Making the manuscript of Marcel Nadjary, a prisoner of Auschwitz-Birkenau camp, legible using a multispectral imaging method

DOI: 10.36155/NK.24.00004

Tomasz Łojewski
lojewski@agh.edu.pl
ORCID 0000-0003-4012-0405

Mirosław Maciaszczyk
miroslaw.maciaszczyk@auschwitz.org
ORCID 0000-0002-2238-5218

Wojciech Płosa
wojciech.plosa@auschwitz.org
ORCID 0000-0001-5471-7486

notes 24_2022
konserwatorski

Summary: Tomasz Łojewski, Mirosław Maciaszczyk, Wojciech Płosa, *Making the manuscript of Marcel Nadjary, a prisoner of Auschwitz-Birkenau camp, legible using a multispectral imaging method*

The Auschwitz-Birkenau State Museum has the manuscripts of the members of Sonderkommando in its collection. These manuscripts were found near the remains of gas chambers on the site of the former Auschwitz II-Birkenau camp. These manuscripts, in the form of letters or longer notes, are largely illegible or barely legible due to damage (mainly caused by contact with water). In recent years, the Auschwitz-Birkenau State Museum has made several attempts to use multispectral imaging (MSI) to make the notes legible. This publication presents the results of the latest research on the notes of Marcel Nadjary, a member of the Sonderkommando, which were found in 1980 and consist of 12 pages of

text written in the Greek language. In the analysis, an MSI system was used to capture a series of images over 12 wavelengths (from 380 to 940 nm) as well as fluorescence images. The images were analysed using statistical classification methods to find overlapping text elements from many component images of the data matrix. This allowed new images to be created that did not correspond to any single wavelength but that allowed the text elements we were looking for to become visible. In the data analysis, we used the Hoku package – a new IT tool created for the needs of MSI.

The notes of Marcel Nadjary

Among the original documents stored in the collection of the Archive of the Auschwitz-Birkenau State Museum in Oświęcim, is a manuscript authored by Marcel Nadjary, a Jew from Greece, who was a member of the so-called Sonderkommando in KL Auschwitz.

The notes of Marcel Nadjary were found on 24th October 1980 from within the ruins of Crematorium III in Brzezinka at the site of the former KL Auschwitz II-Birkenau. The first attempts to decipher the manuscript did not bring satisfactory results. Large fragments of the text turned out to be illegible because moisture had seriously affected the state of preservation of the pages[1].

What makes this text unique is primarily related to the fate of its author. Marcel Nadjary [Nadjari], born on 1st January 1917, was a soldier of the Greek army. After the occupation of his homeland by the Germans in 1941, he joined the ranks of the communist ELAS guerrilla. In 1943, due to the wounds he sustained, he had to leave his unit and go to Athens to undergo treatment. On 30th December

1 The manuscript of Marcel Nadjary is not the only text authored by a member of the Sonderkommando, which is located in the collection of the Archive of the Auschwitz-Birkenau State Museum in Oświęcim. The museum also has at its disposal the original notes of Zalmen Lewental and the manuscript created by Leib Langfus; the manuscript of Zalman Gradowski is kept in the form of a copy.

1943, he was arrested and imprisoned in an Athenian prison. Then, on 2nd April 1944, he found himself in a group of 2,500 Jewish men, women, and children whom the Germans placed in cattle cars and transported to KL Auschwitz. The transport arrived on 11th April 1944. As a result of the selection, 320 men and 328 women were sent to the camp. In KL Auschwitz, he received prisoner number 182,669. Soon afterwards, he found himself in the Sonderkommando. In January 1945, after the evacuation of the prisoners of KL Auschwitz, he was sent to KL Mauthausen, where he was given prisoner number 119116. From there, he was transported to the Gusen II sub-camp, where he survived until its liberation by the Allies in May 1945.

The author Marcel Nadjary, as one of the members of the Sonderkommando, was a direct witness to the process of mass extermination of Jews who died in the gas chambers of KL Auschwitz II-Birkenau. According to the contents of his manuscript, he was aware of the fate that awaited him due to his membership in the special camp kommando, and this conviction was probably one of the reasons why he documented his experiences. The text of Nadjary, as an eyewitness of the crime, has great historical significance because it allows us to learn the details of the functioning of the machine of mass extermination of Jews in KL Auschwitz-Birkenau. It should be remembered that people employed in the Sonderkommando were strictly isolated from other prisoners so that they could not provide them with any information about the nature of the work for which they found employment[2]. By reading the manuscript authored by Marcel Nadjary, one can easily sense this atmosphere of isolation and confinement. The author also expresses the concern that the atrocities described by him may be unbelievable for a possible future reader of this account. While presenting the killing of people in the gas chambers, Nadjary points out how highly mechanical and well-organised this process was. The members of the Sonderkommando had, among other things, the task of reassuring the newly arrived. The future

2 *Zagłada* [*Mass Murder*], [in:] *Auschwitz 1940–1945. Węzłowe zagadnienia z dziejów obozu* [*Auschwitz 1940–1945: Central Issues in the History of the Camp*], vol. 3, Oświęcim 1997, pp. 163–172.

victims were deceived and informed that they would allegedly be taken to the bathhouse, and that after the bath, in the camp itself, they would reunite with their relatives, with whom they had been separated during an earlier selection on the ramp. The very interior of the gas chamber was also arranged in such a way as to be indistinguishable from a washroom. After all, water pipes and showers were installed under the ceiling, and before going inside, future victims were ordered to undress and leave their clothes and footwear in proper order so that it would be easy to find these items after leaving the bathhouse. While the gas chamber's door was closing behind those condemned to extermination, the SS men began working straight away, pouring Zyklon B pellets inside through special openings in the roof of the building. The author provides first-hand information on the time needed to kill the people crowded in the gas chamber. He also describes how the chamber was ventilated once the killing process was completed and how the corpses were removed and then burned in the crematoria ovens. Nadjary probably wrote the notes on 3rd November 1944, as this date appears in the text. Therefore, this would have happened just after the revolt of the members of the Sonderkommando, which took place on 7th October 1944. On that day, members of the unit employed in Crematoria II and IV, organised in the resistance movement, instigated a fight with the SS men. Three members of the camp staff and 250 Sonderkommando prisoners were killed in the altercation. These events caused the process of mass extermination of Jews in KL Auschwitz-Birkenau to be gradually halted, and the buildings of the gas chambers and crematoria in KL Auschwitz II-Birkenau were successively destroyed by the Nazis themselves to cover up the traces of their crimes.

Against all odds, Marcel Nadjary survived, and the testimony he has written also survived.

The state of preservation of the find

Marcel Nadjary wrote his notes on 12 pages of unprinted paper. The paper was formed from non-coniferous wood pulp using mass production methods.

Sheets sized 20.3 × 27.8 cm were folded in half, perpendicular to the longer side. On the fold line of the sheet, visible lacunae indicate that pages have been torn out of the notebook. All pages show signs of being folded in half, and a stronger splotching can be noticed on the first page. These traces prove that the pages were stored or transported in a folded form for some time.

The main content of the notes was handwritten in the Greek language. The first page, addressed to a potential finder of the notes, was written in three languages – German, Polish and French, and in different handwritings. This attests to the participation and help of other people. Marcel Nadjary used different inks to write the notes, which is supported by the diverse state of their preservation assuming that the destructive factors were the same. A multispectral study showed that at least two types of blue ink were used to write the text, which became visible at different radiation lengths. The author's numbering of pages from 1 to 10 also became visible, written in ink on the upper corners of the pages. The numbering is clearly visible on pages 1, 2, 3, 4, 5, 6, 7, and 10. Numbers 8 and 11 are faintly visible, but numbers 9 and 12 were not found – they could have probably been marked in places where the paper was destroyed. Marcel Nadjary wrote the date on the upper part of the second page: 3/11/44.

The author of the notes placed them in a glass flask wrapped in a leather case (photo 1). The documents were found at a depth of about 30 cm underground. The flask in which they were located was cracked and did not constitute protection from water, so the notes were exposed to moisture for a very long time. High dampness created favourable conditions for the development of microorganisms, and long-term exposure to water and dampness, combined with periodic freezing and unfreezing of the documents, caused physical and chemical damage to the paper – weakening its structure and creating cracks. Water contributed not only to the damage of the paper substrate but also to the irreversible smudging of the inks and their migration through the adjacent pages. As a result, the written text is mostly illegible. Out of past attempts to decipher it, the researcher Pavel Polian obtained the best results[3].

In 2004, the found notes were subjected to conservation treatments aimed at securing the integrity of the documents and slowing down the natural processes of paper degradation. The surface of the paper was gently cleaned of dirt using brushes and a cleaning powder. The paper was strengthened and deacidified by applying a water solution of magnesium bicarbonate with the addition of methylcellulose from an airbrush. Tears in the paper were glued underneath with Japanese paper by applying starch glue. The notes have been stored in constant humidity and temperature conditions in dust covers and a folder made of acid-free paper.

Photo 1.
Case and flask in which the notebook of Marcel Nadjary was found

3 P. Polian, *Das Ungelesene lesen. Die Aufzeichnungen von Marcel Nadjari, Mitglied des jüdischen Sonderkommandos von Auschwitz-Birkenau, und ihre Erschließung*, "Vierteljahrshefte für Zeitgeschichte" 2017, no. 65, pp. 597–618.

Multispectral imaging

The smudging of lines of text on notebook pages often makes it impossible to decipher the majority of the contents. Therefore, to make the remnants of ink lines blurred by water legible, a multispectral imaging (MSI) method was used. This technique is widely used in the analysis of heritage objects, including in deciphering the contents of damaged documents or documents deliberately rendered unreadable. For a more comprehensive description of how to capture component multispectral images and process them further, see paper[4]. Examples of the most known and successful use of this technique include the deciphering of the Archimedes Palimpsest[5] and David Livingstone's faded notes[6]. However, MSI is not the only method used to decipher illegible texts – charred papyri from Herculaneum were digitally developed and deciphered using the X-ray microtomography method[7], and Marie-Antoinette's secret correspondence was deciphered using an XRF scanner[8]. In the years 2013–2022, the

4 C. Jones, C. Duffy, A. Gibson, M. Terras, *Understanding multispectral imaging of cultural heritage: Determining best practice in MSI analysis of historical artefacts,* "Journal of Cultural Heritage" 2020, vol. 45, pp. 339–350; A. Tonazzini, et al., *Analytical and mathematical methods for revealing hidden details in ancient manuscripts and paintings: a review*, "Journal of Advanced Research" 2019, vol. 17, pp. 31–42; A. Cosentino, *Identification of pigments by multispectral imaging; a flowchart method*, "Heritage Science" 2014, vol. 2 (8), pp. 1–12; M. Picollo, C. Cucci, A. Casini, L. Stefani, *Hyper-Spectral Imaging Technique in the Cultural Heritage Field: New Possible Scenarios*, "Sensors" 2020, vol. 20 (10), pp. 2843: 1–13.

5 K. T. Knox, *Enhancement of overwritten text in the Archimedes Palimpsest*, [in:] *Computer Image Analysis in the Study of Art (D. G. Stork and J. Coddington)*, San Jose, CA, USA, Proc. SPIE, vol. 6810, 2007.

6 K. T. Knox, R. L. Easton Jr., W. A. Christens-Barry, K. Boydston, *Recovery of handwritten text from the diaries and papers of David Livingstone*, "Computer Vision and Image Analysis of Art II" 2011, vol. 7869, pp. 786909: 1–9.

7 I. Bukreeva et al., *Virtual unrolling and deciphering of Herculaneum papyri by X-ray phase-contrast tomography*, "Scientific Reports" 2016, vol. 6, pp. 27227: 1–6.

8 A. Michelin, F. Pottierand, C. Andraud, *2D macro-XRF to reveal redacted sections of French queen Marie-Antoinette secret correspondence with Swedish count Axel von Fersen*, "Science Advances" 2021, vol. 7 (40), pp. eabg4266: 1–9.

authors of the current paper have made several attempts[9] using MSI, in which the MSI equipment configurations listed below were used.

There are several ways to obtain multispectral images. These can be divided into two basic groups – scanning systems with simultaneous recording of all spectral channels and single-channel recording one by one. In this first case, it is possible, after proper processing of the recorded data, to obtain hundreds of images corresponding to different wavelengths in the examined range, and in the case of the equipment described in a previous paper[10], it was more than three hundred component images. Such a large amount of information allows the selection of a particular place in the image to obtain its spectrum (reflectance), which in some cases opens the way to its chemical identification. Scanning systems, however, have disadvantages that hinder their use in the area of artefact analysis: large size of the equipment (lack of mobility), significantly worse image quality for the extreme parts of the spectral range in which the matrix is sensitive (for CCD/CMOS cameras with a silicon matrix, this means noisy images in the ultraviolet – UV and infrared range), low geometric resolution of the obtained images (usually 1–2 MP) and the inability to capture fluorescence images.

During the capture of separate photos corresponding to subsequent wavelengths, it is possible to set the exposure parameters individually and optimise it to the dynamic range of the camera sensor. As a result, the quality of images for all wavelengths is very good (high signal-to-noise ratio), and additionally – due to the high resolution of currently available industrial cameras – single images can be 4, 20 or even over 60 MP. These values are not accidental because they correspond to the configurations of the MSI equipment used by the authors of

9 Previous results have been published in *Marcel Nadjari's Manuscript November 3, 1944. Conservation and legibility enhancement through multispectral imaging*, the Auschwitz--Birkenau State Museum in Oświęcim, Oświęcim 2020.

10 D. K. Chlebda, T. Łojewski, *Obrazowanie hiperspektralne w analizie dokumentów i konserwacji sztuki* [*Hyperspectral Imaging in the Analysis of Documents and in Art Conservation*], "Notes Konserwatorski" 2016, no. 18, pp. 55–75.

this paper to analyse M. Nadjary's manuscript. Capturing a photo for a narrow spectral range requires the use of band-pass filters on the camera (i.e., those that transmit light of a narrow, strictly defined range of wavelengths, called *band--pass*) or a system of lamps that allows the object to be illuminated with the light of a selected wavelength. The authors used both of these methods.

Photo 2.
Multispectral capture of the notebook pages (photo by Mirosław Maciaszczyk)

Capture and analysis of multispectral images

Equipment configuration

The multispectral images shown in the further part of the publication were captured with a set consisting of the following elements (photo 2):

- a system of LED lamps allowing 12 wavelength bands to be obtained in the range of 382–940 nm;
- a full-spectrum, monochrome, cooled CMOS camera with a Sony IMX455 sensor and a resolution of 61 MP (9568×6380 px);
- a motorised filter wheel with filters for capturing fluorescence images;
- an apochromatic lens in the entire used spectral range (UV-VIS-IR 60 mm 1:4 APO Macro produced by Jenoptik).

Due to the use of the above-mentioned lens, it was not necessary to adjust the focus when switching from UV, through visible light, to infrared, and the obtained images did not require time-consuming adjustment of dimensions and shifts for a series of photos (registration).

For subsequent pages of the manuscript, reflectograms were made at 12 wavelengths 382, 405, 420, 455, 500, 523, 598, 630, 665, 734, 850, and 940 nm. Additionally, fluorescence images were captured for each page by placing a filter cutting off the radiation above the selected wavelength between the camera and the lens. LRGB CMOS filters produced by Baader were used, and their transmittance cut-off points corresponded to the wavelengths 395 (B), 410 (UV), 485 (G), and 590 nm (R) (these letters are used later in the text). A total of about 10 fluorescence images were captured for each page of the manuscript, illuminating them with radiation of a wavelength from 382 to 523 nm through an appropriate selection of filters.

Photos with a resolution of 16 bits were saved in tiff format. The size of a single file was 122 Mb. Therefore, the simultaneous processing of 20 channels of this size was a serious computing challenge. A computer with a new generation processor (Intel i7 12 generation) and fast RAM memory (DDR5) along with the specialised software described below were used to develop the results.

Software used

Two specialised software programs were used to process the MSI images: ENVI (Exelis Inc.) and Hoku (Keith Knox/Rochester Institute of Technology).

ENVI software, available on the market since 1994, has a dominant position among software used in the analysis of multispectral images (mainly satellite ones) and is widely used in the analysis of heritage images because it offers several advanced methods for statistical image analysis. Hoku package is an emerging product designed to make palimpsests and other undecipherable manuscripts legible through MSI analysis. This package is now available for testing by experts who research heritage objects. The package is and, according to its creator's declarations, will remain free (GNU license). In the opinion of the authors of this article, the availability of free high-quality software for the analysis of multispectral heritage images may be of great importance for the popularisation of this technique because it significantly reduces the costs of an entire MSI station and the threshold of difficulty in mastering the data processing. (ENVI software is expensive and difficult to use.)

Hoku is a Java-based software package that runs on all popular operating systems (Windows, Mac OS X, Linux). The package is available for download on the creator's website[11] along with instructional videos (in the English language) and a comprehensive description that introduce the issue of making manuscripts legible and the usage of the package's subsequent functions. The graphical user interface of the Hoku package looks different than in most other popular programs. After launching Hoku, a window is displayed, which is divided into three sections: *Cupboard*, *Desktop,* and *Shelf*. The *Cupboard* section contains all the procedures for opening, displaying, processing, and saving graphic files. The user creates his own data processing algorithm by transferring appropriate procedures from the *Cupboard* area to the *Desktop* area and combining them into a logical sequence that can be saved under a proper name and transferred to the *Shelf* area for future use. An example that does not require further explanation is the sequence *ReadImage – Rotate – Sharpen – Show – WriteImage*. For each of the component procedures, the user defines all the relevant parameters himself. By combining the approximately 35 available

11 http://www.cis.rit.edu/~ktkpci/Hoku.html.

procedures, very complex algorithms adapted to a specific task can be created. Some advanced methods of statistical analysis (e.g., the method of *Principal Component Analysis* – PCA and that of *Spectral Angle Mapper*) and a perfectly working tool for image registration are already available in the package. Macro creation options allow the ability to speed up and automate a workflow when developing a series of MSI images of a similar nature (e.g., subsequent pages of the same manuscript).

Due to its original structure, the Hoku package may seem difficult to master for a novice user. After a short time, however, a user becomes proficient in constructing ready-made tasks and creating a collection of his own algorithms, which can be used later when starting to analyse subsequent MSI images.

During the image processing of Marcel Nadjary's notebook, the following methods were used to increase the legibility of the text:

- the creation of false-colour images by selecting three spectral channels or fluorescence images in which the lines of text were the most visible;
- statistical analysis of selected spectral channels of the most visible text using PCA, MNF (*Minimal Noise Fraction*), and ICA (*Independent Component Analysis*) methods, selection of newly created channels and creation of an image in false colours.

In the infrared range, the text written in blue ink with organic pigment(s) was disappearing, and at 850 and 940 nm, most lines of the text stopped being visible on the image of the pages. In UV reflectography, only clear marks were visible. The contrast between the substrate and the ink was low, and this method did not give useful results for poorly visible fragments. UV fluorescence also did not make the invisible lines legible, although the contrast between the substrate and the ink improved. The best legibility results were obtained for fluorescence induced by green light (i.e., light of 523 nm), image capture >590 nm (R filter), and on reflectograms captured with illumination by red light (598, 630, and 665 nm). In comparison to the reflectograms obtained in red light, the stains on the pages were less visible on the fluorescence images of type 523/590.

Exemplary legibility results

The captured photos with the greatest legibility and the new monochromatic images generated as a result of the statistical analysis formed the basis (called a data cube) for creating a large number of false-colour images. Usually, there is no one way to combine these images that is clearly more legible than the others – for one combination of spectral channels, a fragment may be more visible, but it may be less legible on other combinations. The results obtained for three pages: 1, 3, and 13, are shown below, and similar results were obtained for the remaining pages of the document. The illustrations show ordinary photographic reproductions recorded in visible light and a selected false-colour image, where significant progress was achieved in making the text visible. The fact that the document (except for the first page) is written in the Greek language (which the authors do not know) hindered the work – if we knew the original language, we could guess the illegible letters, words, and sometimes even whole phrases and work on deciphering individual fragments, the visibility of which is necessary to learn the contents.

As a result of the exposure to water, the ink from the second page was transferred to the first page, creating dark stripes and the visible shape of Greek letters in a mirror image. This made it difficult to decipher the original lines of text (photo 3). After making it legible, in the middle part of the first page, we could read the words written in Polish (letters still invisible are placed in parentheses): *Bardzo proszę niniejszy (lis)t doręczyć najbliższemu konsulowi Grecji.* [*Please deliver this (lette)r to the nearest Greek Consul.*]

For pages 3 and 13 (photos 4 and 5), we managed to achieve very good legibility of the contents, and the new channels obtained after statistical processing were particularly useful.

Summary

The results of making Marcel Nadjary's notebook pages legible despite their damage by water are an example of the possible techniques we have at our disposal today in the documentation and analysis of historical documents. Due to the development of technical measures (cameras and multispectral lighting) and software dedicated to MSI analysis, it is possible to recover previously unknown information from objects that have been destroyed or on which text has been intentionally crossed out or removed (e.g., palimpsests). Imaging is a non-invasive method, and the equipment can be easily transported to the place where the object is located. The only technical requirement is access to a darkened room during the capture.

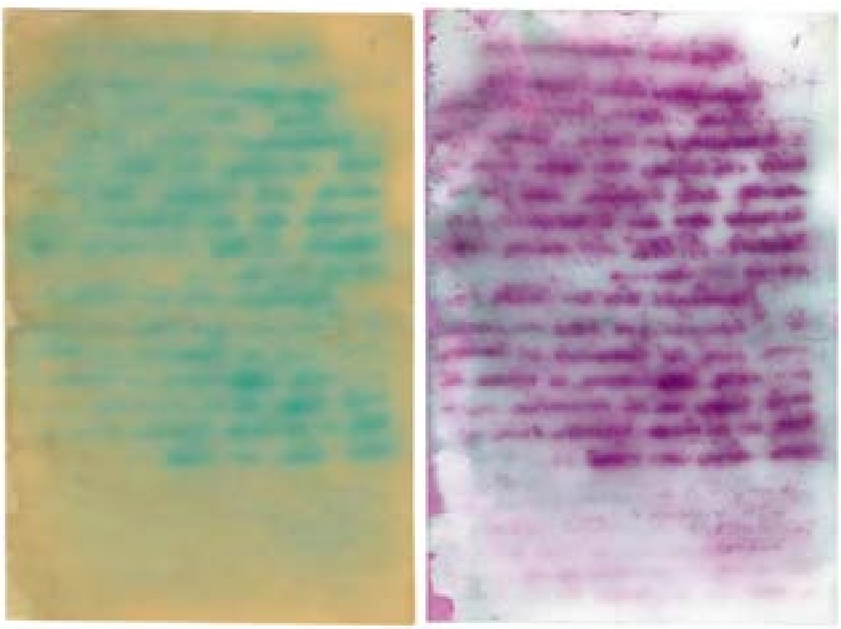

Photo 3.
Page 1 of Marcel Nadjary's notebook: original appearance – scan (left) and after making the text legible (a false-colour image composed of channels generated in the MNF analysis)

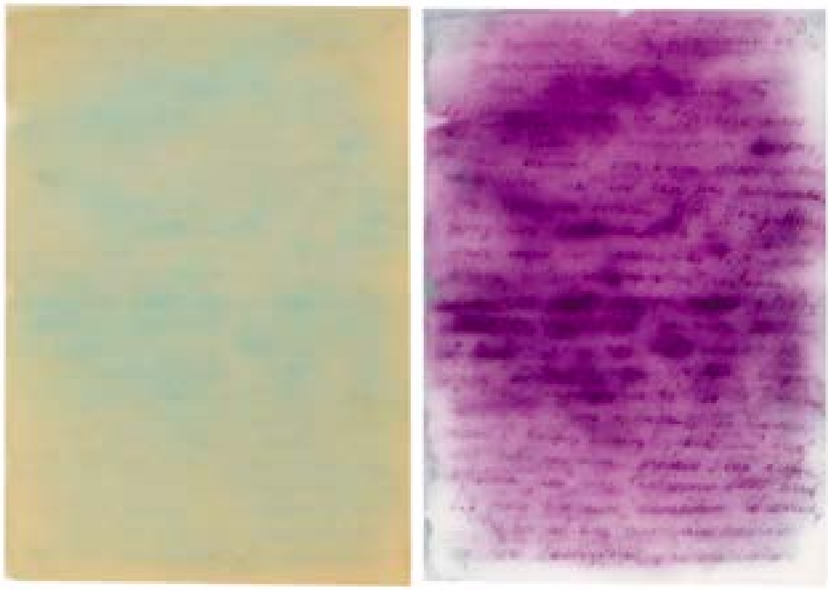

Photo 4.
Page 3 of Marcel Nadjary's notebook: original appearance – scan (left) and after making the text legible (a false-colour image composed of channels generated in the MNF analysis)

Photo 5.
Page 13 of Marcel Nadjary's notebook: original appearance – scan (left) and after making the text legible (a false-colour image composed of channels generated in the MNF and ICA analyses)

Translated by
Aleksandra Leśniewska