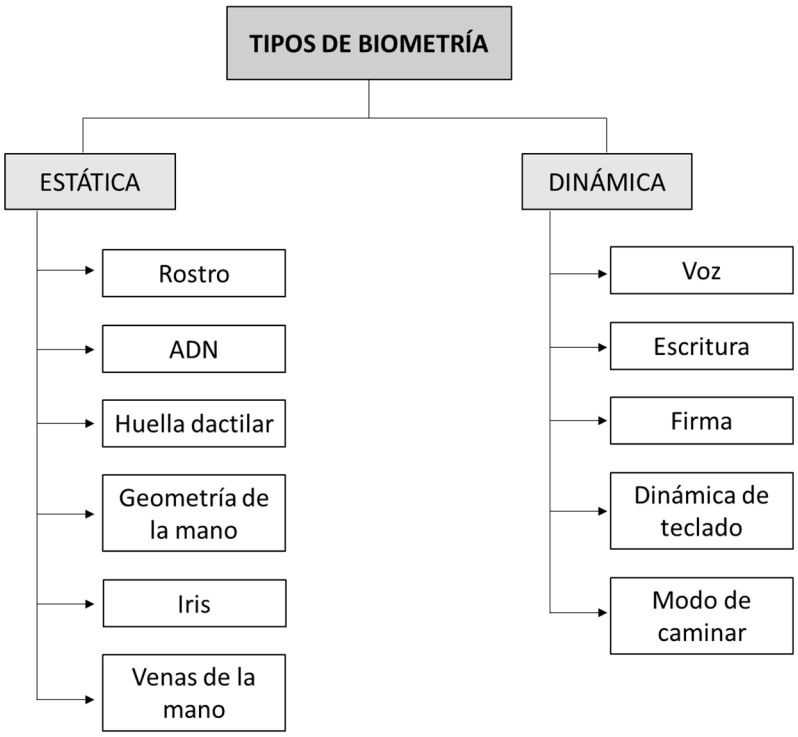
characteristics, known as biometric features, include, among others, face, hand and finger geometry, the voice, the iris of the eye, and perhaps most famously, the fingerprint.

Biometrics encompasses physiological, biological and behavioural characteristics that can be used to authenticate a person's identity. It is establishing itself as an essential component for the accurate identification of individuals. This growth is because biometric features are intrinsically unique, cannot be shared or misplaced, and encapsulate the distinctive body shapes that characterise each individual.

3.2. BIOMETRIC CLASSIFICATION AND TECHNIQUES

There are different ways to classify biometrics according to the chosen distinguishing feature. This paper presents a method of biometric classification according to selected biometric characteristics. Biometrics can thus be classified into two distinct models: dynamic biometrics and static biometrics. The following outlines the most common techniques used in each type. (Zorita, 2003).

Figure 4.
Classification of biometrics according to chosen biometric traits



Dynamic biometrics, also called behavioural or behavioural biometrics. As the name itself indicates, it consists of the study of people's behaviour, acquired over time.

Static, physical or physiological biometrics, on the other hand, is based on the study of physical features of the individual's body, which have an inherent genetic basis and remain relatively constant throughout life. Therefore, two key elements distinguish

this model from dynamic biometrics: temporality and reference to body structure (Escajeado, 2015). It is worth noting that the knuckles fall within this group.

3.3. REQUIREMENTS FOR BIOMETRIC TRAITS

As mentioned above, biometric traits are unique and distinctive physical or behavioural characteristics that can be used to identify or verify the individual's identity.

Understandably, not all physical characteristics of individuals are viable for use in biometric recognition systems. A biometric must have certain qualities in order to form a basis for a biometric recognition system; otherwise, the ability of the system to provide an optimal level of efficiency and security would be compromised.

Several authors have postulated various theories with the purpose of establishing the essential requirements for physical and behavioural characteristics to be used as identifiers in a biometric recognition system. According to Anil K. Jain et al. (2008), the properties that the biometric parameters must meet are:

- Universality: Every human being has or exhibits the characteristic.
- Singularity or uniqueness: the trait must uniquely distinguish each individual.
- Permanence: the characteristic must be maintained over time and under different environmental conditions.
- Immutability: the trait remains unchanged over time.
- Measurability: the characteristic has to be quantitatively measurable.
- Performance: the trait enables the recognition of an individual quickly, robustly and accurately.
- Acceptability: refers to the quality of being accepted by the majority of the population.
- Invulnerability: guarantees the system's resistance to fraudulent access methods.

Maltoni et al. (2005) include a comparative table of the most commonly used biometric techniques according to the degree of compliance with the above requirements, which is presented below.

Table 2:
Comparison of the properties of different biometric traits.

	DNA	Fingerprint	Hand geometry	Veins	Signature	Voice
Universality	HIGH	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM
Uniqueness	HIGH	MEDIUM	MEDIUM	MEDIUM	LOW	LOW
Permanence	HIGH	HIGH	MEDIUM	MEDIUM	LOW	LOW
Measurability	LOW	MEDIUM	HIGH	MEDIUM	HIGH	MEDIUM
Performance	HIGH	HIGH	MEDIUM	MEDIUM	LOW	LOW
Acceptability	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH
Invulnerability	LOW	MEDIUM	MEDIUM	LOW	HIGH	HIGH

4. THE FKP TECHNIQUE FOR CHILD PORNOGRAPHY OFFENCES

4.1. KNUCKLES AS BIOMETRIC FEATURES

According to the Real Academia Española (n.d.), the knuckles are the "outer part of any of the joints of the fingers, where the bones of which they are composed are joined".

The anatomy of the toes gives them the ability to bend forward and resist backward movement. This asymmetric peculiarity results in the formation of creases and wrinkles in the palm of the hand, which are unique to each person. This makes this region an area of interest for biometrics specialists.

4.1.1. Requirements for biometric features on knuckles

As previously explained, any physical and behavioural characteristic must fulfil certain qualities to be viable as a biometric trait. In this section, the extent to which knuckles qualify as biometric traits will be examined.

Knuckle print refers to the inherent skin patterns that form at the joints on the back surface of the fingers. (Pawar, Ballal, Padale, Sawant y Garje, 2015). Therefore, every individual who has fingers will also have knuckles, which proves its universality.

It has recently been observed that knuckle prints have a wide range of textures and can be used in a unique way to identify a person. This uniqueness is determined by the specific characteristics of the local ridges and their respective relationships. According to Deogaonkar, Kahar, Parab, Rajpure and Bhosle (2016), the characteristic points consist of two local ridges that are classified as: ridge end, the point where a ridge ends abruptly; and ridge bifurcation, the point where a ridge splits or diverges into a branch.

This technique, called FKP, is based on the analysis of these local ridges and their characteristic points. It is a morphological comparison in which the observable features, their general characteristics and their individualising particularities are listed, highlighting both their concordances and their discrepancies.

While it is true that this comparison is made on previously identified minutiae, there is currently no predetermined number of characteristic points to ensure the reliability of the process. This situation relates to one of the requirements that may be most deficient: measurability.

Another requirement where the degree of compliance is also lower is acceptability. FKP is a relatively new technique and is still under development, which makes it an unfamiliar method to society. However, it has been implemented as evidence in court proceedings in some countries such as the UK and Spain, as will be shown below. Therefore, if it is ultimately a technique that continues to develop, it is only a matter of time before its acceptability in society increases.

The performance of the FKP is based on an expert's ability to properly differentiate the characteristic points by analysing clues such as ridge orientation, ridge continuity, ridge trend and so on. A priori, an expert is able to discern these characteristics without any problems and check them against an unambiguous image. However, this capability is conditional on optimal image quality and the ridge structure not being completely deteriorated.

In relation to this deterioration and, therefore, the permanence of this biometric feature, unlike fingerprints, the knuckle surface is less likely to leave impressions on different materials or to erode over time. This quality is due to the fact that people hold objects with the inside of their palms rather than the back of their hands, thus reducing the likelihood of information loss. (Márquez, Ruiz, Orozco y Márquez González, 2022).

The uniqueness of the texture pattern produced by bending the knuckles, which has been discussed above, translates into the presence of numerous unique characteristics that are highly inimitable. This characteristic reinforces its resistance to attempts at impersonation or fraud (invulnerability).

Finally, in relation to immutability, when the idea of the possible biometric use of knuckles arose, initial studies were carried out and supported by the University of Dundee in Scotland. (Black, MacDonald-Mcmillan y Mallett, 2014). The main objectives of these investigations were to verify both the uniqueness and the immutability of the knuckles. The results showed the stability of this biometric trait over time by comparing the same person's knuckles at different periods.

4.1.2. Advantages and disadvantages of the FKP technique

Knuckle patterns appear to be a promising avenue for future advances in the field of biometrics. This is based on the fact that FKP has certain advantages over other methods.

Among these advantages is the richness in textural characteristics, which gives them a high discriminative power. In addition, the ease of accessing the feature and

capturing images without the need for physical contact is highlighted (Badrinath, Nigam y Gupta, 2011).

On the other hand, knuckles are a static biometric trait, so they are not influenced by emotions or other behavioural factors, unlike dynamic biometrics.

However, despite the advantages of FKP, there is scant published work on the subject, which means that the field of study is largely uncharted, which could affect aspects such as reliability and automation.

The lack of research in this area also means that there is still no classification of ridge shapes or patterns, unlike, for example, fingerprints, which could facilitate comparative analysis and improve performance.

In addition, identification procedures using the morphological matching method involve the selection of the most suitable doubtful images for analysis, which is quite time-consuming. This process is mainly based on sharpness criteria, which contribute to a better definition of features and characteristic points. Other factors such as position, orientation and dimensions also play a role, as these factors need to be as similar as possible in the two images to be compared.

The quality of the images is also decisive in automated biometric systems as the result of the characteristic point extraction from the input images depends on it. Low quality may generate numerous false characteristic points, the omission of a significant amount of genuine features or the introduction of significant errors in their location, both in terms of position and orientation. (Deogaonkar et al., 2016).

4.2. THE USE OF THE FKP TECHNIQUE IN CHILD PORNOGRAPHY OFFENCES

4.2.1. International context

The application of biometrics extends to the identification of individuals in a variety of contexts, including law enforcement. It has become clear that hands are a perfect biometric feature as they contain many unique traits, such as vein patterns and knuckle patterns, which have been used to combat child sexual abuse and child pornography offences.

Professor Sue Black, from the Department of Anatomy and Forensic Anthropology at the University of Dundee, has led the implementation of hand-based biometric identification in this context, working with a number of law enforcement agencies to identify child sex offenders using this method.

Black, while working on child sexual abuse cases, noted the scarcity of experts capable of analysing biometric features of the hand. The initiative then arose to establish a global database of hand-specific characteristics and a programme that could analyse and compare them.

Thus, in 2019, the H-unique project was born at Lancaster University, funded by the Directorate General of the European Commission, which represents the first effort at multimodal automatic interrogation of the visible anatomy of the hand, by analysing and

interpreting human variability in images. (Black et al., 2019). This project, which is interdisciplinary in nature, is supported by anatomists, anthropologists, geneticists, bioinformaticians, image analysis experts and computer scientists.

The fundamental purpose of the research is to explore the inherent and acquired variability of the hand in the search for unique characteristics. The project is still under development and is expected to be completed in December 2024.

Some cases in which this type of biometrics has been applied are presented below. It should be noted that the cases to be addressed took place in the UK. However, this method has also been used in other countries, including Spain.

4.2.1.1 First conviction of a paedophile using FKP technique

In 2009, Dean Lewis Hardy was sentenced to six years in prison after pleading guilty to sexually abusing young girls in 2004.

On a trip to Thailand and Cambodia, Hardy took photographs of four girls between the ages of eight and ten, which included snapshots of a hand in contact with two of the girls being sexually abused.

The photographs were found in 2007 during a police search of his home, based on previous information. A total of 63 photographs were found stored on memory cards belonging to two cameras and on the computer's hard drive. (Press Association, 2009).

Sue Black and her team determined that the distinctive freckles and finger crease lines seen in the abuse images were identical to those on Hardy's left hand.

In addition to the 63 photographs pertaining to his trip, Hardy was found to be in possession of five images downloaded from the Internet, which were also of an inappropriate nature. (Orpington: Paedophile identified by freckles jailed for six years, 2009).

Hardy was finally convicted at Southwark Crown Court in central London after pleading guilty to two counts of indecent assault on a girl under the age of 13, as well as four counts relating to taking indecent photographs of minors, plus one count of possessing indecent photographic material (Dean Hardy, 2012).

4.2.1.2 Other cases with high social impact

Another case in which Sue Black played a crucial role was the dismantling of the largest child exploitation ring identified in Scotland to date. A total of eight individuals were charged with committing sexual assault and abuse of children and distributing at least 125,000 illicit images related to the abuse. (Eight members of paedophile ring found guilty, 2009).

Neil Strachan was the individual who triggered Operation Algebra, in which the network was dismantled when indecent images were discovered on computers he used in his work environment. For several months, he exchanged messages with other members of the network about sexual fantasies involving children.

Strachan was caught in an image attempting to rape an 18-month-old child he was babysitting on New Year's Eve 2005. This image, known as the "Hogmanay image", proved to be crucial in the investigation. The only parts of Strachan's body visible in the image were his penis and his left hand. It was this photograph that Sue Black analysed in detail. Thanks to a mistake by Strachan's legal team, an image was made available that, according to Black, "gave him a clear view of the defendant's thumbs".

Black compared the left thumb in the photograph with Hogmanay's image and found matching details, including an unusually shaped lunula at the base of the nail. (Guay, 2017). In October 2009, Strachan was sentenced to life imprisonment with a minimum of 16 years, which was reduced to nine years on appeal.

Another case with great social repercussions was the case of Jeremy Oketch. This impact was reflected in the production of a documentary by the BBC entitled "The hands that convicted a paedophile" (2018), detailing the capture of this criminal, specifically his identification from his hands.

The incident occurred on 19 July 2014, when a woman contacted police in Greater Manchester, England, to report that she had discovered indecent images of a two-year-old girl on her partner's computer.

Although Oketch was suspected, his face was hidden in the images and there was no solid evidence to secure a conviction. (Langran y Stewart, 2018).

In this context, Professor Black took images of the offender's hands in the video and compared them with photographs of the suspect's hands to look for common features, analysing knuckles, vein patterns, areas of pigmentation, etc.[13].

He could see that there were common features in both images. In conclusion, assailant and suspect were the same person: Jeremy Oketch. On 12 March 2015, Oketch was sentenced to 15 years in prison for the rape of the girl.

4.2.2. National context

At the national level, Guardia Civil has been a pioneer in the implementation of this technique, being the only police force to have adopted its use. The institution has carried out its own study to verify the feasibility of using knuckles as a valid biometric trait for the identification of individuals.

The research, which is not published as it was conducted internally at the institution, consisted of a study involving photographs of the right and left hands and thumbs of a total of 250 people. The purpose of this study is to demonstrate conclusively that it is possible to identify a person by the creases in their hands, in the same way as fingerprints, as each individual has unique creases.

[13] Et cetera.

The two main aspects to be demonstrated were intravariability, which implies that no two folds of the same person's ten fingers are the same, and intervariability, which indicates that the folds of one person are different from those of any other person.

As it is crucial to verify the constancy and invariance of these characteristics over time, since its inception in 2016, photographs have been taken of the same people on up to two additional occasions: in 2017 and 2022[14]. It has been corroborated that there has been no change in these characteristics. Even among univiteline twins, who share identical genetic information, this fold distinction has been found to remain constant.

4.2.2.1. Protocol for collecting undisputed samples from perpetrators of sexual offences.

In 2018, the Identification Department of the Criminalistics Service of Guardia Civil considered it prudent to establish a protocol for the taking of indubitable samples from perpetrators of such crimes, particularly those from whom photographic or video material related to the abuse has been confiscated.

The protocol establishes that in addition to carrying out the lophoscopic examination, three photographs of the back of the hands will be taken, preferably by the personnel of the Criminalistics Laboratories of the Judicial Police Organic Units. These images will include:

- A detailed photograph of the back of the right hand.
- A detailed photograph of the back of the left hand.
- A detailed photograph of the back of the left and right thumb.

Subsequently, the photographs will be renamed to include the SIGO file number[15] to ensure that they are linked to the relevant case.

It should be noted that, in addition to the photographs established by the protocol, it is important to capture images of the hand in an identical arrangement to that depicted in the dubbed image, thus allowing for an effective comparison between two visually similar representations. Since the person taking them will not always know exactly which dubbed sample to imitate, it is advisable to take multiple photographs from different angles.

4.2.2.2. Analysis of existing cases

In Spain, perhaps due to the novelty of the technique and the lack of knowledge of its application in research, only five cases have used knuckle identification thus far.

The first case took place in Malaga in 2016, when a mother discovered seven colour-printed photographs in her ex-partner's office while she was cleaning her home. In them, female genitalia could be seen, and around them some hands, presumably of the aggressor, in his home as she recognised some of the items that appeared in the photograph. The sexual organs depicted belonged to the woman's daughter when the child

[14] Data provided by the Identification Department of the Criminalistics Service.

[15] Integrated Operational Management System.

was 11 years old. Although the mother claimed that the hands were those of her ex-partner, only the backs of the hands were shown, which prevented direct confirmation of the identity of the individual. This incident marked the first occasion on which the Criminalistics Service was confronted with the task of identifying a person from their knuckles. The suspect was already in prison custody for another offence, which made it easier to obtain photographs of his hands. This identification process contributed significantly to the sentence issued in May of the following year, which condemned the perpetrator to ten years in prison. (Echagüe, 2018).

Since then, other such requests have been received, although not all of them could be implemented. An illustrative case also occurred in 2016, when a judge in Madrid showed interest in using this procedure to investigate an incident involving a camp monitor who photographed the private parts of the children in his care, including his hands in the images. However, the detainee refused to allow his hands to be photographed, a common obstacle in such cases. However, one of the photographs was able to identify the individual from his fingerprint, which facilitated his identification.

Perhaps the most prominent case in the media in which the FKP technique has been applied was that of the former religion teacher Pedro Antonio R.L., who committed sexual abuse against 14 minors and four adults between 2013 and 2016 at the La Salle Nuestra Señora Maravillas school in Madrid. (Durán, 2018).

In some photographs related to this case, the defendant's hands were seen performing the abuse. Although the judge authorised Guardia Civil officers to photograph the individual's hands in order to carry out the knuckle comparison, he refused to cooperate. However, Guardia Civil, having 78 photographs to carry out the tests, was able to identify him thanks to an image in which the left index finger and the back of the thumb were clearly visible, which were used as reference points. The characteristics of the papillary ridges of the index finger unequivocally matched the defendant's fingerprint. Moreover, the knuckle creases present in that photograph were identical to those observed in eight other snapshots showing the back of the religion teacher’s hand. (Ortega, 2019). The trial took place in 2018, and the former religion teacher accepted a plea deal that resulted in a 130-year prison sentence.

4.2.2.3. Knuckle analysis procedure: the expert report

Within the field of forensic science, the preparation of a forensic cross-checking report can play a decisive role in the identification of the alleged perpetrators of a criminal act, especially in situations where the only evidence available is an image.

As previously mentioned, the FKP technique is not standardised and lacks a universally recognised method. Spain is no exception.

Guardia Civil has opted for a procedure that combines fingerprint and morphological matching. This method is carried out manually, which implies a direct matching without using an automated biometric system.

The morphological comparison consists of the analysis of the dubious image, after having undergone quality improvement processes to define the characteristic points, which are compared with an indisputable image obtained from photographs captured

following an established protocol, evaluating the degree of coincidence between the two samples.

This type of matching is combined with fingerprint matching. This is based on the fact that the marks and lines drawn by the expert to mark the identifying points are analogous to those used in fingerprint comparison, indicating that they are based on that method.

If one compares the expert report made on a knuckle comparison with the more widespread fingerprint report, one can see that the former does not make as strong a conclusion as the latter, but requires further explanation. This is because the knuckle matching process is not quantifiable and therefore requires more detailed justification.

Both reports address aspects such as morphology, location, arrangement and directionality of the biometric features in question. However, the fingerprint report refers to the presence of "at least twelve identifying points", a detail absent in the knuckle report.

This aspect is at the root of the inherent disadvantages of knuckle-based expertise. Since quantitative analysis cannot be applied, it is based on identifying similarities and assessing whether discrepancies are explainable. Therefore, the conclusion does not issue a direct affirmation or denial as to whether or not the challenged sample belongs to the suspect, but merely determines its compatibility.

5. CONCLUSIONS

As a starting point for this work, the complexity and seriousness of the crime of child pornography was raised in the previous phase of the work. One of the main priorities of police forces globally is the identification of the person who appears in this type of content in addition to the victim, i.e. the person who commits the sexual abuse against the child.

From this premise, the basic hypothesis of the present work was posed, with the question of whether "The identification of paedophiles is possible thanks to an image of their knuckles".

In order to fulfil the final objective of the work, it was necessary to assess whether the knuckles met the established criteria to be considered a biometric trait. It has been concluded that they can indeed be classified as such, as they meet the established requirements, with acceptability and especially measurability being the criteria with the lowest degree of adequacy.

Throughout the research, some limiting factors have emerged that are vitally important to consider when conducting police expertise based on the FKP technique.

Firstly, it has become clear that the use of knuckles as biometric traits is very recent and there is a lack of studies on them. This results in a lack of consensus on the procedure to be used for matching, as well as the absence of a classification on shapes or patterns and of a database, although this is under development.

Another limit in the use of this technique is the quality of the images, as this is crucial for an effective comparison and to clearly observe the characteristic points

necessary to identify a person. Despite technological advances that have improved the quality of the images, it is still a conditioning factor for an optimal comparison.

It is also noteworthy that although some studies have been carried out on the automation of the technique, there is no database or consensus on the best system, and none is currently in use in the police field. In return, a direct, morphological comparison is carried out, but each expert does it in his own way, as there is no reference. This leads to more time and the need for an unambiguous image that is as similar as possible in position, orientation and dimensions for an effective comparison.

However, despite all these limitations, the use of knuckles to identify paedophiles is a fact of life. In this context, the expert report that is produced is important, as it is the report that will be presented in court and that confirms or refutes the identification of the person. Within this framework, another limit mentioned above, measurability, plays a role. In this type of report, accuracy is critical and a quantifiable limit is required to state with certainty the identity of a person, i.e. a numerical limit of identifying points, something that cannot currently be done with knuckles. Therefore, even if some identity has been confirmed, the report's conclusion needs further justification, which may influence the judge's assessment and turn this evidence into circumstantial evidence, i.e. it reinforces other existing evidence.

Finally, after the research carried out during the process of this work, the following conclusion is reached:

Despite the challenges that remain to be overcome, studies so far suggest that knuckles are stable and permanent over time, supporting their potential as a reliable biometric trait. As such, they represent a promising avenue for future advances in biometrics and a tool that can be used to strengthen other clues in cases where there is no choice but to identify a person by the back of their hand, as is the case in many child pornography cases.

Therefore, it is clear that the hypothesis put forward at the beginning of the paper is fulfilled, since a paedophile can be identified through his knuckles.

5.1. PROPOSALS FOR IMPROVEMENT AND FUTURE WORK

In accordance with the results obtained in this research, certain reflections have emerged that merit consideration for further work to continue the study that has been carried out, as well as proposals for improvement in the field of study and police treatment of this matter.

First of all, it is suggested that a programme capable of recognising characteristic points and containing an international database be implemented to make the relevant comparisons. This initiative is currently under development and is tentatively scheduled for completion by December 2024. Once completed, it would be interesting to implement it in Spain.

On the other hand, further studies related to knuckle creases are needed. Although some work has been carried out in other countries, Spain should do its own. In this regard, some research should be done to identify and classify the different shapes of knuckle

ridges, and even incorporate some statistics to assess the frequency of occurrence of these patterns. It would also be of great relevance to carry out a jurisprudential analysis as judgements are issued, in order to examine the value given by judges and the details that pose the greatest problems.

At the police level, it would be advisable to establish an agreed procedure for morphological matching. In this way, if, in the end, it is not feasible to implement an automated system or, once implemented, for whatever reason, it is not feasible to carry out the comparison, the expert would have a reference to follow.

Finally, in order to take a photograph of the hand, judicial authorisation or the consent of the alleged perpetrator is required, which, if the perpetrator is guilty, is usually refused. This is important because, as mentioned above, the two images to be compared must be similar. Often, the knuckle in the dubious image is in a position or orientation that has not been picked up by the protocol photos and, therefore, cannot be matched. It is proposed to extend the range of photographs to be taken in the protocol and to include a high-resolution 360° recording so that when the time comes, the screenshot can be taken from the angle that suits you best.

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