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EXPLORING ARTIFICIAL INTELLIGENCE CHALLENGES IN THE DIGITIZATION OF TECHNICAL DOCUMENTATION: A PRELIMINARY STUDY[6]

Abstract

Introduction: *The study investigates the challenges of preserving corporate technical documentation. It explores artificial intelligence's potential to transform archival material for better utilization.*

Methods: *The research conducts an overview of regulations governing the preservation of corporate archival material and a pilot study on digitized technical documents from the Regional Archives Maribor, aiming to establish foundational practices for artificial intelligence's processing of technical documentation.*

Results: *Preliminary results indicate artificial intelligence's effectiveness in enhancing digitized technical heritage material. The study identified possible threshold indicators for the baseline quality of digitized documents that ensure artificial intelligence can process the data authentically.*

Discussion: *The findings suggest that while artificial intelligence can significantly improve borderline usable material, it cannot assist with unreadable originals. The study emphasizes the importance of selecting appropriate artificial intelligence models and maintaining human oversight in the process.*

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1 INTRODUCTION

There has yet to be a particular focus on preserving corporate archival material in developed market economies. The responsibility for maintaining and utilizing such material typically falls under the responsibility of its creator, who also holds exclusive ownership rights. In most cases, however, these creators represent economic entities. Technical documentation, including plans, bills of materials, catalogues, drawings, notes, sketches, etc., forms a crucial part of this corporate archival material.

We possess a significant volume of technical documentation in the Republic of Slovenia before 1990. During that period, legislation mandated that socially-owned companies transfer their respective archival materials to the relevant archives. However, post-1990, the approach to corporate archival material, including technical documentation, underwent a transformation after the shift to private ownership. Unlike before, it no longer receives comprehensive state protection. Instead, the responsibility for safeguarding it is largely entrusted to the respective economic entities. Acquiring this documentation, transferring it to the archives and digitizing it are very important tasks. In such tasks, archivists also face the challenge of scanning large document formats that are difficult to scan at sufficient resolution.

The rapid development of machine learning is transforming the way we utilize archival material. Machine learning algorithms require extensive data for their training and to produce user-desired results. With old, historical technical documentation[7], we encounter challenges due to a shortage of reliable information in the form of an insufficient volume that would provide enough data for machine processing.

The current research serves as a pilot or preliminary study focusing on the digitization of technical documentation. Its primary objective is to lay the groundwork for the way for further subsequent research and practical applications, facilitating the authentic manipulation of digitized material within a virtual environment. The study examines the utilization of digital tools through a sample of digitized technical heritage material from the *Pokrajinski arhiv Maribor*. Our aim is to

7 In the upcoming sections of this paper, we will regard technical documentation as part of the visual material.

identify the threshold values in the digitization of image material, ensuring that artificial intelligence, in its broadest sense, can authentically process the data.

The paper is structured as follows. In the second chapter, we provide a brief overview of the challenge related to the availability of a sufficient amount of authentic technical documentation (as corporate archival material). This sets the stage for understanding the dimensions of the challenge. Moving on to Chapter 3, we examine in detail the development and procedures of image enhancement using artificial intelligence (AI) algorithms. We also provide a brief overview of other algorithms facilitating the processing of information, including objects and text, present on visual material. Chapter 4 details the methodology of our work, outlining the approach to processing visual material at the limit values of document scanning for our pilot research. In Chapter 5, we present the preliminary results and draw broader conclusions regarding the appropriateness of utilizing AI on the mentioned problem, taking into account various circumstances.

2 A BRIEF OVERVIEW OF REGULATIONS GOVERNING THE PRESERVATION OF CORPORATE ARCHIVAL MATERIAL IN SELECT MARKET ECONOMY NATIONS

Established in 1948, the International Council on Archives is a global organization dedicated to promoting awareness and preservation of archival material worldwide. Within this institution, the Section on Business Archives, founded in 1990, focuses on the global preservation and utilization of corporate archival material. The third edition of the study 'Business Archives in International Studies (2021),' edited by Alison Turton, provides an overview of business archives in twenty-one reference countries, following a country-by-country review presented by experts. The study traces the evolving awareness of corporate archival materials, beginning in the United States.

In numerous countries, diverse approaches to the preservation of corporate archival material are evident. Lasewicz and Ryan (2021) highlight, for instance, that despite groundbreaking developments in the USA, programs for preserving and utilizing such material primarily support private economic entities, given the absence of specific legislation in this field. In Sweden, efforts to preserve corporate archival material date back to 1698, gaining momentum after 1870 during a period of robust industrial development, as observed by Gidlöf and Sjöman (2021).

However, specific legislation for corporate archival material is still lacking in Sweden. Turning to Italy, a substantial shift in the perception of the importance of corporate archival material has occurred over the last thirty years, particularly post-World War II. This evolution in Italy is evident through the establishment of associations, the initiation of archivist courses, and the creation of regional business archives, as outlined by Del Giudice (2021). Austria, on the other hand, displays a diversity of approaches, with Rigele (2021) noting the emergence of numerous corporate archives in private companies over the last twenty-five years, despite the absence of a specific state strategy for this domain. In contrast, China stands out with an exponential breakthrough in corporate archival material management since the establishment of the National Archives Administration in 1954, emphasizing centralization, standardization of management, and information transformation, as detailed by Yingfang and Rui (2021). China has successfully implemented an effective mechanism for controlling corporate archival material, including a comprehensive digitization initiative since 2014, extending to broader applications in data storage.

3 IMPROVING IMAGES USING AI: DEVELOPMENT AND TECHNIQUES

The evolution of image processing, starting in the mid-1950s, unfolds through general-purpose approaches and technological constraints of the late 1960s. During this era, a pursuit of optimizing images through synthetic additions emerged, complemented by the development of multiprocessor computer concepts and subsequent advancements in processor and memory technology. These innovations lay the foundation for contemporary applications in home computers and digital cameras (Rosenfeld, 1969).

As technology advances, the integration of AI becomes a driving force in ongoing endeavors for document content analysis, improvement, and recognition. In recent years, AI has emerged as one of the most rapidly advancing scientific techniques with practical applications (Anantrasirichai and Bull, 2022). Nevertheless, these efforts are also notable for contributions from various events such as the International Document Image Binarization Contest, as well as conferences like ICDAR and ICFHR (Philips and Tabrizi, 2020).

Artificial neural networks were initially explored for processing raster image material, particularly for scaling, as early as 1997 (Plaziac, 1999). Two algorithms were tested, yielding positive results (ibid.). However, at that time, the technology was deemed insufficiently powerful for widespread use, as the process was slow and overly memory-intensive (ibid.). Remarkably, over the last decade, technological advancements have made the technology more potent and accessible, leading to a surge in methods rooted in AI and machine learning (ML).

3.1 ENHANCE INFORMATION CONTENT USING NEURAL NETWORKS

The information-theoretic concept of inequality in data processing asserts that isolated local processing cannot augment the information content. This aligns with the objective of our study to enlarge images—extracting more details from limited data points. To compensate for missing information, AI or ML algorithms leverage (augment) knowledge gained during the learning process on numerous samples. Figure 1 illustrates how a neural network enlarges an image by applying acquired knowledge.

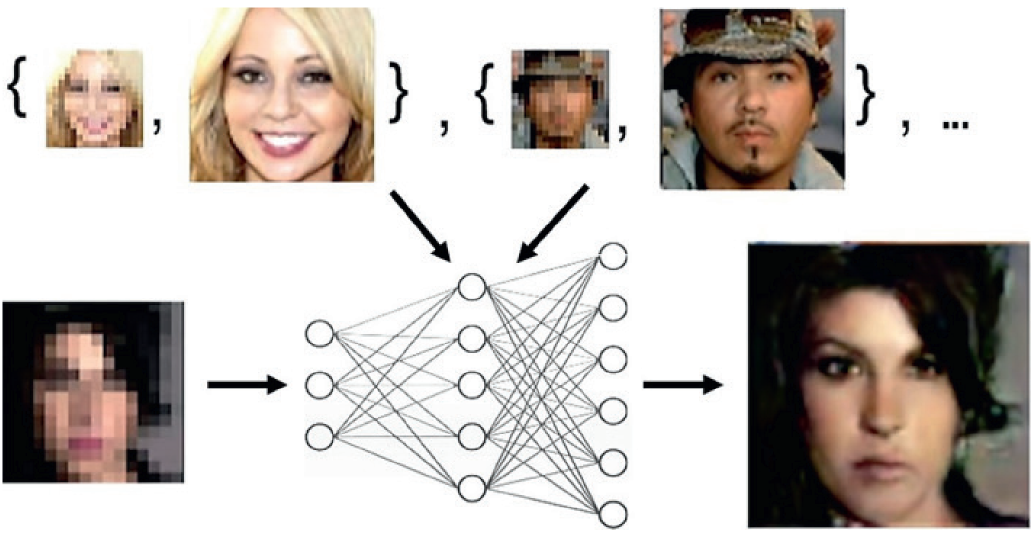

Figure 1: Schematic representation of the use of an artificial neural network for image enlargement (adapted from Litt, 2017).

In the subsequent Figure 2, we can discern the distinction between bicubic interpolation (classical approaches) and AI zoom. The first column displays the downscaled original, the second column showcases the bicubic interpolation method, the third column demonstrates AI results, and the last column presents the original image.

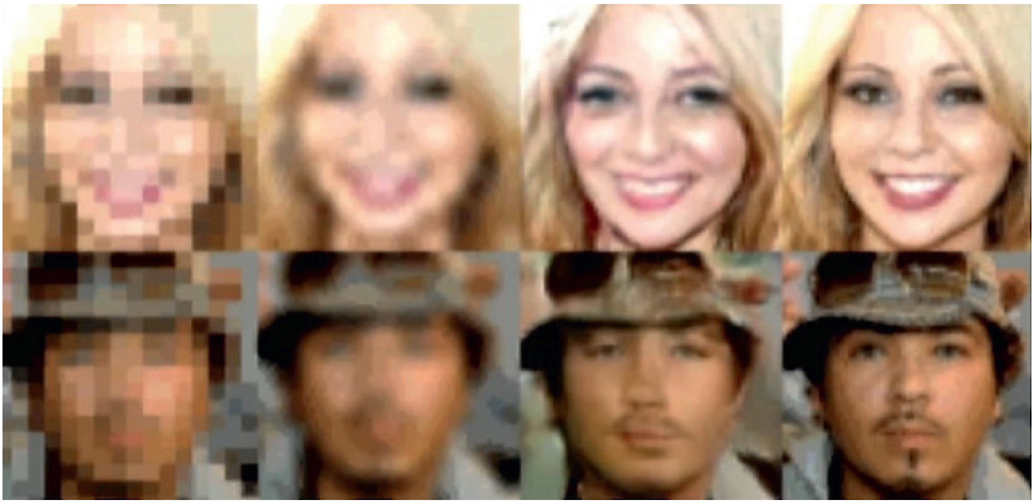

Figure 2: Differences between resolution enhancement algorithms (downscaled original, bicubic enlargement, AI zoom, original) (Litt, 2017).

The enhancement provided by AI algorithms to the zoomed image's perceived quality is evident. However, a noticeable distinction arises between the third and fourth columns. While the AI-generated image appears convincing, it's crucial to note that all additional details are essentially speculative, introduced through an educated guess.

The initial neural networks, assessing augmentation quality through basic error minimization algorithms during the learning process, showed subpar performance (Litt, 2017). However, in 2014, generative adversarial neural networks (GAN) emerged, featuring two components—the generator and the discriminator—alternating in the scaling process (Goodfellow et al., 2014). The generator produces enlargements, and the discriminator assesses the appropriateness of the result. Both components learn their procedures during the learning process. Each image enlargement involves an iterative cycle of proposals and rejections, sometimes spanning several hundred repetitions. Yet, this iterative process yields remarkably impressive results (Litt, 2017; Isikdogan, 2019). Such neural networks can generate a substantial amount of information, producing convincingly effective outcomes.

Enhanced digitized technical documentation, as detailed in the preceding chapters, opens up new possibilities for leveraging information from image material. Although these procedures are still in their early stages, the fields of construction and architecture are witnessing initial efforts to employ artificial intelligence tools for interpreting and analyzing building plans. These efforts encompass vectorization, segmentation, and the perception of building plans presented as visual material (Paudel, Dhakal, and Bhattarai, 2021).

The latest implementations of AI utilize various algorithms, including Support Vector Machine (SVM), Generative Adversarial Network (GAN), Convolution Neural Network (CNN) and Deep Neural Network (DNN). However, researchers encounter a scarcity of visual material, such as plans of rooms, buildings, machines, etc., which hinders mass data processing and consequently slows down machine learning with the aforementioned AI algorithms (Chen, Ye, Milne, Hillier, and Oglesby, 2022).

4 RESEARCH METHOD

In our preliminary research, we used large technical heritage blueprints scanned at 100 DPI (dots per inch). These plans contain valuable information about historical buildings and facilities in Maribor in different time periods. In some cases, plans are difficult to read and distinguish due to the low resolution.

We examined the potential enhancement of documents through AI-based general-purpose tools, aiming to assess the outcomes and identify the parameters influencing result quality. Our chosen general-purpose tools were selected with following consideration:

- They are the most accessible, both to creators and archives. Some are available as online services where we can quickly check the options they offer.
- AI algorithms are built into the filters of general-purpose graphics software or offered as stand-alone applications that also offer easy testing.
- They are developing at the fastest pace. By using these, the user is sure that he is using the most advanced technology possible and has the feeling that he is using a tool that offers the best possible.
- Not at last users learn to use general-purpose tools the easiest and fastest, as various educational content is available for them in the form of different and easily accessible manuals in a wide variety of formats.

Figure 3 below illustrates our initial experimentation on a scaled segment of the plan, featuring a signature and stamp. The first image presents a reduced original (to accentuate the issue), the second image depicts its enlargement using classic filters in the Photoshop application, and the third image showcases an enlargement created with the Topaz GigapixelAI software, consistently utilized in all subsequent tests. It becomes evident that the last image is visually the most appealing.

Figure 3: Reduced original (50 DPI), classic (Photoshop) zoom, AI zoom (Topaz Photo AI).

4.1 DESCRIPTION OF THE MATERIAL

The selection contains 500 plans with a resolution of 100 DPI. For the test, we selected two plans (Figure 4 and 5) from the technical documentation, where the insufficient resolution of the scan came to the fore and on which we had problems reading the inscriptions and distinguishing the details.

1. SI_PAM_0011_044_00005-060a

Dimensions: 147.22 cm by 105.69 cm at 100 DPI

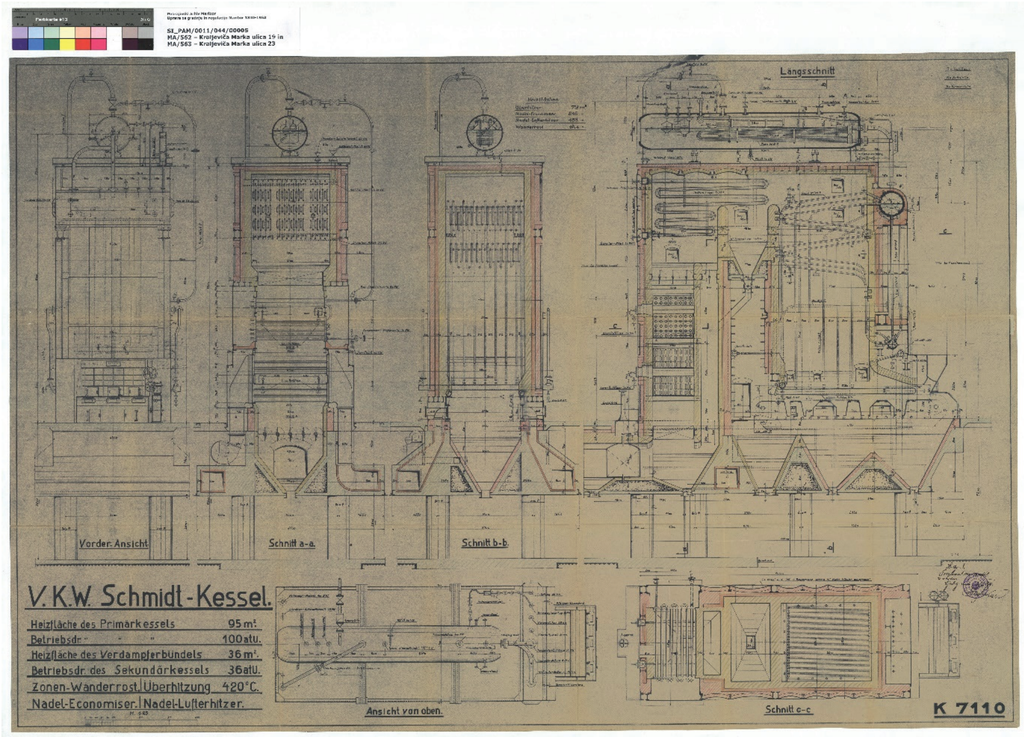

Figure 4: First plan.

Remarks on the sample: The plan is conditionally readable, on problematic parts (folds) it turns out that 100 DPI does not allow reliable data processing. An experienced machinist would probably be able to correctly read or guess all the values and inscriptions.

2. SI_PAM_0011_044_00005-062a

Dimensions: 121.46 cm by 93.17 cm at 100 DPI

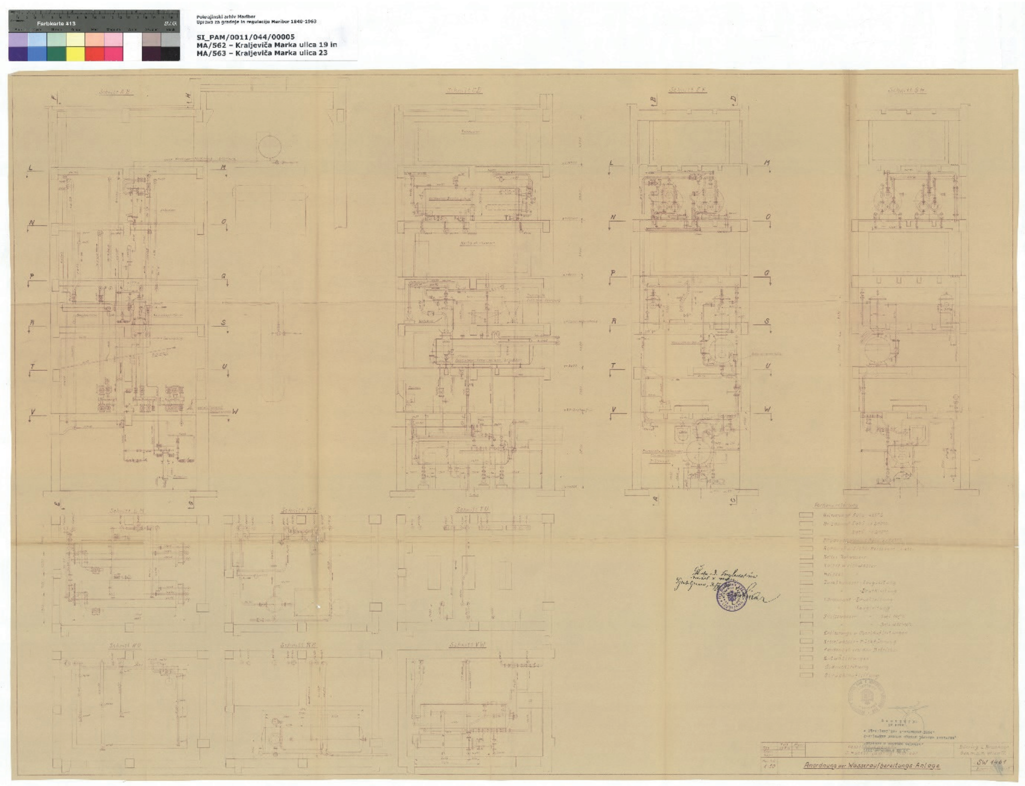

Figure 5: Second plan.

Remarks on the sample: The plan is not sufficiently readable. It suffers from insufficient scanning resolution and poor contrast of the original.

4.2 SIMULATION OF EVEN WORSE INPUT MATERIAL

In order to simulate an even worse situation than the given one, we selected some details on each of these two plans and lowered their resolution from 100 DPI to 75 DPI and 50 DPI. The following Figure 6 shows all selected cropped details.

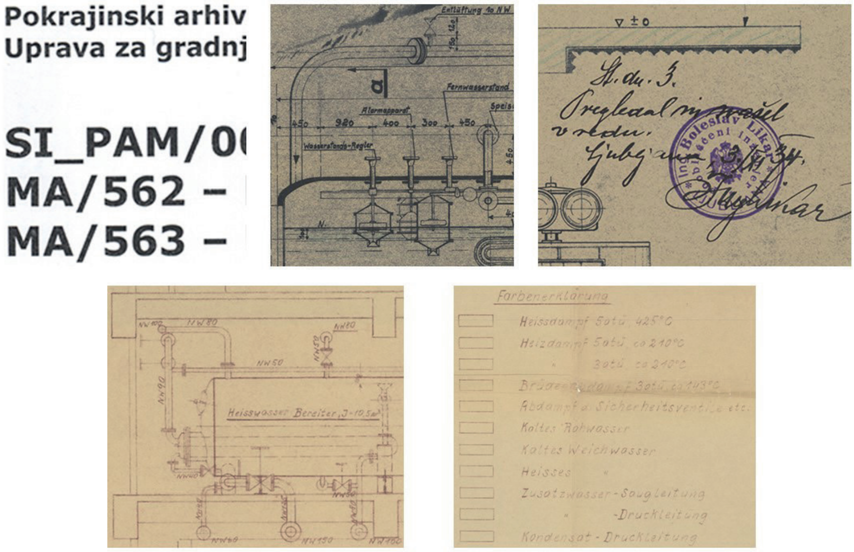

Figure 6: Cropped details of both samples (subsamples 1–5).

4.3 SELECTION OF SCALER AND SELECTION OF AI MODEL

The array of software designed to enhance image resolution is extensive and diverse. Image enlargement is a standard feature in almost all graphic processing tools, and the spectrum of online services is even broader. In recent years, specialized applications focusing on upscaling, sharpening, and noise removal have emerged. For our AI scaler, we opted for the widely advertised solution in 2023, Topaz Gigapixel AI.

Next, we needed to determine which scaling model within the application yielded the most convincing results. The software provides six models, each tailored to specific material types as defined by the equipment manufacturer:

1. Standard (Description in the application: Best choice across various images, suitable for all photography but may cause artifacts with fur and feathers).
2. Lines (Description in the application: Previously called "Architecture," ideal for architecture, cityscapes, typography, and images with thick lines).
3. Art & CG (Description in the application: Suited for any non-photographic image, including computer graphics, art, drawings, or scans).
4. HQ (Description in the application: Optimal for high-quality images from modern cameras, particularly those with many details and few compression artifacts, or as a final step after denoising and sharpening).

5. LowRes (Description in the application: Previously called "Compressed," recommended for images with blocky compression artifacts, preserving more detail than the Very Compressed model).
6. Very Compressed (Description in the application: Ideal for images with significant compression artifacts, such as small-sized, scanned, or old digital images).

We selected the Art & CG model, tailored for our use cases, and this choice was visually validated through a detail comparison. The distinctions between the models are illustrated below in Figure 7.

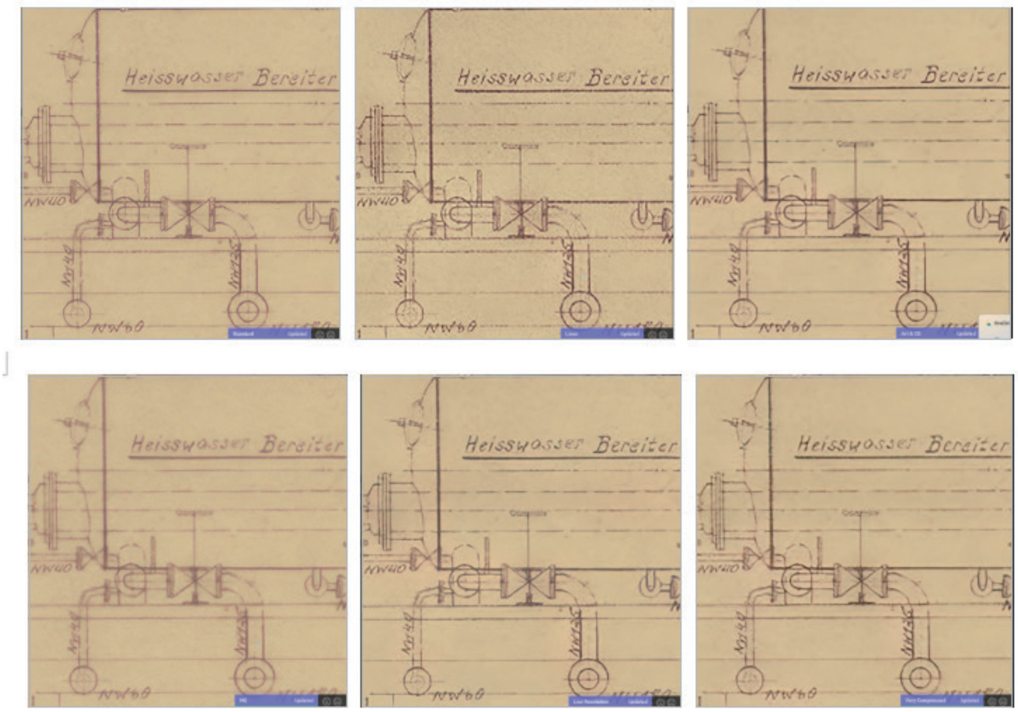

Figure 7: Differences between AI zoom models (1 to 6) offered by the software.

5 RESULTS

In the following, we present in more detail the results of the material processing trial at different source DPI.

Subsample 1 processing

Results in short: A dramatic improvement in visual image and readability can be seen. Enlarging the printed text is no problem for the AI model. There are no defects, or they are not noticeable. Figures 8–10 shows original subsample at 50, 75 and 100 DPI and processed by AI model next to it.

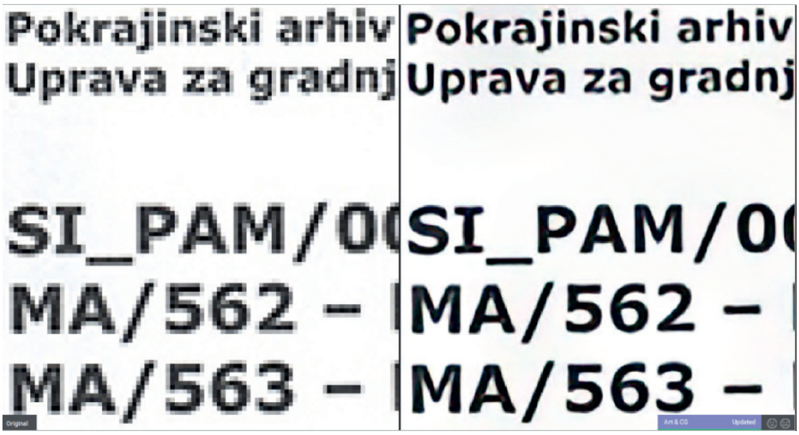

Figure 8: Subsample 1 at 50 DPI

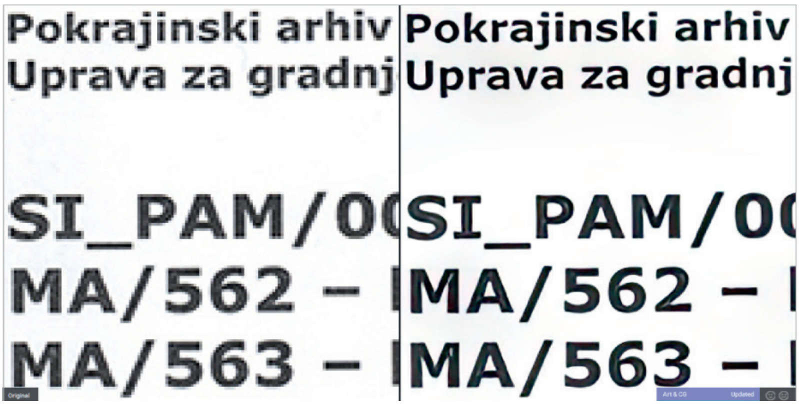

Figure 9: Subsample 1 at 75 DPI

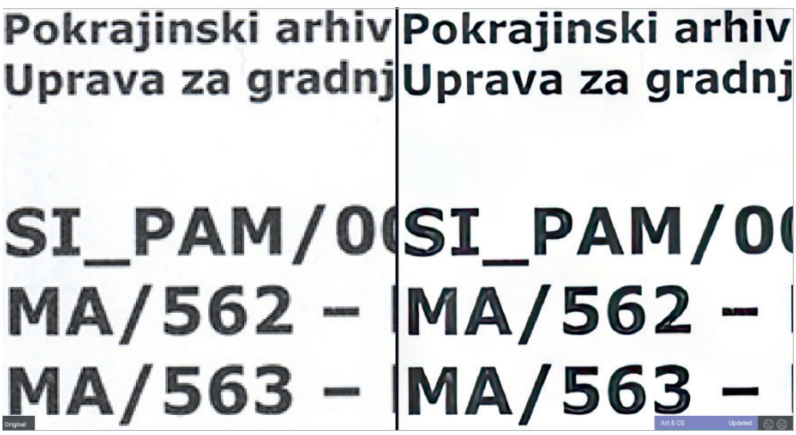

Figure 10: Subsample 1 at 100 DPI

Subsample 2 processing

Results in short: It can be seen that the readability of the plan increased slightly at the lowest resolution (50 DPI), where the model also tried to remove background noise. In the other two samples (75, 100 DPI), the improvement is obvious and almost flawless. Figures 11–13 shows original subsample at 50, 75 and 100 DPI and processed by AI model next to it.

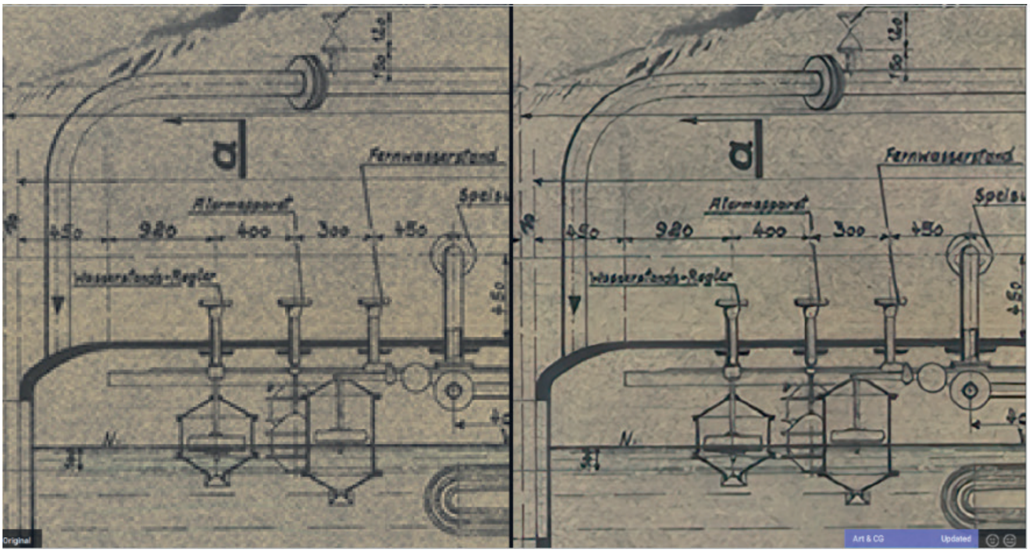

Figure 11: Subsample 2 at 50 DPI

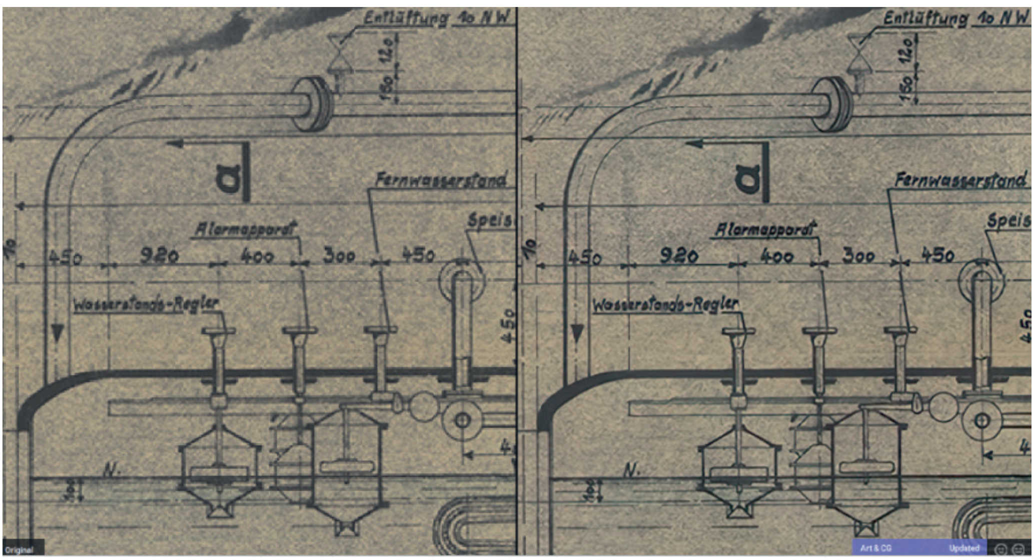

Figure 12: Subsample 2 at 75 DPI

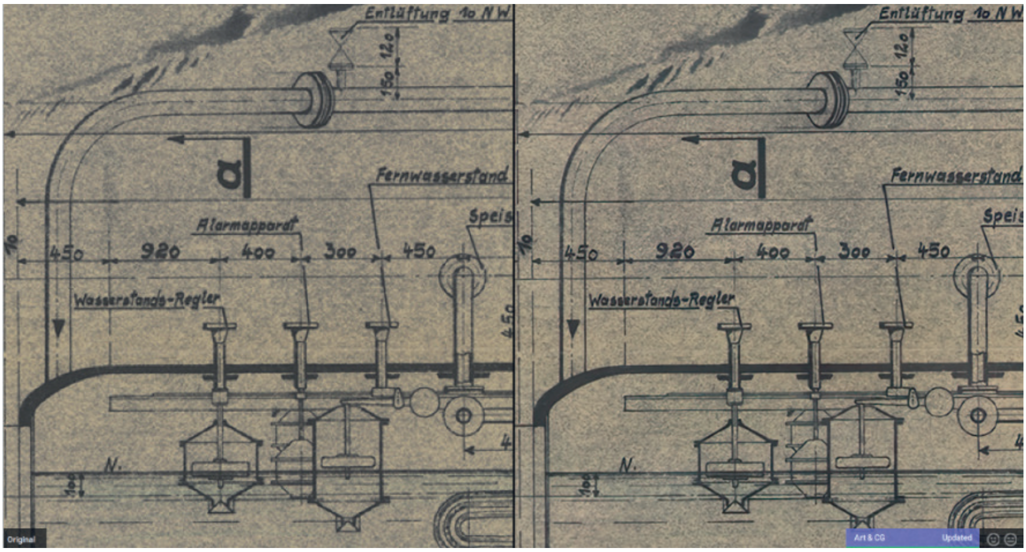

Figure 13: Subsample 2 at 100 DPI:

Subsample 3 processing

Results in short: In all three cases, background noise removal is noticeable. The written text has become suitably smoothed when zoomed in, and the inscriptions in the stamps are even easier to read. Figures 14–16 shows original subsample at 50, 75 and 100 DPI and processed by AI model next to it.

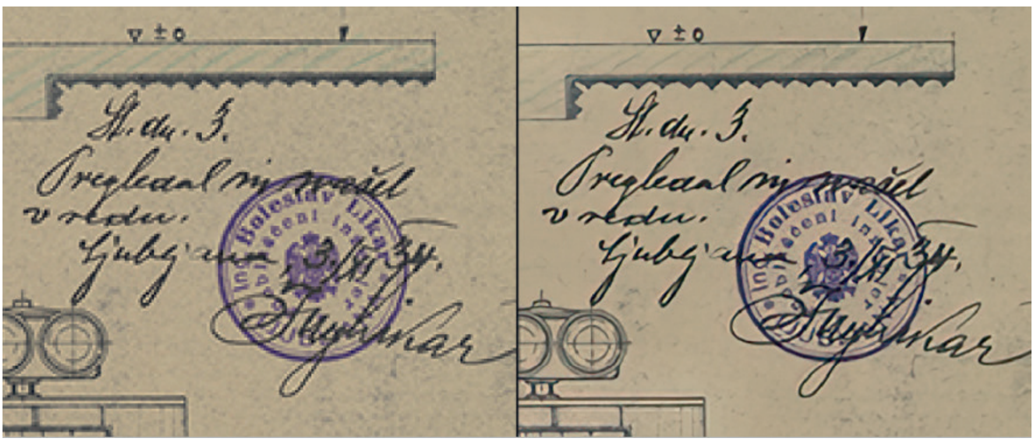

Figure 14: Subsample 3 at 50 DPI.

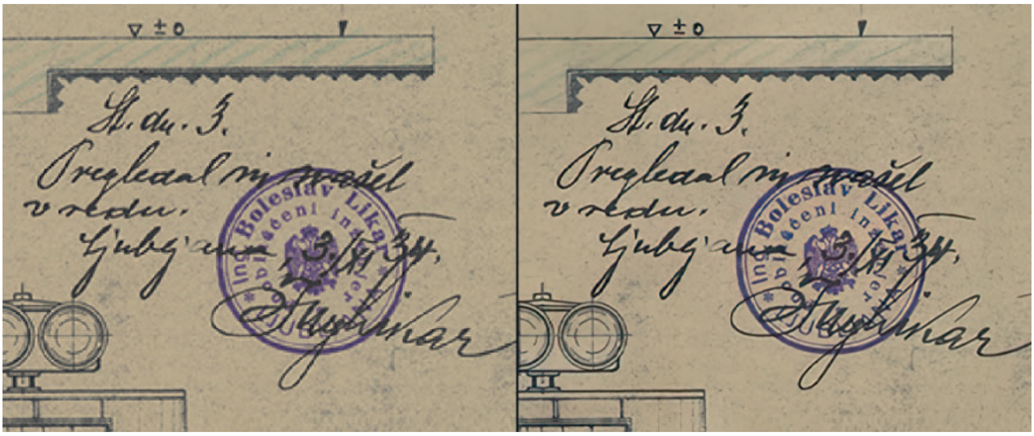

Figure 15: Subsample 3 at 75 DPI.

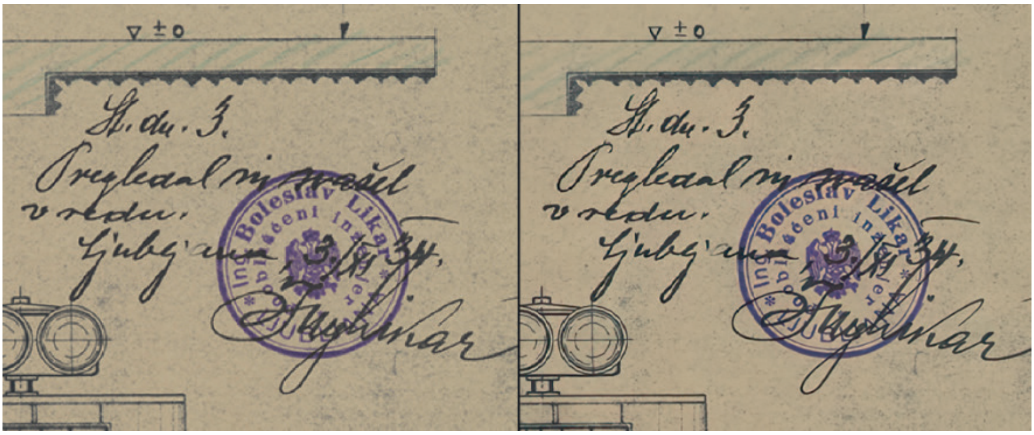

Figure 16: Subsample 3 at 100 DPI.

Subsample 4 processing

Results in short: It is a fundamentally less readable plan, which is scanned in insufficient resolution, the original is also poorly contrasted. We can see that at the lowest resolution (50 DPI), the model failed to improve the readability of the design. Improvements can be seen with the larger two (75 and 100 DPI). There is also pronounced noise cancellation. Figures 17–19 shows original subsample at 50, 75 and 100 DPI and processed by AI model next to it.

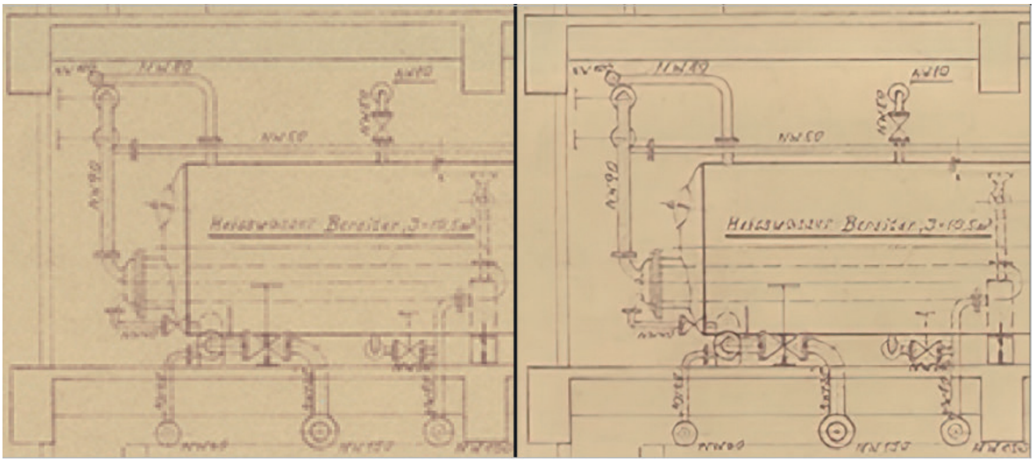

Figure 17: Subsample 4 at 50 DPI.

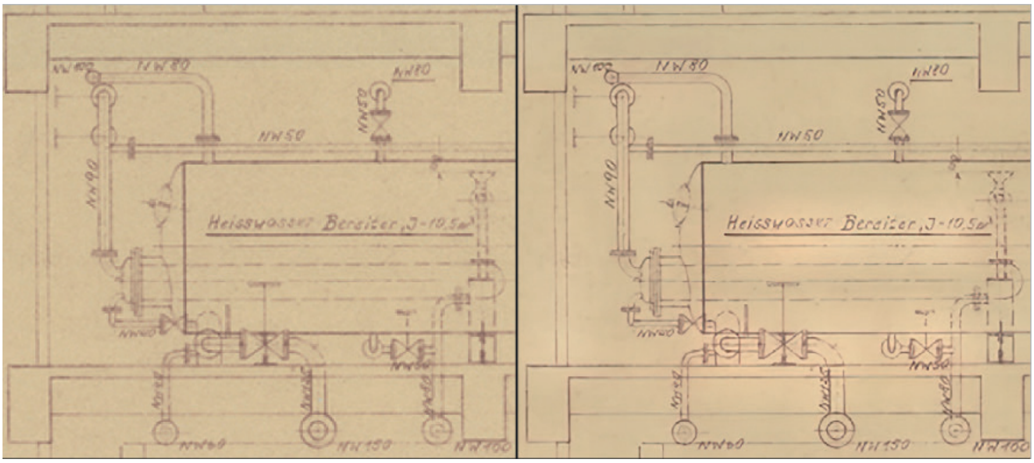

Figure 18: Subsample 4 at 75 DPI.

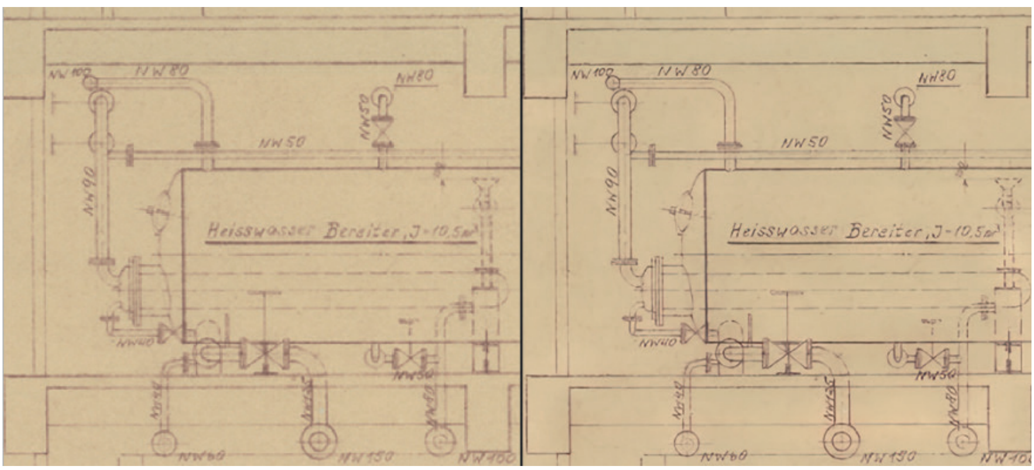

Figure 19: Subsample 4 at 100 DPI.

Subsample 5 processing

Results in short: At the lowest input resolution, the model failed to significantly increase the readability of the text, but at larger samples it can be traced and contributes to easier readability. Figures 20–22 shows original subsample at 50, 75 and 100 DPI and processed by AI model next to it.

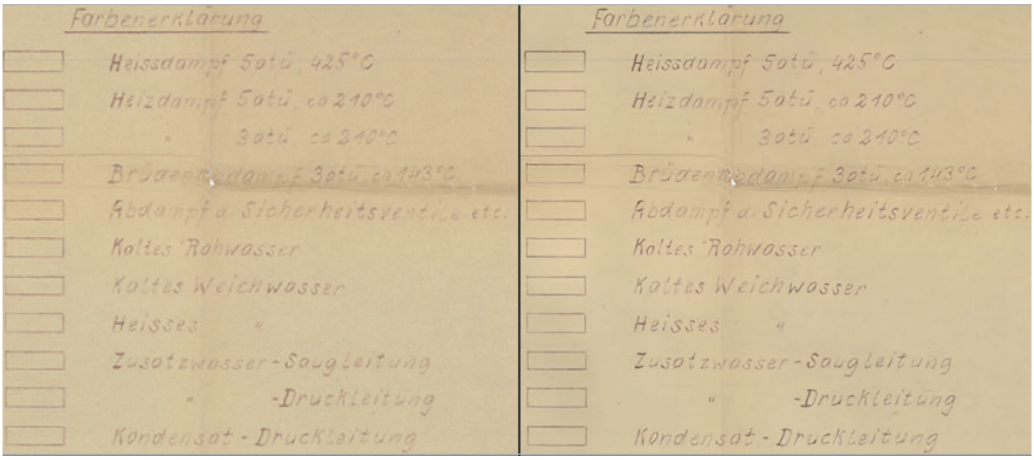

Figure 20: Subsample 5 at 50 DPI.

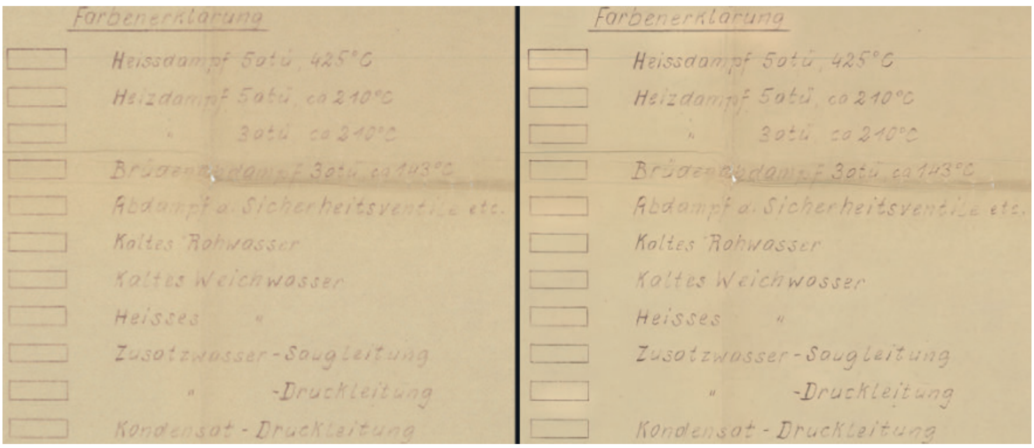

Figure 21: Subsample 5 at 75 DPI.

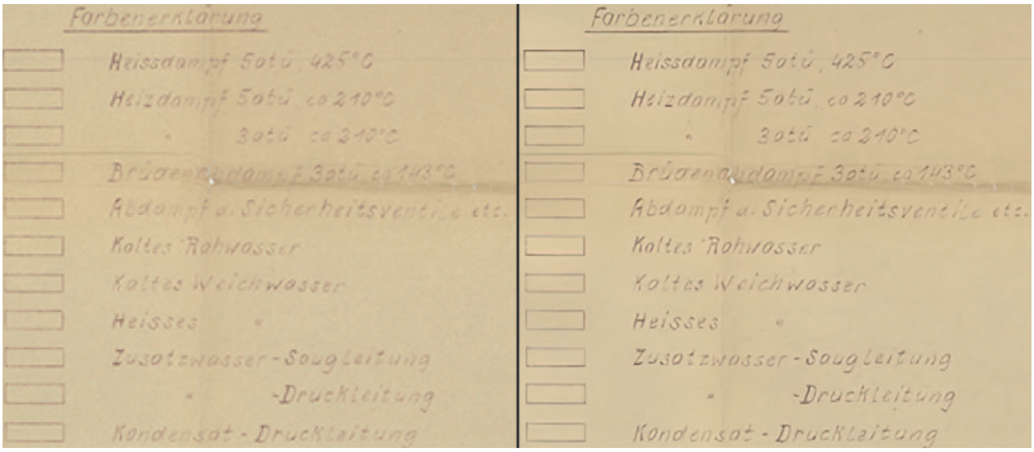

Figure 22: Subsample 5 at 100 DPI.

We can summarize the fundamental findings in following conclusions:

- If the original material is unreadable, even AI cannot assist.
- AI effectively handles borderline useful material, suggesting that rescanning may not be necessary in some cases.
- AI performs strongly and convincingly when the original material is already readable.
- The application of AI yields excellent results for printed text, with surprisingly successful improvements for manuscripts and stamps.
- AI removes noise universally, even when unnecessary. Attention should be paid to this feature in cases where noise reduction is undesired.
- In general, AI produces superior results compared to traditional zoom methods.

During the sample processing, we formulated several recommendations:

- The selection of the built-in zoom model is crucial. Since 2022, when similar research was conducted (Hribar, 2022), models have become available that avoid excessive detail invention and know when to refrain. Multiple options should be tested before finalizing the choice.
- We still advocate scanning with the highest possible resolution that is practical and economically feasible.
- All AI-processed images must undergo thorough review before release to the end user.
- Algorithms should not be pushed to their extreme performance limits; a 2x or 4x times magnification is the maximum expectation.

6 CONCLUSION AND DISCUSSION

Based on our preliminary study we can conclude that the use of AI and ML algorithms is becoming increasingly prevalent, with developers integrating AI support into software. Users often remain unaware of the solutions they employ and potential unintended consequences (Santiago, 2023).

Content creators sometimes embrace the latest and experimental methods to present visually appealing and technically flawless content. Algorithms for resolution enhancement, relying on AI or ML, perform automatic restoration interventions by inventing missing information based on learned patterns. While effective, especially with similar learning patterns, it's crucial to recognize that these algorithms don't "understand" content.

Further, pushing algorithms to extreme limits, where extensive invention is required, may lead to obvious and sometimes misleading errors. Lack of information doesn't always impede the invention process. Errors may also occur when the material doesn't align with the learning samples so archivists must be vigilant about unwanted artifacts that can mislead users, particularly in scaled images where AI-generated zooms may be indistinguishable.

The authors however propose appropriately marking AI-processed material or noting it in metadata. As automatic evaluation and selection processes preserving larger versions of files is most likely, but it can happen that larger files were AI generated. We advise that original files should always be retained due to potential shortcomings in enlarged image material.

In summary, archivists must possess sufficient knowledge of AI, enabling them to be critical to AI solutions and be able to share insights with content creators. However, recognizing AI's characteristics and legal implications can be time-consuming therefore establishing criteria for AI solutions on heritage and archival material is crucial for upholding principles and ethics. Human involvement in the material processing loop needs to remain essential as current narrow AI models still make many commonsense errors. Mechanisms to limit bold imaginativeness or hallucinations of AI are still under development (Anantrasirichai and Bull, 2022; Davis and Marcus, 2015).

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