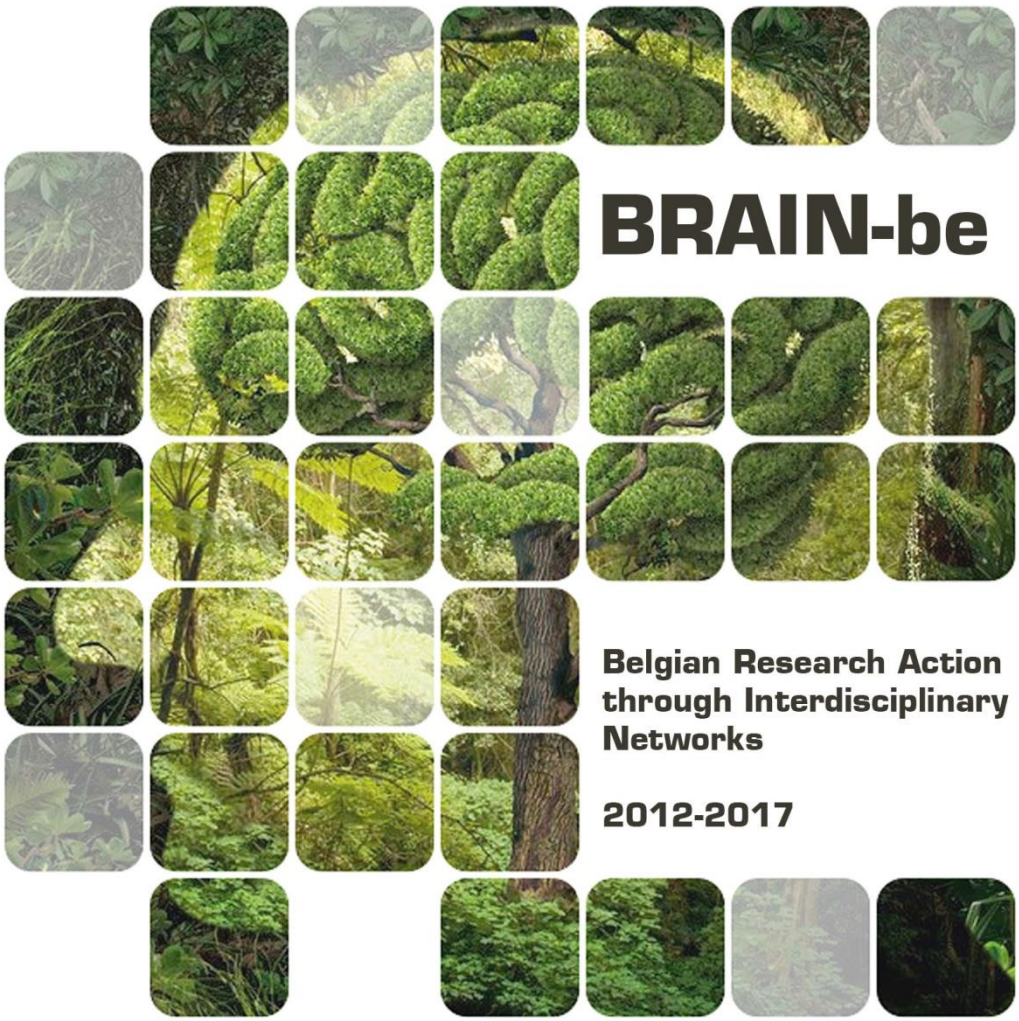

FINGERPRINT

Innovative Visual Data Management for Drawings and Prints Collections

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Axis 6: Management of collections

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NETWORK PROJECT

FINGERPRINT Innovative Visual Data Management for Drawings and Prints Collections

Contract - BR/154/A6/Fingerprint

FINAL REPORT

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ABSTRACT

FINGERPRINT (Innovative Visual Data Management for Drawings and Prints Collections) is an interdisciplinary project, involving art history, art technical research, digital imaging, image processing, conservation science and collection and data management. The focus is the oeuvre of Pieter Bruegel the Elder in Belgian collections. Advanced digital imaging, processing and laboratory analyses are used to monitor and evaluate the genesis of drawings and prints of Bruegel, from the unique preparatory drawings through proof impressions to later states and editions. The methodology of Fingerprint had four phases: Data acquisition, Data processing, Data comparison and Model Construction and Toolbox. The research contributed to the construction of a toolbox for assessment drawings and prints. Using HR imaging, Photometric Stereo and Multispectral imaging (KU Leuven); MA-XRF (KIK-IRPA), the necessary tools are provided to present the results to expert scholars (Vienna 2018, Brussels 2019). A procedure and protocol have been developed, not only to assist curators and scholars to assess their collections, but also to help collection managers and decision makers in developing preservation, management and exhibition policies for their collections of works on paper. All data and images created within the project by KU Leuven partners will be disseminated through the KBR digital data platform.

Keywords

Technical art history
Collection management
Digitization
Advanced Imaging
Digital imaging for artistic heritage
Digital collection management
Printmaking
Old Master drawings
Pieter Bruegel the Elder
Collections of prints and drawings

1. INTRODUCTION

FINGERPRINT is an interdisciplinary collection- and data management project, involving art history, art technical research, digital imaging, image processing, conservation science. The aim is to monitor and evaluate with advanced digital imaging, statistical processing and laboratory analyses the phases of the genesis of a print, from the unique preparatory drawings over proof impressions to later states and editions.

Until recently art historical research on prints and drawings depends for the largest part on traditional art historical methods based on observation with the naked eye and on the subjective memory and knowledge of connoisseurs. The aim of this project is to develop tools to automatically perform an objective artifact analysis, and software to visualize, compare and order large numbers of complex visual and material data.

The graphic works of Pieter Bruegel the Elder (ca. 1520-1569) in the collection of the Royal Library of Belgium forms a test corpus for the FINGERPRINT project. The tools and methods developed to gather and threat the data will be designed to answer specific questions regarding the prints and drawings from this corpus. The questions regard collection management, technical art history and conservation science and but also production, distribution and consumption history of the corpus of artifacts of Bruegel.

In the framework of the research project numerous secondary goals have been reached. First of all the entire Bruegel collection of KBR has been digitized in high resolution (KU Leuven) and is online available to the public (Belgica). Furthermore a very thorough condition assessment of this collection has been performed. This study has not only provided the necessary data for the development of the protocols and toolbox but has served as documentation for a conservation treatment and remounting of a selection of the prints (exhibited in the ‘Bruegel in Black and White exhibition at KBR in 2019-2020). During this research a paper conservator (Anouk Van Hooydonk) has been formed and further know-how has been passed on to the conservation staff of KBR (Electre Totolidis). During the research an art historian / curator (Drs. Maarten Bassens) has been formed. Bassens doctoral research (KBR and KU Leuven) has focused on the states and edition history of the prints of Pieter Bruegel the Elder. In the framework of this research data provided by the FINGERPRINT digitisation protocols and toolbox (both KU Leuven) have been used and have been put into art historical context using archival research and in depth research of historical letterpress fonts used on Bruegel prints.

The created datasets on the multiple research platforms of FINGERPRINT, handed over to KBR, and the new interpretations will be accessible for the scientific community and the general public linked to the descriptions of the artifacts in the online public access of the collection of the Royal Library of Belgium. Through special processing algorithms visual data can be analyzed. The innovative tools developed during this project to assess this collection/corpus, can be used in the future to research similar collections or part of collections. On a federal level the protocols and toolbox can be used as benchmark and provide data for decision making on the management and conservation policy of federal collections of works of paper.

1. STATE OF THE ART AND OBJECTIVES

State of the art

Modern scholarship on printmaking - in this case focusing on Bruegel and his circle - emphasizes topics as the technical aspects of print production, nature and provenance of the techniques and materials used, distribution networks, consumption patterns and commercial aspects of print production and consumption, collection history and the material history and condition of the surviving objects. For these aspects evidence can be found within the surviving objects themselves by means of the proposed techniques and tools, and by classifying and comparing the large datasets gathered in this way (see paragraph below). The acquired digital data and knowledge can contribute to a better management of the collection resulting in the improvement of conservation and exhibition conditions.

The last comprehensive studies of Bruegel's drawings and prints date from 2001 and 2006, at which time technical research on drawings was still limited and was not yet fully applied by the scholars of drawings. For earlier ink research on prints and drawings in general, see: Zerdouin Bat-Yehouda 1983, *1995-1996 (Galileo's manuscripts: L Giuntini et al. NIM-B 95 (1995) 389; P. Del Carmine et al. NIM-B 113 (1996) 354; F. Lucarelli et al. NIM-B 6(2) (1996) 24); (C. Neelmeijer et al. NIM-B 189 (1995) 390-393) and 1995 (P. Kristiansson et al. NIM-B 104 (1995) 584-589.*

Objectives

New developments in non-invasive/destructive analytical and imaging equipment from 2010 on gave broader possibilities in ink research (Strilic, M., e.a. Non-destructive characterisation of iron gall ink drawings: Not such a galling problem, *Talanta The International Journal of Pure and Applied Analytical Chemistry*, 2010, n°81 and Hahn, O., "Analyses of Iron Gall and Carbon Inks by Means of X-ray Fluorescence Analysis: A Non-Destructive Approach in the Field of Archaeometry and Conservation Science", *Restaurator: International Journal for the Preservation of Library and Archival Material*, 2010, vol 31, nº1, p.41–64.).

One of the objectives of the Fingerprint project was focusing on ink research in specific details from the drawings in detailed dimensions (less than a millimeter as pen-lines, brushstrokes, pointing, hatching in different inks), allowing to examine in a non destructive way drawings on paper, and to differentiate materials (inorganic) and techniques used by the artist. This would be a challenge for the complementary fields of new art-technical and art-history research. Until 10 years ago the Bruker Art Tax point measurements were the "state of the art" and were giving information on the elementary composition of the inks (see for ex. Watteeuw & Van Bos 2014). The development of MA-XRF scanning (equipment first in Belgium in 2016, KIK-IRPA) enlarged the possibilities for analysing larger surfaces of the artworks and drawings in specific. The combination with techniques such as photometric stereo (KU Leuven, developed for documentary heritage in the RICH project, since 2014) and multispectral imaging were explored in the last five years in other graphic arts such as manuscript illumination (KU Leuven and KIK-IRPA). Until the start of the Fingerprint project no in depth research was done on the differentiation of the inks of old master drawings.

The methodology to document in 2D+ the drawings and the way they are transferred to the printed version was never studied, as equipment was not developed yet for these kinds of small scale artefacts on paper. The challenge to examine the works on paper by Pieter Bruegel the Elder in the KBR and Royal Museums of Fine Arts would enlarge the possibilities to harvest more performant information on the masters oeuvre in a non-invasive, detailed and accurate way by using MA-XRF scanning (KIK-IRPA, MA-XRF, M6 Jetstream,

Bruker AXS Germany, Rh tube, 5okV, 6ooiiA, spot size 150pm, steps of 125pm, 10 ms/pixel) and high resolution imaging with the Portable Light Dome (photometric stereo, KU Leuven, for specifications, see below). Beside drawings this methodology was executed the last years for the Codex Eyckensis Project (KU Leuven & KIK-IRPA, publication forthcoming 2021), the inks on the Khirbed Mird Papyri (ongoing) and the Breviary of Geraardsbergen (publication forthcoming 2021).

The Fingerprint project started with the identification and selection of a corpus of drawings and prints, focusing on Bruegel. A detailed investigation of historical materials and techniques was developed using various imaging techniques: **1.** standardized multimodal photography (i.e. combining high resolution visual, backlight and raking visualisations to document the condition of the object at the time of registration, all in high resolution at 600 dpi), **2.** Multi-Light Reflectance imaging, aka Photometric Stereo (i.e. revealing very detailed and shallow variations, pixel-based, regarding surface orientation and reflective responses of the materials, using the Portable Light Dome system (PLD)), **3.** Multi-Spectral Imaging (i.e. MSI, characterisation of surface materials by establishing their spectral behaviour with narrow band radiation, using the MSI component of the PLD system and/or converted NIKON DSLR and 13 spectral bandpass filters) and **4.** non-destructive macro X-Ray Fluorescence mapping analyses (i.e. MA-XRF, analytical techniques to define the elemental composition of materials, using the M6 Jetstream). The combination of these advanced digital imaging techniques have allowed to substantiate the modern scholarship on printmaking (see 4. Results). All data was brought together in the Fingerprint Digital Working Environment (a digital asset management system based on Canto Cumulus) enabling access to the data to all team members.

For the identification of changes in printed lines, “Automated Objective Quality Measure” was developed. The characteristics of each print in the corpus was assessed in a survey, using visual and analytical techniques. The final aim was the development of matrix representations for evaluation of a corpus of drawings and prints and the development of a prediction model. The outcomes of the model can be compared with the observations of traditional connoisseurship and serves as additional feedback to the connoisseur. To this end renowned connoisseurs in this field have been asked to make their judgment, carefully noting their argumentation and methodology. In this way the model outputs can be evaluated in comparison to the traditional visual art historical methods.

The resulting data can be accessed through the online public access collection database of the Royal Library of Belgium.

3. METHODOLOGY

The Methodology of Fingerprint had 4 Phases: Data acquisition, Data processing, Data comparison, Model Construction and Toolbox.

1. Data acquisition

1.1. Documentation & Art historical assessment of the drawings & prints of Bruegel

The description and documentation of the corpus of Bruegel's drawings and prints relied on the experience of the Print curator of the Royal Library and his assistant, advised by specialised print scholars from the follow-up committee. The selection of the corpus was based on existing art historical and material knowledge gathered from the most recent publications and from the collection files, following established art historical methods such as stylistic and technical analysis and involving historical (archival) evidence.

Corpus of Prints of Pieter Bruegel the Elder

In practice all the prints known to have been designed by Bruegel during his lifetime, or created after his works and designs in the decades after his death (repertoried in New Hollstein 2006), have been selected for research.

However, emphasis was put on prints of which the KBR collections contained numerous impressions in different states (any deliberate alteration of the printing matrix visible in the resulting impressions) and/or editions (clearly discernible – and sometimes historically documented – batch of impressions, sometimes discernible by ink type, paper type, additional letterpress text…). From Bruegels print 'Elck', for example, no less than five very distinct impressions were available in the KBR collection.

In order to enlarge the datasets of single prints, travelling to other collections to scan their impressions with the same set-up and according to the same protocols has been considered. Due to budgetary limitations this has proven impossible. Instead prints from a private collection (Sven Estercam) and two art dealers (Rob Camp and Tyr Baudouin) have been brought to KBR for scanning.

Corpus of the four examined drawings by Pieter Bruegel the Elder and one of a follower.

Due to the extreme rarity of Bruegel drawings the researched corpus was limited to three preparatory drawings for prints of which the attribution has never been debated ('Luxuria' and 'Justitia' from KBR and 'Prudentia' from the Royal Museum of Fine Arts) one free drawing ('Angler at stream under a tree' at KBR) of which the attribution has been widely accepted since Mielke (1997) and one landscape drawing ('View of the Strait of Messina' at KBR) considered an early copy. Since the seminal catalogue-raissoné by Hans Mielke in 1996 expert opinion on the small corpus of drawings deemed authentic by the author has remained virtually unchanged. Mielke excluded virtually all studies 'after nature' from the corpus leaving only drawings with a very 'finished' appearance, among which are many preparatory drawings for prints (tree drawings of the researched group 'Justitia', 'Luxuria' and 'Prudentia'). This implies that any trace of the creative process (sketches and studies after life, composition studies etc.) are virtually lacking. (Van Grieken 2019) Our objective was to search for traces of this creative process within the finished drawings themselves. To obtain this our datasets were extended by further research (IR reflectography, MA-XRF mapping) performed by Prof. dr. Maximiliaan Martens (U Gent) and Dr. Marina Van Bos and Dr. Christina Currie (KIK/IRPA) as subcontractors of the Fingerprint project.

Special attention has been paid to questions regarding the relationship between preparatory drawings and the resulting prints. By visualising the indentations made in the paper of the preparatory drawing during the transfer of the outlines of the design to the printing plate it was possible to gain more insight into the working methods of their respective engravers (Philips Galle and Pieter van der Heyden). For this reason the tree preparatory drawings (Justitia, Luxuria and Prudentia) kept in two federal collections (KBR and RMFA) have been a focal point.

Fig. 1. Pieter Bruegel the Elder, *Stream with an Angler,* c. 1554. Pen and brown ink, 345 x 235 mm. Brussels, KBR, inv. no. S.II 113145.

Fig. 2. Pieter Bruegel the Elder, *Luxuria* (Lust). 1557. Pen and grey-brown ink, contours indented, 225 x 296 mm, Brussels, KBR. inv. no. S.II 132816.

Fig. 3. Pieter Bruegel the Elder, *Prudentia* (Prudence). 1559. Pen and dark brown ink, contours indented, 224 x 300 mm.
Brussels, Musées royaux des Beaux-Arts de Belgique / Koninklijke Musea voor Schone Kunsten van Belgie, inv. no. 4060/490.

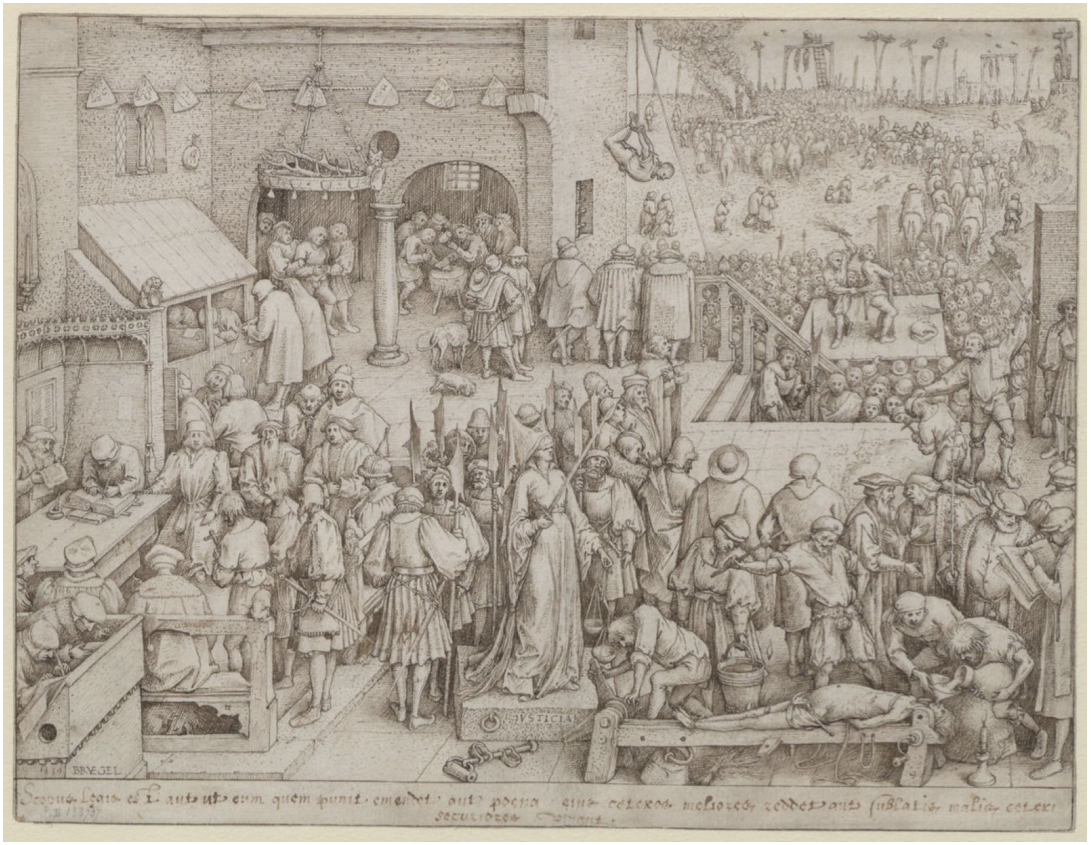


Fig. 4. Pieter Bruegel the Elder, *Justitia* (Justice). 1559. Pen and grey-brown ink, contours indented, 225 x 295 mm, Brussels, KBR, inv. no. S.II 133707.

Fig. 5. Circle of Pieter Bruegel the Elder, View on the Strait of Messina, pen on paper, 153 x 523 mm, Brussels, KBR, inv. no. F -2011-138.

1.2. Art-conservation Assessment (Survey) of the drawings and prints of Bruegel

The corpus was assessed in great detail, observing characteristics and the "material pedigree" of each print or drawing. The survey documented, by means of visual assessment, historic and actual condition of the artifacts. Information collected in faze 1.1 supported the observations. The method of recording the information has been standardized and followed a strict workflow scheme (see Fig. 6). The survey was executed by Anouk Van Hooydonk

(KBR) supervised by Lieve Watteeuw. The data were recorded in an Access database (see Fig. 7). The survey reports were a fundamental part of developing in depth knowledge of the artifact. They will further contribute to a future art-conservation plan for the KBR collections. Conservation plans provide institutions with a framework for managing the preservation and conservation of their collections. Collection surveys identify the conservation needs of the collections and can also identify problems with storage and display environments.

The protocol developed for the conservation survey for the KBR Print collection consists of the following elements:

Basic identification of works in Access
Transmitted Light study and processing in Access
Condition report per piece in Access
Disassembly of inlay or carrier
Reviewing the condition reports
Discussion + determination area of interest

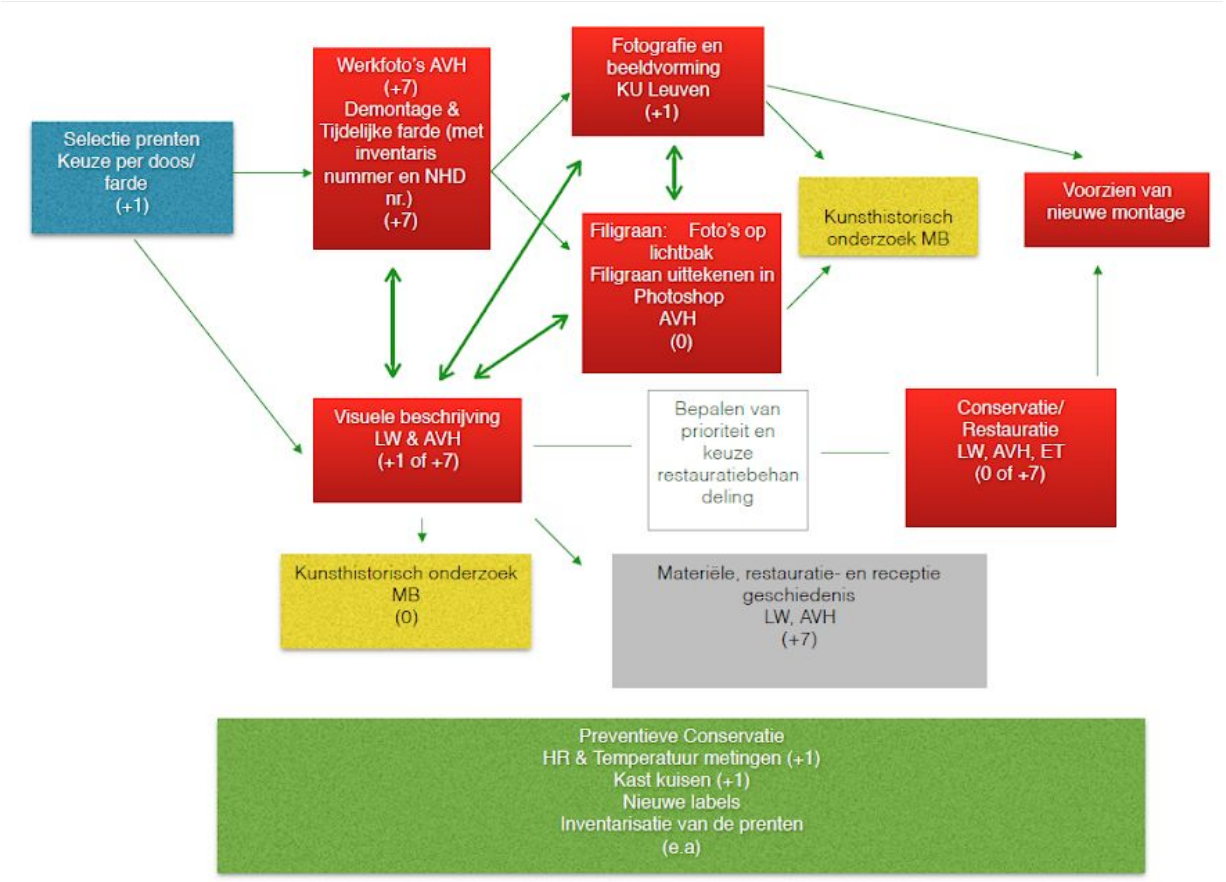
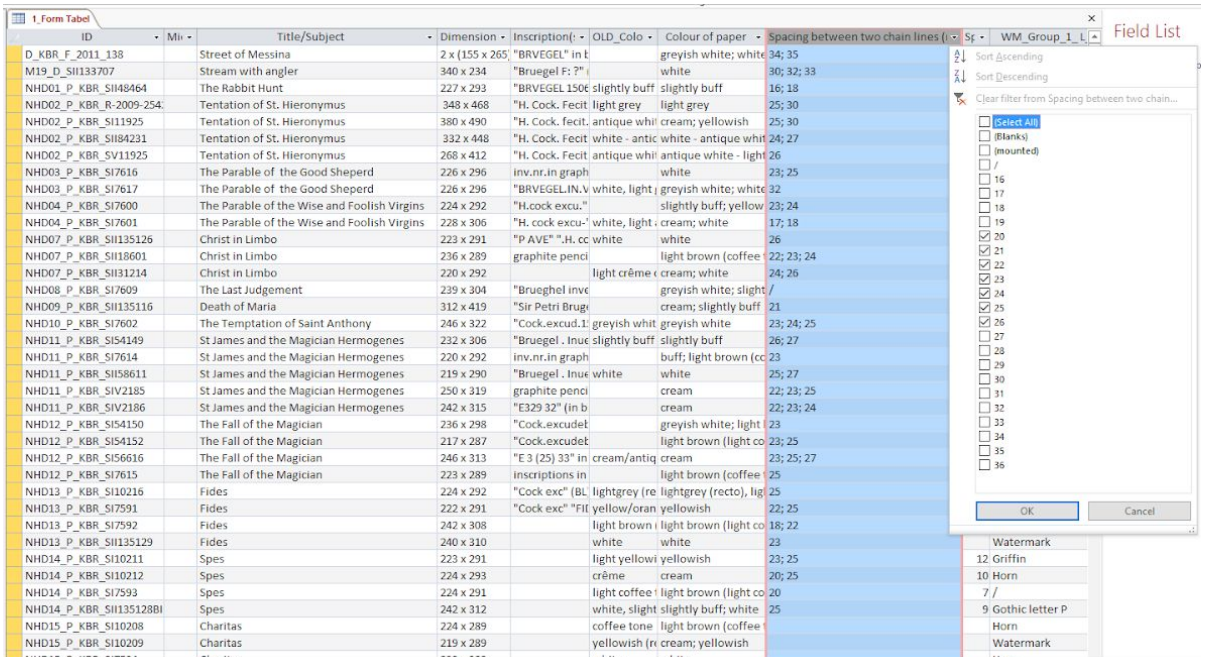


Fig. 6. Art-conservation assessment workflow scheme

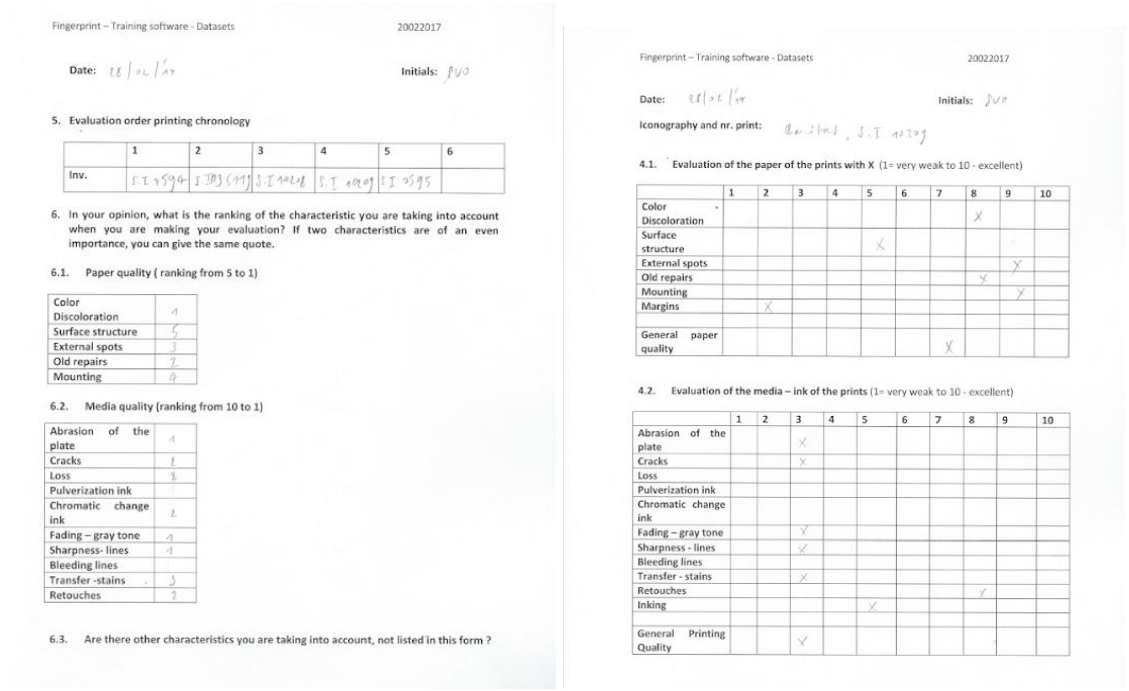


ID	Title/Subject	Dimension	Inscription(s)	OLD_Colo	Colour of paper	Spacing between two chain lines (i	WM_Group_1_L
D_KBR_F_2011_138	Street of Messina	2 x (155 x 265	"BRVEGEL" in b		greyish white; white	34; 35	
M19_D_SII133707	Stream with angler	340 x 234	"Bruegel F: ?" (		white	30; 32; 33	
NHD01_P_KBR_SII48464	The Rabbit Hunt	227 x 293	"BRVEGEL 1506	slightly buff	slightly buff	16; 18	
NHD02_P_KBR_R-2009-254	Tentation of St. Hieronymus	348 x 468	"H. Cock. Fecit	light grey	light grey	25; 30	
NHD02_P_KBR_SI11925	Tentation of St. Hieronymus	380 x 490	"H. Cock. fecit.	antique whi	cream; yellowish	25; 30	
NHD02_P_KBR_SII84231	Tentation of St. Hieronymus	332 x 448	"H. Cock. Fecit	white - antic	white - antique whit	24; 27	
NHD02_P_KBR_SV11925	Tentation of St. Hieronymus	268 x 412	"H. Cock. Fecit	antique whi	antique white - light	26	
NHD03_P_KBR_SI7616	The Parable of the Good Sheperd	226 x 296	inv.nr.in graph		white	23; 25	
NHD03_P_KBR_SI7617	The Parable of the Good Sheperd	226 x 296	"BRVEGEL.IN.V	white, light	greyish white; white	32	
NHD04_P_KBR_SI7600	The Parable of the Wise and Foolish Virgins	224 x 292	"H.cock excu."		slightly buff; yellow	23; 24	
NHD04_P_KBR_SI7601	The Parable of the Wise and Foolish Virgins	228 x 306	"H. cock excu-	white, light	cream; white	17; 18	
NHD07_P_KBR_SII135126	Christ in Limbo	223 x 291	"P AVE" ".H. cc	white	white	26	
NHD07_P_KBR_SII18601	Christ in Limbo	236 x 289	graphite penci		light brown (coffee	22; 23; 24	
NHD07_P_KBR_SII31214	Christ in Limbo	220 x 292		light crême	cream; white	24; 26	
NHD08_P_KBR_SI7609	The Last Judgement	239 x 304	"Brueghel inve		greyish white; slight	/	
NHD09_P_KBR_SII135116	Death of Maria	312 x 419	"Sir Petri Brug		cream; slightly buff	21	
NHD10_P_KBR_SI7602	The Temptation of Saint Anthony	246 x 322	"Cock.excud.1	greyish whit	greyish white	23; 24; 25	
NHD11_P_KBR_SI54149	St James and the Magician Hermogenes	232 x 306	"Bruegel . Inue	slightly buff	slightly buff	26; 27	
NHD11_P_KBR_SI7614	St James and the Magician Hermogenes	220 x 292	inv.nr.in graph		buff; light brown (co	23	
NHD11_P_KBR_SII58611	St James and the Magician Hermogenes	219 x 290	"Bruegel . Inue	white	white	25; 27	
NHD11_P_KBR_SIV2185	St James and the Magician Hermogenes	250 x 319	graphite penci		cream	22; 23; 25	
NHD11_P_KBR_SIV2186	St James and the Magician Hermogenes	242 x 315	"E329 32" (in b		cream	22; 23; 24	
NHD12_P_KBR_SI54150	The Fall of the Magician	236 x 298	"Cock.excudeb		greyish white; light	23	
NHD12_P_KBR_SI54152	The Fall of the Magician	217 x 287	"Cock.excudeb		light brown (light co	23; 25	
NHD12_P_KBR_SI56616	The Fall of the Magician	246 x 313	"E 3 (25) 33" in	cream/antiq	cream	23; 25; 27	
NHD12_P_KBR_SI7615	The Fall of the Magician	223 x 289	inscriptions in		light brown (coffee	25	
NHD13_P_KBR_SI10216	Fides	224 x 292	"Cock exc" (BL	lightgrey (re	lightgrey (recto), lig	25	
NHD13_P_KBR_SI7591	Fides	222 x 291	"Cock exc" "FI	yellow/oran	yellowish	22; 25	
NHD13_P_KBR_SI7592	Fides	242 x 308		light brown	light brown (light co	18; 22	
NHD13_P_KBR_SII135129	Fides	240 x 310		white	white	23	Watermark
NHD14_P_KBR_SI10211	Spes	223 x 291		light yellowi	yellowish	23; 25	12 Griffin
NHD14_P_KBR_SI10212	Spes	224 x 293		crême	cream	20; 25	10 Horn
NHD14_P_KBR_SI7593	Spes	224 x 291		light coffee	light brown (light co	20	7 /
NHD14_P_KBR_SII135128B	Spes	242 x 312		white, slight	slightly buff; white	25	9 Gothic letter P
NHD15_P_KBR_SI10208	Charitas	224 x 289		coffee tone	light brown (coffee		Horn
NHD15_P_KBR_SI10209	Charitas	219 x 289		yellowish (r	cream; yellowish		Watermark

Fig. 7. Screenshot of the Art-conservation assessment database (Acces)

1.3. Condition Evaluation by Experts - questionnaire

Through the imaging more detailed technical and visual data were obtained to compare prints resulting from the matrix in its different stages of wear. The criteria were fine-tuned to an assessment of “art historians, connoisseurs” and “conservators”. The evaluation template is monitoring and evaluating - Color – Discoloration / - Surface structure / External spots / Old repairs. (see Fig. 8, example of questionnaire)



Fingerprint – Training software - Datasets 20022017

Date: 18/01/17 Initials: JVO

5. Evaluation order printing chronology

	1	2	3	4	5	6
Inv.	S.I 19594	I.M.J (111)	S.I 10128	S.I 10109	S.I 19595	

6. In your opinion, what is the ranking of the characteristic you are taking into account when you are making your evaluation? If two characteristics are of an even importance, you can give the same quote.

6.1. Paper quality (ranking from 5 to 1)

Color Discoloration	1
Surface structure	5
External spots	3
Old repairs	2
Mounting	4

6.2. Media quality (ranking from 10 to 1)

Abrasion of the plate	1
Cracks	1
Loss	1
Pulverization ink	
Chromatic change ink	2
Fading – gray tone	1
Sharpness- lines	1
Bleeding lines	
Transfer -stains	3
Retouches	2

6.3. Are there other characteristics you are taking into account, not listed in this form ?

Fingerprint – Training software - Datasets 20022017

Date: 11/01/17 Initials: JVO

Iconography and nr. print: Bruegel, S.I 10109

4.1. Evaluation of the paper of the prints with X (1= very weak to 10 - excellent)

	1	2	3	4	5	6	7	8	9	10
Color - Discoloration								X		
Surface structure					X					
External spots									X	
Old repairs								X		
Mounting									X	
Margins		X								
General paper quality							X			

4.2. Evaluation of the media – ink of the prints (1= very weak to 10 - excellent)

	1	2	3	4	5	6	7	8	9	10
Abrasion of the plate			X							
Cracks			X							
Loss										
Pulverization ink										
Chromatic change ink										
Fading – gray tone			X							
Sharpness - lines			X							
Bleeding lines										
Transfer - stains			X							
Retouches								X		
Inking					X					
General Printing Quality			X							

Fig. 8. Example of a filled out experts questionnaire.

The experts were making the evaluation of the 3 sets of prints in different states (early to late) of Pieter Bruegel the Elder in the Print Room of KBR without any tool, only a magnifying glass was available (Justitia, Luxuria, Elck). Most of them are very familiar with the graphic work of Bruegel (Sellink, Van Grieken, Martens, Bassens, Watteeuw, team of conservators of the KBR). For each print 4 to 6 states were available at KBR and placed on a table. All experts reported the difficulty of evaluation of a print and very similar prints in a phased way, as they usually do this with the eye of a trained 'connaisseur". The evaluation took ca. 2 hours of their time and was done at different moments when they visited the print room. The results were very similar and coherent for the 'best' and the 'worst' state of the prints. In between, the range was rather different as they all had an individual appreciation of what a good or lesser state would be (colour and sharpness of the ink, colour of the paper, loss of sharpness of the plate, reworking of the plate…). Also bad condition through damages would influence the evaluation and lower down a good evaluation. The conservators-restorers experts were more focussed on the physical condition, while art-historians experts combined more print-quality and first states to rank higher.

1.4. Art technical Assessment & Scientific Imaging of the drawings and prints of Bruegel

After the first assessment phase of the material, the imaging phase was started. A studio environment was installed on location for the duration of the project enabling for safe digitisation and imaging at the KBR. Specific hardware was acquired such as a Cambo RPS repro stand with backlight module (to be handed over to the KBR after the project). Various protocols and workflows were established for consistent results during the course of the imaging phase. All prints and drawings were photographed at the same resolution (600 dpi), with imaging performance indication based on the Metamorfoze Imaging Guidelines. Next to general high-resolution digitisation, protocols for raking light and backlight were developed. A logbook (see Fig. 9.) was created in a way that imaging could be replicated, e.g. keeping the same reproduction factor, mapping the zones for detailed imaging, etc.

NHD	Type	Location	Shelf mark	Technical data	Date	35 focal po	Aperture	Shutter speed	DPI	Camera height (Cambo)	Camera height (lens)	Height light	Distance light	Lights power	Extra info	Complete filename
DRAWING																
NHD16_	D_	KBR_	SII1333707	_GEN_R_P1_600_N	13/02/2017	80	f/11	1/60e	600	123,5cm		202,7cm	197,2cm	5.2 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_GEN_R_P1_600_N
NHD16_	D_	KBR_	SII1333707	_GEN_R_P1_600_RL	13/02/2017	80	f/11	1/60e	600	123,5cm		Laagste	197,2cm	6.2 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_GEN_R_P1_600_RL
NHD16_	D_	KBR_	SII1333707	_GEN_R_P1_600_RB	13/02/2017	80	f/11	1/60e	600	123,5cm		Laagste	197,2cm	6.2 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_GEN_R_P1_600_RB
NHD16_	D_	KBR_	SII1333707	_GEN_R_P1_600_B	13/02/2017	80	f/11	1/8e +1/3	600	123.5		doorvallend		Volledig		NHD16_D_KBR_SII1333707_GEN_R_P1_600_B
NHD16_	D_	KBR_	SII1333707	_GEN_R_P1_600_B_002	13/02/2017	80	f/11	1/4e+1/3	600	123.5		doorvallend		Volledig		NHD16_D_KBR_SII1333707_GEN_R_P1_600_B_002
NHD16_	D_	KBR_	SII1333707	_GEN_R_P1_600_B_003	22/02/2017	80	f/11	1/2e+1/3	600	123.3		doorvallend		Volledig		NHD16_D_KBR_SII1333707_GEN_R_P1_600_B_003
NHD16_	D_	KBR_	SII1333707	_GEN_R_P1_600_B_004	22/02/2017	80	f/11	1+1/3	600	123.3		doorvallend		Volledig		NHD16_D_KBR_SII1333707_GEN_R_P1_600_B_004
NHD16_	D_	KBR_	SII1333707	_GEN_V_P1_600_N	13/02/2017	80	f/11	1/60e	600	123.5		202,7cm	197,2cm	5.2 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_GEN_V_P1_600_N
NHD16_	D_	KBR_	SII1333707	_GEN_V_P1_600_RL	13/02/2017	80	f/11	1/60e	600	123.5		laagste	197,2cm	6.2 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_GEN_V_P1_600_RL
NHD16_	D_	KBR_	SII1333707	_GEN_V_P1_600_RB	13/02/2017	80	f/11	1/60e	600	123.5		laagste	197,2cm	6.2 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_GEN_V_P1_600_RB
NHD16_	D_	KBR_	SII1333707	_GEN_V_P1_600_B	13/02/2017	80	f/11	1/8e +1/3	600	123.5		doorvallend		Volledig		NHD16_D_KBR_SII1333707_GEN_V_P1_600_B
NHD16_	D_	KBR_	SII1333707	_GEN_V_P1_600_B_002	13/02/2017	80	f/11	1/4e+1/3	600	123.5		doorvallend		Volledig		NHD16_D_KBR_SII1333707_GEN_V_P1_600_B_002
NHD16_	D_	KBR_	SII1333707	_GEN_V_P1_600_B_003	22/02/2017	80	f/11	1/2e+1/3	600	123.3		doorvallend		Volledig		NHD16_D_KBR_SII1333707_GEN_V_P1_600_B_003
NHD16_	D_	KBR_	SII1333707	_GEN_V_P1_600_B_004	22/02/2017	80	f/11	1+1/3	600	123.3		doorvallend		Volledig		NHD16_D_KBR_SII1333707_GEN_V_P1_600_B_004
NHD16_	D_	KBR_	SII1333707	_TL_R_P1_1200_N	13/02/2017	120	f/11	1/60e	1200	111,3 cm		202,7cm	197,2cm	5.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_TL_R_P1_1200_N
NHD16_	D_	KBR_	SII1333707	_TR_R_P1_1200_N	13/02/2017	120	f/11	1/60e	1200	111,3 cm		202,7cm	197,2cm	5.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_TR_R_P1_1200_N
NHD16_	D_	KBR_	SII1333707	_BR_R_P1_1200_N	13/02/2017	120	f/11	1/60e	1200	111,3 cm		202,7cm	197,2cm	5.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_BR_R_P1_1200_N
NHD16_	D_	KBR_	SII1333707	_BL_R_P1_1200_N	13/02/2017	120	f/11	1/60e	1200	111,3 cm		202,7cm	197,2cm	5.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_BL_R_P1_1200_N
NHD16_	D_	KBR_	SII1333707	_TL_R_P1_1200_RL	13/02/2017	120	f/11	1/60e	1200	111,3 cm		laagste	197,2cm	6.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_TL_R_P1_1200_RL
NHD16_	D_	KBR_	SII1333707	_TL_R_P1_1200_RB	13/02/2017	120	f/11	1/60e	1200	111,3 cm		laagste	197,2cm	6.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_TL_R_P1_1200_RB
NHD16_	D_	KBR_	SII1333707	_TR_R_P1_1200_RL	13/02/2017	120	f/11	1/60e	1200	111,3 cm		laagste	197,2cm	6.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_TR_R_P1_1200_RL
NHD16_	D_	KBR_	SII1333707	_TR_R_P1_1200_RB	13/02/2017	120	f/11	1/60e	1200	111,3 cm		laagste	197,2cm	6.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_TR_R_P1_1200_RB
NHD16_	D_	KBR_	SII1333707	_BR_R_P1_1200_RL	13/02/2017	120	f/11	1/60e	1200	111,3 cm		laagste	197,2cm	6.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_BR_R_P1_1200_RL
NHD16_	D_	KBR_	SII1333707	_BR_R_P1_1200_RB	13/02/2017	120	f/11	1/60e	1200	111,3 cm		laagste	197,2cm	6.5 (drager tekening 2 mm dik)		NHD16_D_KBR_SII1333707_BR_R_P1_1200_RB

Fig. 9. Screenshot from an excel file used as logbook.

Once finished, this standardized digitisation protocol provided an exceptionally rich dataset for such an extensive corpus of original graphical work of Bruegel. All data were imported in the Fingerprint Digital Working Environment. (see Fig. 10.)

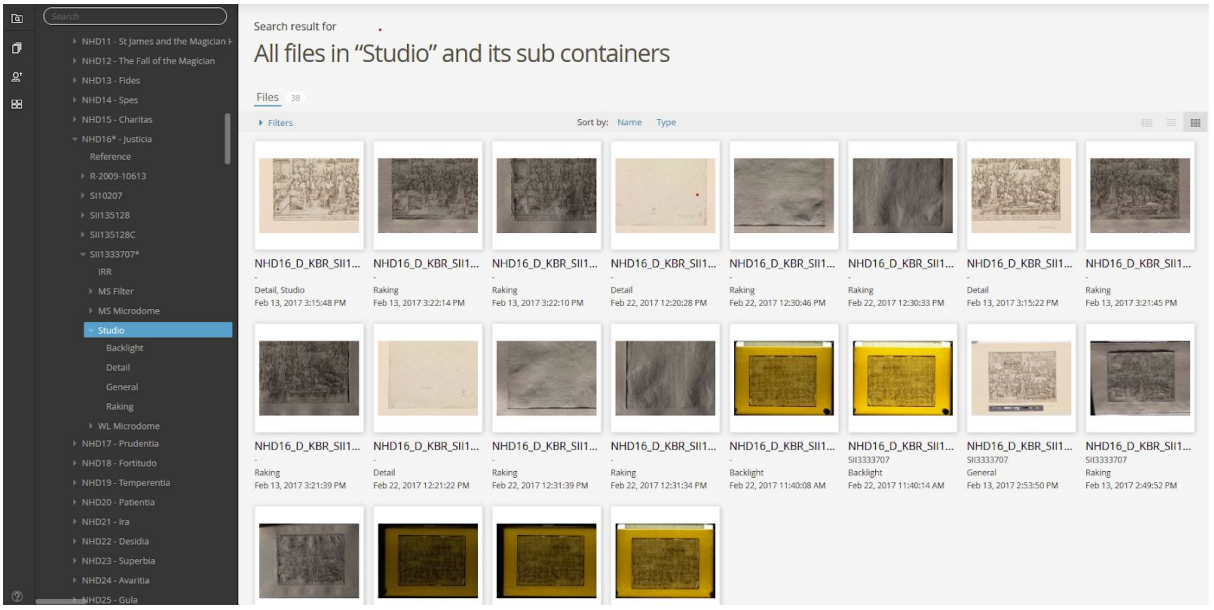


Fig. 10. Screenshot from the online Fingerprint Digital Working Environment

During the first phase, a number of reference datasets has been created on a selection of prints and states showing a clear difference. These datasets allowed us to refine the imaging protocol, create relevant test data and allowed us to implement the Fingerprint Digital Working Environment. This group consisted of the compositions 'Luxuria', 'Justicia' and 'Prudentia'' (preparatory drawings and the different impressions of the resulting prints), and the print Elck that were available in different states and impressions. (see also under 1.1.).

This dataset enabled to start to train the software developed in WP4. During the second year, through close collaboration between art historians (WP2) and engineers (WP4), more specific regions have been imaged through all the prints and states building a large dataset for refining the analysis software.standardized assessment protocols.

Of each drawing or print, a high-resolution 600 DPI general image was made with overhead, raking light and backlight; for each recto and verso (see overview just below). For each drawing or print an assessment was made to define specific zones for closer investigation (where applicable). These zones have been the focus for imaging on all the different states. When it was estimated extra documentation on these or other zones was needed for study or the assessment, additional photographic, multi-light reflectance, multi-spectral or MA-XRF imaging was performed.

Eventually, the full collection of KBR Bruegel drawings and prints has been digitised following the same standardized protocol. Additional collections such as Rob Camp, Sven Estercam, Royal Museum of Fine Arts (Brussels) and Tyr Baudouin have also been digitised, complementing the Fingerprint Dataset. All digitisation and imaging has been carried out by Dieter Daemen, Hendrik Hameeuw and Bruno Vandermeulen (KU Leuven). These recordings are referred to as the Global recordings, taking into account the different lighting conditions and the areas of focus as described here above. (see Fig.11) What follows as illustration is an overview with technical specifications of 1 standard image dataset in the Global recordings:

	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 1/90s f11 600dpi 80 2 standard 5.1 recto
	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 1/90s f11 600dpi 80 1 raking left 6.1 recto
	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 1/90s f11 600dpi 80 1 raking below 6.1 recto
	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 1/3s f11 600dpi 80 1 backlight 100% recto
	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 0.7s f11 600dpi 80 1 backlight 100% recto

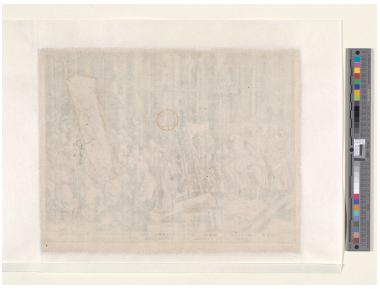
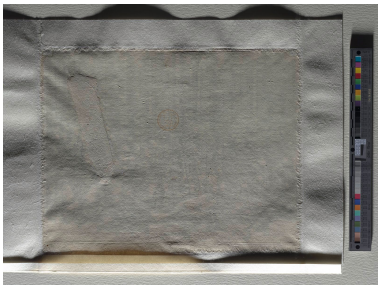
	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 1/90s f11 600dpi 80 2 standard 5.1 verso
	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 1/90s f11 600dpi 80 1 raking left 6.1 verso
	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 1/90s f11 600dpi 80 1 raking below 6.1 verso
	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 1/3s f11 600dpi 80 1 backlight 100% verso
	ISO: exposure: aperture: resolution: focal: illumination sources: illumination position: strength flashlight: side:	50 0.7s f11 600dpi 80 1 backlight 100% verso

Fig. 11. Overview wit technical specifications of 1 standard image dataset in the Global recordings: (for NHD13_P_KBR_SI7592)

In total 238 drawings and prints have been imaged (from KBR + additions form private collections for extra comparisons):

- 600DPI front and back
- 600DPI raking front and back
- 600DPI Backling front and back
- Selection of prints: certain details at higher resolution 1200 dpi

In total 5 original drawings have been imaged (4 from KBR and 1 from RMFAB):

- 600DPI front and back
- 1200DPI front and back
- 600DPI raking front and back
- 1200DPI raking front and back
- 600DPI Backlight front and back
- 1200DPI front and back
- WL Microdome in detail front and back
- MS Microdome in detail front
- MS Filtered captures front and back

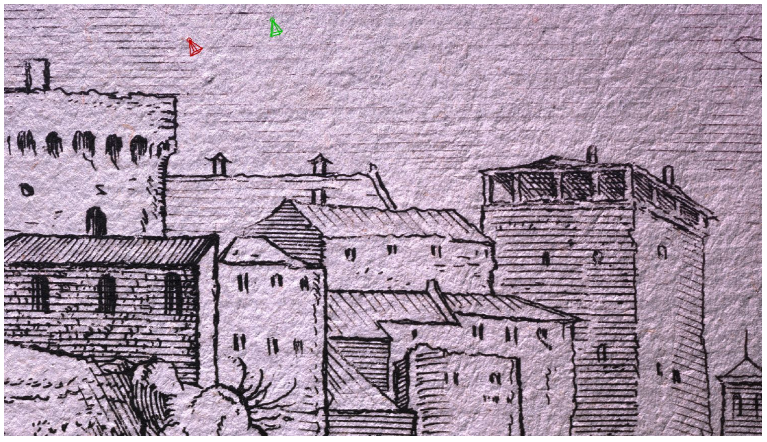
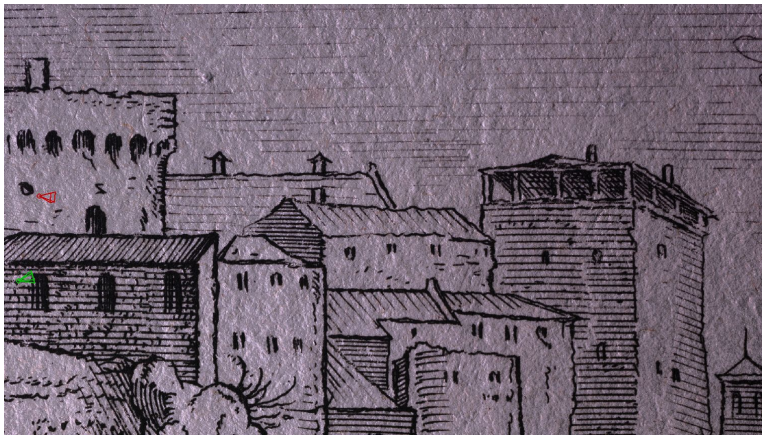
Apart from the multimodal high-resolution photographical imaging, information on surface characteristics (3D and material) has been gathered through the **Microdome**, the interactive imaging device of the Portable Light Dome system (RICH project, Illuminare, KU Leuven). (see Fig. 12). This device, a hemispherical structure dotted on the inside with 228 LED lamps and a single downward looking high-resolution camera (28 million pixels), enables after processing not only an interactive viewing with various filters, but also measurement data in X-Y and Z-axis.

Fig. 12. Bruegel drawings under the Microdome (White Light at the left, Multispectral at the right).

The photometric stereo technique permits to measure in the XYZ axis what permits to monitor the smallest topographical characteristics in a ‘flat’ object as a sheet of paper with media (ink) and traces of use. Thickness of ink lines and incissions (made during transfer from the drawing to the print plate) can be documented and measured in microns. This information is complementary to the high resolution imaging, as they give excellent visual information, but no measurements.

These data can be exported and have been used for the statistical features of the software. Both White Light and Multi-Spectral Microdomes have been used. The systematic study of

historic graphical work with this Multi-Light Reflectance imaging method was at the start of the Fingerprint project a novelty. Before, only experiments with the similar technologie Reflectance Transformation Imaging (RTI) had been introduced into this field. In contrast to the static visual results in the image dataset of the Global recordings, the Microdome results provide the ability to relight the art-work from any direction, revealing aspects of the paper production, quality and condition; and especially on the original drawings. The latter gives the exceptional opportunity to obtain new insights in the printmaking practice; in particular, the aspect the Portable Light Dome system (i.e. in the viewer interface) can visualise and accentuate the extreme shallow remnants of tracing lines. Apart from visualisations in the white light region visible for the human eye), the multi-spectral microdome allows imaging with UV, R, G, B and UV channels on individual basis. As such, each capture allows assessment for each individual spectrum but can also be combined into 3 different channels providing a (false) color image. These (false) color images reveal details not visible to the human eye. What follows as example (Fig. 13.) is a selection of visual results on detail of a single Multi Spectral Microdome recording (on NHD49_D_KBR_SI9412):

	RGB visualisation with particular illumination angle (see light positions: green and red markers)
	RGB visualisation with particular illumination angle (see light positions: green and red markers)

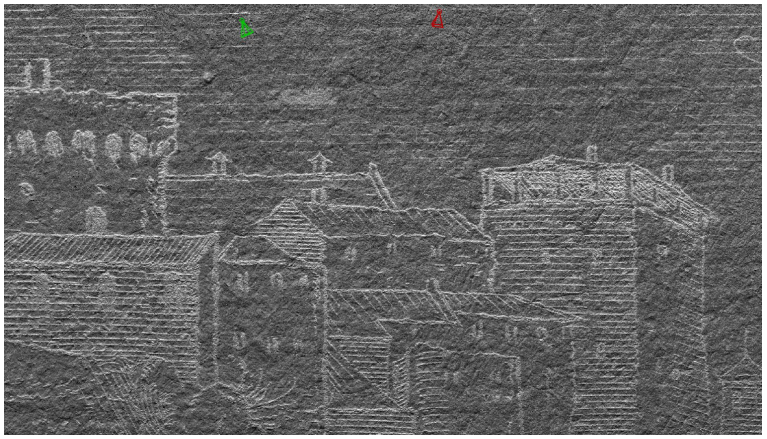
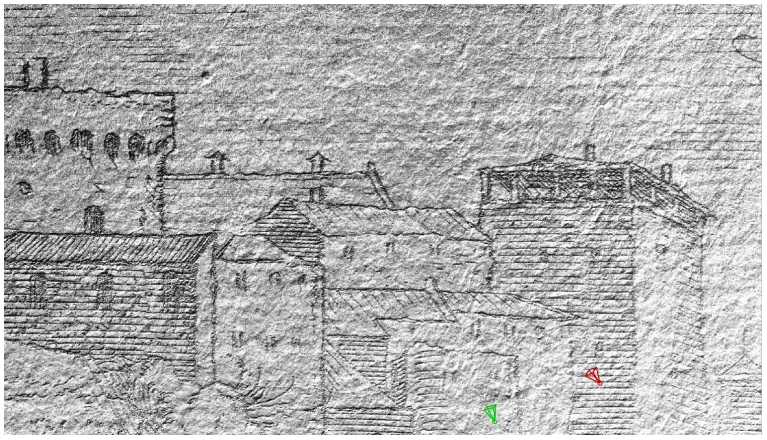
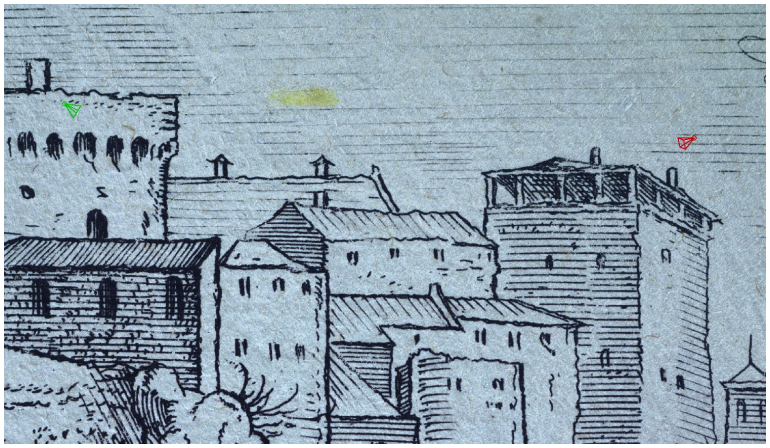
	Visualisation without color with particular illumination angle (see light positions: green and red markers), accentuating relief of ink and paper surface and revealing a degradation/stain in the paper on the upper part of the capture
	Visualisation without color with particular illumination angle (see light positions: green and red markers), accentuating relief of ink and paper surface
	Green-Blue-Ultraviolet visualisation with particular illumination angle (see light positions: green and red markers), revealing (yellow spot) a degradation/stain in the paper

Fig. 13. Selection of visual results on detail of a single Multi Spectral Microdome recording on NHD49_D_KBR_SI9412

In addition photographical **Multi-spectral imaging** (combination of converted NIKON D610, CoastalOpt UV-VIS-IR lens and a 13 Mid-Opt spectral narrow band filter set) has been carried out on drawings and coloured prints for searching and visualization of underdrawings, preparation layers and ink variations.

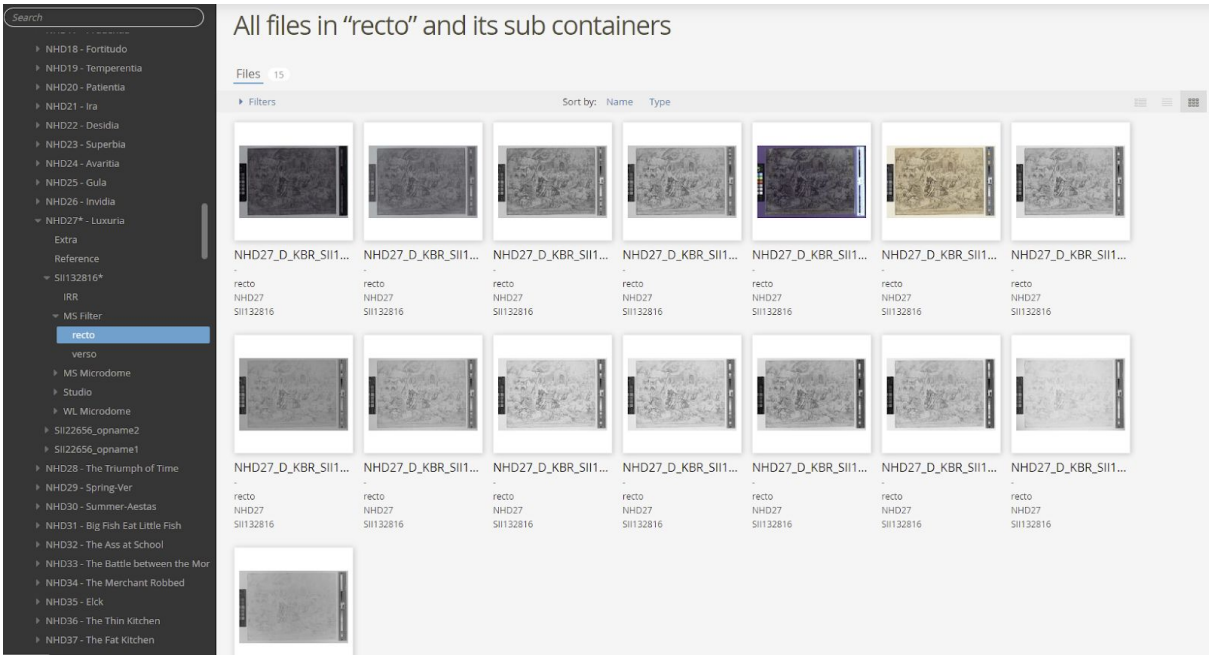


Fig. 14. Thirteen different narrow band captures ranging from UV over VIS to IR in addition to an RGB rendering of the object for comparison and an UV fluorescence image, here presented in the Fingerprint Digital Working Environment

To further substantiate the art technical assessment for a number of cases (i.e. on the original Bruegel drawings) non-destructive **macro X-Ray Fluorescence** mapping analyses have been performed with the M6 Jetstream by Bruker AXS (a collaboration with the Royal Institute for Cultural Heritage laboratories, KIK-IRPA). This analytical technique allows to define the elemental composition of targeted materials, such as the composition of the attributed inks. The imaging mapping tool gives insights in the distribution of specific chemical elements across the scanned surface and helps defining and understanding the traditional drawing practices during the Bruegel era.

Both the *Global recordings* as well as the Microdome recordings are considered in the imaging analysis phase to perform and fuel the development of an “Automated Objective Quality Measure”; an exceptionally rich, standardized and unique input dataset for this challenge.

For the dissemination of the acquired Microdome datasets the interactive viewer software solutions have also been further developed, especially to allow online consultation (see 4. Scientific results: Pixel+).

1.4. Data management

To keep track of all the imaging and project documents, a flexible digital asset management system was deployed as a working environment (Fingerprint Digital Working Environment), granting access to all the project partners and the follow-up committee. This working environment was used to store, apart from the consultation copies (in jpg) of the high-resolution imaging, working documents, images and logbooks. Full screen previews in

high resolution of up to 4 different files allowed easy comparison between different captures and/or states of prints. (see Fig. 15.)

All raw and processed data is kept in a separate archive (not online accessible). All data will be handed over to the KBR for ingestion in their information system enriching current data about the prints. In total 805 capturs from drawings were made (Global Recordings, Microdome White Light and Multi-spectral recordings and Narrow Band Multi-Spectral) and 4333 captures from prints were made (Global Recordings, Microdome White Light). For each drawing/print a highly detailed excel file was created to follow up the digitisation process. Technical information such as height of the camera, position of the light, etc. was captured, ensuring reconstruction of the dataset. In total 7842 digital assets were managed in the online Fingerprint Digital Working Environment. In total this amasses more than 3 Tb of raw data.

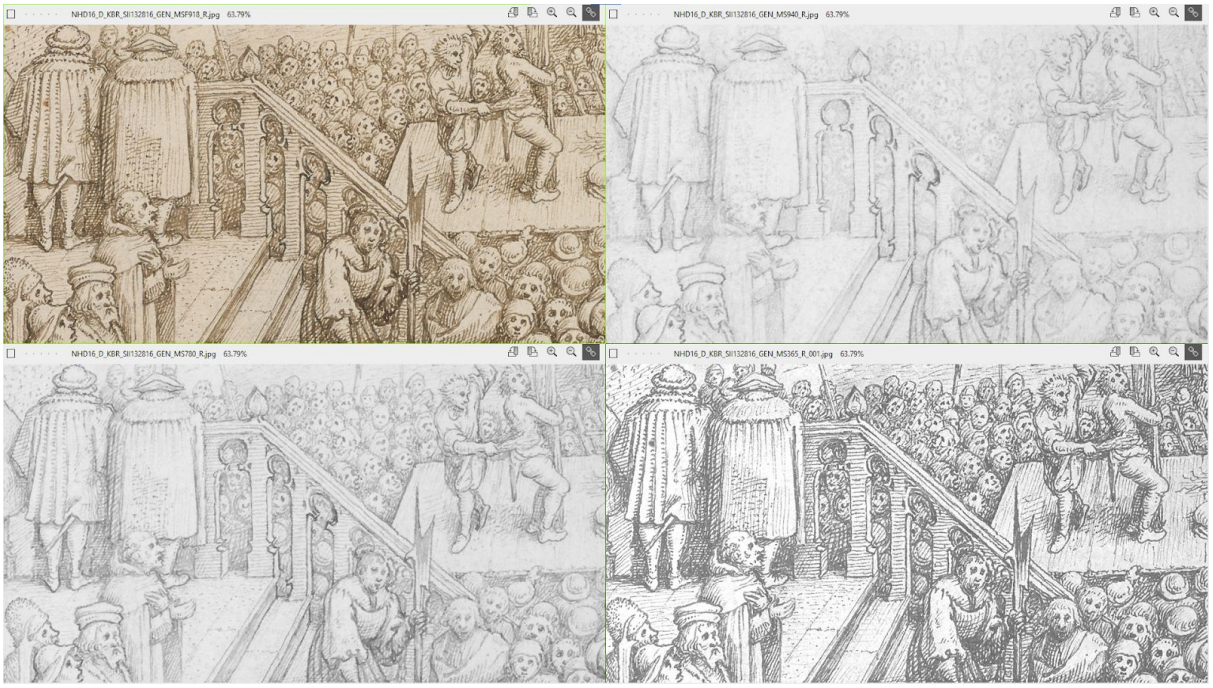


Fig. 15. Full size screen comparison in Canto Cumulus between different multi-spectral recordings: VIS, IR 940, IR 730, UV 365. Detail of the drawing Justicia, KBR, SII1333707.

2. Data Processing of the Imaging data

Software development for “Automated Objective Quality Measure”
The technical work and software implementation basically followed three main periods (P1, P2, P3) During the first period (P1), basic statistical features and shape descriptors have been implemented that were expected to define quality and degradation in a very general context. In the beginning the consortium had started to record a number of reference datasets, and these have been used for the initial experiments.

During the second period P2, expert information has been included in the process.
As an extra interdisciplinary effort between the art historians and the imaging engineers (Lieve Watteeuw and Marc Proesmans), a list of possible quality features have been

created, inspired by the technical definitions in a computer vision context on the one hand, and the typical nomenclature used in traditional connoisseurship on the other. These quality measures serve as guidelines or additional argumentations for the connoisseurs to complete their judgements.

Possible differences in interpretation of the quality measures were taken into account during the processing. It was also expected that the relationship between the quality feature and the shape descriptor is not necessarily linear. During WP2, the collection of artifacts has grown, and more insights were gained in the relationships between the artifacts.

The purpose of the investigation is to find possible correlations between the scores of the connoisseurs, and the imagery itself. Using a variety of image feature descriptions, statistical methods are explored, to evaluate these features, and assess what features are enabling us to objectively describe the more intuitive judgments of the connoisseurs.
This leads to a number of more dominant feature and shape descriptors that contribute to an objective quality label of the artifacts. The “Automated Objective Quality Measure” grasps the quality measure for which there is a consensus. At the same time, it leaves room for variations in the responses and a certain amount of justified subjectiveness. Some more insights on this process are given below.

In the final period WP3, the insight gained from the previous periods led to a prototype interface. The interface served two purposes:

(*) On the one hand, there is the visualization of the feature responses, which depend on their characteristics. Image statistics can be shown both globally as well as locally, the latter are visualized as an overlay on the input 2D+/3D digital input. For this, several modes have been provided. Statistics are shown in terms of graphs, block diagrams, histograms, scatter plots. Image-based representations are shown inline as bounding box areas using adaptive thresholds, gradient and false color mapping of the filter output, and other types of shaders.

(*) On the other hand, the user has the necessary controls to indicate specific areas for training and evaluation, create overlays for comparison, and export in a state-of-the-art format for publication and dissemination. The interface was tested by the art historian and paper conservators, and, based on their feedback, the approach was fine-tuned and adjusted.

As will be explained in the remainder of the text, we made distinction between specific design on the PLD user interface, and the approach to perform quality analysis on this specific data.

3. Data comparison

3.1. “Expert data input”

During WP1 art historians with connoisseurship of Bruegel Prints & drawings have been confronted with a series of artifacts/states of prints in the Print Room of the Royal Library. Each responder had the same data set of items to evaluate through a questionnaire. They gave appreciation only through visual assessment and experience in valorisation of unique

historical graphic materials. Based on mutual interaction between art historians and imaging engineers, a set quality measures served as additional guidelines. They provided scores and made a ranking of best to poor quality.

3.2. "Analytical correlation and classification".

Recordings: Imaging scientist and paper/print technologists analysed and processed the acquired measurements and data files, gained on the same corpus.
The majority of the recordings that have been carried out using the *Global* recording method provide high resolution data under defined lighting conditions (overhead, raked, backlight), yet are therefore manageable in terms of storage and processing requirements. The *Dome* recordings are bulkier but have as major advantage the ability to extract 2D+ and 3D information and provide additional insight in the evaluation process. Furthermore, the Dome processing's ability to mimic the overhead and raking light conditions of the Global recordings, makes it a natural candidate to integrate the visualization tools.

Corpus variation: depending on the choice of features or descriptors (see below), the output statistics may be depending on the content of the prints. Of particular interest are the prints that presented the same content but showed a clear difference in state. They provided valuable insight in the selection and correlation process.

Connoisseur evaluation vs. Image descriptors: There are natural variations in the assessments of the connoisseurs which may also vary depending on the prints. A first task is to merge these evaluations into a consensus agreement for each of the print. The consensus can be calculated by analysing multiple distance matrices. The subsequent step is to find the correlation between these consensus scores and the image descriptors.

Image descriptors: In order to describe the image statistics, we opted for a filter bank approach, containing handcrafted filters at different scales. As indicated above, the discussions with the connoisseurship revealed a specific nomenclature that can be related to specific image processing filters, such as there are: contrast, line quality, sharpness, etc. It's quite obvious that this nomenclature is also very specific for the given dataset, and does not easily translate to possibly other types of art or cultural artifacts. For this reason, we have chosen to apply a fixed filter bank, consisting of n-th order gradient filters, line filters, grey-value based morphological filters, etc.

Next, given the filter output, N-th order statistics are applied (i.e *standardized moments*, cfr wiki) to provide feature representations that serve as input in the correlation process. As an alternative, we considered supervised learning algorithms which are available to learn the features or output the scores, each with its strengths and weaknesses, but such methods are very data hungry and from this perspective, the amount of data-vs-expert input is "limited", so these have not (yet) proven ideal for the jobs, or they tend to overfit.

classification: In order to arrive at a model prediction, the inverse correlations are used. The correlations listed in the survey were ill-defined because of overlapping aspects. The scores or evaluations provided by the connoisseurs shows variations.

3.3 "Expert data" has been confronted with the "analytical data"

The prediction model is designed to output an "Automated Objective Quality Measure". It can be seen as a virtual connoisseur that provides its own assessment of the print. Yet the model is not meant to 'confront' the individual connoisseurs with their own assessment, yet it can help them position the print's quality more objectively, given 'consensus agreement' from external assessments.

The model output needs to be formulated in a "*nuanced"* context, as we will try to explain below, and henceforth also the need for proper visualization or interpretation. There are for instance following observations:

(*1) For one thing, our analysis is carried out on the global scale, yet the quality assessment of the print can be influenced by local defects. The assessment of local parts was not in the scope of this project, yet it would provide added value. Providing such annotations exist, specific learning mechanisms can be investigated to detect such defects.

(*2) Some of the quality measures can overlap in the statistical framework. The dimensionality of the problem is still to be investigated, which could result in a reduction of the feature space that is required eventually.

(*3) Although much care has been taken to unify the recording and lighting circumstances during the photography, which also unifies the input of the connoisseurs, the approach cannot model the real physical interaction with the prints, which could affect the scores.

(*4) In correspondence to the above, the assessment leaves room for a certain amount of justified subjectiveness, some features can result in opposing judgements, or may depend on the context. Certain local defects can also influence the judgement of the expert, which as already explained in (*1), On the other hand though, an overall quality measure can depend on the quality of the material itself, thickness, characteristics that would require specific recordings circumstances.

On the other hand, this strategy generates new insights on the relationship between imagery and quality, and can possibly be applied to other print-like artifacts or other types of datasets.

4. Data model & toolbox construction

There are two angles on toolbox development.

(1) First, the confrontation/comparison contributed to the construction of prediction models and consequently to a toolbox for assessment of print collections. Different tools for visual assessment and comparison of the different states have been studied during a technical analysis. The final aim is to verify how the statistics can be presented to the specialists, to enable them to compare, and layer and merge visually the different states. The underlying idea is that the general statistics from a given data set is plotted in matrix representations,

and the processing of specific selections are positioned within these plots and provide a way to show the “value” of a print compared to the expert input.

The analysis and the visualizations are developed using available open source programming and scripting tools (c++, python), and OpenCV as the main image processing environment.

(2) Next, there is the Domes software platform, which is a custom interface. It contains the necessary user interface tools to visualize the imagery, and provide dedicated viewing on processing results. Within the Pixel+ project (RMAH, BRAIN-BELSPO, Pioneerproject, 2017) an open source tool was developed for the online consultation of Portable Light Dome datasets enabling, among others, viewing and dissemination of the Fingerprint Microdome data (White Light and Multi-Spectral). In this context, the viewer software of the microdome has been enhanced with more export functionalities.
The interface would allow the visualization of these specific processing results (1), yet, due to the very specific nature of the data itself and the custom way of processing for this data (see earlier discussion), the work serves as a proof of concept to be able to integrate such mechanism in the viewer, but it does not (yet) immediately fit the general purpose mindset of the PLD tools, as they are built to cope (visualize and process) with very heterogeneous types of cultural heritage objects, i.e. not only prints. Further comments can be found in the next section.

4. SCIENTIFIC RESULTS AND RECOMMENDATIONS

4.1. Art Historical research on the Bruegel prints

A part of the research on Bruegel prints encapsulates comprehensive biographies on the publishers of the Bruegel prints as well as a catalogue raisonné of the graphic work, comparable to the New Hollstein of 2006. The important questions regarding the collaboration between Bruegel and the print publisher Hiëronymus Cock was explored in the Phd of Maarten Bassens (2016 -). Hiëronymus Cock worked in the late 1560s with the printer Sander Jansen. However, for much of the graphic undertakings of Bruegel, we remain oblivious. The FINGERPRINT toolbox makes it possible to carefully image, measure and compare the font types used in the added letterpress text. By identifying the used fonts the figure of Christophe Plantin came into focus. Plantin is known to have collaborated regularly with Cock for providing letterpress texts for his prints and maps. As he was the only printer active in Antwerp using the modern French fonts found on some of the Bruegel prints it is more than likely that this famous Antwerp printer was responsible for the letterpress texts printed on some of the successive editions of e.g. Bruegel's *Elck* or *Everyman*. (see Fig.16) Using this method these editions of the print can be more closely dated to the period 1555-1570.

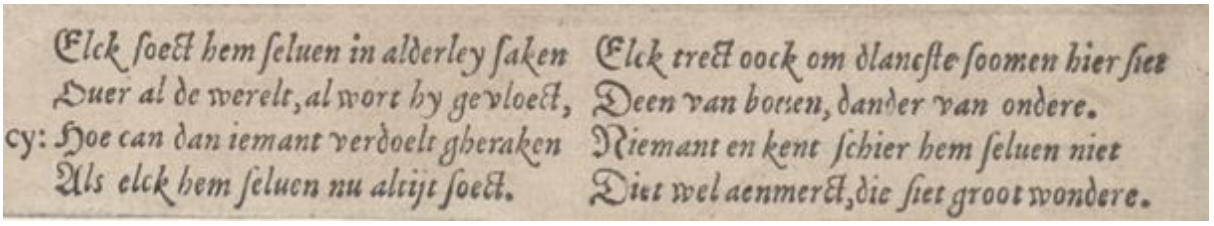


Fig. 16. Detail of the Flemish verses of the newly discovered C-version of Bruegel's print *Elck.*

The identities of the authors of the Latin quotes or phrases which were cut into the printing plate (see Fig. 17) to supplement some allegorical ingenuities of Bruegel was explored. Reference is thereby often made to the Dutch writer and printmaker Dirck Volkertsz. Coornhert (1522-1590), a collaborator of Cock, for the presented homilies or platitudes in Bruegel's series of the *Vices* and the *Virtues*. The relationship with the so-called *Zodiacus Vitae* by Palingenius, a heretical poem which was placed on the Index in 1559 was shown. This research is a part of Maarten Bassens PhD research on Bruegel.

Fig. 17. Detail of the inscriptions on Bruegel's *Desidia*. The Latin phrase stems from the *Zodiacus Vitae* of Marcellus Palingenius.

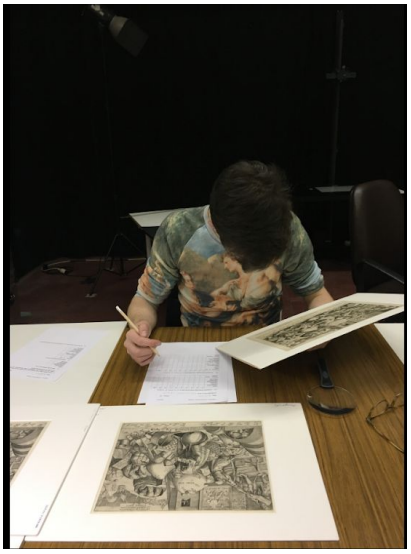


Fig. 18. Visual assessment of the Bruegel prints at KBR (2017)

4.2. Art Technical research on the Drawings

Revealing the use of combined inks in Bruegel drawings

Four drawings by Pieter Bruegel the Elder - three from the Print Room of the Royal Library in Brussels and one from the Royal Museum of Fine Arts of Belgium in Brussels - were studied in detail. (see: Watteeuw, Van Bos et al. 2019). These are a landscape, *Stream with an Angler* dated 1554, from the 'Lugt group', and three figurative allegories drawn as preparations for prints, *Luxuria,* dated 1557, *Prudentia* and *Justitia,* both dated 1559. (See Fig. 1-4) The four drawings were examined and photographed in a standardized studio set-up: high-resolution photography with frontal and raking light, recto and verso, and with transmitted light; ultraviolet light (UV); multispectral photography with filters; photometric stereo with KU Leuven's Portable Light Dome (PLD white light and multispectral); infrared reflectography (IRR). For analytic research the drawings were transported to the Royal Institute for Cultural Heritage (KIK-IRPA) in Brussels for: macro-X ray fluorescence mapping (MA-XRF).

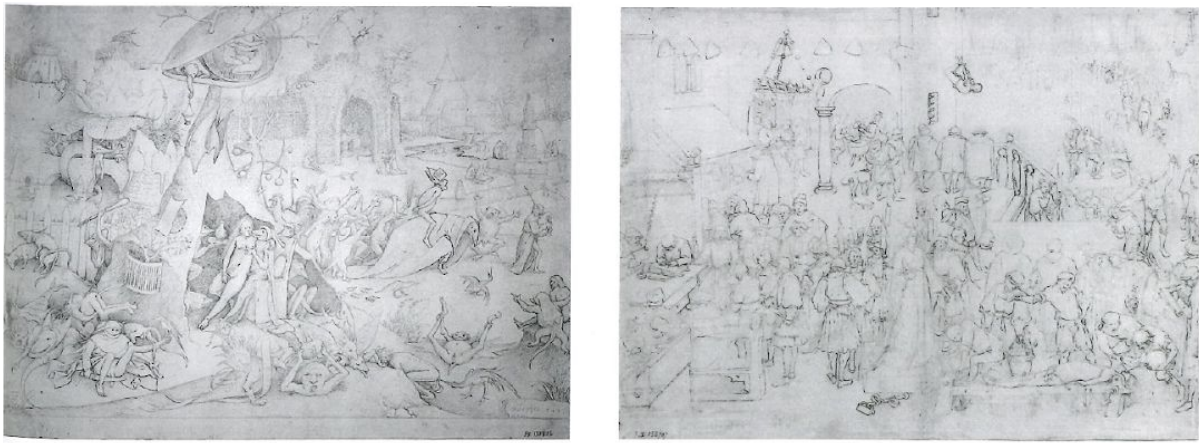


Fig. 19. Infrared photographs (IRR) of Luxuria and Justitia

The three figurative allegorical drawings studied *(Justitia, Prudentia* and *Luxuria)* are made with fine solid lines, with detailed dots and small details in the hatching, because they functioned as a cartoons for engravings, while the vertical landscape of *Stream with an Angler* is drawn with atmospheric free pen strokes. Visually, the colours of the inks differ, as the allegorical drawings are drawn in grey-black or brownish ink, in contrast to the large tree near the river, executed in red-brown ink. During the research it became clear that the ink media used by Bruegel are different in the four drawings. This can be seen in the infrared reflectography of the drawings, which do not reveal any underdrawing but only the ink of the lines of the finished drawing. Bruegel did not use any preparatory lines on the paper. It is highly likely that, for these allegorical drawings, separate sketches were made to prepare these complex compositions, but these are lost. More information about the ink used for the drawings is gained with the combination of non-destructive chemical analyses (MA-XRF) and multispectral imaging (IR photography and multispectral micro-dome (MS MD), which revealed the mixed composition of the inks: iron-gall ink combined with carbon ink. The varying components of iron-gall ink, made from gall nuts, iron sulphate, water and a binder, resulted in inks of diverse tones and hues, from light brown to black. Carbon ink, made from wood soot soaked in water, was blacker. This combination of the two is evident from the infrared images, where the lines revealed are exactly the same as those visualized through the MA-XRF analyses; the infrared images show the carbon, while the XRF technique (which cannot monitor carbon) detects the iron. (see Fig. 19-20). Visually, adding carbon gave the ink a deep black lustre compared to the more brownish iron-gall ink. Combined inks are not so commonly used in drawings as the 'pure' iron-gall ink, but they were easy to make and not expensive. The two drawings from 1559, *Justitia* and *Prudentia* (preparatory drawings for the two engravings in the print series of the *Seven Virtues,* 1559-60, published by Hieronymus Cock), clearly have different characteristics. The ink medium of *Justitia* is completely visible in IR, the result of using an ink containing carbon, but in *Prudentia* only one small female figure in the centre appears in IR, thus demonstrating the overall use of an iron-gall ink except for this little figure drawn in a carbon- containing ink. The ink of *Luxuria,* 1557 (a preparatory drawing for the *Seven Capital Sins'),* is similar to the one used *in Justitia.* The use of combined iron-gall and carbon inks has a tradition going back to antiquity, as Pliny mentioned it as *atramentum.* Italian artists such as Titian used combined inks and it is possible that they were known in the workshop of Giulio Clovio. Recipes for combined inks are found in medieval illuminators' treatises, such as the important one compiled by Jean Le Begue in Paris in 1431. The treatise written by Alexis of Piedmont/ Alexius Pedemontanus, *De Secretis libriVII,* in Lyon, *c.* 1558, also mentions the preparation of mixed inks. Bruegel was certainly familiar with strong shades of mixed inks through his presumed training and experience as an illuminator, and would also have encountered the practice during his Italian journey.

Fig. 20. IRR of a detail of Justicia showing the mixed use of carbon and iron-gall ink

More information on Bruegel's drawing inks was revealed by the set of computerized images of elemental analyses of the iron-gall ink made by XRF mapping. (see Fig. 21) It became clear that some areas are drawn in iron-gall inks of different chemical composition: in addition to the main component of iron, differing amounts of copper, lead or zinc are visualized in separate images. Slight differences in the composition of the metal components reveal the differences in the iron-gall inks the artist used in different phases of the drawing. In practice, this means Bruegel used another composition of ink. For example, the iron-gall ink of *Justitia* contains iron and zinc, with the exception of the vertical zone of ca. 15 mm on the left of the drawing, which is worked out in an iron-gall ink without zinc. This might suggest a particular working session of some hours, when the artist used a different ink composition prepared in another inkwell. A second example is the dark cross-hatching to simulate windows and shaded interiors in *Luxuria,* created with an iron-gall ink containing a higher quantity of zinc. The detailed hatching on the left side of the tree trunk, and in the architecture and figures, is done with an iron-gall ink containing a larger component of lead. The naked figure on the right of the tree is drawn with two different compositions of iron-gall ink. The difference when zinc is present in the ink is also seen in the multispectral micro-dome false colour images. In *Prudentia,* some final details are filled with a dense hatching with an ink containing zinc. These hatchings in ink of a different composition are done most probably at the final stage of the drawing's creation, when Bruegel spent a few successive sessions completing his drawing. We can reach this conclusion only through the elemental analyses of the inks, since these differences are not detectable with the human eye.

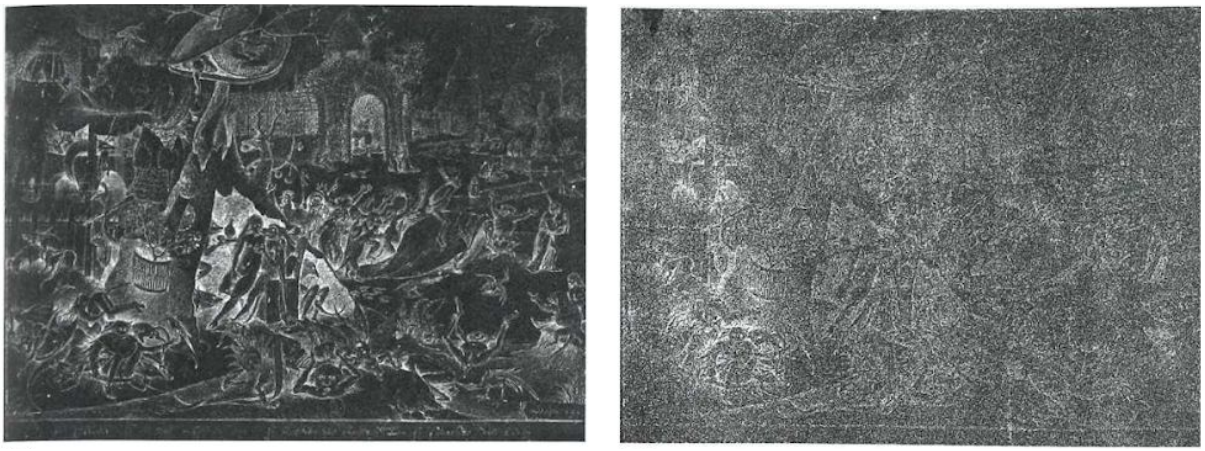


Fig. 21. Luxuria. MA-XRF images showing (a) the distribution of iron and (b) the higher prevalence of lead in the iron-gall ink on the left side of the trunk.

Bruegel's drawing *Stream with an Angler,* depicting a majestic tree near a river with three little figures, was created overall in a warm, mid red-brown coloured ink with a free hand. Analysis revealed a carbon ink mixed with an iron-gall ink, containing, in addition to iron, an admixture of nickel (Ni) and manganese (Mn). The artist most probably added some earth colours, such as ochres, signalled by manganese, to the iron-gall ink to enhance the colour of the ink. This technique of adding pigments to inks can also be observed in Bruegel's grisaille paintings and has been found in earlier grisaille illuminations by Jean de Tavernier, a master illuminator working for the Burgundian court in the 15th century. The presence of nickel in the ink is unusual, however. Nickel is an element accompanying natural iron-based ore, and is rarely found in drawing inks, or artists' media in general, in the 16th century. In Michelangelo's drawing *A youth beckoning; and a right leg* (c. 1505) in the British Museum, small amounts of nickel were also detected in the drawing medium. Bruegel might have selected this ink recipe, as already mentioned above, from his experience of Italian drawing practice. Nonetheless, nickel remains uncommon in iron-gall inks in the 16th century; it appears more often in iron-gall inks for drawings from the 17th century onwards. The warm brown ink with some reddish shade is found in numerous drawings by Bruegel, not only landscapes, but also allegorical drawings (preparatory for prints).

In conclusion: The standardized high-resolution photographic documentation and analyses of the four drawings kept in Brussels collections reveal Bruegel's great skill as a draughtsman. The characteristics of the ink indicate his knowledge of miniature painting and of Italian drawing techniques. The art-technical study shows that none of the studied pieces has an underdrawing, transfer lines or composition lines: the drawings were executed straight on to the paper. The use of iron-gall ink or combined iron-gall/carbon ink was clearly a deliberate choice by the artist, in order to gain certain effects in contours or in extremely detailed hatching. The differences in the elemental chemical components of the iron-gall ink (iron in combination with copper, lead or zinc) might result from the phases of work needed by Bruegel to finish the drawing: he might have worked on it for a few days or over a longer period. In contrast, the fluently drawn *Stream with an Angler* is in ink of uniform composition, containing carbon and iron with admixtures of manganese and nickel, suggesting that the drawing was made in one session. The colour of the inks may have faded through ageing, so that lighter ink may indicate a principally iron-gall ink, while darker ink may be the result of adding some dissolved carbon to the iron-gall component.

4.3. Quills used by Bruegel - an experiment

The quills used by draughtsmen such as Pieter Bruegel were most probably cut from the larger feathers of the right side wing of geese or swans or smaller birds such as doves, chickens or sparrows. To document and understand the drawing practice, an experimental set-up was done at KU Leuven with a colleague draughtsman, Joris Snaet, who worked with collected and prepared quills on old handmade rag paper. This experiment was repeated by Tinus Vermeersch, an artist focusing on historical drawing techniques. The results were also shown at the Vienna Bruegel exhibition. (see Fig.21) Historical treatises were used to prepare and harden the quills in the lab. The following conclusions could be made: Bruegel was right-handed, because the ink on the left side of a quill stroke - where he started his line - is thicker than the right endpoint. The quills were aged either naturally or artificially, meaning that the feathers were either a few years old or hardened. To allow the shaft of the feather to dry out, the quills had to be cured by putting them in hot ashes or sand for a certain time. When fresh, the shaft would have been too weak to draw with and the natural fat would have interfered with the flow of the ink and the splitting of the nib. The method of hardening quills was described in several 16th-century calligraphic treatises. Palatine suggests in 1540 in his *Libro nuovo d'imparare a scrivere* that the hardening of feathers by putting them in hot ashes was widespread. Bruegel, apparently trained as an illuminator and draughtsman, selected and prepared his quills and cut the nib to a specific thickness of point to allow him to create the line he wanted (0.05-1 mm thick). During the creation of a drawing, the nibs were resharpened with a quill knife, to produce the desired thickness for each line of ink. The nib had to be sharpened every few minutes, and the entire shaft of one quill could easily be used up on a particular detail. For one drawing he might have used more than two dozen quills. (see: Watteeuw, Van Bos et al. Wenen, 2019).

Fig. 22. Details of Bruegel/Brueghel signatures on the five drawings (standard Metamorfoze photographs)

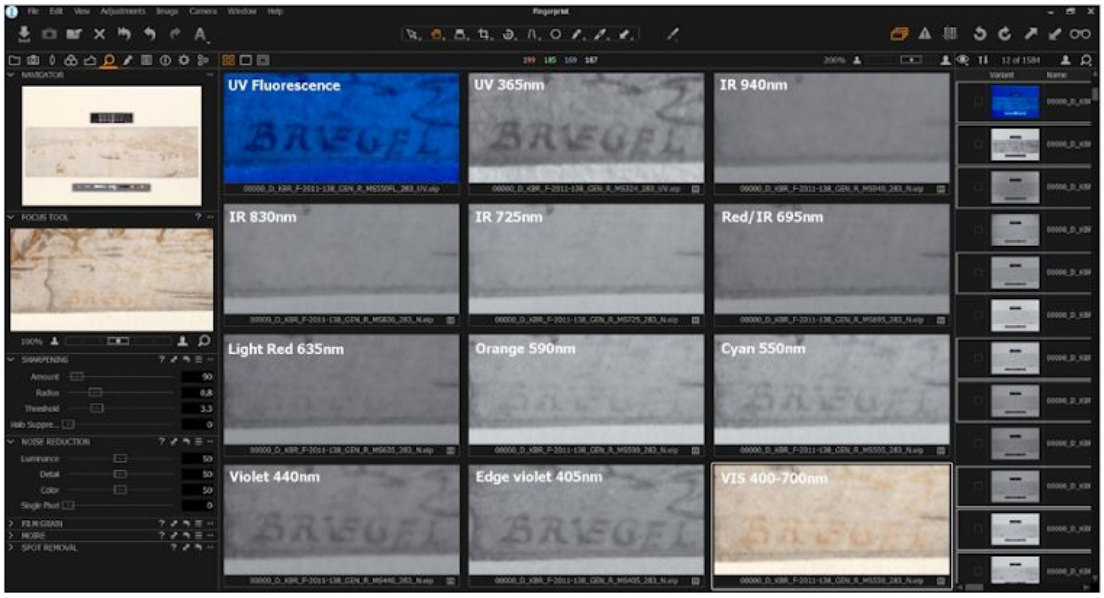


Fig. 23. Screenshot from comparison viewing mode in Capture One Pro 10.2.1 of details of Strait of Messina - KBR F-2011-238: results of recordings with various MS filters.

4.4. Digitization protocol

Next to the focus on the drawings, the full print collection of Pieter Bruegel the Elder in the collection of KBR has been digitised in high resolution in a standardized manner. A digitisation protocol was set up ensuring consistency over time and over the collection during the digitisation phase. A highly detailed excel document was created for each NHD-iconography and each individual drawing/print enabling follow up of the digitisation process.
The full dataset is a digital corpus allowing comparison between states and prints in high detail. The digitisation protocol was set up in straightforward manner so that other institutes, who want to compare their print or drawing holdings to the Fingerprint corpus, can create comparable datasets relatively easily. As high-resolution digitisation infrastructure anno 2021 is becoming more and more standard equipment in institutes worldwide, digitising drawings and prints at 600 dpi can become a standard practice. The datasets will be published online in the Belgica catalogue of the KBR, which will become IIIF compliant in the near future. As such drawings and prints from the Fingerprint corpus can be easily compared to holdings in other collections through viewers such as the Mirador viewer. In addition to that, the MIrador viewer (version 2 and recently version 3) allows you to layer images on top of each other so both global recordings (General, raking and back light images) and imaging sets (White Light and Multi-Spectral Portable Light Dome recordings, Narrow-Band Multi-Spectral images, …) can be disclosed on top of each other bringing together rich datasets. A demonstrator is currently being developed within the 3Pi project (KU Leuven, Diagnosis of Papyrus, Paper, Parchment manuscripts through advanced Imaging, AKUL/17/001, FWO: I009918N).

Research in the Metropolitan Museum of Art with the MD
During a workshop on the Portable Light Dome in the Metropolitan Museum of Art, New York (USA), (22-23/10/2018), Hendrik Hameeuw, an unfinished woodblock with a drawing by Bruegel (the *Dirty Bride)* was imaged. (See: Watteeuw 2019)

4.4. Pixel +

Within the Pixel+ project (RMAH, BRAIN-BELSPO, Pioneerproject, 2017) an open source tool was developed for the online consultation of Portable Light Dome datasets enabling, among others, viewing and dissemination of the Fingerprint Microdome data (White Light and Multi-Spectral), for an example of the implementation see: https://www.heritage-visualisation.org/examples.html.

As indicated in the previous section, any form of quality processing has not been introduced within the interface due to the very specific nature of the data, but the visualization is prepared. As the quality analysis exercise does serve as a proof of concept, the intention is to explore similar forms of processing on other types of datasets, and verify if the underlying approach can be generalized.

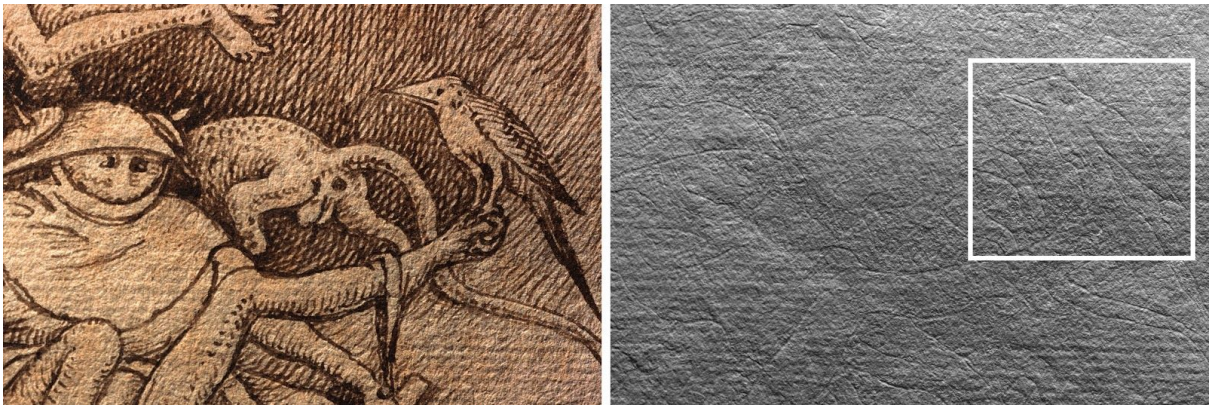


Fig. 24. Detail on original graphic work drawn by Pieter Bruegel the Elder in 1557 (SII132816, Luxuria) Multispectral single-camera multi-light acquisition dome (MS Microdome, PLD system). The color rendering (left) represents the drawing as it appears to the human eye (based on albedo values). With the shaded rendering (right) the topography of the surface can be studied. In this case, it visualizes the tracing lines (very shallow indentations in the paper) made by a stylus used by the engraver to transfer Bruegel's design from the paper version onto the copper plates to produce prints. No other visualization technique documents this feature with the same success rate.

4.5. Final conclusions and recommendations

The developed tools and datasets have proven to add valuable and detailed information that extends upon classical observation with the naked eye and traditional connoisseurship. The toolbox does not make these traditional art historical and curatorial approaches superfluous. On the contrary; the research project has shown that a combination of methods and results leads to more detailed and refined insights.

The creation of multimodal, rich datasets (global recordings in high resolution, multi-light and multi-spectral, KU Leuven in addition to MA-XRF, KIK-IRPA) for the full corpus of original graphical work of Bruegel lays a foundation for future research. The digital corpus as such can act as a primary source for advanced research. New developments in platforms such as IIIF will enable the dissemination of different datasets within one viewing environment. A demonstrator is currently in development within KU Leuven (3Pi project, KU Leuven).

As we have seen, during the research, the protocols, tools and resulting data have been compared and confronted with the findings of more traditional art historical research and curatorial data. The traditional methods like stylistic analysis, technical analysis, history of draughtsmanship, history of paper making and history of printing techniques, but also the analysis and historic contextualisation of the letterpress types used on the prints, provide the necessary context and art-historical framework.

Certain auxiliary research methods such as the identification, localisation and dating of paper have not yet been exploited to the fullest as this was not the primary focus of the project. However, the rich multimodal datasets can provide assistance in this matter. It is clear that the combination of methodologies can be further developed, extended and adapted for future research on collections of works on paper in Federal institutions, but certainly also on an international level. Within the framework of the Fingerprint project the data harvesting of Bruegel prints and drawings according to the developed protocols and tools has been limited to two Federal collections in Brussels (KBR, Royal Museum of Fine Arts) although by way of experiment the tools have also been applied on the Japanese print collection of the Art and History Museum in Brussels, and on a woodblock by Bruegel in the Metropolitan Museum in New York (see Watteeuw 2019).

'Automated Objective Quality Measure' is still in an experimental phase but has proven to be potentially helpful in guiding established connoisseurs and restorators beyond the limits of their visual capacities and memory. It is clear that the technique has to be developed further and that it will benefit specifically the research on very large corpuses of works (specifically prints existing in hundreds of impressions rather than unique drawings) where the comparative capacities of the human brain are largely insufficient. In future developments the tool could further incorporate, process and order complex data such as paper type and structure, color, and chemical variations in ink, but also historical/archival data.

In general the developed protocols and toolbox can be used to assess and further monitor the condition of works of paper (movement of paper, discoloration of inks etc.). Therefore the protocols and toolbox can be applied to monitor (parts of) Federal and other collections of works on paper. In this context the expertise developed on a Federal level with KU Leuven and KIK/IRPA can be continued in future projects that involve conservation issues and that can serve to acquire data for policy making :

- Assessment and monitoring of storage conditions: Planning a (long term) conservation policy for different types of works on paper in Federal collections. Providing consistent data for decision making regarding conservation policy of federal collections of works on paper. (KBR, Royal Museums of Fine Arts, Art and History Museum).
- Assessment and monitoring of transport and exhibition conditions: Providing data for decision making regarding lending, transport and exhibition policy of federal collections of works on paper. (KBR, Royal Museums of Fine Arts, Art and History Museum).

It is clear that future research can be applied on other corpuses and can be expanded beyond the Federal collections and Belgian borders. Applied on a more massive international scale the assessment of groups or collections of works of paper following the same protocols and toolbox can provide large datasets that potentially offer more insights for

researchers. Contacts with the researchers of the Rembrandt Research Project at the Rijksmuseum Amsterdam - for the assessment of prints and drawings by Rembrandt - have been established during the project and there has been an informal exchange of methods and ideas for future developments and protocols. The international contacts during the Bruegel Vienna conference (Van Grieken and Watteeuw members of the scientific board) and the Brussels exhibition (Van Grieken and Bassens, curators and Watteeuw in the board) where most fruitful and explore the possibility of enlarging the research to the drawings of Pieter Bruegel the Elder in foreign institution, to enlarge the knowledge of the main artist. The plan is explored for future collaborations with collections holding works by Pieter Bruegel the Elder.

5. DISSEMINATION AND VALORISATION

Fingerprint Bruegel **expert meeting** in the Royal Library of Belgium 27 July 2017

Fig. 25. Visual assessment of the Bruegel prints by a visiting expert group: Mag. Elke Oberthaler, Dr. Sabine Pénot, Alice Hoppe-Harnoncourt, Prof. Dr. Ron Spronk, Prof. Dr. Manfred Sellink.

Conferences:

London, 21 September 2017, The Courtauld Institute of Arts,
Blocks Plates Stones: Print Matrices/Printing Surfaces in Research and Collections
https://www.ies.sas.ac.uk/sites/default/files/files/events/conferences/BARSEA/BlocksPlatesStones-Programme-Final.pdf

Brussels, March 30, 2018, KBR
J. Van Grieken, FINGERPRINT Het grafisch werk van Pieter Bruegel de Oude doorgelicht, KBR Wetenschapslunch.

Brussels, 12-14 September 2018, Royal Museums of Fine Arts.
-L. Watteeuw, M. Van Bos, J. Van Grieken and M. Bassens, View on the Strait of Messina, Circle of Pieter Bruegel the Elder: Drawing Techniques and Materials Examined
-M. Bassens, 'Diet wel aenmerct, die siet groot wondere'. Retracing Pieter Bruegel's Printing Press(es) by Means of a Typographical Inquiry
The Bruegel Succes Story, Symposium XXI for the Study of Underdrawing and Technology in Painting.
http://org.kikirpa.be/programs/bruegel2018.pdf

Vienna, 6-8 December 2018, Kunsthistorisches Museum.
J. Van Grieken, L. Watteeuw, "*The Function of Drawings in the Oeuvre of Bruegel. Study of his Working Methods, Materials and Techniques*", The Hand of the Master: Materials and Techniques of Pieter Bruegel the Elder. https://www.bruegelthehandofthemaster2018.org/

Brussels, 25 januari 2019, RMBLF
M. Bassens, “A Matter of Letters. A Re-examination of Bruegel’s Print Editions from a Typographical Point of View”, *Pieter Bruegel the Elder and his Predecessors: Culture and Visual Arts in the Late 15th and 16th Centuries (*Vlaamse werkgroep mediëvistiek (VWM) en Réseau des médiévistes belges de langue française

Antwerp, February 3, 2019. Royal Museum of Fine Arts.
J. Van Grieken, “Het grafische werk van Pieter Bruegel de Oude doorgelicht.Het FINGERPRINT-project, zondaglezing.

Brussels, 1 July 2019, KBR.
M. Bassens, “Pieter Bruegel the Elder and the Royal Library of Belgium. An Introduction to the FINGERPRINT project”, *The Age of Bruegel in Context (Summer Course Vlaamse Kunstcollectie)*

Brussels, 29 November 2019, KBR, Centre National d’Histoire des Sciences.
-M. Bassens, “The Knowledge of Language. Reinterpreting Bruegel’s Prints Through Latin Phrases and Typographical Additions”
-L. Watteeuw, “*Pieter Bruegel’s drawing methods”,* The Image of Knowledge. Art and Science at the time of Bruegel. http://www.astrolabium.be/spip.php?breve31

Antwerp, 8 December 2019, Rockox&Snijdershuis.
M. Bassens, “Branding Bruegel. Van de tekentafel tot het album van de prentverzamelaar”, *Zondagslezingenreeks*

Antwerp, 7 March 2020, Museum Plantin-Moretus.
M. Bassens, “Vreemde versieringhen van sinnekens. Een ontleding van de prenten van Pieter Bruegel de Oude”, *Algemene vergadering Vereniging van Antwerpse Bibliofielen*

Exhibitions:

Vienna, Kunsthistorisches Museum, 2 October 2018-13 January 2019
Bruegel The Hand of the Master (Curated by Elke Oberthaler, Sabine Pénot, Manfred Sellink, Ron Spronk and Alice Hoppe-Harnoncourt)

> *Bruegel. The Hand of the Master* was the first ever exhibition to unite paintings, drawings and prints by Pieter Bruegel the Elder. It was the result of six years of research that also involved input from numerous experts in the fields of art history, conservation and science. The curatorial team invited these experts to present findings from their own research at the 2018 symposium *The Hand of the Master: Materials and Techniques of Pieter Bruegel the Elder*. All the papers presented at the symposium are collected in this publication, *Essays in Context*, a special 450th anniversary edition in commemoration of the death of Pieter Bruegel the Elder in 1569. The focus is on insights derived from the artworks themselves.

Fig. 26. Presentation of the FINGERPRINT research project at the exhibition ‘Pieter Bruegel, The Hand of the Master’, Vienna, KHM, 2018-2019. The various technical documents are explained. In the showcase the tools and results of the Bruegel quills experiment with studies and sketches made by Tinus Vermeersch and Joris Snaet in Bruegel's style and using historical drawing techniques.

The results of the investigations into Bruegel's drawings and paintings using modern imaging techniques, the natural sciences and dendrochronology, as well as the observations by the paintings' restorers, provide brand-new information. The analysis of Bruegel's compositions and what he actually depicted (objects, clothes, gestures) is seen within the wider context of the life and times of the artist and his patrons. Rounded up by the latest research into Bruegel's life, the historical art market and previous attitudes to his oeuvre, the entire volume is intended to offer new directions for future study.

BOZAR, *Prints in the Age of Bruegel,* 26 February ’19 — 23 June ’19 (Curated by Joris Van Grieken and Maarten Bassens)

The exhibition *Prints in the Age of Bruegel*, presented jointly by BOZAR and the Royal Library of Belgium, paints a picture of print production in the Southern Netherlands in the age of Bruegel. The famous painter’s own production is only the tip of the iceberg: in the shadow of this giant there are many gems of printmaking to be discovered. The medium was both varied and flexible, used for several forms of visual communication ranging from newsprints to political propaganda. Far from everything that rolled off the presses was intended to be art, although talented painters, sculptors and architects almost always guaranteed a good design. The arrival and flourishing of the art of printmaking in the age of Bruegel is therefore not just an artistic success story. Brilliant craftsmanship and a bold spirit of enterprise also played a major role

Brussels, KBR, 5 October 2019-16 February 2020
The World of Bruegel in Black and White, (Curated by Joris Van Grieken and Maarten Bassens)
https://www.kbr.be/nl/the-world-of-bruegel-in-black-and-white/

Bruegel is a world-renowned painter, but in the 16th century it wasn't his paintings he was known for – it was his graphic work which brought him widespread fame. This 2019 exhibition offered the opportunity to get up close and personal with Bruegel's famous prints. As a pioneer in the rediscovery of Bruegel's lesser-known masterpieces, KBR exhibited its complete collection of prints during this special Bruegel year. In the exhibition special attention was paid to the creative and technical processes used by Bruegel and his collaborators to create printed images. Much of the new findings and the technical data and images that were presented at the exhibition derive from the FINGERPRINT research project.

Fig. 27. View of the exhibition 'The World of Bruegel in Black and White' at KBR (2019-2020)

Websites and blogs

https://fingerprintbruegel.wordpress.com/

https://www.kbr.be/en/projects/fingerprint/

https://enrichingheritage.wordpress.com/2016/11/08/introducing-fingerprint-an-interdisciplinary-research-project-on-the-graphic-works-of-pieter-bruegel-the-elder/

http://www.heritage-visualisation.org/viewer/

https://belgica.kbr.be/BELGICA

Press

https://dailyscience.brussels/nl/fingerprint-project-doet-vragen-rijzen-over-authenticiteit-bruegel-tekeningen/07/12/2018/

https://www.vrt.be/vrtnws/nl/2019/10/14/bruegel-in-zwart-wit-en-als-streetart-in-brussel/

https://www.vrt.be/vrtnws/nl/2019/09/28/leuvense-onderzoekers-bestuderen-prenten-van-bruegel-vaste-han/

https://faro.be/blogs/julie-lambrechts/nieuwe-dimensies-werpen-verdiepende-blik-op-erfgoed

https://nieuws.kuleuven.be/nl/campuskrant/2019-2020/campuskrant-2019-2020-nr-1/leuvense-onderzoekers-leggen-diepste-vezels-van-bruegel-tekeningen-bloot

https://bruegel.vlaamsekunstcollectie.be/nl/nieuws/fingerprint-project-legt-diepste-vezels-van-bruegeltekeningen-bloot

https://bruegel.vlaamsekunstcollectie.be/en/news/fingerprint-research-project-reveals-deepest-layers-bruegel-drawings

https://expo.bib.kuleuven.be/exhibits/show/fingerprint/fingerprint2

https://dailyscience.brussels/nl/fingerprint-project-doet-vragen-rijzen-over-authenticiteit-bruegel-tekeningen/07/12/2018/

6. PUBLICATIONS

peer review:

Vandermeulen, Hameeuw et al. 2017

Bruno Vandermeulen, Hendrik Hameeuw, Lieve Watteeuw, Luc Van Gool, Marc Proesmans, “Bridging Multi-light & Multi-Spectral images to study, preserve and disseminate archival documents”, in: Archiving 2018: Final Program and Proceedings, Springfield - Society for Imaging Science and Technology, 64-69.

(DOI: 10.2352/issn.2168-3204.2018.1.0.15)

Van Grieken 2019

Joris Van Grieken, “Functions of Drawings by Pieter Bruegel the Elder” in: M. Sellink, R. Spronk, a.o. (eds.), in: A. Hoppe-Harnoncourt, E. Oberthaler, S. Pénot, M. Sellink, R. Spronk (eds.), Bruegel, The Hand of the Master, Essays in Context, Vienna: Kunsthistorisches Museum, Veurne: Hannibal Publishers, 2019, pp. 46-48.
(see PDF in annex 2)

Watteeuw, Van Bos et al. 2019

Lieve Watteeuw, Marina Van Bos, Maarten Bassens, Joris Van Grieken, Cristina Currie, Bruno Vandermeulen, Hendrik Hameeuw and Maximiliaan Martens, “Four Drawings by Pieter Bruegel the Elder: Art-Technical Research”, in: A. Hoppe-Harnoncourt, E. Oberthaler,

S. Pénot, M. Sellink, R. Spronk (eds.), Bruegel, The Hand of the Master, Essays in Context, Vienna: Kunsthistorisches Museum, Veurne: Hannibal Publishers, 2019, pp. 52-59.
(see PDF in annex 1)

Watteeuw, Van Bos et al. 2021
Lieve Watteeuw, Marina Van Bos, Joris Van Grieken and Maarten Bassens, “Art-technical research on the drawing View on the Street of Messina (circle of Pieter Bruegel the Elder). Draftsmen’s techniques and materials examined”, in: *Proceedings to the Bruegel Success Story (XXIst Symposium for the Study of Underdrawing and Techology in Painting)*, Peeters, Leuven, 2021, pp. 465-472
(see PDF in annex 1)

others:

Van Grieken, Watteeuw et al. 2017
Joris Van Grieken, Lieve Watteeuw, Bruno Vandermeulen, Marc Proesmans and Maarten Bassens, “Fingerprint onderzoekt Pieter Bruegel de Oude. De start van een interdisciplinaire studie van zijn tekeningen en prenten”, in: Science connection. Het magazine van het Federaal Wetenschapsbeleid, 54 (juli-augustus-september 2017), p. 32-36. (appeared also in French)

Bassens 2019
Maarten Bassens, “Bruegel in all his states. How small details in the printing plate can make a world of difference”, in: Bassens, Van Grieken et al. 2019: pp.34-49.
(see PDF in annex 3)

Bassens, Van Grieken et al. 2019
Maarten Bassens and Joris Van Grieken (eds.), *Bruegel. The Complete Graphic Works*, London and Veurne: Thames & Hudson and Hannibal Publishers, 2019. (appeared also in French and Dutch)
(see PDF in annex 3)

Watteeuw 2019
Lieve Watteeuw, “Bruegel’s drawing for the *Dirty Bride* (c. 1566): A FINGERPRINT project case study”, in: Bruegel in Black and White, The Complete Graphic Works, 2019: pp.50-57.
(see PDF in annex 3)

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ANNEXES

Annex 1: Publications PDF and MA-XRF Maps:

Watteeuw 2019
Lieve Watteeuw, “Bruegel’s drawing for the *Dirty Bride* (c. 1566): A FINGERPRINT project case study”, in: Bruegel in Black and White, The Complete Graphic Works, 2019: pp.50-57.

Watteeuw, Van Bos et al. 2019
Lieve Watteeuw, Marina Van Bos, Maarten Bassens, Joris Van Grieken, Cristina Currie, Bruno Vandermeulen, Hendrik Hameeuw and Maximiliaan Martens, “Four Drawings by Pieter Bruegel the Elder: Art-Technical Research”, in: A. Hoppe-Harnoncourt, E. Oberthaler, S. Pénot, M. Sellink, R. Spronk (eds.), Bruegel, The Hand of the Master, Essays in Context, Vienna: Kunsthistorisches Museum, Veurne: Hannibal Publishers, 2019, pp. 52-59.

Watteeuw, Van Bos et al. 2021
Lieve Watteeuw, Marina Van Bos, Joris Van Grieken and Maarten Bassens, “Art-technical research on the drawing View on the Street of Messina (circle of Pieter Bruegel the Elder). Draftsmen’s techniques and materials examined”, in: *Proceedings to the Bruegel Success Story (XXIst Symposium for the Study of Underdrawing and Techology in Painting)*, Peeters, Leuven, 2021, pp. 465-472.

Annex 2: Publications PDF:

Van Grieken 2019
Joris Van Grieken, “Functions of Drawings by Pieter Bruegel the Elder” in: M. Sellink, R. Spronk, a.o. (eds.), in: A. Hoppe-Harnoncourt, E. Oberthaler, S. Pénot, M. Sellink, R. Spronk (eds.), Bruegel, The Hand of the Master, Essays in Context, Vienna: Kunsthistorisches Museum, Veurne: Hannibal Publishers, 2019, pp. 46-48.

Annex 3: Publications PDF:

Bassens, Van Grieken et al. 2019
Maarten Bassens and Joris Van Grieken (eds.), *Bruegel. The Complete Graphic Works*, London and Veurne: Thames & Hudson and Hannibal Publishers, 2019. (appeared also in French and Dutch)

Containing:

Bassens 2019
Maarten Bassens, “Bruegel in all his states. How small details in the printing plate can make a world of difference”, in: Bassens, Van Grieken et al. 2019: pp.34-49.

Watteeuw 2019
Lieve Watteeuw, “Bruegel’s drawing for the *Dirty Bride* (c. 1566): A FINGERPRINT project case study”, in: Bruegel in Black and White, The Complete Graphic Works, 2019: pp.50-57.

Annex 4: Fingerprint File Naming Protocol