



Additional Materials

Seminar on Image Registration
26 July 2021



TOWARDS
A NATIONAL
COLLECTION



UKRI
Arts and
Humanities
Research Council

Part of the Towards a National Collection Initiative – Practical Applications of IIF Project
PI: Joseph Padfield, The National Gallery

The National Gallery | The British Library | The University of Edinburgh | The National Portrait Gallery | Royal Botanic Garden
Edinburgh | Stanford University Libraries | Science Museum Group | Digirati | Victoria and Albert Museum | IIF Consortium



Nathan Daly
Catherine Higgitt &
Maria Melchiorre
The National Gallery

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Why?

- To create images of an entire painting if capture region is restricted
- To create high resolution composites (including focus stacking)
- To precisely align different image or data modalities
- *[Automatically identifying locations of high magnification details / Image comparison]*

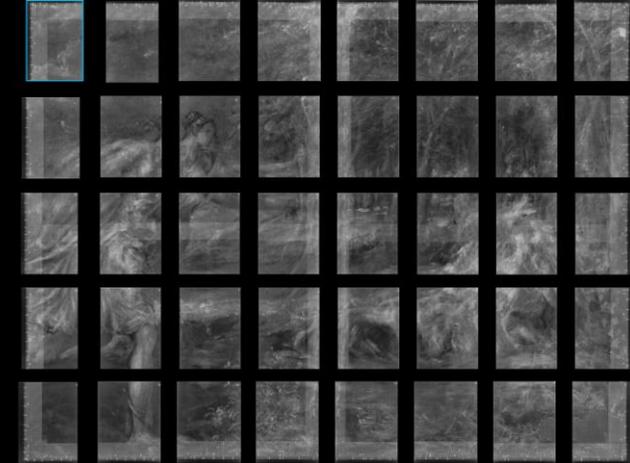


Visible – composite of 80 details shown

TITIAN, NG6420



X-ray mosaic



Scans of individual X-ray plates

Detailed study of images and spectroscopic imaging data underpins all of the Gallery's art historical, scientific and conservation work and how we understand how a painting was created, the materials used and how it has changed over time

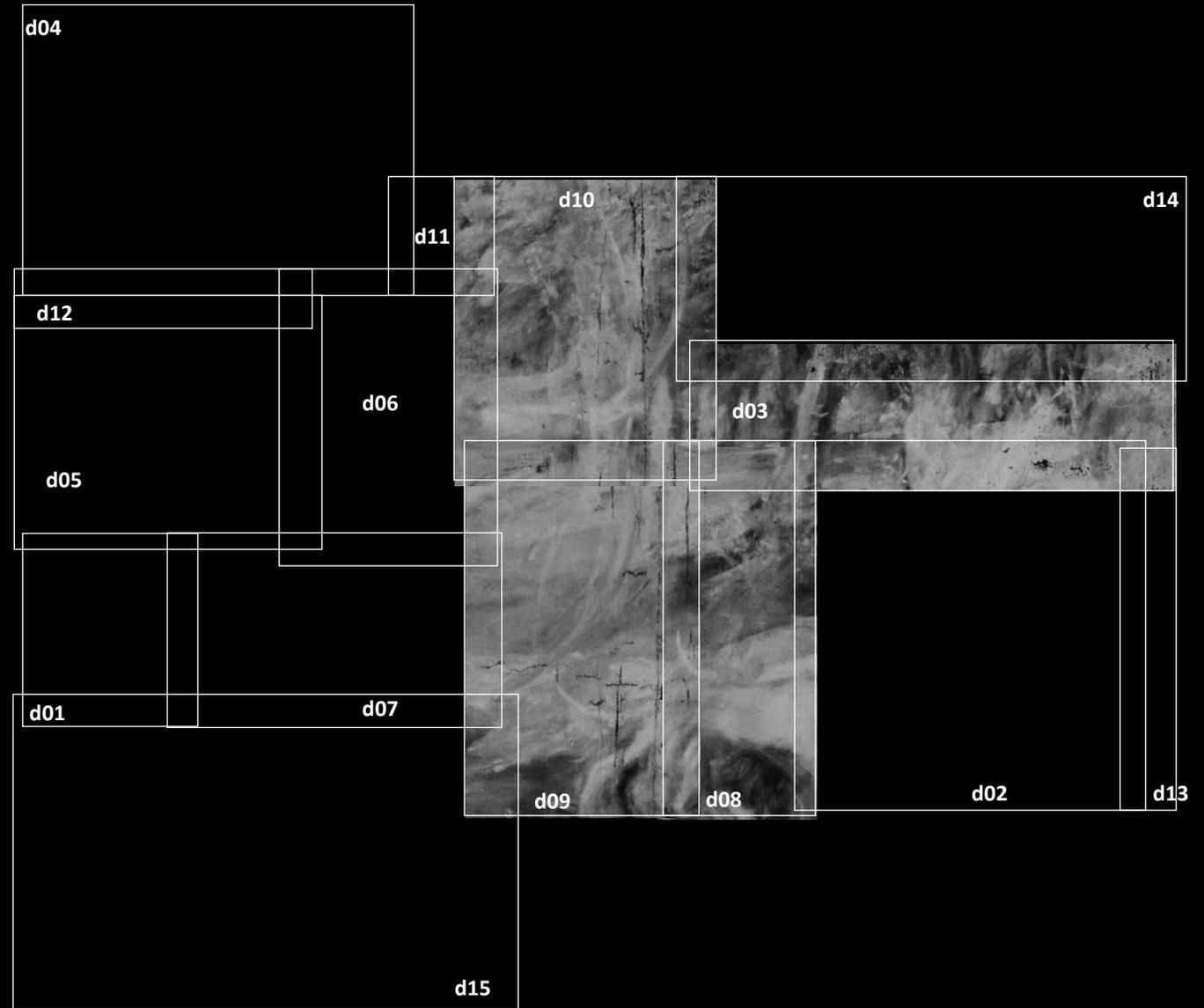
How?

Currently use various approaches depending on imaging (or spectroscopic imaging) modality involved and intended use of the resulting images (or datacubes)

All are feature-based methods and either rely on:

- piece-wise mosaicking

Issue that errors can perpetuate when done piecemeal



TITIAN, NG6420, lead XRF map

How?

Currently use various approaches depending on imaging (or spectroscopic imaging) modality involved and intended use of the resulting images (or datacubes)

All are feature-based methods and either rely on:

- piece-wise mosaicking

Or

- registering to a target image



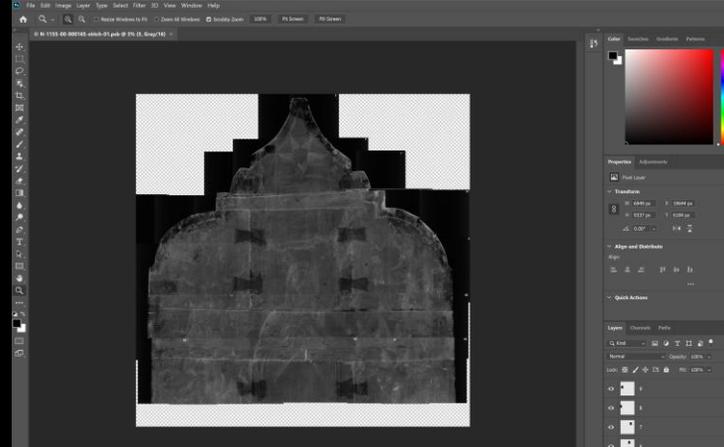
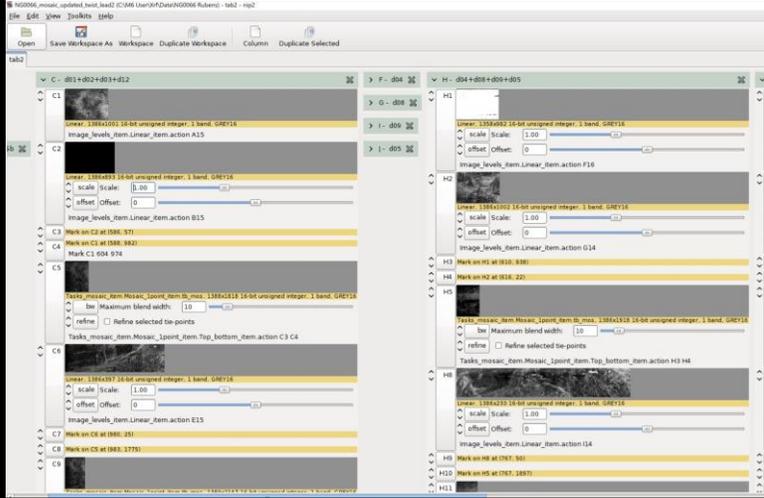
TITIAN, NG6420, lead XRF map

2D images

Manual

to

(semi)-automatic



NIP2/VIPS

- Mosaic and register
- 4 point registration
- Entirely manual, very slow and can perpetuate errors as done piecemeal
- Changes resolution of images
- Cannot currently handle data cubes

GIMP or Photoshop

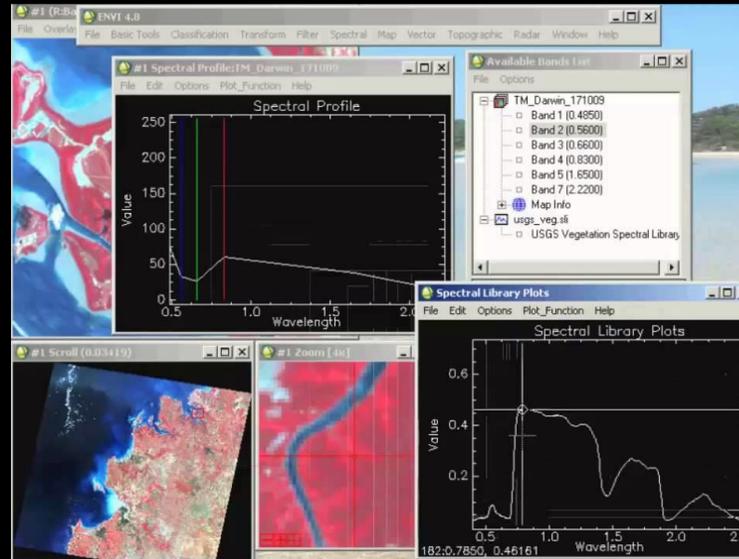
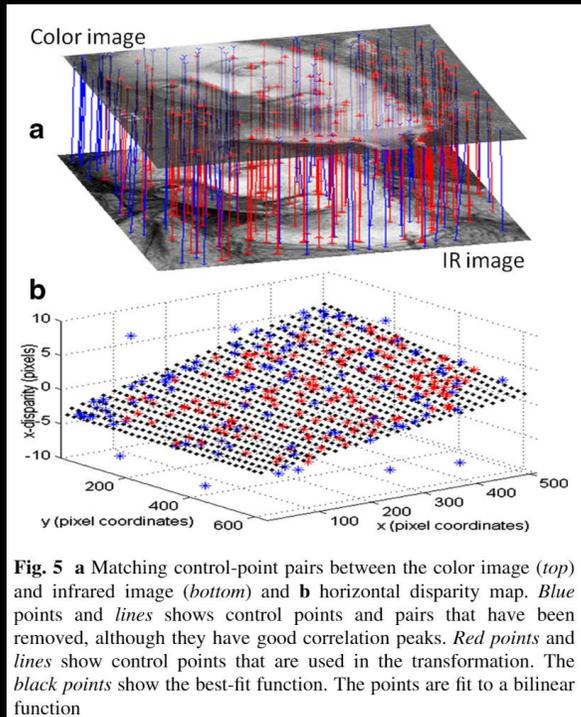
- Mosaic and register
- Entirely manual
- Often used as a pre-step before using PTGui or for rough alignment
- File size issues
- Cannot handle data cubes

PTGui

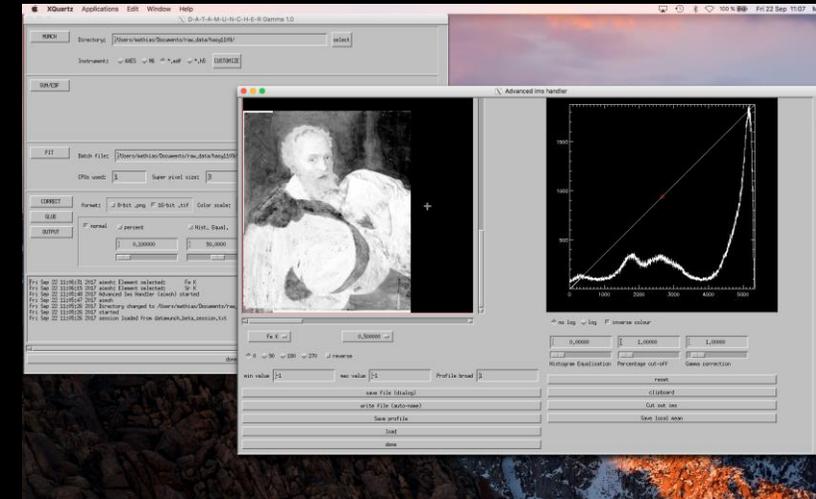
- Mosaicking only
- Really designed for panoramas
- Use approximately 300 control point to align two images (required human intervention)
- Used routinely for visible and X-ray images
- Focus stacking possible
- Cannot handle data cubes

3D datacubes / 2D images

(Semi)-automatic



L3HARRIS GEOSPATIAL



<https://sourceforge.net/projects/datamuncher/>

NGA's HSI Register tools

- Automatic but requires skill to use and suitable computer hardware
- Registers and mosaics in one step
- Can ingest, join and explore datacubes (e.g. HSI or XRF)

Art Register and X-ray Register also available for 2D images but have been less used at National Gallery, London

ENVI

- Automatic but requires skill to use and suitable computer hardware
- Mosaicking of datacubes possible
- Expensive proprietary software

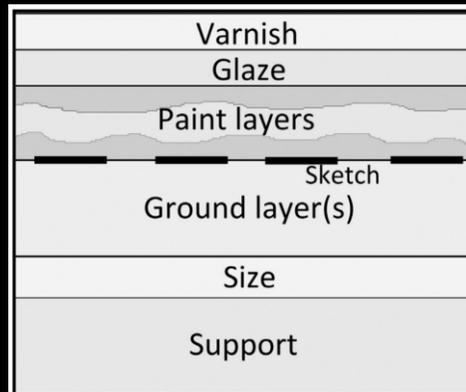
Registration of datacubes also possible but not tried at National Gallery, London

Datamuncher/PyMCA

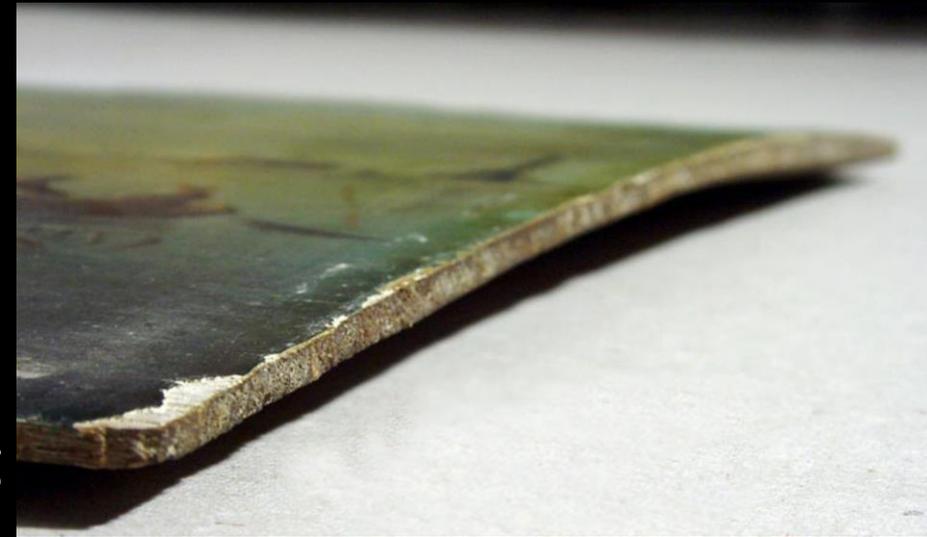
- Ingests XRF datacubes and "mosaics" so large element maps can be produced
- Not really registering at datacube level e.g. not suitable for further data processing
- Automatic but requires skill to use and suitable computer hardware

Intrinsic difficulties

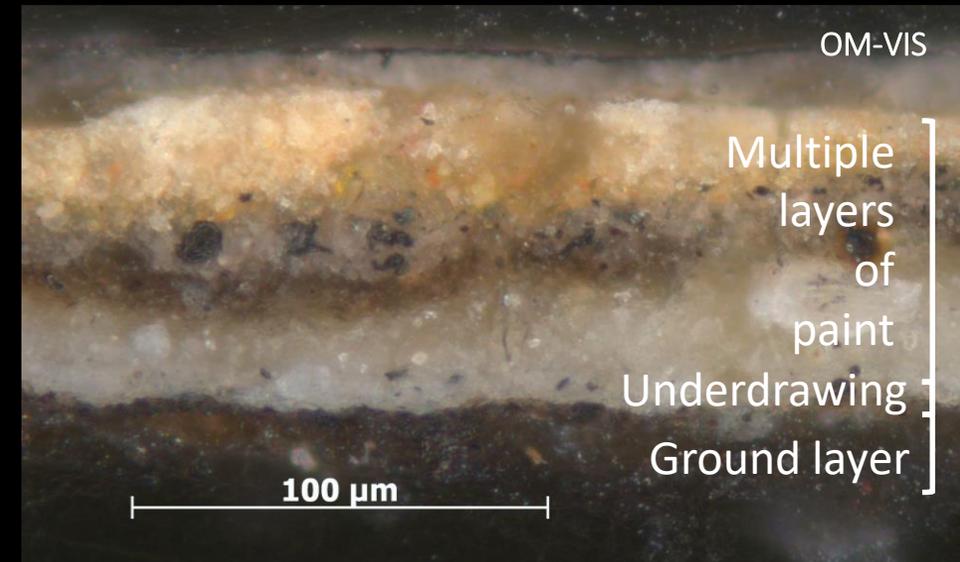
- Paintings are not flat
- Variable resolution of different imaging modalities
- Various types of distortion intrinsic to capture methods + inaccuracies in positioning of camera/painting
- Paintings are 3D objects: different features may be revealed with different imaging modalities (and at different depths) making alignment challenging
- Scale/frequency of detail needed for feature-based methods e.g. flat planes of colour



Alfeld & Broekaert, 2013
[10.1016/j.sab.2013.07.009](https://doi.org/10.1016/j.sab.2013.07.009)



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Leonardo da Vinci, *Virgin of the Rocks*, (NG1093), sample from Virgin's robe, mounted as a cross-section

Other difficulties

- How to deal with the regions of overlap?
- How to balance sub-images or sub-datatubes 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.

What does the future of image registration look like?

- Ideally able to ingest set of sub-images or datacubes and align these to a target image
 - but what resolution target is best?
- Automated but with high degree of user and ability to extract the transforms applied
 - i.e. useful to be able to look into the black-box and make choices if you wish!
 - manually roughly align and then computer refines or computer to handle whole process?
- Able to deal with really large images
- Control of how to deal with resolution variations / resolution matching
 - e.g. interpolation, super-resolution or resolution reduction, etc.
- Ability to mosaic and register datacubes for further processing/extraction of spectra etc.
- Need for range of methods for different imaging modalities and depending on desired use of resulting images/datacubes vs standardised workflows?
- Improved viewers to compare/share/display results
 - how best to store/share the large numbers of image sets generated – often with multiple annotated sets for a single painting being produced in different ways to demonstrate or record specific features?
 - how best to share/display datacubes?
 - how to record information about image or datacube processing including mosaicking/registration steps and how to associate image sets etc?



Maria Villafane

The National Gallery
& Imperial College

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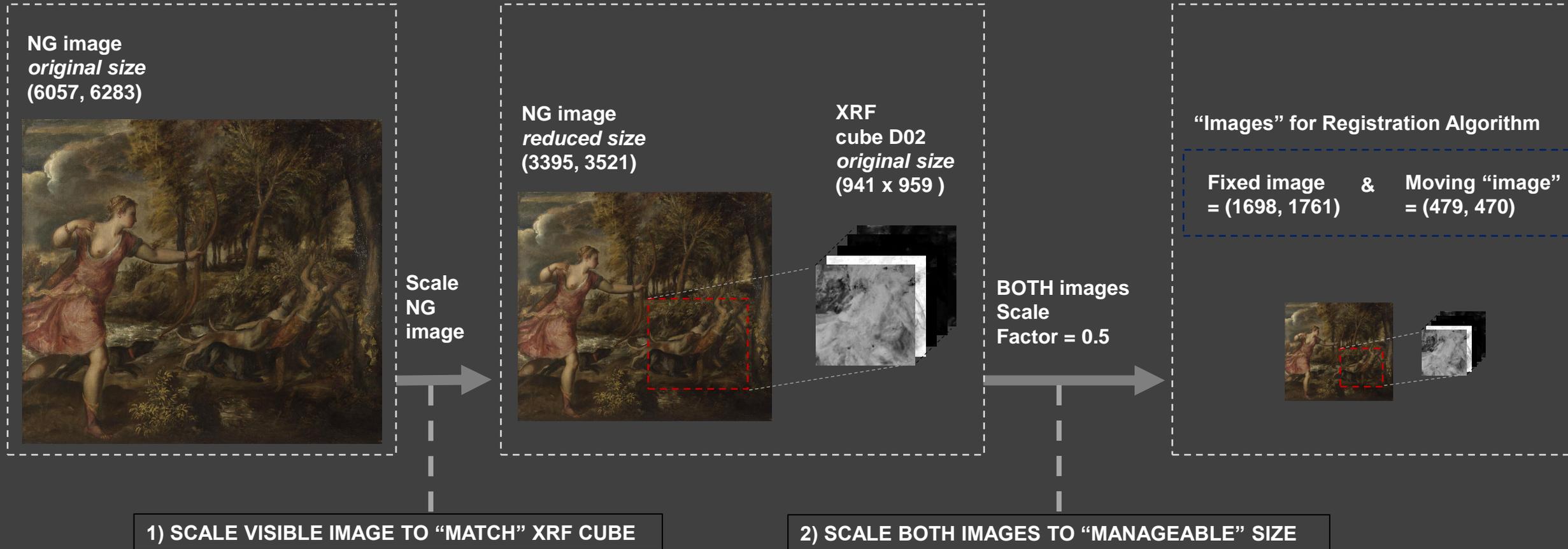
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Multimodal image registration of Old Masters Paintings

Setup images: Scale and estimated location



Multimodal image registration of Old Masters Paintings

Setup images: Scale and estimated location



Multimodal image registration of Old Masters Paintings

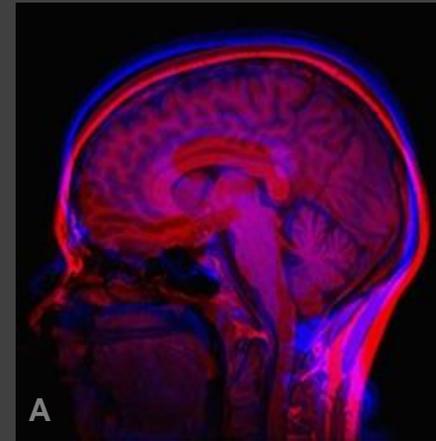
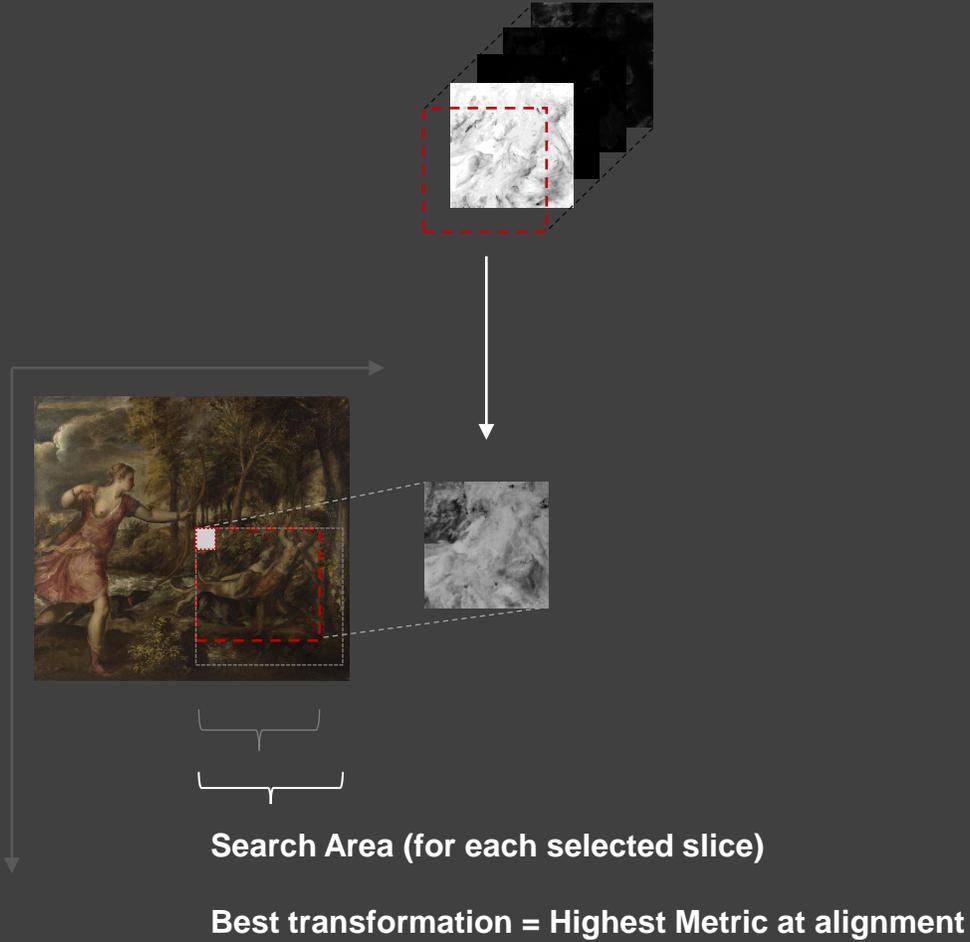
SimpleElastix Registration

SEARCH 1



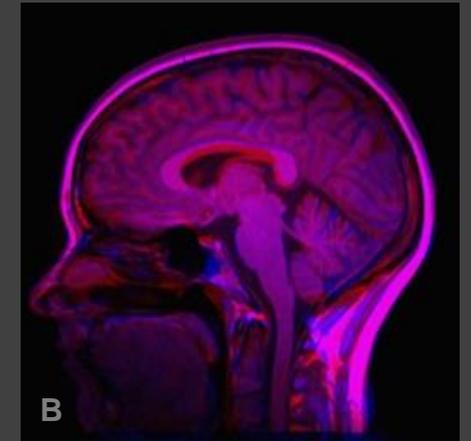
SimpleElastix Registration

SEARCH 1



Poor Alignment

↓
Low Metric



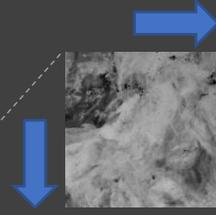
Good Alignment

↓
High Metric

Multimodal image registration of Old Masters Paintings

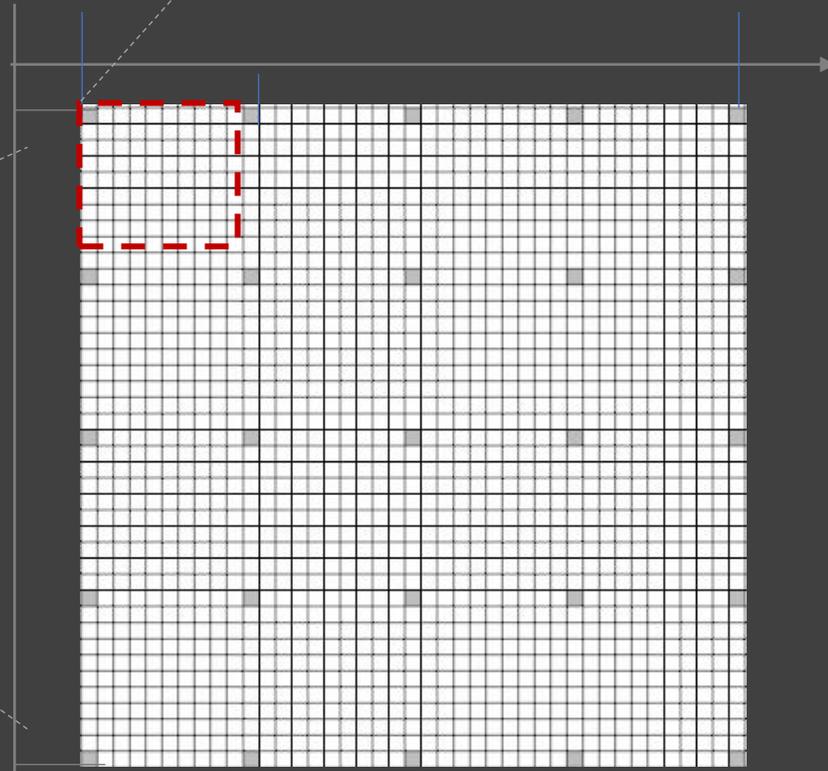
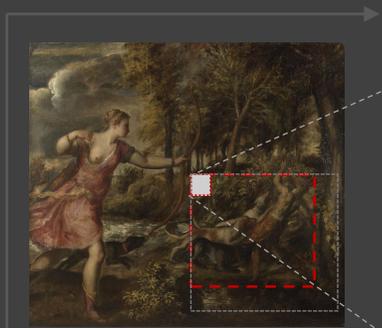
SimpleElastix Registration

SEARCH 1



Transformations to test:
Translation x,y (every 10 pixels)
rotation
scaling

4-parameter
search

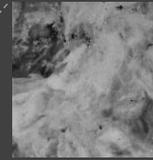


41x41
4-parameter

Multimodal image registration of Old Masters Paintings

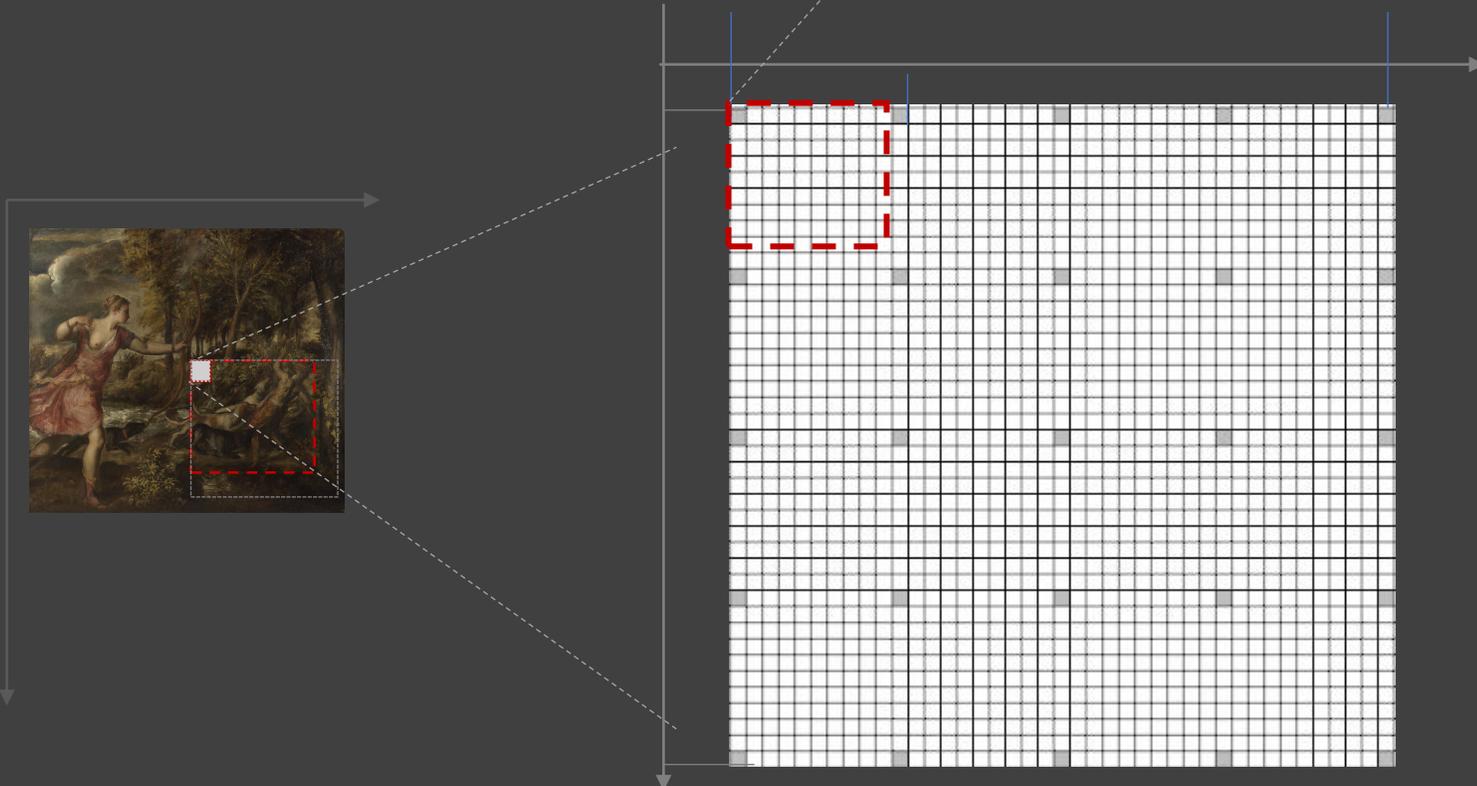
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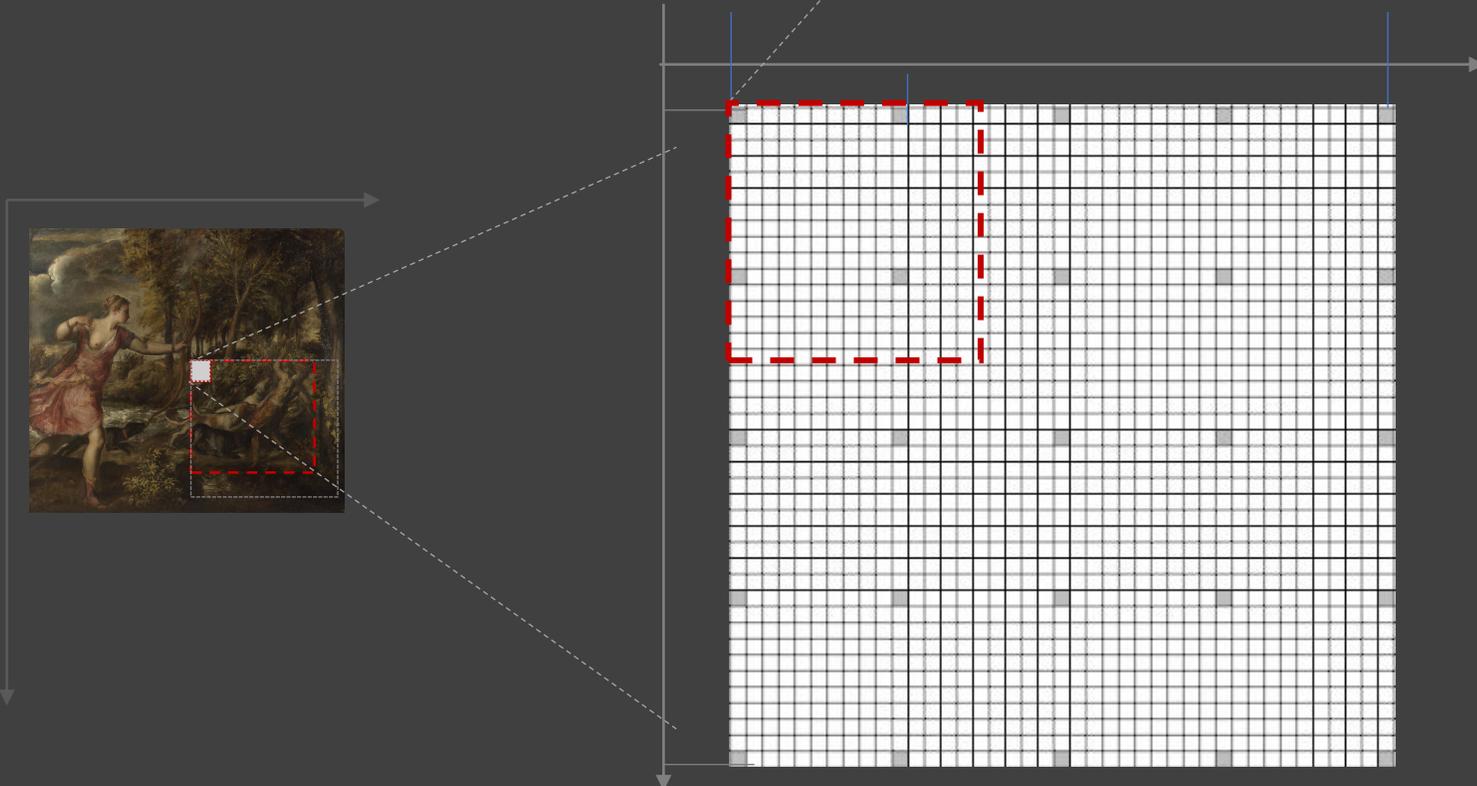
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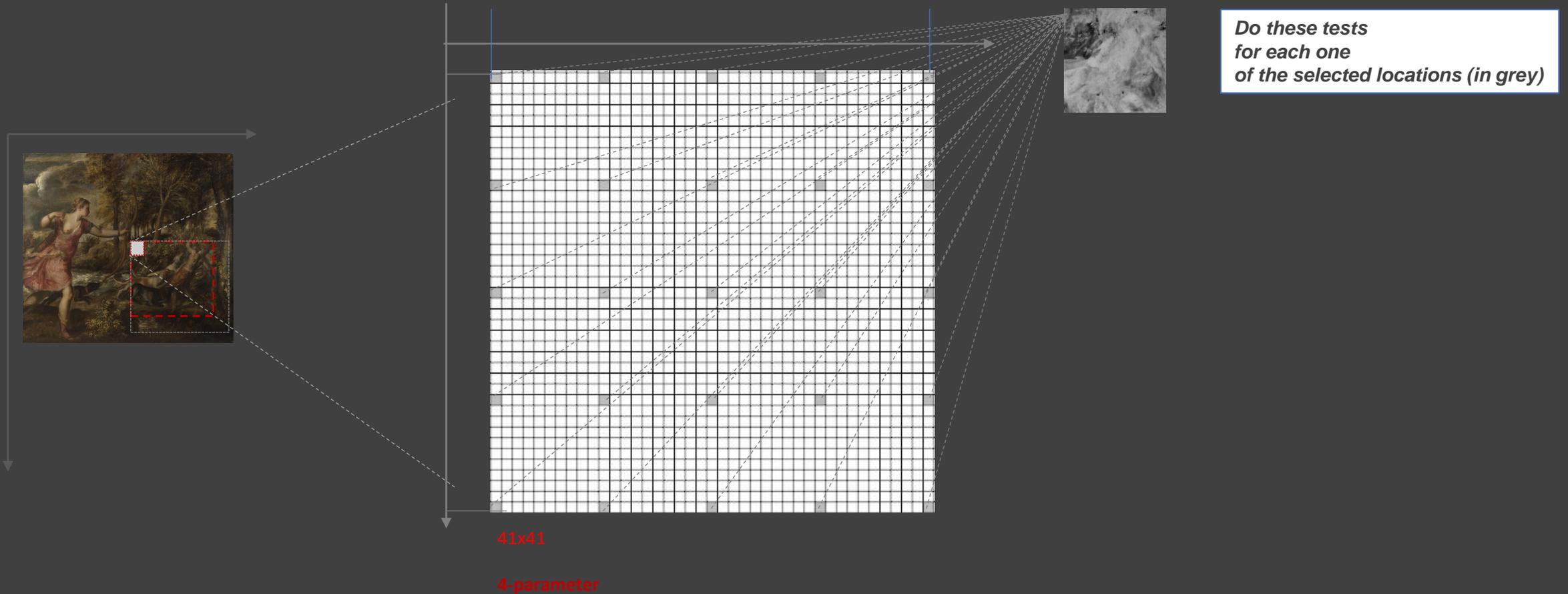
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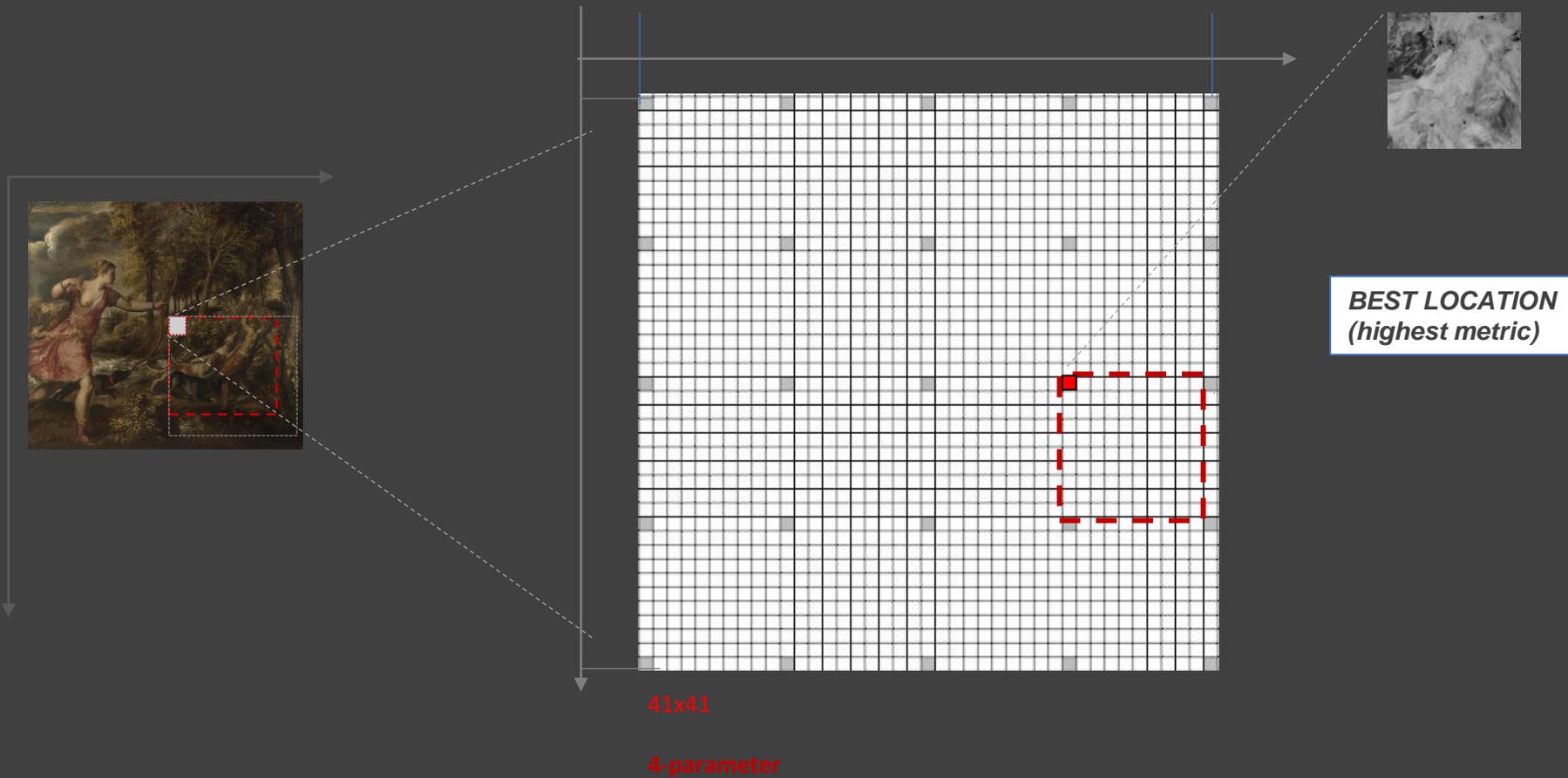
SimpleElastix Registration

SEARCH 1



SimpleElastix Registration

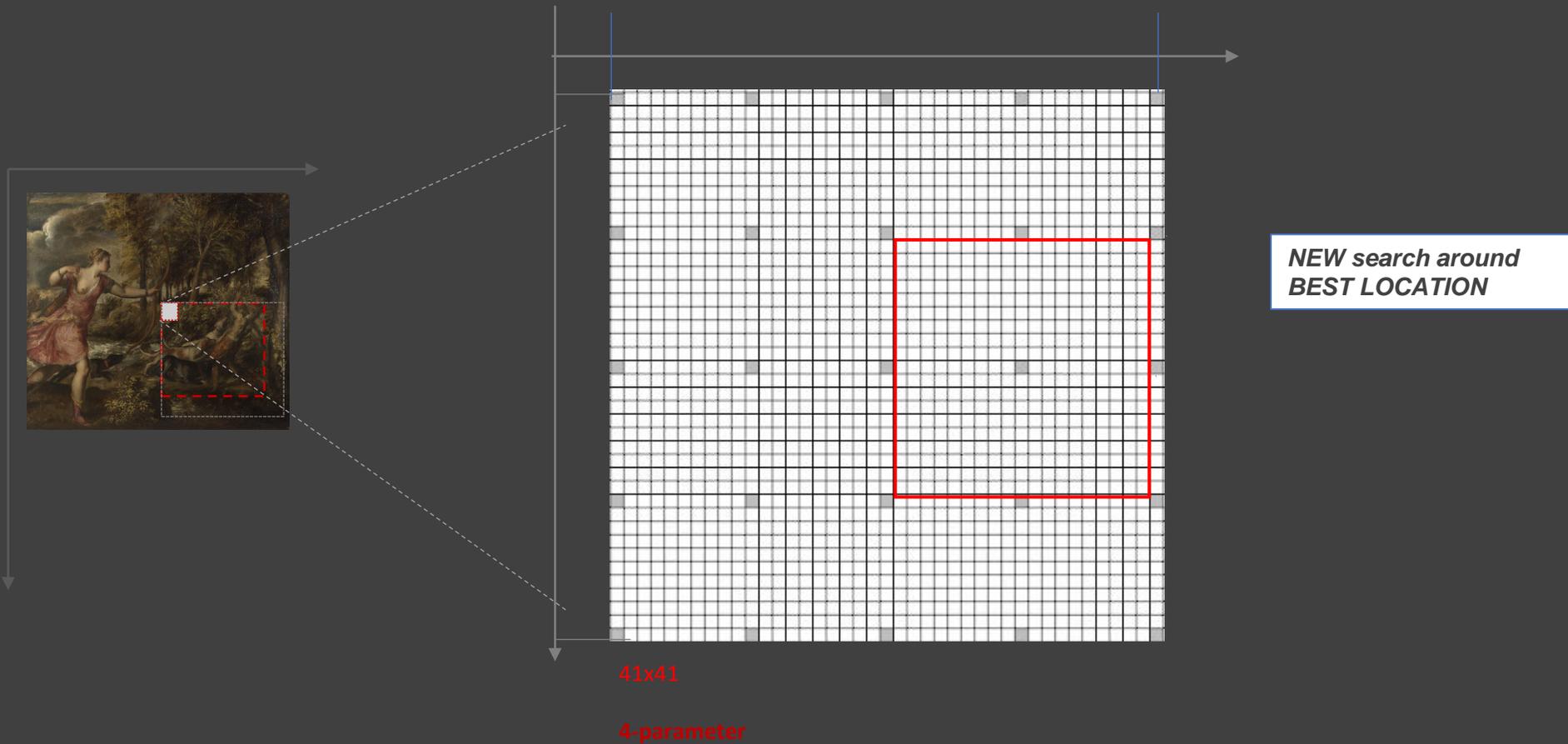
SEARCH 1



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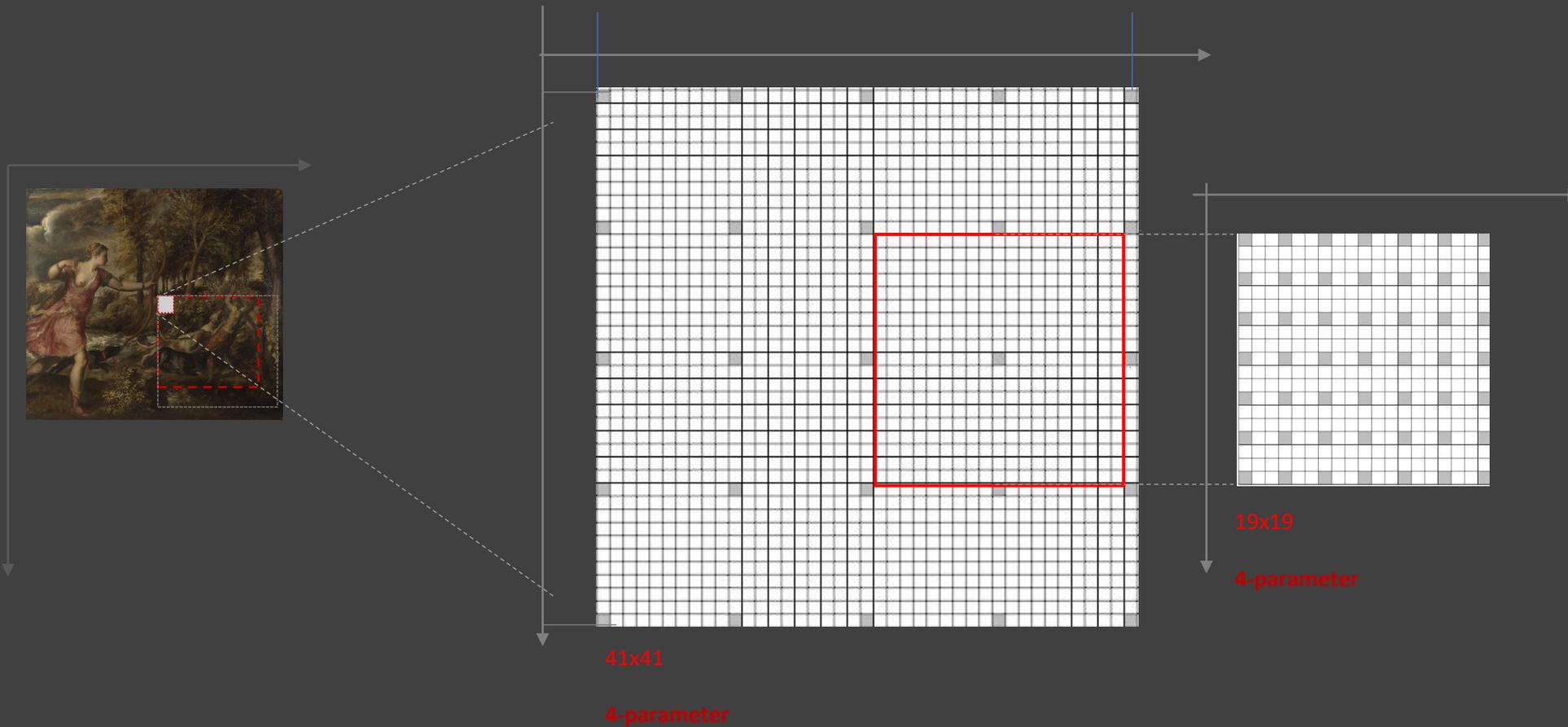
SimpleElastix Registration

SEARCH 1 => SEARCH 2



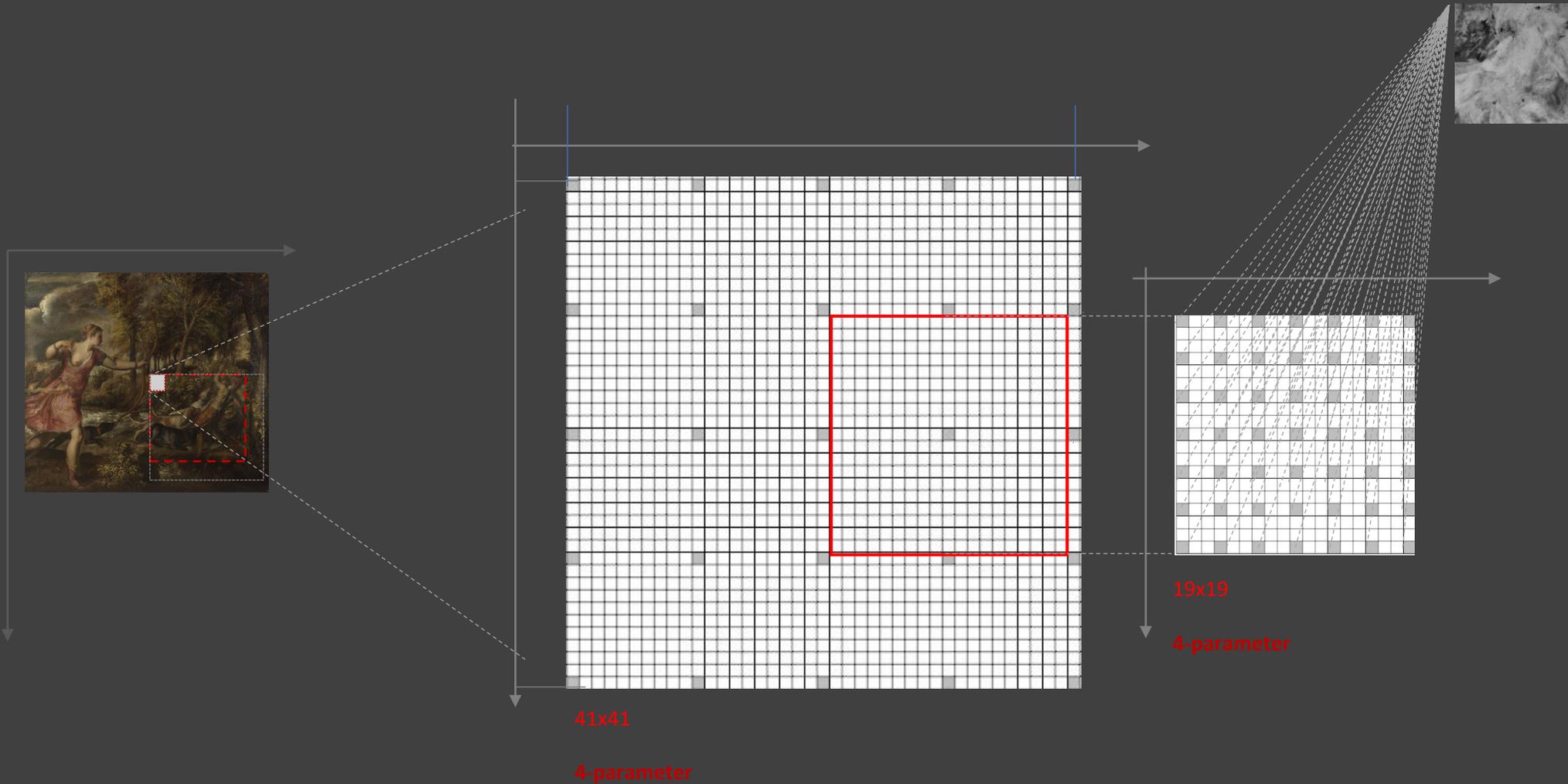
SimpleElastix Registration

SEARCH 2



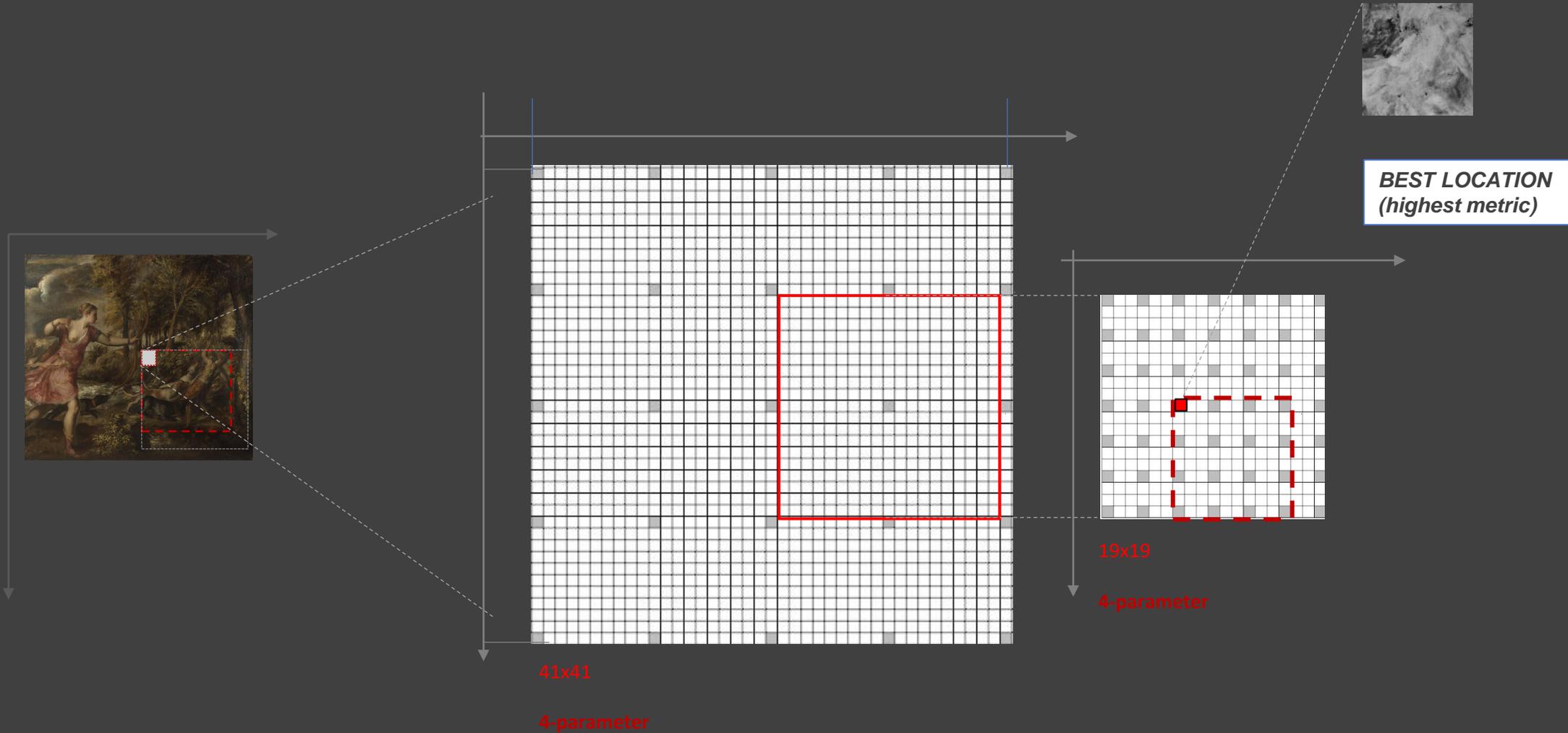
SimpleElastix Registration

SEARCH 2



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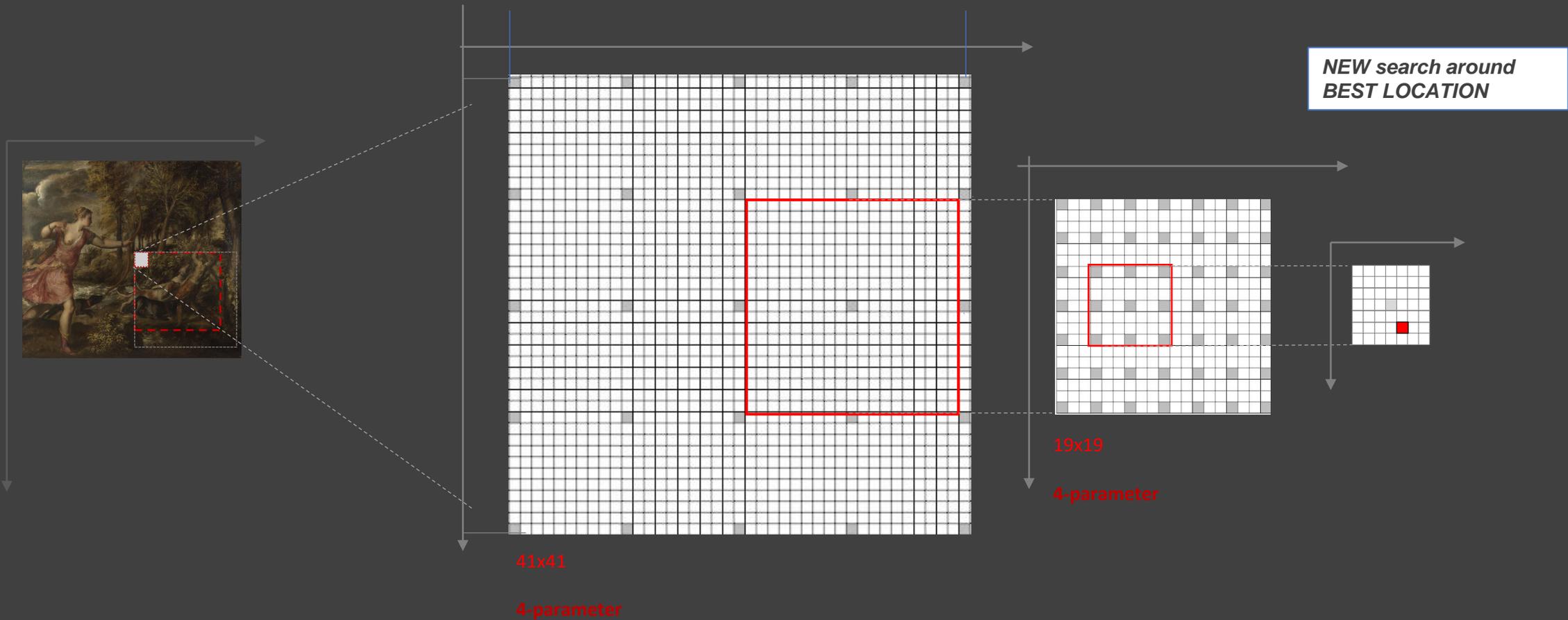
SEARCH 2



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SEARCH 2 => SEARCH 3



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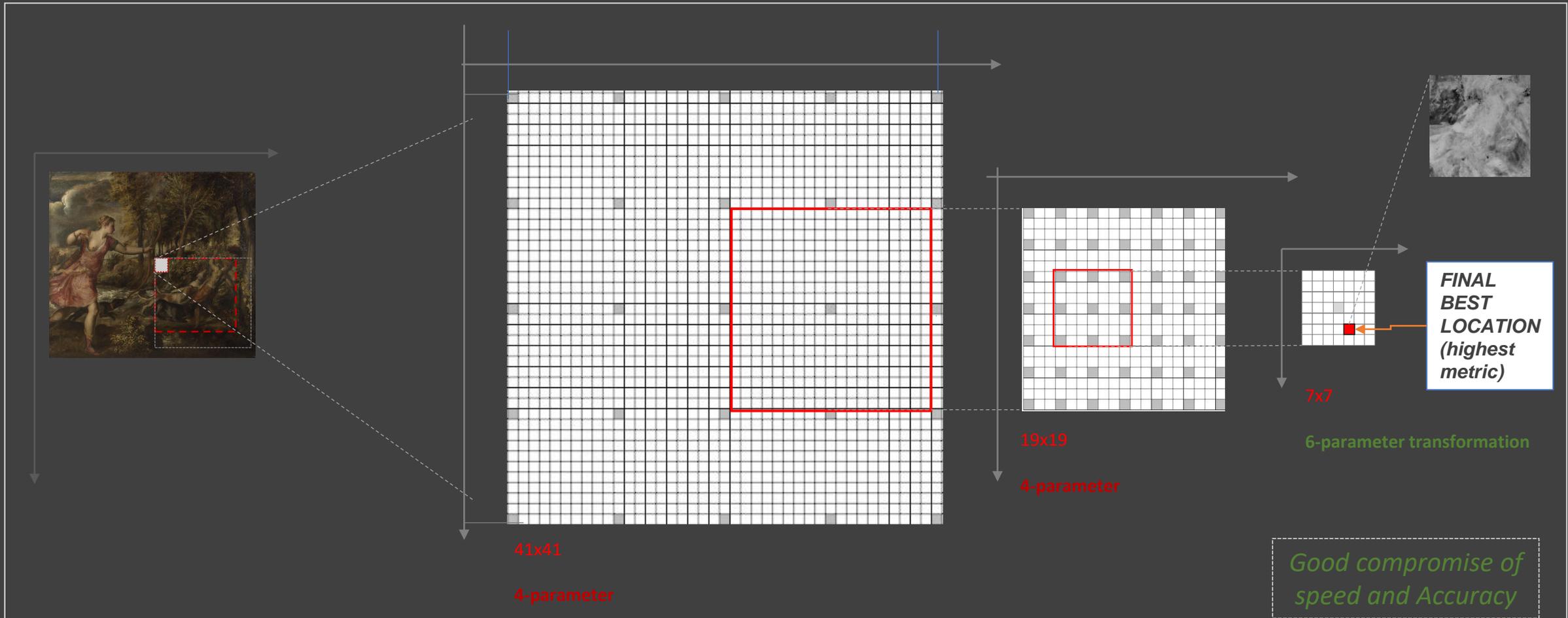
SEARCH 3

3 searches

Search # 1 - 41x41, step=10
(spacesize=> search in 5x5 locations)

Search # 2 - 19x19, step=3
(spacesize=> search in 7x7 locations)

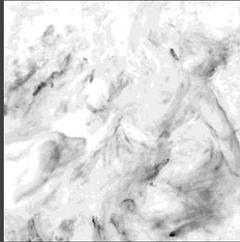
Search # 3 - 7x7, step=1
(spacesize=> search in 7x7 locations)



SimpleElastix Registration

SEARCHES → REPEAT FOR ALL DATACUBES

XRF DATACUBES TO REGISTER



d02 = 941 x 959 pixels



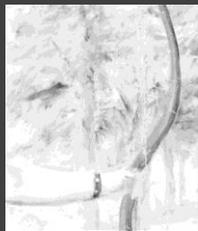
d03 = 1289 x 391 pixels



d09 = 596 x 967 pixels



d08 = 411 x 966 pixels



d10 = 710 x 832 pixels

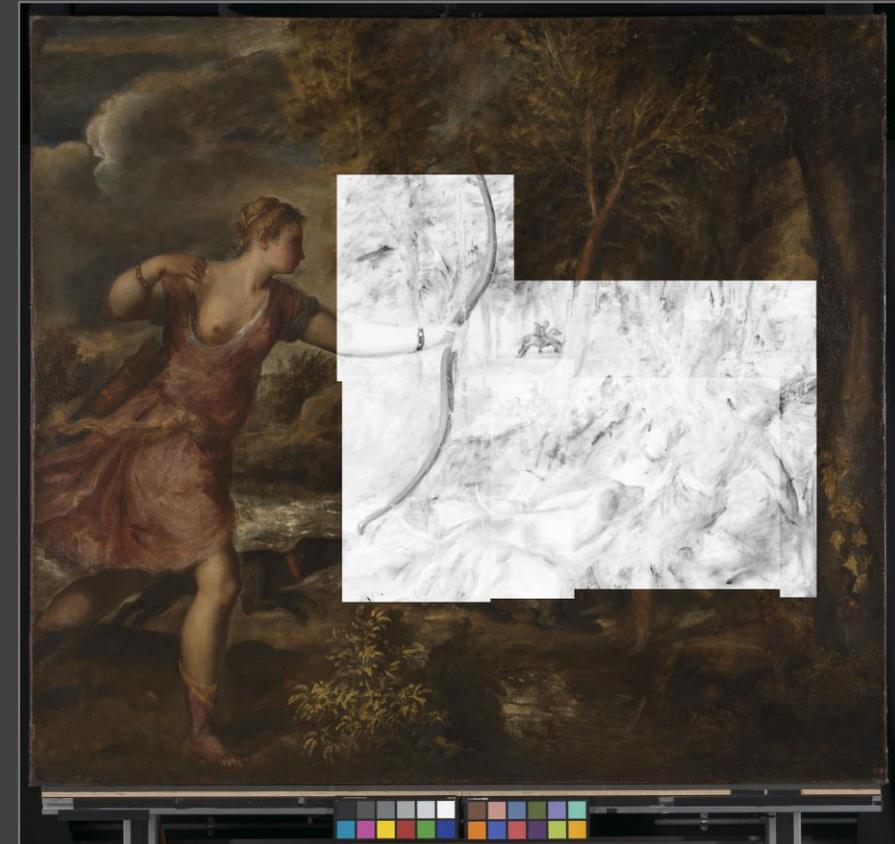


d13 = 148 x 963 pixels

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.

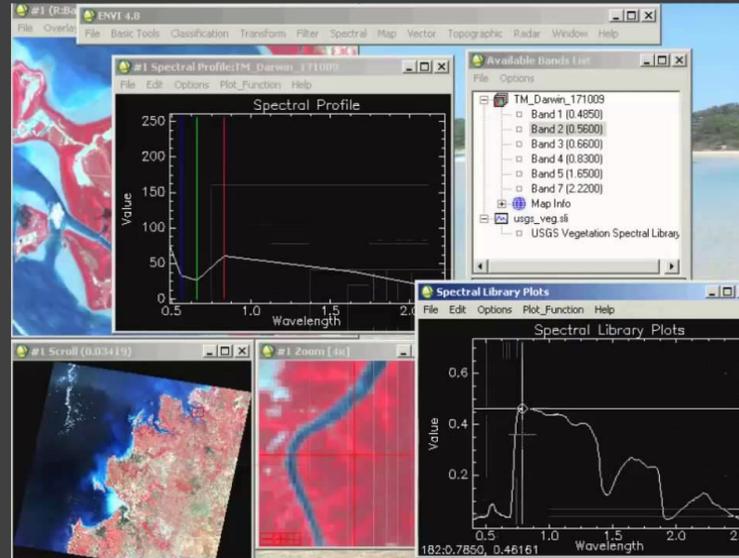
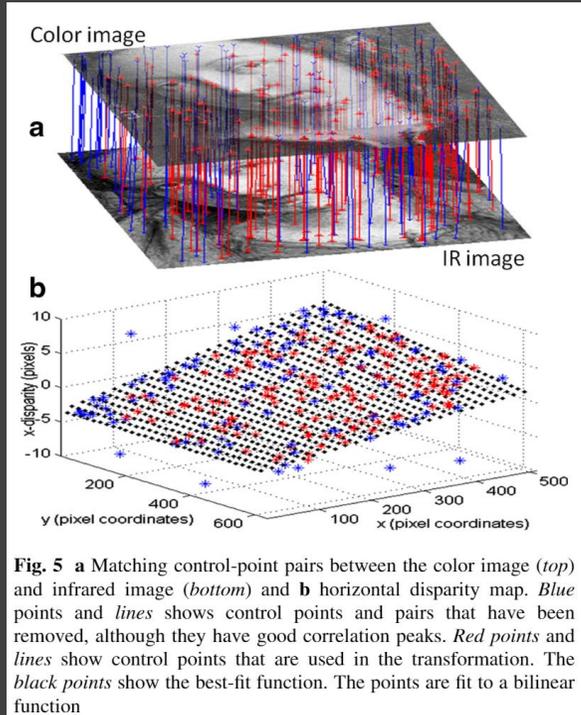
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Thank you for your attention

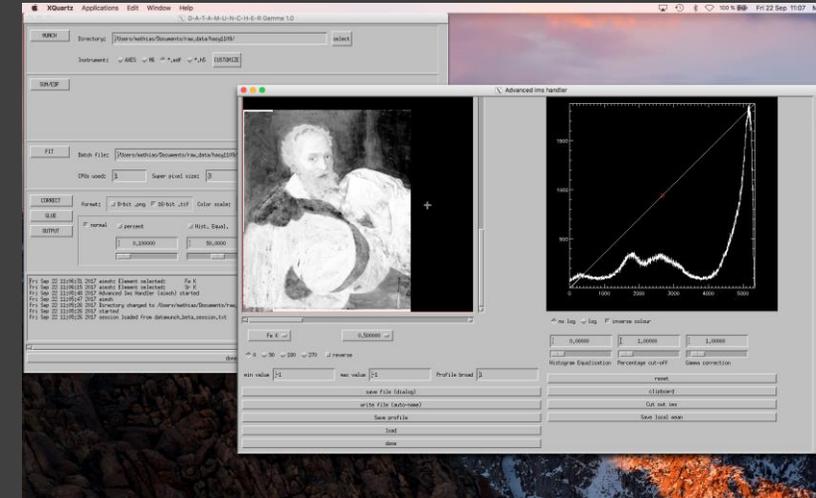
Maria Eugenia Villafane – Collaborative Doctoral Partnership PhD research project
Supervised by Prof. Pier Luigi Dragotti (Imperial College London) and Dr. Catherine Higgitt (The National Gallery)

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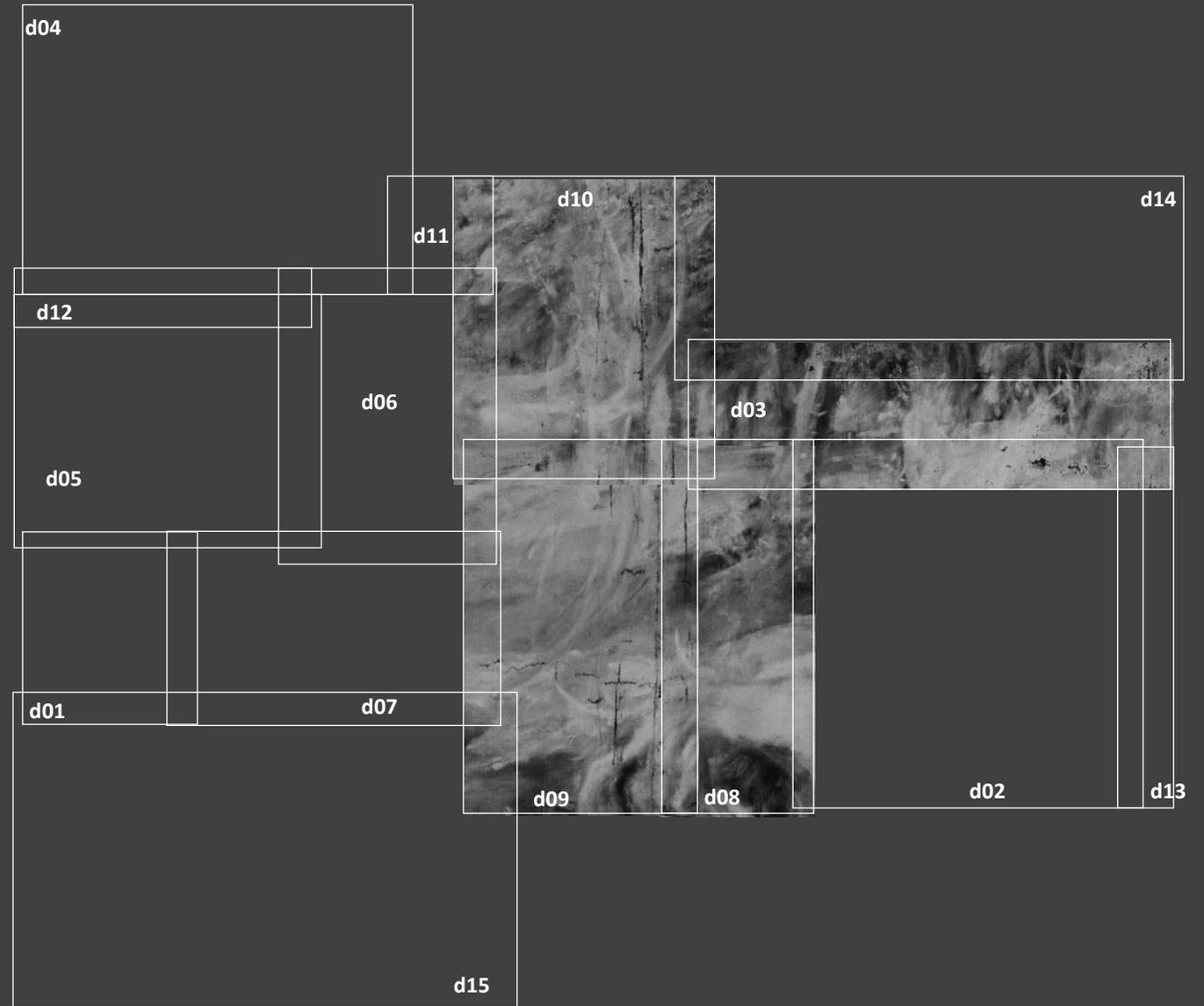
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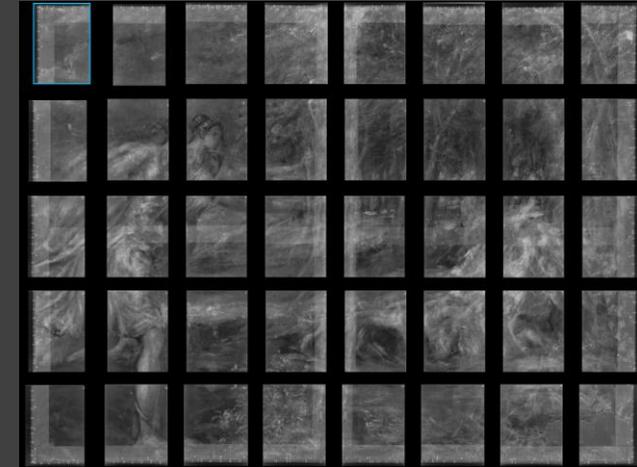


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The logo for the Victoria and Albert Museum, consisting of the letters 'V', '&', and 'A' in a large, black, serif font. The logo is positioned on the left side of the slide, partially overlapping a white circular area that is cut off by a black curved shape on the right.

V&A

Luca Carini

A Collaborative Effort: Raphael
Reassembled by Luca Carini and
Giovanni Benigni (Vatican Museums)

A Lightning Talk prepared for the 2021 IIF
Conference

<https://youtu.be/IOPZ5Gx-sH8?t=3240>