TOWARDS A NATIONAL COLLECTION

UKRI Arts and Humanities Research Council

THE NATIONAL GALLERY

National Portrait Gallery

THE UNIVERSITY of EDINBURGH

BRITISH LIBRARY

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iiif

The Practical Applications of IIIF Project Presents:

Seminar on Image Registration

26th July 2021

https://tanc-ahrc.github.io/IIIF-TNC/

https://www.nationalcollection.org.uk/

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An Allegory ('Vision of a Knight'), by Raphael, about 1504. NG213. Photo: Copyright © 2016–2021 The National Gallery

Arctic Ocean
Arctic Ocean
Greenland
Iceland
Finland
Russia
Canada
United States
North Atlantic Ocean
Kazakhstan
Mongolia
China
South Korea
Japan
Afghanistan
Iraq
Iran
Pakistan
India
Thailand
Algeria
Libya
Egypt
Saudi Arabia
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
Kenya
DRC
Tanzania
Angola
Namibia
Botswana
Madagascar
South Africa
Venezuela
Colombia
Peru
Brazil
Bolivia
Chile
Argentina
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Papua New Guinea
Australia
Southern Ocean
Google My Maps

The Practical Applications of IIIF Project Presents:

A Seminar on Image Registration

Agenda:

- Welcome
- Brief introductions to each of our speakers and their work
- Discussion

Topics for Discussion:

- Why do we want to register images?
- How should we go about image registration? And how good is ‘good enough’?
- How would we like to accomplish image registration in the future? Is there a place for IIIF in these workflows?

Andrew Bruce

The National Gallery

Seminar on Image Registration
26 July 2021

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PI: Joseph Padfield, The National Gallery

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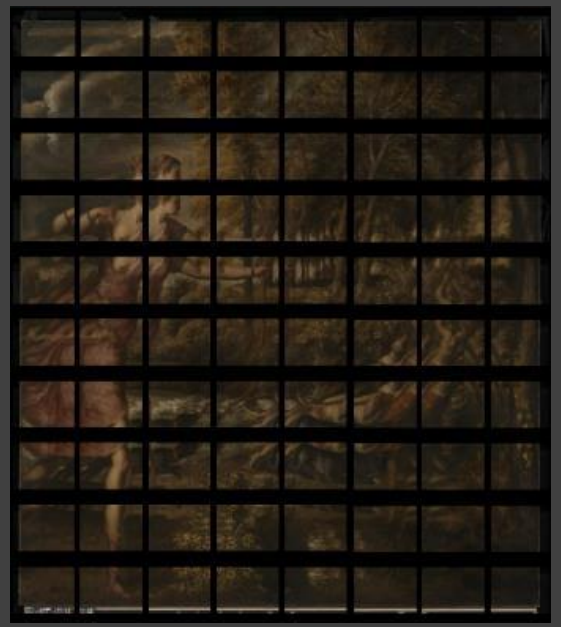
Andrew Bruce
Photographer at the National Gallery

Image Registration Processes

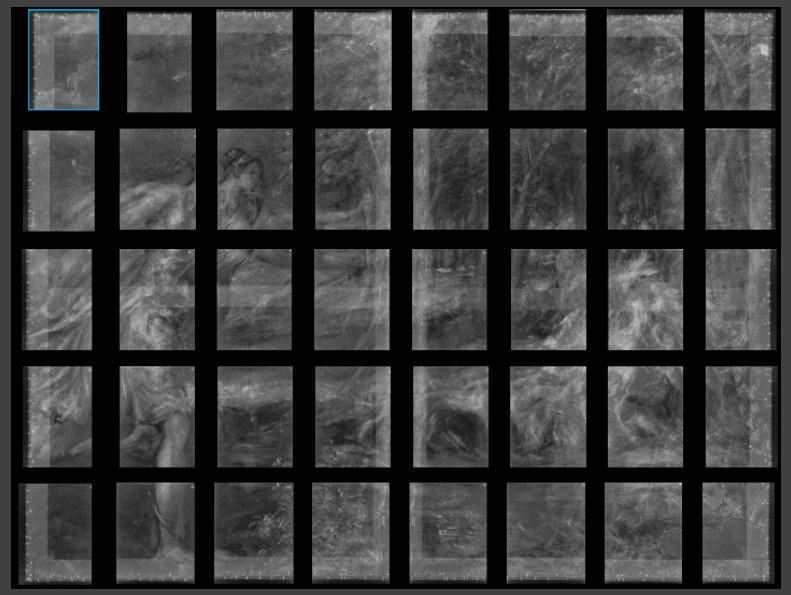
- Mosaicking (Registering image to image to create a larger composite image).
  Of **visible light** and **X-radiography** images.

- Aim is to image every painting with a spatial resolution of 600ppi (42.3µm).

- Producing 2 to 3 mosaicked images per week.



Visible light – composite of 80 details.
11.03GB
47125x42182px



Transmission X-ray – composite of 40 details.
523MB
24668x22259px

Titian, The Death of Actaeon. NG6420

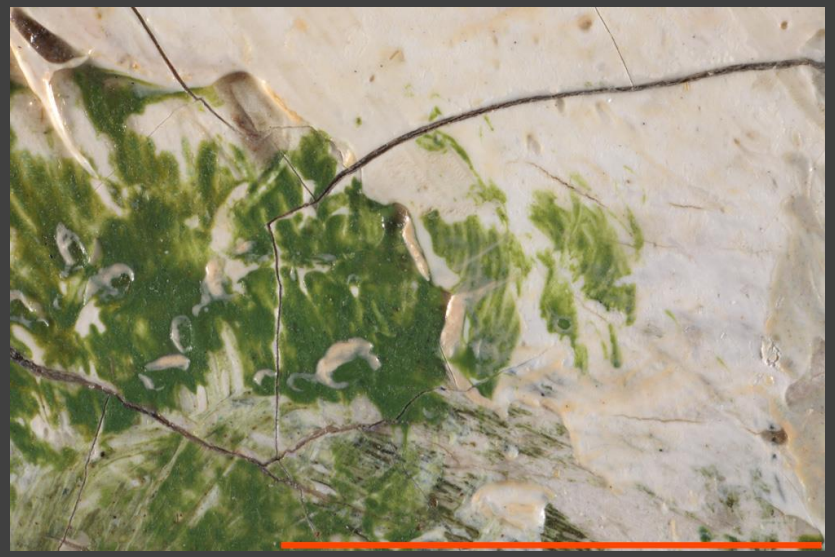
Imaging at high spatial resolution for mosacking and focus stacking

600ppi Tile
Hasselblad H5D 200MS, H 120mm mkII macro lens
Sensor Dims: 8176 x 6132px
Capture Area: 346 x 259mm

600 Pixels per inch
1px = 42.333µm
1mm = 23.6px

1200ppi Tile
Hasselblad H5D 200MS, H 120mm mkII macro lens
Sensor Dims: 8176 x 6132px
Capture Area: 173 x 129mm

1200 Pixels per inch
1px = 21.166µm
1mm = 47.24px



Focus-Stacked Photomacrograph
Canon 5D markIV, MP-E 65mm lens
Sensor Dims: 6720 x 4480px
Capture Area: 7.54 x 5.03mm

22638 Pixels per inch
1px = 1.122µm
1mm = 891.25px

= 5mm

Precise imaging for precise registration

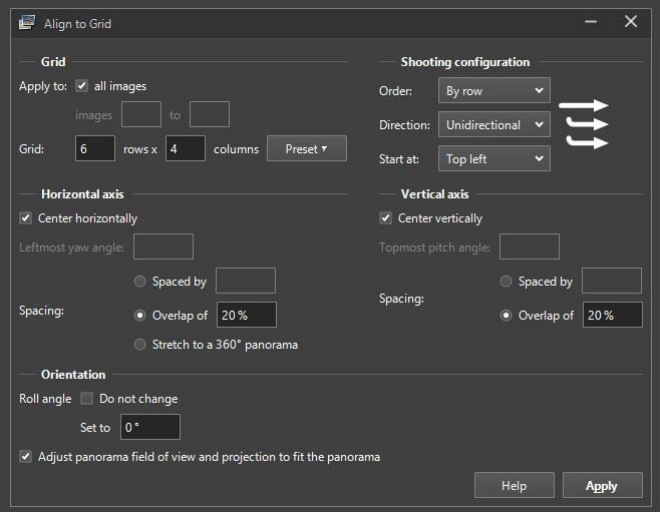
- Uniform and repeatable illumination, no matter the radiation source. Flat-field correct for uniformity.
- Whether the imaging device is stationary, and the painting is moving, or only the imaging device is moving and whether it is panning or tracking. Whether the radiation source is stationary or moving. These factors will influence the processing of the images and subsequent registration.
- Work with long focal length flat field lenses to minimising geometric distortion (Or a longer SID in X-radiography) and correct for distortion.
- Use lenses optimised for the magnification range you are capturing.
- Procedures for precise and repeatable alignment of the imaging device and painting.

How?

Very manually...

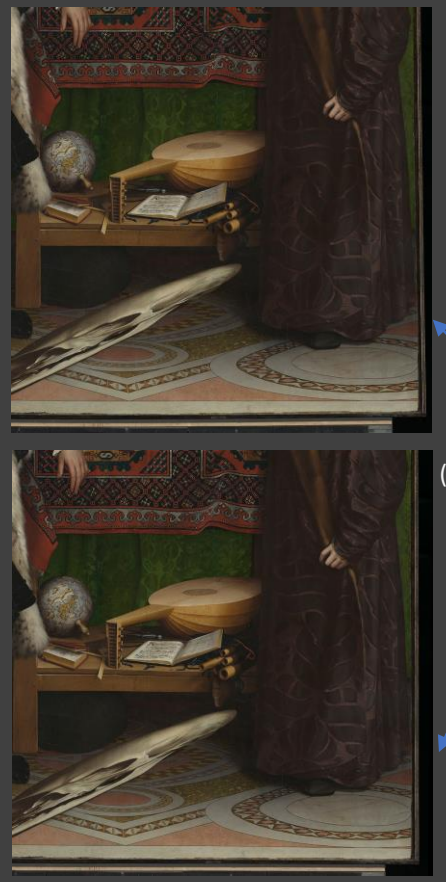
Using PT Gui for mosaicking.
Superb software; very fast, very automated, very stable, easy to use, logical UI, multiband blending, smart seam placement, Lanczos16 interpolation, colour managed.
But is designed for spherical panoramas and does not by default register images with the level of precision that we require.

Registration in PT Gui is accomplished through automated image to image feature identification – the offshoot of this process is that any errors in registration are cumulative, for paintings with significant warping (not perfectly flat surface) the resulting image suffers from geometric distortion due to the change in distance from the surface of the painting to the imaging device and resultant change of magnification.



Align to grid feature in PT Gui

NG5787 details. 4.2GB 26176x29216px



NG1314 detail. 31.8GB 106654x105532px

X-radiography parallax

NG253. Detail showing area of overlap from two X-radiographs.

Parallax issues with registering X-radiography caused by beam divergence.

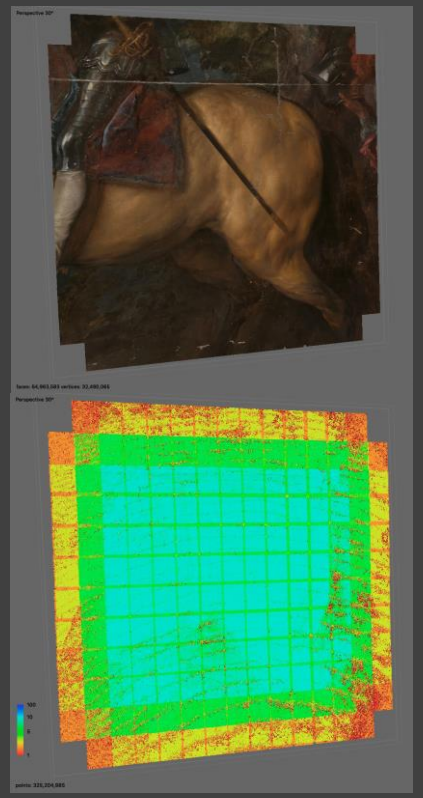
Mosaicking transmission X-radiographs so that all features register perfectly is impossible unless the source remains stationary throughout the capture process. This is often not practical or possible.

A large enough source to image distance is required so that the angle of beam divergence is kept as small as practically possible.

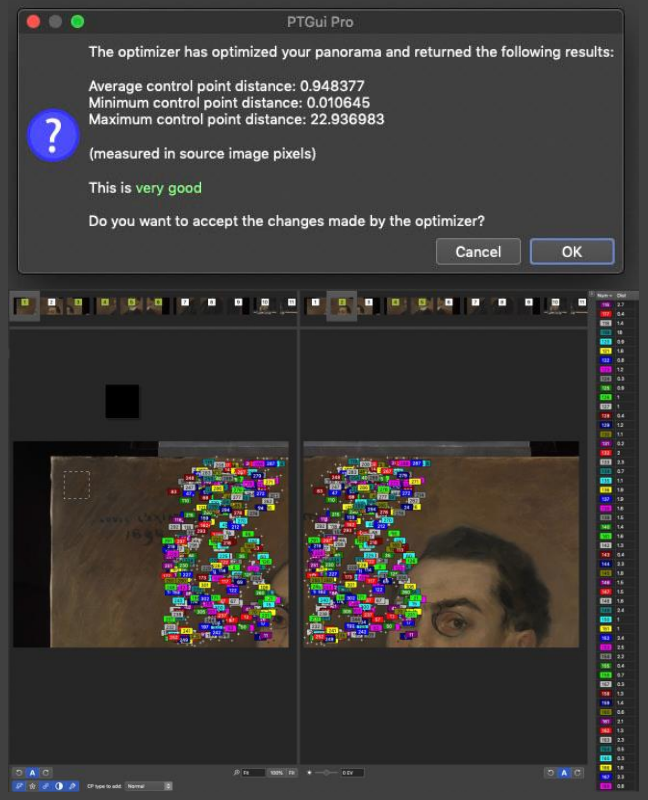
Some misalignment is inevitable, so software which places seams at points where there is minimal difference (so the resulting composite image at least doesn't have any visually jarring areas of misalignment).

How do we assess and express the precision with which images are registered?

- Confidence Heatmap within Agisoft Metashape (Photogrammetry Orthomosaic).
- Average, minimum and maximum pixel distance between control points in PT Gui.
- A script from Digital Transitions that produces a JPEG to aid visual inspection of composite image files made in Photoshop.



NG1172



NG6691

NG6691. 1.7GB 15087x19695px

Nathan Daly

The National Gallery

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Approaches to the mosaicking and registration of images and spectroscopic imaging data at the National Gallery

Catherine Higgitt / Nathan Daly / Marta Melchiorre (Scientific)

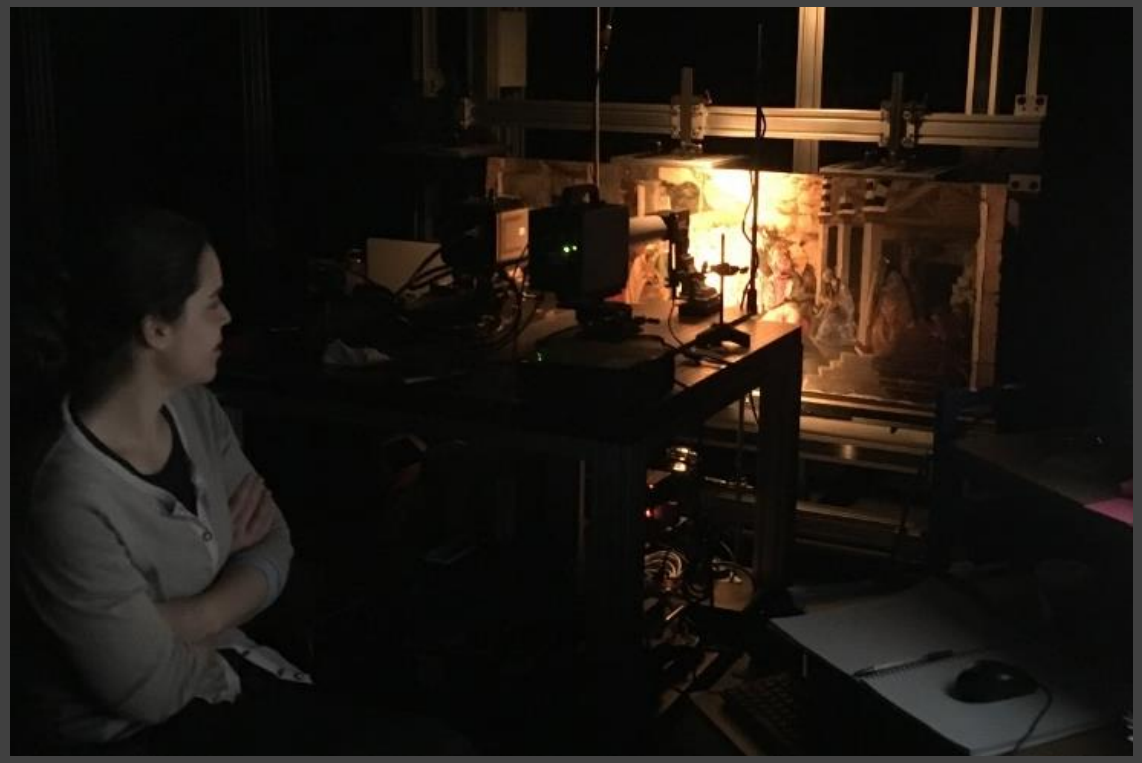
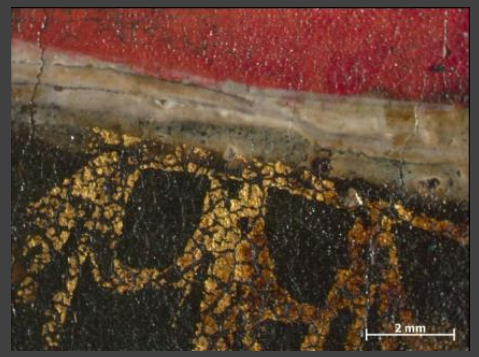
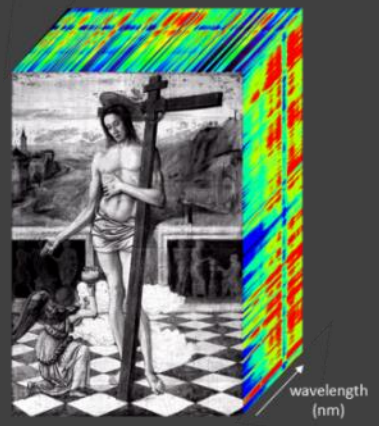


Image modalities

– Visible light (incl. UV induced) at various magnifications
– Infrared reflectrography
– X-radiography
– 3D imaging
– MA-XRF scanning
– Reflectance/Hyperspectral imaging



MA-XRF SCANNING



REFLECTANCE/HYPERSPECTRAL IMAGING

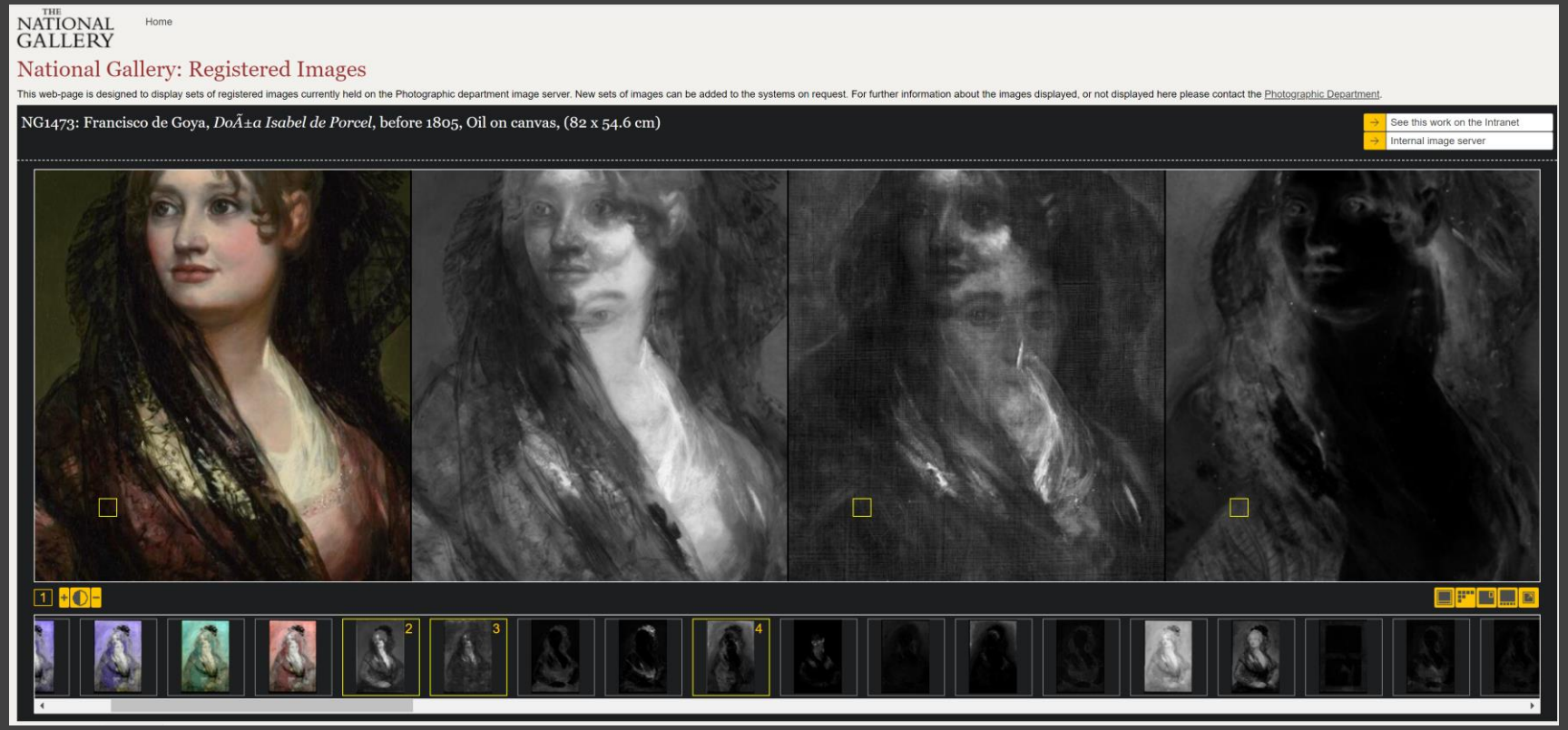
3D IMAGING (surface texture mapping)

Engaging with the registered images

– Those generating the technical images often using overlays in Photoshop or GIMP – very large files, not everyone can handle these and not good for external sharing

– Interested in alternatives for use within and outside the Gallery e.g. side-by-side viewer; curtain viewer

– With spectroscopic imaging techniques, ideally would be able to register entire data cubes for further spectral investigation



Difficulties

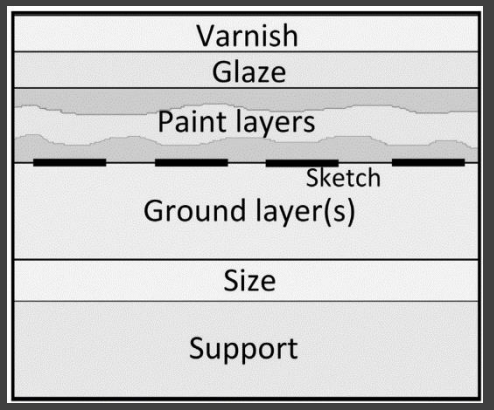
– Paintings are 3D objects – not entirely flat, signal in different modalities could be from different layers or components thereof

– Multi-modality challenges – difference in intrinsic distortions, signal type, resolution

– Mosaicking & registration challenges – error propagation, overlap regions

– Most registration approaches are feature-based, which can be challenged by multi-modal datacubes

– Other difficulties – datacube size/processing power, documentation of methods



Alfeld & Broekaert, 2013
10.1016/j.sab.2013.07.009

TITIAN, NG6420, lead XRF map

Other difficulties

– How to deal with the regions of overlap?
– How to balance sub-images or sub-datacubes when combining?
– File sizes (and formats in some cases)
– Computing power requirements
– How to record information about image or datacube processing including mosaicking/registration steps and how to associate image sets etc.
– Need to register/mosaic images by different means or against different target images depending on intended use of the images, etc.

Maria Villafane

The National Gallery & Imperial College

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Multimodal image registration of Old Masters Paintings

THE NATIONAL GALLERY

Imperial College London

Maria Eugenia Villafane – Collaborative Doctoral Partnership PhD research project
Supervised by Prof. Pier Luigi Dragotti (Imperial College London) and Dr. Catherine Higgitt (The National Gallery)

Multimodal image registration of Old Masters Paintings

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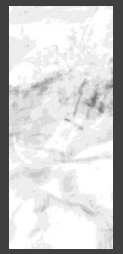
1. Introduction

XRF DATACUBES TO REGISTER

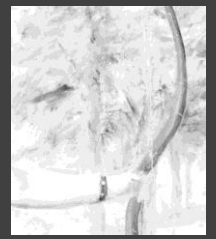
d02 = 941 x 959 pixels

d03 = 1289 x 391 pixels

d09 = 596 x 967 pixels



d08 = 411 x 966 pixels



d10 = 710 x 832 pixels

d13 = 148 x 963 pixels

AREAS SCANNED

DATACUBES AT FINAL LOCATION WITHIN VISIBLE IMAGE OF THE PAINTING

NG6420 Titian - Death of Actaeon. Ensemble of registered XRF images showing (inverted) presence of Fe-Ka within the painting.

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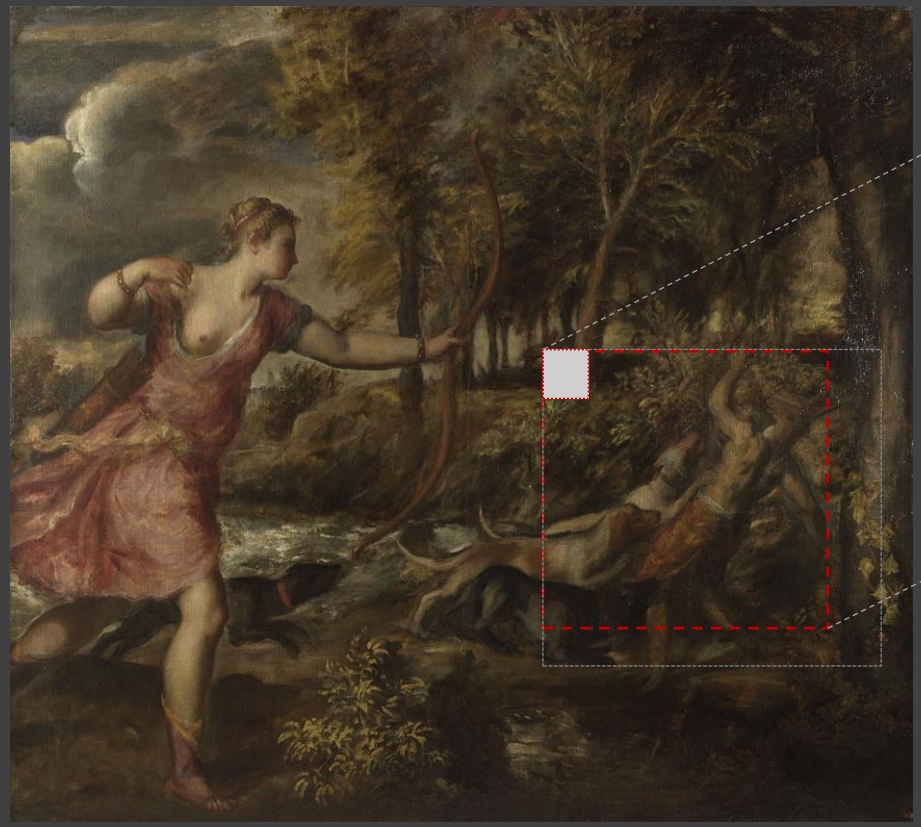
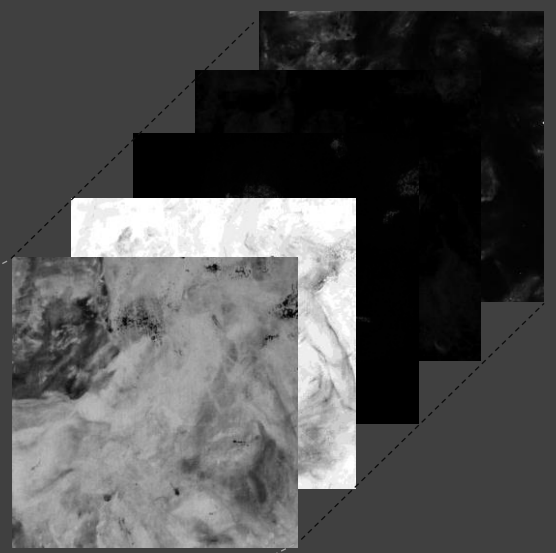
3. XRF Datacube = Selection of elemental maps





Selection of elemental maps

(Slices from Datacube = Stack of images aligned by construction)

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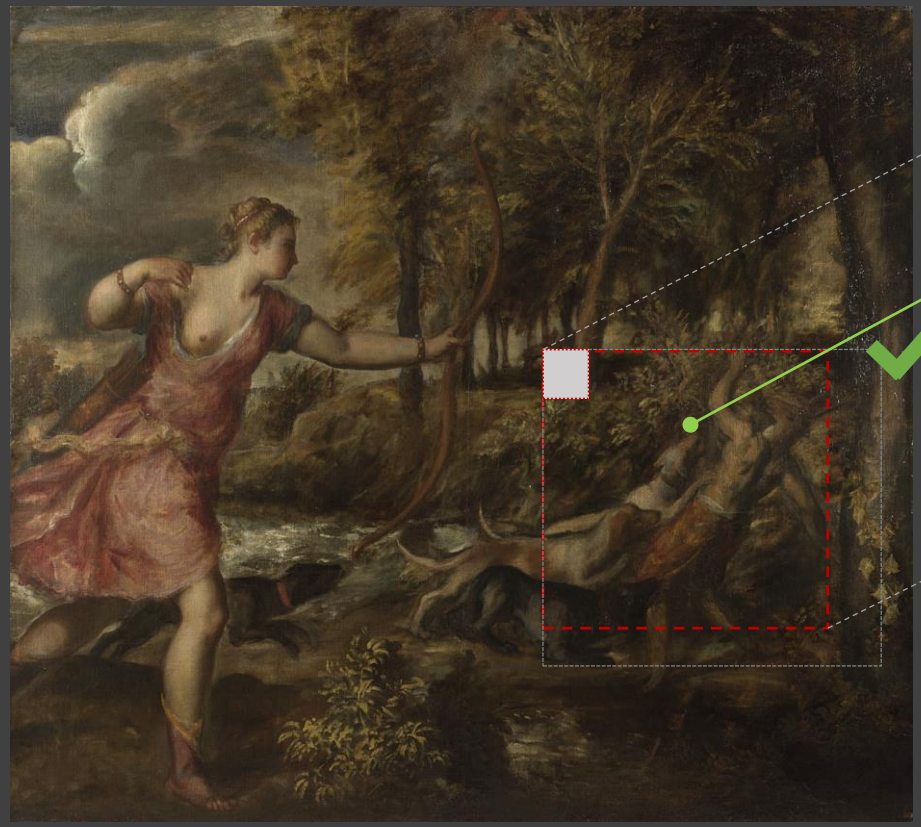
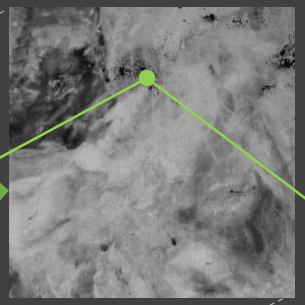
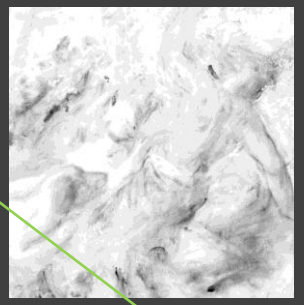
3. XRF Datacube = Selection of elemental maps

Feature detection + descriptors







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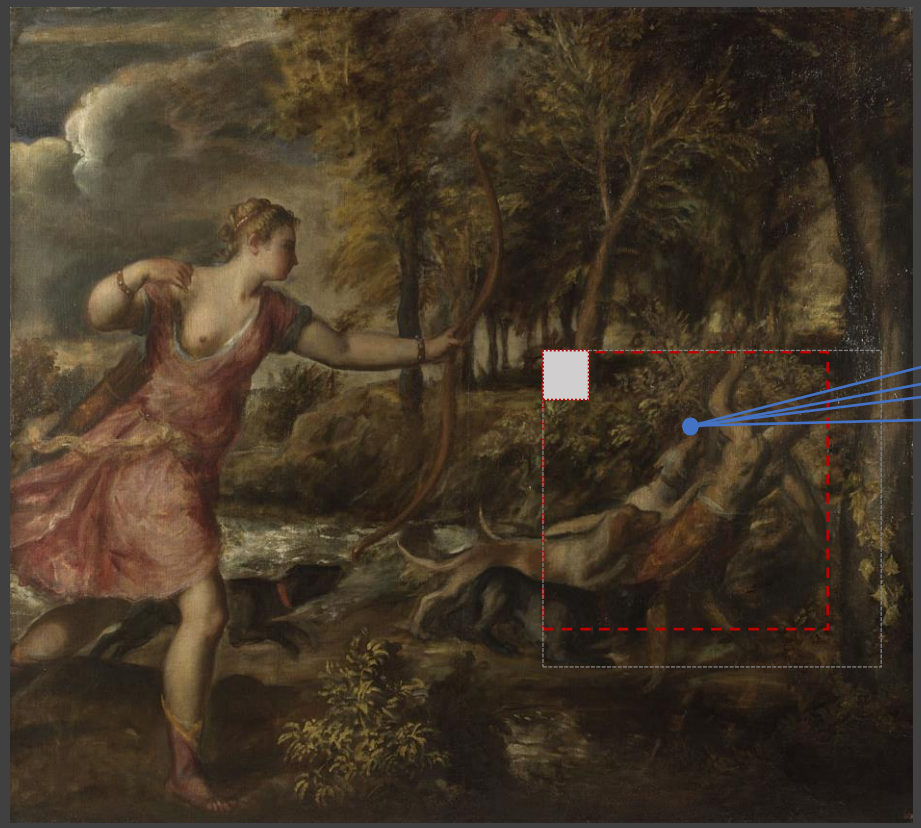
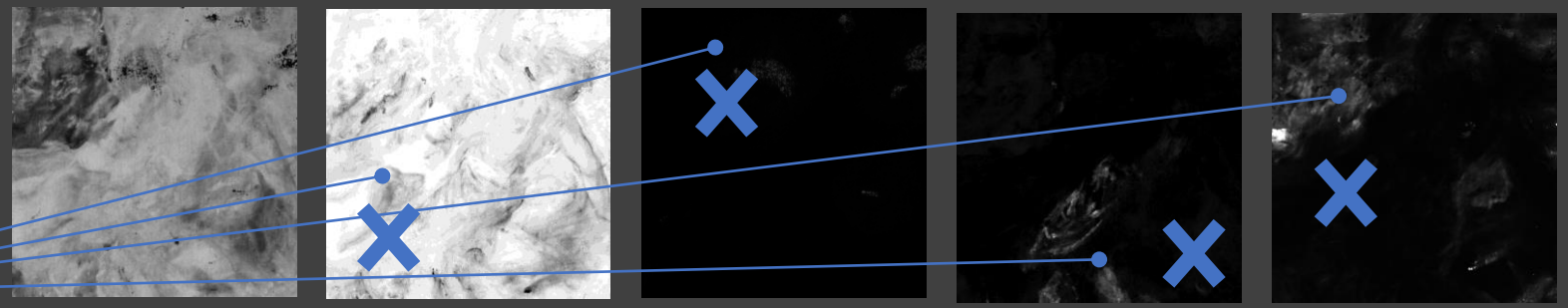
3. XRF Datacube = Selection of elemental maps

Feature detection + descriptors





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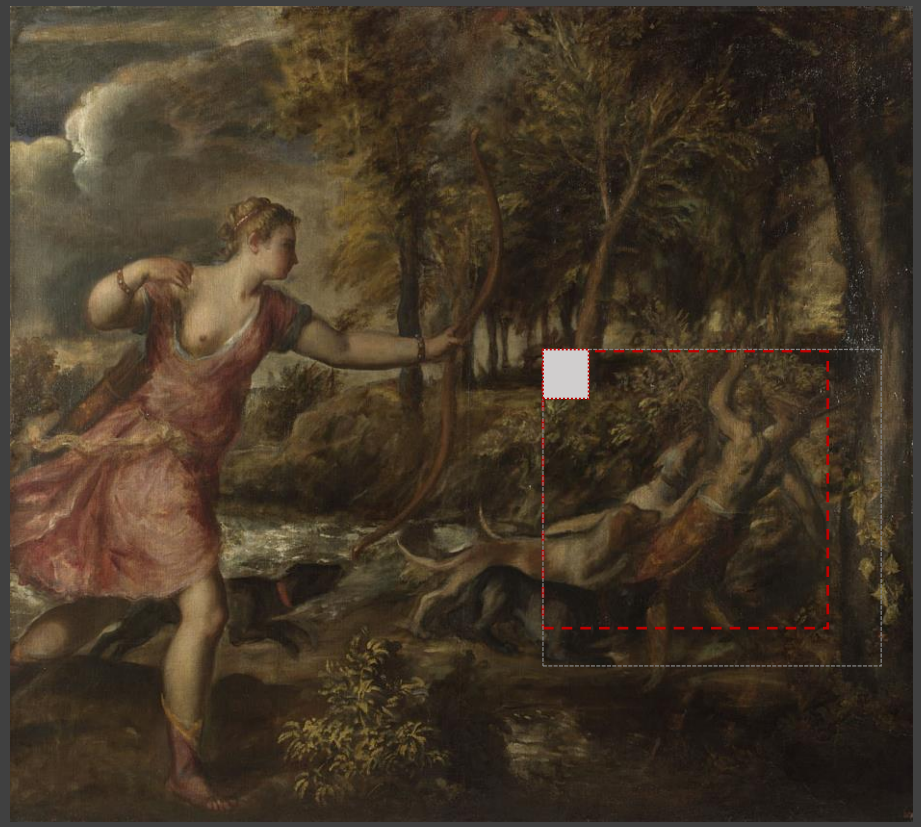
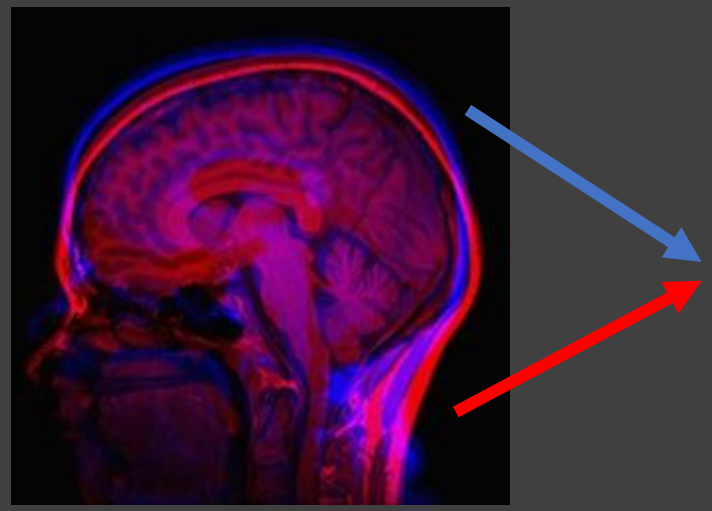
3. XRF Datacube = Selection of elemental maps



Mutual information as a metric for alignment



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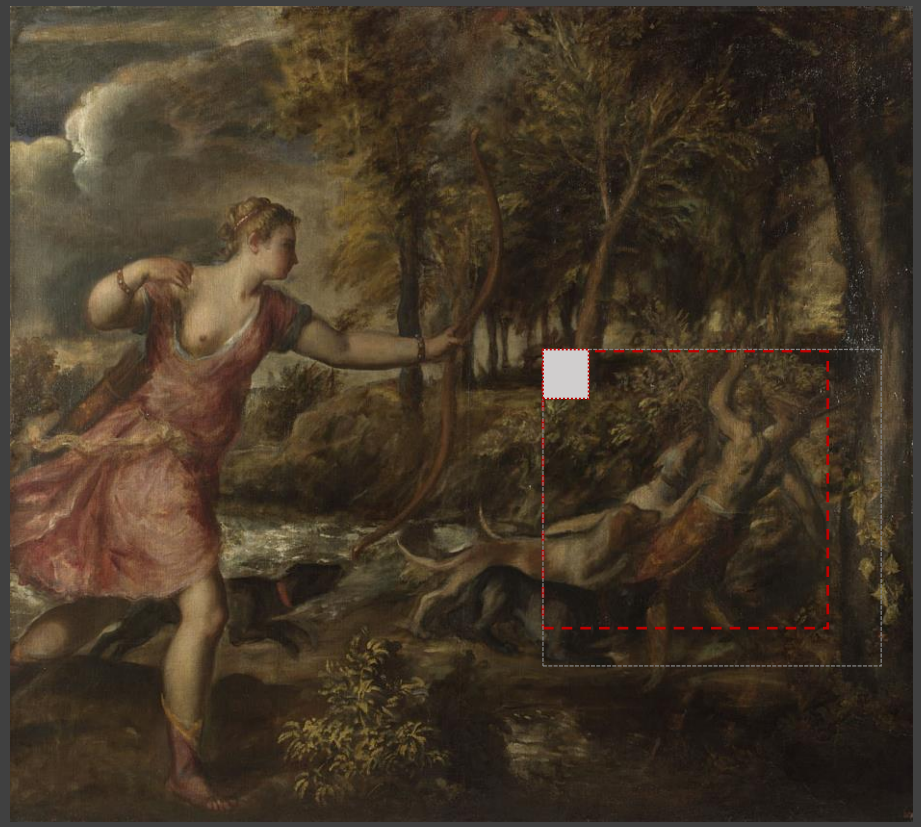
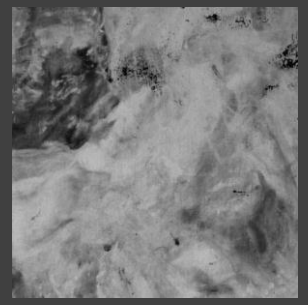
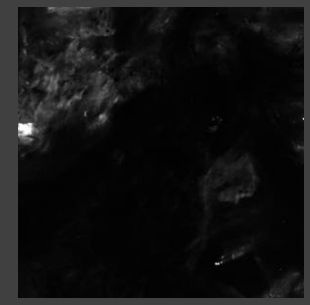
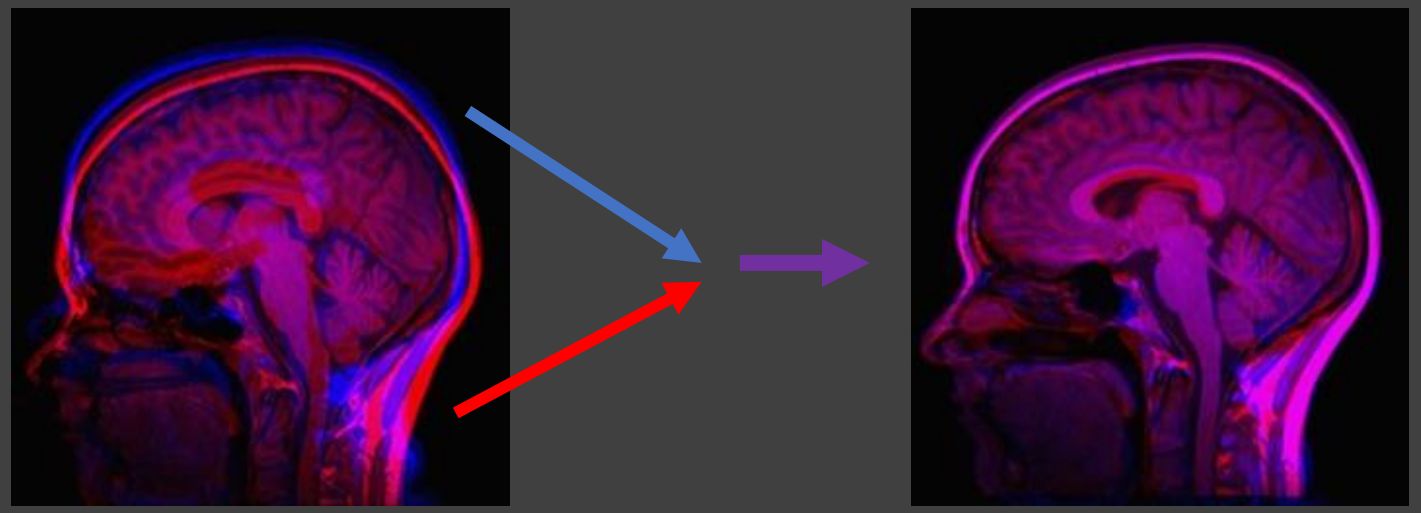
3. XRF Datacube = Selection of elemental maps







Mutual information as a metric for alignment



"SimpleElastix": developed for the medical imaging sector, supports registration based on various transform models (rigid, affine, nonrigid), similarity measures (e.g., mutual information) and optimisation methods (e.g exhaustive search)

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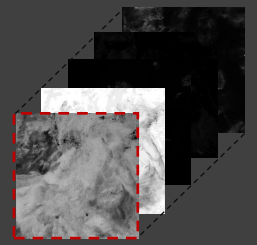
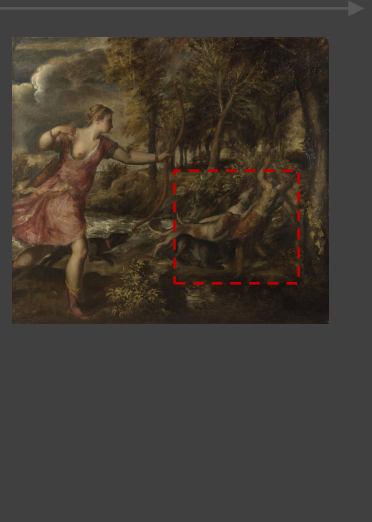
4. “SEARCHES” at increased resolution



Registration of XRF Datacube



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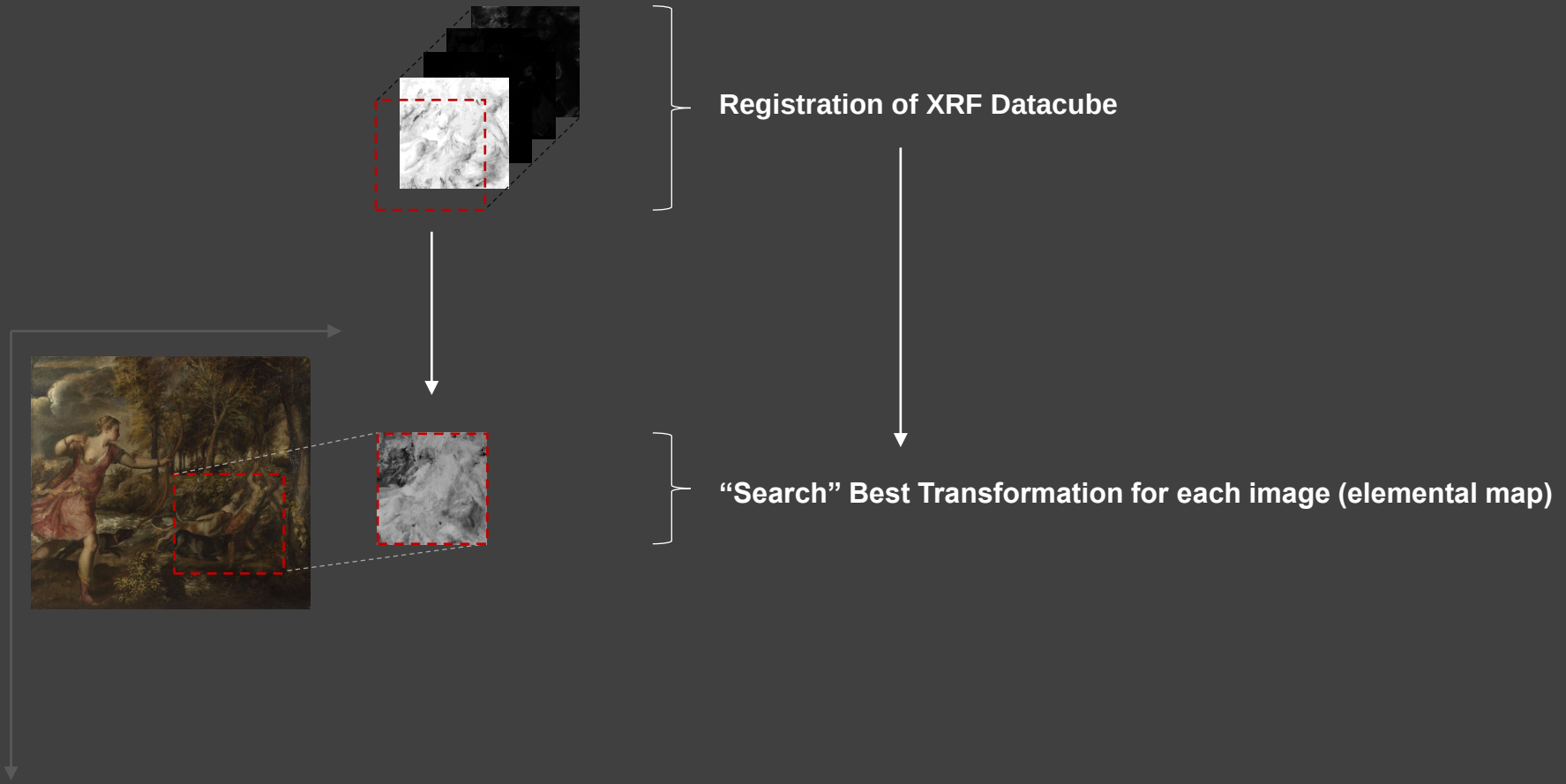
4. “SEARCHES” at increased resolution



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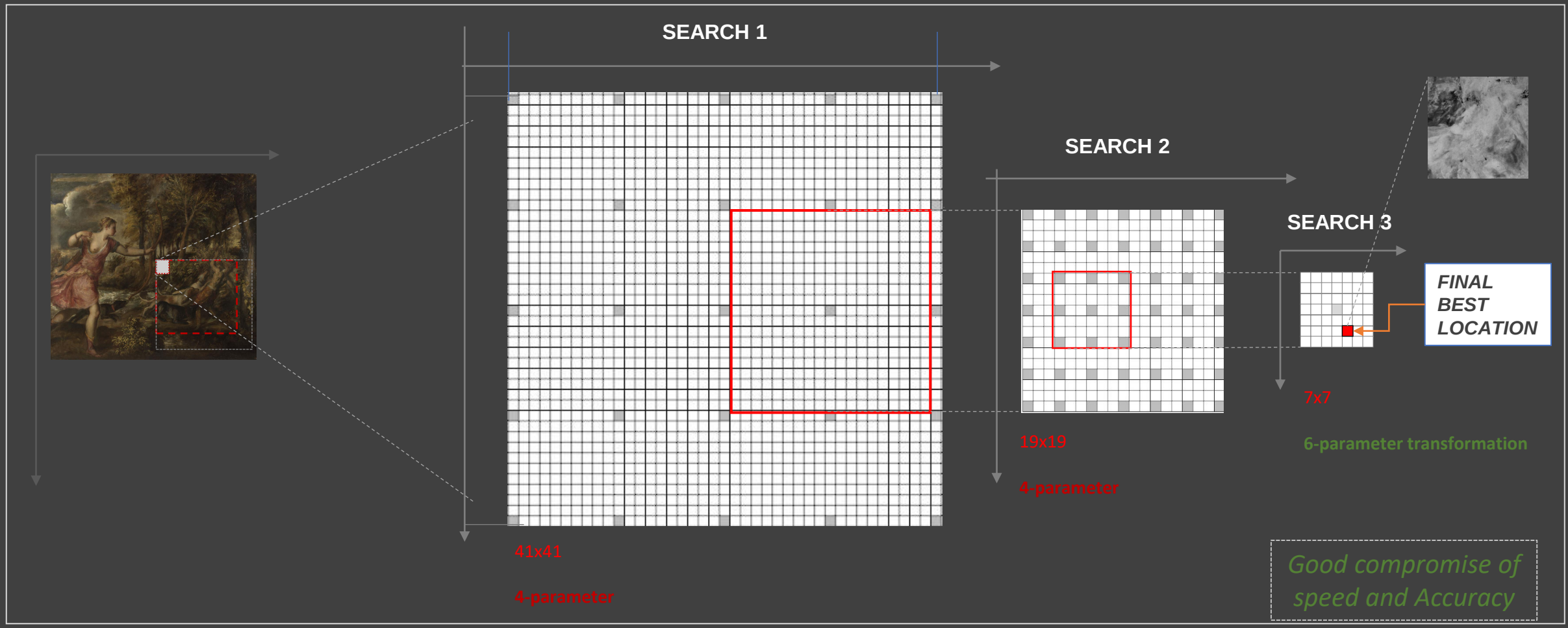

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Thank you for your attention

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Luca Carini

The V&A

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Luca Carini

https://vanda.github.io/vam-talks/presentations/2021/tanc-registrations.html

Ryan Baumann

Duke University

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Joanne Dyer

The British Museum

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Keats Webb

The Smithsonian

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John Delaney

The National Gallery of Art

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Software Tool for Automatic Registration and Mosaicking of Conservation Images

Damon M. Conover[1], John K. Delaney[1,2], Murray H. Loew[1]

[1] George Washington University, Department of Electrical and Computer Engineering, Washington, D.C.
[2] National Gallery of Art, Department of Scientific Research, Washington, D.C.

15 May 2013

John K Delaney, Senior Imaging Scientist
National Gallery of Art

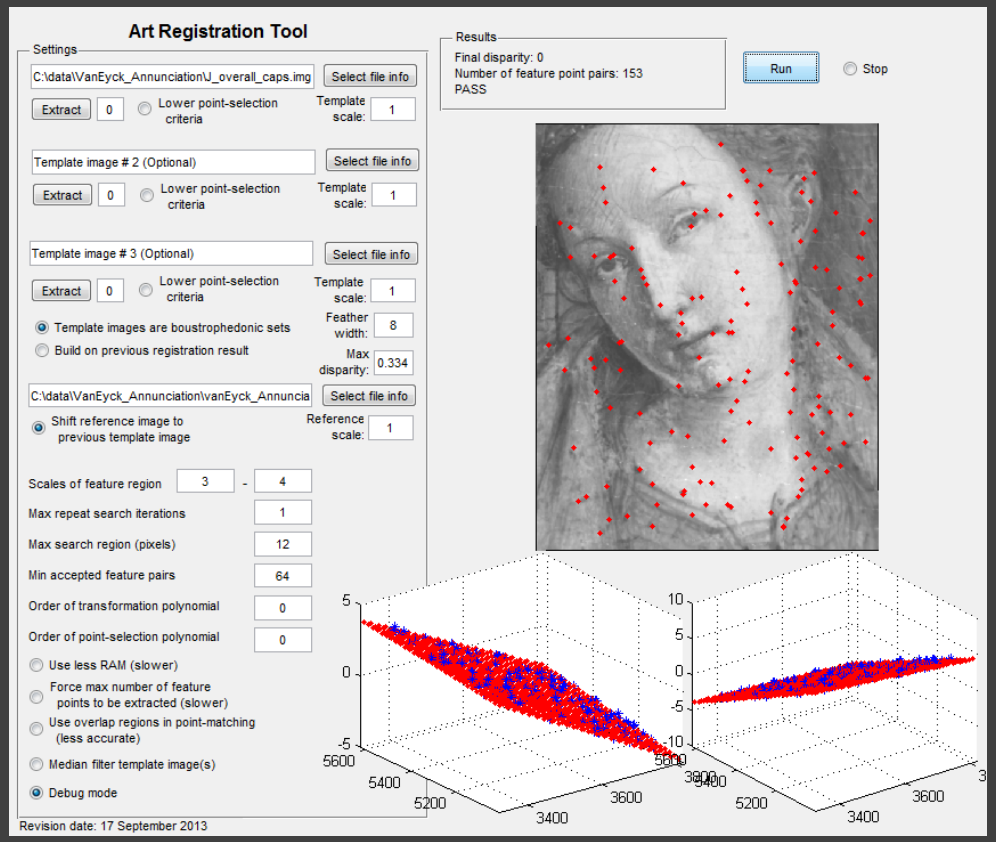
Image Processing Tools For Paintings & Works On Paper

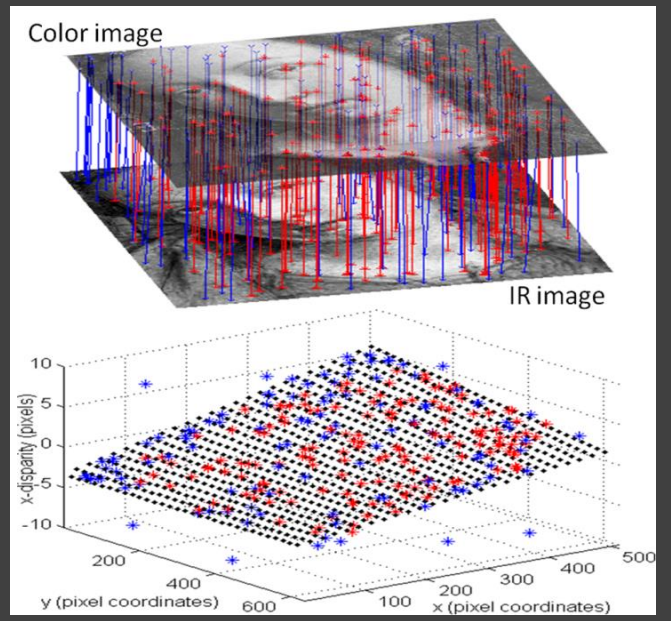
Image Mosaic & Registration Open Sourcre Software Tools

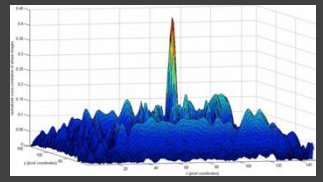
Developed in MatLab, Complied and runs on PC or Mac
For: Multispectral IRR, X-radiograph, Hyperspectral, XRF Maps

Uses a reference image to automatically reregister & mosaic images
Current used by conservators and scientists at 6 museums

Conover et al. *Applied Physics A* 119, no. 4 (2015), 1567–1575.







Color Reference Image

Giovanni di Paolo, *The Adoration of the Magi*, (c. 1450), Andrew W. Mellon Collection

Detail Color

X-ray Image Detail

Detail MS-IRR

Giovanni di Paolo, *The Adoration of the Magi*, (c. 1450), Andrew W. Mellon Collection

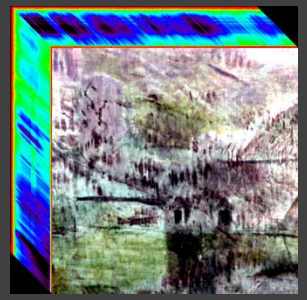
Detail Color

Mosaic Hyperspectral Cubes

Collection of 4 to 100 images cubes registered to color image for mosaic

- Corrected for scan mirror distortion using 4th order cube

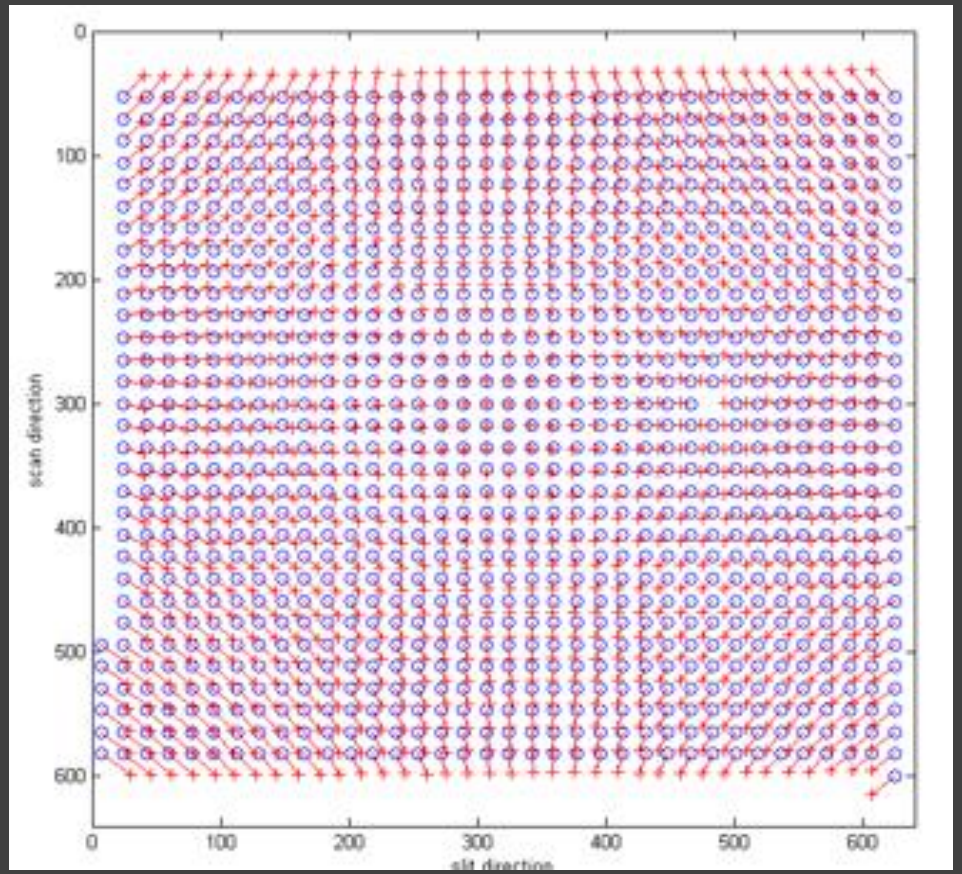
P. Gauguin's "*Brittany Landscape*", (1888)
Chester Dale Collection



12 image cubes collected

640x640 by 256 bands

Scan-mirror distortion



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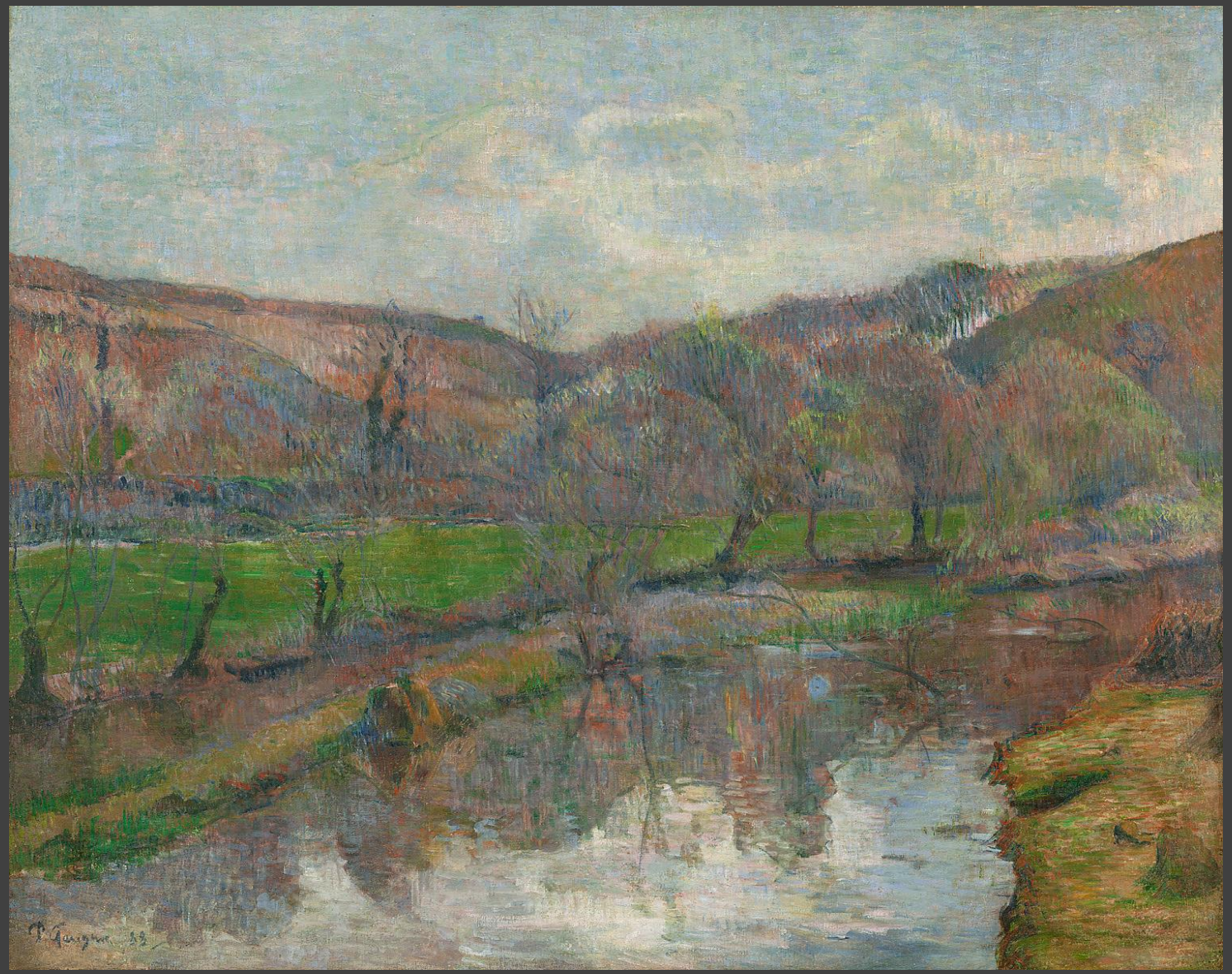

Conservator: C. Christensen

Chester Dale Collection

HS-IRR – *False Color (1100, 1350, 1650 nm)*

Conservator: C. Christensen

Chester Dale Collection

Rob Erdmann

The Rijksmuseum

Seminar on Image Registration
26 July 2021

TOWARDS A NATIONAL COLLECTION

UKRI Arts and Humanities Research Council

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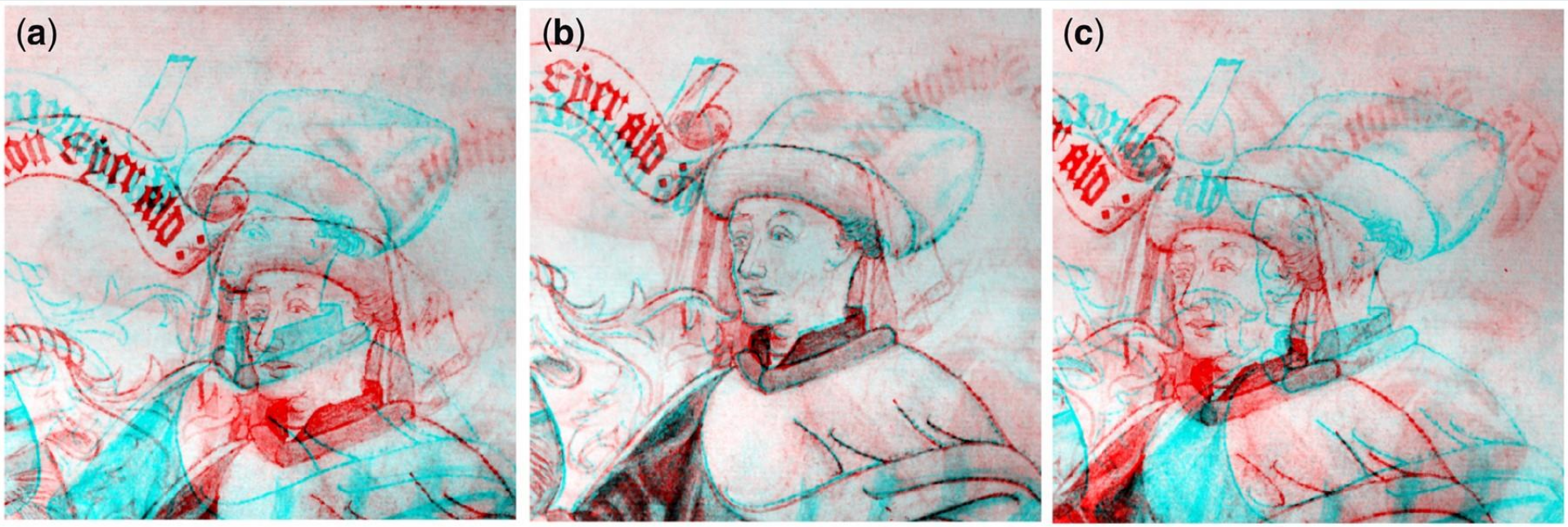
Practical IIIF Project
Seminar on Image Registration

Adam Gibson
UCL Institute of Sustainable Heritage
UCL Medical Physics & Biomedical Engineering

Silverpoint drawing by Leonardo da Vinci

Jones C, Donnithorne A, Terras M, & Gibson AP. (2018). Leonardo brought to Light: Multispectral Imaging of Drawings by Leonardo da Vinci. STEM for Britain 2018, UK Parliament, Westminster, London, UK, 12 March 2018. http://doi.org/10.5281/zenodo.1208430



15th Century drawings of Aldermen of City of London, held by London Metropolitan Archives

Jones C, Christens-Barry WA, Terras M, Toth MB, Gibson AP (2019) Affine registration of multispectral images of historical documents for optimized feature recovery. *Digital Scholarship in the Humanities*, fqz054, https://doi.org/10.1093/llc/fqz054

Further reading

Heritage imaging

- Jones C, Duffy C, Gibson AP & Terras M. (2020). Understanding Multispectral Imaging of Cultural Heritage: Determining Best Practice in MSI Analysis of Historical Artefacts. *Journal of Cultural Heritage*. https://doi.org/10.1016/j.culher.2020.03.004

- Jones C, Christens-Barry WA, Terras M, Toth MB, Gibson AP (2019) Affine registration of multispectral images of historical documents for optimized feature recovery. *Digital Scholarship in the Humanities*, fqz054, https://doi.org/10.1093/llc/fqz054

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- Giacometti, A., Terras, M. M., Campagnolo, A., Macdonald, L., Mahony, S., Robson, S., . . . Gibson AP (2015). The Value of Critical Destruction: Evaluating Multispectral Image Processing Methods for the Analysis of Primary Historical Texts. *Digital Scholarship in the Humanities* 32(1) p101-122. doi:10.1093/llc/fqv036

Medical imaging

- Fitzgerald A, Tie X, Hackman M, Cense B., Gibson AP & Wallace, V. (2020). Co-registered combined OCT and THz imaging to extract depth and refractive index of a tissue-equivalent test object. *Biomedical Optics Express*. 11(3) pp. 1417-1431 https://doi:10.1364/boe.378506

- Proverbio, A., Siow, B.M., Lythgoe, M.F., Alexander, D.C. and Gibson AP, 2014. Multimodality characterization of microstructure by the combination of diffusion NMR and time-domain diffuse optical data. *Phys. Med. Biol*, 59(11), p.2639.

Charles Willard

University College London

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Charlie Willard
UCL Institute of Sustainable Heritage
UCL Medical Physics & Biomedical Engineering

E. Poynter - Israel in Egypt

Willard, C., A. Gibson, and N. Wade. "High-resolution visible and infrared imaging for large paintings: a case study of Israel in Egypt by Poynter." *Optics for arts, architecture, and archaeology VII*. Vol. 11058. International Society for Optics and Photonics, 2019.

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John Cupitt

Imperial College

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1990 – 2005, The National Gallery, London

libvips, Colour calibration, Multispectral imaging, Infrared, X-ray, etc.

2005 – 2021, Imperial College, London

Proteomics, Pulmonary PET-CT, Neonatal MRI
CHARISMA, IIIF pyramid generation

https://github.com/jcupitt/libvips

Giles Bergel

Oxford University

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The Visual Geometry Group's Image Comparator

Practical Applications of IIIF Image Registration Seminar

30th July 2021

Giles Bergel

University of Oxford

Visual Geometry Group

People

Research

Publications

Demos

Data

Software

Practicals

Projects

http://www.robots.ox.ac.uk/~vgg/

Image Comparator (IMCOMP)

Shrinivasan Sankar, Abhishek Dutta and Andrew Zisserman

Overview

Image Comparator (or, IMCOMP) is a web application to automatically compare a pair of images using geometric and photometric transformations. It is an open source project maintained by the Visual Geometry Group.

Here are some features of IMCOMP:

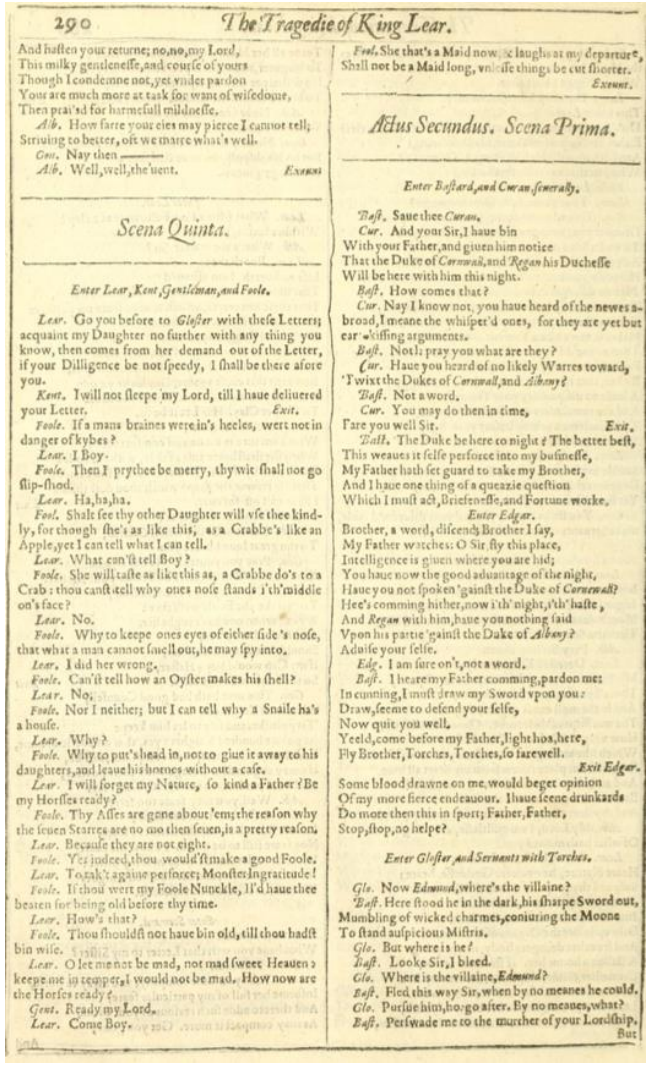
- available as an online tool that can be accessed from any modern web browser
- a large number of visualizations are available to help users spot the difference between two images
- Supports photometric transformation to compensate for colour differences between two images
- Supports different types of geometric transformations (e.g. similarity, affine, thin-plate spline, etc.) to enable comparison of images containing many types of deformations.
- Results can be saved as an image.

Online Application

Click here to load the IMCOMP online tool

http://www.robots.ox.ac.uk/~vgg/software/imcomp/

Initial use-case spotting variation in typesettings



290 The Tragedie of King Lear.

And haſten your returne; no,no,my Lord,
This milky gentleneſſe,and courſe of yours
Though I condemne not,yet vnder pardon
Your are much more at taſk for want of wiſedome,
Then prai'sd for harmefull mildneſſe.
Alb. How farre your eies may pierce I cannot tell;
Striuing to better, oft we marre what's well.
Gon. Nay then ——
Alb. Well,well,th'euent. *Exeunt*

Scena Quinta.

Enter Lear, Kent, Gentleman, and Foole.

Lear. Go you before to *Gloſter* with theſe Letters; acquaint my Daughter no further with any thing you know, then comes from her demand out of the Letter, if your Diligence be not ſpeedy, I ſhall be there afore you.
Kent. I will not ſleepe my Lord, till I haue deliuered your Letter. *Exit.*
Foole. If a mans braines were in's heeles, wert not in danger of kybes?
Lear. I Boy.
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Fool. Shalt ſee thy other Daughter will vſe thee kindly, for though ſhe's as like this, as a Crabbe's like an Apple,yet I can tell what I can tell.
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Lear. No.
Foole. Nor I neither; but I can tell why a Snaile ha's a houſe.
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Foole. Thy Aſſes are gone about 'em; the reaſon why the ſeuen Starres are no mo then ſeuen,is a pretty reaſon.
Lear. Becauſe they are not eight.
Foole. Yes indeed,thou would'ſt make a good Foole.
Lear. To taſk't againe perforce; Monſter Ingratitude!
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Lear. How's that?
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Gent. Ready my Lord.
Lear. Come Boy.

Foole. She that's a Maid now, & laughs at my departure, Shall not be a Maid long, vnleſſe things be cut ſhorter. *Exeunt.*

Actus Secundus. Scena Prima.

Enter Baſtard, and Curan ſeuerally.

Baſt. Saue thee *Curan*.
Cur. And your Sir,I haue bin
With your Father,and giuen him notice
That the Duke of *Cornwall*,and *Regan* his Ducheſſe
Will be here with him this night.
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Cur. Haue you heard of no likely Warres toward, 'Twixt the Dukes of *Cornwall*,and *Albany*?
Baſt. Not a word.
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Brother, a word, deſcend Brother I ſay,
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You haue now the good aduantage of the night,
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He's comming hither,now i'th'night,i'th'haſte,
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Baſt. I heare my Father comming,pardon me:
In cunning,I muſt draw my Sword vpon you:
Draw,ſeeme to defend your ſelfe,
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Some blood drawne on me,would beget opinion
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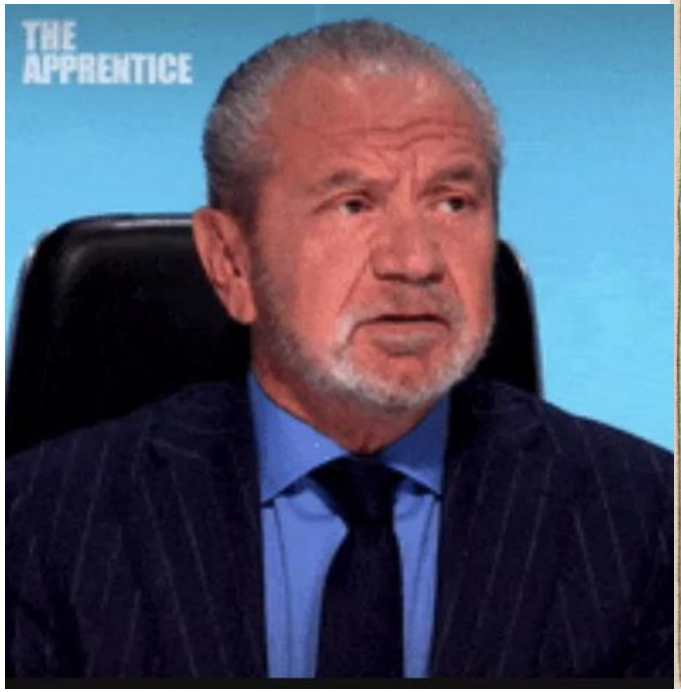

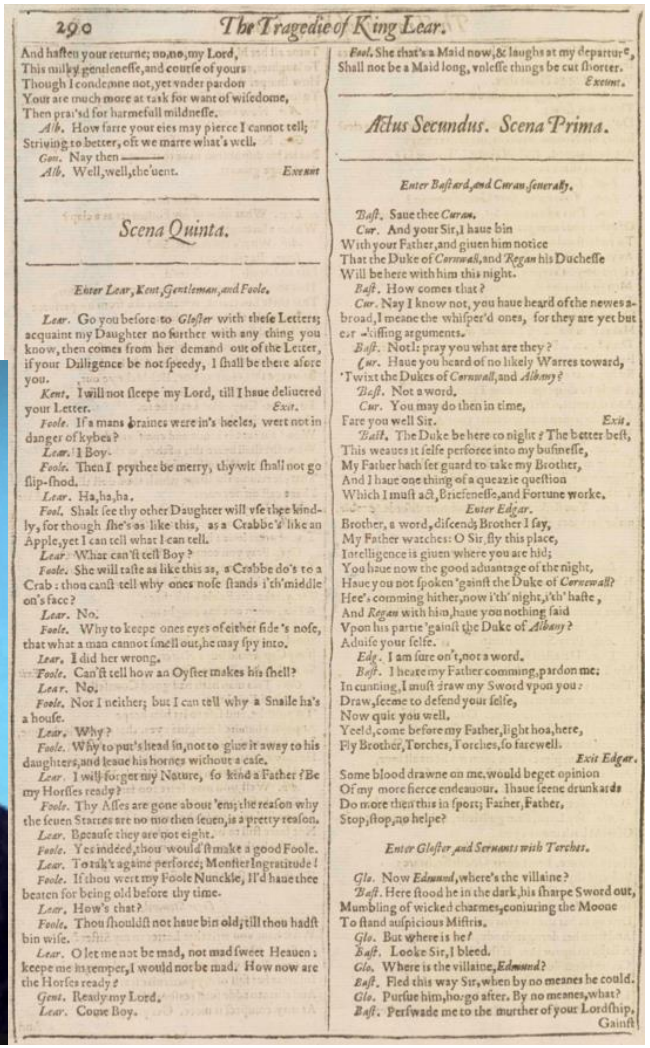

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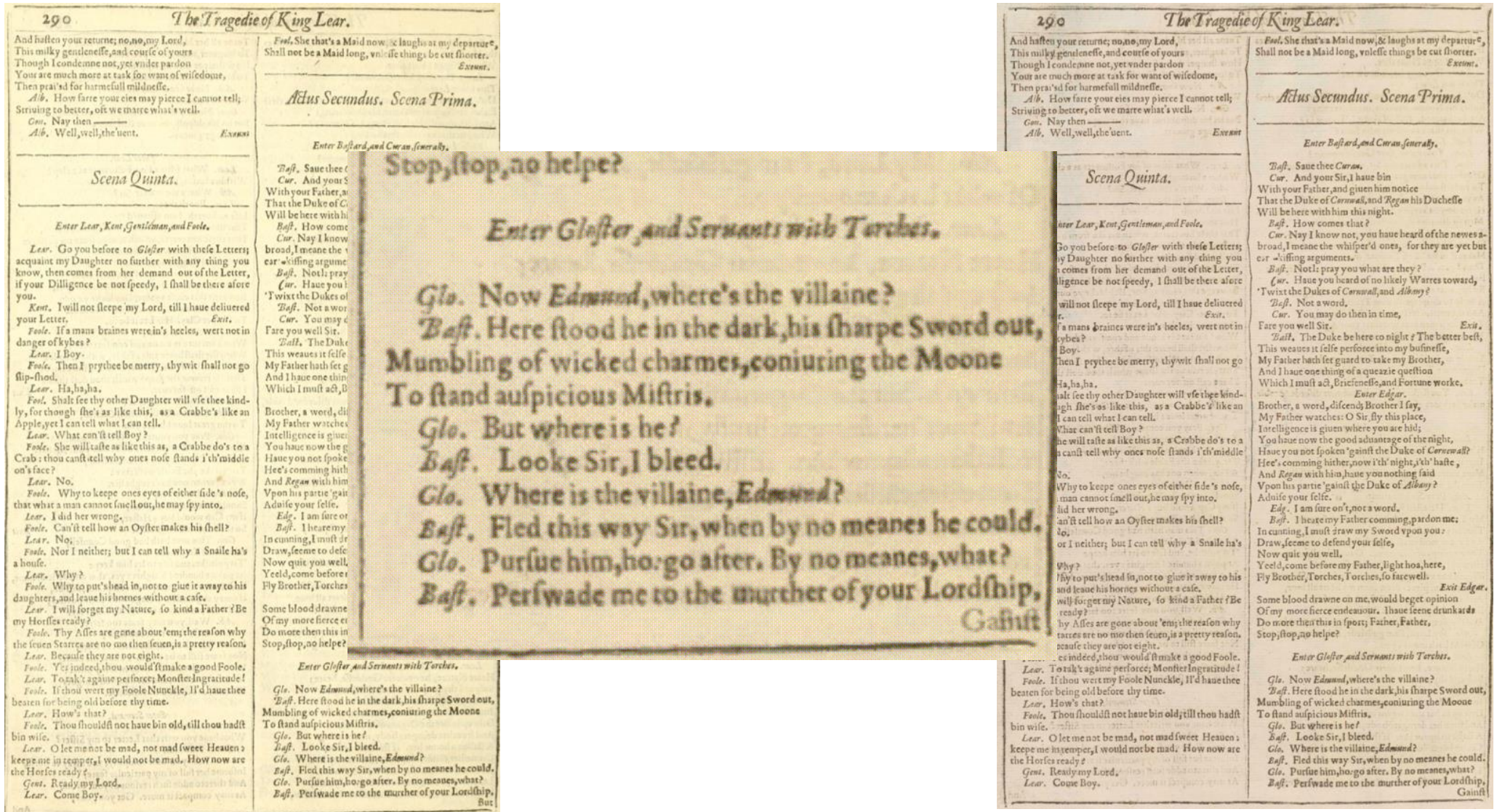
Shakespeare First Folio *Works* (1623): Bodleian and Boston Public Library copies



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Lear. Why?
Foole. Why to put's head in, not to giue it away to his daughters, and leaue his hornes without a case.
Lear. I will forget my Nature, so kind a Father? Be my Horses ready?
Foole. Thy Asses are gone about 'em; the reason why the seuen Starres are no mo then seuen, is a pretty reason.
Lear. Because they are not eight.
Foole. Yes indeed, thou would'st make a good Foole.
Lear. To take't againe perforce; Monster Ingratitude!
Foole. If thou wert my Foole Nunckle, I'd haue thee beaten for being old before thy time.
Lear. How's that?
Foole. Thou shouldst not haue bin old, till thou hadst bin wise.
Lear. O let me not be mad, not mad sweet Heauen; keepe me in temper, I would not be mad. How now are the Horses ready?
Gent. Ready my Lord.
Lear. Come Boy.

Fool. She that's a Maid now, & laughs at my departure, Shall not be a Maid long, vnlesse things be cut shorter. *Exeunt.*

Actus Secundus. Scena Prima.

Enter Bastard, and Curan, seuerally.

Bast. Saue thee *Curan.*
Cur. And your Sir, I haue bin With your Father, and giuen him notice That the Duke of *Cornwall*, and *Regan* his Duchesse Will be here with him this night.
Bast. How comes that?
Cur. Nay I know not, you haue heard of the newes abroad, I meane the whisper'd ones, for they are yet but ear-kissing arguments.
Bast. Not: pray you what are they?
Cur. Haue you heard of no likely Warres toward, 'Twixt the Dukes of *Cornwall*, and *Albany*?
Bast. Not a word.
Cur. You may do then in time, Fare you well Sir. *Exit.*
Bast. The Duke be here to night? The better best, This weaues it selfe perforce into my businesse, My Father hath set guard to take my Brother, And I haue one thing of a queazie question Which I must act, Briefenesse, and Fortune worke.

Enter Edgar.

Brother, a word, discend Brother I say, My Father watches: O Sir, fly this place, Intelligence is giuen where you are hid; You haue now the good aduantage of the night, Haue you not spoken 'gainst the Duke of *Cornewall*? Hee's comming hither, now i'th' night, i'th' haste, And *Regan* with him, haue you nothing said Vpon his partie 'gainst the Duke of *Albany*? Aduise your selfe.
Edg. I am sure on't, not a word.
Bast. I heare my Father comming, pardon me: In cunning, I must draw my Sword vpon you: Draw, seeme to defend your selfe, Now quit you well. Yeeld, come before my Father, light hoa, here, Fly Brother, Torches, Torches, so farewell.

Exit Edgar.

Some blood drawne on me, would beget opinion Of my more fierce endeauour. I haue seene drunkards Do more then this in sport; Father, Father, Stop, stop, no helpe?

Enter Gloster, and Seruants with Torches.

Glo. Now *Edmund*, where's the villaine?
Bast. Here stood he in the dark, his sharpe Sword out, Mumbling of wicked charmes, coniuring the Moone To stand auspicious Mistris.
Glo. But where is he?
Bast. Looke Sir, I bleed.
Glo. Where is the villaine, *Edmund*?
Bast. Fled this way Sir, when by no meanes he could.
Glo. Pursue him, ho: go after. By no meanes, what?
Bast. Perswade me to the murther of your Lordship,

But

Gainst

Stop, stop, no helpe?

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Registration of visual materials

Proof and published states of Robert Morison's Historia Plantarum (1680)

Ghent Altarpiece Restoration

Image Comparator wishlist

- Improved feature extraction (SIFT requires textured images)
- Improved registration of image details
- Change detection
- IIIF integration