

УДК 025.85

<https://doi.org/10.20913/1815-3186-2021-4-39-49>

Imaging Techniques for Survey of Book Collections

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Abstract. Covers and book bindings, especially in library collections, may serve as an important hidden information source for researchers and readers. The article describes the experience of the National Library of the Czech Republic, its Collection Preservation Division, in testing of the X-ray system and Video spectral comparator VSC 8000 to apply non-destructive methods in exploring materials and damages in different layers of the books, and shows its advantages. The systematic evaluation of the X-ray system on the typical examples of book materials of different time-periods showed, that non-destructive radiological methods of book investigation can detect problematic materials and conditions of their destruction beforehand not only in material itself, but in the entire object – the book. It showed that the hidden information can be obtained without breaking or damaging of top layers. Moreover, these materials can be older than the book itself. Video spectral comparator is applied on nonvisible, uneasily recognizable texts, for example faded by light, mechanical or other principle of damage. Thus, gained information serves for historical, art, and scientific knowledge of book binding and texts.

Keywords: book collections, book binding, X-ray radiation, radiography, video spectral comparator, visualisation

Citation: Vávrová P., Neoralová J., Novotná D., Součková M., Popelková D., Matysová M., Blecha T., Kazanskii A. Imaging Techniques for Survey of Book Collections. *Bibliosphere*. 2021. № 4. P. 39–49. <https://doi.org/10.20913/1815-3186-2021-4-39-49>.

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Received 08.02.2021

Revised 04.10.2021

Accepted 08.11.2021

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D. Popelková, M. Matysová, T. Blecha, A. Kazanskii, 2021

Техника для визуализации при обследовании книжных коллекций

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Аннотация. Книжные обложки и переплеты, особенно из библиотечных коллекций, являются для исследователей и читателей важным источником информации, часть которой может быть скрыта в самом материале. В статье описывается опыт отдела охраны книжных фондов Национальной библиотеки Чешской Республики в тестировании рентгеновской системы и видеоспектрального компаратора VSC 8000 для недеструктивных методов исследования книжных материалов и повреждений разных слоев книг. В ходе работы эффективность этих исследований была доказана. Систематическая оценка рентгеновской системы на типичных примерах книжных материалов разного времени показала, что недеструктивные радиологические методы исследования книг позволяют заранее обнаружить повреждения не только в отдельном материале, но и во всей книге; при этом исследуемые материалы могут быть старше самой книги. Таким образом, скрытую информацию можно получить, не нарушая и не повреждая верхние слои материалов. Видеоспектральный компаратор был применен в исследовании плохо распознаваемых текстов, например выцветших или имеющих механические и другие повреждения. Полученная информация послужит для исторических, художественных и научных исследований в области переплета книг и книжных текстов.

Ключевые слова: книжные коллекции, книжный переплет, рентгеновское излучение, рентгенография, видеоспектральный компаратор, визуализация

Для цитирования: Ваврова П., Неоралова И., Новотна Д., Соучкова М., Попелкова Д., Матысова М., Блеха Т., Казанский А. Техника для визуализации при обследовании книжных коллекций // *Библиосфера*. 2021. № 4. С. 39–49. <https://doi.org/10.20913/1815-3186-2021-4-39-49>.

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*Статья поступила в редакцию 08.02.2021
Получена после доработки 04.10.2021
Принята для публикации 08.11.2021*

Introduction

Bookbinding represent a rich source of not only textual and pictorial information, but they are also a physical document of art handicraft of a bookbinder, of contemporary technological trends of production, and last but not least a document of history of the proper existence reflected in defects from wear and tear and natural decomposition of materials. Technology of book making and its damages are often hidden under layers of materials, and it is difficult to find them out without invasive intervention. By the help of radiography making use of X-rays, it is possible to non-destructively penetrate under the surface of external layers to internal structures and structural elements of book binding. Within the frame of grant project of the Ministry of Culture NAKI II entitled “Use of imaging techniques for the study of hidden information in bookbinding”, the workplace of the Department of Research and Development Laboratories of the National Library of the Czech Republic (NL CR) was equipped with a radiographic cabin and a video spectral comparator. Information on used technologies, materials, and their conditions are fundamental also for historical, art, and scientific knowledge of bookbinding.

Possibilities of non-invasive survey of a compact book binding are very limited. It is impossible to penetrate most parts of the binding structure without violation of surface layers (Duivenvoorden et al., 2017; Pouyet et al., 2017). The only possibility, how to look inside the book binding system without its damage, are non-invasive imaging and analytical methods. Know-how, construction, and materials of book bind-

ing are irreplaceable for preservation of books from modern and historical book collections in good physical conditions. Book binding is a complicated system of functionally interconnected mechanical elements of various materials. Historical and modern book bindings represent a plentiful source of information in a form of records, however, which largely carry also binding structure. Another tracked problem is work with information in book collections – information recorded on paper may be lost by degradation of underlay and writing materials, by mechanical damage or even removing, by action of chemical or physical factors. The information is usually hidden also in case, when sticking of sheets of paper occurs, or a book block was not cut into pieces, caked by fire, sticking after intervention of water and other materials, or by the action of microorganisms. Locked up information of priceless value, both in historical, and in modern bindings can be nowadays obtained by the help of non-invasive methods such as multispectral imaging technologies. This way acquired information serves for historical, art, and scientific knowledge of book bindings. It serves as a basis of planning strategy of care, protection, preservation or restoration of the object (Hradilová et al., 2015).

Video spectral comparator VSC 8000

Video spectral comparator VSC 8000 instrument (Fig. 1) was purchased for analyses of book collections, book bindings, and hidden information, within the frame of NAKI project.

Video spectral comparator VSC 8000 is the equipment, which is used for macrophotography



Fig. 1. Video spectral comparator VSC 8000-resized

Рис. 1. Обновленный вариант видеоспектрального компаратора VSC 8000

in selectable wavelengths of light. It makes possible to get wide-spectrum videogram in ultraviolet (UV), visible (VIS), and in infrared (IR) regions of light spectra at up to 453 different settings, and hidden layers which are thus visualized, as well as damaged or removed texts, and it is possible to diagnose conditions of materials, historical corrections, or interventions. The device was originally developed for the needs of the customs service, state institutions, and forensic workplaces for verification authenticity of documents, passports, cheques, paper money, etc. NL CR purchased this highly sophisticated equipment for survey and recurring visualization of damaged handwritten records, coloured layers in texts, and in pictorial sections. Thanks to the combination of advanced digital recording and multispectral LED lighting with sophisticated software interface, the equipment offers a complex solution for specialized survey of book entities with illegible or otherwise impaired records. The equipment disposes of a combination of a coloured infrared camera with spectral range of 350–1100 nm, and a carousel with camera filters containing over 16 various filters. The equipment contains also a micro-spectrophotometer for fast measurement of absorption, reflectance, transmittance, and transparency within the range of 400–11000 nm with resolution of 3 nm. The solution of internal space makes it possible to insert even larger book volumes. The object is shifted to an ideal position with a software tool by the help of a motorized table inside the chamber. Comparative functions of software include automatic analysis, automatic setting of filters and lights for highest picture contrast, 2D measurement, pseudo-colours, measurement of colour scheme, comparison of live and saved pictures, reading the pictures, and also creation of visual cube (hyperspectral) in adjustable wavelength range of 400–11000 nm in steps of 1–20 nm. The instrument is irreplaceable for obtaining such a range of visual data also in regard of time savings

(necessary for survey of extensive book collections) (Schreiner, Holle, 2011).

Selected samples (test books) could be now scanned in accessible settings of the instrument for verification of possibilities and search for equipment limits, and writing materials, damages, watermarks, creasing, spots of unknown origin, etc. could be monitored.

An interesting problem is identification and distinguishing ink pencils from those of graphitic ones. An ink pencil of any colour presents high risk in conservational or restoring interventions, and its identification is very difficult due to visual similarities with purely graphite pencil releasing no colour in dampness.

The equipment was also exploited for analyses using fluorescence of some substances or living microorganisms. Different tones of fluorescence are exploited e.g. for distinguishing genuine ivory and artificial ivory (nitrocellulose).

Adjustments of acquired pictures were carried out with the help of Adobe Photoshop programme, graphic software intended for adjustments of bitmap files. Also, other software of company Adobe Systems was used for presentation and final adjustment of outputs of the project – Adobe Illustrator for work with vectorial graphics, and Adobe InDesign for making pictures public (typography of documents, posters and other promotional materials).

Results of systematic evaluation of Video spectral comparator VSC 8000

A model sample was used for illustration of individual tools and functions of the video spectral comparator – decorated letter – 1 D (initial in manuscript) (pigments bonded using gum arabic on parchment) in Figure 2.

This sample of decorative capital letter D was used because it represented a combination of color layers (inorganic pigments and bonds) and underdrawing

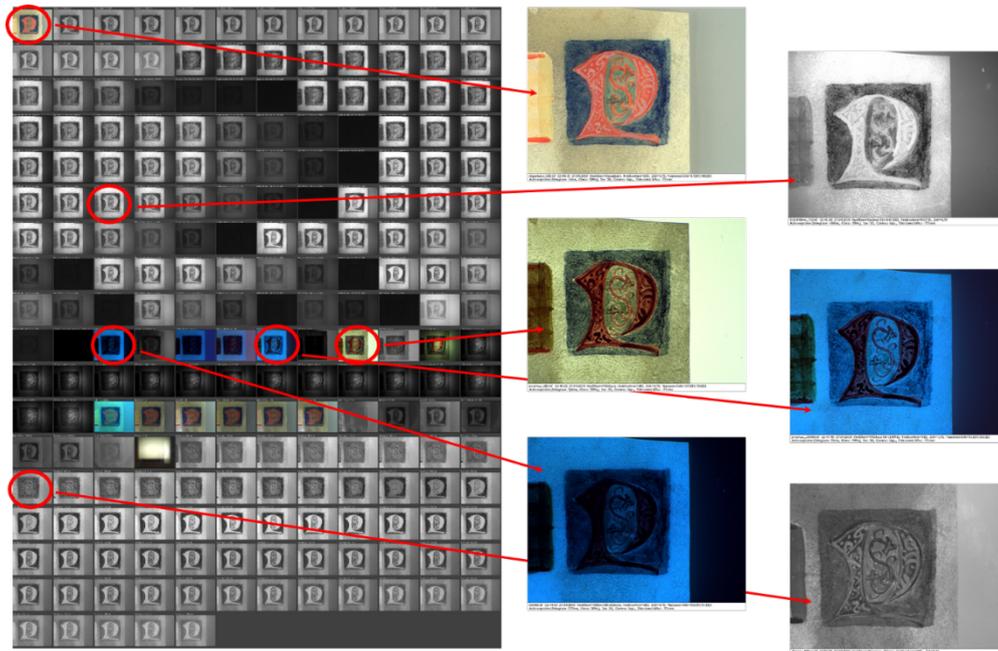


Fig. 2. Model sample letter D preview images made by automatic investigation function (left) and individual pictures (right)

Рис. 2. Смоделированные образцы буквы «D» в режиме предпросмотра, сделанные с помощью режима автоматического исследования (слева), и отдельные изображения (справа)

on the parchment and simulation of the real illumination in historic manuscripts. By the Automatic investigation, it is possible to see the document at all selected settings of lights and corresponding filters, individual views are saved at the same time (Fig. 2). It is thus possible to find out easily and quickly the regions of spectrum interesting for possible more detailed investigation in unknown samples. In case of sensitive documents, it is possible to save views directly in full resolution, so that other expositions were no longer necessary. Then the entire sequence at selecting full spectral possibilities of the instrument takes exactly 7 min 40 sec. (scanning 163 pictures).

Hyperspectral viewer (HSI) makes it possible to monitor differences in spectral behaviour

of materials – their absorption and reflectance in a given range. In full range from 400 to 1000 nm, it is possible to set scanning with a minimum step of 4 nm. It is necessary to set optimum camera exposition (“calibration” for white paper) before scanning a document, in this case the whole sequence takes 10 minutes.

On the basis of measurements using a microspectrophotometer, it is possible to highlight so-called similar regions of a spectrum. This tool makes possible differentiation of two seemingly equally coloured materials, which vary in spectral behaviour (e.g. two similar pigments or inks), nevertheless, it concerns software picture coloration, and its accuracy has its limits (Fig. 3).

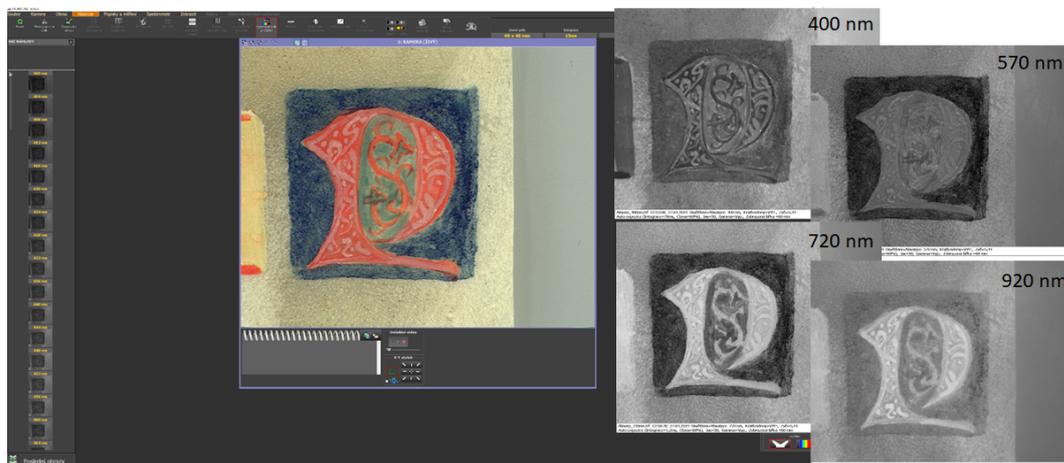
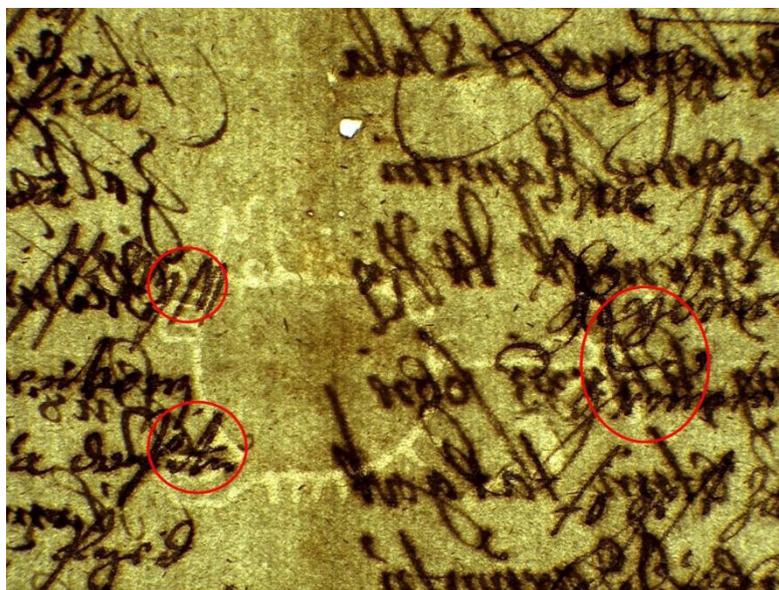


Fig. 3. Model sample “initial D” hyperspectral viewer mode

Рис. 3. Смоделированный образец «заглавной буквы D» в гиперспектральном режиме просмотра

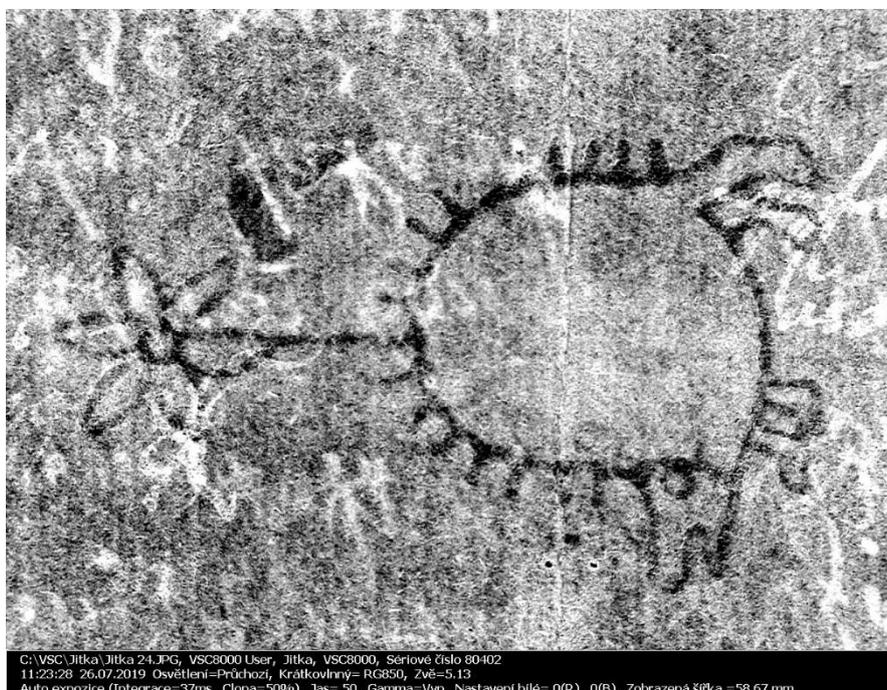
Instrument VSC 8000 makes it possible to utilize inbuilt modes of lighting and filters, which are tested. As an example, the application of different combination of lights and filters is mentioned during visualization of historical filigree on hand made paper from 16th century (Fig. 4¹). The filigree was selected for its simple shape. It represents a hedgehog with

hexaphyllous bloom, which is a filigree of Jihlava papermill from Staré hory. The filigree is partly concealed by hand written calligraphy with ferro-gallic ink. It concerned a free bifoliate paper so that complications were not solved at visualization of the filigree in the book block “in situ” (Fig. 5). The filigree concealed with printed writing, which is by itself yet



C:\VSC\Default\Default 26.JPG, VSC8000 User, Default, VSC8000, Sériové číslo 80402
10:12:08 24.05.2019, Osvětlení=Průchozí, Krátkovlnný=VID, Zvš=3,95
Auto expozice (Integrace=9ms, Clona=50%), Jas= 50, Gamma=Vyp., Zobrazená šířka =76,20 mm

Fig. 4. Initial picture of the filigree in passing through VIS light displays of filigree
Рис. 4. Исходное изображение филигранны при прохождении через световые дисплеи VIS



C:\VSC\Jitka\Jitka 24.JPG, VSC8000 User, Jitka, VSC8000, Sériové číslo 80402
11:23:28 26.07.2019, Osvětlení=Průchozí, Krátkovlnný=RG850, Zvš=5.13
Auto expozice (Integrace=37ms, Clona=50%), Jas= 50, Gamma=Vyp., Nastavení bílé= 0(R), 0(B), Zobrazená šířka =58,67 mm

Fig. 5. Resulting difference after adjustment of brightness and contrast
Рис. 5. Конечный результат после настройки яркости и контрастности

¹ Initial picture of the filigree in passing through VIS light displays not only filigree itself, hence the thinned spot of paper, but also hand writing on both sides. It is just it, what complicates “legibility” of the entire filigree. The filigree contour is not perceptible at all (see the marked sites) in places of overlapping letters from both sides.

less permeable for light radiation compared to hand writing, will be tested in the next stage of the project.

The used modes of visualization tested especially passing through lighting and incident lighting in combination with various filters inbuilt in VSC 8000 master unit. Investigation of absorption in near infrared radiation (hereinafter NIR) was carried out while using appropriate camera filters.

VSC 8000 can also serve for material identification. The photo of two prayer books (Fig. 6–8) shows the difference between imaging natural and synthetic materials evoked by enlightenment by various

sources of light with various wavelengths. Plastic is displayed in the picture in green, and bone cover in blue colour. The graphic adjustment consists in cut off, alignment, and retouching surface of books by the help of a tool – a point retouching brush.

Cabin configuration for digital radiography – X-ray system

The cabin configuration for digital radiography – an X-ray system - includes a shielded lead cabin, in which X-ray generator for digital application



Fig. 6. Prayer book with cover of synthetic material
Рис. 6. Молитвенник с обложкой из синтетического материала



Fig. 7. Prayer book with cover made from natural bone
Рис. 7. Молитвенник с обложкой из натуральной кости



Fig. 8. Prayer book identification of materials
Рис. 8. Идентификация материалов молитвенника

is located, and a flat digital detector capable of live preview and adjustment of picture while taking photos in a connected computer. Photos are processed in original software, which at the same time controls the source of radiation, processes picture, and saves the record in a form of static picture and video. The cabin itself is equipped with an electronically operated sliding table, capable of movement in horizontal and vertical directions.

The object under examination is placed between the source of radiation and the radiation detector in position enabling to obtain a picture of the given element of book binding. Degrees of grey in the acquired picture represent higher or lower degree of absorption of X-rays in the given part of the object. Darker shades correspond to materials more absorbing radiation (especially metals), lighter areas represent materials less absorbing radiation (paper, textile, leather etc.). Thickness of the radiographed material is also another factor determining total quantity of absorbed radiation (and, therefore, also shade of grey in the picture). Last but not least, the degree of grey depends also on graphic adjustments, which are performed after acquisition of the picture with the view of provision optimum visibility of details of X-rayed elements.

By the help of X-ray radiation, it is possible to produce photos, conveying important information on technology of book manufacturing, on some types of wear and tear, or e.g. on materials used in manufacturing. These photos may be an important element in historic, art, and scientific investigation of books and book bindings. Investigation of optimal settings of the equipment with combination of graphic adjustments occurs in cooperation of X-ray equipment operator, and graphic designer. Especially the largest possible distinctness of the surveyed element as well as the largest possible top-grade quality of the picture are taken into account.

Suitable graphic arrangement includes always picture alignment, cut off by the help of a trimming tool, and background retouch of the picture using as a tools patch and point retouching brush. After it, adjustments follow concerning first of all distinctness of book binding elements, which are important for investigation. Sharpness of the picture, brightness, contrast, gamma correction, exposition, and level modification of gloominess or luminosity are adjusted. To highlight individual parts, application of a particular tool by the help of masking only the given part can be carried out.

This equipment was purchased for detailed testing of possibilities and limitations of X-ray radiation in the survey focused on visualization of hidden elements, layers, or damages in book binding material layers. Possibilities for book binding surveys in situ are very limited. It is impossible to penetrate to most parts of the binding structure without violation of top layers. In historical collections,

recycled materials often occur in binding, such as sliced up parchment foils, sheets of books, letters, spoiled print waste, and other materials, which may be older than the exemplar itself. These materials can be found in the spine of a book under coating, on covers, as winglets, entire sticking of covers or endpaper. Locked up information of priceless value of historical and modern bindings can be just obtained by the help of radiography.

Subsequent suitable graphic arrangement is also no less important, again corresponding with the bookbinding element, which we want to display, and its material. Here it concerns especially focusing the pictures, adjustment of brightness, contrast, gamma correction, exposition, picture alignment, and for lucidity also e.g. clearing of book background, rotation, and cut off. Insufficient visibility of the required element on the picture can be compensated by graphic adjustments.

Installation of the device in the NL CR and its influence on possibilities of imaging depend on settings of selected parameters of the equipment located in the NL CR, and also found internal structures of book bindings, which are not visible without book destruction. Visualized information then will make it easy to make decisions for restorers or conservators, what steps will or will not be necessary to carry out for book preservation, or how to care about the book.

The first part of systematic evaluation was carried out to understand which materials and elements of book binding are viewable by the help of the instruments, and in case of successful imaging also what settings during taking of photographs are optimal, and what graphic adjustments are good for the given material and element. Systematic survey is also the part of this topic, what type of construction and which materials are advisable for holding a book in the required position and distance from the detector during taking of photographs so that the smallest possible affection of the picture occurs by fixation system itself. Selection of the most suitable settings out from several pictures acquired at slightly different settings selected on the basis of the mentioned principles proceeded by visual evaluation of the acquired and subsequently adjusted pictures within the frame of cross-disciplinary team – a radiologist, a restorer, a bookbinder, and a graphic designer. Here, it concerns not only the suitable degree of lightness of the picture and suitable contrast; as it is obvious, in some cases it is necessary to make compromise at selection of settings so that all requirements placed on the picture are satisfactorily met (Van, 2003; Van et al., 2006).

Results of the procedure of book binding radiography

Within the frame of the project, investigation is under way in the area of using X-ray radiation for the study of books with the utilization of X-ray

cabin, with which the workplace was equipped within the scope of the project. The object under examination is placed between the source of radiation and the radiation detector in the position allowing displaying the given element of book binding in the appropriate manner, whereas the entire measurement proceeds inside the closed cabin, which shields radiation. The object is radiographed using radiation produced by an X-ray tube housed in the upper part of the cabin, and the picture is taken by a flat panel detector embedded in the lower part of the cabin with output directly to control PC. Grades of grey in the acquired picture represent higher or lower degree of X-ray absorption in the given part of the object (Fiala et al., 2013; Trojek, Trojkova, 2015). Darker shades in the picture in the event of a positive correspond to materials more absorbing radiation (especially metals), lighter areas represent materials less absorbing radiation (paper, textile, leather etc.). Another factor determining total quantity of absorbed radiation (and thus also shade of grey in the picture) is also thickness of the radiographed material (Osterloch et al., 2007; Pietikanen, 1996). Last but not least, the grade of grey depends also on equipment settings during picture acquisition, and on graphic adjustments, which are performed after picture acquisition with a view to provide optimum visibility of details of X-rayed elements.

Materials typical for books are paper, textile, wood, leather, parchment, and in smaller extent also metals, but there occur for example even plastics or bones. With respect to different physical properties of these materials, different settings of equipment are needed for optimum imaging book binding elements made of them, of their structure and pertinent defects. It concerns especially suitable settings of electric current and voltage on X-ray tube, distance of X-ray tube from the detector, and distance of the X-rayed object from the detector. Selection of suitable position of a book (or more positions of the same book for obtaining more comprehensive information gradually) is also fundamental, as well as that of suitable construction, which holds the book in required position and distance from the detector, including suitable materials of this construction.

No less important is also subsequent suitable graphic arrangement, again corresponding to the element of bookbinding, which is to be imaged, and with its material. Here, it concerns especially final focusing the pictures, adjustment of brightness, contrast, gamma correction, exposition, alignment of picture, for lucidity, and e.g. clearing background of books, rotation and cut off. Insufficient visibility of the required element on the picture can be compensated by graphic adjustments.

Typical examples of suitable imaging of book binding elements

In the following part, particular examples of application of the above-mentioned principles on particular samples are given, with the view of selection of suitable device setting (Fig. 9–12). Selection

of the most suitable settings out from several pictures acquired at slightly different settings selected on the basis of the mentioned principles proceeded by visual evaluation of the acquired and subsequently adjusted pictures within the frame of a cross-disciplinary team. It concerns not only the suitable degree of lightness of the picture and suitable contrast; as it is obvious, in some cases it is necessary to make compromise in selection of settings so that all requirements placed on the picture are satisfactorily met.

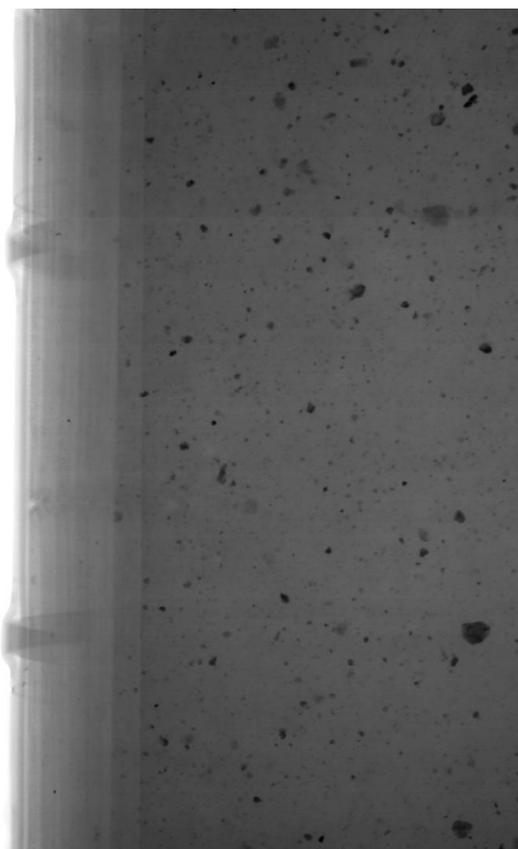


Fig. 9. Spine of a book with false raised bands. There is a distinct incision for sewing in the spine, which is positioned outside the placing of strips of false raised bands. The book is placed 66 cm above the detector coated with foil, X-ray tube distance is 79 cm from the detector, voltage on X-ray tube is 110 kV, current 300 A. Graphic arrangement: cut off; brightness 150; contrast 14; levels of shift of white (Odyssey of Homer, William Cowper, 1855)

Рис. 9. Корешок книги с фальшивыми рельефными полосами.

В корешке имеется отчетливый разрез для шивания, который расположен снаружи от размещения полос ложных рельефных полос. Книга расположена на 66 см выше детектора, покрытого фольгой, расстояние от рентгеновской трубки составляет 79 см от детектора, напряжение на рентгеновской трубке 110 кВ, ток 300 А. Графическое расположение: отключено; яркость 150; контрастность 14; уровни смещения белого (Книга Odyssey of Homer, William Cowper, 1855)

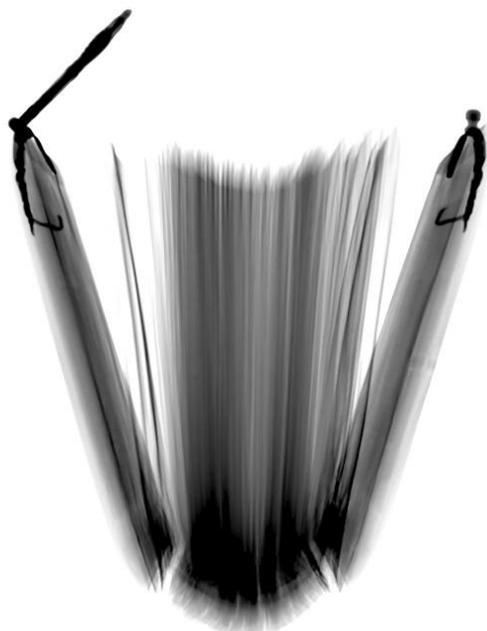


Fig. 10. Picture of a vertically placed book. Clips are fixed to the book cover by hooked metal wire. The book is placed directly on the detector coated with foil, X-ray tube in distance of 49 cm from the detector, voltage on X-ray tube 120 kV, current 300 A. Graphic arrangement: cut off; gamma correction 2.00; exposition +1.50. *Pomněnky ve vínek nebeský* by Václav Beneš-Třebízský, 19th Century

Рис. 10. Изображение вертикально расположенной книги.

Зажимы крепятся к обложке книги металлической проволокой в виде крючков. Книга помещена непосредственно на детектор, покрытый фольгой, рентгеновская трубка на расстоянии 49 см от детектора, напряжение на рентгеновской трубке 120 кВ, ток 300 А. Графическое расположение: обрезка; гамма-коррекция 2,00; экспозиция +1,50 (Книга *Pomněnky ve vínek nebeský* by Václav Beneš-Třebízský, 19 в.)

Investigation of the possibility of imaging various materials used in book production can be demonstrated for example on a book with wooden boards which are covered with a brass sheet (Fig. 11).

Notwithstanding precise performance of the cover, the book with bone slices on the boards is also unexpectedly sewn using metal staples (Fig. 12).

Conclusions

The objectives of the investigative activities within the frame of project NAKI “Use of imaging techniques for the study of hidden information in book binding” is a specialized survey of extensive library collections focused on hidden information in books, in book-bindings, reading illegible texts, visualizing commonly invisible details, etc.

Tests proceeded on the effectiveness of individual imaging technologies – spectral video spectral



Fig. 11. Book with metal cover, cut off; rotation; retouch by the help of a tool – point retouching brush; brightness 90; contrast 48; curves Nebeklič, 19th Century
Рис. 11. Книга в металлической обложке, обрезка, поворот; ретушь с помощью кисти для ретуши с острием инструмента; яркость 90; контрастность 48; кривые (книга 19 в. Nebeklič)

comparator and radiography. Selected methods were tested with the view of verification of their safeness for materials of book collections and their possible damage. Tests for displaying filigrees were carried out.

Graphic adjustments were utilized for the possibility of detailed survey of pictures acquired from the instruments intended for the survey and testing of materials of book collections of NL CR, which are important in light of scientific research, material analyses, and restorer survey. These were carried out by the help of programme Adobe Photoshop, a graphic software designed for adjustments of bitmap files in 2019. Also other software of company Adobe Systems was used for presentation and final adjustment of the outputs from the project – Adobe Illustrator for work with vector graphics, and Adobe InDesign for composition of documents, posters, and other promotional materials.

Non-destructive survey using radiography will help to detect problematic materials and their conditions non-destructively before substantial damages take place not only in the material itself, but in the entire object – the book. Thus, gained information serves for historical, art, and scientific knowledge of book binding. Radiography thus becomes a significant tool for obtaining pieces of knowledge on book binding and its physical conditions without destructive interventions.

By the help of the video spectral comparator, it is possible to obtain relatively exact filigree contours, which are not burdened by errors, as are

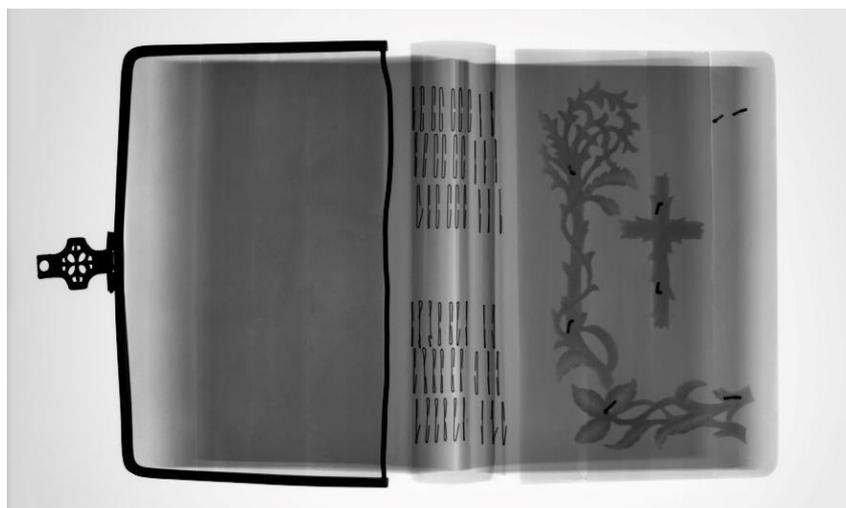


Fig. 12. Book boards, cut off; brightness 91; contrast -17; level shift lbacha Posvátní zvukové, P. J. Herčík, 2nd half of 19th Century

Рис. 12. Книжные доски, обрезка; яркость 91; контрастность – 17; сдвиг уровня (Книга lbacha Posvátní zvukové, P. J. Herčík, вторая половина 19 в.)

manually repainted outlines. That can be achieved by means of comparison of pictures acquired by various modes. To be able to define at least a little general mode applicable for different sorts of paper, it is necessary to repeat this process in a large number of authentic materials. It is not possible to visualize one filigree for several hours or even days (Schreiner, Holle, 2011; Van, 2003; Van et al., 2006). After this primary testing, where all modes were checked, further testing may be narrowed to several suitable combinations of lightings and filters,

however, it is necessary to take into account that very much different paper always may appear, which will have to be approached individually.

Acknowledgments

This task was performed within the frame of a grant program of the Ministry of Culture of Czech republic in project NAKI with title “Use of imaging techniques for the study of hidden information in book binding” with ID no. DG18P02OVV024.

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