

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
Rev: 1			Page: Page 1 of 59	

Deliverable Number 2.7

Case studies Version 1.0 Related WPs: WP2 “Architecture” Related tasks: T2.4 “Case studies”

	Affiliation / Position	Name
Author	Prof. Dr.	Renaldas Raišutis
Verifier		
Issued:	2024.09.30	Update:

Abstract / Motivation for the research:

The aim of the presented deliverable document is to present case studies and validation of simulated, medical, real world patrimonial data (Digital Health 4.0 & Industry 4.0 sectors)

Deliverable Number	D2.7	Lead Beneficiary	2. KTU
Deliverable Name	Case studies Version 1		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	PU - Public
Due Date (month)	12	Work Package No	WP2

Description
Case studies and validation of simulated medical real world patrimonial data (Digital Health 4.0 & Industry 4.0 sectors)

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 2 of 59

KEYWORDS:

- DICOM
- Industry 4.0 / 5.0
- Digital Health
- NDT
- Patrimonial data
- Watch making industry

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 3 of 59

TABLE OF CONTENTS

1. INTRODUCTION	6
1.1 DATA BEING STORED IN DNA.....	6
1.2 Main parts of the report:.....	6
1.3 Description of the DICOM standard.....	7
2. CASE STUDY NO.1: SIMULATED DICOM IMAGES	10
2.1 Simulated 2D image of the fixed intensity	10
2.2 Simulated 2D image of the variable intensity	13
2.3 Simulated 2D image of the variable intensity of multiple circles.....	16
3. CASE STUDY NO.2: DNAMIC LOGO IMAGE AND VIDEO (FRAMES).....	18
3.1 DNAMIC logo image	18
3.2 DNAMIC video frame (image).....	21
4. CASE STUDY NO.3-1: VETERINARY DIAGNOSTIC IMAGES OF CANINE LESIONS (DIGITAL HEALTH 4.0/5.0).....	25
5. CASE STUDY NO.3-2: NDT IMAGING (INDUSTRY 4.0/5.0) IMAGES	26
6. CASE STUDY NO.4: PATRIMONIAL / DIGITAL ARCHIVE DATA	32
7. THEORETICAL DESCRIPTION OF DIGITIZED DATA ENCODING INTO DNA AND DECODING	46
8. CONCLUSIONS.....	49
9. REFERENCES	50
10. ANNEXES	51

 kaunas university of technology 1922			 Co-funded by the European Union
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 4 of 59

TABLE OF FIGURES

- DICOM specification and TAGS tables
- Case study No.1: Simulated DICOM images and their properties tables
- Case study No.2: DNAMIC logo images, DNAMIC video (frames) and their properties tables:
- Case study No.3-1: Veterinary diagnostic images of canine lesions (DIGITAL HEALTH 4.0/5.0) and their properties table
- Case study No.3-1: NDT IMAGING (INDUSTRY 4.0/5.0) images and their properties table
- Case study No.4: Patrimonial / digital archive data (pdf file of Swiss watch making industry), images and their properties tables
- The algorithm of encoding/decoding workflow

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 5 of 59

ABBREVIATIONS

- DNA - deoxyribonucleic acid
- DICOM - Digital Imaging and Communications in Medicine
- NDT – Non-destructive Testing
- PNG - Portable Network Graphics
- SVG - Scalable Vector Graphics

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 6 of 59

1. INTRODUCTION

The DNAMIC project aims to revolutionize data storage through its innovative DNA-based solution, ensuring long-term sustainability, cost-effectiveness and compliance with international standards.

Using both simulated medical data and real-world patrimonial datasets, this report offers a thorough assessment of our end-to-end and intermediate solutions to show the general adaptability and resilience of our approach. Inspired from the Digital Health 4.0 / 5.0 sector, the validation method combines a wide range of simulated datasets and images, arranged as 2D and 3D arrays. These databases especially follow the DICOM (Digital Imaging and Communications in Medicine) standard, which is extensively used for digital health records and diagnostic imaging. Apart from medical records, we incorporate nondestructive testing (NDT) data from important Industry 4.0 / 5.0 sectors including energy, transportation, aviation and development / manufacturing of advanced materials. This integration seeks to evaluate the cross-domain application of our ideas. At last, real-world patrimonial datasets are used to validate and evaluate the universality and efficiency of our DNA data storage approach over several use cases and sectors, so stressing its flexibility in both industrial and healthcare environments.

1.1 DATA BEING STORED IN DNA

Different types of data we will store and read in DNA:

- Simulated DICOM / DNAMIC logo and videos (frames) / Diagnostic medical and non-destructive testing (Digital Health 4.0 & Industry 4.0 sectors) / Real world patrimonial data;
- The initial size of the data (digital images) we intend to operate in storing and reading is between 100 kB and 1 MB of data;
- Patrimonial data from the Swiss Digital Archive (e.g. watch industry data: images, pdf documents).

1.2 Main parts of the report:

The main parts of the report:

- Description of the DICOM standard;
- Introduction and description of 4 case studies (examples): simulated DICOM / DNAMIC logo and videos (frames) / medical & NDT / real world patrimonial data;
- Theoretical description of data encoding in DNA and decoding workflow, block diagram of the algorithm.

 kaunas university of technology 1922				 Co-funded by the European Union		
Organisation:		Kaunas University of Technology				
Project:		DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING				
Grants:		EIC Pathfinder Challenges 2022 Project No.: 101115389				
Title:		2.7 Case studies Version 1.0				
				Rev: 1	Page: Page 7 of 59	

1.3 Description of the DICOM standard

The Digital Imaging and Communications in Medicine (DICOM Standard) is a technical standard used for the digital storage and transmission of medical images and related information. It is managed by the Medical Imaging & Technology Alliance (<https://www.dicomstandard.org/authenticate-mita/>)- a division of the National Electrical Manufacturers Association (<https://www.dicomstandard.org/authenticate-nema/>).

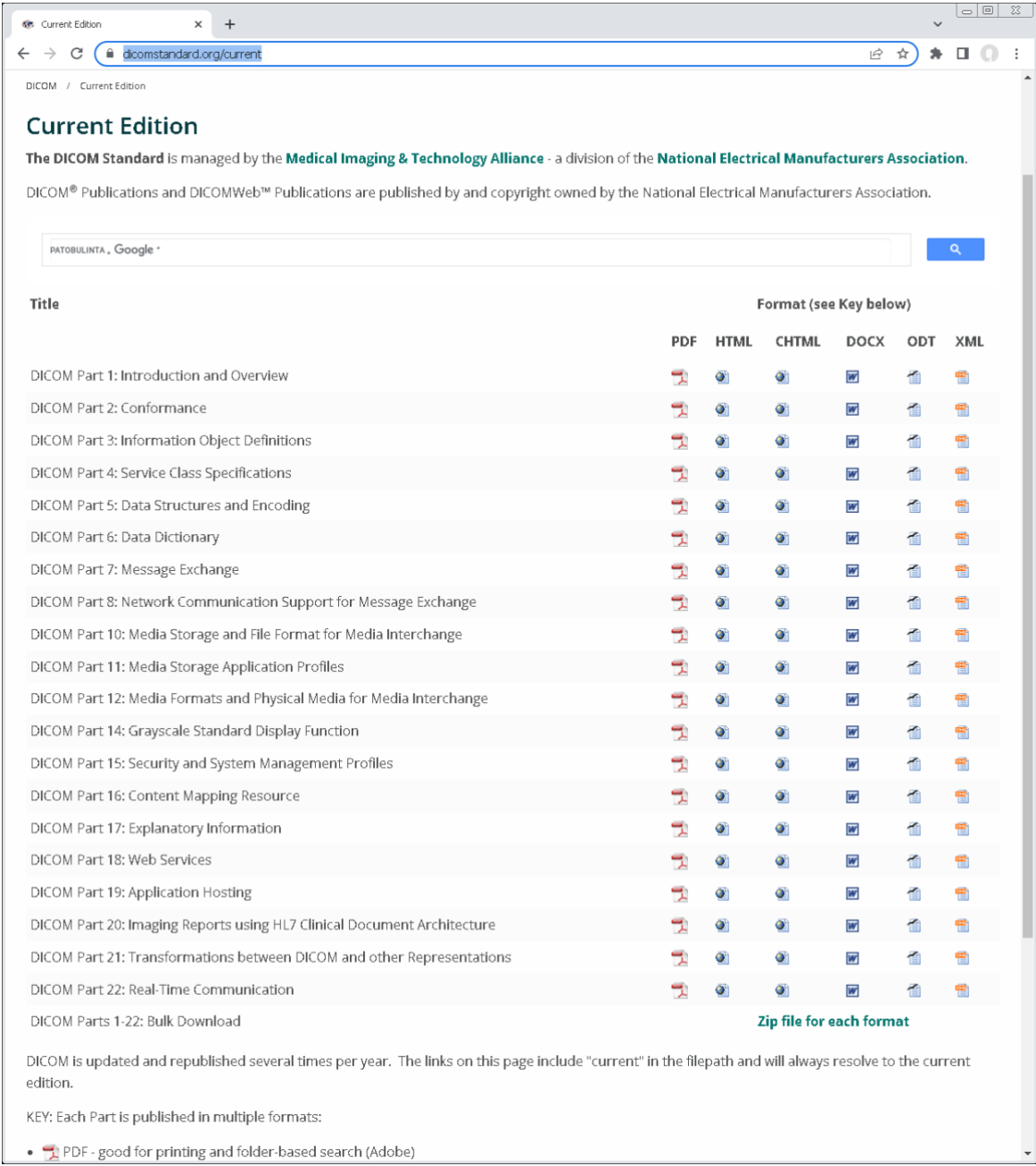
DICOM® Publications and DICOMWeb™ Publications are published by and copyright owned by the National Electrical Manufacturers Association.

DICOM enables communication between medical imaging software and hardware (X-ray, MRI, US etc), created by different manufacturers. DICOM files are being stored and accessed by picture archiving and communication systems (PACS).

The DICOM image format is being used almost for any diagnostic medical image, video frames, data and digital records. In a sector of NDT there are also diagnostic images, videos and data acquired using X-ray, ultrasonic, optical imaging, eddy current etc. Due to the Industry 4.0 and NDT 4.0 guidelines and intentions to use unified Data format, DICOM seems to be the best option.

The contents of the detailed specification of DICOM (<https://www.dicomstandard.org/current>) is presented in Fig.1.1. The examples of DICOM TAGS being used in DICOM images are presented in Table 1.1.

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 8 of 59



Current Edition

The DICOM Standard is managed by the **Medical Imaging & Technology Alliance** - a division of the **National Electrical Manufacturers Association**.

DICOM® Publications and DICOMWeb™ Publications are published by and copyright owned by the National Electrical Manufacturers Association.

PATOBULINTA, Google

Title	PDF	HTML	CHTML	DOCX	ODT	XML
DICOM Part 1: Introduction and Overview						
DICOM Part 2: Conformance						
DICOM Part 3: Information Object Definitions						
DICOM Part 4: Service Class Specifications						
DICOM Part 5: Data Structures and Encoding						
DICOM Part 6: Data Dictionary						
DICOM Part 7: Message Exchange						
DICOM Part 8: Network Communication Support for Message Exchange						
DICOM Part 10: Media Storage and File Format for Media Interchange						
DICOM Part 11: Media Storage Application Profiles						
DICOM Part 12: Media Formats and Physical Media for Media Interchange						
DICOM Part 14: Grayscale Standard Display Function						
DICOM Part 15: Security and System Management Profiles						
DICOM Part 16: Content Mapping Resource						
DICOM Part 17: Explanatory Information						
DICOM Part 18: Web Services						
DICOM Part 19: Application Hosting						
DICOM Part 20: Imaging Reports using HL7 Clinical Document Architecture						
DICOM Part 21: Transformations between DICOM and other Representations						
DICOM Part 22: Real-Time Communication						
DICOM Parts 1-22: Bulk Download	Zip file for each format					

DICOM is updated and republished several times per year. The links on this page include "current" in the filepath and will always resolve to the current edition.

KEY: Each Part is published in multiple formats:

- PDF - good for printing and folder-based search (Adobe)

Fig.1.1. The contents of the detailed specification of DICOM (<https://www.dicomstandard.org/current>)

 kaunas university of technology 1922			 Co-funded by the European Union
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 9 of 59

Table 1.1 Examples of DICOM TAGS being used in DICOM images

Line No.	Definition of the DICOM Tags
1	% Define DICOM tags
2	dicom_tags.PatientName = 'Test Patient';
3	dicom_tags.PatientID = '123456789';
4	dicom_tags.Modality = 'US';
5	dicom_tags.Modality = 'US';
6	dicom_tags.StudyDate = '2024-02-19';
7	dicom_tags.SeriesDescription = 'Phantom Image';
8	dicom_tags.PixelSpacing = [1, 1]; % Pixel spacing in mm
9	dicom_tags.SliceThickness = 2; % Slice thickness in mm
10	dicom_tags.StudyID = 'Study1';
11	dicom_tags.Manufacturer = 'MATLAB Phantom';
12	dicom_tags.InstitutionName = 'Test Institution';
13	dicom_tags.StudyDescription = 'Phantom Image Study';
14	dicom_tags.SeriesDescription = 'Phantom Image Series';
15	dicom_tags.StudyDate = datestr(now, 'yyyymmdd');
16	dicom_tags.StudyTime = datestr(now, 'HHMMSS');
17	dicom_tags.ReferringPhysicianName = 'Dr. Senior Data Scientist';
18	dicom_tags.OperatorName = 'Tech Data Scientist';
19	dicom_tags.ManufacturerModelName = 'MATLAB Simulation';

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 10 of 59

2. CASE STUDY NO.1: SIMULATED DICOM IMAGES

2.1 Simulated 2D image of the fixed intensity

The 2D image of the circle of fixed intensity on the black background was simulated using the “Matlab” software package (“Mathworks”, United States). The resolution of the image is 256 x 256 pixels. The image is shown in Fig.2.1.1. The cross section of the image along the x-axis at y=125 pixels (blue line representing pixels values, Fig.2.1.1) is presented in Fig.2.1.2 and the image properties in Fig.2.1.3. It was decided that the first step would be to record this image in the DNA.

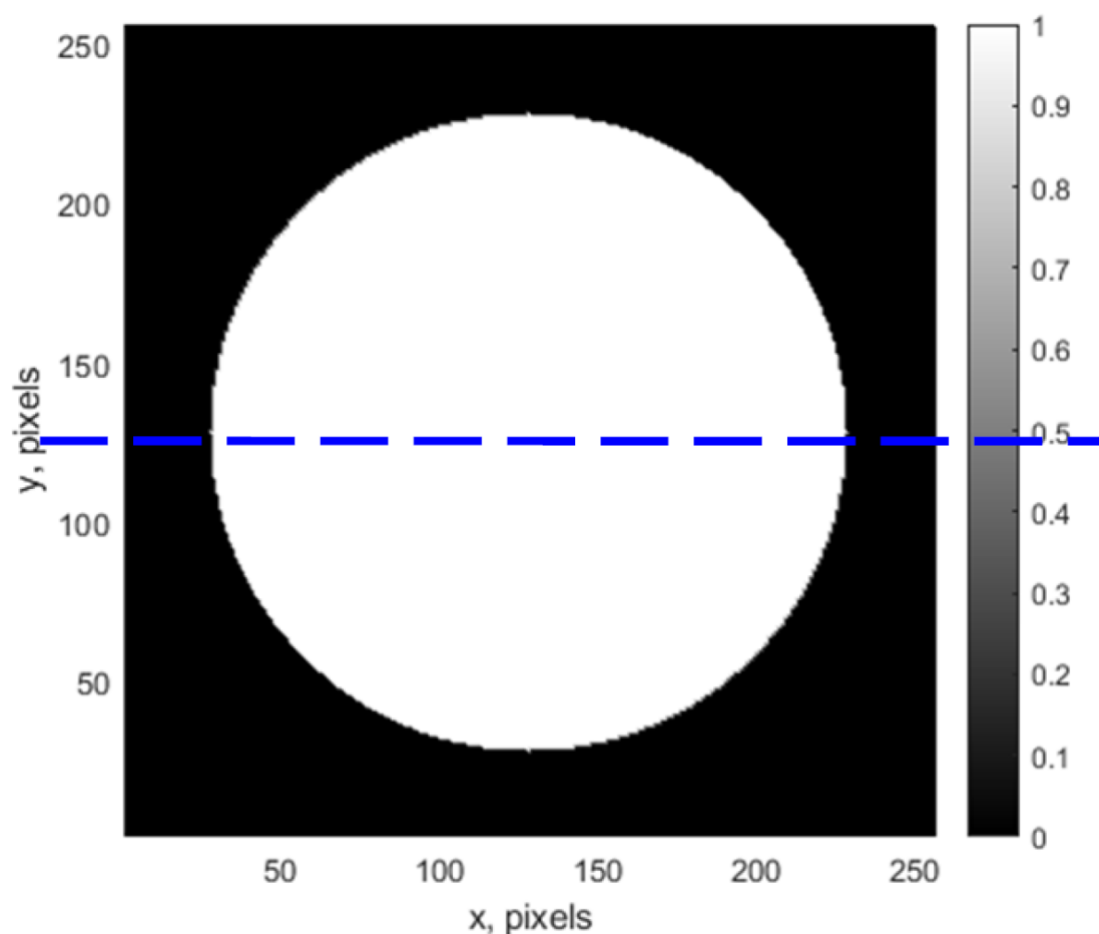


Fig.2.1.1. Simulated 2D image of the fixed intensity (resolution 256x256 pixels, size 2.06 KB)

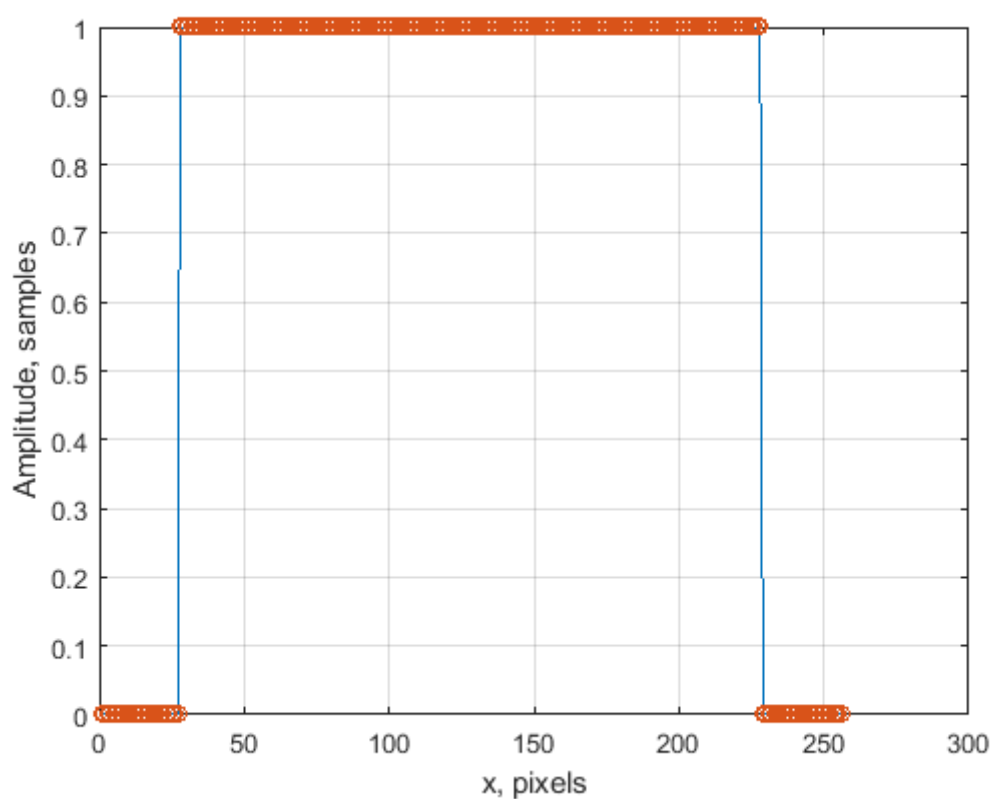


Fig.2.1.2. The cross-section of the fixed intensity image along x axis at y=125 pixels, representing pixels values

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 12 of 59

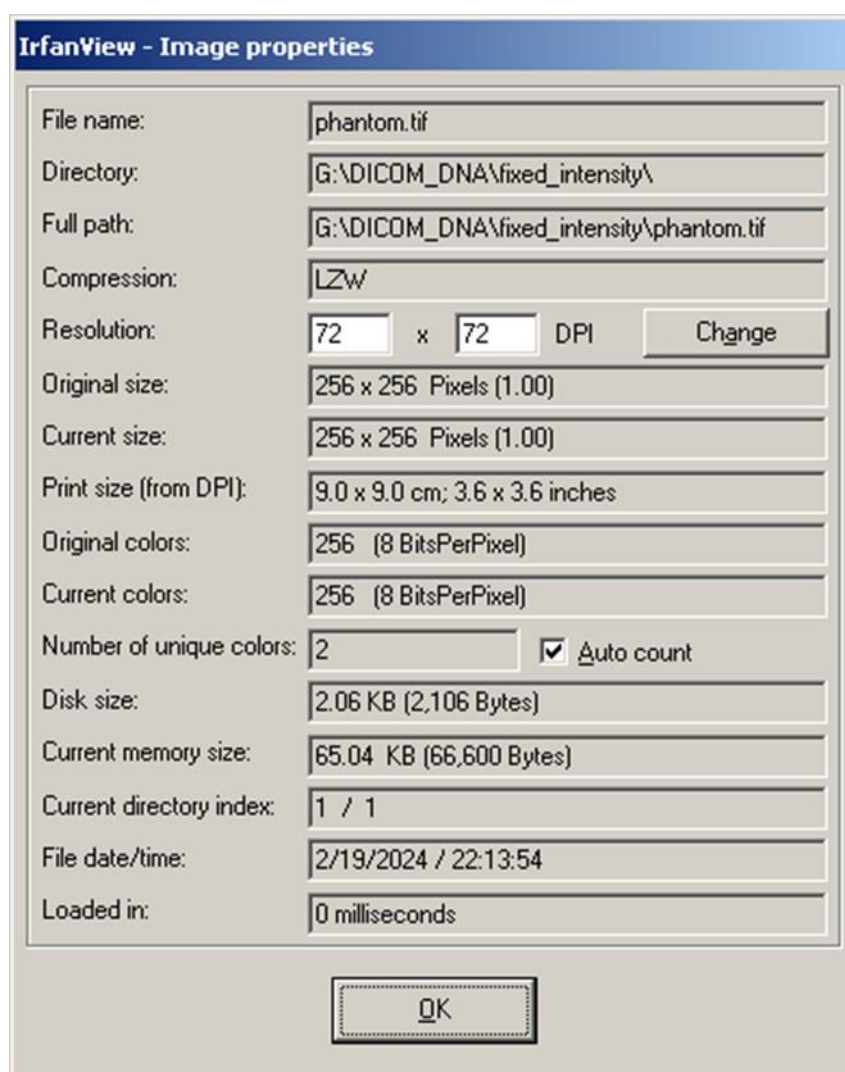


Fig.2.1.3. Properties of the fixed intensity image

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 13 of 59

2.2 Simulated 2D image of the variable intensity

The 2D image of the circle of variable intensity in the black background was simulated using the “Matlab” software package ("Mathworks", United States). The resolution of the image is 256 x 256 pixels. The image is shown in Fig. 2.2.1. The cross section of the image along the x-axis at y=125 pixels (blue line, representing pixels values, Fig.2.2.1) is presented in Fig.2.2.2 and the image properties in Fig.2.2.3. This image could be useful in further research to test the quality of the encoding/decoding process and error correction algorithms.

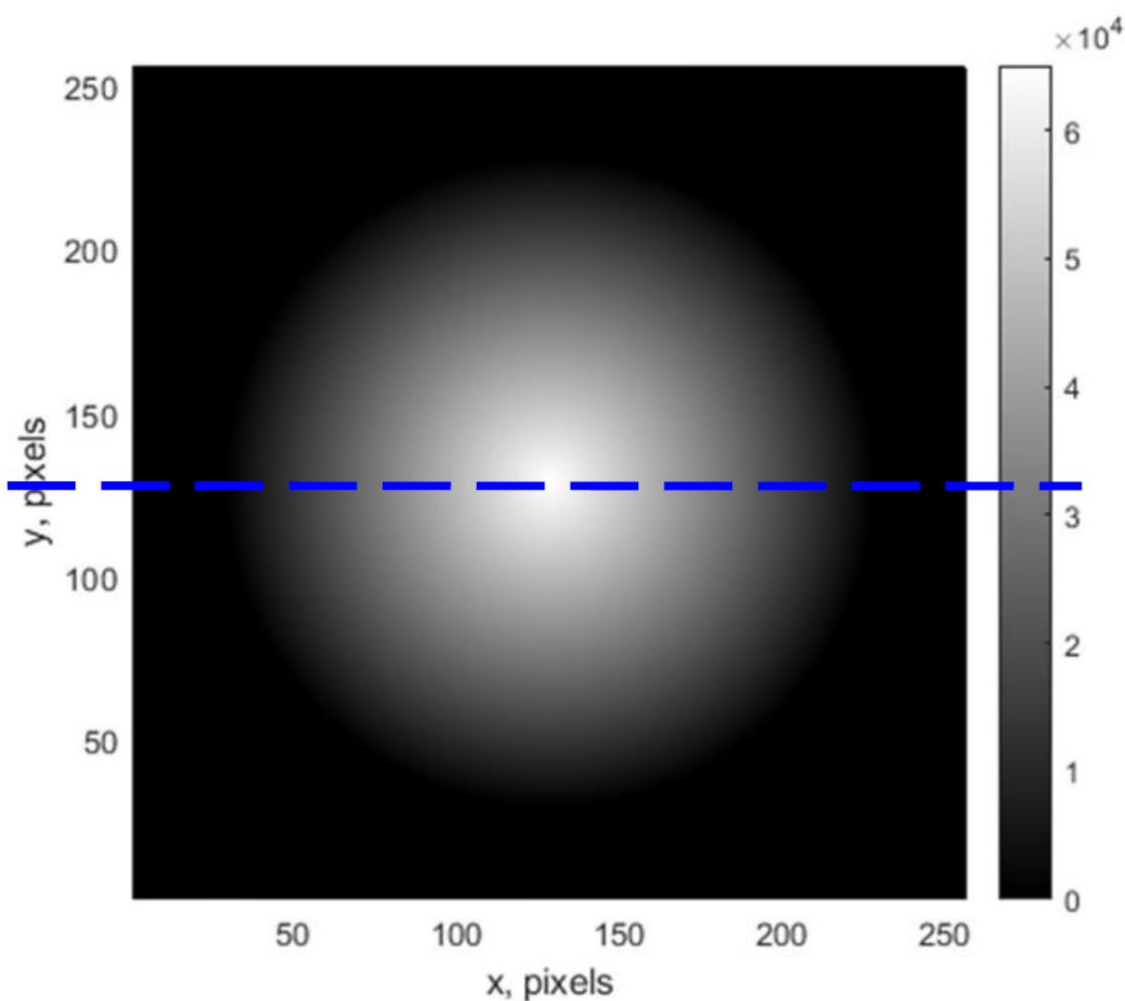


Fig.2.2.1. Simulated 2D image of the variable intensity (resolution 256x256 pixels, size 61.39 KB)

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 14 of 59

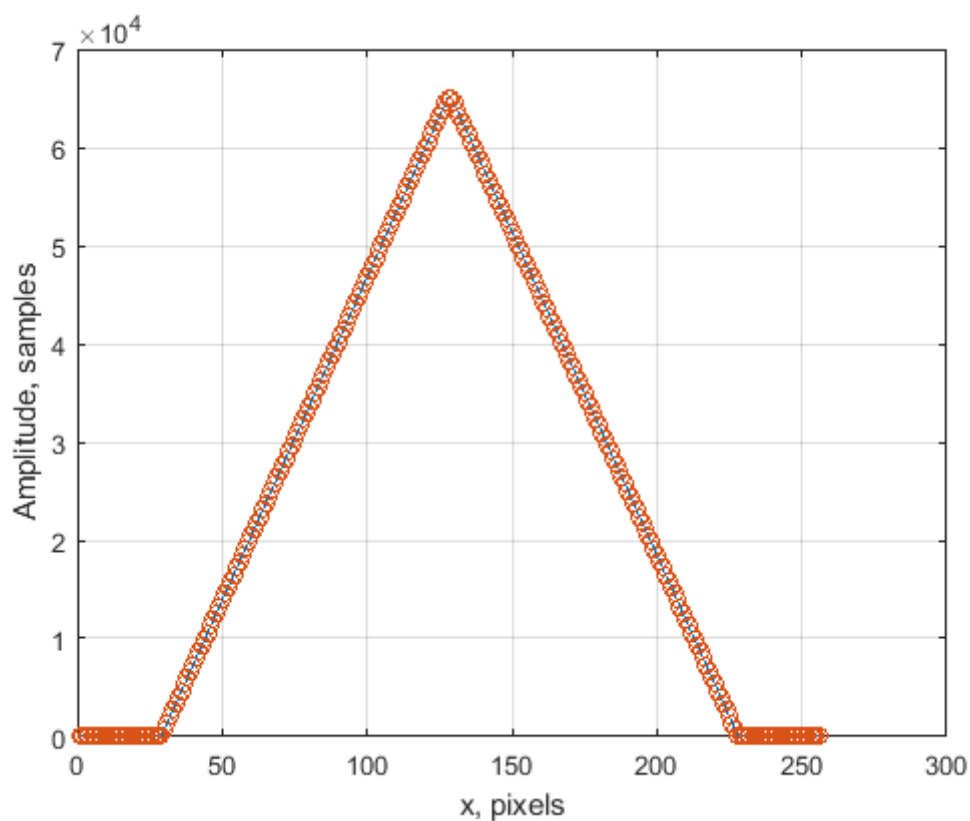


Fig.2.2.2. The cross-section of the variable intensity image along x axis at y=125 pixels, representing pixels values

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 15 of 59

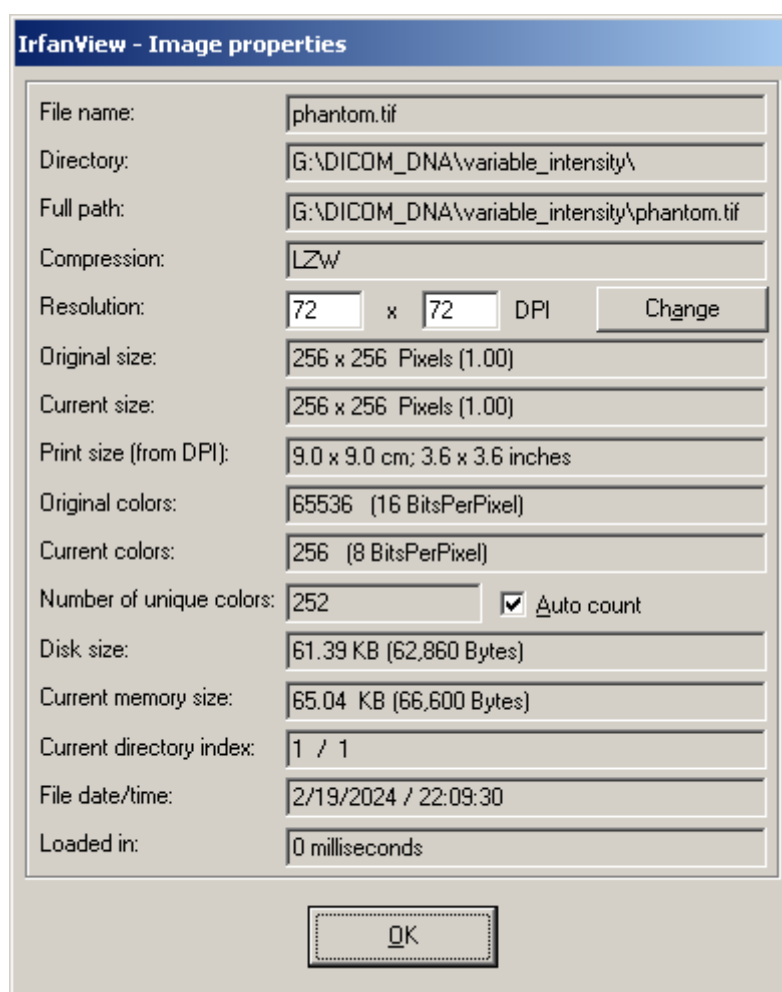


Fig.2.2.3. Properties of the variable intensity image

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 16 of 59

2.3 Simulated 2D image of the variable intensity of multiple circles

The 2D image of the variable intensity of several circles (about eight) in the black background was simulated using the “Matlab” software package ("Mathworks", United States). The resolution of the image is 256 x 256 pixels. The image is shown in Fig.2.3.1. The image properties are shown in Fig.2.3.2. This image could be useful in further research to test the quality of the encoding/decoding process and error correction algorithms.

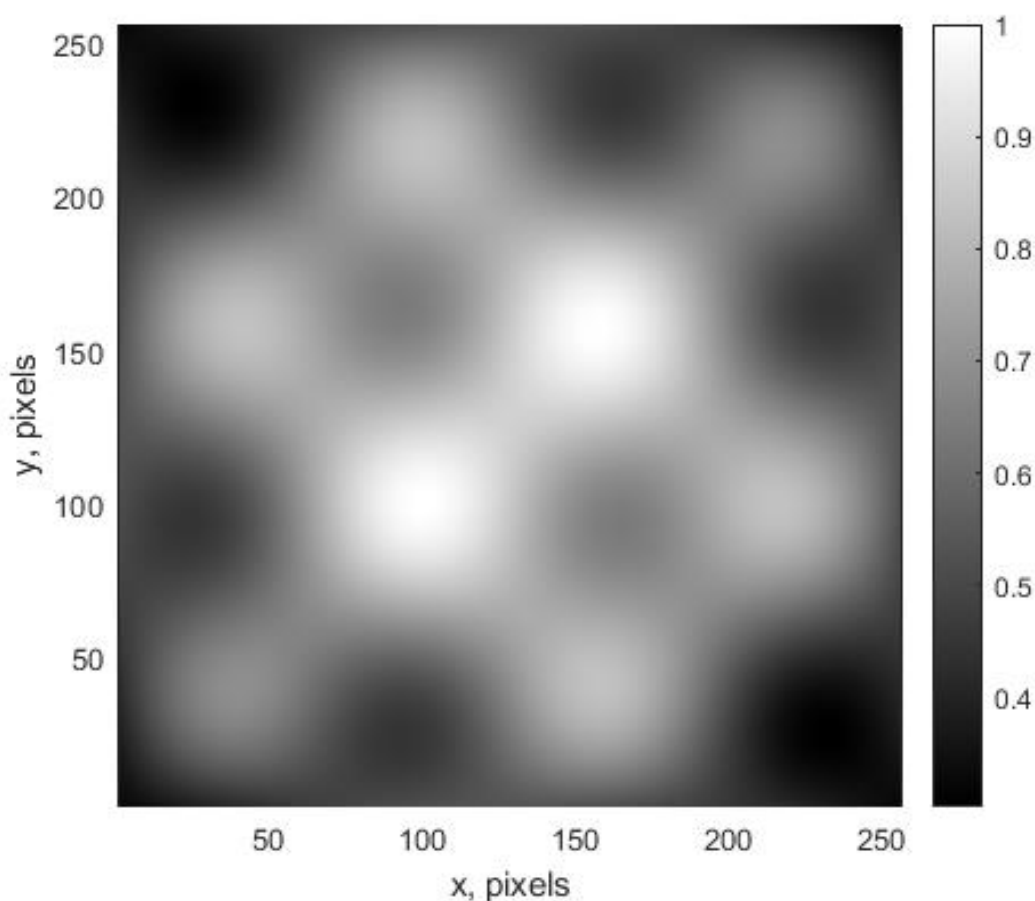


Fig.2.3.1. Simulated 2D image of the variable intensity of multiple circles (resolution 256x256 pixels, size 37.62 KB)

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 17 of 59

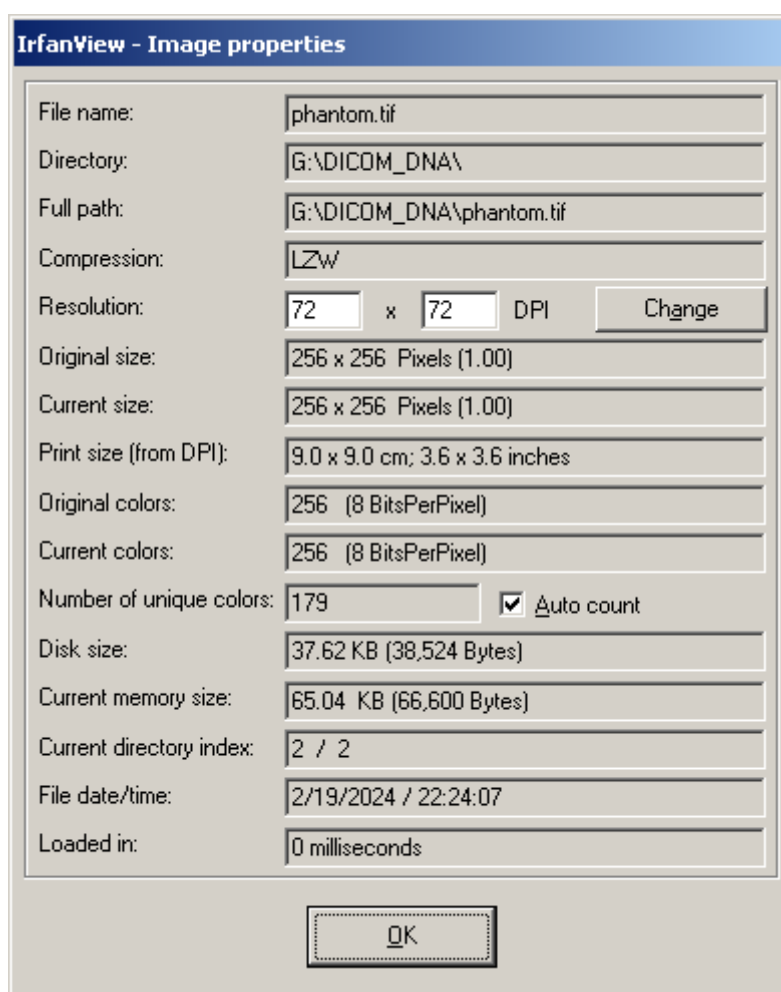


Fig.2.3.2. The image properties of the variable intensity of multiple circles

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 18 of 59

3. CASE STUDY NO.2: DNAMIC LOGO IMAGE AND VIDEO (FRAMES)

3.1 DNAMIC logo image

A Portable Network Graphics (PNG) file representing the DNAMIC logo, "dnamic_logo_transparent_background-01-1.png", was selected to demonstrate the ability to encode and store different image and video formats in DNA. Figure 3.1.1 shows this image and its special features are described in Figure 3.1.2. The PNG file mentioned was chosen because of its popularity and suitability for digital media. We converted the raster-based PNG file into a vector format using the Scalable Vector Graphics (SVG) file "dnamic_logo_transparent_background-01-1.svg", thereby optimising the image for DNA encoding. By ensuring a more effective representation of the image, this conversion ensures lossless scaling and a simpler encoding mechanism for DNA storage. The SVG format is an ideal choice for testing DNA data storage techniques, as it reduces storage complexity and maintains image quality at different resolutions by using mathematical descriptions of shapes and colours rather than pixel-based data. The image properties of the svg file of DNAMIC logo to be stored in DNA is presented in Fig.3.1.3.



Fig.3.1.1. Portable network graphic file (png) of DNAMIC logo „ dnamic_logo_transparent_background-01-1.png“ (resolution 1600 x 334 pixels, size 20.21 KB)

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 19 of 59

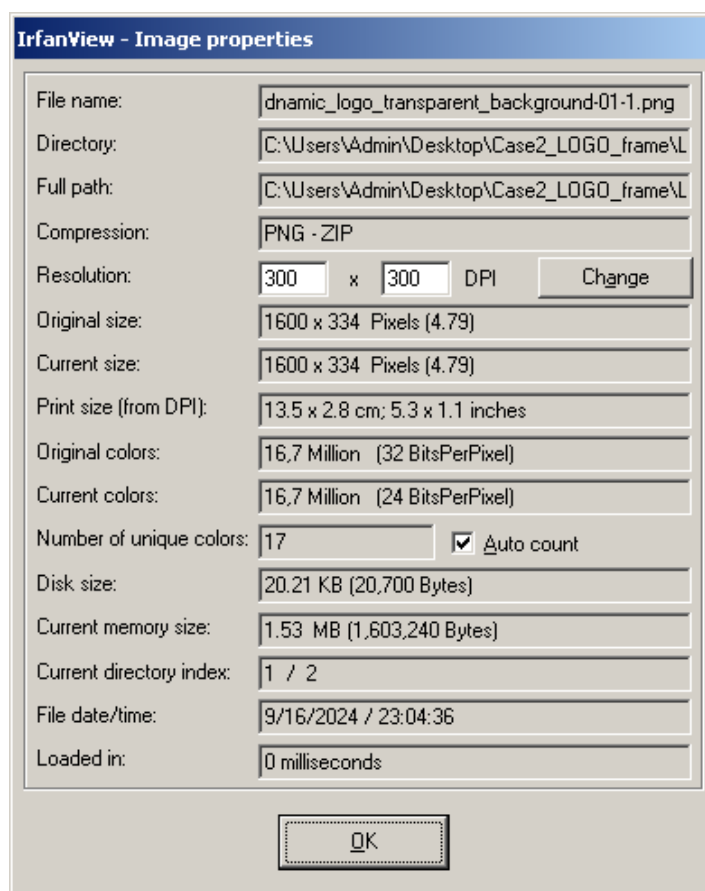


Fig.3.1.2. The image properties of the portable network graphic file (png) of DNAMIC logo (resolution 1600 x 334 pixels, size 20.21 KB)

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 20 of 59

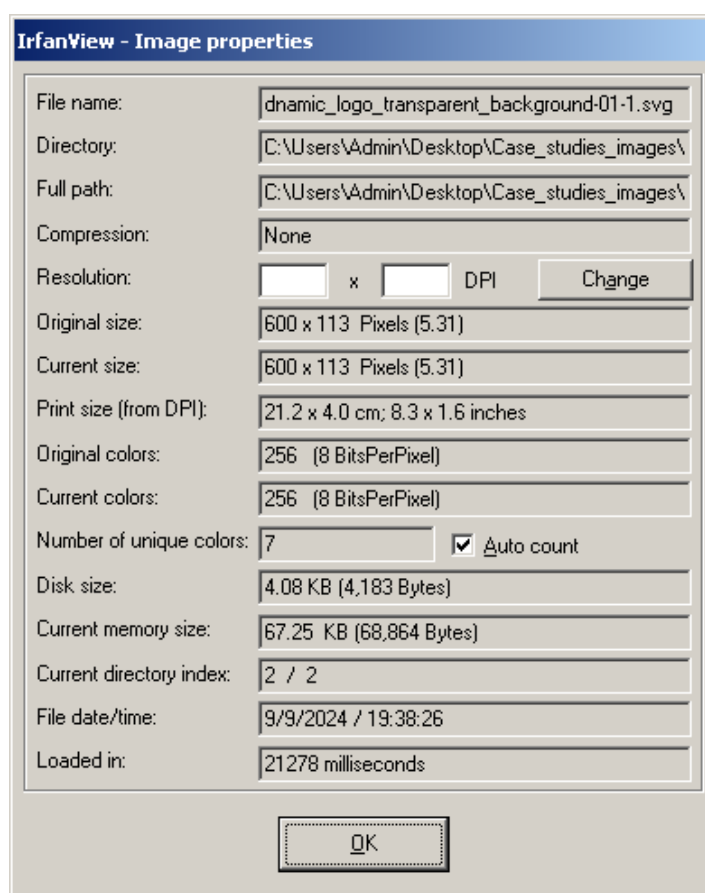


Fig.3.1.3. The image properties of the Scalable Vector Graphics file (svg) of DNAMIC logo (resolution 600 x 113 pixels, size 4.08 KB)

 kaunas university of technology 1922				 Co-funded by the European Union		
Organisation:		Kaunas University of Technology				
Project:		DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING				
Grants:		EIC Pathfinder Challenges 2022 Project No.: 101115389				
Title:		2.7 Case studies Version 1.0				
				Rev: 1	Page: Page 21 of 59	

3.2 DNAMIC video frame (image)

The screenshot of the DNAMIC video (mp4), resolution 1920x1090 pixels, video file size 378 MB, duration 3 min 10 seconds, is presented in Fig.3.2.1. The properties of the DNAMIC video (mp4) are presented in Fig.3.2.2.

„DNAMIC“ video with FR subtitles (YOUTUBE):

<https://www.youtube.com/watch?v=Z2P5xT8j0mQ>

DNAMIC video with ENG subtitles (YOUTUBE):

<https://www.youtube.com/watch?v=LlaZK5UT7Js>

The selected frame of the DNAMIC video (mp4) was resized and saved as a jpg file "DNAMIC VIDEO 18_1.1.18_resized.jpg", (resolution 1920x990 pixels, size 434.5 KB), presented in Fig.3.2.3. Properties of the selected and resized frame image are presented in Fig.3.2.4. In order to further reduce the size of the image file, it was resized to 800 x 413 pixels to reach 114.00 KB. Resized selected frame of DNAMIC video (mp4) and saved as jpg file "DNAMIC_VIDEO_frame_resized_800_413" to be stored in DNA, (resolution 800x413 pixels, size 114.00 KB), are presented in Fig.3.2.5. Properties of the selected and resized frame image are shown in Fig.3.2.6.

 1922 kaunas university of technology		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 22 of 59

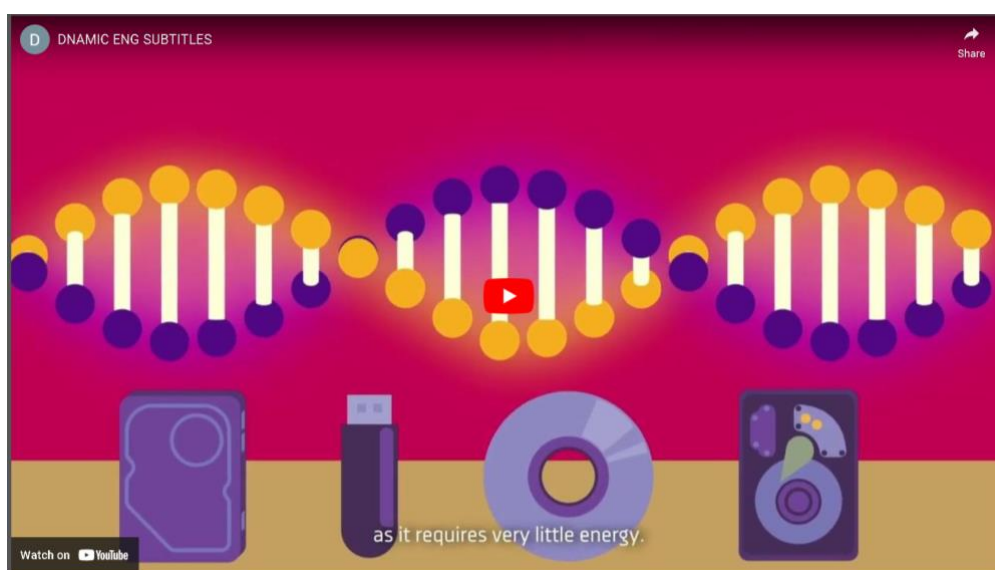


Fig.3.2.1. Screen of the DNAMIC video (mp4), resolution 1920x1090 pixels, video file size 378 MB, duration 3 min 10 seconds

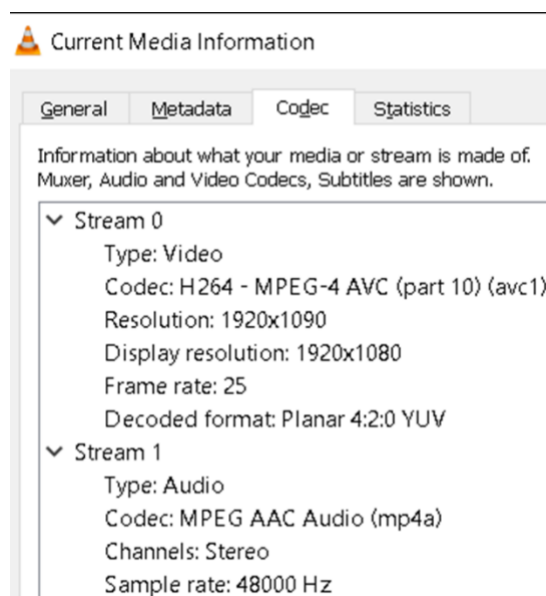


Fig.3.2.2. Properties of the DNAMIC video (mp4)

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 23 of 59



Fig.3.2.3. Selected frame of the DNAMIC video (mp4) was resized and stored as jpg file “DNAMIC VIDEO 18_1.1.18_resized.jpg”, (resolution 1920x990 pixels, size 434.5 KB)

File name:	DNAMIC VIDEO 18_1.1.18_resized.jpg		
Folder:	C:\Users\user\Desktop\		
Full path:	C:\Users\user\Desktop\DNAMIC VIDEO 18_1.1.18_re		
Compression:	JPEG, quality: 100, subsampling ON (2x2)		
Resolution:	96	x	96 DPI Change
Original size:	1920 x 990 Pixels (1.90 MPixels) (1.93)		
Current size:	1920 x 990 Pixels (1.90 MPixels) (1.93)		
Print size (from DPI):	50.8 x 26.2 cm; 20.00 x 10.31 inches		
Original colors:	16,7 Million (24 BitsPerPixel)		
Current colors:	16,7 Million (24 BitsPerPixel)		
Number of unique colors:	25764	☒	Auto count
Disk size:	434.54 KB (444.964 Bytes)		
Current memory size:	5.44 MB (5,702,440 Bytes)		

Fig.3.2.4. Properties of the selected and resized frame image

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 24 of 59



Fig.3.2.5. Resized selected frame of the DNAMIC video (mp4), and stored as jpg file "DNAMIC_VIDEO_frame_resized_800_413", (resolution 800x413 pixels, size 114.00 KB)

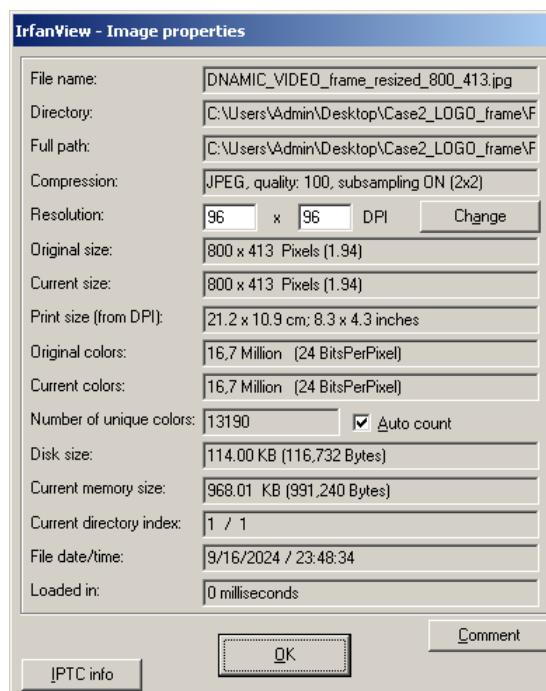


Fig.3.2.6. Properties of the selected and resized frame image

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 25 of 59

4. CASE STUDY NO.3-1: VETERINARY DIAGNOSTIC IMAGES OF CANINE LESIONS (DIGITAL HEALTH 4.0/5.0)

In order to represent the sector of Digital Health 4.0 /5.0, veterinary diagnostic images of canine lesion were selected as case study No.3-1. Images have been acquired under permission No. DZLAEP-2021/3 of the Ethical Council of Animal Welfare and Protection (Latvia University of Life Sciences and Technologies, Jelgava, Latvia).

Digitisation of H&E-stained slides of canine lesion specimens was performed using a Panoramic 250 FLASH III DX brightfield slide scanner (3DHitech Kft., Budapest, Hungary) equipped with a 20×/0.8 NA Plan-Apochromat objective (Carl Zeiss, Germany). Conventional white light (WL) images were taken for subsequent histological analysis. The pathologist then examined the digitised WL images of each specimen and characterised the structural features of the specimens by providing a diagnosis of the tumour. Autofluorescence (FL) images were acquired using the yellow channel (YFL) of the instrument. The obtained images to be stored in DNA are presented in Fig.4.1 and properties of the combined image are presented in Fig.4.2.

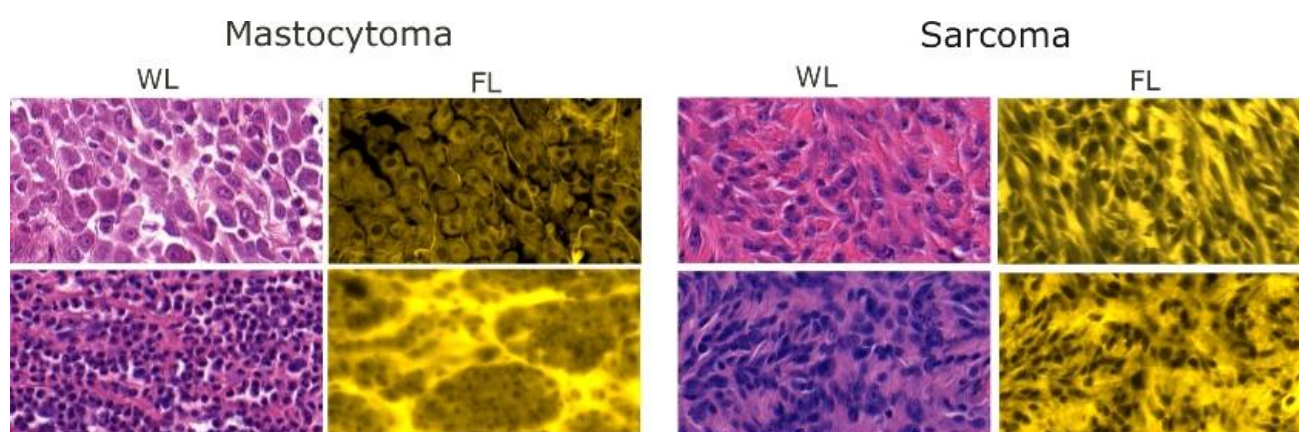


Fig.4.1. Optical images of canine lesions: Mastocytoma (left panel) and Sarcoma (right panel), to be stored in DNA. WL - white light, FL – autofluorescence. Properties of the combined image (resolution 1920x616 pixels, size 814.57 KB)

 kaunas university of technology 1922				 Co-funded by the European Union		
Organisation:		Kaunas University of Technology				
Project:		DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING				
Grants:		EIC Pathfinder Challenges 2022 Project No.: 101115389				
Title:		2.7 Case studies Version 1.0				
				Rev: 1	Page: Page 26 of 59	

Compression:	JPEG, quality: 100, subsampling ON (2x2)			
Resolution:	500	x	500	DPI Change
Original size:	1920 x 616 Pixels (1.18 MPixels) (3.11)			
Current size:	1920 x 616 Pixels (1.18 MPixels) (3.11)			
Print size (from DPI):	9.8 x 3.1 cm; 3.84 x 1.23 inches			
Original colors:	16,7 Million (24 BitsPerPixel)			
Current colors:	16,7 Million (24 BitsPerPixel)			
Number of unique colors:	143490	☒ Auto count		
Disk size:	814.57 KB (834.119 Bytes)			

Fig 4.2. Properties of the combined image presented in Fig.4.1 (resolution 1920x616 pixels, size 814.57 KB)

5. CASE STUDY NO.3-2: NDT IMAGING (INDUSTRY 4.0/5.0) IMAGES

To meet the needs of Industry 4.0 / 5.0, a globally relevant 3D printing method for PCBs has been selected. This method offers unique opportunities to print PCBs for critical electronics at the point of installation (data and communication centres, power supply infrastructure, patient life support equipment etc.). This is essential in the event of global natural disasters and pandemics, as well as in military conflicts where the production and supply chains of electronic components are disrupted. It is also becoming increasingly relevant in the context of the widespread development of space applications, such as the International Space Station, lunar and Mars missions.

Non-invasive NDT technologies such as ultrasonic inspection, X-ray and thermal imaging are used to ensure quality control of these printed circuit boards. Each of these technologies, which operate on different physical principles, provides diagnostic images of the internal structure of the object being inspected, which can be used to detect various defects in the manufacture of printed circuit boards and avoid defects in the final product.

 kaunas university of technology 1922				 Co-funded by the European Union		
Organisation:		Kaunas University of Technology				
Project:		DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING				
Grants:		EIC Pathfinder Challenges 2022 Project No.: 101115389				
Title:		2.7 Case studies Version 1.0				
				Rev: 1	Page: Page 27 of 59	

Using simultaneous deposition for conductive and dielectric ink, the DragonFly LDM electronic sub-assembly technology (the inkjet additive manufacturing technology) allows the serial fabrication of state-of-the-art electronic PCBs in laboratory circumstances. Design and manufacturing of electronic devices using in-house resources also offers the extra advantage of avoiding the possible leakage of product technological information, the copying of devices, or the introduction of hidden flaws during manufacturing, so mitigating the risks connected with designing and manufacturing products in external, third-party environments. The concept of PCB printing is presented in Fig.5.1.

The DragonFly LDM equipment ensures multi-material deposition process with several benefits: fast device design, safe manufacturing, simple product change, etc. [Fried, 3D printing technologies for electronics. J. Imaging Society Jpn. 2017, 56, 617–620].

Using several composite materials, PCBs were manufactured by simultaneously depositing traces using a silver nanoparticle suspension and substrates under acrylate inks, hence producing the electronic components of the device. Research on structural changes in the product could help to pinpoint the origins of flaws and adjust the additive manufacturing technique until the intended quality is reached. Using Altium Designer (San Diego, CA, USA) software package and then created using conventional and additive manufacturing technology, a specialized PCB was designed to compare and evaluate the possible potential of several NDT approaches: thermography, ultrasonic inspection (acoustic microscopy) and radiography. Using the DragonFly LDM, additive manufacturing of PCBs was conducted keeping the same stack-up as in the case of production using the conventional method. The primary distinction between the manufacturing technologies applied was that the base is UV-curable acrylate (Dielectric Ink 1092 NanoDimension, Waltham, MA, USA), for the DragonFly LDM. An AgCite 90072 Silver Nanoparticle Conductive Ink (NanoDimension, Waltham, MA, USA) was employed concurrently as a conductive substance in PCB manufacture. Apart from defect free PCBs, another additively produced board was designed with artificial flaws. It was decided not to produce artificial delamination-type flaws, which would replicate disbonding between the conducting layer and substrate. This choice was taken to guarantee the repeatability of such defects and to manage the defect size and location, so addressing challenges. Consequently, among the flaws noted were missing vias, tracks, and SMD pads as well as a wrong pitch between pads and tracks with width decrease.

More details about DragonFly LDM technology and printed PCB inspection are presented here: [Jasiūnienė, E.; Raišutis, R.; Samaitis, V.; Jankauskas, A. Comparison of Different NDT Techniques for Evaluation of the Quality of PCBs Produced Using Traditional vs. Additive Manufacturing Technologies. Sensors 2024, 24, 1719. <https://doi.org/10.3390/s24061719>]

The principle of the combined NDT using three non-invasive inspection techniques (ultrasonic inspection, X-ray and thermography) is presented in Fig.5.2.

 kaunas university of technology 1922			 Co-funded by the European Union
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 28 of 59

Obtained NDT images of printed circuit boards (defective and defect free) using the combined NDT of three non-invasive inspection techniques (ultrasonic inspection, X-ray and thermography) are presented in Fig. 5.3. The prepared resulting image (resolution 2364x3649 pixels, size 743.76 KB) to be stored in DNA of the obtained NDT images of printed circuit boards (defective and defect free) using the combined NDT of three non-invasive inspection techniques (ultrasonic inspection, X-ray and thermography) is presented in Fig. 5.4. The properties of the resulting image to be stored in DNA of the obtained NDT images of printed circuit boards are presented in Fig. 5.5.

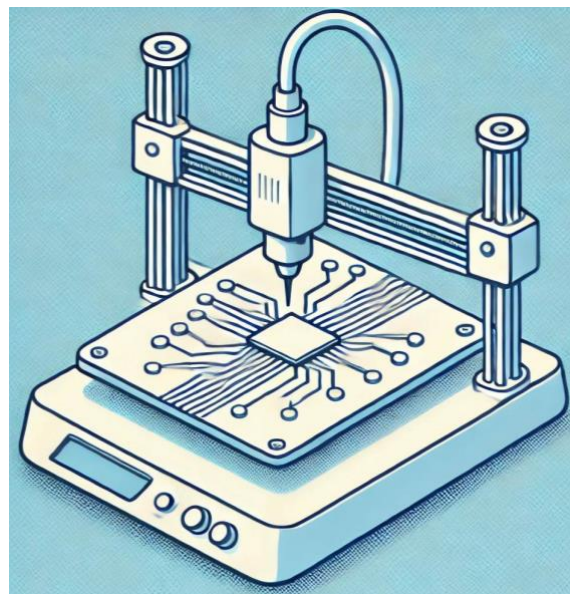


Fig. 5.1. The concept of PCB printing. Remark: An AI generated image using OpenAI's DALL-E is presented for illustrative purposes.

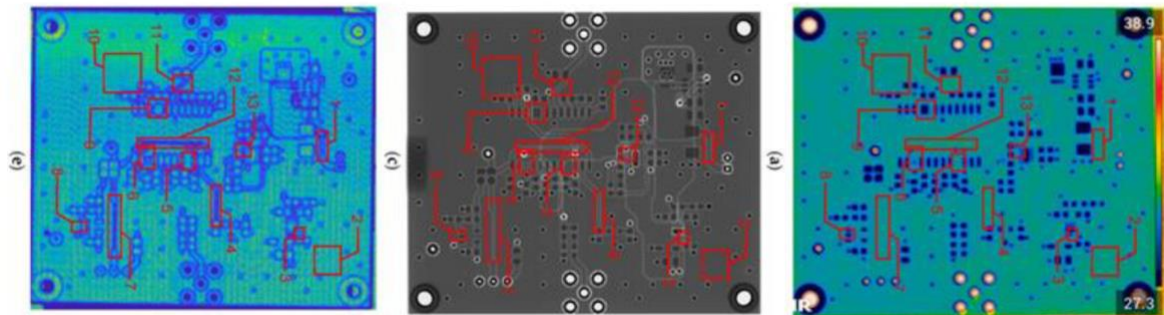
 kaunas university of technology		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 29 of 59



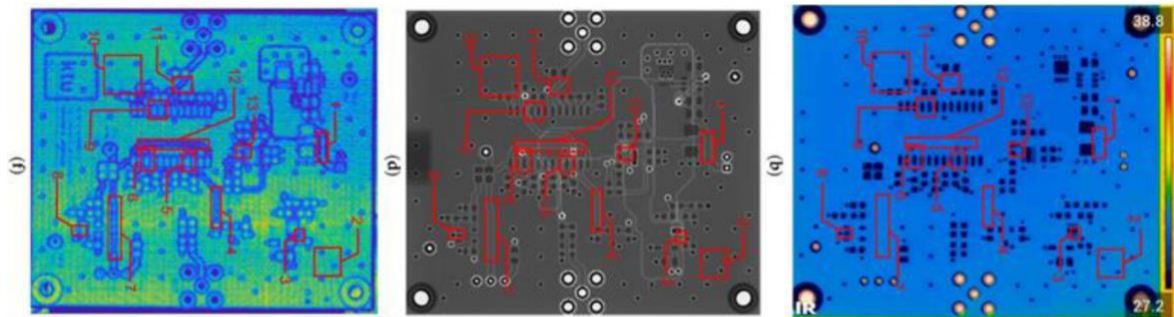
Fig 5.2. Combined NDT using three non-invasive inspection techniques: ultrasonic inspection, X-ray and thermography. Remark: An AI generated image using OpenAI's DALL-E is presented for illustrative purposes.

 kaunas university of technology		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 30 of 59

Defective PCB sample



Defect free PCB sample



Ultrasonic



X-ray



Thermography

Fig 5.3. Obtained NDT resulting image of printed circuit boards (defective and defect free) using the combined NDT of three non-invasive inspection techniques: ultrasonic inspection, X-ray and thermography

 kaunas university of technology		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 31 of 59

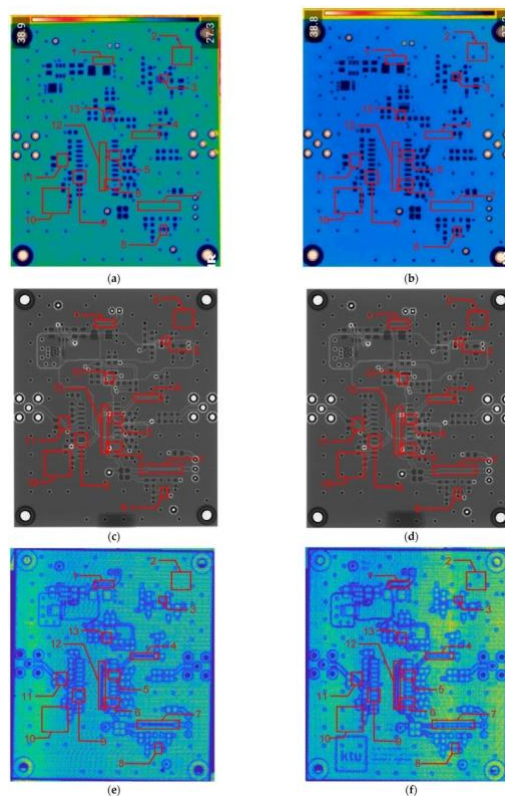


Fig 5.4. Prepared resulting image (resolution 2364x3649 pixels, size 743.76 KB) to be stored in DNA of the obtained NDT images of printed circuit boards (defective and defect free) using the combined NDT of three non-invasive inspection techniques: ultrasonic inspection, X-ray and thermography

Compression:	JPEG, quality: 69, subsampling ON (2x2)
Resolution:	x DPI Change
Original size:	2364 x 3649 Pixels (8.63 MPixels) (0.64)
Current size:	2364 x 3649 Pixels (8.63 MPixels) (0.64)
Print size (from DPI):	83.4 x 128.7 cm; 32.83 x 50.68 inches
Original colors:	16,7 Million (24 BitsPerPixel)
Current colors:	16,7 Million (24 BitsPerPixel)
Number of unique colors:	☒ Auto count
Disk size:	743.76 KB (761,614 Bytes)
Current memory size:	24.68 MB (25,878,748 Bytes)

Fig. 5.5. Properties of the image to be stored in DNA of the obtained NDT images of printed circuit boards

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 32 of 59

6. CASE STUDY NO.4: PATRIMONIAL / DIGITAL ARCHIVE DATA

Patrimonial data from the Swiss Digital Archive (e.g. watch industry data: images, pdf documents) was selected as case study No.4. Partner Haute Ecole Spécialisée de Suisse occidentale (HES-SO) provided a PDF file with embedded pictures „20240906_Cejare_Erismann-Schinz-Grenier_EN.pdf“, thanks to the precious contribution of Christelle Donius, of CEJARE, St-Imier, Switzerland. CEJARE, le Centre jurassien d'archives et de recherche économiques, in Saint-Imier, Switzerland. CEJARE is an association dedicated to the conservation of industrial and economic archives. The records from a watch components company, as pdf file, is presented in Fig.6.1.

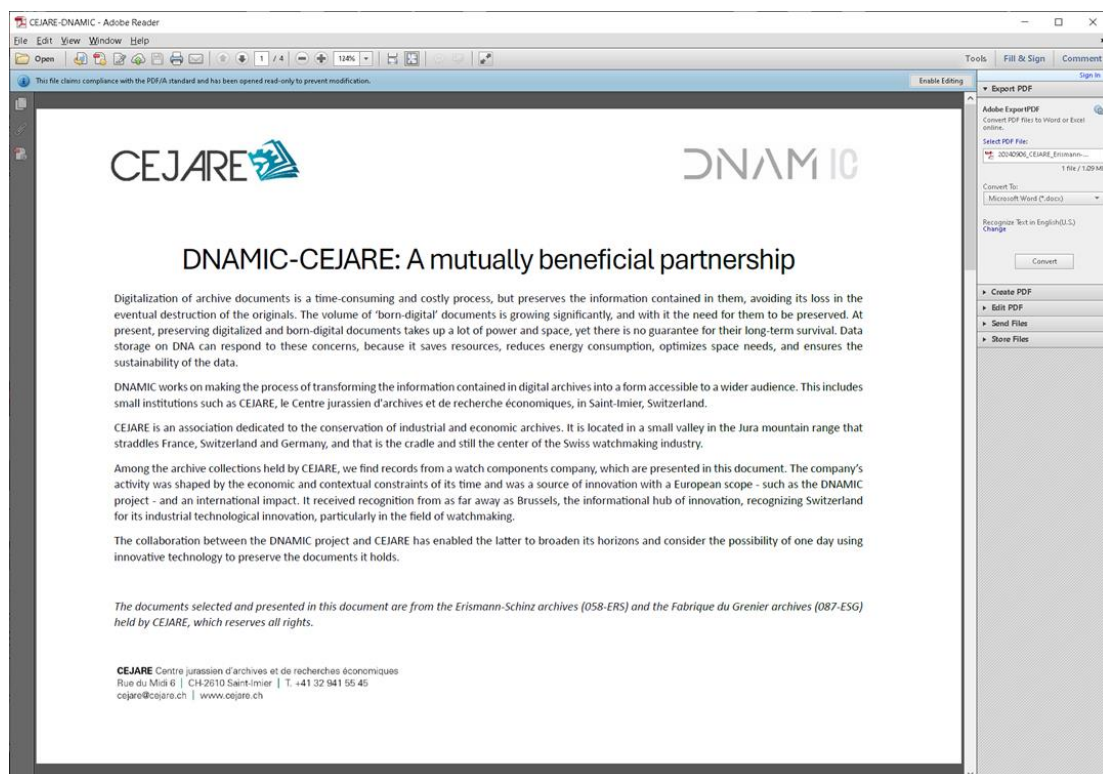


Fig.6.1. The records from a watch components company (pdf file, file size 1.14 MB, 4 pages, 6 pictures)

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 33 of 59

The content of the file is presented in Annex 1: Patrimonial data file of Swiss Digital Archive "watch 20240902_Cejare_Erismann-Schinz-Grenier en.pdf".

Extracted from pdf Image No.1 (jpg), resolution 907x616 pixels, size 133.09 KB, is presented in Fig.6.2. Properties of extracted from pdf Image No.1 (jpg) are presented in Fig.6.3. Extracted from pdf Image No.2 (jpg), resolution 907x616 pixels, size 152.97 KB, is presented in Fig.6.4. Properties of extracted from pdf image No.2 (jpg) are presented in Fig.6.5. Extracted from pdf Image No.3 (jpg), resolution 1100x1442 pixels, size 234.66 KB, is presented in Fig.6.6. Properties of extracted from pdf image No.3 (jpg) are presented in Fig.6.7. Extracted from pdf Image No.4 (jpg), resolution 900x1275 pixels, size 205.82 KB, is presented in Fig.6.8. Properties of extracted from pdf Image No.4 (jpg) are presented in Fig.6.9. Extracted from pdf Image No.5 (jpg), resolution 1024x726 pixels, size 171.54 KB, is presented in Fig.6.10. Properties of extracted from pdf image No.5 (jpg) are presented in Fig.6.11. Extracted from pdf Image No.6 (jpg), resolution 11150x1595 pixels, size 238.46 KB, is presented in Fig.6.12. Properties of extracted from pdf image No.6 (jpg) are presented in Fig.6.13.

Extracted from pdf Image No.6 (jpg), resolution 11150x1595 pixels, size 238.46 KB, presented in Fig.6.12 was selected to be stored in DNA at the first attempt.

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 34 of 59

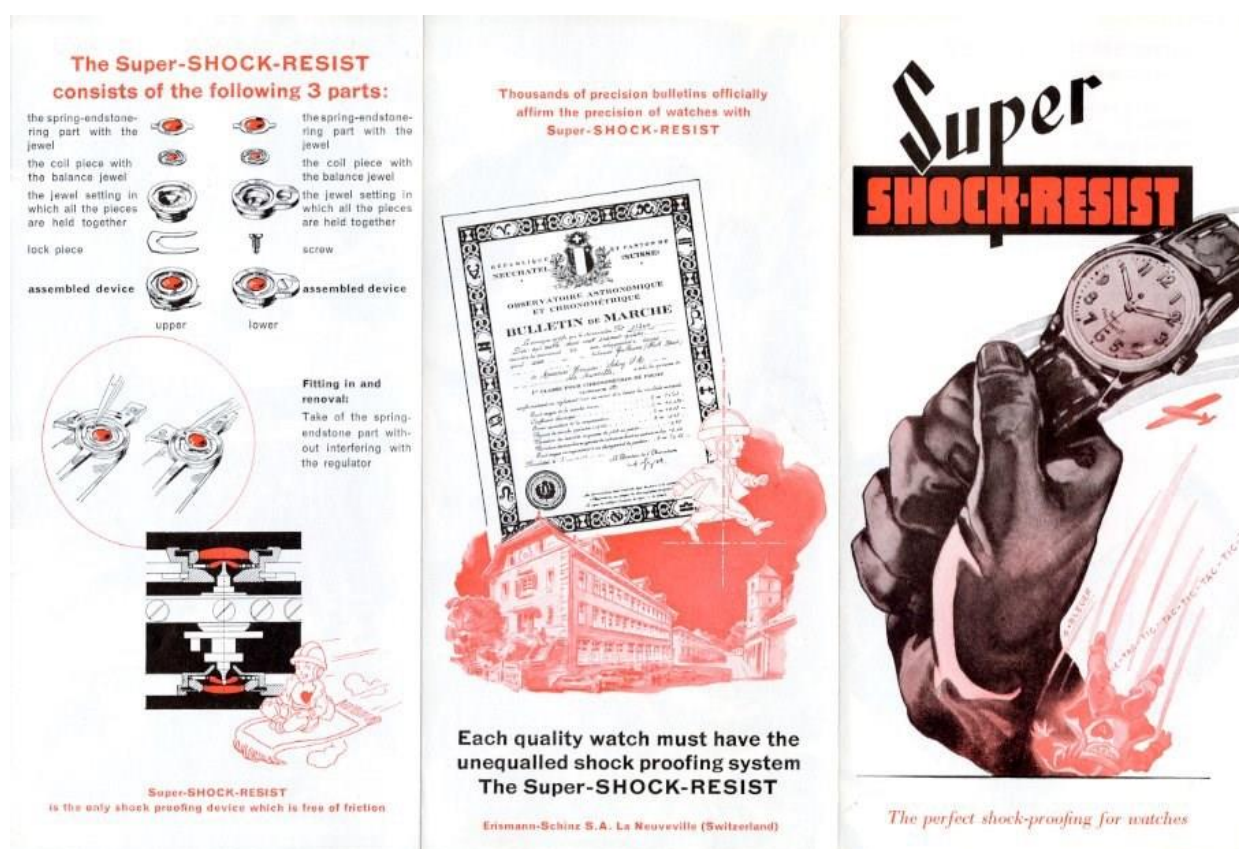


Fig.6.2. Extracted from pdf Image No.1 (jpg), resolution 907x616 pixels, size 133.09 KB

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 35 of 59

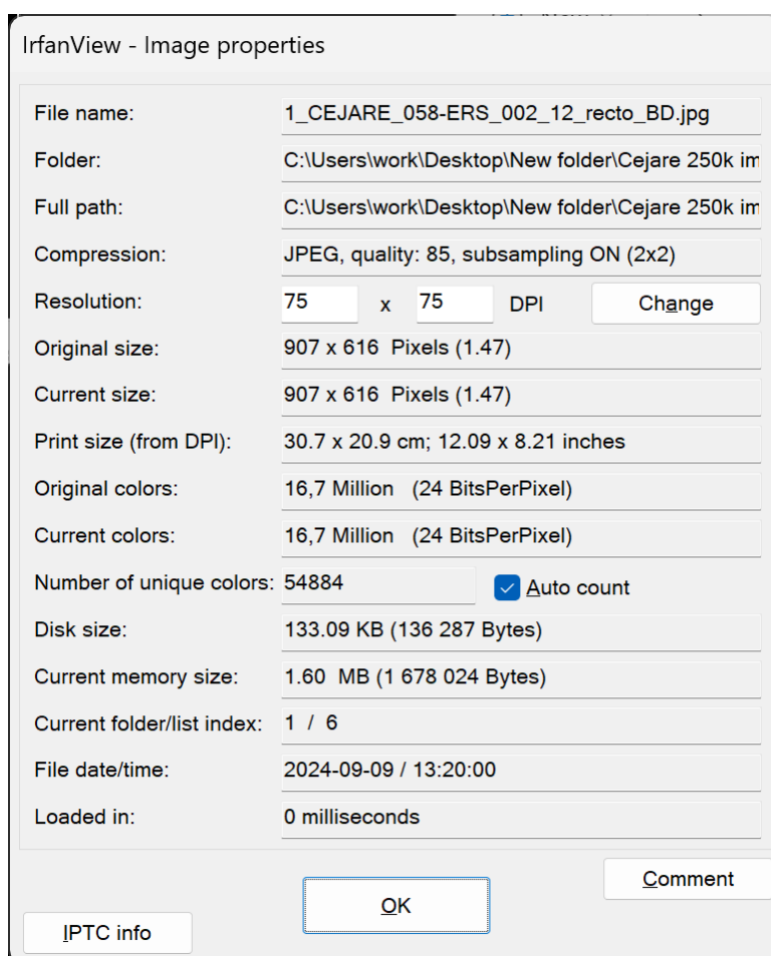


Fig.6.3. Properties of the extracted from pdf Image No.1 (jpg), resolution 907x616 pixels, size 133.09 KB

 1922 kaunas university of technology		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 36 of 59



Fig.6.4. Extracted from pdf Image No.2 (jpg), resolution 907x616 pixels, size 152.97 KB

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 37 of 59

IrfanView - Image properties

File name:	2_CEJARE_058-ERS_002_13_verso_BD.jpg		
Folder:	C:\Users\work\Desktop\New folder\Cejare 250k im		
Full path:	C:\Users\work\Desktop\New folder\Cejare 250k im		
Compression:	JPEG, quality: 85, subsampling ON (2x2)		
Resolution:	75	x	75 DPI Change
Original size:	907 x 616 Pixels (1.47)		
Current size:	907 x 616 Pixels (1.47)		
Print size (from DPI):	30.7 x 20.9 cm; 12.09 x 8.21 inches		
Original colors:	16,7 Million (24 BitsPerPixel)		
Current colors:	16,7 Million (24 BitsPerPixel)		
Number of unique colors:	22571	☒	Auto count
Disk size:	152.97 KB (156 646 Bytes)		
Current memory size:	1.60 MB (1 678 024 Bytes)		
Current folder/list index:	2 / 6		
File date/time:	2024-09-09 / 13:20:00		
Loaded in:	15 milliseconds		

IPTC info
OK
Comment

Fig.6.5. Properties of the extracted from pdf Image No.2 (jpg), resolution 907x616 pixels, size 152.97 KB

 kaunas university of technology 1922				 Co-funded by the European Union		
Organisation:		Kaunas University of Technology				
Project:		DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING				
Grants:		EIC Pathfinder Challenges 2022 Project No.: 101115389				
Title:		2.7 Case studies Version 1.0				
				Rev: 1	Page: Page 38 of 59	



Fig.6.6. Extracted from pdf Image No.3 (jpg), resolution 1100x1442 pixels, size 234.66 KB

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 39 of 59

IrfanView - Image properties

File name:	3_CEJARE_058-ERS_014_2_h_BD.jpg		
Folder:	C:\Users\work\Desktop\New folder\Cejare 250k im		
Full path:	C:\Users\work\Desktop\New folder\Cejare 250k im		
Compression:	JPEG, quality: 80, subsampling ON (2x2)		
Resolution:	600	x	600 DPI Change
Original size:	1100 x 1442 Pixels (1.59 MPixels) (0.76)		
Current size:	1100 x 1442 Pixels (1.59 MPixels) (0.76)		
Print size (from DPI):	4.7 x 6.1 cm; 1.83 x 2.40 inches		
Original colors:	16,7 Million (24 BitsPerPixel)		
Current colors:	16,7 Million (24 BitsPerPixel)		
Number of unique colors:	447	☒	Auto count
Disk size:	234.66 KB (240 288 Bytes)		
Current memory size:	4.54 MB (4 758 640 Bytes)		
Current folder/list index:	3 / 6		
File date/time:	2024-09-09 / 13:20:00		
Loaded in:	16 milliseconds		

IPTC info
OK
Comment

Fig.6.7. Properties of the extracted from pdf Image No.3 (jpg), resolution 1100x1442 pixels, size 234.66 KB

 1922 kaunas university of technology		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 40 of 59



Fig.6.8. Extracted from pdf Image No.4 (jpg), resolution 900x1275 pixels, size 205.82 KB

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 41 of 59

IrfanView - Image properties

File name:	4_CEJARE_087-ESG_004_BD.jpg				
Folder:	C:\Users\work\Desktop\New folder\Cejare 250k im				
Full path:	C:\Users\work\Desktop\New folder\Cejare 250k im				
Compression:	JPEG, quality: 80, subsampling ON (2x2)				
Resolution:	600	x	600	DPI	Change
Original size:	900 x 1275 Pixels (1.15 MPixels) (0.70)				
Current size:	900 x 1275 Pixels (1.15 MPixels) (0.70)				
Print size (from DPI):	3.8 x 5.4 cm; 1.50 x 2.13 inches				
Original colors:	16,7 Million (24 BitsPerPixel)				
Current colors:	16,7 Million (24 BitsPerPixel)				
Number of unique colors:	4620	☒	Auto count		
Disk size:	205.82 KB (210 759 Bytes)				
Current memory size:	3.28 MB (3 442 540 Bytes)				
Current folder/list index:	4 / 6				
File date/time:	2024-09-09 / 13:20:00				
Loaded in:	0 milliseconds				

IPTC info
OK
Comment

Fig.6.9. Properties of the extracted from pdf Image No.4 (jpg), resolution 900x1275 pixels, size 205.82 KB

 1922 kaunas university of technology		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 42 of 59



Fig.6.10. Extracted from pdf Image No.5 (jpg), resolution 1024x726 pixels, size 171.54 KB

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 43 of 59

IrfanView - Image properties

File name:	5_CejARE_058-ERS_006_medaille_BD.jpg		
Folder:	C:\Users\work\Desktop\New folder\Cejare 250k im		
Full path:	C:\Users\work\Desktop\New folder\Cejare 250k im		
Compression:	JPEG, quality: 86, subsampling OFF		
Resolution:		x	DPI Change
Original size:	1024 x 726 Pixels (1.41)		
Current size:	1024 x 726 Pixels (1.41)		
Print size (from DPI):	36.1 x 25.6 cm; 14.22 x 10.08 inches		
Original colors:	16,7 Million (24 BitsPerPixel)		
Current colors:	16,7 Million (24 BitsPerPixel)		
Number of unique colors:	46732	☒	Auto count
Disk size:	171.54 KB (175 658 Bytes)		
Current memory size:	2.13 MB (2 230 312 Bytes)		
Current folder/list index:	5 / 6		
File date/time:	2024-09-09 / 13:20:00		
Loaded in:	16 milliseconds		

IPTC info
OK
Comment

Fig.6.11. Properties of the extracted from pdf Image No.5 (jpg), resolution 1024x726 pixels, size 171.54 KB

 1922 kaunas university of technology	DYNAMIC	 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
			Rev: 1 Page: Page 44 of 59

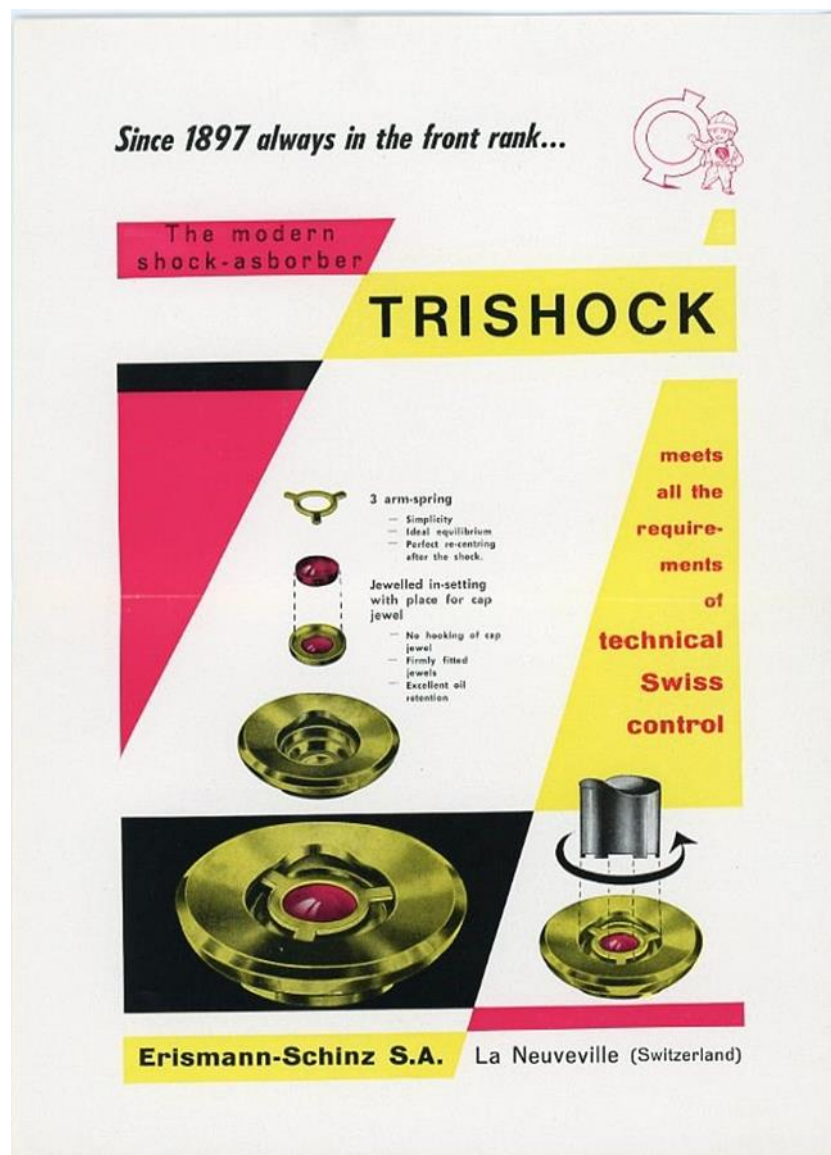


Fig.6.12. Extracted from pdf Image No.6 (jpg), resolution 11150x1595 pixels, size 238.46 KB

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 45 of 59

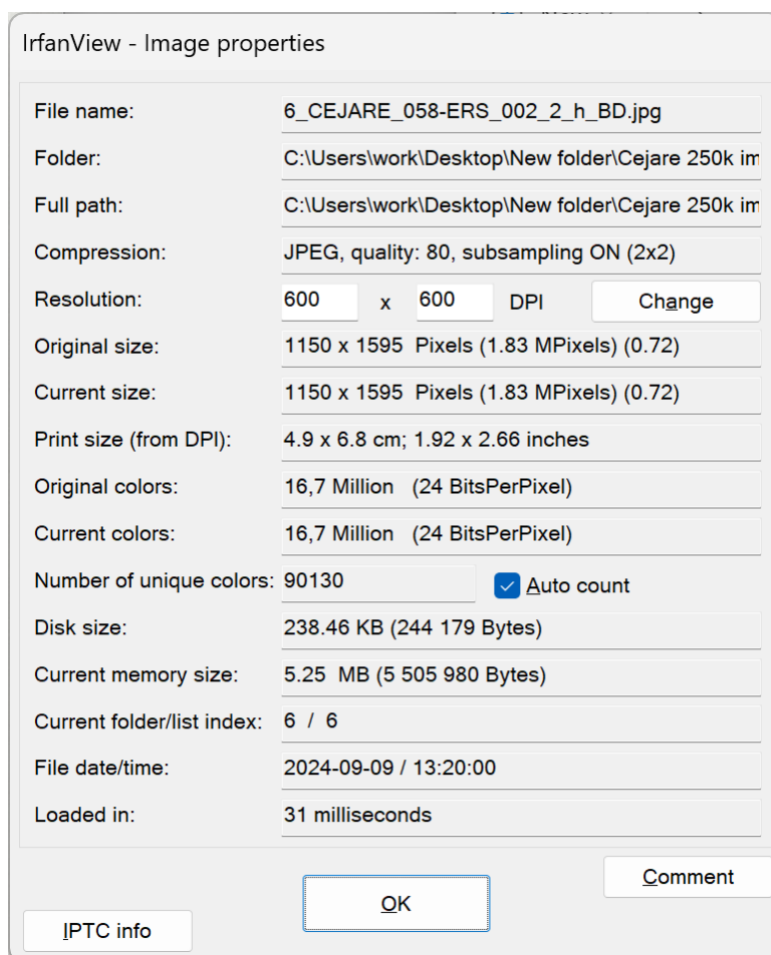


Fig.6.13. Properties of the extracted from pdf Image No.6 (jpg), resolution 11150x1595 pixels, size 238.46 KB

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 46 of 59

7. THEORETICAL DESCRIPTION OF DIGITIZED DATA ENCODING INTO DNA AND DECODING

The theoretical description of the encoding of digitised data into DNA and decoding includes the encoding/decoding workflow:

- 1) Binarisation of input data (images, documents, files);
- 2) Conversion of binary data into ATGC sequences (encoding);
- 3) Conversion of ATGC sequences into binary data (decoding);
- 4) Conversion of binary data back to input data (images etc.);
- 5) Application of error correction algorithms.

The algorithm of encoding/decoding workflow (provided by Université de Genève (UNIGE)) is presented in Fig.7.1. The presented algorithm is dedicated to encode digital data (images, etc.) into DNA sequences, store them, and subsequently decode the DNA sequences back into digital data (pictures, etc.). To guarantee data integrity in spite of any storage or transmission faults, the procedure consists in various processes including binarization, encoding, error correction and decoding. The main steps of the algorithm are:

1. Input files description: First transformed to a binary format (sequences of 0 and 1), the input data (such as photos, text or video files). In the case of pictures, the picture thresholding is applied then each pixel of a picture is converted into binary (0 or 1) values depending on the type of data, therefore changing grayscale or colour images into binary images. Reducing the amount of binary data by means of series of identical bits is known as run-length coding. Though it is not always relevant, this stage is generally used to compress data before encoding.
2. Encoder: The encoder makes DNA sequences from the binary digital data. Binary data (0 and 1) are mapped into sequences of the four DNA nucleotides: A (adenine), T (thymine), C (cytosine) and G (guanine). Throughout DNA synthesis and sequencing, the coding process guarantees precision and stability:
 - No homopolymers: The technique avoids long lengths of the same nucleotide (e.g., "AAAA") as homopolymers can cause significant sequencing error rates.
 - Balanced G+C content: The method guarantees that the ratio of G and C nucleotides to the total number of nucleotides (G+C+T+A) lies between 0.4 and 0.6. A high or low G+C content might influence the stability and secondary structure of the DNA, so this equilibrium is absolutely important.
 - Strand length: Usually maintained at a predetermined length (e.g., 100–200 nucleotides), generated DNA strands maximize synthesis and sequencing efficiency.

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 47 of 59

- Integration of error correction: Following DNA sequence encoding of the binary data, error correction codes like the Golay code are used to strengthen the data storage integrity. Operating on 24-bit segments, the Golay code algorithm adds redundancy to find and fix up to three mistakes each segment.
 - Other codes as Reed-Solomon or Hamming codes could be applied depending on the application.
3. DNA synthesis: the encoded DNA sequences are produced physically into DNA strands. Appropriate biochemical limitations have to be observed in this stage to prevent mistakes such synthesis failures or secondary structures.
 4. Storage and retrieval: The produced DNA finds a stable surroundings. Should retrieval be needed, the DNA is sequenced back into computer data sequences.
 5. Decoder: it rebuilds the original digital data from the sequenced DNA. During decoding, the alignment and clustering are being performed; incoming sequences are grouped and aligned to discover the most likely original sequence and eliminate sequencing faults. A consensus sequence produced reflects the best accurate reconstruction of the original coded data. The decoder uses error correcting techniques to precisely rebuild the binary data. Different error correcting techniques could be applied based on the coding:
 - The Golay decoder detects and fixes up to three mistakes per 24-bit segment using the redundancy in each one.
 - Reed-Solomon codes: suitable for usage in applications with extended sequences of errors and fixing burst errors.
 - Hamming codes are effective for double-bit error detection and single-bit error correction.
 - Convolutional codes: Designed to manage bit flip errors at random.
 6. Conversion back to the original data format: the rectified binary data is transformed back to its original digital format (picture, text, video, etc.) using inverse operations corresponding with the first binarization and data preparation stages.

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 48 of 59

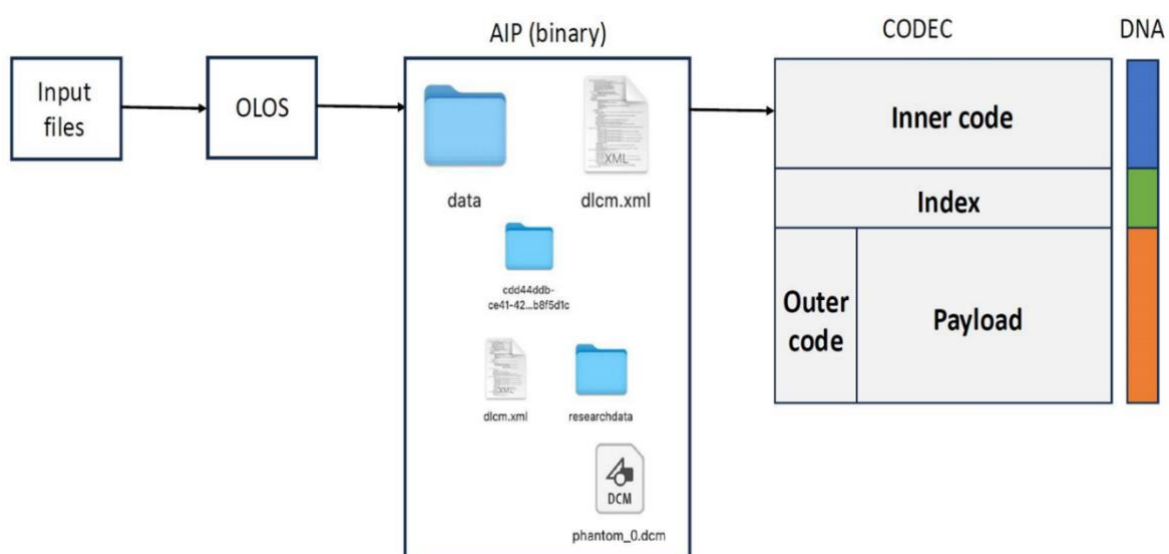


Fig.7.1. The algorithm of encoding/decoding workflow (provided by Université de Genève (UNIGE))

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		Rev: 1	Page: Page 49 of 59

8. CONCLUSIONS

- The research performed effectively showed the feasibility of preparation for encoding, storing, and decoding various types of digital data in synthetic DNA. Medical diagnostic photos (veterinary images of canine lesions), industrial NDT testing images, DNAMIC logo, movie and patrimonial archive data comprised the broad spectrum of varied data types (4 case studies were presented). Between image size of 100kB and 1MB, the investigated storage capacities displayed scalability for bigger data sets. Digital Health 4.0 (medical and veterinary diagnostics), Industry 4.0 (non-destructive testing) and digital archiving (Swiss watch producing industry data) among other sectors encompass the application of DNA data storage for many industrial areas.
- The DICOM (Digital Imaging and Communications in Medicine) standard was effectively incorporated into the DNA storage workflow, enabling the storage of complex medical imaging data and metadata tags, also preserving data integrity and compatibility with current medical imaging systems.
- By means of encoding and storage of patrimonial data from the Swiss Digital Archive, the study revealed DNA's suitability as a long-term digital preservation solution for archiving of historically important material.
- The research designed and carried out a structured workflow for encoding digital data into DNA sequences and precisely decoding it again. The thorough block diagram and algorithm explanation ensures repeatability and offer a clear approach.
- Enhanced encoding for sequencing and synthesis of DNA: The work covered the pragmatic limitations of DNA synthesis and sequencing including homopolymer avoidance, balanced G+C content and strand length restrictions. Stable and dependable DNA strands for data storage emerged from efficient management of these limitations throughout the encoding process.
- Though the findings are encouraging, the study points up various issues including errors correction, data retrieval speed and synthesis cost that must be resolved if DNA data storage is to become economically feasible. Future researcher will concentrate on improving error correction algorithms, optimizing encoding techniques and lowering synthesis and sequencing costs.

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 50 of 59

9. REFERENCES

- <https://www.dicomstandard.org/authenticate-mita/>
- <https://www.dicomstandard.org/authenticate-nema/>
- <https://www.dicomstandard.org/current>
- Fried, 3D printing technologies for electronics. J. Imaging Society Jpn. 2017, 56, 617–620
- Jasiūnienė, E.; Raišutis, R.; Samaitis, V.; Jankauskas, A. Comparison of Different NDT Techniques for Evaluation of the Quality of PCBs Produced Using Traditional vs. Additive Manufacturing Technologies. Sensors 2024, 24, 1719. <https://doi.org/10.3390/s24061719>

 kaunas university of technology 1922			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 51 of 59

10. ANNEXES

- Annex 1: Patrimonial data file of Swiss Digital Archive "watch 20240902_CEJARE_Erismann-Schinz-Grenier en.pdf"

 kaunas university of technology 1922				 Co-funded by the European Union	
Organisation:		Kaunas University of Technology			
Project:		DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:		EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:		2.7 Case studies Version 1.0			
				<i>Rev: 1</i>	<i>Page: Page 52 of 59</i>

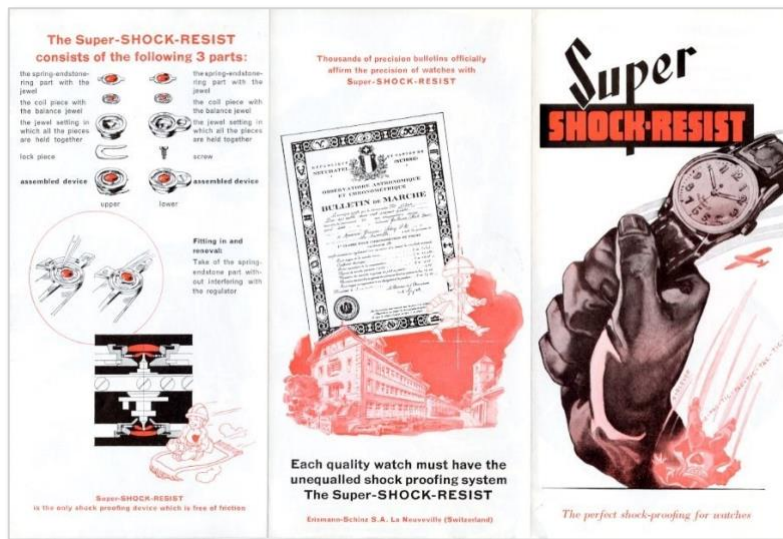


Erismann-Schinz at the Fabrique du Grenier: watchmaking innovation to protect against shocks

The CEJARE (Centre jurassien d'archives et de recherche économiques) in Saint-Imier is a conservation center for company archives in the Bernese Jura and the Jura region, a major industrial hub since the 19^e century, and is home to numerous archives from the watchmaking industry. The center is a privileged witness to watchmaking expertise and innovation in Switzerland. As part of its collaboration with the DNAMIC project, the center is offering a selection of digitized documents as candidates for encoding and preservation in DNA form. These documents illustrate innovation within a regional company producing watch components to optimize quality.

 kaunas university of technology 1922		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
	Rev: 1 Page: Page 53 of 59		

The origins of Erismann-Schinz



Its founder, Alphonse Erismann, set up his stamping business in La Neuveville in 1898. He went on to found the Erismann-Schinz company in the early 20th^e century, which later became known more widely as the Fabrique du Grenier, named after the town's landmark building. Over the years and events that marked the first part of the century, both sectorally and internationally, the company evolved. The aftermath of the First World War was a period of elation that encouraged inventions. La Fabrique followed this trend, focusing its innovation on shock absorber systems.

Figure 1: Side A of a trifold advertising brochure presenting the Shock-Resist, with, from left to right: description of the technology, reproduction of a Bulletin de marche issued by the Observatoire astronomique et chronométrique of the Canton of Neuchâtel, and the flyer's front cover.

 kaunas university of technology 1922				 Co-funded by the European Union	
Organisation:		Kaunas University of Technology			
Project:		DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:		EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:		2.7 Case studies Version 1.0			
					Rev: 1
					Page: Page 54 of 59



Figure 2: Side B of the tri-fold brochure shown in figure 1, listing the benefits of the technology (left) and highlighting their use in sports, representative of the evolution of customs and peacetime.

 kaunas university of technology			 Co-funded by the European Union
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
Rev: 1			Page: Page 55 of 59

The product of success

After a first product was patented on the eve of the 1929 financial crisis, followed shortly afterwards by the death of the founding father, financial constraints prompted his sons to find a way of making a strong statement to keep the factory afloat. After a few years of refinement, the Shock-Resist was revealed to the world in 1934, with a series of "shock" advertising campaigns (Figure 1 and Figure 2). One of these involved the release of thousands of balloons with cards attached (Figure 3). Capable of absorbing shocks from all directions, the invention not only won technical recognition, but was also widely used by the general public, particularly in sporting activities, as a result of a change in morals encouraged by peace.

Figure 3: Balloon release in 1938, with competition for the longest distances covered (over 2,000 km). People turning over cards from the most remote landing sites receive a watch equipped with Shock-Resist.



 kaunas university of technology 1922				 Co-funded by the European Union	
Organisation:		Kaunas University of Technology			
Project:		DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:		EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:		2.7 Case studies Version 1.0			
				Rev: 1	Page: Page 56 of 59



Figure 4: Advertising published during the Second World War (1941) featuring the quality of Shock-Resist personified.

When the Second World War broke out, the invention continued to be used in soldiers' watches. The product, already well known and still benefiting from advertising campaigns as shown in the 1941 advertisement (Figure 4), was recognized for its efficiency by decision-makers, and preferred to its competitors. Buoyed by this prosperous wave, the company reorganized to improve efficiency.

		 Co-funded by the European Union	
Organisation:	Kaunas University of Technology		
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING		
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389		
Title:	2.7 Case studies Version 1.0		
		<i>Rev: 1</i>	<i>Page: Page 57 of 59</i>

Continuing innovation

Nevertheless, conscious of the need to constantly innovate in its chosen field of impact resistance, the Fabrique continued its innovative research. In the 1960s, the company continued to register patents to protect its inventions, including the Trishock. Gérard Erismann, son of the creator of Erismann-Schinz, who took over his father's activities, received awards for the internationally recognized quality of the watch components he produced (Figure 5). Like the Shock-Resist created in the 1940s, this innovation is also widely advertised (Figure 6).

 kaunas university of technology			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 58 of 59

A virtuous partnership

While digitizing archival documents is a time-consuming and costly process, it does have the advantage of preserving a trace of the information contained in the documents, thus making up for the eventual destruction of the originals. As for "born-digital" documents, their volume is growing fast, and their value is increasing content also deserves to be preserved. At present, the preservation of these two types of digital archive is energy- and space-intensive, without ensuring their long-term survival. Data preservation on DNA can meet these ambitions, offering resource savings, energy sobriety, space optimization and data durability.

Figure 5: Vermeil medal awarded to Gérard Erismann at the 14th Salon International des Inventeurs in Brussels in 1965, for his innovative "Trishock" shock absorber bearing.



 kaunas university of technology			 Co-funded by the European Union	
Organisation:	Kaunas University of Technology			
Project:	DNA MICROFACTORY FOR AUTONOMOUS ARCHIVING			
Grants:	EIC Pathfinder Challenges 2022 Project No.: 101115389			
Title:	2.7 Case studies Version 1.0			
			Rev: 1	Page: Page 59 of 59

Figure 6: advertising brochure presenting the Trishock developed in the 1960s. The mascot, guardian of watch movements against shocks, already present on Shock-Resist promotional documents in the 1930s, is still present.

DNAMIC works to make the process of transforming the information contained in digital archives accessible to all. This includes small institutions such as CEJARE, an association for the conservation of industrial and economic archives nestled in a small Swiss valley in the Jura, the cradle of a still active watchmaking industry, straddling France, Switzerland and Germany. Among the archive collections held by CEJARE are the documents from a watch component company presented in this document. The company, whose activity was shaped by the economic and contextual constraints of its time, was - as the DNAMIC project is - a source of innovation with a European and international reach, receiving recognition as far afield as Brussels, Switzerland's information hub, which recognized Switzerland for its industrial technological innovation, particularly in the field of watchmaking.

The encounter between the DNAMIC project and CEJARE has enabled the latter to open up its horizons and envisage the possibility of one day using innovative technology to preserve the documents it holds.

The documents presented here come from the Erismann-Schinz collection (058-ERS) and the Fabrique du Grenier collection (087-ESG), both of which are the property of CEJARE, with all rights reserved.

CEJARE Centre jurassien d'archives et de recherches économiques
 Rue du Midi 6 | CH-2610 Saint-Imier | T. +41 32 941 55 45
 cejare@cejare.ch | www.cejare.ch

