Solving the Problem of Forensic Identification of a Person's Appearance Based on Video Materials: An Integrated Approach

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Abstract

[Purpose] The purpose of this study is a comprehensive investigation of modern techniques and developments for recording and analyzing data about the criminal.

[Methodology/Approach/Design] Theoretical and empirical methods, such as statistical analysis, synthesis, induction and deduction, were used for the study. The practical scope of this article includes research by Chinese, Ukrainian, Russian and English researchers in this field. Scientists studied the theoretical and practical scientific literature on the topic, as well as the achievements of modern science in the field of improving video surveillance systems, in order to analyze.

[Findings] It was found that in the context of digitalization, law enforcement agencies can gain access to personal biometric data of citizens, which, on the one hand, simplifies the search for an alleged criminal, and on the other hand, intrudes into the privacy of citizens,

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thereby violating the law. However, modern security systems and artificial intelligence built into surveillance cameras undoubtedly help solve crimes.
[Practical Implications] The applied value of this study lies in the identification of current issues of both Ukrainian criminal legislation and legislation related to the protection of personal data and their use by law enforcement agencies of such states as the People's Republic of China, the United States of America, the United Kingdom, the Russian Federation.

Keywords: Personal Identification. Video Surveillance System. Forensic Portrait Examination. Forensic Examination. Appearance Features.

INTRODUCTION

In the scientific literature, the issues of forensic identification of a person's appearance from video materials is an urgent and debatable issue. This subject touches on several issues at once, namely the preservation of personal data, including biometric data, the legality of obtaining evidence, modern means and methods of identifying a person's appearance, damage or intentional modification of video material, the choice of the most successful examination. All these questions come before investigators, forensic scientists, and experts in the investigation of crimes. Therefore, it is important to know how modern CCTV cameras work, and what methods are used for identification. The analytical work carried out in this study comes down to the following theses.

Today, Ukraine uses a video surveillance system comprising 4 thousand cameras (gordonua.com, 2022). Video recording within the framework of various programs also functions in such countries as the United Kingdom, USA, China. All these video recording systems are aimed at the safe presence of citizens in public areas: airport, metro, parks, hospitals, shopping centers, and more. The footage in this case is direct evidence of the presence or absence of a crime.

Due to the complete consolidation of the mechanism of committing an offense, there are no special difficulties in constructing versions. However, the procedure for identifying the perpetrator of this incident rarely yields positive results and requires additional efforts (PODVOLOTSKY, 2015). The conventional approach to a video frame, as an analog of a photographic image, which lies in the examination of the elements of appearance from two-dimensional photographs, is ineffective due to inferior quality. It is impossible to differentiate the signs of the facial part of a person's head on a videogram (BULGAKOV, 2014). Furthermore, criminals can use techniques of intentionally masking their faces with clothing items and intentionally tilting their heads (PODVOLOTSKY, 2015; CHERNIAVSKYI et al., 2019). In such cases, it is difficult for an expert to use conventional comparative methods of portrait

examination since all kinds of negative factors have a substantial impact on the display of appearance features (KHARITONOV, 2013). Today, forensic science has advanced further and uses a complex forensic examination.

The practice of assigning examinations of video recordings is replete with examples of assigning studies called "complex", combining questions from the field of portrait and video technical examinations (ZININ, 2003). As for the improvement of video surveillance systems, it is impossible not to mention the following innovations. For example, in the United States, a computer software is actively used that can take biometric data of a person, which allows identifying the criminal with a higher probability.

The most advanced device embedded in the CCTV camera system is a total station, which allows analyzing the appearance features of a person remotely and comparing them with the data archive. The results of comparing the sizes, shapes, absolute and relative magnitudes of objects (or elements of appearance) located at the scene of the incident will first determine the degree of suitability of the video presented from the scene for identification, and then identify the appearance of a person from the presented videos (BULGAKOV, 2014; KORZHYK et al., 2017b). Chinese video surveillance systems are also aimed at perceiving, to a greater extent, the dynamic properties of a person: their gestures, movements, gait (LIU and WU, 2021).

The relevance of this study is conditioned upon the fact that modern forensic science is currently discussing the use of personal data that citizens voluntarily give to computer programs, as well as the video recording system. To regulate and clarify objective opinions, it is necessary to address the means and methods of forensic science in the investigation of the appearance of persons suspected of committing a crime. The originality of this study lies in the comprehensive investigation of the approaches of various authors to this issue. The subject under study is considered from the standpoint of Russian, Ukrainian, English, and Chinese authors of modern science. The main elements of scientific originality lie in an in-depth study of statistical data, modern approaches and legislative methods of regulation.

MATERIALS AND METHODS

The main methodological tool of this study was an integrated approach to the phenomena identified in the subject under study. The main general scientific methods of cognition in the analysis of information were empirical and theoretical methods. The fundamental method of research is to highlight the systematic and statistical analysis, thanks to which the statistical data of the Prosecutor's Office of Ukraine, theoretical works of Ukrainian, Russian, Chinese, and American researchers, as well as the criminal procedure legislation of Ukraine were

considered. The theoretical framework of this study included the articles and papers of the following authors: E. G. Barkovskaya (2009), I. N. Podvolotsky (2015), V. G. Bulgakov (2014) and others. This study was carried out in several stages.

During the first stage of this study, theoretical methods were used, such as analysis, synthesis, concretization, generalization. The study mainly involved methods of system analysis of data from both Ukrainian and Russian studies. The authors of the present paper applied a comprehensive approach to the study of the material. The logical construction of this article lies in the consideration of means and methods of modern forensic science in identifying appearance features of a person who has potentially committed a crime. On this basis, the thesis is put forward that modern video surveillance systems in some cases have shortcomings in quantitative and qualitative indicators, which leads to incorrect identification of the criminal's identity. An integrated approach suggests the theoretical nature of the study.

The second stage of this study investigates the problematic issues of improving the video surveillance system in more detail. Using the induction method, the mechanisms of operation of CCTV cameras and defects were identified, such as damage to the material, low quality, lack of sound, and more. The theoretical framework of the second stage of the study included the research conducted by A.V. Kharitonov (2013), A.M. Zinin (2003), and others. Thanks to the use of deduction methods in this study, sequences of hypotheses were deduced, as well as an assessment of the test results. Statistical analysis revealed that modern legal science has controversial issues in the use of biometrics and other personal data identified during the study of video materials. Within the framework of this study, the main positions regarding the identification of the criminal's identity by appearance features were established.

At the third stage, as a result of this study, the work of system data analysis was completed, theoretical and practical conclusions were clarified, the results obtained were generalized and systematized during the use of an integrated approach to the study of the subject under consideration. Within the framework of this methodology, this paper considered many studies on the means and methods of investigating crimes and identifying a person suspected of committing a crime by appearance features. This paper critically examines and evaluates the use of complex forensic expert opinion upon considering video materials, as well as the comparison of appearance features by static and dynamic characteristics of a person. The study focuses on the use of new developments in the video recording system. Thus, using the methods of scientific analysis, the development vectors

of forensic science are identified according to modern technologies already operating in Ukraine, Russia, China, the USA, and the UK.

RESULTS

Forensic Methods of Personal Identification by Video Images

According to Article 84 of the Criminal Procedural Code of Ukraine (2012), evidence in a criminal case is various factual data, based on which, according to the procedure established by law, the body of inquiry, the investigator, and the court establish the presence or absence of a socially dangerous act, the guilt of the person who committed this act, and other circumstances relevant to the correct resolution of the case. For any evidence used by a person to be legitimate, it must meet the criteria of relevance and admissibility (HORSMAN, 2021). The person conducting the investigation evaluates the evidence according to their inner conviction, based on a comprehensive, complete, and objective analysis of all the circumstances of receiving the video, as well as its content according to the general rules. In the modern world, video cameras are a way of recording events and in some cases constitute a direct evidence base, recording the presence or absence of a crime, therefore, the analysis of the video image can reveal the qualification of the offence.

The video allows identifying both obvious things such as the time of year, time of day, the scene of the incident, the number of participants and some other data, as well as hidden circumstances: information about the filming conditions, about the technical settings of the filming camera, about the inviolability of the video recording from unauthorised interference, about the correctness of the playback of the recording, about the adequacy of the display of appearance features, about the belonging of the display of the incident participant to a particular person, etc. (PODVOLOTSKY, 2019). However, it is important to understand that the video surveillance system cannot always register personal features and identify a particular person from quantitative and qualitative characteristics. This circumstance is related to the particular qualitative characteristics of the video camera such as:

(1) quantitative indicator: single cameras, cameras placed in inaccessible places, cameras that take an overview from one angle or point;
(2) quality indicator: low-quality resolution, noise on video, video without sound or in black and white image.

These characteristics lead to the fact that an essential part of the human appearance—the facial part and the head cannot be detected, and the criminal may

also intentionally use disguise items such as hooded clothing, a face mask, a certain tilt of the head (BAI et al., 2021). A critical issue for criminal law is the complexity of video recording as evidence base material. The study of video footage is not only a complex procedure, but also a process that affects various areas of research. Thus, the following specialists are involved in personal identification:

(1) technical issues of obtaining video images are handled by experts in the field of video technical expertise;
(2) identification of a person by appearance features—specialists of portrait examinations;
(3) identification of a person by the image of a corpse and its remains—specialists of medical and forensic examinations (PODVOLOTSKY, 2019).

In forensic investigative practice, sometimes there is a problem of identifying a person by photographic images in which a person's face is missing or unsuitable for identification, but there are images of individual body parts – hands, whole hands, bare feet, individual naked body parts (SHEN et al., 2021). In these ambiguous circumstances, a forensic medical examination is prescribed, where an expert can compare the structural features, the condition of the skin, the relative values of the elements of the human body, and in certain cases, if there are a sufficient number of coincident features forming a unique complex, a categorical positive identification conclusion is possible. If there are substantial differences in the structural features of the body parts depicted in the photograph and the structure of the corresponding body parts of the person being verified (identified), it is necessary to formulate a categorical negative conclusion (ROMANKO et al., 2017).

Thus, during the investigation of a crime, the following actions are performed in front of forensic experts and investigators. Firstly, as part of the preliminary study, the received video materials are analysed in parallel with the investigator's decision on the appointment of an expert examination (CRIMINAL PROCEDURAL CODE OF UKRAINE, 2012). Secondly, their external design should correspond to the description in the resolution. Thirdly, the specialist compares the technical parameters indicated on the video information carrier (device type, recording format, time and place of recording, etc.). Finally, the possibility of an expert laboratory in studying the content of the video is determined.

Proceeding from the legal regulation of examining the video recordings as evidence, when identifying appearance features, it is necessary to comply with the

requirements for the description of the appearance not only by a forensic specialist, but also by other subjects involved in establishing (identifying) a person's identity (CRIMINAL PROCEDURAL CODE OF UKRAINE, 2012). The improvement of the video surveillance system is also necessary to increase the detection of crimes. This thesis is confirmed by the statistical data of criminogenic circumstances in Ukraine for 2021. According to the statistical portal that generates the Crime Index, Ukraine as of 2021 ranks 54th in the world (out of 135) in terms of crime (Analytical portal word and case, 2022). The most common crime in Ukraine is theft. According to the article "Theft" in 2013 there were 242.769 offenses, in 2014 – 226.833, in 2015 – 273.756, in 2016 – 312.172, in 2017 – 261.282, in 2018 – 238.492, in 2019 – 197.564, in 2020 – 138.562 (Analytical portal word and case, 2022) (see Fig. 1).

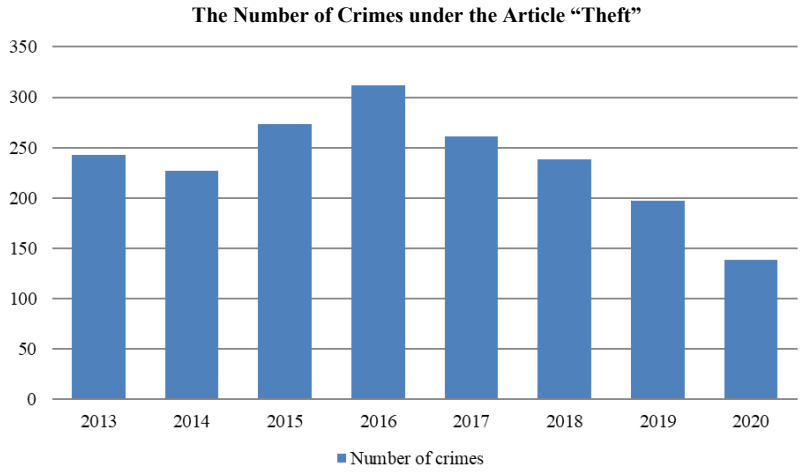

Figure 1 – Crime Analysis from 2013 to 2020

Prospects for Improving the Video Recording System for Identifying Criminals

To solve such issues in forensic science, a promising direction has been identified related to the development of computer software for the process of identifying a person based on video footage, which allows comparing not only static, but also dynamic characteristics of a person (PODVOLOTSKY, 2015; ZAKHAROVA, 2017). Even though portrait identification by dynamic features is still in its infancy, analysis and comparison of the parameters of the amplitude of movements of the head, arms and legs, increasingly often allows establishing the volume of unique dynamic characteristics for each person that is sufficient for solving identification tasks (KHARITONOV, 2013). Some techniques of modern

computer technologies are already actively involved in personal identification, e.g., the use of "3D technologies". To create three-dimensional "3D images", the programmes "Liberty" by Chiron, "Harmony" by Integrated Research, "Matador" by Parallax, "Media Suite Pro" by Avid are used. Software packages "Flint, Flame and Inferno" by Discreet Logic, "Pandemonium" by XAOS, as well as "StereoPhoto Maker", "Axara 2D to 3D Video Converter", "3D Maker" and "Free 3D Video Maker", etc. (PODVOLOTSKY, 2015). These programmes help forensic scientists and experts recreate models in real configurations and volumes, which leads to the most detailed identification of the victim's identity.

The practices of the USA demonstrate positive statistics, where computer software is used to take biometric data of a person and draw parallels and identities between them. This quality of work contributes to a prompt response and allows timely signalling the security panel to take measures to detain the criminal. Another modern way to solve the shortcomings of video surveillance cameras is a total station—a device in the camera that allows remotely analysing the appearance features of a person and compare them with a database (BLOKHIN et al., 2011). This instrument measures distance and angular magnitudes, records the coordinates and placement of individual points, and includes an optoelectronic device that records the time and metric results of laser beam reflection (PODVOLOTSKY, 2015; KORZHYK et al., 2017a).

The results of comparing the sizes, shapes, absolute and relative magnitudes of objects (or elements of appearance) located at the scene of the incident will first determine the degree of suitability of the video presented from the scene for identification, and then identify the appearance of a person from the presented videos (BULGAKOV, 2014). The main advantage of these improvements is the creation of exact three-dimensional models of appearance, which can be identified with models stored in the archives of law enforcement agencies. The new generation of video recording systems is aimed precisely at the dynamic characteristics of a person: their gait, facial expressions, gestures.

Thus, modern video surveillance systems help forensic experts investigate crimes by reconstructing the appearance of persons who arouse suspicion, as well as to identify appearance features with models stored in data records. Substantial improvements of the cameras would be the introduction of special systems for recognising the dynamic parameters of a person's appearance into their operation, as well as the analysis of the structure, thermal, colour and tone complexion features.

DISCUSSION

In historical retrospect, the issues of identifying human appearance were the key in the investigation of crimes. The tasks of diagnosing and identifying a

person by individual parts of the body were solved at the dawn of criminal registration, when the forehead, cheeks, hands were branded, or self-mutilation was carried out by cutting off fingers, pulling out nostrils, etc. After the introduction of anthropometric identification and fingerprinting in the 19th century, the task of establishing identity was being solved using techniques developed in these systems (KRYLOV, 1975; VILKS and BERGMANIS, 2018). Therewith, the methodological framework of such examinations was the basics of trace evidence. The scientific foundations and methods of forensic portrait examination were developed within the framework of the forensic doctrine of the person's appearance features, which is a branch of forensic technology that investigates the patterns of imprinting the appearance features of a person in various representations. The description and use of portraits at the initial stages of personal identification contributed to the solution of identification tasks.

Thus, it became possible to identify a person in the presence of substantial deviations from the norm, traces of surgery, for example, deformity of the fingers, other diseases that individualize the hand (ROMANKO et al., 2017). This approach should also apply to images of other parts of the body, proceeding from the provisions of the theory of forensic identification, the expert should have data that note the features of objects that have an individual nature, which requires the involvement of various branches of medicine, along with anatomy. The terminology of identification of personality and its features has numerous issues in science. For example, in forensic science, the term "personal identification" is interpreted as the identification of a particular person who has an individually unique complex of innate and acquired anatomical, functional, genetic, and mental properties (GETMAN and KARASIUK, 2014). These properties are called personality traits.

Thus, it is possible to identify the identity of a living person (criminal, detainee) and a corpse (dismembered, skeletonized, unknown person) (ROMANKO et al., 2017). When the identification of a person is carried out in the investigation, first of all, one contemplates the image, and the factual object of the investigation is the head of a person, their face as including a set of appearance features that determine the individuality of a person and are used to establish the identity. As N.V. Terziev (1956) noted, such a role of the head and facial features is determined by the fact that this object can be described by more than a hundred features. V.A. Snetkov (1979) believed that the number of the largest features of the face is more than fifty, while he explained that in each large feature, with an in-depth study of it, it is possible to distinguish comprising elements characterized by a certain set of features.

Thus, a person's face can be described by a much larger number of features than 50, going by the degree of detail of these features. However, it is not always

possible to distinguish so many features. The researchers' calculations were performed proceeding from the signaletic photographs that most fully display the personal features to identify them, but even portraits made for identity documents, where the face is presented only full-face, allow for the identification of a person by the appearance features (VON BOTH and SANTOS, 2021). At the same time, there are cases of identification of a person by the image of a part of the face (including the eye, temple, cheek, and ear), the hand and other parts of the human body (in the presence of individualizing signs) (Gusev, 2003). Today, photo portraits and video portraits are exposed to a complex of factors that can change the reliability of the displayed person's appearance features. The key ones are as follows:

(1) factors of technical characteristics of video recording devices;
(2) factors of the video recording process;
(3) factors of the video playback process;
(4) factors of operation of the video recording medium (PODVOLOTSKY, 2019).

A review of the content of groups of factors allows noticing the presence of several key circumstances affecting the completeness and reliability of the appearance on the video (ILYIN, 2018). Among the disadvantages of the classification, attention is drawn to the excessive allocation of "factors of video recording conditions", since they are absorbed by "factors of the video recording process". It appears that the group of "factors of video storage conditions" should be supplemented with information about the parameters of the use of the video recording medium, which can be renamed into an operational factor that combines both the use and storage of the video recording medium. An urgent task of a preliminary study of portrait video recordings obtained using digital technologies of shooting and file processing is to detect signs and establish the fact of intentional interference with the original. In fact, this task is equivalent to determining the fact of changing the original content of an electronic document. Modern digital editing tools allow retouching not only static photo portraits, but also entire films, where fragments recorded in different settings and at separate times are combined (ILYIN, 2018).

To date, operational solutions in the field of identifying a video recording and its signs with a particular person have been achieved in the UK and the USA. One of the most technologically equipped cities is London, where about 420.000 CCTV cameras are installed, as well as in Beijing, where 470.000 cameras are installed, and Washington is in third place in the world with a massive gap – only 30.000 cameras. Some elements of facial recognition technology are used not only

by the police, but also by Transport for London, the public transport operator, to monitor passengers, and British hospitals – for patients (NEWS PORTAL VEDOMOSTI, 2022). This facial recognition system, albeit helping the police timely identify the criminal, still invades the privacy of citizens. At present, there is no legislative framework in the state that could regulate the privacy of citizens while satisfying the economic and legal component (VILKS and KIPANE, (2018).

There is also an issue in the United States concerning the introduction of advanced video surveillance cameras in public places and educational organizations. Schools create databases with photos of people who are forbidden to be on their territory, and if the SN Technologies software integrated into the cameras identifies them, the school administration receives an alert. In addition, the SN Technologies software can identify weapons in the hands of people (NEWS PORTAL VEDOMOSTI, 2022).

Within the framework of the "Safe City" program, over 4 thousand video cameras with a facial recognition system have been installed in Kyiv, which were primarily equipped with cameras at metro stations (GORDONUA.COM, 2022). For example, the practices of Japan demonstrate that it is possible to develop a security system that identifies a person by the pattern of blood vessels on the palm. For this, a camera is used that takes a picture of the user's palm, after which the built-in computer compares this picture with the images stored in the database (MELE et al., 2021). The camera operates in the near-infrared wavelength range, so the images reveal blood vessels located under the skin, the pattern of which is unique to each person, as well as the pattern on the retina and iris of the eye. When identifying a person, a special algorithm is used, which considers the number of blood vessels, their location, and localization of their intersection points (ALEKSANDROV, 2017).

As noted earlier, an innovation in the video recording system is the recognition of dynamic human properties, which include such features as voice, gait, facial expressions, handwriting, gestures, keyboard handwriting, personal signature, as well as behavioral characteristics based on features typical of subconscious movements in the process of reproducing any complex action. It appears very promising to use the biometric parameter "face geometry", where about 12–40 characteristic elements from the full available set are scanned. No less promising is the use of the biometric parameter "face thermogram", which uses cameras that capture infrared radiation and can operate even in complete darkness.

The recorded information signs do not depend on the facial temperature, nor on the plastic surgeries performed on it, nor on the ageing of the subject, and the infrared camera allows receiving a thermogram even at a considerable distance

from the person who is its carrier. Such systems are already used for access control with a high degree of responsibility and reliability. They provide close to 100% recognition accuracy (ALEKSANDROV, 2017). As for the People's Republic of China, researchers have progressed in improving the video surveillance system and have done their studies in this area. In particular, in the 3D module, aligned local appearance images extracted using a dense three-dimensional assessment of a person's appearance are used in combination with global image and video embedding streams to study more detailed identification functions (SHI et al., 2022).

Furthermore, to overcome the influence of modality mismatch, the CMIL module provides a link between global image and video streams, interactively distributing temporal information in the video to the channels of image characteristics maps. Other Chinese scientists are developing a video-based re-identification system that is attracting increasingly more attention from researchers (LIU and WU, 2021). The critical issue for this task, in their opinion, is to learn how to reliably represent the characteristics of the video, which can be weakened by the interference of factors such as occlusion, lighting, background, etc. Many previous works use spatiotemporal information to represent pedestrian video, but correlations between parts of the human body are ignored. To take advantage of the interconnection between various parts, the researchers propose a new neural network of intra-frame and inter-frame graphs (I2GNN) to solve the problem of re-identification of a person based on video.

These facial recognition systems are used at Hong Kong International Airport, where new biometric technologies are used for faster and unhindered interaction with passengers at the airport. For example, a modern system called SmartGate is used in Australia. This is an automatic system that enables the passengers arriving at international airports in Australia to independently complete passport control without the airport staff. It uses biometric passport data and facial recognition technology to perform customs and immigration checks, which are usually performed by border service officers. The increasing use of facial recognition leads to the expansion of facial databases and an increase in the number of tracking cameras (BYLYEVA and LOBATYUK, 2021). However, such a number of cameras using biometrics and other data of citizens can be a potential threat when databases leak, which will generate a new number of crimes (VILKS and KIPĀNE, 2020).

Thus, the main problem for forensic investigation at this stage of the development of surveillance cameras is the inferior quality of recording and images. This problem leads various researchers to solve by using advanced software technologies (SUMARI et al., 2020). This practice demonstrates the advisability of research not only within the framework of using one type of

expertise, but through a comprehensive examination, namely using special knowledge in the field of computer technology, habitoscopy, video technical expertise. In turn, the lack of an integrated approach and methodology leads to inefficient expenditure of not only human resources, but also the time frame that could be used.

CONCLUSIONS

This study is aimed at a full and comprehensive approach to considering the role of video materials in identifying the appearance features of a potential criminal. Based on the data obtained, the following conclusions were made. Firstly, the criminal procedure legislation of Ukraine is based on the principles of international law, which obliges to attribute any evidence to certain compliance parameters, within which they must be observed. In particular, it is necessary to observe the nature of relevance, admissibility, and reliability. Within the framework of the subject under study, video materials involving a citizen should not only specifically name statistical features of their appearance, but also reliably correlate them with dynamic features. Today, the use of video surveillance systems involves such issues as quantitative and qualitative deformations of video material. To solve this problem, many states, such as the United Kingdom, the United States, and China, introduce modern achievements of computer software for better recognition of appearance. Such systems are total station, improved lenses, artificial intelligence system, infrared radiation, biomaterial collection, and quantitative magnification of video cameras.

Secondly, video materials obtained from CCTV cameras need to be analyzed. In these cases, personal identification is performed using forensic methods and invited experts. Thus, to identify the appearance features, the following examinations are performed: forensic, forensic medical, forensic portrait examinations, as well as numerous methods developed by the forensic science. To use the video as an evidence base in court, it is necessary to meet the criterion of legality. In this case, it is necessary to strictly observe the verified sources of information, without coming into contact with the private lives of other citizens. This condition is difficult to meet in the period of digitalization and globalization of society, which makes the scientific discussion on this subject an international issue. An increase in the number of methods and systems for recording a person's appearance, its static and dynamic features, is necessary for the recognition of persons who have committed a crime. Due to the fact that criminals are constantly improving ways of hiding their appearance features, forensic scientists, experts, law enforcement agencies face the task of developing a new diagnosis of the criminal's identity not only by external, but also by biometric and other data. An enormous amount of research is involved in this area,

which allows recognizing gait, movement, sound, if there is such a recording, as well as editing and video recording errors.

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