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ON THE FORMATION OF EXPERT OPINIONS USING THE LASER METHOD OF SPECTRAL ANALYSIS AND SPECIAL SOFTWARE

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The work includes the general principles of expert opinion formation on works of artistic merit with the use of laser method of spectral analysis and special software. This article contains an example of direct research, which results show the described principles and approaches.

Introduction

Authentication of objects of art and historical value is an actual trend in the study of various objects of the world cultural heritage. As a result of that an art expert examination is becoming an increasingly popular trend in the activity of various professionals engaged in the study of such a kind of objects. As a rule, the purpose of an art expert examination is to determine the object's value, its historical epoch, state of preservation and authorship.

Experts distinguish two types of art expert examinations: (1) attribution – the study of an object in order to determine its key characteristics, classification and price; (2) a fine art appraisal – verification of an object, in other words its correspondence to stated characteristics (as a rule, this type of examination confirms or denies the attribution results).

Despite the fact that the indicated examinations intersect in many aspects, we need to determine their main tasks. So, the main task of attribution – is to classify an object – to state the type of art or handicraft (to start with global differences, for example, a painting, a sculpture, a weapon, etc.); to determine its genre, age, place of manufacture, belonging to a particular school, and so on; to determine materials used to make an object under study, as well as their composition (where possible and necessary); the state of an object, its preservation, the presence or absence of defects; the time of manufacturing – (epoch, period, year); the price of an object under study.

On the other hand, the main tasks of a fine art appraisal are: to determine cultural and historical value of an object; its singularity and authorship (the author is unknown and must be identified; the author might be known, but it must be proven that an object under study was made by him (her); its originality (an original, a copy, an author's copy); to fix alterations, restoration works; to authenticate an object.

It should be noted that at this point laser spectral analysis [1] is playing an important role in the process of an art expert examination, and – special software which is able to process an art expert examination data, to accumulate the results, to make a required conclusion, to analyze accumulated data, and so on.

On peculiarities of laser method of spectral analysis

The method of laser induced breakdown spectroscopy (LIBS – Laser Induced Breakdown Spectroscopy) has significant advantages over traditional methods of atomic emission spectroscopy, as it provides a direct analysis, possibility of on-line analysis, simultaneous multi-element analysis with high spatial resolution and the

ability to layer by layer analysis. In addition, the hardware and software of the method can be developed in a field portable version, which is particularly important for decision of problems of environmental medium.

Laser spectral analysis is a modern variant of the classical atomic emission spectral analysis. Emission atomic spectral analysis consists of the following steps [4]: (1) selection of a representative sample reflecting the average composition of the material being analyzed or the local distribution of defined elements in the material; (2) the introduction of the sample into a source of radiation in which the evaporation of solid and liquid materials, the dissociation of compounds and excitation of atoms and ions take place; (3) the registration of the spectrum (or visual observation) using spectral instrument; (4) the decryption of the obtained spectra with the help of tables and atlases of the spectral lines of chemical elements. Typically, the evaporation of the sample and the excitation spectrum of its vapors occur in one and the same light source for a spectral analysis, for example, in a flame in the electric arc or spark.

The basis of the quantitative analysis of the emission is a direct relationship expressed by formula (1) and which connects the concentration (atomic density) determined by the chemical element (N_z) with the intensity of the detected spectral lines of atomic elements of the same element:

$$I = F_1 \Delta t (Lld)\, \Omega \frac{hc}{4\pi\lambda_0} A_{ij} g_i \frac{N_z}{U_z} \exp\left(-\frac{E_i}{kT}\right) \int_{-\infty}^{\infty} P(\lambda) d\lambda , \qquad (1)$$

Where F_1 – dimensionless coefficient taking into account the efficiency of the registration system, Δt – the time interval recording, Lld – volume of the zone of plasma luminescence, projected on a photo-detector (L – thickness of the plasma volume, l – the height of a pixel of CCD detector, d – the width of the entrance slit of the spectrograph), Ω – the spatial angle of collection of plasma radiation h – Planck's constant, c – the speed of light λ_0 – the wavelength of maximum of emission lines A_{ij} – the probability of transition from the upper level i to the lower j, g_i – the statistical weight of the level i, U_z – the sum of the states of the atoms of a chemical element E_i – energy of the upper level i, k – Boltzmann constant T – the plasma temperature, $\int_{-\infty}^{\infty} P(\lambda) d\lambda = 1$ because $P(\lambda)$ – normalized profile of the spectral line.

Laser YAG doped with neodymium is used to ensure the ablation of material samples to be analyzed in terms of microanalysis.

Basic software requirements,associated with the formation of expert opinions

Nowadays, there is software supporting some kind of work related to the process of an express laser examination. However, there is a need to make a common base of research results in various branches, as well as complex and many-sided data processing. So, it's actual to expand a universal web-based system [4] in two aspects: to create the storage with the possibility of following data analysis and to develop the support system for examination of objects of different nature, in particular, objects of artistic value (works of art, including paintings).

The offered universal system is aimed at a web browser use; it is modular and is expandable. The following features should be pointed as applied to this system. The system has to store expanded data about the object under study, its characteristics, as well as about the materials used to create it. It should be noted that the whole expert's work connected with preparation and writing of a report takes a long time and isn't enough automated. Moreover, also there is no software which is able to get necessary information about objects of research and expert opinions. So, the offered system and, in particular, the module connected with the expert opinion formation is an actual development.

For the obtaining of data model structure methodology and the general principles of the methodology of conceptual design are used [2, 3, 6]. The system essence is extracted, restrictions on data integrity, constraints and user constraints are defined.

At this stage, it specifies the main essence of the existing universal system that supports some aspects of an express laser expertise, as well as fragments related to the expert opinions and the works of artistic value are modified.

So, the basic essences of the data model are as follows: «The work of art» (ARTWORK) – stores information about all objects of art available to the system; «Type of works of art» (ARTWORK_TYPE) – includes attributes related to the type of works of art; «The author of works» (AUTHOR) – information about the author; «Historical period» (HISTORICAL_PERIOD) – the historical period in which the work was created; «Location works» (GEOGRAPHIC_PLACE) – Information about the location of the work (museum, collection, etc.); «Images» (FOTO) – photos of the work; «Materials» (MATERIAL) – Information about the Materials of the work; «Paint» (PAINTS) – Information about the colors (for pictures); «Metals» (METALS) – information about metals; «Other materials» (OTHER_MATERIALS) – contains information on possible other materials; «Technology» (TECHNIKS) – a technique in which a work is created; «Passport research» (PASSPORT_RESEARCH) – Information about the research; «Country» (COUNTRY) – a country where the art object is located; «The instrumental method» (INSTRUMENTAL_METHODS) – method of the research; «Notes on the date» (DATE_REMARKS); «Date of creation» (CREATION_DATE) – date of creation for the work; «Spectrum» (SPEKTR) – research file for a work of art; «The spectral line» (SPEKTR_LINE); «Library of the spectral lines» (LIBRARY_OF_SPEKTR_LINES); «Focus areas» (FOCUS_SECTION (Spectral Research)) – focus areas for research work; «Chemical element» (CHEMICAL_ELEMENT) – information about the chemical element; «Pigments» (PIGMENTS) – information about pigments; «Art genre» (ARTWORK_GENRE) – provides information on the genre of the work of art.

It should be noted that the system is supposed to support the quantitative and qualitative analysis of the various spectral components. To automate the process of searching and comparing of the characteristics of the elements at first, filling the library databases available lines (with all the necessary characteristics) indicating the establishment of registration, as well as the possibility of future recruitment by new registrations and research are provided.

Thus, first of all, the information is included in the following plan in system: an element, the wavelengths of excitation source, an intensity of the line depending on the source of excitation, ionization potential, the presence of self-reversal of lines, accessory to spectrum of the neutral atom or ion. Also, the information is stored on the place of registration of the spectrum and the specific properties of the individual, the date of registration, the experimenter and some other information. All this will contribute to the optimization of work during the spectral analysis.

Characteristics associated with the information model of the atom, include the following: information about the atoms (a unique identifier, description, Russian and English name, symbol, atomic weight) isotopes (a unique identifier, description, Russian and English name, symbol, weight, year of opening) ions (a unique identifier, description, Russian and English names, the charge). Moreover, during the examination, as the composition of a given spectrum, date and place of measurements are important.

Artistic pigments (from Lat. «pigmentum» – «paint») are highly dispersed, powdered dyes, practically insoluble in water, organic solvents, film formers, and other painted environments and capable of forming with them protective, decorative or decorative - protective coatings.

To identify the pigments qualitative and quantitative composition, morphology and coloristic properties must be detected, as each pigment has unique physical and chemical properties, it can be studied by methods of science of materials.

For the successful identification of pigments in the study of an object of cultural heritage, it is necessary to know the range of materials used as pigments in different regions at different times, and their properties, as well as the possibility of analytical methods.

Among the main features of artistic pigments, color, dispersion, hiding power, intensity, light stability and oil absorption would be noted. Moreover, certainly also a classification and properties art pigments are considered.

Thus, after studying of the subject area, as well as related opportunities for development and modification of the universal system, the conceptual data model was designed, which is the basis for the collection and storage of data related to an express laser expertise and the objects of artistic value (Figure 1).

A diagram of variants of using reflects the necessary functions to support operation of the system, coupled with the formation of expert opinions. The main users of the system are: Administrator, Expert, Registered users and Guests.

It is obvious that the main task of the Administrator is a system administration.

Administration includes such features as: modification of metadata; search, view and data modification; user definition. In addition to the features listed above, the administrator administers the database and the application itself directly and moderates the system data. Modifying metadata is provided via the integrated interface of a database management system (DBMS). Moderating is provided the data through an appropriate interface of the Administrator.

The main task of the experts is an extended work with the system. Due to this role of the experts are: the addition and modification of data related with the object of research and expertise, the choice of research methods, preparation of reports of

various plan, analytical reports and the summary document of the examination, search data, including complicated search terms, as well as the ability to determine the structure data that will be added to the database. Data analysis can be extended by definition of the required methods of analysis or data representation.

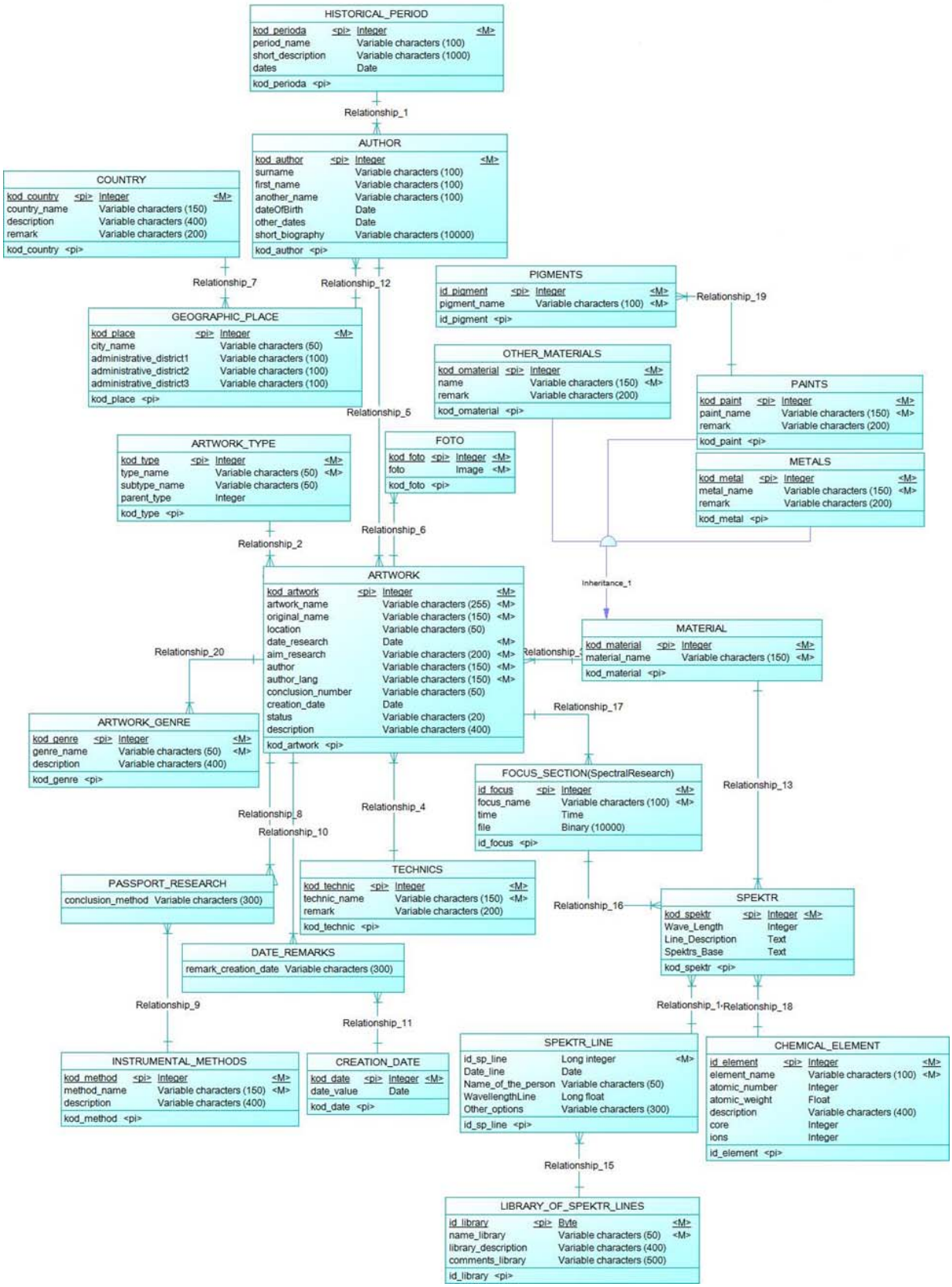

Fig. 1. Conceptual data model associated with the study of objects of artistic value

Data work functions expert performs by means of the user interface – the application form for an expert work (an expert personal account interface).

It should be noted that, in preparing the final document examiner is required to consider the following aspects: the kind and the type of object, name, dimensions, type membership, composition, creation date, etc. Given the fact that objects paintings and objects of artistic value are exposed to examination most often, are next aspects of scientific expertise are total: question decision about authorship (the establishment, confirmation or rejection of authorship); dating of the work and determination of the school of painting; definition of the iconography of the work; question decision about originality or derivative character of work; a distinction on the type of secondary (copy, author or co-authorship repetition, belonging to the studio, a circle, a follower of the master school, imitation, falsification, pastiche); determining of the state of conservation and defining of the artistic level of the works, etc.

The main function of a registered user is viewing of the information you need and adding comments. We should also note the following remark: due to the fact that the development is intended for professional use, and there is growing interest in the examination of objects of artistic value, at registration the user must indicate their professional interests and activities, as well as to pass moderation, after which he will have access to the respective functions.

All the functions available to the user through a personal account interface. In addition to these members some of the functions to view and to search for information are available for guests of the system.

It should be noted that the system proposes support of execution of the quantitative and qualitative analysis of the various spectral components. To automate the process of searching and comparing of the characteristics of the elements at first, filling the library databases available lines (with all the necessary characteristics) indicating the establishment of registration, as well as the possibility of future recruitment by new registrations and research are provided.

The total architecture of the system realization is based on three-level client-server architecture. The system is represented as three levels with minimal connection to each other: the database; server application and user application [4].

General requirements for the examination of art objects using the method of LIBS and laser systems for express support expertise will be formulated. Due to the fact that the general system of support for laser an express examination is under construction today to support the examination of art objects are separate subsystems (modules), in particular, visualizer of spectrum by means of which processing of the spectrograms and the system of accumulation of experimental data take place.

1. Determination of the purpose and objectives of the current study. For example, the attribution of artistic work authorship, historical period, determination of the degree of uniqueness of the object, etc.

2. Identification of areas of focus of the laser radiation, their fixation on the image of an object.

3. Analysis of the art object, using the mobile version of the laser emission spectral analyzer with two pulse mode of generation.

4. Processing of the spectrograms using the Visualizer spectra [5].

5. Work with databases accumulated samples, spectral databases, data on pigments, etc. Putting of research results into a database.

6. Preparation of the final conclusions of the examination and presentation of the reporting file in template required.

7. For forcing of analytical sheets, reports, and trend data stored in the database. Treatment of expertise data about objects of research by using OLAP-technology and mathematical methods for processing of large amounts of data.

Example of expertise carried out using a laser method of spectral analysis, and specialized software

As the objects of the laser-emission analysis three paintings were taken: two works «Surrender of the fortress-Abbas Abbad» (1832, oil on canvas) and the «Surrender of the fortress of Erzerum June 27, 1829» (1834, oil on canvas), location – Gomel, owned by well-known artist of the XIX century Yanuariy Sukhodolskiy (19.09.1797-20.03.1875) and the authorship of Sukhodolskiy for a third of the work (title – «Episode of insurrection of 1830-1831», Poland, mid-19th century., Location – Grodno, see Fig. 2) is necessary to establish or disprove. Thus, the purpose of the study was the confirmation / refutation of authorship of Yanuariy Sukhodolskiy, identification of possible establishment of time limits of the test piece.

In the study of works of art referred to above, the following research methods were used: laser emission spectral analysis and visual exploration. It should be noted that the study of pictures using a laser method of spectral analysis in the study of the authenticity of works of art is actually. First of all, due to the fact that, in practice, to the first third of the twentieth century, every author had used the own paint prepared based on the available pigments, natural minerals, vegetable pigments, earth pigments, etc. Typically, each author kept his own recipes of preparing of colors. Because of this, the authorship of the artists of past centuries can be installed on the pigments and mixtures of colors that they used in creating of their works of art.

Spectral analysis of objects of art was produced in art museums of different cities of Belarus («The State Historical and Archaeological Museum» and Grodno Palace and «Park Ensemble» Gomel). There is a slight difference between the intensities of the spectral lines of colors in the spectrograms obtained, which may be caused by varying of the concentration of chemical compounds contained in the pigments.

The laser light is focused to a spot of diameter of about 1 mm. Investigations were carried out at the work in double-pulse mode. The first pulse shaped laser plasma flame, and the second - it is further excited. The delay between pulses is 6 ms, repetition rate of laser pulses is 5 Hz. Laser pump current was 22 A. The dual laser pulse energy at the specified parameters of the pump is 28 mJ. Pulsed laser radiation was produced on different colors of the studied pictures, and then the data is displayed in the program window QSp Client. The obtained spectra of paints of a picture of an unknown author under the study (Figure 3), was compared with those of authentic samples of paint of Yanuariy Sukhodolskiy and was processed using a visualizer implemented spectra [2].

Figure 4 presents the spectrogram of white paint, which is used to create all three pictures. Note that the lower range – this is script of Yanuariy Sukhodolskiy (1797-1875) «Surrender of the fortress-Abbas Abbad 1832, oil on canvas», the upper range is the original of Yanuariy Sukhodolskiy (1979-1875) «Surrender of the fortress of Erzerum June 27 1829», oil on canvas, medium – the sample by an unknown artist (presumably Sukhodolskiy) «Episode of uprising of 1830-1831, Poland, mid 19 century». As it is evident from the spectrogram (see. Figure 3), as a white paint to write all the pictures white plumbum pigment were used with the addition of chalk. In the spectrograms traces of copper are visible, which could get to the paintings during transport when close contact with objects where copper incorporated into its composition. So spectrograms obtained in the study of white pigment, are identical.

Fig. 2. The tested object with the focus areas of the laser radiation on the surface of the paint layer of work

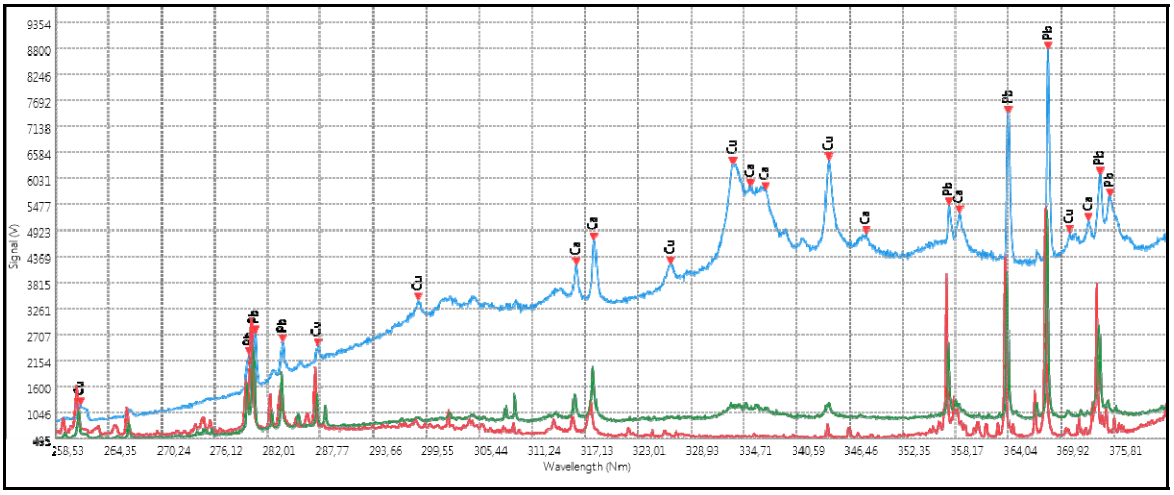

Fig. 3. Spectrogram of white pigment

In addition, samples of the following colors that are present in all three study patterns were also analyzed: dark-green, black and red. Dark-green background of color layer of the objects indicates on the presence of large amounts of chromium, indicating that as a green pigment mixture on basis of chromium oxide Cr2O3 was used. This pigment (Cr2O3 or Sr2O32H2O) as art coating of paint has been applied in the XIX century. The presence of zinc in the resulting spectra indicates on the presence of zinc white pigment ZnO in color paste, which began to use in oil painting from the middle of the XIX century. Furthermore, in the color paste also impurities were found containing Mg, Ca. The study of black paint layer of all three paintings has showed that among elements included in its composition, calcium is significantly dominated and the presence of magnesium is observed. Therefore, it can be concluded that as the black paint elephant bone was used. The relatively small amount of copper is also recorded, i.e. possible addition of black pigment - copper oxide CuO. For pigments, red basic paint layer contains mercury - cinnabar (HgS), diluted by lead white pigment and chalk with the addition of small amounts of magnesium and aluminum. The spectrograms obtained in the study were identical. The only exception is the fact of differences in the intensities of the spectral lines that can be caused by a discrepancy in concentrations of chemical compounds that are part of the paint pigment. So, from the conducted technical and technological research, we can conclude about creation time of the investigational product – about the middle of the XIX century. Thus, the results of technical and technological research do not deny authorship of the artist Yanuariy Sukhodolskiy.

Conclusion

The general approaches connected with the formation and processing of expert opinions on the objects of artistic value are represented in the article. The laser method of spectral analysis for the study of objects of artistic value and structural methodology to develop basic principles and models of the general system to support the formation of expert opinions were used as main methods. As an example, the use of the software developed (in particular, the module – Visualizer spectra [4, 5]) for the analysis of the samples taken spectrograms was demonstrated. Certainly, the results are actual for both the specialists and experts, as well as for scientists, who are developing the methodology of structuring and treatment of data/

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The results obtained during the execution of State Program of Science Research «Development of methodology and tools for building a universal storage, processing and analysis of structured data of a large amount of practice-oriented focus»