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Modern technologies for technical follow-up of documents

Viktor S. Sezonov[1*], Olha M. Sezonova[2]

[1]PhD in Law, Associate Professor. ORCID: https://orcid.org/0000-0002-2580-2953.
Kharkiv Research Forensic Center of the Ministry of Internal Affairs,
61036, 34 Kovtun Str., Kharkiv, Ukraine

[2]PhD in Law. ORCID: https://orcid.org/0000-0001-7545-7046.
Kharkiv National University of Radio Electronics,
61166, 14 Nauky Ave., Kharkiv, Ukraine

Abstract
The relevance of the study of modern document research technologies is determined by the growing pace of innovative and technical progress, which produces high-tech achievements that are used not only for rational purposes, but also for the purpose of high-quality falsification of documents to achieve illegitimate and selfish goals. The purpose of this article was to study the latest methods of document forgery and existing technologies for their detection with the aim of assessing the level of development of modern expert research in this field. In order to achieve the above-mentioned result, a complex methodological approach was used in the study of this topic, which consists in the consistent application of methods of scientific knowledge, analysis of the acquired knowledge, their systematization and generalization with the aim of building a system model of the modern process of technical documentation research, as well as the application of comparison and evaluation methods in order to identify weaknesses in the use of existing technologies, the method of scientific forecasting of development prospects in this field. As a result of the study, the general theoretical, methodological and procedural provisions governing the document examination process were highlighted, the known and most used methods of falsification of documents were defined, the methodology for establishing the characteristic features of various types of forgeries and the technical means used for their detection were studied, and the available in this field were outlined problems and prospects for overcoming them. The knowledge gained in this way logically contributes to the formation of fundamental information baggage, which should be used in expert work to achieve the most accurate and justified results. The conducted research has a high applied value, as it focuses on the most optimal and effective modern examination technologies in the field of document circulation, highlighting their characteristic features and advantages, emphasizing the growing need to use the latest technological advances in the examination of documents

Keywords:
falsification; examination; diagnostics; identification; evaluation of results; innovative progress; software and analytical complex; computer reproduction equipment

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*Corresponding author

Introduction

Document management is an integral part of a civilised society. It mediates the rational interaction of social participants. A document is a significant object in a wide variety of manifestations of public relations. Therefore, it is extremely important to regulate the document verification procedure as a means of mediating the occurrence of certain legal consequences. The issue of document forgery began to exist almost simultaneously with the appearance of the document itself. Over time, within the framework of economic and technological development, the system of social relations moved to the highest levels of an organisation. At the same time, the methods of forgery were also modified. Rapid innovative development has led to the emergence of new types and opportunities for document falsification.

Today, the technical expertise of documents is becoming increasingly relevant. This is due to the spread of a wide variety of methods of forgery in document management. The development of computer technologies has contributed to the emergence of information technology fraud, which in the modern realities of social relations in the online mode acquires the status of a global concern. Therefore, it is important to examine the available technologies of document technical examination for forgery. Many scientific and journalistic publications are devoted to the study of modern technologies of technical examination of documents. Fundamental is the study by O.V. Vorobey & A.V. Kofanov [1], devoted to the general provisions and fundamental principles of technical examination of documents.

Quite persistently and meaningfully at the present stage, attention is focused on the need to introduce innovative technologies in the process of document examination. This issue was addressed by N.V. Ghadan [2], who insisted on the objective importance of introducing modern technologies into expert examination to obtain justified and highly accurate results; and O.Yu. Savchuk [3], who was engaged in the study of computer programmes used in handwriting expertise.

Modern research on certain methods of falsification of documents was carried out by scientists H.M. Kutskir [4] (problematic aspects during signature examination); O.I. Lytvytska & O.P. Lytvytskiy [5] (issues of examining the authenticity of photographic images); V.G. Peliushok [6] (problems of detection of technical editing at the present stage); I.V. Hora & I.I. Popovych [7] (certain aspects of technical expertise establishing the statute of limitations for the production of document details). The methodology of expert examination of certain types of documents and their requisites is the subject of the study by L.S. Talyanchuk [8], S. Naumenko, S. Bruhan & O. Kataraga [9].

Document examination technologies were also studied by D. Ellen, S. Day & C. Davies [10] (methodology of scientific examination of documents) [10], K. Martire, B. Growns & D. Navarro [11] (techniques used in the examination of handwriting in written documents), I. Dror, K. Scherr, L. Mohammed, C. McLean, & L. Cunningham [12] (practical aspects of expertise work with the examined documents), L. Mohammed [13] (signature examination), N. Hamasaki, K. Nakamura, N. Nitta, & N. Babaguchi [14] (features of handwritten and technically generated texts, characteristics of font properties of computer software). The current theory of expert examination in this field is generated by the practical experience of conducted examinations Therefore, the theoretical purpose of this study is a systematisation of the practical aspects of the conducted examinations.

The high pace of dynamic technological development determines the imminent need for the use of modern equipment and high-tech advances in the process of determining the authenticity of the document. Sufficient material and methodological support for expert activities is the key to obtaining effective and accurate results in the most optimal time frame.

Examination of a document for its authenticity is now the leading area of world expert research. The European Network of Forensic Science Institutions (ENFSI), which is an international organization that includes leading European expert institutions (73 expert institutions and forensic laboratories from 39 European countries), is actively engaged in cooperation in this area by promoting the exchange of knowledge and experience [15]. ENFSI operates under progressive strategic plans that provide for the continuous strengthening of ties between the members of the organisation, the development of their international activity through cooperation with other research institutions and the expansion of the membership. In its activities, ENFSI is guided by international standards of forensic science.

The strategic plans of the ENFSI provide for improving the quality of expert practice and control over the credibility of examinations. This organisation assists and guides its members in improving their expertise and helps them to obtain international accreditation. It includes the European Academy of Forensic Expertise, which ensures consistent professional development of experts and encourages focus on international standards. The Academy organises seminars, conferences and expert projects [15].

Within the ENFSI there are working groups functioning by types of examinations, which actively accumulate world expert experience and disseminate among member institutions up-to-date information on innovations in the expert field by holding meetings in alternate countries. Among the working groups on the exchange of experience in the technical expertise of documents in ENFSI, there are expert groups in the following areas: *Digital Imaging* (examination of digitised images), *Documents* (technical examination of documents), *Forensic Information Technology* (computer-technical expertise), *Handwriting* (handwriting expertise);

Forensic Speech and Audio Analysis (phonoscopic examination) [15]. Transnational exchange is the key to the effective development of the expert domain, focused on the application of the most advanced world technologies.

The purpose of the study is the identification of existing problems in the process of applying modern technologies of document examination through the analysis of ways to detect various forgeries, as well as to outline possible prospects for the development of expert examinations in the overcoming of existing issues.

Materials and Methods

A significant amount of scientific data, presented in the form of monographs, author's articles, collective scientific works, experimental findings and methods, was subject to the detailed study of the specific features of technological examination of documents at the present stage. This study was mainly theoretical in nature. At the same time, an important stage of the study, which had applied significance, was the identification of the problems existing in the studied area and providing recommendations for its solution. The application of a comprehensive methodology of scientific research contributed to the formation of a meaningful understanding of the general principles of the process of technical examination of documents, types and methods of document forgery, characteristic signs of falsification, ways of detecting them and the tools used for this purpose, available effective technologies aimed at achieving optimal examination results.

The process of technical examination of documents traces the unity and interdependence of theory and practice, when expert knowledge, far from being narrow-profile, serves as the basis for the examination, and the results of the examination become a methodological asset for further practice. This relationship has led to dynamism, consistency and interdisciplinarity as the fundamental principles of applying the methodology of scientific comprehension in this area. The research of the topic of this article is mediated by the application of the methodology of scientific knowledge. The latter is a complex and multi-level process, each of the stages of which is a kind of step in the growing trend of achieving the main objective of the study. The stages of scientific cognition are implemented through the use of certain methodological tools.

The study of modern technologies of technical examination of documents naturally began with the analysis of scientific and journalistic achievements in a given matter. The application of the analysis method helped to form an understanding of the progress in this area. The diagnostic method was used in the processing of existing technologies for detecting falsifications in document control, and the method of morphological analysis contributed to the comprehension of the characteristic features of existing methods of document forgery. The systematic application of these methods has become the key to a deep study of the subject matter. The synthesis method combines the knowledge gained at the previous stage. To consider expertise as a complete process consisting of clearly defined stages, each of which aims to perform certain tasks, the method of scientific systematisation was used. Using the method of generalisation, the application of which was the logical step following the previous two stages of the study, it was possible to consider the process of expert examination in terms of its systematic nature.

The next stage of the research involves the comparison of the obtained data on the existing technologies of technical research of documents to identify the advantages and disadvantages in their application, which is integral to the comprehension of this subject. The next stage of the study used the method of evaluation of the data obtained through the research process to identify the existing issues in this area, their causes, and preconditions.

The final stage involved the application of the method of scientific forecasting. This method became a logical result and manifestation of the scientific novelty of the research because with its help it was possible to identify ways to overcome the existing issues in this area and predict the prospects for its progressive development.

The above methodological tools step by step contributed to the fundamental study of the application of modern technologies in the technical examination of documents. The comprehensiveness of the applied methodological approach made it possible to fully reveal the essence of the study and achieve the set objective.

Results

1. General aspects of technical examination of documents. In its essence, a document is a material object that carries information about any facts. Actually, the term "document" is of Latin origin: *documentum*, which translates as evidence, testimony [16]. From this perspective, it always has a certain semantic load, which consists in recording facts or events or implies the occurrence of certain significant consequences. Thus, document is an important object of a socially oriented environment and mediates the interaction between the participants of society.

Documents include written papers, graphs, photographs, phonograms, and video materials. They can be official (form and content are fixed by regulations) and unofficial (documents of everyday use: notebooks, diaries, letters). Through documents, subjects of social relations are identified, execute transactions, exercise subjective rights and obligations, that is, acquire a certain status in society. The procedure for concluding such documents is regulated at the legislative level of any legal state. Given the significance of this object in the process of social interaction, the legal aspect of its application is evident, and it in fact generates legally significant consequences. In this respect, the study of the validity of the document, compliance with the procedure of its preparation provided by the regulations is a critical area of technological work.

Technical examination of documents is the process of establishing the authenticity of the object under study by identifying the method by which the document was produced, as well as establishing the original content of the document, the fact of making changes to it, identifying individual structural elements of the document (requisites) [17]. The objects of technical examination of documents are: banknotes and financial circulation documents (bills, shares, checks, excise duties, etc.); postal documents (stamps, envelopes, postcards); travel documents; identity documents; documents on education and work experience; lottery tickets; the material used for the production of the document (paper, ink, printing ribbons): means used to create the document (printing forms, computer and reproduction equipment). Furthermore, as part of the technical examination of the document, various products made of different materials (wood, cardboard, fabric) with traces of the document creation (stamp imprint or dye residue, pressed traces of the applied text) may be examined.

The objects of research are divided into comparative and those that are compared (examined). Comparable are the samples provided by the interested parties for the examination and the samples made during the examination by the expert himself. The objects that are examined are documents that are involved in the procedural case, and documents that relate to the case based on the results of the expert examination [18]. The purpose of the technical examination of the document is to establish its authenticity or forgery. To confirm the authenticity of the object under study, it must have the following essential components (requisites) in its structure: name, date, place of preparation, participants, content, signatures, seals or stamps. The absence of any of the above details entails the impossibility of establishing its authenticity, and therefore invalidity in the legal sense [16]. In addition to the details, the material (base) of the document and various substances (colouring, correcting, binding) are also subject to technical research of the document, as already noted above. A forged document is characterised by the fact that its content or attributes do not match the actual reality. There are two types of forgery: physical, in which changes are made to the content of the document or the form of its preparation is not observed; and intellectual, in which the rules regarding the form and content of the document are observed, but the latter contains deliberately false data [16].

The tasks to be solved by technical examination of documents can be subdivided into diagnostic and identification [1]. The diagnostic task is to identify the fact of the presence of additions or erasures, invisible or faded inscriptions, preliminary technical preparation when making a signature. As a rule, this type of examination does not require the availability of comparison samples and is carried out within one available free sample. Diagnostic examination of documents aims to establish the facts of changes to the document; replacement of document sheets; replacement of photographs in the document; the presence of hidden elements. During diagnostics, it becomes possible to determine the sequence of execution of document details and reproduce the primary text of the document.

The diagnostic task begins with an inspection of the sample. The general condition of the document, type of printing, font features, image quality are subject to visual examination. In this case, magnifying devices (magnifiers) are used. At the diagnostic stage, the properties of the material and paint, the consistency of their use for this type of product are also studied. If during the diagnosis of the sample there is a discrepancy between the method of manufacturing of the object under study (for example, the sample was made using electrophotography) and the corresponding objects of this group (usually the method of metallography was used), then there is a reasonable basis for concluding that the sample is a forgery [5].

Recently, due to the expanding range of printing products containing innovative features (holograms, bar codes, *QR*-codes), it is not enough to have one object of research for certain diagnostic studies, but it is necessary to provide experimental samples for comparison. It concerns the analysis of documents containing special security features (passport, driver's license, diploma, banknote) [1].

Identification tasks of technical examination of documents are aimed at determining who and how exactly created a particular requisite of the document, and what means, tools and materials were used for this purpose. During the identification, the method of preparing the document and the method of making changes to it, the means of preparing the text of the document, the nature of the signature and the seal on the document, and the method of concealing the elements of the document, if any, are established. This type of task requires several experimental samples of the document. For example, to determine the method of applying a seal to a document, it is necessary to provide several samples of documents with different degrees of intensity of its imprinting, applying a seal to a document on different types of surfaces (hard, soft, horizontal, vertical, static, dynamic), applying a seal immediately after filling with ink, throughout the period of use and when the ink is exhausted.

The identification study of the object uses the methods of a separate and comparative study of free and experimental samples in order to identify common and distinctive features, to evaluate each of these features, both individually and in aggregate (this includes the study of the content of the text and its placement, features of typing, the presence of clichés and defects of the devices with which the text is applied). Technical examination of documents can be roughly classified into the following types: an examination of the document for falsification depending on the method of forgery; restoration of the original content of the document (if it is

lost due to forgery or due to the passage of time); establishment of the method of production of the document and its details; reproduction of the whole document by its parts (examination of torn, burned or chewed documents); study of texts of small volumes; examination of prints of seals and stamps; identification of materials used in the creation of the document; determination of the statute of limitations for the creation of the document.

An important condition for an effective technical analysis of the document is compliance with the rules for providing samples for examination and the rules for handling them. Most often, it is the original documents that are subject to examination. Samples must be provided in sufficient quantities for the examination. If necessary, the document must be supplemented with related items (mechanisms used to produce the object under study, fountain pens, bottles of ink or paint, ampoules of paste used to complete the document). Samples for expert examination must be placed in an envelope, and the signature on this envelope must be made before placing the experimental sample in it. It is unacceptable to bend documents that are subject to examination, to put any marks on them. The objects of an examination must be protected from exposure to moisture and light, high and low temperatures, and when in contact with them using tweezers and rubber gloves [1].

Documents can act as written and physical evidence. In the first case, the document contains certain objective data and serves as a confirmation of a particular fact (documents certifying transactions, acts, and conclusions). In the second case, it is not the content of the document that is of interest, but the very fact of its existence. In this regard, technical research, in addition to the content, is subject to a variety of aspects related to the object of research: material, time and method of preparation, the identity of the performer. Such an examination becomes criminalistic in nature.

2. Methods and modern technical tools for document examination. When conducting a technical examination of documents, a fairly extensive set of methods is used, among which, in addition to highly specialised methods (photographic, microscopic, physical and chemical), general scientific methods (measurement, observation, experiment, inspection, comparison) and formal and logical methods of cognition (induction and deduction, hypothesis and analogy, analysis and synthesis, generalisation) are also used [8]. Currently, technical examination of documents requires the use of effective methods and high-quality means of examination. The most effective methods are naturally considered to be special examination methods, including: physical, chemical, combined physical and chemical methods, as well as methods of visual and microscopic examination, photographic method [8].

A striking example of the use of the physical method in the technical examination of documents is wet copying, which is based on the principle of diffusion, in which substances from the test sample penetrate into a specially prepared moistened medium to simplify the research process (for example, when examining a signature). Physical methods are widely used in the examination of intersecting strokes, detection of additions, washes and mashing, signs of mechanical interference in the sample structure (luminescence, X-ray, spectral methods) [12]. Chemical methods make it possible to determine the composition of the document material and colouring substances. Chemical methods are essential in the analysis of invisible and faded writings. These are chemical droplet reactions, and experiments with reagents. However, this group of methods involves the risk of damage to the test sample. Physico-chemical methods of examination are the most commonly used. An effective example of such symbiosis is the diffusion-copying method of document examination, in which, as a result of contact of the test sample with photographic materials, substances penetrate into the photoemulsion layer, resulting in the so-called hidden image, which remained invisible under normal conditions [8].

The physicochemical method of thin-layer chromatography can determine the brand of ink used to create the document. This method is based on the effect of certain chemicals (solvents) on the base of the paint, resulting in the separation of the constituent parts of the writing material (thus distinguishing between dyes of different types or classes) [12].

Visual examination of the document is carried out by applying a variety of techniques related to the use of light rays. For example, the examination of an object in oblique light involves an increase in the degree of visibility of the content of the sample as a result of the exposure of the beam at an angle up to 90 degrees; and the study in through light reveals signs of replacement of parts of the sample by observing the different intensity of the light beam passed through the document.

The most common is the analysis of the sample in vertical light when the light beam interacts with the sample at an angle of 90 degrees [10]. This technique allows to examine the properties of the sample material and to identify their differences in case of forgery. The method of light filters is widely used to enhance contrast and detect signs of chemical exposure to the sample. The use of infrared and ultraviolet rays allows examining those properties and features of the sample that are invisible to the naked eye.

The microscopic method of study is an opportunity to examine the object in larger scale and focus on details that are not visible during visual inspection. There is optical and electron microscopy. Optical microscopy is used to study the surface structure of the sample material and the printing method. Electron microscopy is a method of studying the sample an order of magnitude higher, as it allows magnifying the image up to two hundred thousand times. It is used to study the features of the morphological structure of substances that make up the sample material and sample props [8].

The photography method is widely applied at the present stage. The photo can be measured (using a ruler) and contrasted (using light filters), photographed in micro-, macro-scales (if necessary, reducing or enlarging the image), or in invisible spectral zones (using ultraviolet or infrared light). During the examination of documents, it is advisable to use a set of existing methods to achieve the most optimal, accurate and qualitative results. The implementation of the above methods is carried out using a variety of technical means (measuring, lighting, reproducing, optical, computer).

Rulers, protractors, callipers, magnifiers, and micrometres are used to visually inspect and determine the size of the sample as a whole and its individual parts. Important in this case is the lighting factor, which is achieved with soffits, lamps (fluorescent and incandescent), spotlights, lanterns, and special devices of ultraviolet radiation and infrared lighting. Darkfield illumination is commonly used at the present stage of the technical examination of documents [8].

Microscopes are essential for the technical examination of documents. Modern microscopes are equipped with video cameras so that the image obtained under the microscope is displayed on the monitor screen. With oblique illumination, by using a microscope it becomes possible to detect signs of damage to the protective film of the document material (curling). The latest technologies allow the simultaneous application of various research methods. An example is a complex television-spectral-luminescent microscope, which makes it possible to study an object in a continuous range of visible light, oblique illumination, and ultraviolet light. Such functional symbiosis allows achieving the scale of sample magnification and its illumination level up to 140 times [8].

Today, a large number of documents are equipped with various security systems (logos, barcodes, holograms), which are applied to the document with special inks. The latter exhibit the property of glowing under UV or infrared rays. During the technical examination of such documents to transform an invisible image into a visible one by means of photography, the hardware and software complex *"Regula"* and the video spectral comparator *"Foster + Freemen"* are widely used, which have advantages in the speed of fixing the result [8]. Also effective in the analysis of documents containing security features is the use of the device "ESED", equipped with optical lenses and different types of lighting. The advantage of such equipment is its light weight, which allows it to be used as a portable device [8].

When studying an object in the invisible spectrum, portable ultraviolet ray source lamps are most often used. The results obtained are recorded using photo and video cameras. Of great interest is the high efficiency of the ultraviolet emitter *"Crime-lite 2"*, which is a symbiosis of the main source of white light for the basic study and seven auxiliary coloured sources of intense radiation for enhanced effect in detecting traces on the test sample [8]. One of the most advanced means of technical examination of documents is Raman spectrometer, which is used to analyse dyes by combining them with light scattering and studying changes in the frequency of newly formed spectral lines [8]. The use of complex installations that combine a microscope, a computer and a printer is quite effective because it provides a simultaneous examination of the sample and recording of the results.

The current stage of technical examination is characterised by complexity, both in the methodology of the experiment and in the means of its implementation. The latest software and analytical complexes are widely used, as they allow to maximise the image as much as required for this particular sample, under different lighting conditions with automatic selection of the most optimal and fixing the detected signs of forgery using high digital quality photographic equipment [5]. Besides, such software systems ensure the existence of a systematised electronic database of expert studies, which is of great practical importance for further expert activities. Modern video systems provide expert reports with graphic images of the examined samples and with highlighting of those aspects, features, and parameters that the expert relied on when drawing up the conclusion. It is important to highlight the innovative development in such areas of expert examination of documents as handwriting analysis. This type of expertise involves the use of mathematical modelling methods and statistical methods. Therefore, the introduction of an automated stage of processing expert data is the key to obtaining accurate and timely results. Currently, when examining handwriting, including when examining texts of small volume (signature), software packages are widely used, which are based on: registering the time limits for the execution of individual fragments of the object of research and comparing the data obtained with the experimental sample; automatic measurement of distances between the points into which the object of examination is conditionally divided, and comparative characteristics of the obtained data for the original and the sample under study; studying the structural and geometric features of samples and their elements (analysis of the resolution density of the dye to determine the pace of writing and the force of pressure) [9]. Today, computer programmes "Cedar-Fox", "Neuro-Script", "Muvalizer", complex software "Globalgraph", which are based on the methods of scanning and graphometry, are used quite effectively in such examinations [3].

The American Programme "Cedar-Fox" analyses individual features of handwriting and signature samples. At the same time, the object of examination is translated into a digitised format, and all identified features are displayed in the form of systematised statistical data. European programmes "Neuro-Script" and "Muvilizer" specialise in the processing of scanned images of the object of examination in spatial and dynamic

parameters, deliver the obtained findings regarding the study of writing pace and pressure on the writing material, and, if necessary, have the function of a visual video presentation of the expert examination. The Polish programmes "Reygraf" and "Kinegraf" are quite effective. The first analyses the correlation between handwriting and pressure by establishing patterns in the length of strokes and their angles. The second programme examines the lines of handwriting and determines the direction of the writing movement [9].

Kyiv Scientific Research Institute of Forensic Expertise, which has been part of the ECFI since May 2017, has developed a computer programme "VESNA", which specialises in identifying the characteristic features of signatures made in non-standard conditions [15; 9]. With this technical means, it becomes possible to provide an expert opinion on the authenticity of the signature and the conditions in which it was written. This invention is a real gem of Ukrainian technological development. This software product should be further upgraded to provide for the examination of not only short texts, but also a full examination of all details of the document. Technical examination of documents naturally relies on the achievements of technological progress and is based on the use of innovative technologies, which allows for achieving highly accurate results.

3. Methods of document forgery and ways to detect them. The most common ways of document forgery is the replacement of elements by erasing, adding, correcting, or etching. Mechanical interference with the content of the document occurs when erasing, as evidenced by the violation of the integrity and thickness of the paper, the remnants of erased marks found during the examination. During the technical examination, the additions are established by the following signs: unevenness of interline and inter-letter spaces, uneven slope of identical characters, different degrees of dye intensity. To detect the fact of correction in the document, the top layer of the document is inspected for damage, the shade and intensity of the text colour is compared. Evidence of etching include the presence of small cracks and various spots on the material, formed as a result of exposure to chemical substance, and changes in the surface characteristics [16]. When detecting the above signs, both conventional optical devices and contrast light filters, chemical counterparts, luminescent methods are used. Significant in this case is the examination of the tool, with the help of which the document text was created, its coating capacity (the extent to which the stroke is covered with paint) in individual traceological manifestations of strokes.

There is also such method of document forgery as washing, which results in the removal of the document text by applying various substances. This means changing the colour of the text to a state invisible to the naked eye. The technical study of such a sample is carried out by using the method of photography (shooting an object in reflected ultraviolet rays) and diffusion-copying method (in which the light sensitivity of the text under study changes due to the penetration of a special photoemulsion into its structure) [1]. Application of the latter is growing in popularity due to the high efficiency of the results obtained. At the same time, new methods of detecting forgery are more often used in the course of expert examination: dry unlit photographic paper or light fingerprint film, which eliminate the danger of damaging the object under study [1]. One of the ways to forge a document is to replace parts of it, such as its pages or parts of the text. Signs of such forgery are detected at the diagnostic stage by identifying violations or inconsistencies in the numbering and material of pages, the presence of remnants of mechanical intervention (pasting), mismatch of font features, lack of stamp on the pasted photo, etc.

There are also such falsification methods as filled and crossed-out texts. In detecting such counterfeiting, electrophoresis and television techniques are frequently applied [1]. The essence of the electrophoresis method is that under the influence of high frequency current particles of various dyes move in different directions, which allows for detecting the presence of foreign substances that are different from the native dye of the text. The method of television installations allows for capturing what is not immediately observable. With this method, it is possible to choose the most optimal angle for the examination and set the radiation intensity. The use of TV cameras in reflected infrared rays is effective in detecting filled or crossed-out writings [1].

Modern methods of technological examination make it possible to recreate the contents of damaged documents, even if they were exposed to high temperatures. Expert practice proves that the content of the document can be reproduced if it was exposed to a temperature not exceeding 250 degrees Celsius [19]. Working with such samples requires care and caution. This involves using sharp-edged tweezers, glass tubes, rubber pears, direct airflow, and friction electrification methods to place the remains of a charred document on a pre-prepared surface [1]. To eliminate brittleness, the surface of such samples is processed with glycerine solution, mineral oils, or water vapour, which gives the sample elasticity. During transportation, pieces of the burned document can also be placed in a glass or on a cotton pillow covered with a thin layer of paper. The text of the burned document is reconstructed by applying photographic methods (illumination in the presence of colour contrast of the text; shooting in the dark with underexposure of the negative when the text is made with a graphite pencil or ballpoint pen; shooting in infrared light, if the text is made with typographic ink or black ink), contrast methods, methods of processing with various solutions (hydrogen peroxide, fluorescents, heated alcohol with ether and gasoline), methods of heat treatment [1].

A separate area of expert examination is the establishment of the original content of the so-called

faded documents, that is, those that have undergone the deterioration process. An important aspect is to identify the signs of natural (when the document is old) or artificial (when the document has been exposed to the factors that caused the fading) deterioration. Characteristic features of such documents are traces of mechanical intervention (bending, damage), discolouration of texts, and changes in the colour and material properties of the document. A variety of methods are used to detect faded texts: taking photographs using light filters when the text is partially faded; the contrast method when the text is highly faded; the developing method, in which the sample is immersed in a developer and then placed on a clean transparent material (e.g. glass); the method of ultraviolet and infrared irradiation; and, depending on the type of materials used in the writing of the text, the method of chemical reagents can be used (for example, alcohol is effective when working with text that has been written with methylene blue dye) [1].

A signature examination is an important part of the technical examination of documents. The signature has a certifying value, so establishing its authenticity is a priority task of the expert. Recently, signature forgery, which involves the use of special techniques, is becoming more and more widespread. Unlike graphic forgery, in which the handwriting is imitated with the preservation of the native properties of the handwriting of the person who forges the signature, in technical forgery the latter is completely excluded, which greatly complicates the process of establishing the fact of forgery. The sign of a technical forgery of a signature is any traces of the methods used to produce the forged signature (different levels of colour density, intermittent strokes, mismatching of colours, etc.)

One of the methods of signature forgery is wet transfer, in which the colouring substance of the real signature with the configuration inherent to the author is transferred to the forged document using a special material, such as PVC film [4]. A sign that an expert can recognise while examining such a document may be the loss of the original colour of this signature and compensation for this aspect by applying new paint over the transferred signature.

A common method of forgery is the use of facsimile (cliché). A sign of its application in the examination is the absence of characteristic grooves on the material, which are left by writing instruments. As a rule, clichés are used for large volumes of documents [4]. Recently, forgery of signatures by means of copying and reproduction equipment has become increasingly widespread. In this case, the photo of the signature is transferred to the forged document. The technical examination of such a sample reveals signs of non-handwritten execution due to the lack of characteristic relief and the possible peeling of paint when bending the document.

The above-mentioned features are established by using a system of expert examination methods. Thus, besides microscopic observation, it is efficient to examine the document under infrared rays, as it becomes possible to detect foreign dye. Optimal at the present stage of technological development is the use of the electron-optical converter method [1]. This device allows for the detection of the presence of a foreign colouring substance that remains transparent in infrared irradiation.

A modern way to forge a signature is to use a plotter, which is essentially an advanced pantograph. The specific feature of this method of forgery is a fairly accurate imitation of a handwritten signature. Creating a signature using a plotter involves scanning the original and transferring it to a graphic editor, in which the scanned sample is then reproduced using the selected graphic tools, after which the forgery is printed with all the configuration features of the original, including the pace of signature application. Identification of signs of forgery in this case is impossible without modern computer technology [4].

The current stage of technical development is highly dynamic. New advanced copying and character-synthesizing devices (e.g., thermal transfer and dye-sublimation printers for high quality printing of graphic images) are introduced on a constant basis. The accessibility of such office equipment causes an increase in the level of falsification of documents: from blanks to banknotes. The process of technical expertise of such objects faces new tasks related to the need to master the features of new equipment and identify the characteristic features of products made with its help.

Today, the examination of seal impressions and stamps is becoming very important. The reasons for frequent falsification, in this case, are due to the certifying feature of this item. Among the techniques of seal forgery are: letterpress, gravure, flat printing, clichés, use of copying equipment, and drawing [16]. During the examination of this element, the symmetry of the arrangement of the signs and the features of the dye are studied, the method of microscopic examination, ultraviolet and infrared rays are used. The complexity of the examination, in this case, is determined by the advent and broad availability of new techniques for the manufacture of seals (stamps), in particular by laser engraving, which is almost impossible to distinguish from the real one. Quite popular at this stage is the use of seals and stamps with a stamp cushion, which serves as reliable protection against drying out of the rubber base of the seal (stamp) and guarantees its permanent readiness for use. At the same time, the use of multi-colour rubber-based stripes can serve as a reliable protection against the forgery of such an element.

The priority direction of technical examination, mainly of criminological orientation, is nowadays the examination of the age of documents. The objects of this examination are most often such details of documents as signatures, seals, handwritten and printed texts. An important condition is the provision of the source document for this examination. Document age expertise solves several tasks: determining the time when each of

the elements available in the document was made and determining the chronology of the creation of these elements. It requires a comprehensive review from the expert, in which, among other things, it is necessary to exclude the potential artificial antiquing of the document.

Key in determining the time of sample creation are chromatographic methods that allow identifying the type of text ink and the degree of solvent evaporation. The experimentally determined solvent is then evaporated in the laboratory, and the observation of this process provides quantitative indicators for calculating the approximate date of ink application. An additional method of examination is the use of a spectrograph, which makes it possible to establish the presence of impurities in the ink, and traces of chemical exposure [7]. Only a harmonious combination of the comprehensive methodological approaches, the special knowledge of the expert and the use of advanced technologies in the process of expert examination of documents can serve as a reliable guarantee of obtaining accurate and correct conclusions about the authenticity of the document.

Discussion

Modern technical examination of documents is a complex, multifunctional and high-tech process. The accuracy and relevance of the expert opinion depend on a combination of objective and subjective factors (level of expert knowledge, exhaustiveness of methodological support, high level of technical capabilities of the equipment, and compliance with the rules of handling samples for research).

Today, there are a large number of effective studies in the field of document forgery. Traditional methods of forgery and ways to detect them have been widely studied by O. Vorobey & A. Kofanov [1]. The fundamental work of these authors is of high applied significance. The works of various scientists are devoted to separate methods of falsification and means of detecting them. Thus, H.M. Kutskir [4] in the study of technical methods of signature forgery came to the conclusion that each of them is characterised by its own set of features that are unique to it. Operating with knowledge of such sets of characteristic features, an expert will be able to successfully detect a forgery [4]. O.I. Lytvytska & O.P. Lytvytskiy [5] proposed a number of material and statistical methods for detecting signs of interference in the primary image of a photographic document.

A significant place in the process of expert examination of documents is given to methodology. L. Talyanchuk [8] proposed the division of methods used in conducting a technical examination of documents into general, general scientific and special methods. Such a classification is rational and well-grounded since accurate and effective expertise should involve a fairly extensive knowledge base, which includes both broad and specialised competencies. The complexity of the applied methodology in the examination of documents was also favoured by American scientists D. Ellen, S. Day & C. Davis [10] and the European archivist theorist H. Booms [20].

At the same time, the modern dynamics of technological development require new approaches in the methodology of expert examination. O. Savchuk [3] notes progressiveness in the direction of conducting expertise using computer technology, in particular in the study of document texts. N.V. Ghadan [2] details modern technologies of expert examination, while identifying a number of advantages that their implementation in the examination process provides. O. Vikhlyaev & I. Germanyuk [21] argue that the trend in the development of the latest technologies sets the leading direction for improving economic expertise related to the introduction of electronic document management. The same opinion is expressed by researcher I. Rechtman [22], who focuses on the latest technologies as a guarantee of effective documentary examination in the face of high-tech fraud [22]. S. Naumenko, S. Bruhan & O. Kataraga [9] advocate for the introduction of computer aids when performing identification tasks of small text examination, while N. Syrotenko, R. Tamoshiunaite & V. Abrosymova [23] highlighted the effectiveness of traditional methods for the study of short texts, provided that there is a sufficient number of samples.

The most promising area for the optimisation of expert work in the technical examination of documents should be further improvement of identification methods through the widespread use of computer technology. Computer diagnostics has an advantage over subjective diagnostics, as it eliminates errors caused by failing to recognise any subtle signs. It also delivers substantial time-saving benefits by automating the data processing stage. Today, the tasks of technical examination of documents are complicated by the extensive use of the latest technology. Thus, if previously documents were forged by printing or typing, now this process is performed by means of computer systems. Under such conditions, the detection of the fact of technical editing requires not only special expert knowledge but also relevant modern practices.

V. Peliushok [6] argues that altering parts of a document using a personal computer (hereinafter referred to as PC), is called reprinting and is a manifestation of technical editing of the document. Among the signs of technical editing, she singled out the following: differences in the structure and toner of strokes, mismatching of identical printed characters, the presence of printing defects, traces of erasing and scraping, discrepancies in the overall placement of characters, displacement of vertical and horizontal lines, lack of a protective surface grid of the document material [6]. Similar features of the edited documents were proposed by scientists N. Hamasaki, K. Nakamura, N. Nitta & N. Babaguchi [14].

Modern PCs are equipped with text and graphic editors, which are widely used in document forgery. In this case, the original document is modified using

the relevant computer software by placing another image or text or correcting the existing content, with the resulting forged document being printed. The text of the document can also be edited by photocopying equipment. New text or images are placed over the original document, then the document is photocopied and duplicated. The above methods are often combined in the falsification of documents, while the application of additional equipment in the production of forgeries always complicates the examination process and requires proper technical support.

One of the practical issues of the examination, especially of handwritten texts, is the refusal to provide the original document. This is explained by the reluctance of interested parties to lose the document, because there is a possibility of the document being damaged or destroyed during the examination, for example, due to the use of physical and chemical methods. This problem must be solved by innovative solutions using diagnostic and identification computer programmes, which will reduce the risk of damage to the object of examination to zero. The active use of plotters complicates the process of detecting forgery during the examination of the signature on the document. The signature made using a plotter does not contain signs of delayed coordination during its application and imitates the handwritten signature so accurately that the detection of signs of falsification requires appropriate expert knowledge and methodological support.

At the same time, one can not but note the positive dynamics of the use of interactive PC features in handwriting examinations. Such branches of investigation as computer graphometry and scanography are widely used today [3]. Computer graphometry is used for the structural measurement of text characters, their elements with simultaneous recognition of similar and distinctive features and compilation of the results. Computer scanography makes it possible to study the features of the dye, which is part of the text fill, in the most advanced format, with regard to a large number of known properties and features of dyes.

There are certain obstacles in the process of determining the age of documents. The relevance of this issue is related to the fact that the request for such technical examination of documents accounts for the majority of the total expert demand. First of all, difficulties are caused by the unwillingness, for reasons of a procedural nature, to provide the original document for examination. As in the examination of handwritten texts, there is a certain probability of such a sample being damaged, since the relevant research involves the use of so-called "destructive methods" (methods of physical and chemical exposure). Besides, the experiment, apart from basic knowledge in the legal field, also requires fundamental knowledge in chemistry and physics, which gives grounds to argue about the inherent high level of competence required of the expert.

Now there is no single methodology for conducting this kind of examination. Experts usually use a comprehensive approach. Therefore, it is essential to have proper multifunctional and versatile material and methodological support for the examination process, including high-tech modern computer diagnostic and copying equipment.

A separate area of technical examination of documents at the present stage of the development of public relations is the examination of electronic documents. Electronic document management is a relatively new and underdeveloped phenomenon. However, the relevance of this area of research is exceptionally high. Today's business world is the space of information technology (hereinafter referred to as IT), which is evolving at a rapid pace. The IT industry is literally replacing paperwork because it offers advantages in saving space and time, which is extremely beneficial in a frantic rhythm of life. An example of the relevance of electronic document management was the 2020 pandemic, due to which almost the entire business world switched to remote work via digital interactions. At the same time, the need for the examination of documents containing e-data has increased. Therefore, it is particularly important to further explore this area of technical examination of documents.

Digital technologies are being introduced at an accelerated pace in our new digitalised society. At the same time, there is a rapid increase in financial crime, which is based on the realisation of fraudulent schemes using IT technologies. Naturally, there is a growing demand for countering this type of offence, and it requires high-tech expert examinations [21]. Scientists M. Cam, H. Fielding & R. Cohn [24] have repeatedly stressed that expert knowledge is extremely important for conducting a quality examination, and therefore must be constantly improved. Currently, there are certain challenges in this area, primarily related to the necessity to have, in addition to basic, specialised knowledge in the IT industry. The same point of view is expressed by M. Politzer [25], who emphasises that for a quality examination it is desirable to combine the knowledge of experts with the knowledge of IT specialists.

Indeed, the expert is faced with the tasks of recreating erased data; analysing the server activity of PC users; detecting suspicious accounts; working with cloud storage; processing a huge amount of virtual data on the subject of their illegality. The solution to such complex tasks is impossible unless high-tech computer equipment and professional skills of its use are available, which, of course, implies a costly financial contribution. The conversion of paper documents into electronic format (technical images or electronic copies) also allows for fraudulent manipulations, in which a forgery is created by using authentic images of the requisites, however with altered content.

Today, the study of digital document management requires the introduction of fundamentally new

expert methods since traditional methods of document examination are focused on resolving other issues. The adoption of artificial intelligence technologies should become a priority for expert practice. Thus, the transition to advanced technologies is the key to effective and accurate expertise. At the same time, the technological support of expert activity should perform an information and analytical function related to the processing of a significant amount of data to be investigated, as well as allow for the systematisation and archiving of the expert findings. The methodological function of technical support is to equip the examination process with the necessary serviceable and highly efficient equipment. The function of protecting both the expert examination process itself and the results obtained is also important.

It would be beneficial to exchange experience of expert practice at the international level and attract transnational investments in the development of the research industry and its progressive material and methodological support. After all, productive and highly accurate document examination is the key to an effective fight against fraud and forgery, which is the central policy of highly developed countries. Also important is the information and analytical component of international cooperation in improving the expert practice, in particular, the preparation and systematic publication of newsletters that would describe examples of examinations and dictionaries that would facilitate communication between scientists from different countries. The key to the advancement of document examination should be the established interaction between experts and representatives of law enforcement agencies. A similar argument is expressed by the scientists G. Pomerantz, N. Sliger, M. Barba & K. Van Tassel [26], who emphasise the need for clear and effective interaction between expert units and investigative bodies. Thus, the introduction of modern technologies in the technical examination of documents indicates the desire for the progressive development of academic research in this area and commitment to quality international standards.

Conclusions

The study analysed the general provisions of the technical examination of documents, reviewed the main methods of forgery in document management, identified the characteristic signs of falsification in documents and introduced modern technologies used in the identification of document falsifications.

Detection of any kind of forgery is a complex and multi-level process that requires the application of fundamental wide-ranging expertise and effective technologies. As any applied field, the field of expertise has a range of problems that need to be solved. The key among those is material and methodological support with modern technologies, which implies a significant financial investment. However, proper expertise is the key to the eradication of crime, so it is advisable to attract financial assets, both at the level of relevant provisions in state budgets and at the level of individual investment programmes, including transnational ones.

Equally important is a steady increase in the level of expert knowledge because technological progress today is impressively dynamic. In this respect, it is advisable to exchange world experience in research practices within the framework of international conferences, summits, congresses, seminars and meetings. The optimal result of the examination is a consistent conclusion of the high-profile work, which is a symbiosis of the expert's qualitative knowledge and productive technological means by which this knowledge is implemented. After all, the more advanced the methodology and technique used in the expert examination, the more accurate the conclusion.

Furthermore, modern technologies greatly facilitate expert work, saving time and eliminating the subjective possibility of making an error. The automated process has a wide range of programmed operations: identification, measurement, statistical analysis, mathematical modelling, comparison, evaluation and recording of the result. The advantage of using software tools in expert examinations is also in capturing and analysing those attributes that may be invisible during a conventional expert examination. The combination of traditional expert methods with the features of advanced technology is the key to obtaining the most complete and accurate results.

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Сучасні технології технічного дослідження документів

Віктор Станіславович Сезонов[1], Ольга Миколаївна Сезонова[2]

[1]Кандидат юридичних наук, доцент. ORCID: https://orcid.org/0000-0002-2580-2953. Харківський науково-дослідний експертно-криміналістичний центр МВС України, 61036, вул. Ковтуна, 34, м. Харків, Україна

[2]Кандидат юридичних наук. ORCID: https://orcid.org/0000-0001-7545-7046. Харківський національний університет радіоелектроніки, 61166, просп. Науки, 14, м. Харків, Україна

Анотація

Актуальність вивчення сучасних технологій дослідження документів зумовлена прискоренням темпів інноваційно-технічного прогресу, який продукує високотехнологічні досягнення, що використовують не лише в раціональних цілях, а й для високоякісної фальсифікації документів задля досягнення неправомірних корисливих цілей. Метою цієї статті стало вивчення новітніх способів підробок документів і наявних технологій їх виявлення з метою оцінки рівня розвитку сучасного експертного дослідження в зазначеній сфері. Задля досягнення результату під час дослідження цієї теми використано комплексний методологічний підхід, який полягає в послідовному застосуванні методів наукового пізнання, аналізу отриманих знань, їхній систематизації та узагальненні з метою побудови системної моделі сучасного процесу технічного дослідження документації, а також застосування методів порівняння й оцінки задля виявлення слабких рис у використанні наявних технологій, методу наукового прогнозу перспективи розвитку в зазначеній галузі. У результаті дослідження висвітлено загальні теоретико-методичні та процесуальні положення, якими керується процес експертизи документів, означено відомі та найбільш уживані способи фальсифікації документів, вивчено методологію встановлення характерних ознак різного роду підробок і технічні засоби, які використовують для їх виявлення, окреслено наявну в цій галузі проблематику та перспективу для її подолання. Здобуті таким чином знання закономірно сприяють формуванню фундаментального інформаційного багажу, який має використовуватися в експертній роботі задля досягнення найточніших і виправданих результатів. Проведене дослідження має високу прикладну цінність, оскільки акцентує на оптимальних й ефективних сучасних технологіях експертизи у сфері документообігу, висвітлюючи їхні характерні особливості та переваги, наголошуючи на нагальності потреби в застосуванні останніх досягнень техніки під час проведення експертизи документів

Ключові слова:

фальсифікація; експертиза; діагностика; ідентифікація; оцінка результатів; інноваційний прогрес; програмно-аналітичний комплекс; комп'ютерно-розмножувальна техніка