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From analog to digital: digitization and digital preservation of microfilm collections

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Abstract

Background: The advancement of information technology has transformed the management of microfilm collections through digitization. This process aims to align with the increasingly digital information consumption patterns of society, while also preserving information and enhancing accessibility.
Purpose: This study explores the stages of microfilm digitization, the challenges encountered, and applicable digital preservation strategies to ensure the longevity of information.
Methods: Conducted using a qualitative descriptive approach, the research collected primary data through direct observation of the digitization process and secondary data from literature review. The data were analyzed by identifying, categorizing, and explaining key elements such as digitization activities, challenges, solutions, and preservation strategies.
Results: The findings indicate that microfilm digitization consists of three stages: pre-transformation (administrative and equipment preparation), transformation (microfilm scanning), and post-transformation (quality control and file management). Challenges include the dependency of digital output quality on the condition of the microfilm, limited human and financial resources, and the difficulty of sustaining digital access amid technological changes. Solutions include the use of artificial intelligence to improve OCR accuracy and automate metadata analysis. To ensure long-term access, preservation strategies such as data refreshing, format migration, and digital environment emulation are essential. With these strategies, information institutions can safeguard knowledge and reinforce the role of libraries in the digital era.

Keywords:
Artificial intelligence
Digital preservation
Digital transformation
Microfilm digitization

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INTRODUCTION

The dynamics of information technology have led to a transformation in information media, making it more dynamic and accessible. The ease of access in fulfilling information needs is one of the key benefits brought about by digital technology in the field of information. Society continues to leverage digital technology as a means to search for and satisfy its information needs. The information management cycle—from production to distribution and access—has evolved to operate autonomously and at an accelerated pace, in line with the growing individual demand for information. Libraries, as institutions of knowledge, serve as the front line in the transformation of information to ensure alignment with the public's information needs.

The library's role in balancing public information needs is realized through the transformation of its services into digital formats. This shift requires the digital transformation or media conversion of library collections to transfer their content into new formats. Previously physical collections are now being digitized to enhance accessibility and preserve library materials.

Collection preservation is a complex domain within library science that has been practiced since ancient times to safeguard knowledge and cultural heritage for future generations. Preservation activities employ various methods to protect physical collections—such as books, maps, manuscripts, and newspapers—from damage due to intensive use and aging. One such method for extending the lifespan of library collections for hundreds of years is media conversion through microfilm or microfiche.

Microfilm is a technique that converts physical collections into a miniaturized format stored on film reels or microfiche. Specialized equipment, known as microfilm readers, is required to access these collections. Documents originally in paper form, including ancient manuscripts, must be digitized to ensure the longevity and usability of the information they contain. Digitization is a media conversion process that transforms analog or printed collections into digital formats, requiring electronic tools for management (Nurmustafha et al., 2024). Microfilm collections can be preserved for centuries if managed and maintained properly. Microfilm functions as a photographic processing tool in which archival materials are recorded and miniaturized to reduce storage space and usage (Martini, 2021).

The fluctuating nature of technological advancement offers dual benefits for microfilm collections: enhanced accessibility for users—particularly to historical materials—and improved preservation. Digital transformation represents a technological shift that supports the development of digital access to library collections, especially microfilm. The digital transformation of microfilm collections is also a preservation strategy to safeguard the informational content within them. However, even after media conversion, microfilm collections remain vulnerable to damage, particularly to the resulting digital files. Therefore, digital preservation efforts are essential for collections that have undergone digital transformation.

Microfilm digitization is inherently linked to digital preservation, as the latter is a critical step in maintaining the integrity of digital information derived from microfilm. Digital preservation is not merely an auxiliary need but a fundamental requirement to ensure the sustainability of the digital ecosystem. While physical preservation depends on environmental factors, digital preservation faces different challenges, such as technological obsolescence and the risk of digital file loss. Consequently, digital preservation is crucial for maintaining long-term access to digital information. Without proper preservation strategies, stored information and its accessibility may be lost within a few years, threatening the continuity of knowledge in the digital era (Sabharwal, 2015)

To address these challenges, digital preservation must be conducted in a planned and managed manner to ensure the longevity of digital information documents. When executed correctly, digital preservation activities can ensure long-term accessibility to digital information. These activities can be categorized into two levels: basic actions such as creating copies, and more complex efforts involving the preservation of storage media and technological infrastructure (Hidayah & Saufa, 2019). Digital preservation must be implemented to mitigate the risks of hardware and software obsolescence, which serve as the storage media for digital collections (Pramudyo & Perdani, 2022).

Previous research on media conversion of microfilm in libraries has been conducted by Musrifah (2016), dengan judul "Proteksi arsip vital pada Badan Perpustakaan dan Arsip Daerah di Yogyakarta." dan Fatmawati (2022), dengan judul "Alih media digital dalam kegiatan pelestarian informasi". Both studies discuss the role and benefits of digitization in library collections as a means of preserving library materials and archival documents. study found that the protection of vital records at the Regional Library and Archives Agency in Yogyakarta was carried out using a backup method and digital storage. Fatmawati (2022), explained that "the media conversion process is conducted in stages, consisting of pre-conversion, conversion, and post-conversion phases." The two studies differ in terms of their research objects, contexts, and methodologies. Musrifah (2016), focused on the protection of vital records, including microfilm collections, using a quantitative research method, emphasizing physical archive management to prevent disaster-related damage. In contrast, Fatmawati (2022), conducted a theoretical study on information preservation, digital media conversion, and digital reproduction transformation using a literature review method.

Both studies, however, have limitations in their discussion of digitization and digital preservation. Musrifah (2016), did not examine the digitization process in detail, such as scanning stages or digital file management, and instead focused on physical archive management to mitigate disaster risks. Meanwhile, Fatmawati (2022), provided a framework for digital media conversion activities but did not address potential technical challenges such as software obsolescence, file corruption, or specific preservation strategies. Neither study analyzed digital preservation strategies to ensure the long-term sustainability of digital information.

This study introduces a novel contribution by addressing the research gap in the digitization of microfilm collections in libraries. It explores the digitization process, emerging challenges, and technological solutions. Furthermore, it expands the understanding of digital preservation strategies for digitized microfilm collections. By formulating these research problems, this study aims to contribute new insights through an in-depth examination of the microfilm digitization process, technical challenges, technology-based solutions, and digital preservation strategies that have not been specifically addressed in previous research.

RESEARCH METHODS

This study employs a qualitative research method with a descriptive approach to examine the digitization process of microfilm collections and the strategies for preserving digital collections. The descriptive approach was chosen to provide a comprehensive overview of the media conversion process from microfilm to digital format, as well as to identify the opportunities and challenges that arise from this activity. The qualitative research method is used to study the condition of the research object, with the researcher acting as the key instrument. Data collection techniques involve combining inductive or qualitative data analysis results, guided not by theory but by facts discovered during field research (Abdussamad, 2021).

Data collection techniques in this study include comprehensive literature review, participatory observation, and documentation. The literature review involved gathering and analyzing recent scholarly books and articles on digitization processes, microfilm, digital preservation strategies, and technical challenges in microfilm digitization. Participatory observation was conducted by directly engaging in the microfilm digitization process at the National Research and Innovation Agency (BRIN) through a one-month internship program.

The data analysis technique used in this study is descriptive qualitative analysis, aimed at presenting a thorough explanation of the phenomena under investigation (Sugiyono & Lestari, 2021). The researcher collected primary data through direct observation during the microfilm digitization process and secondary data from literature studies. These data were processed by identifying, categorizing, and explaining key elements such as digitization activities, obstacles, solutions, and digital preservation. This process aims to produce a detailed and systematic explanation of the digitization of microfilm collections and their digital preservation.

RESULTS AND DISCUSSION

The implementation of digital transformation for microfilm collections involves more than merely scanning the materials to be digitized. It encompasses a series of systematic steps aimed at enhancing the accessibility of collections that are vulnerable to deterioration. According to the Guidelines for E-book Creation and Media Conversion Standards published by the National Library of Indonesia (2014), there are three procedural stages employed by the National Library in digitizing microfilm collections.

These three stages are as follows: (1) Pre-Digital Transformation Stage. This stage involves preparing all administrative and technical requirements necessary for the digital transformation process. Activities include inventorying and selecting library materials by identifying and choosing the microfilm reels to be digitized, inspecting the physical condition of the materials, evaluating and analyzing the metadata of the collections, determining the appropriate digital file formats, and selecting the digital transformation method. (2) Digital Transformation Stage. This is the core process of converting the collection into digital format. It includes calibrating the digitization equipment to ensure color accuracy and resolution clarity, capturing digital images using scanners, cameras, or OCR (Optical Character Recognition)-based conversion tools. For optimal results, microfilm should be scanned at a minimum resolution of 400 ppi in 8-bit grayscale, with adjustments based on the original document size rather than the film size (Northeast Document Conservation Center, 2017). The next step involves editing or correcting the scanned digital files. To enhance user accessibility, the files are converted into commonly used formats such as PDF or JPG. These files are then compiled into an electronic book, and bibliographic descriptions are written based on the content. (3) Post-Digital Transformation Stage. This stage includes quality control of the digitized collections, ensuring color accuracy, completeness of the collection, and the correct sequence of digital files. The guidelines developed by the National Library of Indonesia are not limited to internal use but can also be adopted by other institutions seeking to implement similar standards for effective digitization and preservation of microfilm collections.

The National Research and Innovation Agency (BRIN) is one of the Indonesian government institutions that houses microfilm collections and actively engages in their digitization. These collections include scientific journals, historical newspapers, books written by historians in Sanskrit, and various scientific research outputs of historical value. Although one of the primary goals of digitizing microfilm collections is to enhance accessibility, not all digitized collections at BRIN are made publicly available. This restriction is in place to protect the intellectual property rights of researchers or related parties, requiring their consent before public dissemination. Consequently, BRIN’s digitization efforts are primarily preservation oriented.

The digitization process at BRIN consists of three stages: pre-digitization, digitization (scanning), and post-digitization. The pre-digitization stage involves preparing the necessary tools before scanning, including wearing latex gloves and masks, recording bibliographic information from the microfilm box labels, inspecting the condition of the microfilm, and cleaning any dirt from the reels. This step aims to identify any damage, dirt, or deficiencies in the microfilm reels prior to scanning.

The next stage is the scanning or digitization process. BRIN uses a scanner called the ScanPro 3000, chosen for its superior capabilities in microfilm digitization. It is important to note that there are two types of microfilm scanners: those used solely for manual reading and those that can connect directly to a computer and allow for real-time editing of scanned results.

The operation of the ScanPro 3000 device is relatively straightforward, following the instructions provided with the equipment. The process begins by placing the microfilm reel on the designated left-side holder of the ScanPro 3000. The reel is then gently pulled across and positioned on the right-side holder. After selecting the type of microfilm to be scanned, the ScanPro device automatically begins scanning the images on the film. At this stage, users can preview and review the scanned images on a computer screen to ensure image clarity.

The scanned images are then transferred to a computer using the built-in ScanPro software. This software allows for editing the scanned images, such as cropping, adjusting image alignment, and enhancing resolution.

The post-digitization stage involves organizing the scanned digital files to ensure document completeness and page order. The digital collection is then processed using Optical Character Recognition (OCR) software to facilitate information retrieval within the digital files. The final digital files are converted into PDF format and uploaded to BRIN's cloud storage system. Once digitization is complete, the original microfilm is returned to a specialized storage facility to prevent potential damage.

Microfilm collections are generally durable, with lifespans ranging from several decades to over a century. However, due to the challenges of maintaining microfilm, degradation often occurs. This degradation typically affects the film surface, resulting in stains or discoloration that compromise the quality of the digitized output (Government of Northwest Territories, 2019). Poor-quality microfilm will yield substandard scans, and even high-resolution scanning cannot guarantee clean and clear results (Northeast Document Conservation Center, 2017). As Rishadi and Marlina (2018) noted:

> "Poor microfilm conditions will result in low-quality scans, with numerous

Figure 1. Manual Microfilm Reader

Source: Author's Documentation, 2023

Figure 2. ScanPro 3000, Digital Microfilm reader

Source: Author's Documentation, 2023

> stains obscuring parts of the film, making the scanned images unclear. If the scanned output is already poor, the subsequent OCR conversion process will be suboptimal." (Rishadi & Marlina, 2018).

To mitigate poor scanning results, several factors must be considered: (1) Microfilm Quality and Imaging Technique: Improper imaging techniques combined with deteriorated microfilm conditions will negatively impact the quality of the resulting digital images. (2) Minimizing Scratches on Microfilm: Microfilm storage often leads to minor scratches on the film surface, which can degrade scan quality. Therefore, surface restoration should be performed before scanning. (3) Use of Specialized Scanning Equipment: It is essential to use scanners specifically designed for microfilm, as their features and specifications significantly influence the digitization process and output quality (Rishadi & Marlina, 2018).

Another challenge in microfilm digitization is the variation in page sizes and the number of pages contained within a single reel. This issue arises because scanning systems typically detect page boundaries at specific angles (IFLA, 2002). However, with microfilm collections containing pages of varying sizes, these systems often fail to accurately identify page boundaries. As a result, the digitized output may suffer from distortions such as overlapping pages, OCR processing difficulties, and indexing errors.

One of the most significant challenges in the digitization of microfilm collections is the limitation of resources. These resources include both financial resources and skilled human resources capable of carrying out the digitization process. Currently, only a few institutions in Indonesia possess microfilm readers, whether in digital or conventional (manual) form. Many of the manual readers are not equipped for digitization. The limited access to microfilm readers is largely due to their high cost. For instance, the ScanPro 3000—one of the few devices capable of digitizing microfilm—is priced in the tens to hundreds of millions of rupiah, according to various online sources.

Additionally, funding for microfilm

digitization is often limited. Microfilm readers are frequently obtained through grants, and only a small number of institutions in Indonesia allocate specific budgets for microfilm digitization. The Preservation Center of the National Library of Indonesia (Perpusnas) is one such institution that conducts microfilm digitization. The center accepts digitization requests from other institutions seeking to digitize their microfilm collections.

Once digitization is complete, the resulting digital files must be maintained to ensure the longevity of the information. Digital documents are more vulnerable to damage, such as storage media failure, data corruption, or loss due to malware attacks. Moreover, maintaining digital collections—commonly referred to as digital preservation—is not a simple task. According to Safri (2019), there are three fundamental stages in digital preservation: (1) Technological Preservation: This involves maintaining the software and hardware used to store and operate digital materials. (2) Refreshing: The process of transferring digital documents to new storage media to prevent data loss due to media degradation. (3) Migration or Reformatting: Changing the configuration or format of digital documents without altering their content to ensure continued accessibility.

To address the challenges outlined above, artificial intelligence (AI)-based technological approaches offer innovative solutions in the digital era of librarianship. AI's automation capabilities help overcome the complexities of library collection digitization—from scanning to digital data management, including metadata processing—more quickly and efficiently than manual methods (Modiba, 2022). AI-supported automatic metadata generation enables topic classification, description creation, keyword extraction (Reiche, 2023), document type classification, contextual analysis, and identification of inter-document relationships, thereby facilitating information retrieval and long-term preservation of digital collections.

A notable example of AI application in microfilm digitization is the initiative by the National Security Research Center (NSRC) at Los Alamos National Laboratory. Since 2020, NSRC has employed AI and machine learning (ML) technologies to digitize over 50 million pages of microfiche and microfilm collections. Through robotic systems and AI/ML-driven automation, the time required for microfilm digitization has been reduced by up to 80%. The integration of AI/ML algorithms into the scanning process automates tasks such as page boundary detection, correction of conventional scanning errors, and metadata identification. Without AI/ML, digitizing a single microfilm reel could take over a week due to the need for manual inspection of focus, contrast, and resolution (Ali, 2021).

To address OCR inaccuracies in low-quality microfilm collections, AI can be integrated into OCR technology to enhance text recognition in blurry images or inconsistent formatting. OCR has existed since the 1950s and has evolved alongside technological advancements. Traditional OCR systems relied on basic pattern recognition algorithms, which often failed to process blurry scans, handwritten text, or unstructured formats. Today, the collaboration between OCR and AI enables the recognition, processing, and interpretation of complex document images using deep learning technologies such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) (Muthusundari et al., 2024).

Convolutional Neural Networks (CNNs) enable OCR systems to detect text patterns in low-quality images, handwritten scripts, and distorted visuals. CNN's strength in image scanning allows OCR systems to quickly recognize and convert characters into machine-readable digital text (Muthusundari et al., 2024). Recurrent Neural Networks (RNNs), on the other hand, process sequential data such as speech, text, or image descriptions. A variant of RNN, known as Long Short-Term Memory (LSTM), is designed to learn long-range dependencies in data (Muthusundari et al., 2024). LSTM is particularly effective for processing sequential text from scanned documents with archaic fonts or inconsistent layouts, as it retains contextual memory across character sequences.

Additionally, Natural Language Processing (NLP) integrated into OCR systems enhances contextual understanding of text, reducing interpretation errors in ambiguous terms or foreign language expressions found in historical documents (Turul & Nassir, 2025). The Library of Congress has also implemented AI-integrated OCR technology in its Chronicling America project to improve discoverability across more than 20 million pages of historic American newspapers (U.S. Senate, 2024). These findings align with the NSRC's results, demonstrating that such technological collaboration significantly improves text recognition accuracy in historical documents, including those with ancient scripts and varying scan quality.

Beyond AI-enhanced text recognition, another innovative approach focuses on image pre-processing to address noise and low-quality scans, known as the Denoising Convolutional Neural Network (DnCNN). DnCNN, a subset of CNN, is trained to recognize and correct visual artifacts such as speckles, scratches, and graininess in scanned images. It uses residual learning strategies to predict and remove noise from noisy images, producing cleaner outputs (Zhang et al., 2017). This capability is particularly useful for restoring low-quality microfilm scans without compromising critical details.

According to the survey titled Digitization and Artificial Intelligence for Archives and Documentary Heritage Materials, which aimed to assess the impact of AI on digitization activities and was distributed across 66 professional lists and forums—primarily within the GLAM (Galleries, Libraries, Archives, and Museums) community—the most frequently used AI-powered OCR applications include: Tesseract: An open-source OCR engine, Transkribus: Commonly used for digitizing archival materials, especially handwritten text, ABBYY FineReader: A commercial OCR solution known for its advanced PDF editing capabilities, and Google Cloud Vision: Supports text extraction from documents and images (Bushey et al., 2025).

However, the selection of these applications should be tailored to specific needs, such as image quality variation and the complexity of text derived from microfilm collections.

Digitizing microfilm is a form of digital preservation aimed at ensuring the long-term survival of the information stored within microfilm collections. As a storage medium, microfilm has a limited lifespan and is vulnerable to environmental damage, including humidity, temperature fluctuations, and light exposure. Therefore, microfilm digitization is not merely a process of converting analog information into digital form—it must be accompanied by a comprehensive digital preservation strategy to ensure continued access to the digitized content.

According to the Digital Preservation Coalition (2015), digital preservation involves managing and ensuring ongoing access to digital materials for as long as possible. The digital preservation of microfilm digitization outputs is a complex process that requires strategies focused on long-term accessibility and the sustainable use of digital resources (Bountouri, 2017).

Microfilm that has been converted into digital format faces a range of new challenges, including file format obsolescence, bit degradation, data alteration, and the risk of digital collection loss due to system maintenance or storage failures (Digital Preservation Coalition, 2015). Therefore, digital preservation is a critical aspect of ensuring the continuity of information and guaranteeing that various types of information resources remain accessible and usable in the future. Digitized microfilm collections represent a form of both conservation and preservation of knowledge. In this context, conservation refers to activities aimed at protecting digital collections from various forms of damage. Conservation efforts can be categorized as active, passive, or preventive, depending on their function in maintaining and safeguarding microfilm collections (Fikri & Sarah, 2022). Digital preservation can be implemented through both preventive and curative approaches. A study by Hidayah & Saufa (2019) outlines several digital preservation methods applied to ancient manuscripts and microfilm collections at the Provincial Archives and Library Agency of Central Java, including: (1) Technological Preservation: This ensures that digitized microfilm files remain accessible and usable over time by maintaining the hardware and software used to process and store the materials; (2) Refreshing: This involves copying digital files to newer storage media before the original media degrade or become obsolete. For example, digitized microfilm files initially stored on CDs—which have a limited lifespan—must be periodically transferred to newer storage devices such as external hard drives or cloud servers. This process can be time-consuming, especially when dealing with large volumes of data, (3) Format Migration: This involves transferring data from one format or system to a newer one to ensure future accessibility. For instance, microfilm files originally stored in PNG or JPG formats may be converted to PDF to facilitate OCR processing. Migration is necessary when file formats or storage systems change.

A key component of digital preservation is the selection of appropriate long-term preservation strategies. There is no single prescribed approach, as strategies depend on the characteristics of the digital object, available human and financial resources

(Bountouri, 2017). According to Keefer & Gallart, as cited in Libraries for Users: Services in Academic Libraries (2011), three digital preservation strategies are commonly used based on resource format, intended use, and technical capacity: (1) Refreshing: The process of transferring data to new storage media to mitigate the risk of data loss due to media degradation. This method is relatively simple and does not require expensive equipment or advanced technical skills, making it suitable for many libraries, (2) Migration: This involves changing the format or storage system to ensure data remains accessible on newer technologies. While commonly used and partially automatable, migration carries risks such as loss of original file features and difficulties in handling complex digital objects.

The international standard ISO 16363:2012 identifies three types of migration in digital preservation: (1) Bitstream Migration: This involves refreshing or replicating digital data without altering the bit structure. Refreshing copies data from one medium to another, while replication creates exact duplicates of the original digital source. (2) Repackaging: This changes the packaging or container of the digital object to match new system structures without altering the content. (3) Bitstream Transformation: This involves altering the bit structure of the digital object so that it can be accessed in a new storage environment. (4) Environment Emulation: Emulation allows digital documents to remain accessible over time without altering their content. It recreates the original software environment on modern systems, enabling files to be opened as if using the original programs. This strategy is often applied to historically significant digital collections, such as archival documents or microfilm data.

This study has several limitations that affect the scope and depth of its findings. First, it does not include expert perspectives from professionals who routinely perform microfilm digitization, relying instead on participatory observation and document analysis. This limits the depth of insight into technical challenges and best practices. Second, the study is confined to a single research site and does not compare practices with other institutions in Indonesia, such as the National Library of Indonesia, which may employ different strategies. Lastly, the study does not evaluate the quality of digitized images, including OCR accuracy.

To address these limitations, future research should involve interviews or discussions with microfilm digitization practitioners to gain deeper insights into challenges and solutions. Further studies should also evaluate the quality of digitized outputs, particularly OCR text accuracy. Finally, future research could explore the impact of digital preservation strategies—such as refreshing, migration, and emulation—on strengthening information preservation efforts in the digital age.

CONCLUSION

The conversion of microfilm collections into digital format represents a strategic effort to preserve information in the digital era. This process involves three main stages: pre-digital transformation (preparation), digital transformation (scanning), and post-digital transformation (quality assessment).

However, the digitization of microfilm collections presents several challenges, including poor microfilm quality, limited human resources and budget, as well as the complexity of digital preservation. Technologies such as artificial intelligence (AI) with deep learning algorithms (Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Denoising CNNs (DnCNN)) offer solutions to enhance text accuracy, reduce image noise, and automate metadata management. Preservation strategies such as data refreshing, format migration, and system emulation are essential to ensure sustainable access to digitized microfilm collections. Nevertheless, this study has certain limitations, such as the absence of practitioner involvement in the digitization process, a focus on a single research location without comparisons to other institutions that may employ different strategies, and the lack of evaluation of the quality of digitized outputs. Future research is recommended to involve practitioners, assess digitization outcomes, and explore the impact of digital preservation strategies on the sustainability of digital collections.

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