Geoinformation techniques to monitor the Urban Chameleon

Geert Verhoeven | Benjamin Wild

projectindigo.eu



The INDIGO graffiti project was funded by the Heritage Science Austria programme of the Austrian Academy of Sciences (ÖAW)



iconic

GRAFFITI
diverse creations



iconic

GRAFFITI
diverse creations



multi-faceted

GRAFFITI
diverse creations

art <> vandalism

graphical <> textual

socio-political criticism <> entertaining

legal <> illegal

tangible <> intangible



multi-faceted

GRAFFITI
diverse creations

art <> vandalism

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multi-faceted

GRAFFITI
diverse creations

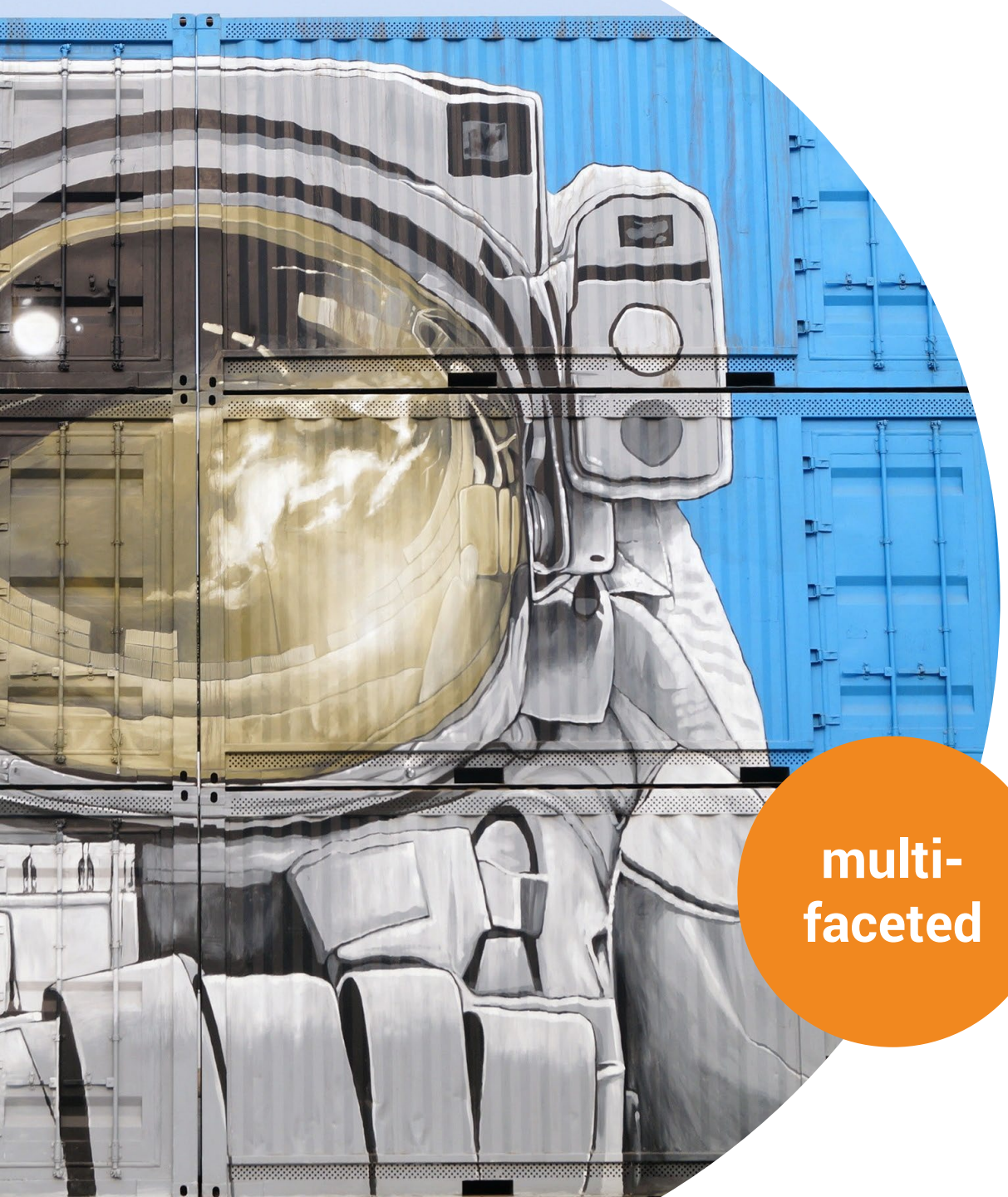
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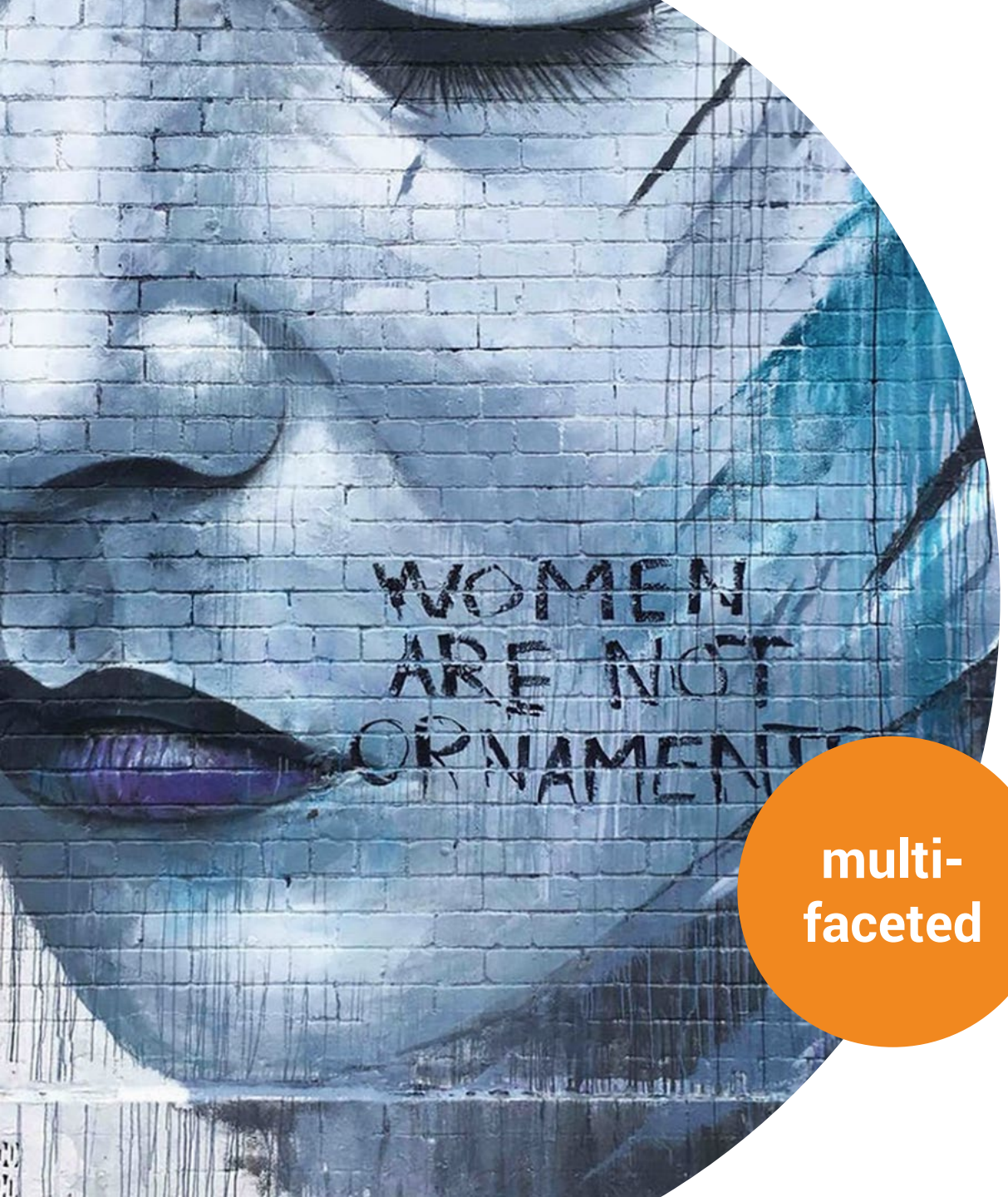
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socio-political criticism <> entertaining

legal <> illegal

tangible <> intangible



graffiti are

unique

complex

short-lived

socially relevant

cultural heritage












KOOER



NEEDING
academic rigour

“For as long as we are imprecise about the artworks we are discussing, our research will be rightfully seen as lacking scholarly rigor.“

de la Iglesia 2015





RECORDING

random

partial

inaccurate

NEEDING
academic rigour

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de la Iglesia 2015





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DISSEMINATION

unstandardised

limited interaction

closed access

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DISSEMINATION

unstandardised

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ANALYSIS

descriptive

fragmentary

biased



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de la Iglesia 2015



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inaccurate

DISSEMINATION

unstandardised

limited interaction

closed access

ANALYSIS

descriptive

fragmentary

biased

SYNERGY

one-sided

partial know-how

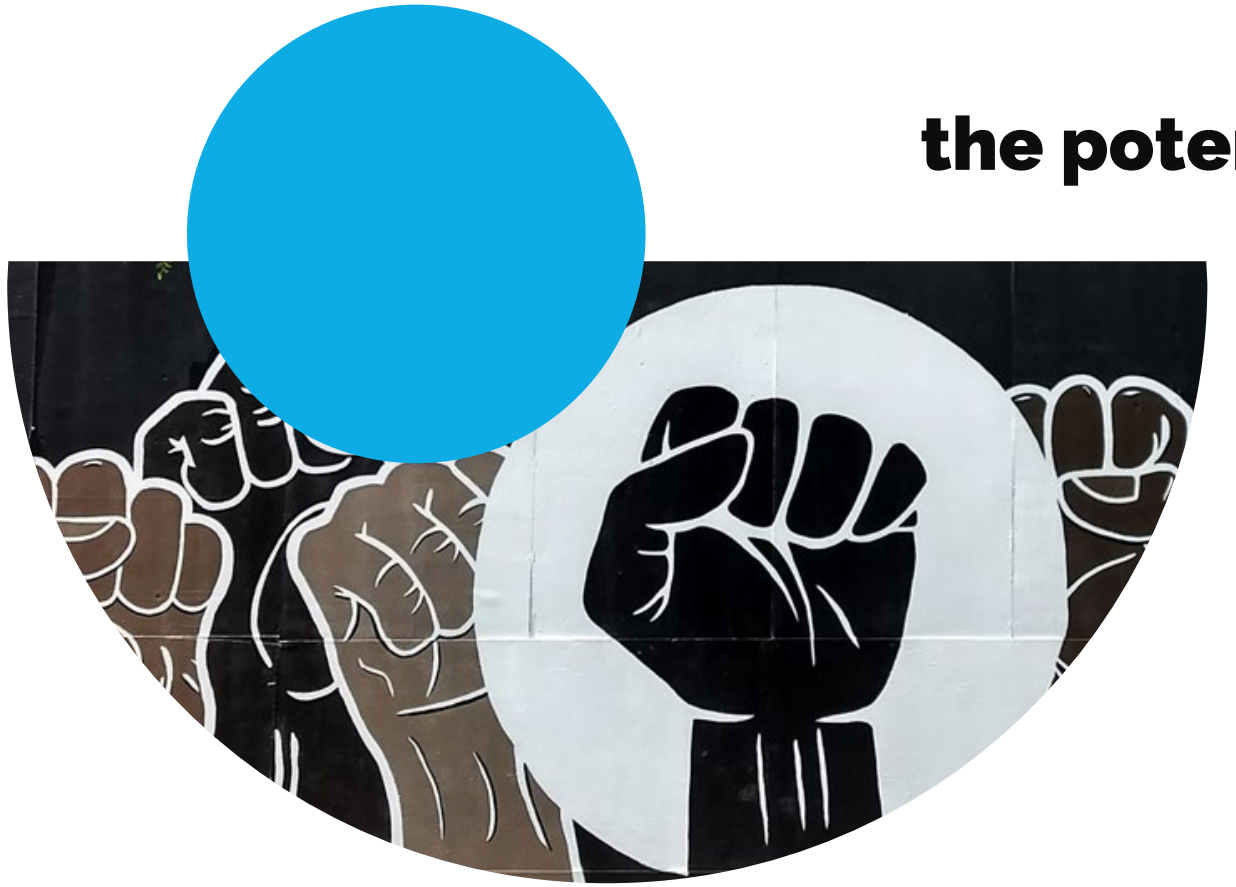
limited output



NEEDING
academic rigour

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de la Iglesia 2015



the potential
of graffiti
to understand
society
is under-exploited

indigo

Inventory and

disseminate

graffiti along the

d**o**naukanal

Inventory and

disseminate

graffiti along the

d**o**naukanal

WHAT

Inventory and

disseminate

graffiti along the

d**o**naukanal

WHAT

WHERE

inventory and

disseminate

graffiti along the

d**o**naukanal

WHAT

WHERE

WHY

digitally preserve

and

analyse

INventory and

DIsseminate

9raffiti along the

d**O**naukanal

WHAT

WHERE

WHY

digitally preserve

and

analyse

ÖAW dch

Universitat Politècnica de València

GiFLE

TU WIEN GEO

vr|vis

Stadt Wien

SPRAY CITY.AT

LUDWIG BOLTZMANN INSTITUTE
Archaeological Prospection and Virtual Archaeology

WHO

INventory and

DIsseminate

Graffiti along the

d**O**naukanal

WHAT

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TU WIEN

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virvis

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SPRAY CITY.AT

Heritage Science Austria programme | **€ 580 k** | **2** years

WHY

Inventory and

disseminate

graffiti along the

donaukanal

WHAT

digitally preserve and analyse

? HOW ?

WHERE

ÖAW

GiFLE

TU WIEN GEO

vrvis

Stadt Wien

SPRAY CITY AT

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WHO

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INDIGO approach

5 research pillars

INDIGO approach

5 research pillars

creation



INDIGO approach

5 research pillars

creation



acquisition



INDIGO approach

5 research pillars

creation



acquisition



processing



INDIGO approach

5 research pillars

creation



acquisition



processing

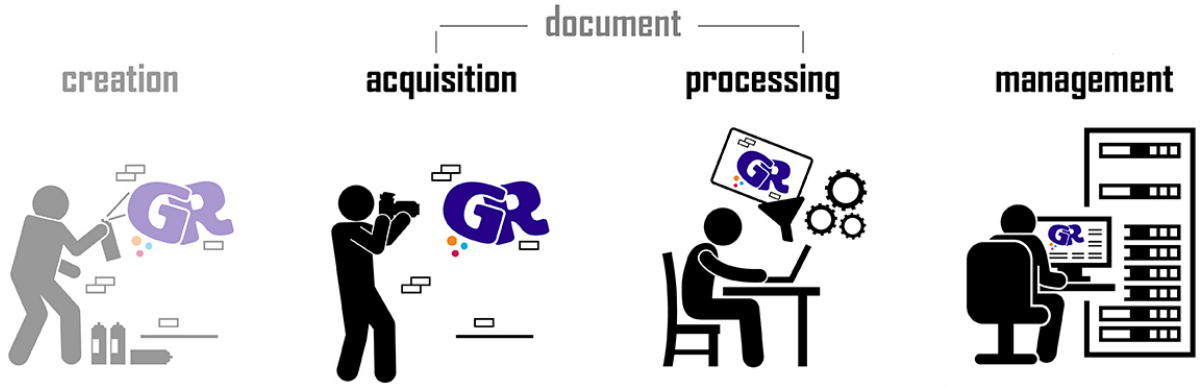


management



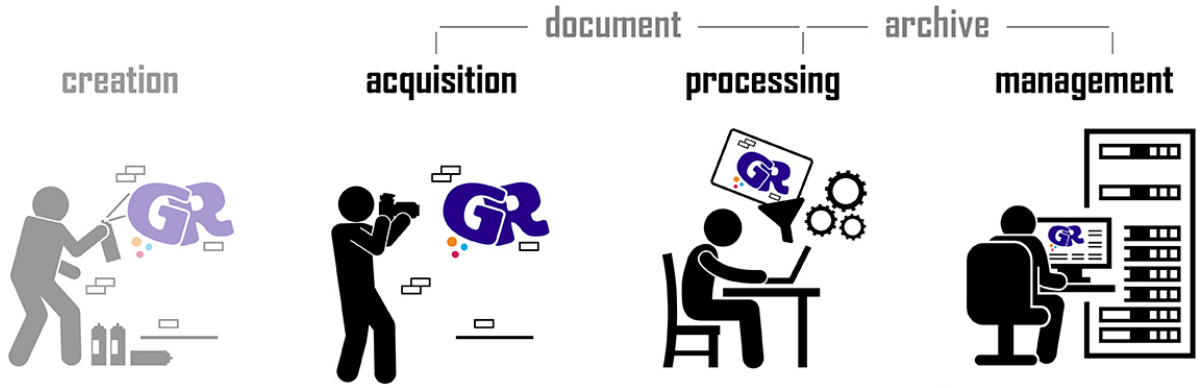
INDIGO approach

5 research pillars



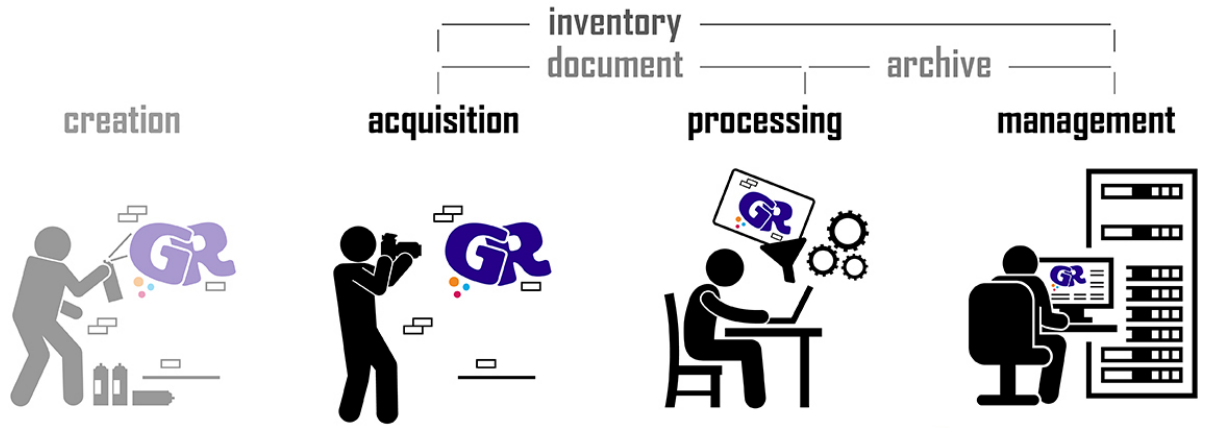
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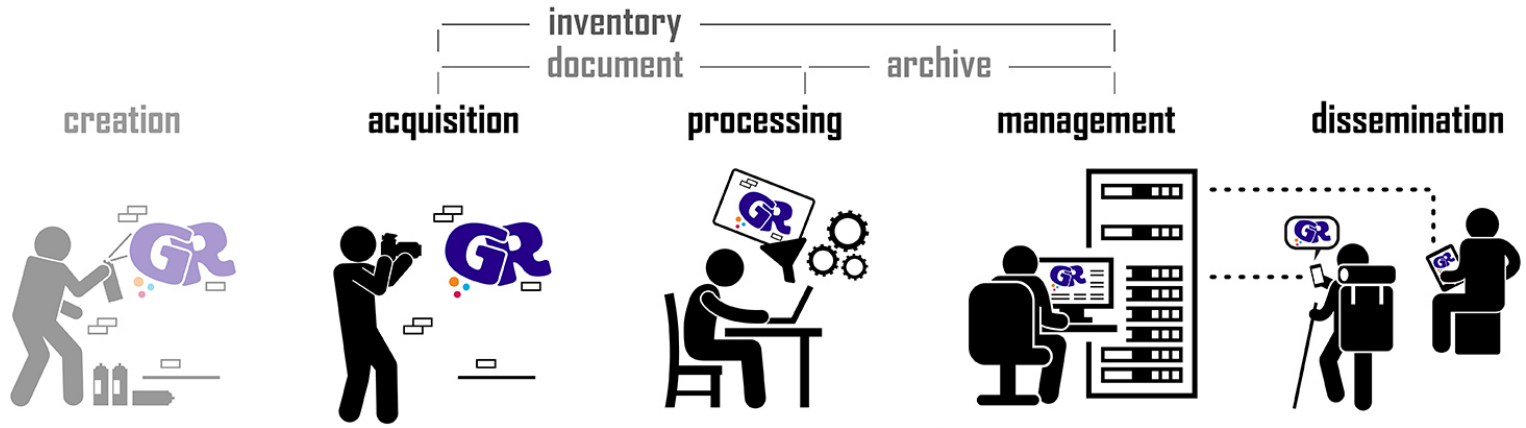
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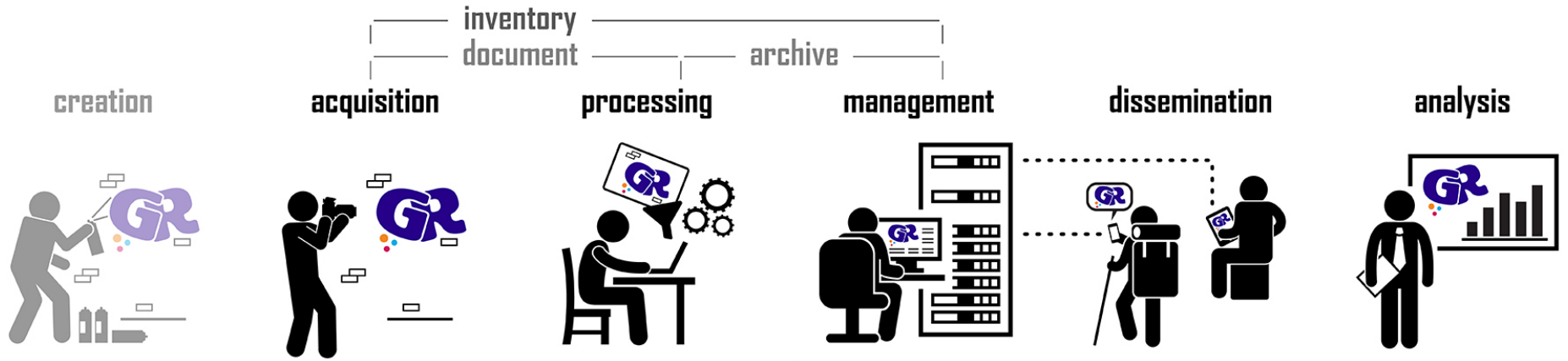
INDIGO approach

5 research pillars



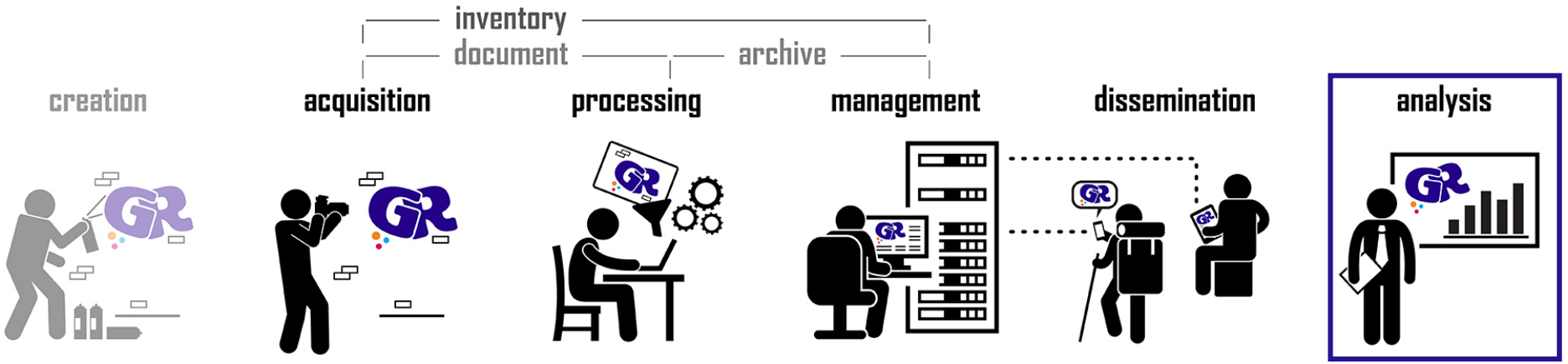
INDIGO approach

5 research pillars



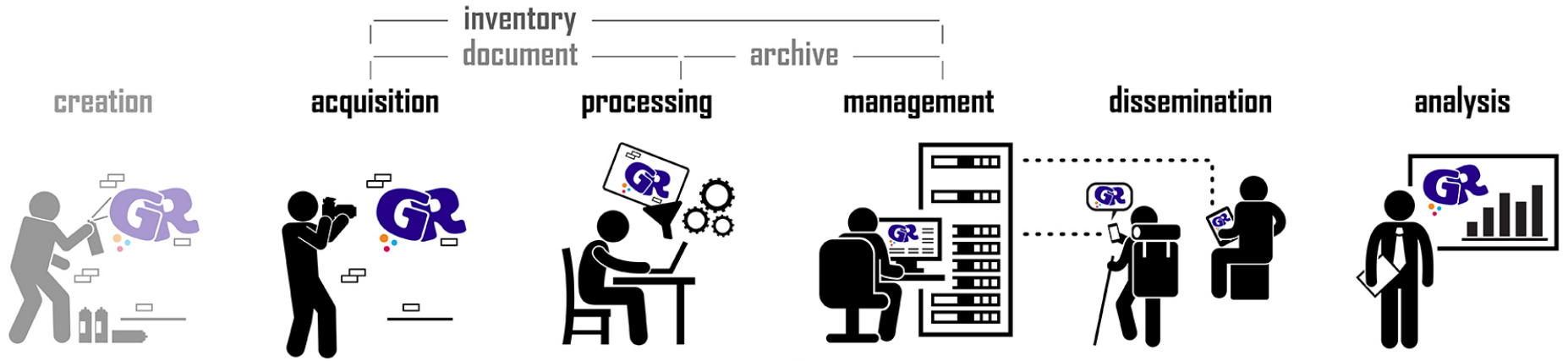
POTENTIAL questions

5 research pillars



POTENTIAL questions

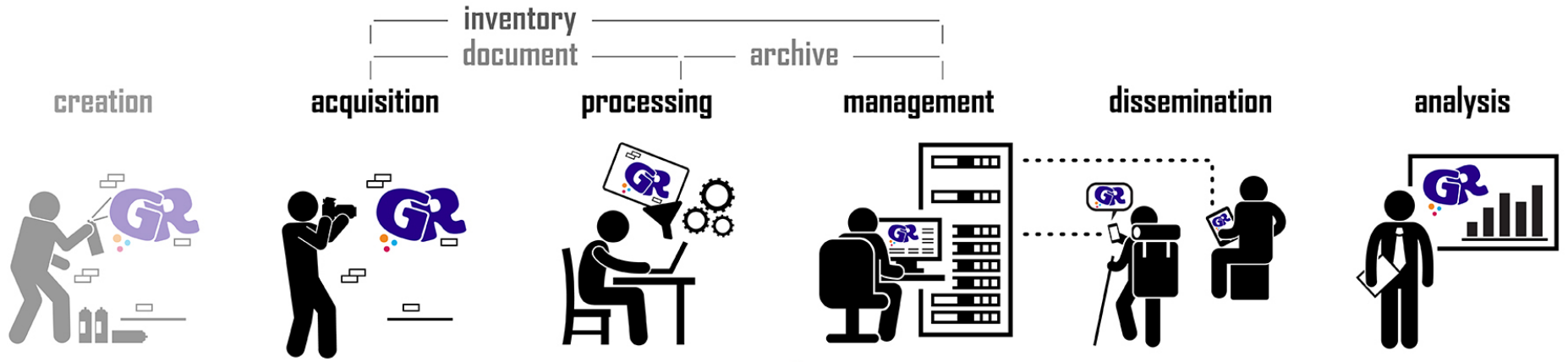
5 research pillars



When and where do political graffiti typically appear ?

POTENTIAL questions

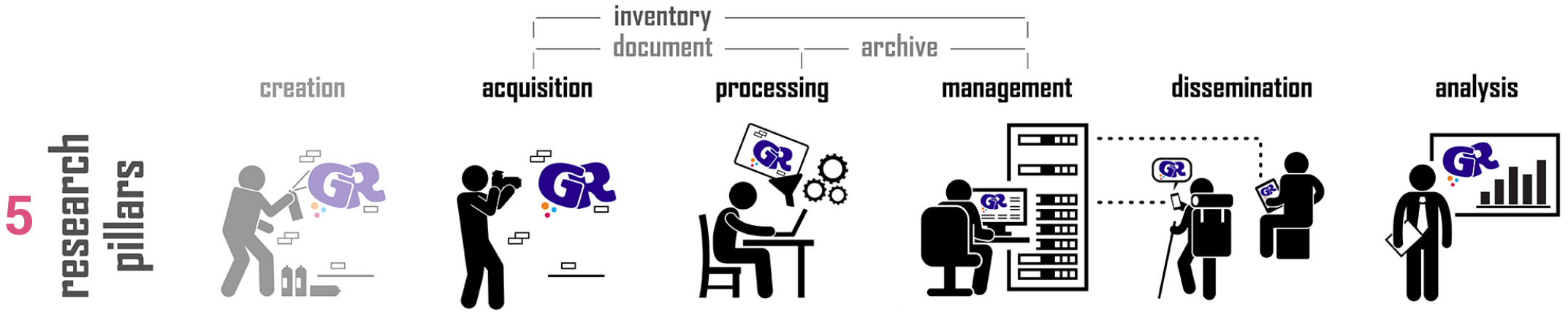
5 research pillars



When and where do political graffiti typically appear ?

What are the main styles and colours of those graffiti, and how long do they – on average – stay visible before they are (partly or entirely) covered ?

POTENTIAL questions



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What type of graffito commonly covers political messages ?

POTENTIAL questions

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GRAFFITI *TEMPORALITY*

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GRAFFITI *TEMPORALITY*

GRAFFITI *TERMINOLOGY*

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GRAFFITI *LOCATION*
GRAFFITI *TEMPORALITY*
GRAFFITI *TERMINOLOGY*
GRAFFITI *CHARACTERISATION*

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GRAFFITI archaeology

GRAFFITI *LOCATION*
GRAFFITI *TEMPORALITY*
GRAFFITI *TERMINOLOGY*
GRAFFITI *CHARACTERISATION*

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GRAFFITI archaeology

ARTEFACT

LOCATION
TEMPORALITY
TERMINOLOGY
CHARACTERISATION

When and where do political graffiti typically appear ?

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SOME results

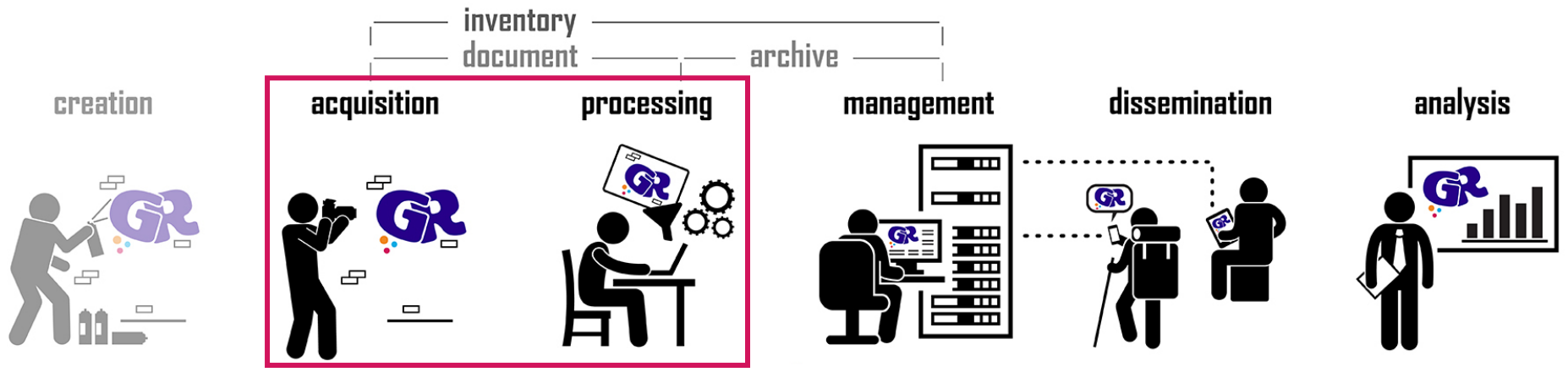
GRAFFITI *LOCATION*

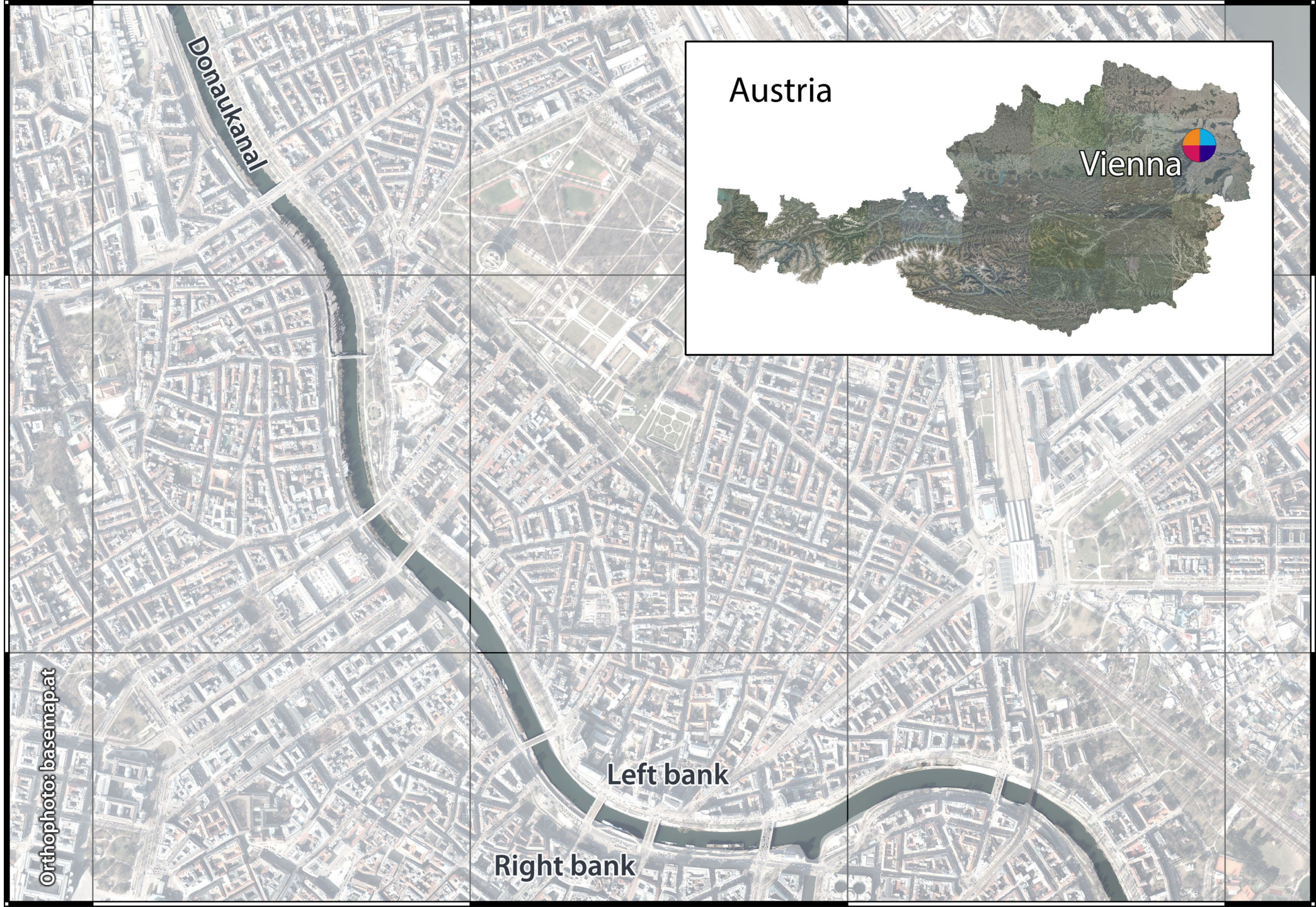
GRAFFITI *TEMPORALITY*

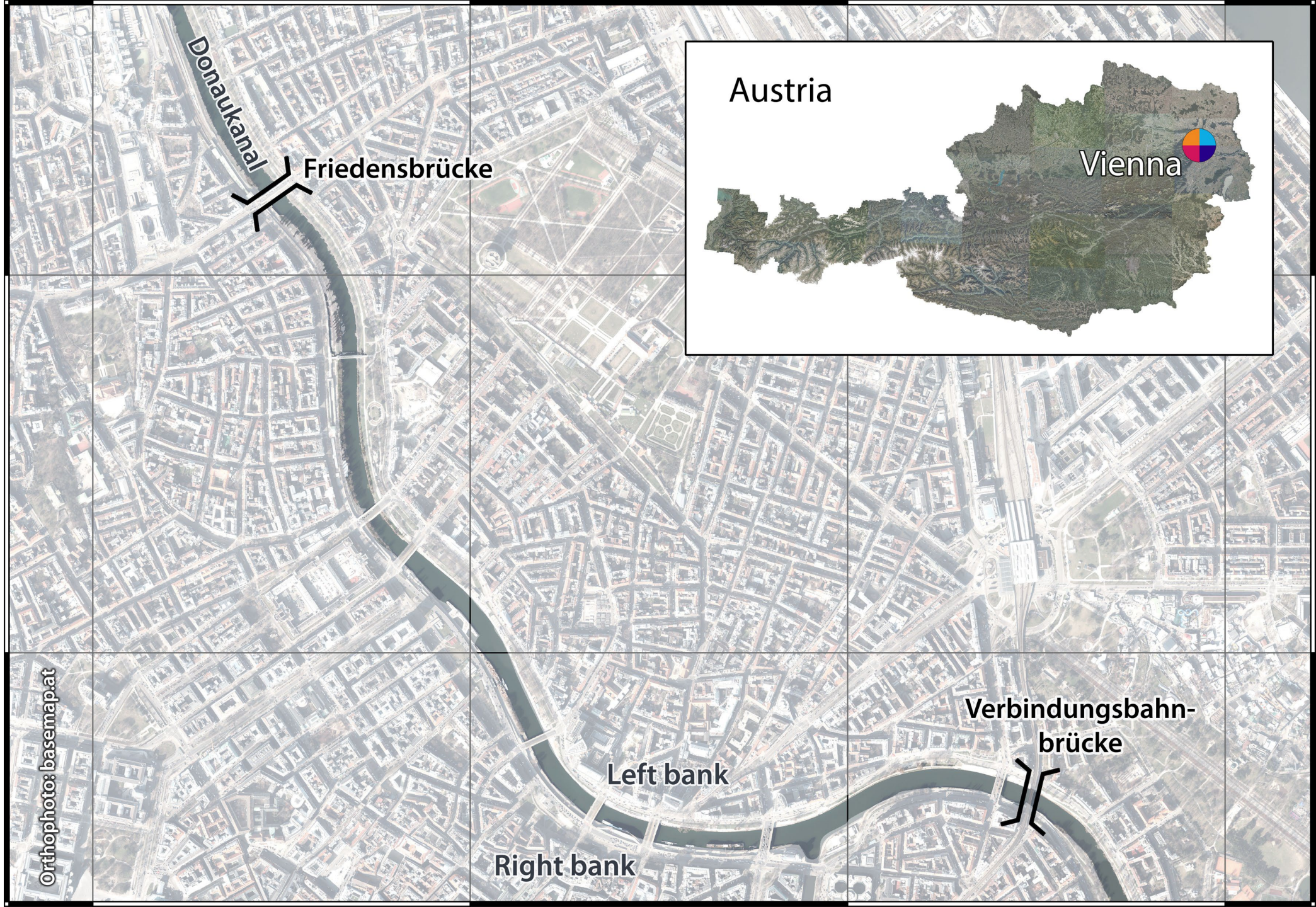
GRAFFITI *TERMINOLOGY*

GRAFFITI *CHARACTERISATION*

5 research pillars

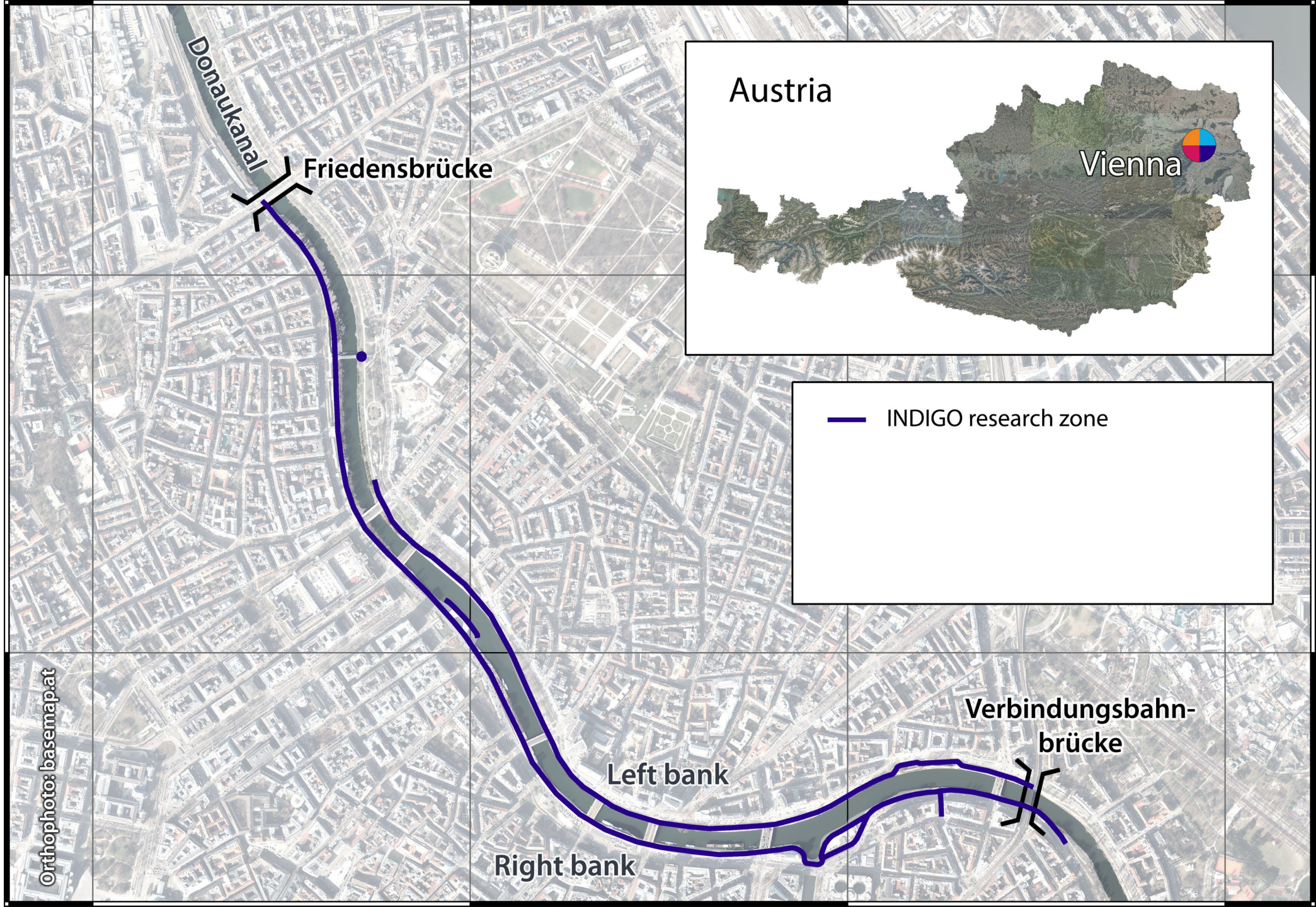



Donaukanal
Austria
Vienna
Left bank
Right bank
Orthophoto: basemap.at


Donaukanal
Friedensbrücke
Austria
Vienna
Orthophoto: basemap.at
Left bank
Right bank
Verbindungsbahn-
brücke

STRETCH

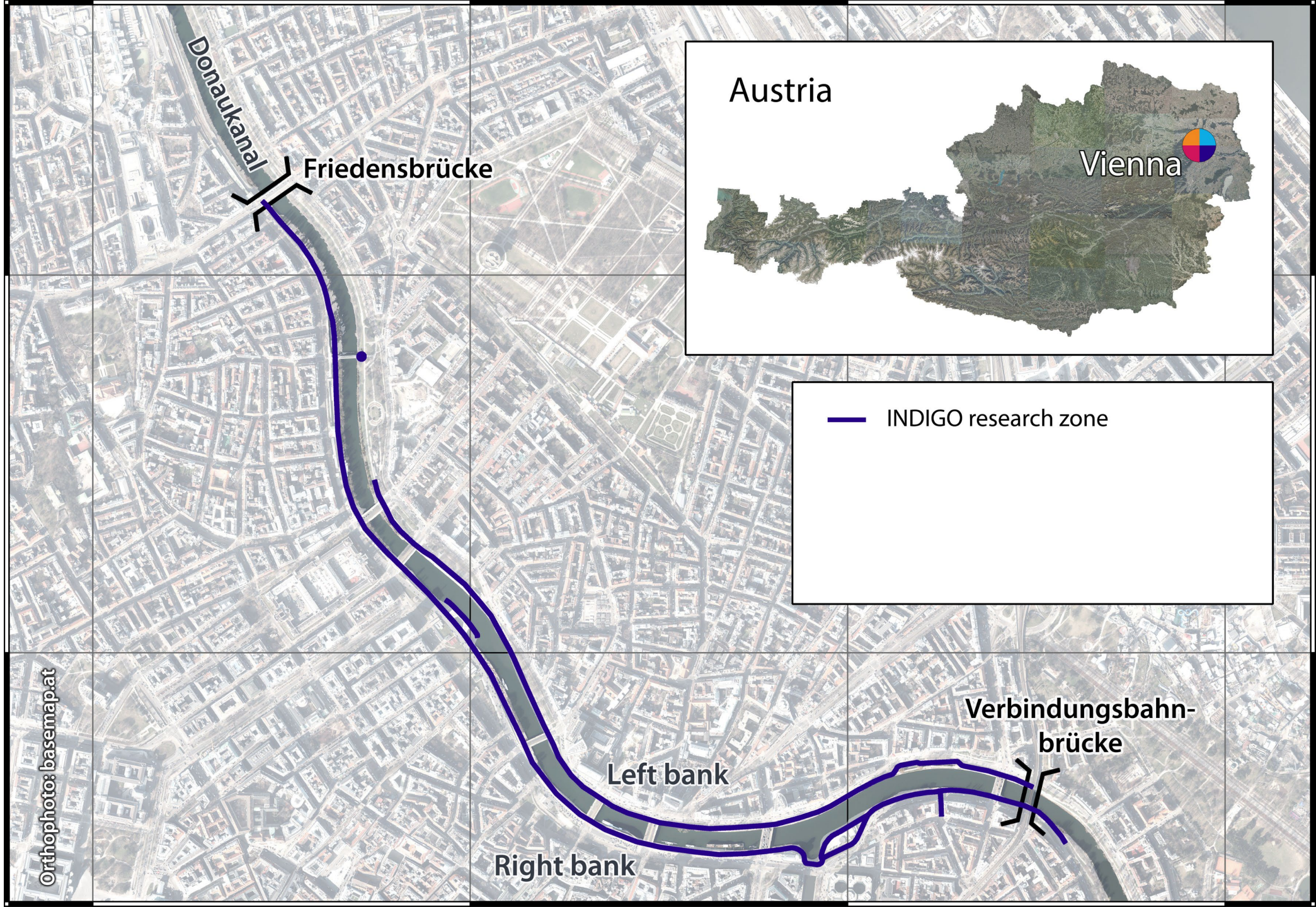
3.3 km



STRETCH

3.3 km

LEFT **RIGHT**



STRETCH

3.3 km

LEFT **RIGHT**



STRETCH

3.3 km

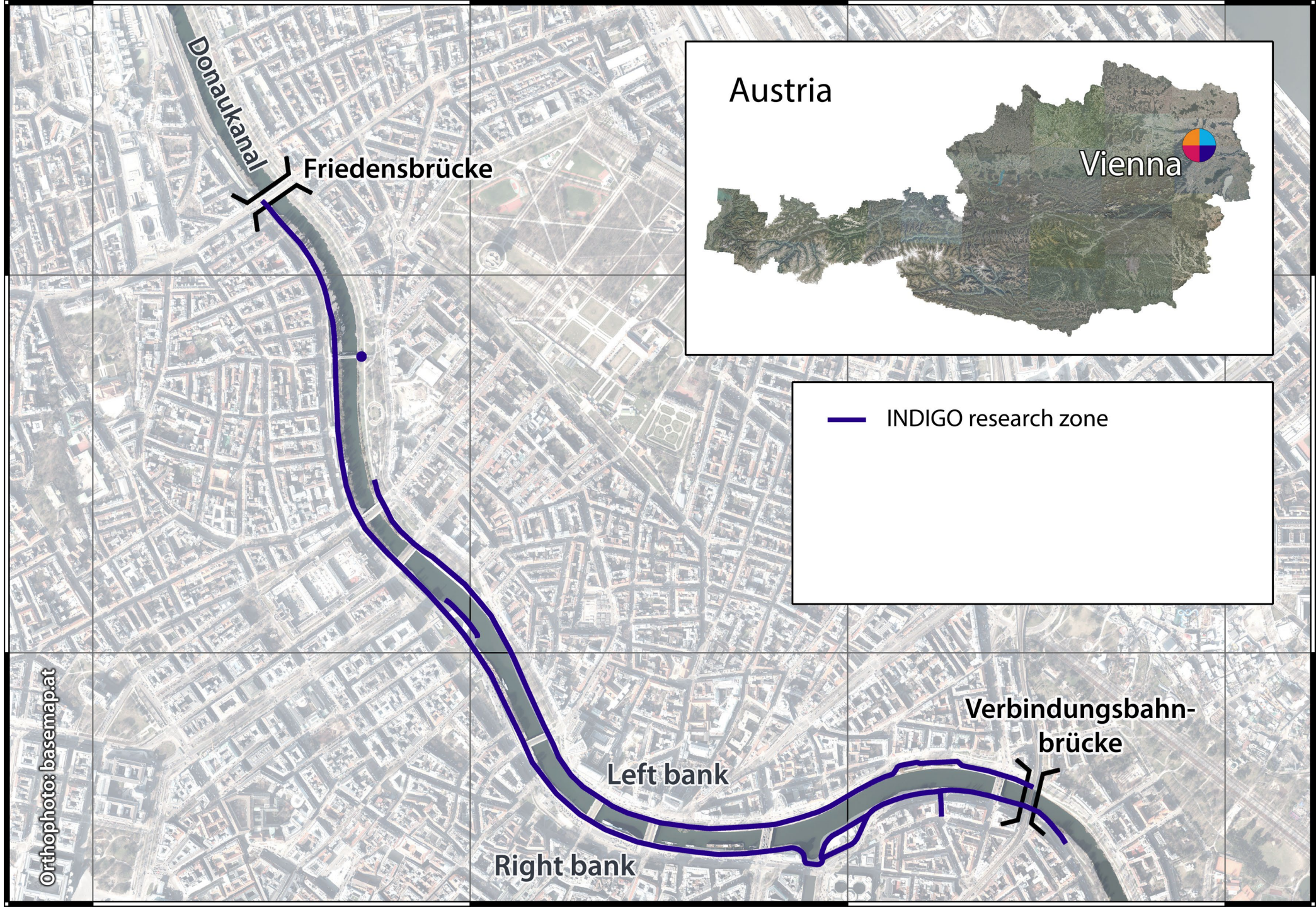
LEFT	RIGHT
UP	UP
DOWN	DOWN



STRETCH

3.3 km

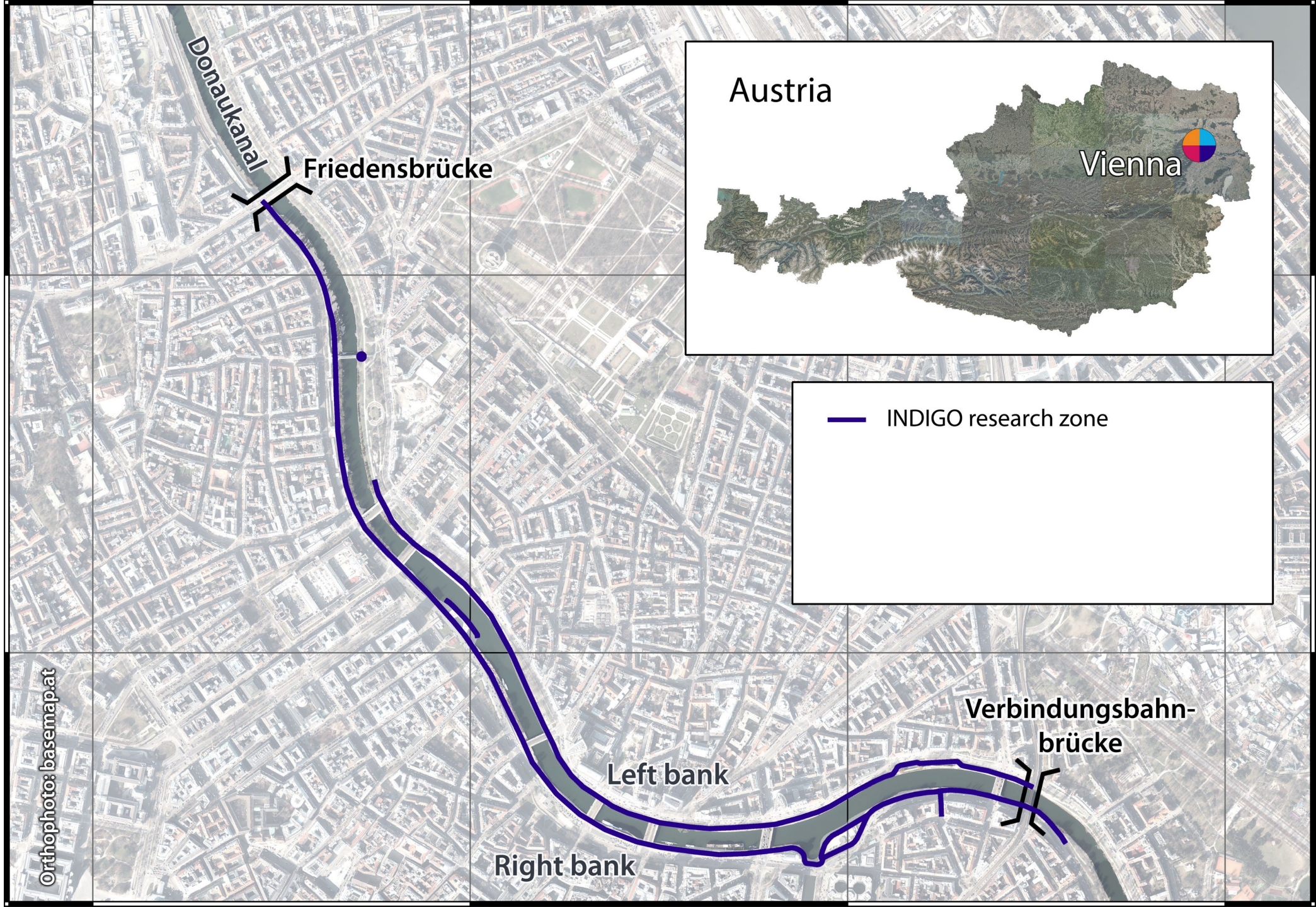
LEFT	RIGHT
UP	UP
3.2 km	5.3 km
DOWN	DOWN



STRETCH

3.3 km

LEFT	RIGHT
UP	UP
3.2 km	5.3 km
DOWN	DOWN
2.1 km	2.3 km



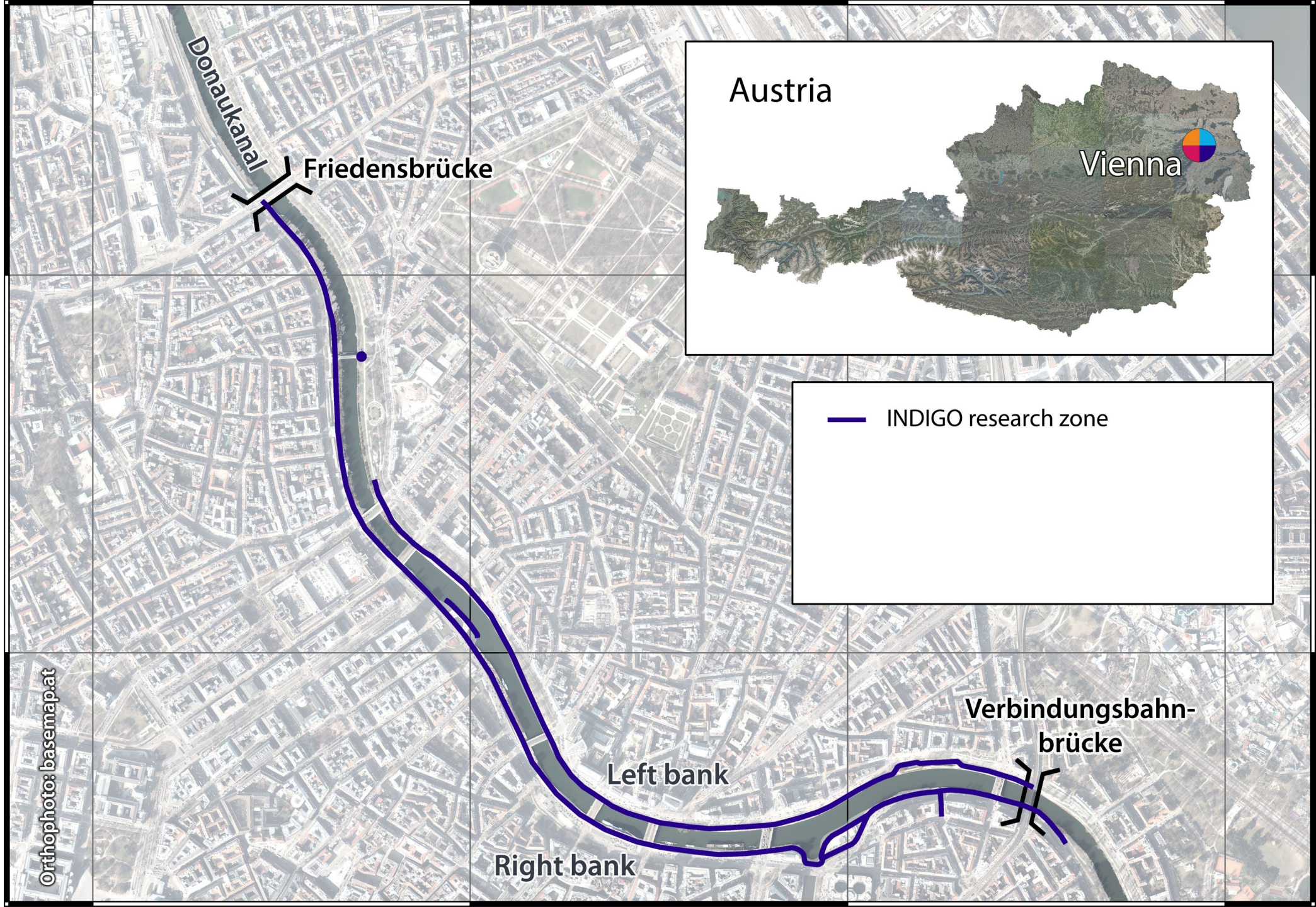
STRETCH

3.3 km

LEFT	RIGHT
UP	UP
3.2 km	5.3 km
DOWN	DOWN
2.1 km	2.3 km

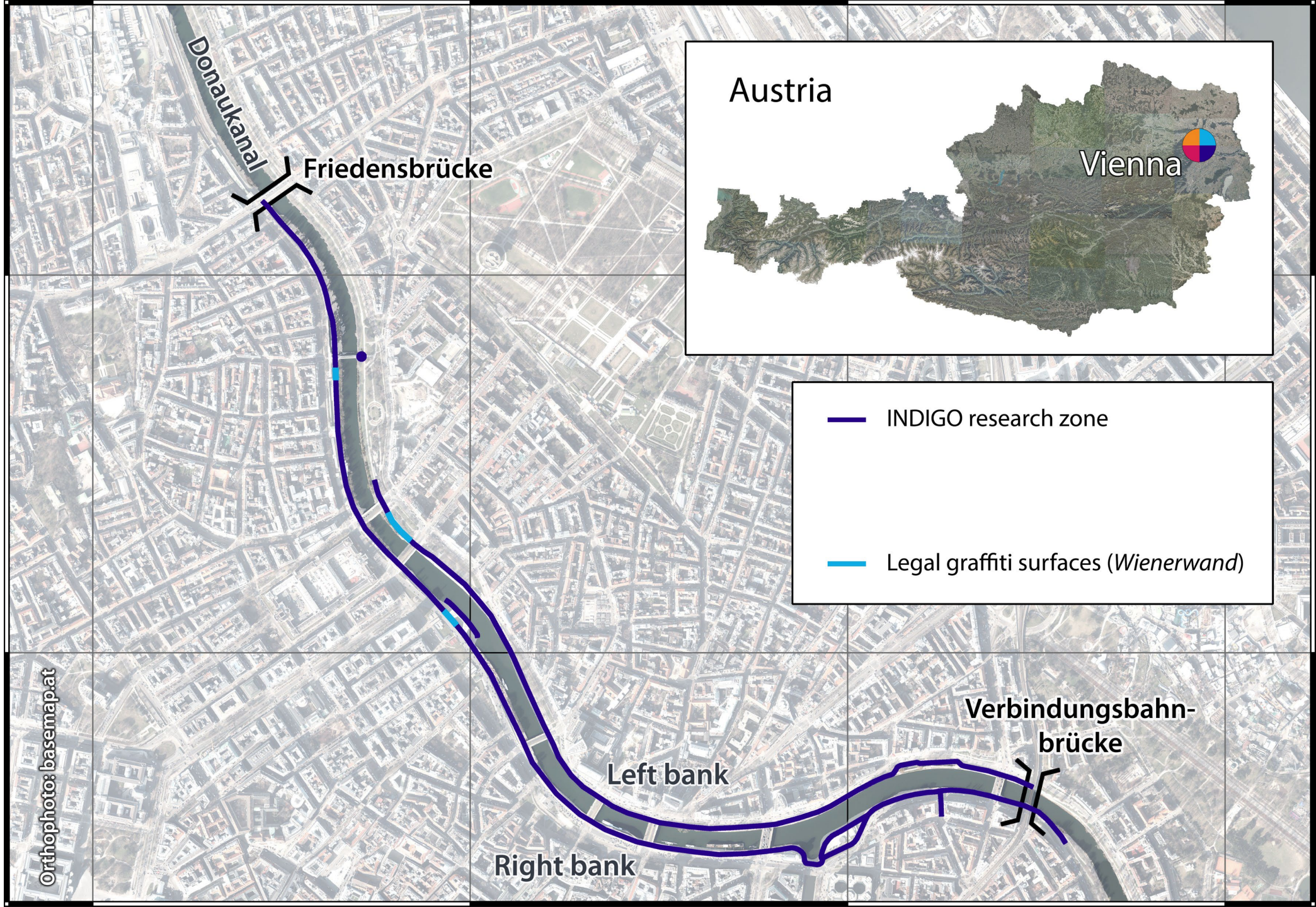
MONITORED SURFACES

12.9 km



MONITORED SURFACES

12.9 km

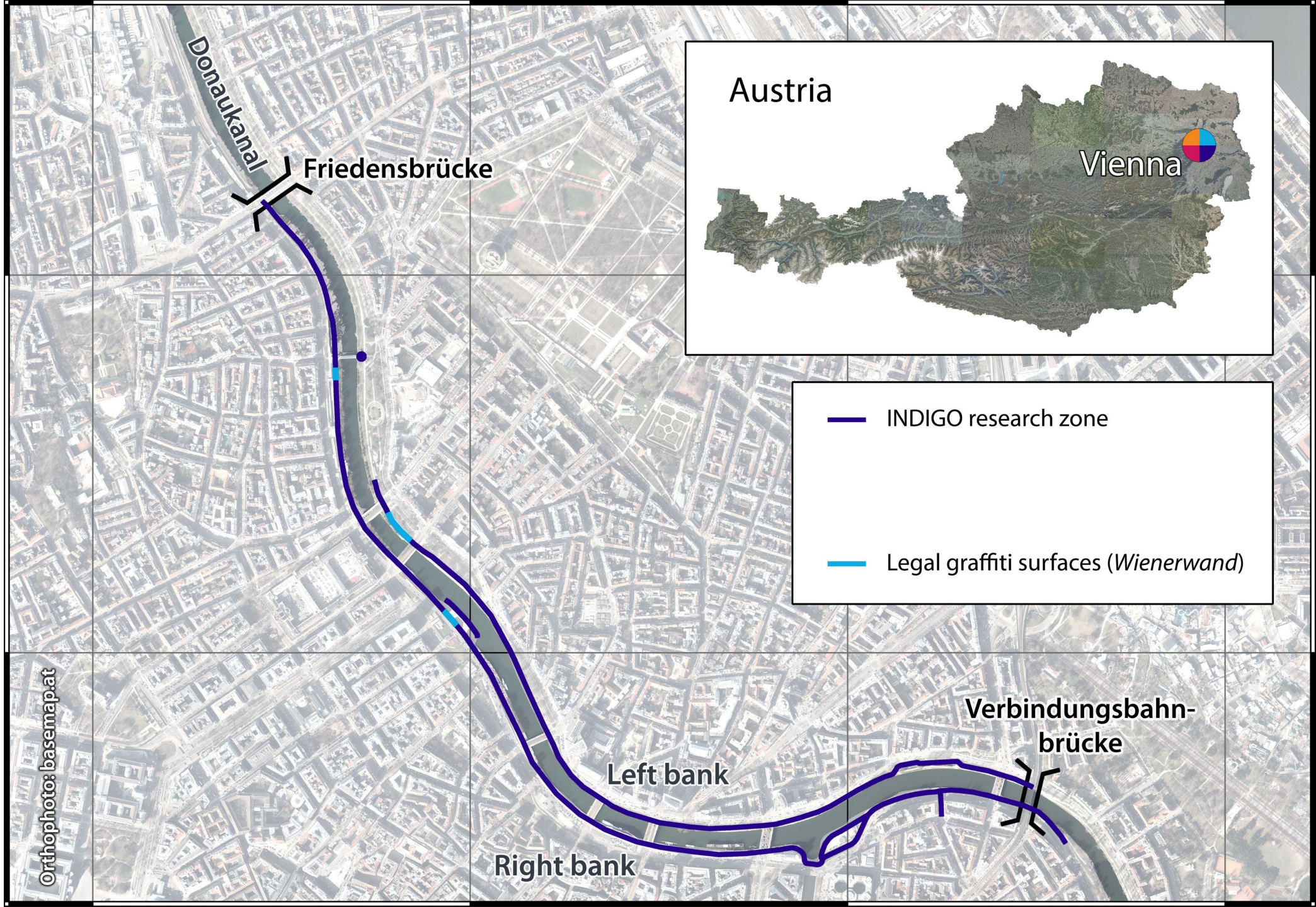


LEGAL SURFACES

0.3 km

MONITORED SURFACES

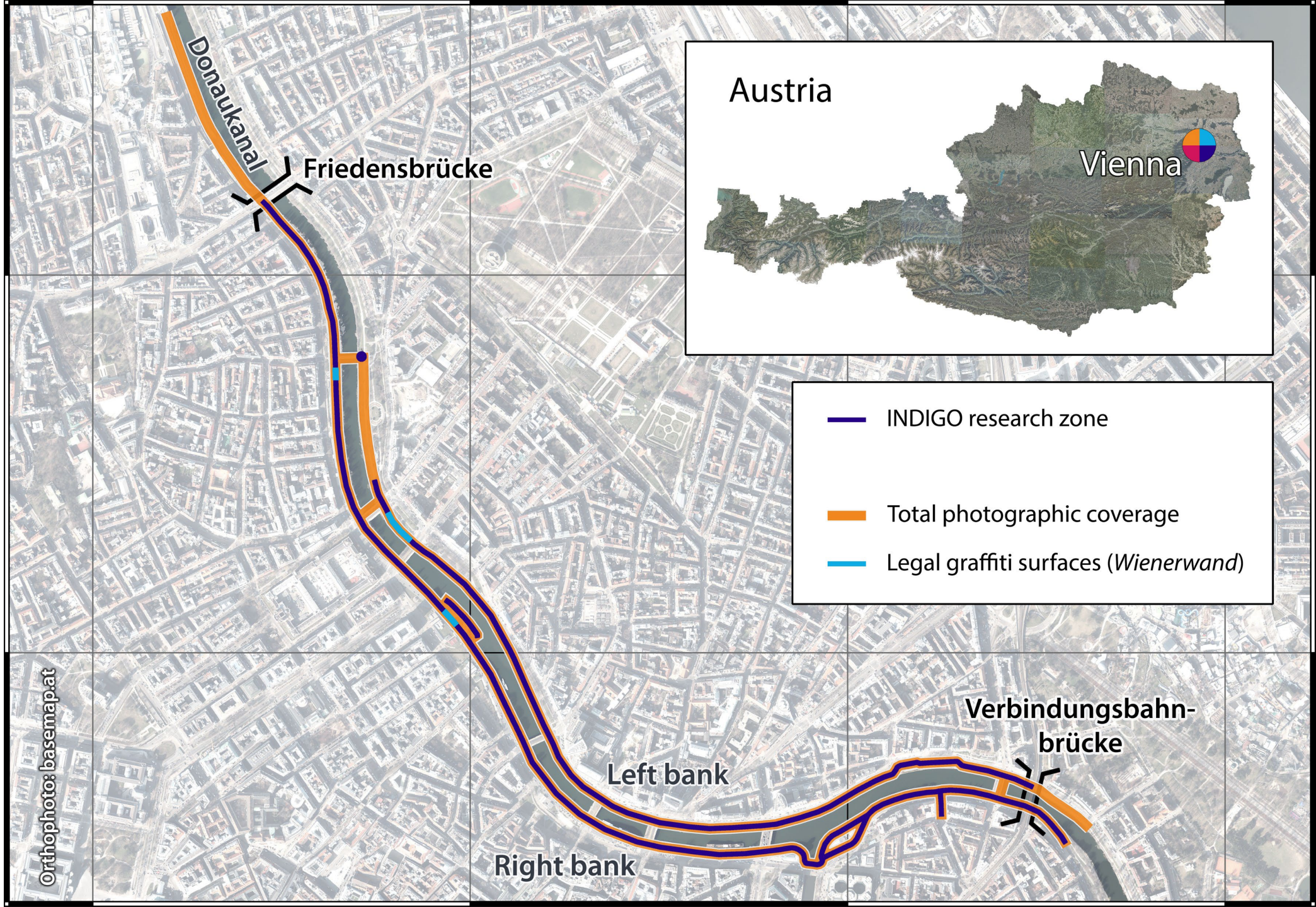
12.9 km



TOTAL COVERAGE
14.0 km

LEGAL SURFACES
0.3 km

MONITORED SURFACES
12.9 km



TOTAL COVERAGE

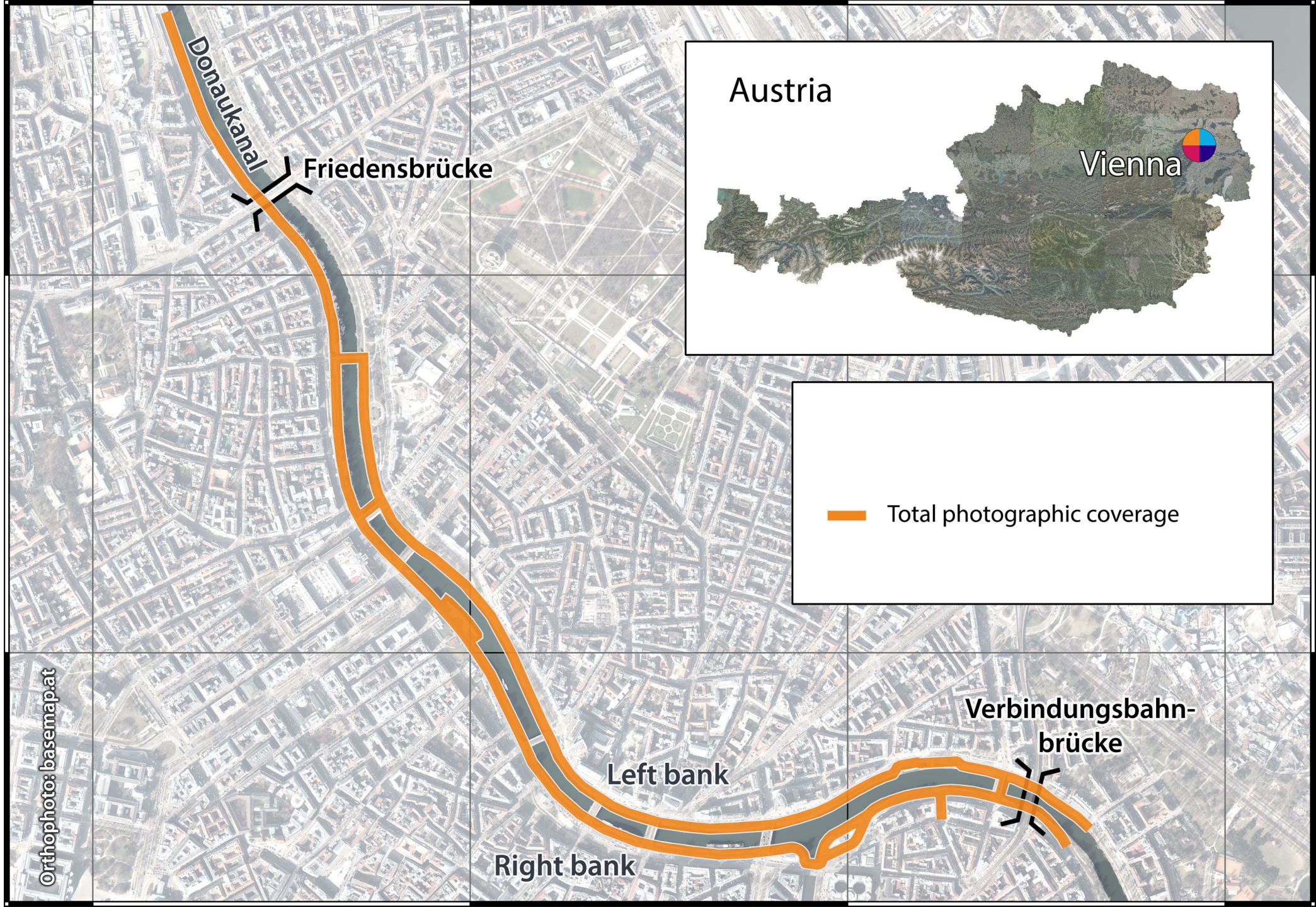
14.0 km

LEGAL SURFACES

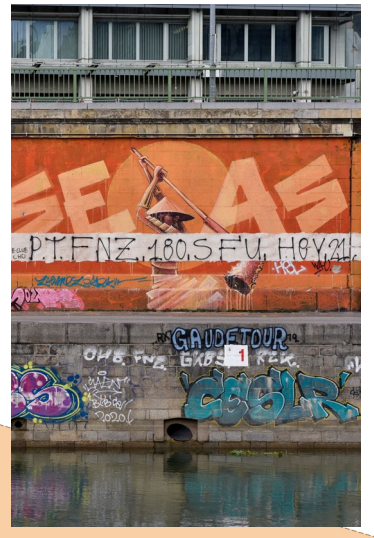
0.3 km

MONITORED SURFACES

12.9 km



TOTAL coverage



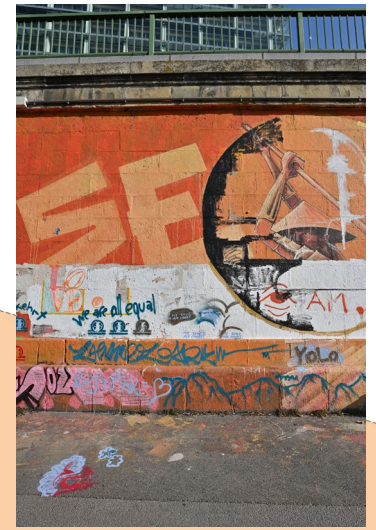
Date	Camera	Lens	Mean GSD	Acquisition time	Image count
30/09/2021	Nikon D750 (24.2 MP p = 5.95 µm)	Nikon AF-S NIKKOR 85mm 1:1.8 G @ f/5.6	3.6 mm	3 h 45 min	2065
01/10/2021				3 h 20 min	2544

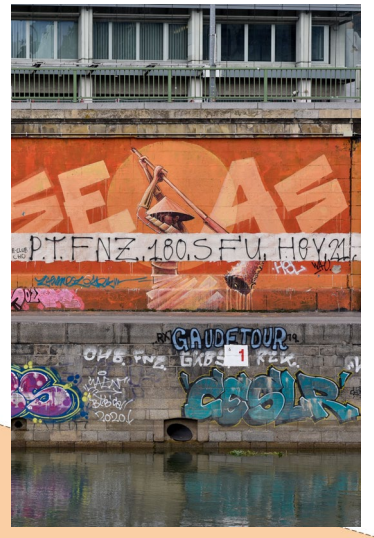
TOTAL coverage



Date	Camera	Lens	Mean GSD	Acquisition time	Image count
26/10/2021	Nikon Z 7II (45.4 MP p = 4.33 µm)	Nikon NIKKOR Z 20mm f/1.8 S @ f/5.6	0.9 mm	7 h	6042
27/10/2021				7 h 45 min	6591
28/10/2021				3 h 40 min	2856
29/10/2021				7 h	6608

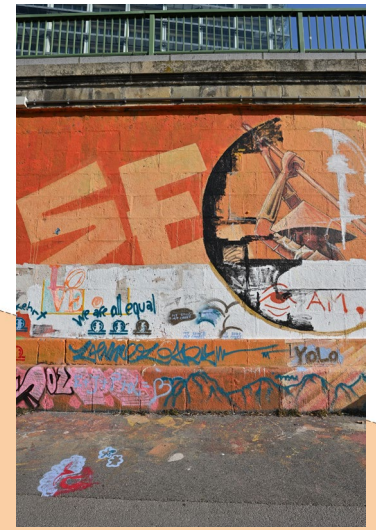
TOTAL coverage

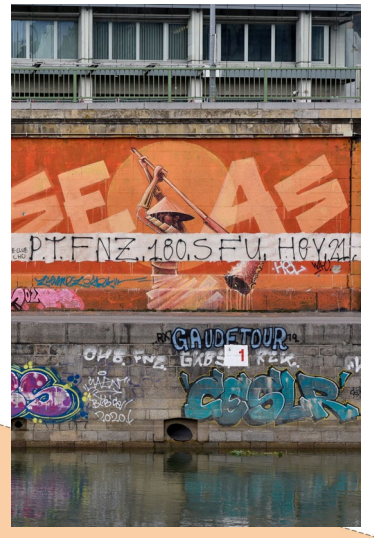




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29/10/2021				7 h	6608
			Total	**32 h 30 min**	**26706**

TOTAL coverage



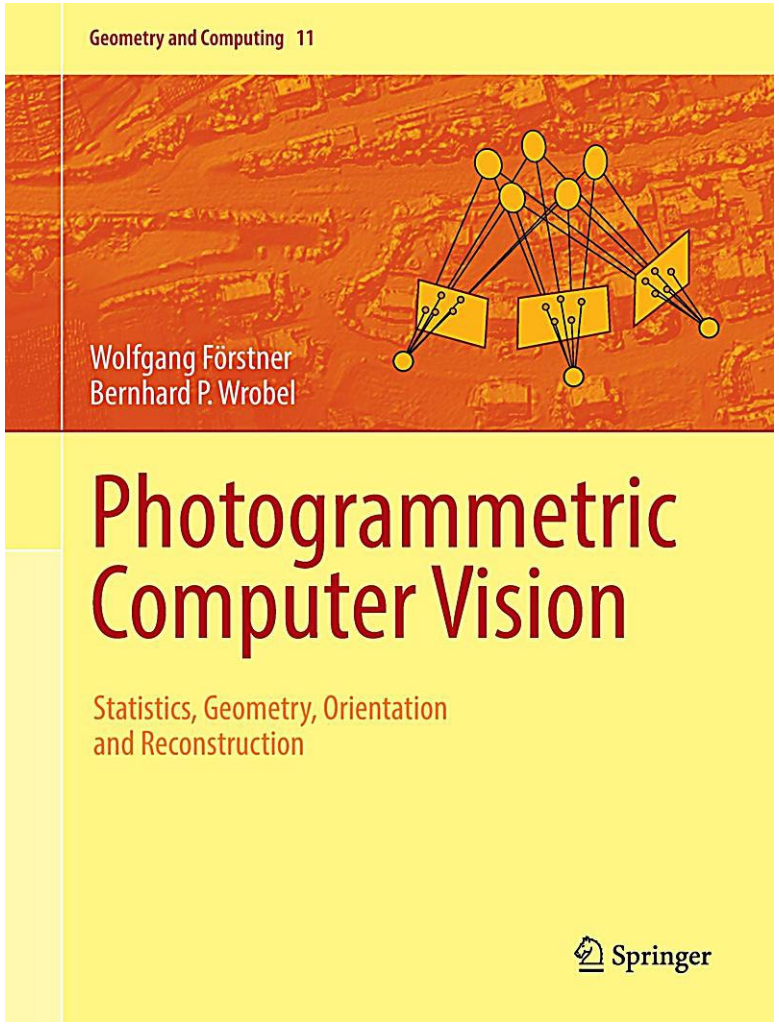


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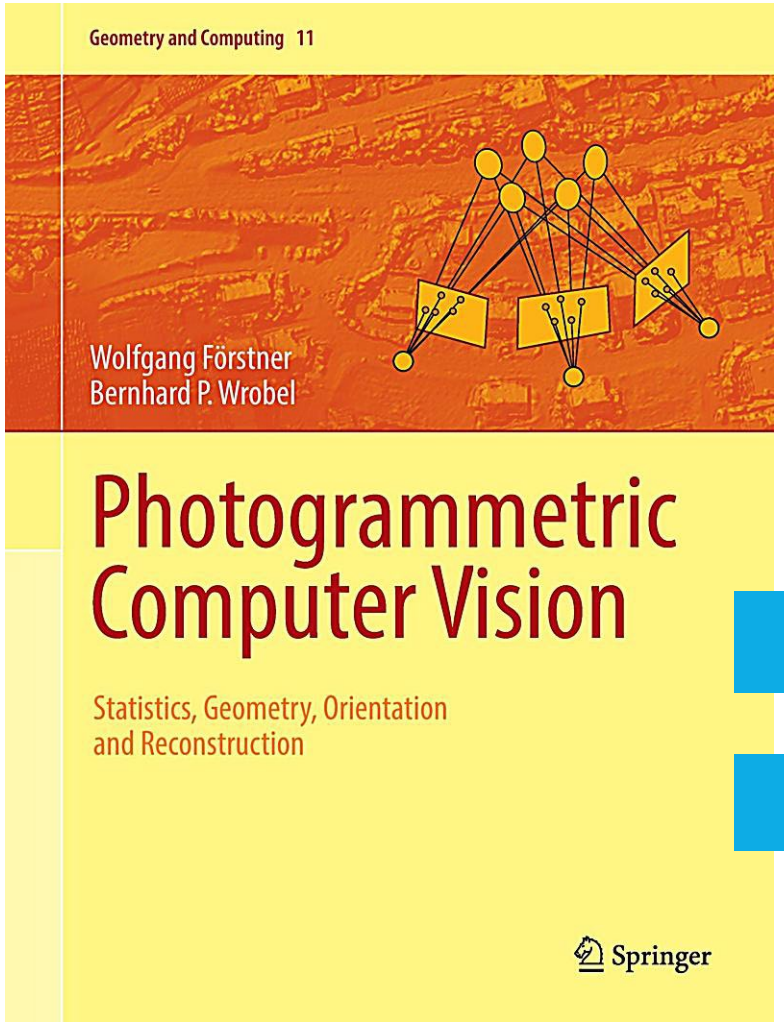
processing



PHOTOGRAMMETRIC computer vision



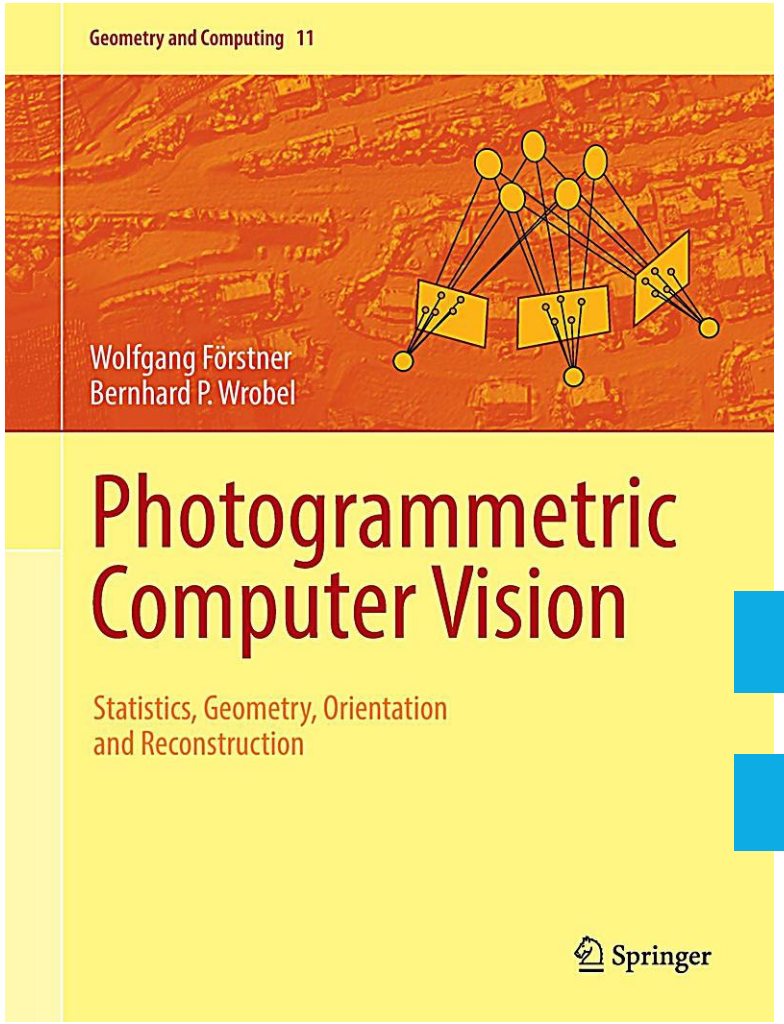
PHOTOGRAMMETRIC computer vision



Structure from Motion

Multi-View Stereo

PHOTOGRAMMETRIC computer vision

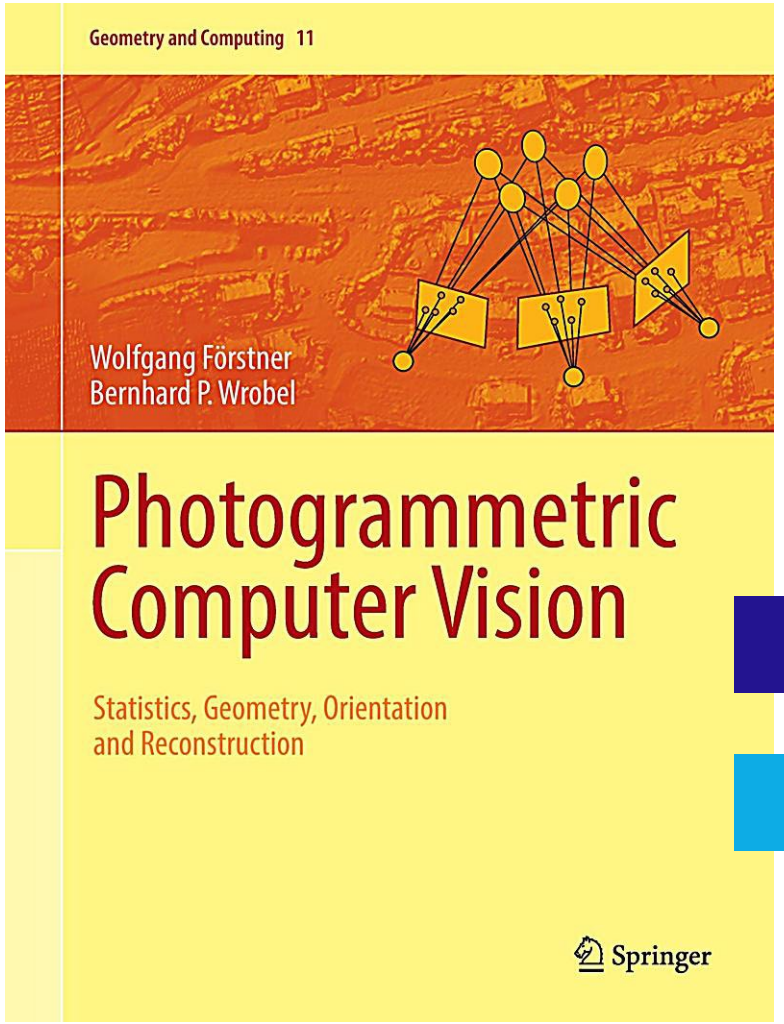


Metashape

Structure from Motion

Multi-View Stereo

PHOTOGRAMMETRIC computer vision



Metashape

Structure from Motion

Multi-View Stereo

STRUCTURE from motion







STRUCTURE from motion







DETECT *FEATURES*

STRUCTURE from motion







DETECT *FEATURES*

STRUCTURE from motion







DETECT *FEATURES*

STRUCTURE from motion

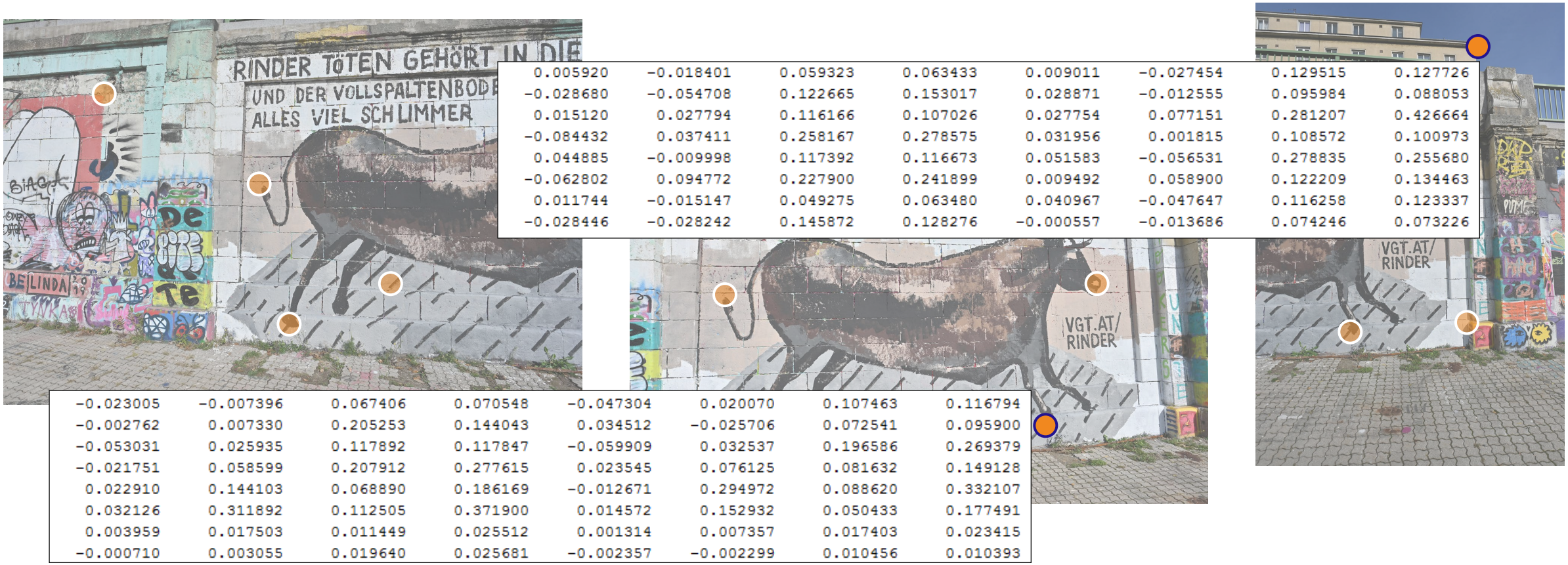






DESCRIBE *FEATURES*

STRUCTURE from motion



0.005920	-0.018401	0.059323	0.063433	0.009011	-0.027454	0.129515	0.127726
-0.028680	-0.054708	0.122665	0.153017	0.028871	-0.012555	0.095984	0.088053
0.015120	0.027794	0.116166	0.107026	0.027754	0.077151	0.281207	0.426664
-0.084432	0.037411	0.258167	0.278575	0.031956	0.001815	0.108572	0.100973
0.044885	-0.009998	0.117392	0.116673	0.051583	-0.056531	0.278835	0.255680
-0.062802	0.094772	0.227900	0.241899	0.009492	0.058900	0.122209	0.134463
0.011744	-0.015147	0.049275	0.063480	0.040967	-0.047647	0.116258	0.123337
-0.028446	-0.028242	0.145872	0.128276	-0.000557	-0.013686	0.074246	0.073226

-0.023005	-0.007396	0.067406	0.070548	-0.047304	0.020070	0.107463	0.116794
-0.002762	0.007330	0.205253	0.144043	0.034512	-0.025706	0.072541	0.095900
-0.053031	0.025935	0.117892	0.117847	-0.059909	0.032537	0.196586	0.269379
-0.021751	0.058599	0.207912	0.277615	0.023545	0.076125	0.081632	0.149128
0.022910	0.144103	0.068890	0.186169	-0.012671	0.294972	0.088620	0.332107
0.032126	0.311892	0.112505	0.371900	0.014572	0.152932	0.050433	0.177491
0.003959	0.017503	0.011449	0.025512	0.001314	0.007357	0.017403	0.023415
-0.000710	0.003055	0.019640	0.025681	-0.002357	-0.002299	0.010456	0.010393

DESCRIBE *FEATURES*

STRUCTURE from motion







MATCH *DESCRIPTORS*

STRUCTURE from motion

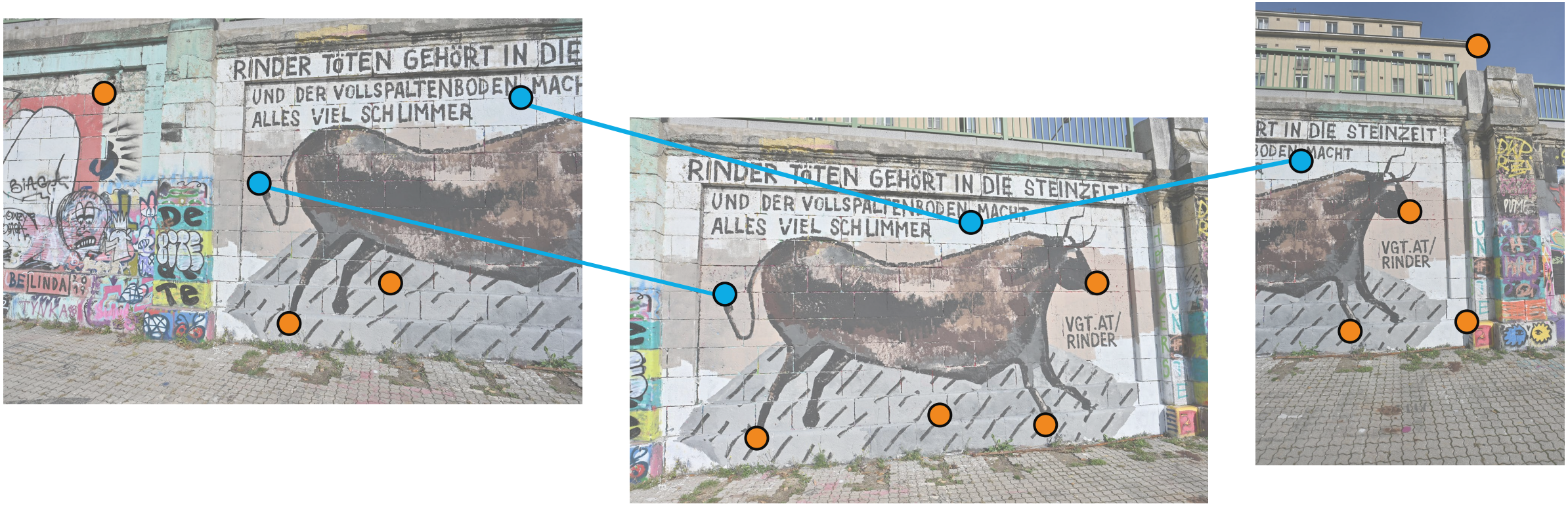






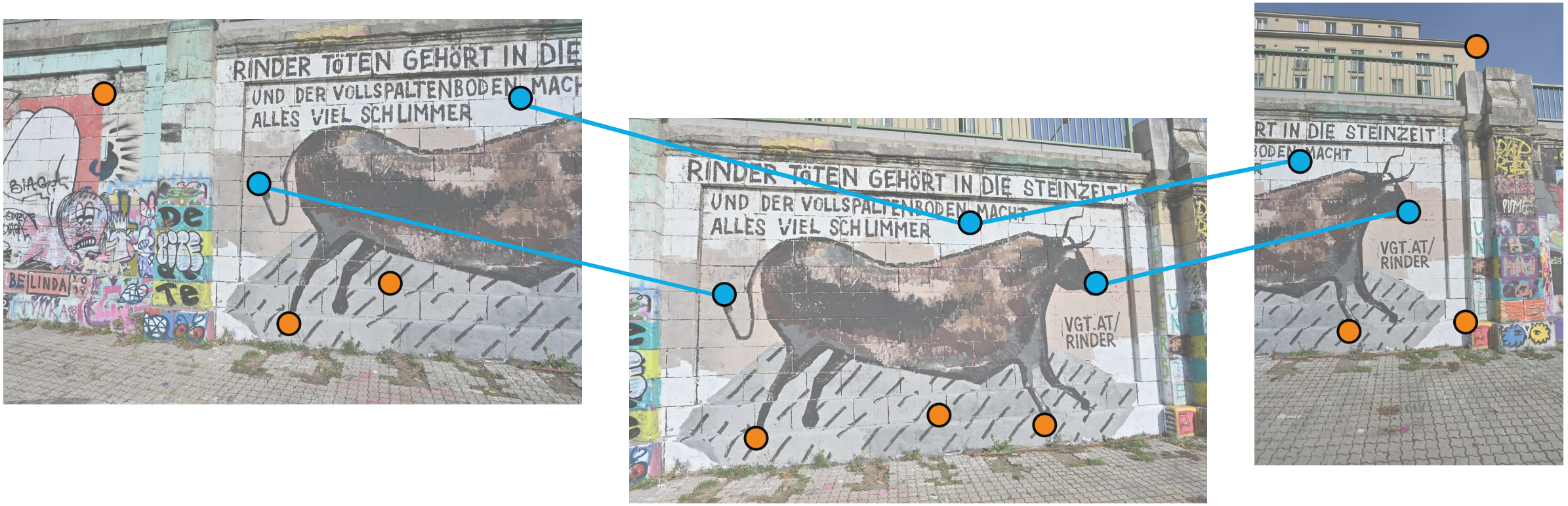
MATCH *DESCRIPTORS*

STRUCTURE from motion



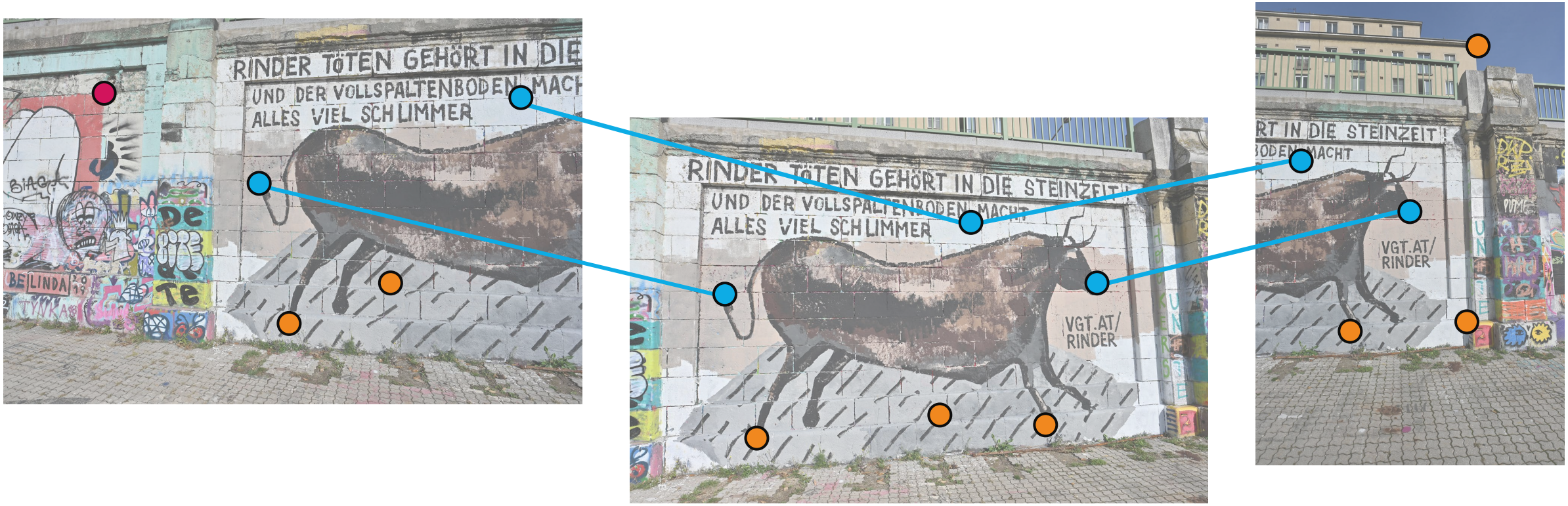
MATCH *DESCRIPTORS*

STRUCTURE from motion



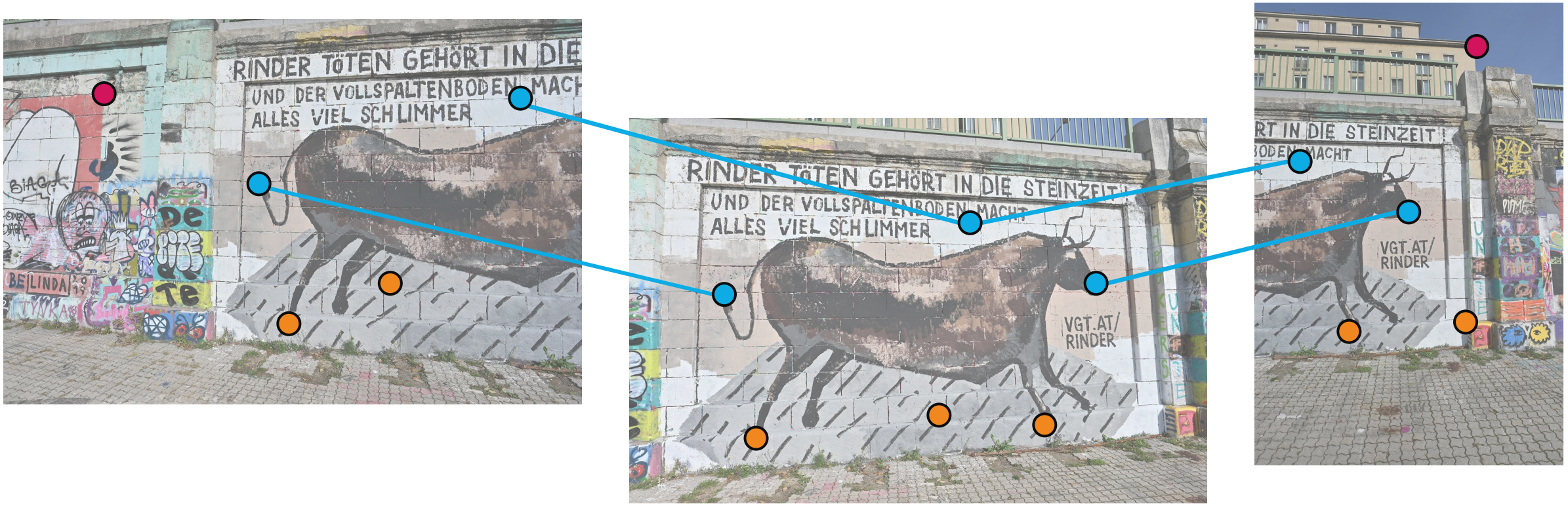
MATCH *DESCRIPTORS*

STRUCTURE from motion



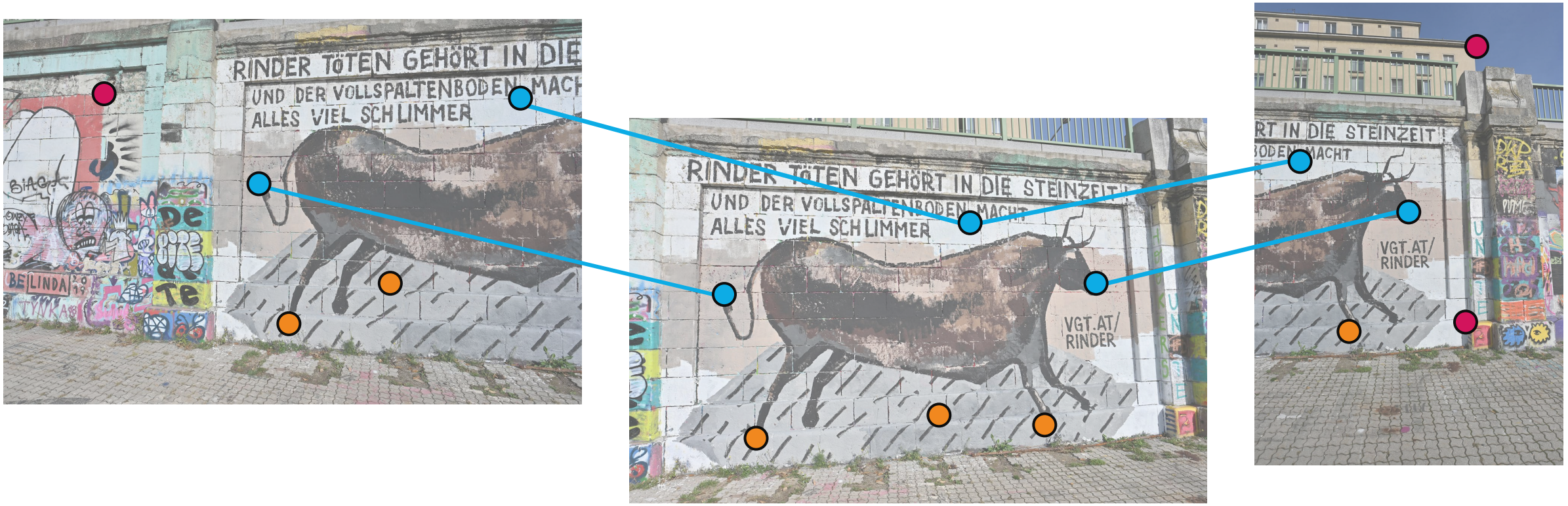
MATCH *DESCRIPTORS*

STRUCTURE from motion



MATCH *DESCRIPTORS*

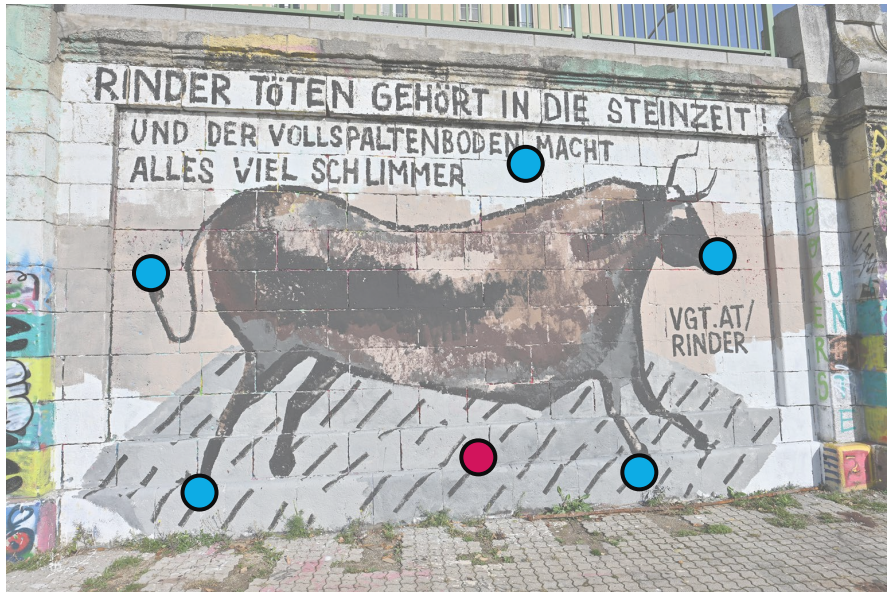
STRUCTURE from motion



MATCH *DESCRIPTORS*

STRUCTURE from motion





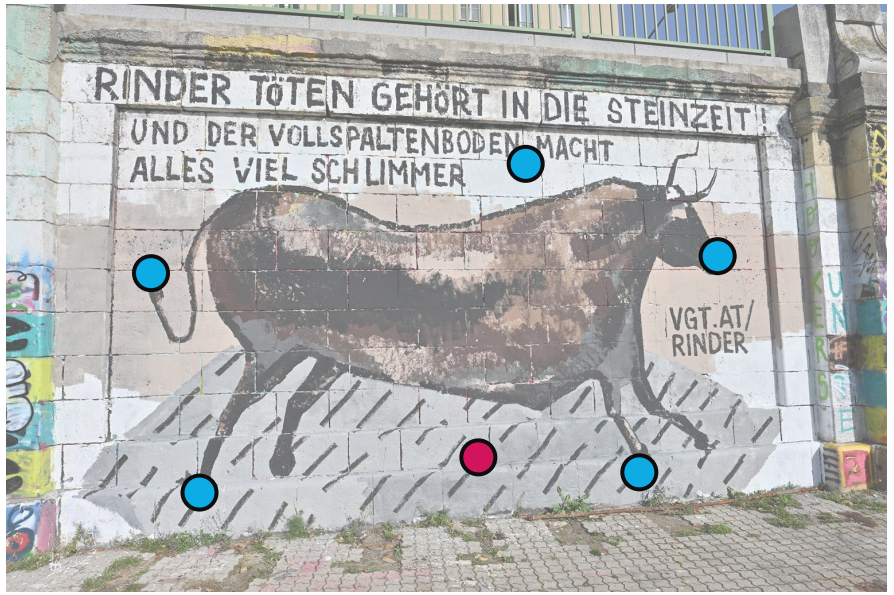


MATCH *DESCRIPTORS*

STRUCTURE from motion



TIE POINTS



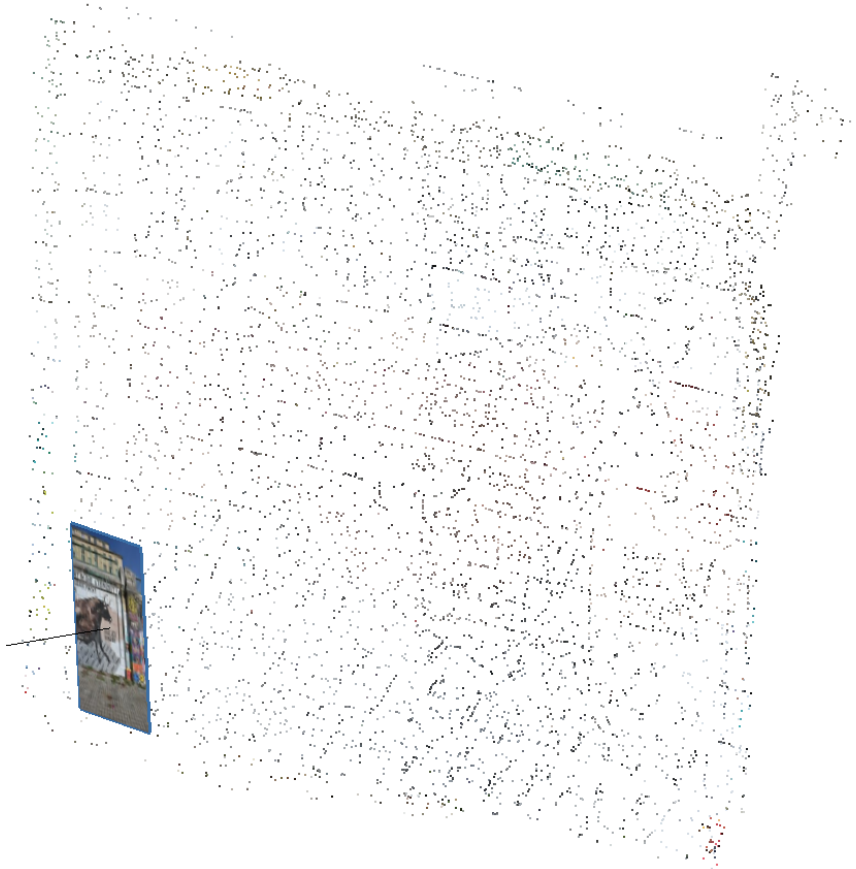


STRUCTURE from motion



TIE POINTS





ESTIMATE *CAMERA EXTERIOR ORIENTATION*

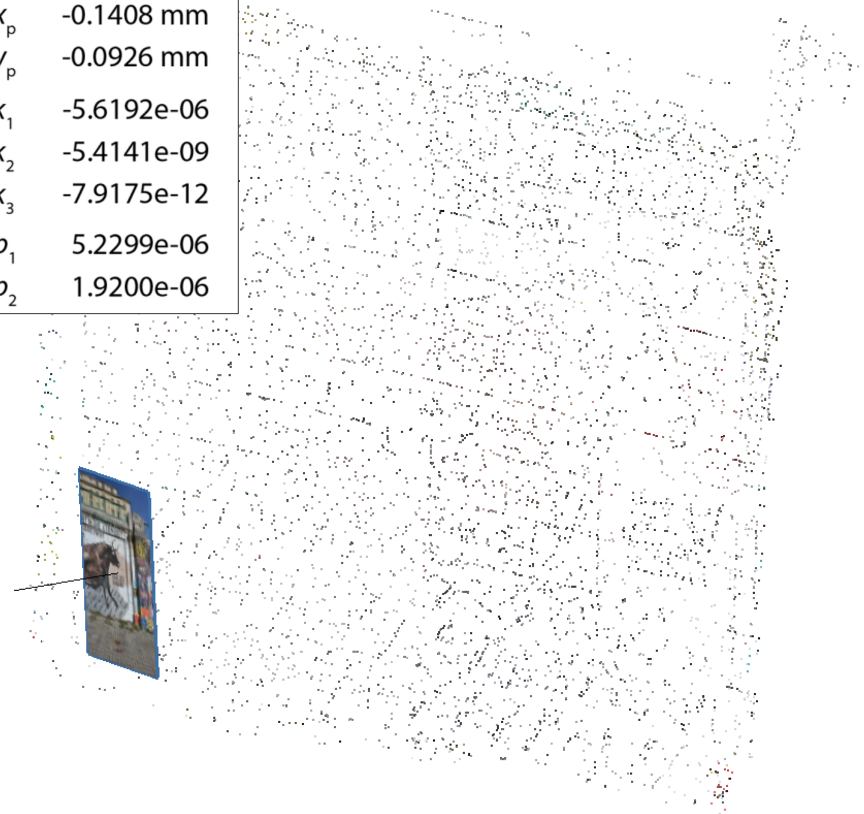
STRUCTURE from motion



TIE POINTS

principal distance	c	20.1546 mm
principal point location	x_p	-0.1408 mm
	y_p	-0.0926 mm
radial distortion parameters	k_1	-5.6192e-06
	k_2	-5.4141e-09
	k_3	-7.9175e-12
decentring distortion parameters	p_1	5.2299e-06
	p_2	1.9200e-06





ESTIMATE *CAMERA EXTERIOR ORIENTATION*

ESTIMATE *CAMERA INTERIOR ORIENTATION*

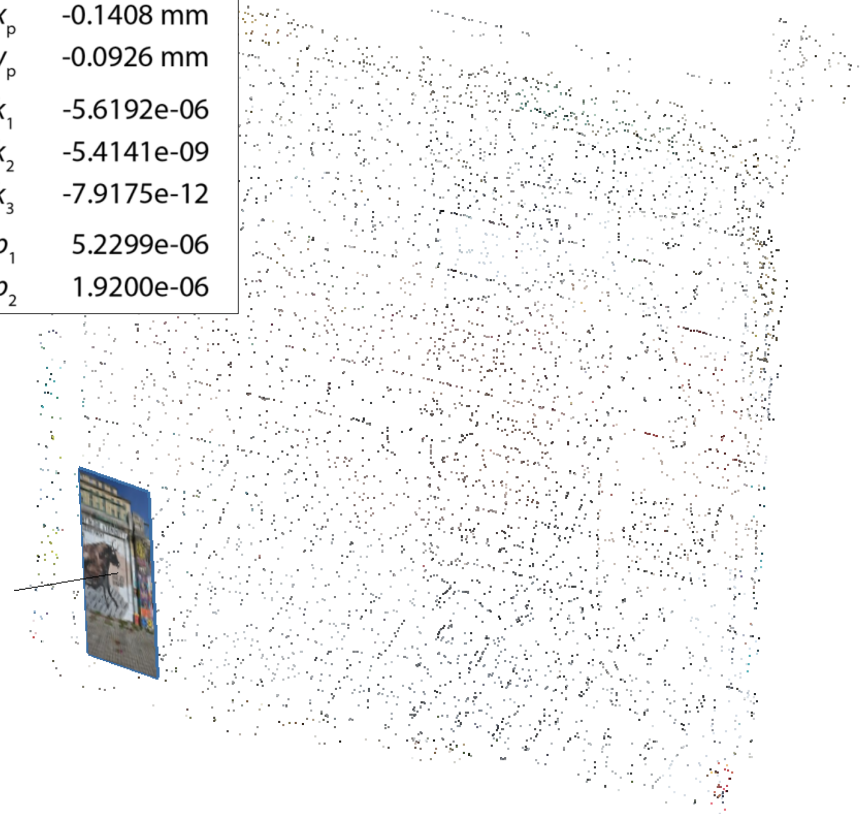
STRUCTURE from motion



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	k_3	-7.9175e-12
decentring distortion parameters	p_1	5.2299e-06
	p_2	1.9200e-06





3D POINTS

ESTIMATE *CAMERA EXTERIOR ORIENTATION*

ESTIMATE *CAMERA INTERIOR ORIENTATION*

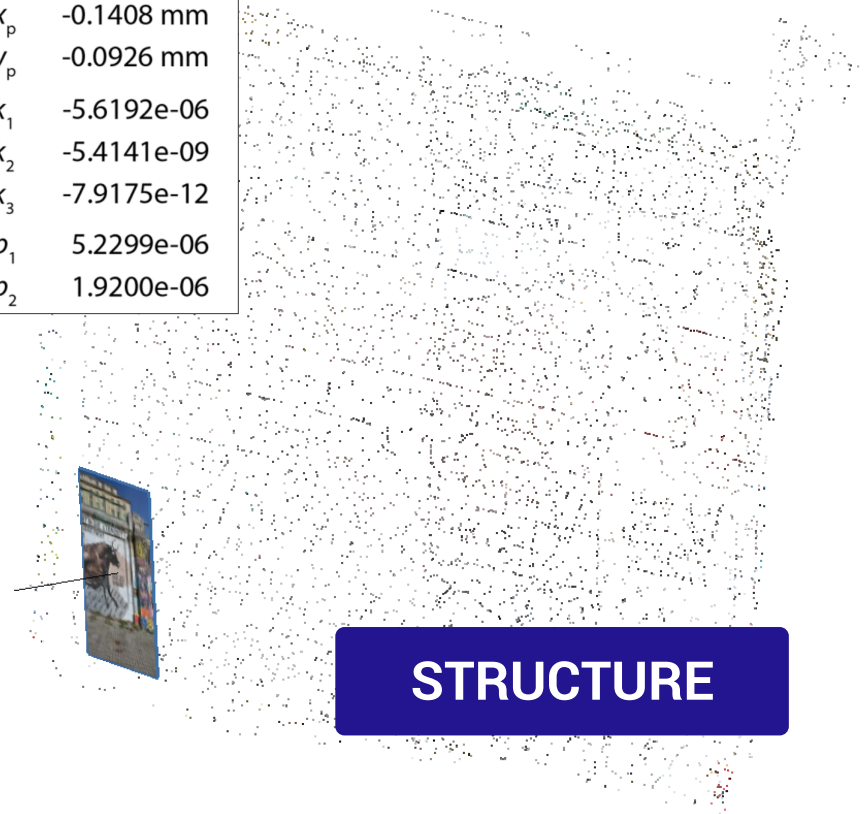
STRUCTURE from motion



TIE POINTS

principal distance	c	20.1546 mm
principal point location	x_p	-0.1408 mm
	y_p	-0.0926 mm
radial distortion parameters	k_1	-5.6192e-06
	k_2	-5.4141e-09
	k_3	-7.9175e-12
decentring distortion parameters	p_1	5.2299e-06
	p_2	1.9200e-06





STRUCTURE

3D POINTS

ESTIMATE *CAMERA EXTERIOR ORIENTATION*

ESTIMATE *CAMERA INTERIOR ORIENTATION*

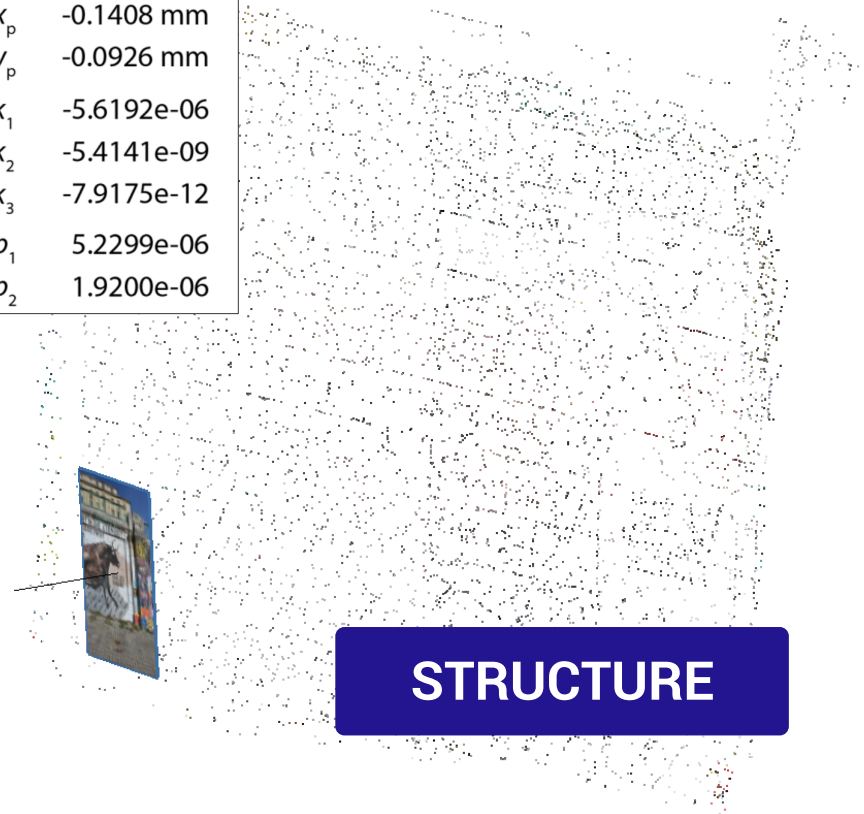
STRUCTURE and from motion



TIE POINTS

principal distance	c	20.1546 mm
principal point location	x_p	-0.1408 mm
	y_p	-0.0926 mm
radial distortion parameters	k_1	-5.6192e-06
	k_2	-5.4141e-09
	k_3	-7.9175e-12
decentring distortion parameters	p_1	5.2299e-06
	p_2	1.9200e-06





STRUCTURE

3D POINTS

ESTIMATE *CAMERA EXTERIOR ORIENTATION*

ESTIMATE *CAMERA INTERIOR ORIENTATION*

STRUCTURE from motion







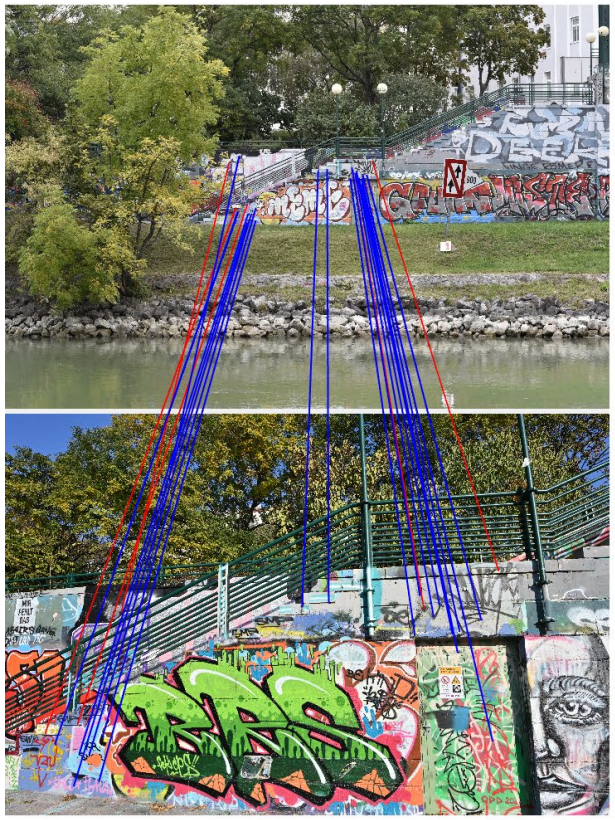
CAMERA EXTERIOR ORIENTATION

CAMERA INTERIOR ORIENTATION

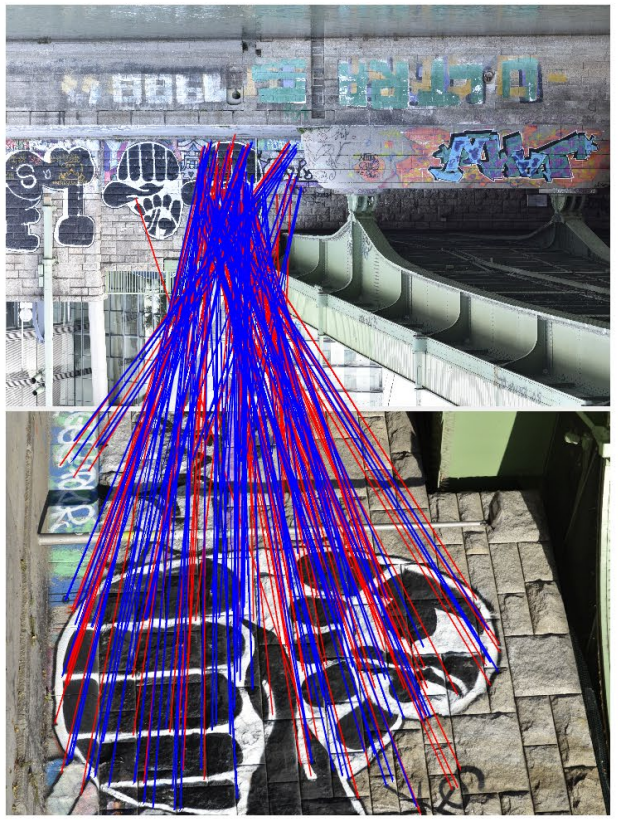
3D POINTS

CAMERA orientation

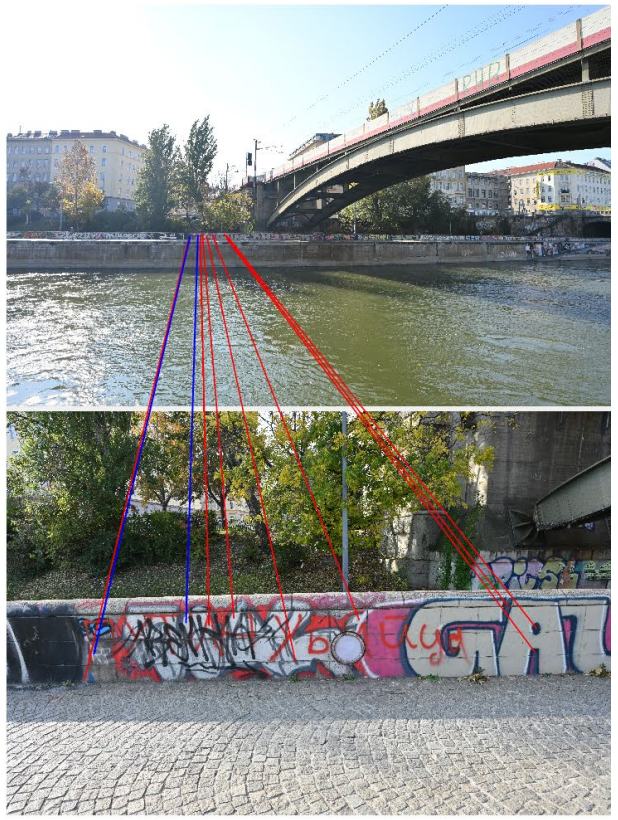
Nikon D750 + 85 mm
30-09-2021



Nikon D750 + 85 mm
30-09-2021



Nikon Z7 II + 20 mm
28-10-2021

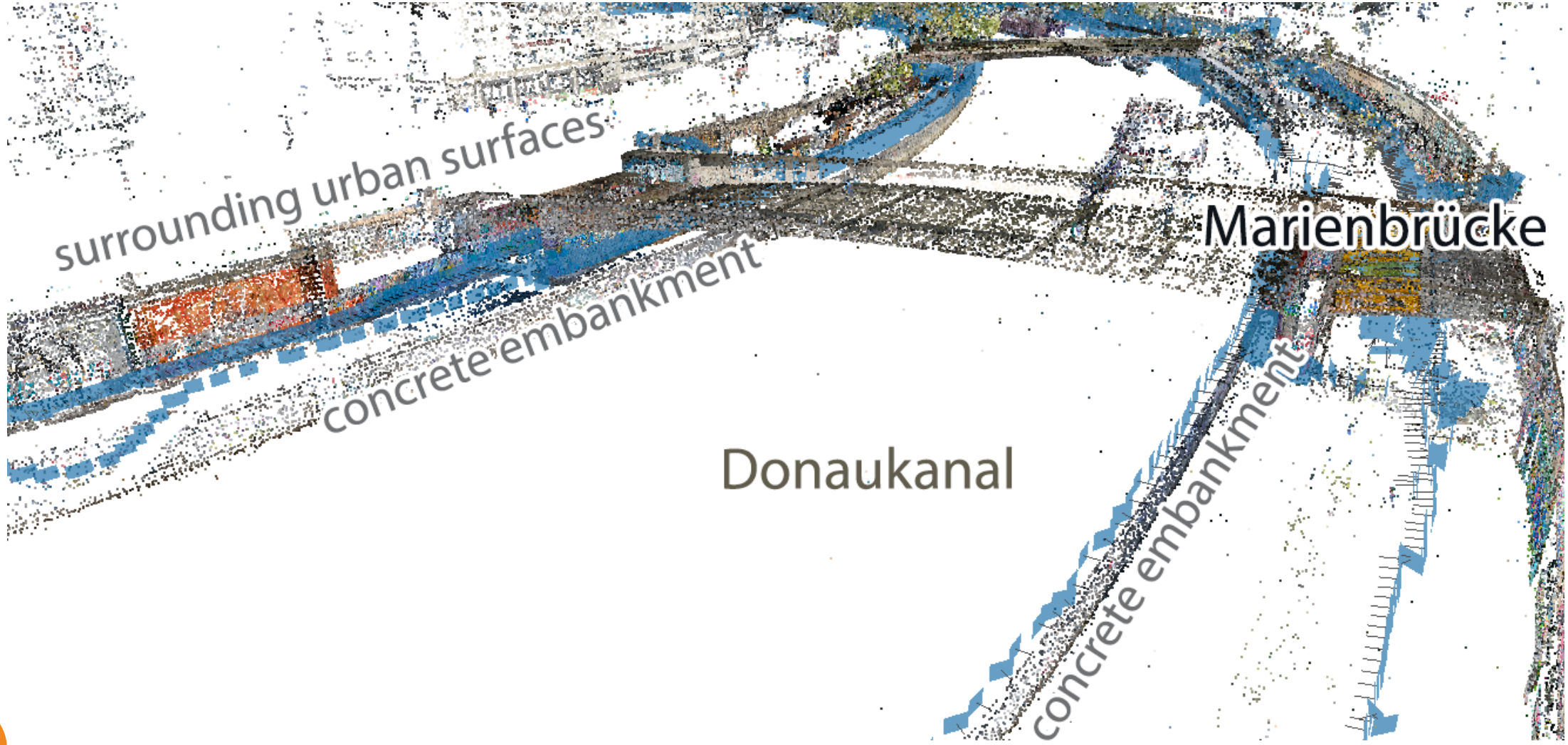


Nikon Z7 II + 20 mm
29-10-2021

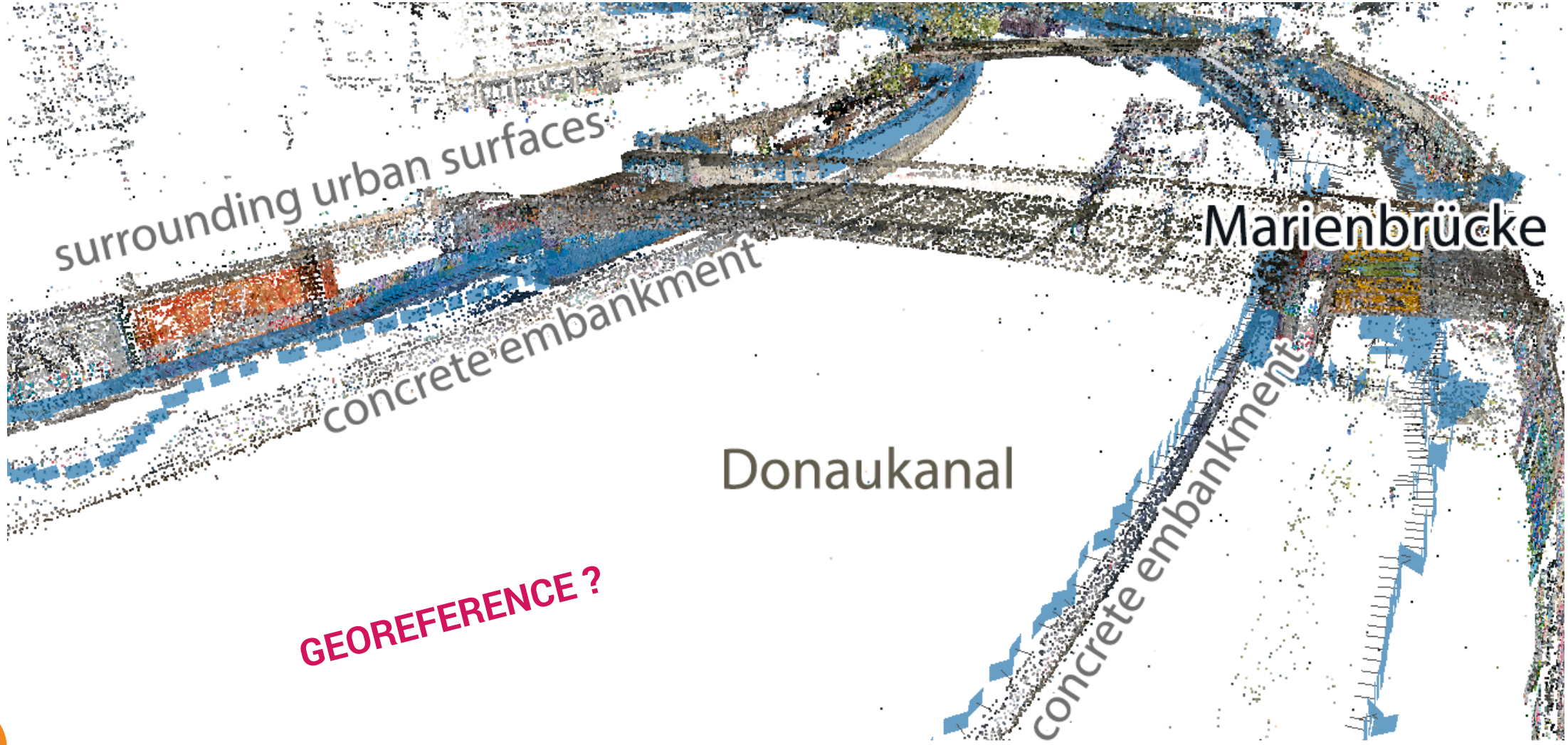
Nikon D750 + 85 mm
01-10-2021

Nikon Z7 II + 20 mm
26-10-2021

CAMERA orientation



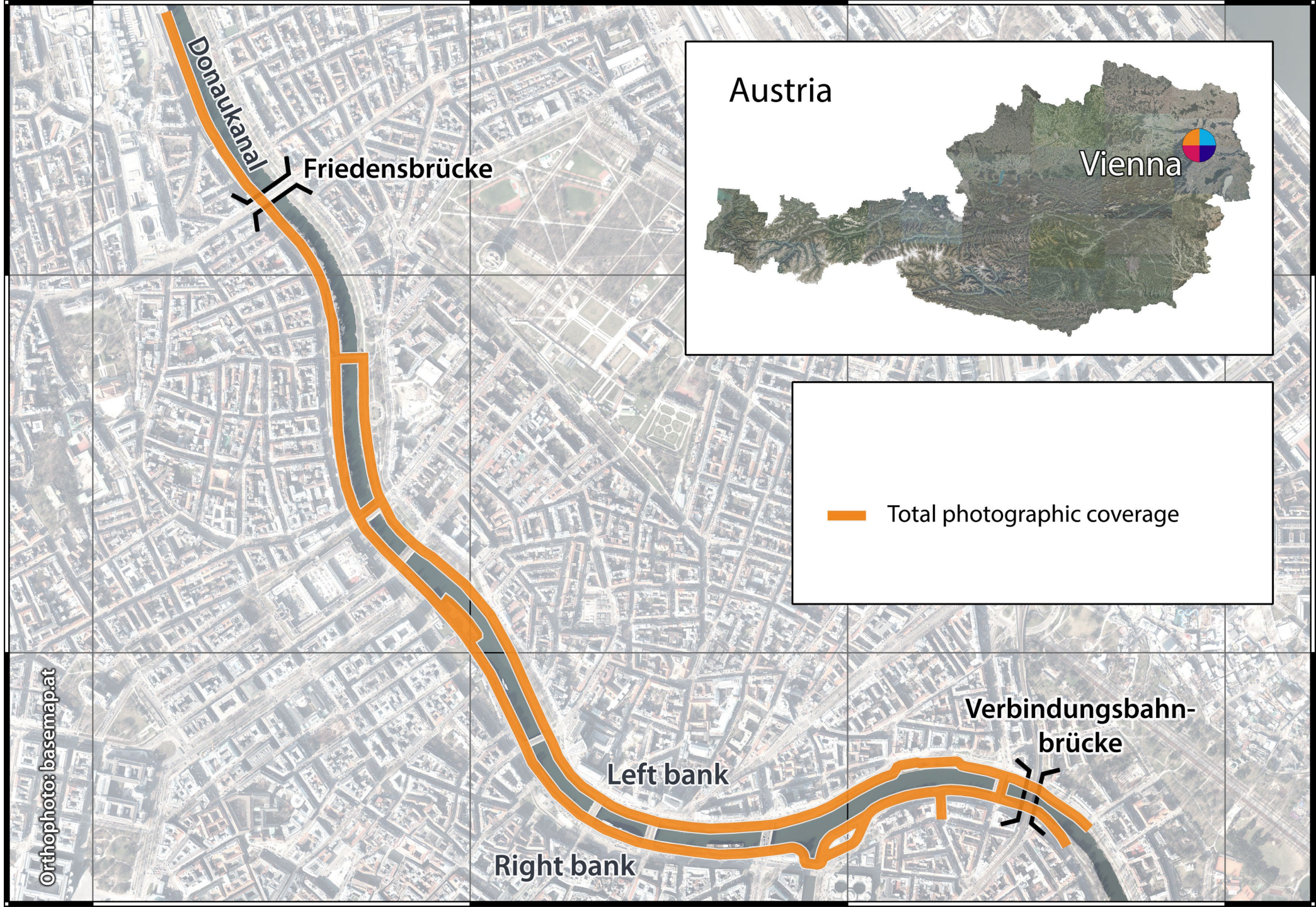
CAMERA orientation



GEOREFERENCE ?

TOTAL COVERAGE

14.0 km

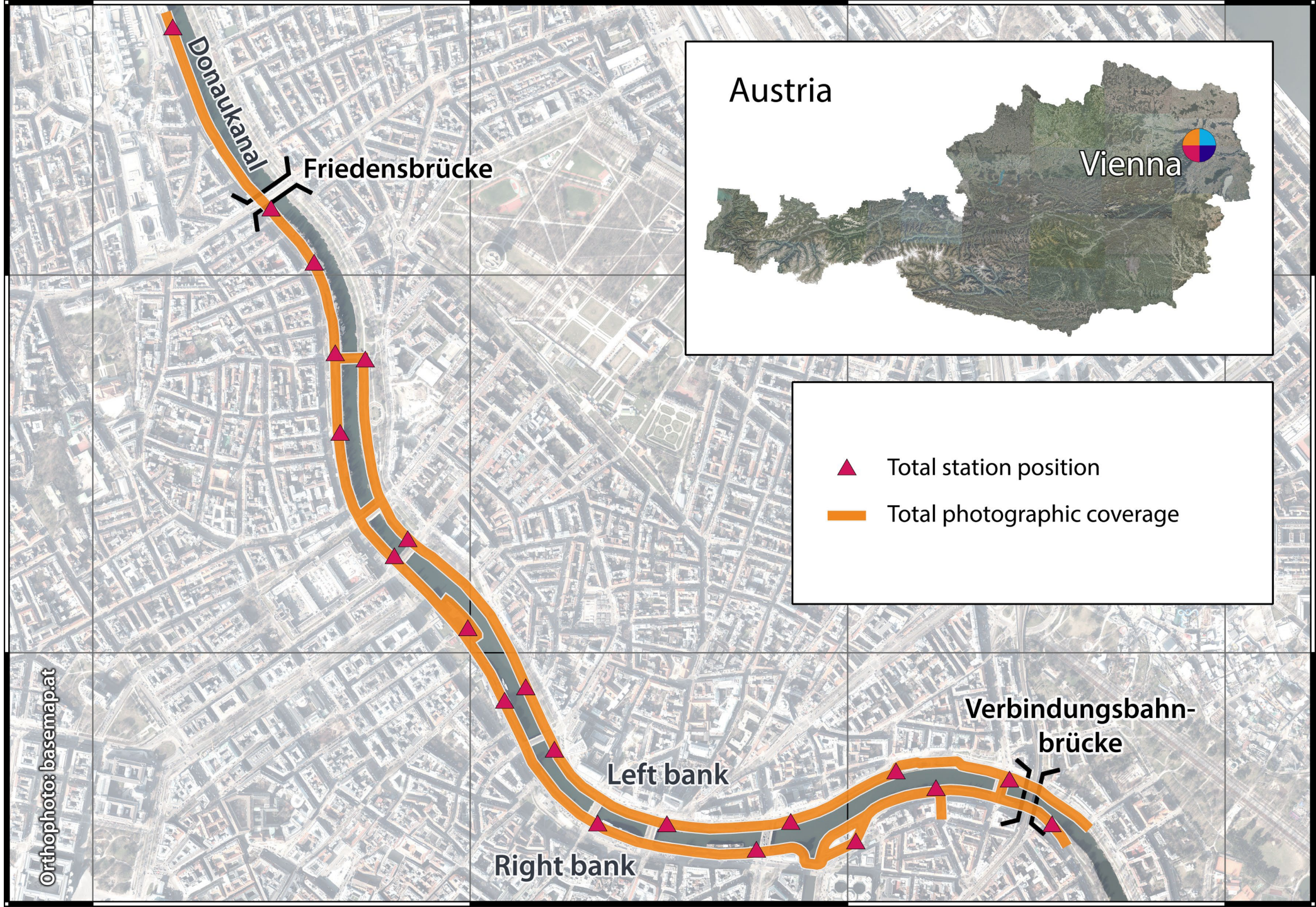


TOTAL COVERAGE

14.0 km

TOTAL STATION POSITIONS

21



TOTAL COVERAGE

14.0 km

TOTAL STATION POSITIONS

21



TOTAL COVERAGE

14.0 km

TOTAL STATION POSITIONS

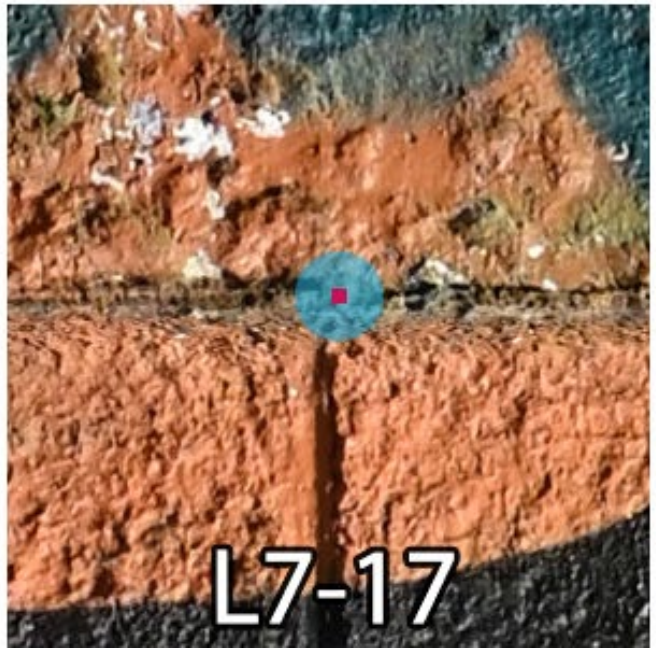
21

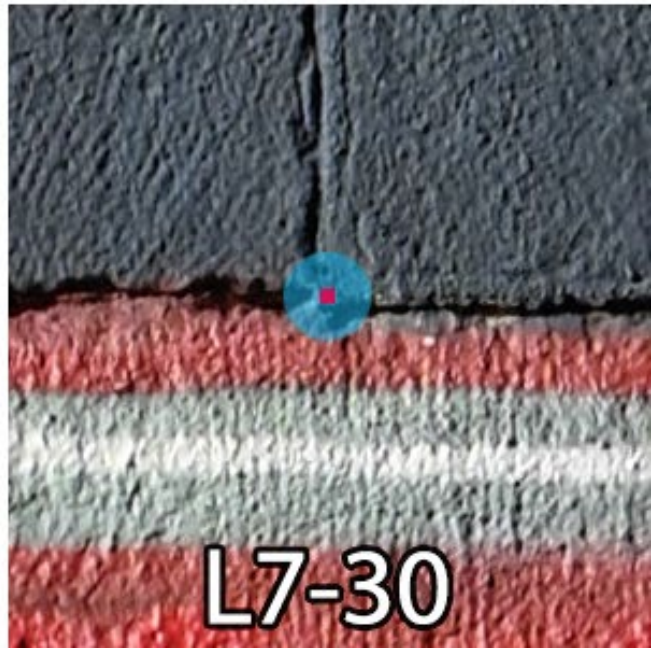
GRAFFITI-SCAPE POINTS

624

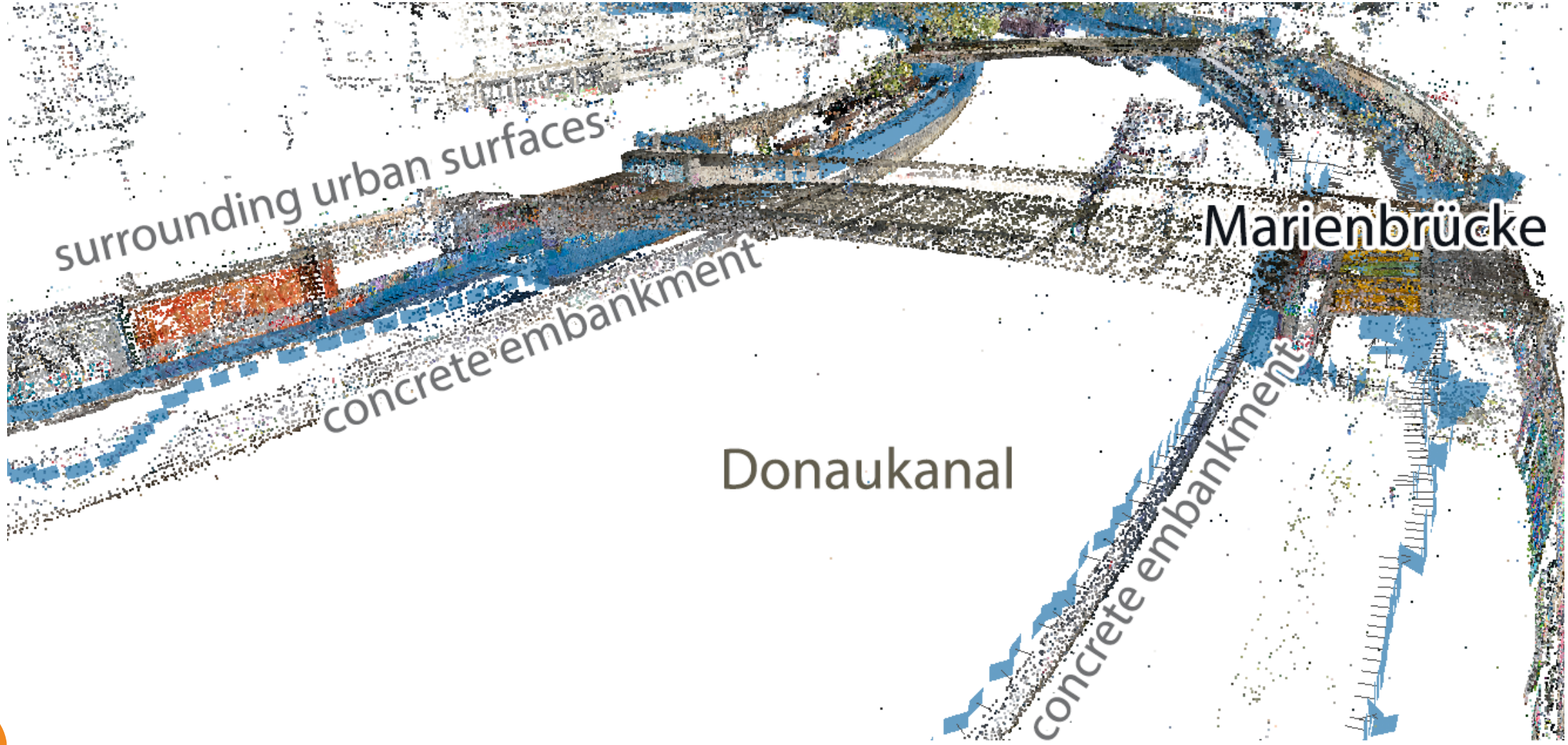




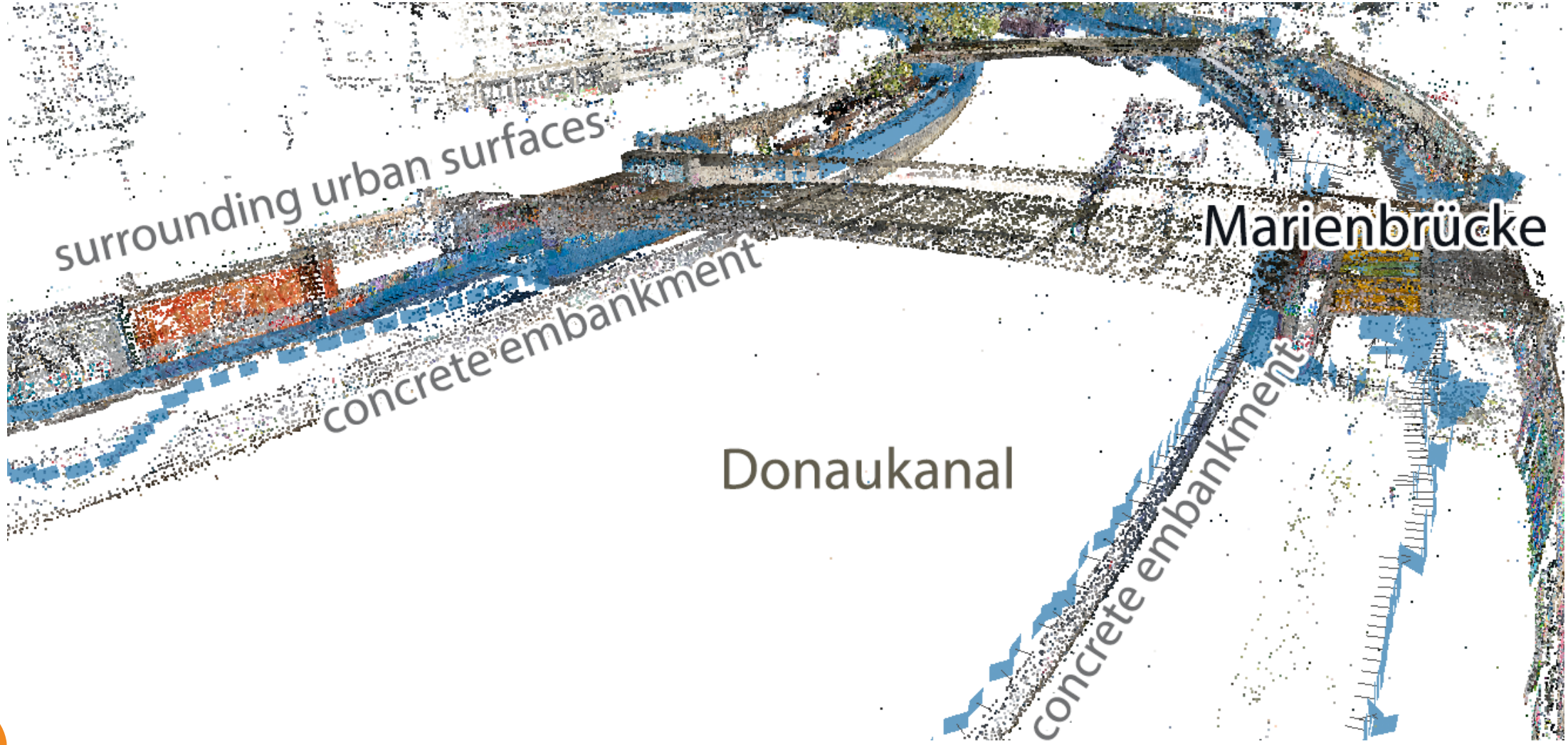




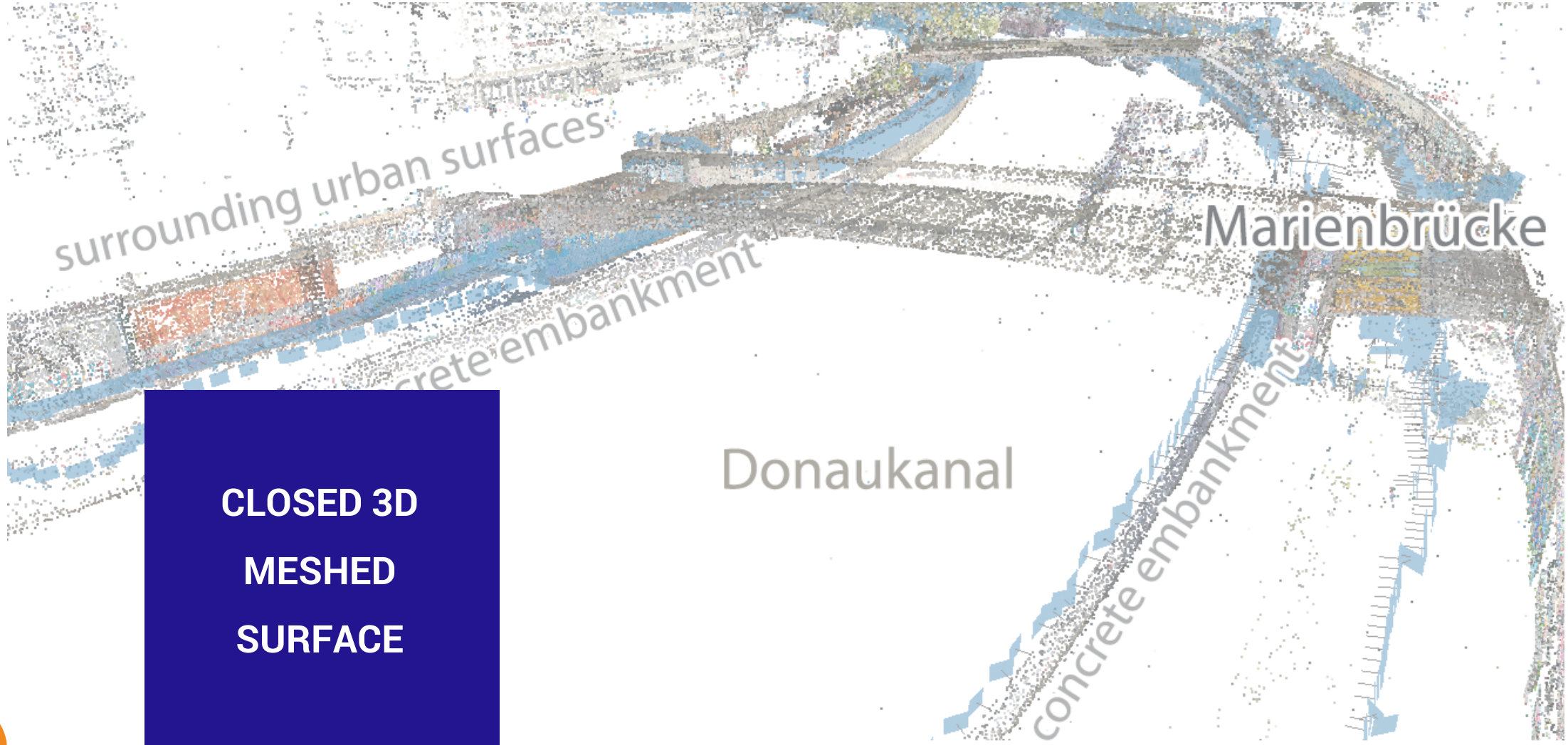
CAMERA orientation



THREE purposes

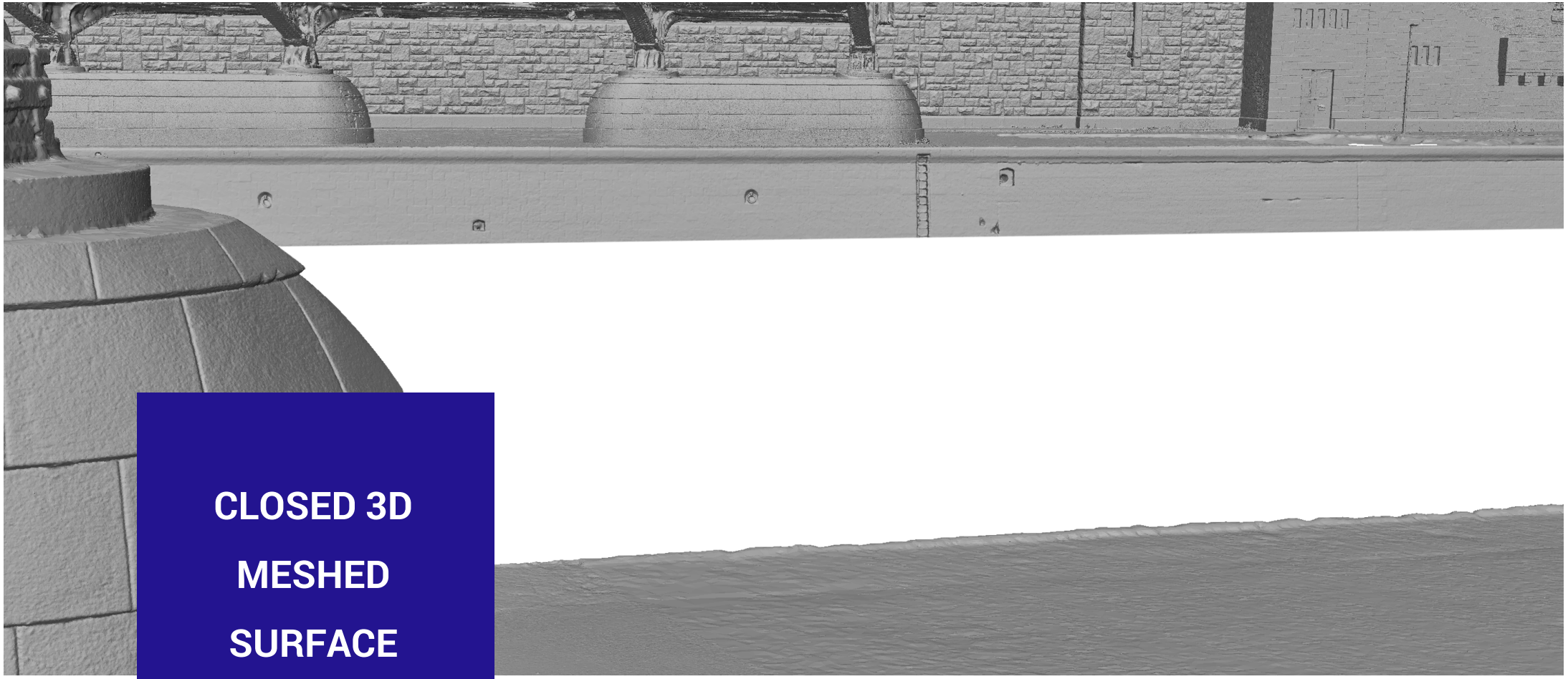


THREE purposes



CLOSED 3D MESHED SURFACE

THREE purposes

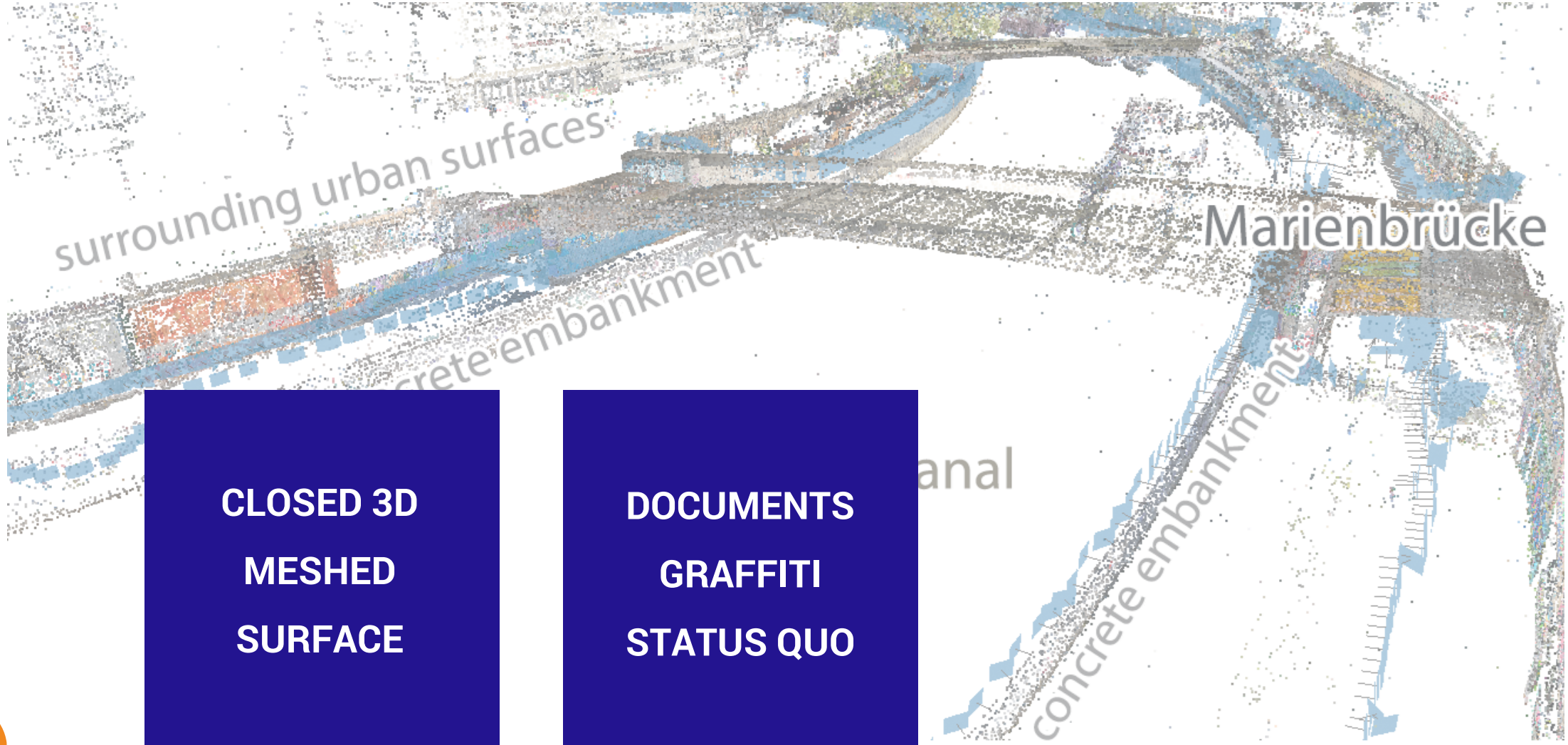


CLOSED 3D

MESHED

SURFACE

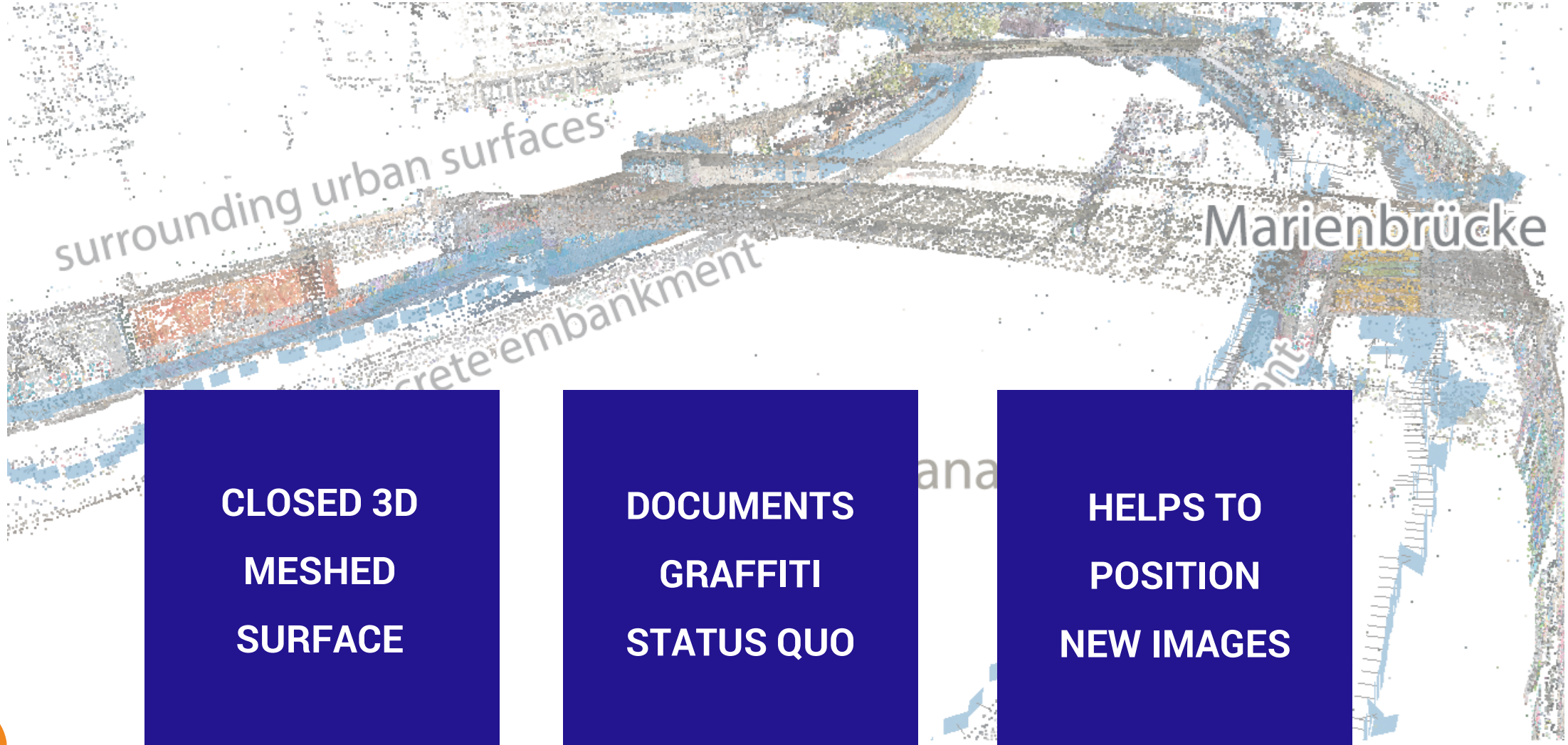
THREE purposes



CLOSED 3D MESHED SURFACE

DOCUMENTS GRAFFITI STATUS QUO

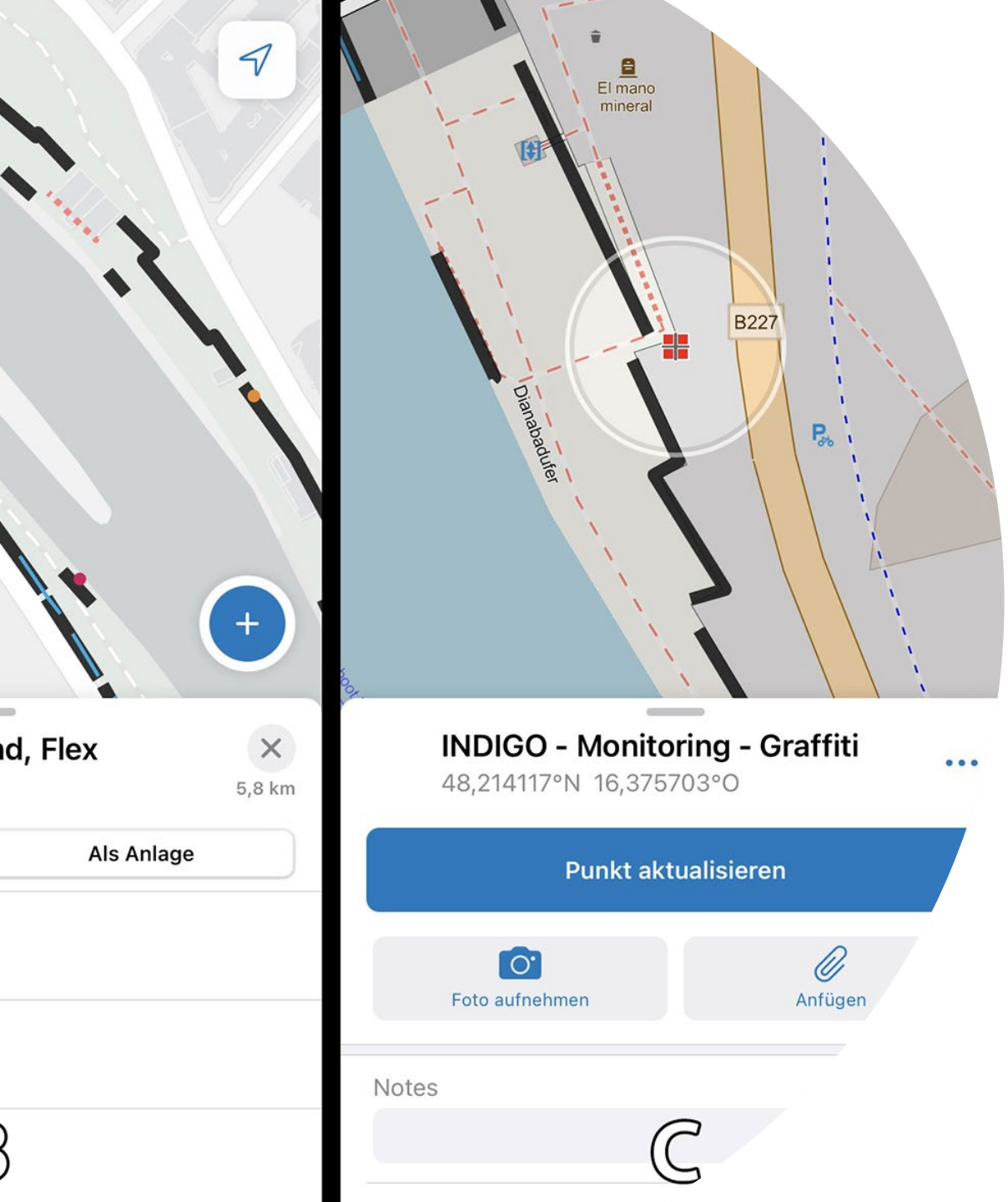
THREE purposes



CLOSED 3D MESHED SURFACE

DOCUMENTS GRAFFITI STATUS QUO

HELPS TO POSITION NEW IMAGES



FOLLOW-UP
photography

Instagram + monitoring app



FOLLOW-UP
photography

Instagram + monitoring app

2 photographers



FOLLOW-UP
photography

Instagram + monitoring app

2 photographers

2 cameras + 2 spectrometers + 2 tablets

identically programmed



FOLLOW-UP
photography

Instagram + monitoring app

2 photographers

2 cameras + 2 spectrometers + 2 tablets

identically programmed

fixed acquisition procedure


Hardware
relies on
'Follow-up' workflow
generates
Output
has
Purpose

Hardware *relies on* 'Follow-up' workflow *generates* Output *has* Purpose



Check the map

Hardware *relies on* 'Follow-up' workflow *generates* Output *has* Purpose



Check the map

↓

Move to closest new graffito

Hardware *relies on* 'Follow-up' workflow *generates* Output *has* Purpose





- Check the map
- Move to closest new graffito
- Focus on ColorChecker

Hardware *relies on* 'Follow-up' workflow *generates* Output *has* Purpose





Check the map

↓

Move to closest new graffito

↓

Focus on ColorChecker

↓

Photograph ColorChecker

1 ColorChecker photo



1. Subdivide photo series

Hardware	relies on	'Follow-up' workflow	generates	Output	has	Purpose







Check the map

↓

Move to closest new graffito

↓

Focus on ColorChecker

↓

Photograph ColorChecker

↓

Measure illumination

1 ColorChecker photo



1 illumination spectrum



1. Subdivide photo series
2. Establish link with spectrometer file
3. Generate correct photo colours (backup)

Generate correct photo colours

Hardware	relies on	'Follow-up' workflow	generates	Output	has	Purpose









Check the map

↓

Move to closest new graffito

↓

Focus on ColorChecker

↓

Photograph ColorChecker

↓

Measure illumination

↓

large graffito → Move maximum 3 m away from graffito

small graffito → Move maximum 2 m away from graffito

↓

Focus on graffito

1 ColorChecker photo



1 illumination spectrum



1. Subdivide photo series
2. Establish link with spectrometer file
3. Generate correct photo colours (backup)

Generate correct photo colours

Hardware *relies on* 'Follow-up' workflow *generates* Output *has* Purpose











- Check the map
- Move to closest new graffito
- Focus on ColorChecker
- Photograph ColorChecker
- Measure illumination
- *large graffito*: Move maximum 3 m away from graffito
- *small graffito*: Move maximum 2 m away from graffito
- Focus on graffito
- Move farther away / Move closer or farther
- Acquire overview photo

1 ColorChecker photo



1. Subdivide photo series
2. Establish link with spectrometer file
3. Generate correct photo colours (backup)

1 illumination spectrum



Generate correct photo colours

1 overview photo



1. Extract graffito outlines
2. Generate tour overview photos
3. Estimate interior & exterior camera orientations

Hardware	relies on	'Follow-up' workflow	generates	Output	has	Purpose













Check the map

Move to closest new graffito

Focus on ColorChecker

Photograph ColorChecker

Measure illumination

large graffito / *small graffito*

Move maximum 3 m away from graffito / Move maximum 2 m away from graffito

Focus on graffito

Move farther away / Move closer or farther

Acquire overview photo

Move again to 3 m from graffito / Move again to 2 m from graffito

Acquire strong network of many overlapping photos of the graffito and its surroundings

1 ColorChecker photo



1 illumination spectrum



1. Subdivide photo series
2. Establish link with spectrometer file
3. Generate correct photo colours (backup)

Generate correct photo colours

1 overview photo



1. Extract graffito outlines
2. Generate tour overview photos
3. Estimate interior & exterior camera orientations

[5, ∞[detailed graffito photos



1. Estimate interior & exterior camera orientations
2. Produce 3D model texture
3. Generate orthophoto mosaic

Hardware	relies on	'Follow-up' workflow	generates	Output	has	Purpose
		Check the map				
		↓				
		Move to closest new graffito				
		↓				
		Focus on ColorChecker				
		↓				
		Photograph ColorChecker		1 ColorChecker photo 		1. Subdivide photo series 2. Establish link with spectrometer file 3. Generate correct photo colours (backup)
		↓				
		Measure illumination		1 illumination spectrum 		Generate correct photo colours
		large graffito ↓ / *small graffito* ↓				
		Move maximum 3 m away from graffito / Move maximum 2 m away from graffito				
		↓				
		Focus on graffito				
		↓				
		Move farther away / Move closer or farther				
		↓				
		Acquire overview photo		1 overview photo 		1. Extract graffito outlines 2. Generate tour overview photos 3. Estimate interior & exterior camera orientations
		↓				
		Move again to 3 m from graffito / Move again to 2 m from graffito				
		↓				
		Acquire strong network of many overlapping photos of the graffito and its surroundings		[5, ∞[detailed graffito photos 		1. Estimate interior & exterior camera orientations 2. Produce 3D model texture 3. Generate orthophoto mosaic
		↓				
		Update the map		Updated monitoring map		Guide follow-up photography

Hardware	relies on	'Follow-up' workflow	generates	Output	has	Purpose





Check the map

Move to closest new graffito

Focus on ColorChecker

Photograph ColorChecker

Measure illumination

large graffito / *small graffito*

Move maximum 3 m away from graffito / Move maximum 2 m away from graffito

Focus on graffito

Move farther away / Move closer or farther

Acquire overview photo

Move again to 3 m from graffito / Move again to 2 m from graffito

Acquire strong network of many overlapping photos of the graffito and its surroundings

Update the map

1 ColorChecker photo

1. Subdivide photo series
2. Establish link with spectrometer file
3. Generate correct photo colours (backup)

1 illumination spectrum

Generate correct photo colours

1 overview photo

1. Extract graffito outlines
2. Generate tour overview photos
3. Estimate interior & exterior camera orientations

[5, ∞[detailed graffito photos



1. Estimate interior & exterior camera orientations
2. Produce 3D model texture
3. Generate orthophoto mosaic

Updated monitoring map

Guide follow-up photography

Hardware	relies on	'Follow-up' workflow	generates	Output	has	Purpose



Check the map

Move to closest new graffito

Focus on ColorChecker

Photograph ColorChecker

Measure illumination

large graffito / *small graffito*

Move maximum 3 m away from graffito / Move maximum 2 m away from graffito

Focus on graffito

Move farther away / Move closer or farther

Acquire overview photo

Move again to 3 m from graffito / Move again to 2 m from graffito

Acquire strong network of many overlapping photos of the graffito and its surroundings



Update the map

1 ColorChecker photo

1. Subdivide photo series
2. Establish link with spectrometer file
3. Generate correct photo colours (backup)

1 illumination spectrum

Generate correct photo colours

1 overview photo

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2. Generate tour overview photos
3. Estimate interior & exterior camera orientations

[5, ∞[detailed graffito photos

1. Estimate interior & exterior camera orientations
2. Produce 3D model texture
3. Generate orthophoto mosaic

Updated monitoring map

Guide follow-up photography

ACCURATE photo coordinates



ACCURATE photo coordinates



RTK GNSS receiver

GPS & Galileo satellites
L1/L2/L5 multi-band
RTK

Position

ACCURATE photo coordinates



RTK GNSS receiver

GPS & Galileo satellites
L1/L2/L5 multi-band
RTK

Position

IMU

3-axis gyroscope
3-axis accelerometer
3-axis magnetometer

Rotation

ACCURATE photo coordinates



RTK GNSS receiver

GPS & Galileo satellites
L1/L2/L5 multi-band
RTK

Position

IMU

3-axis gyroscope
3-axis accelerometer
3-axis magnetometer

Rotation

Feedback

LEDs & status display

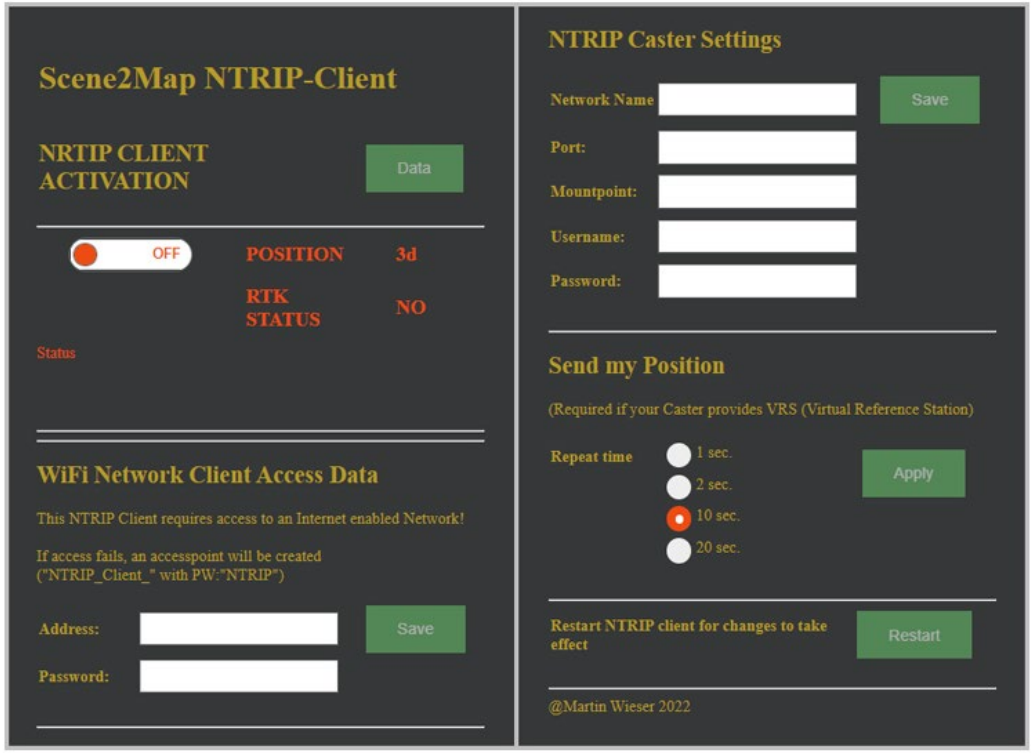
ACCURATE photo coordinates



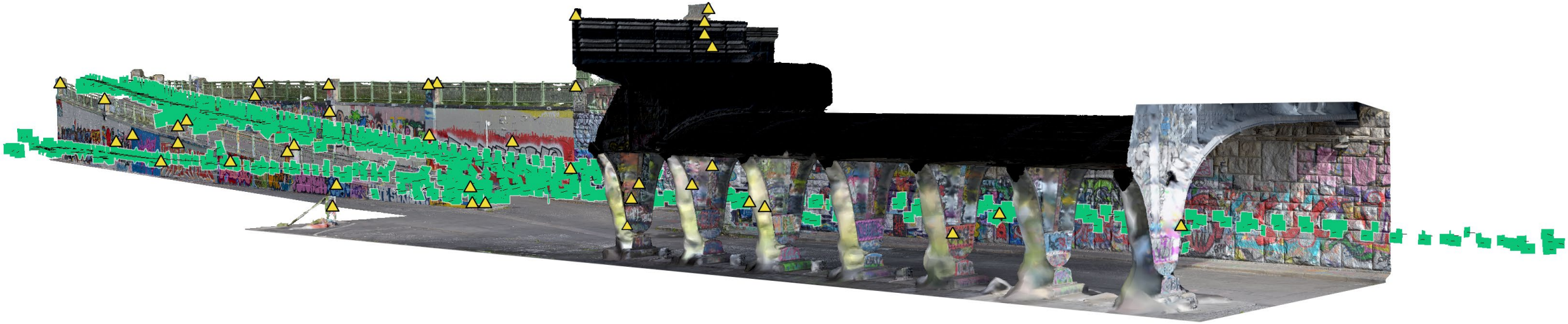


ACCURATE photo coordinates

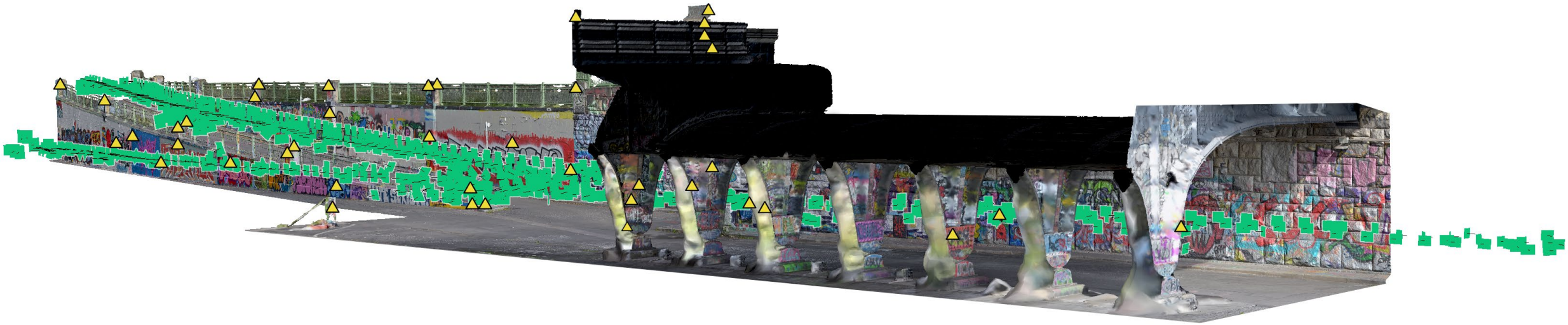




ACCURATE photo coordinates



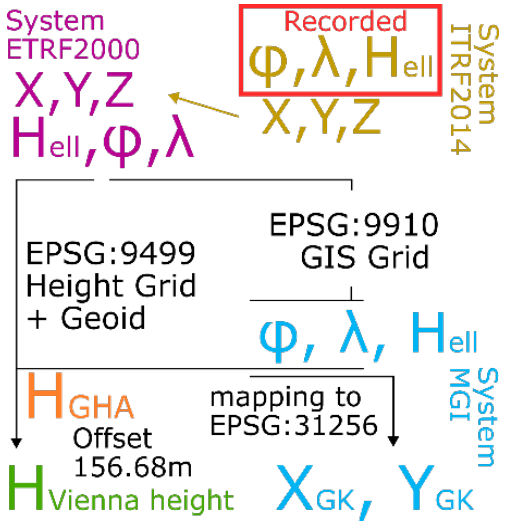
ACCURATE photo coordinates



Georeferencing accuracy metric	Value
$RMSE_x$	5.3 mm
$RMSE_y$	4.0 mm
$RMSE_{xy}$ (total planimetric accuracy)	6.6 mm
$RMSE_z$	5.8 mm
$RMSE_{xyz}$ (total 3D positional accuracy)	8.8 mm

ACCURATE photo coordinates



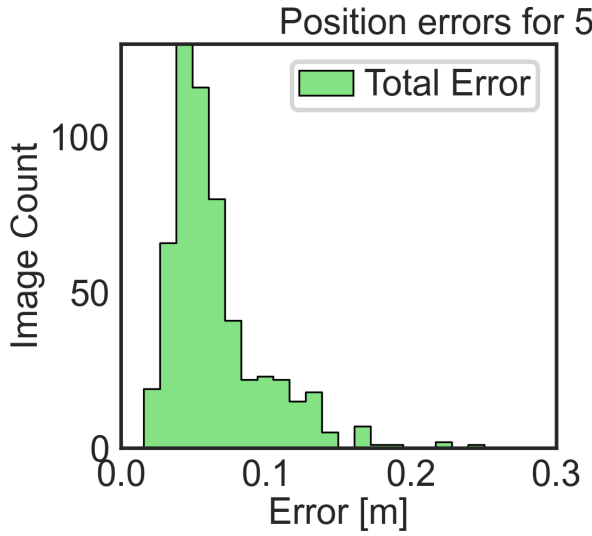


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ACCURATE photo coordinates

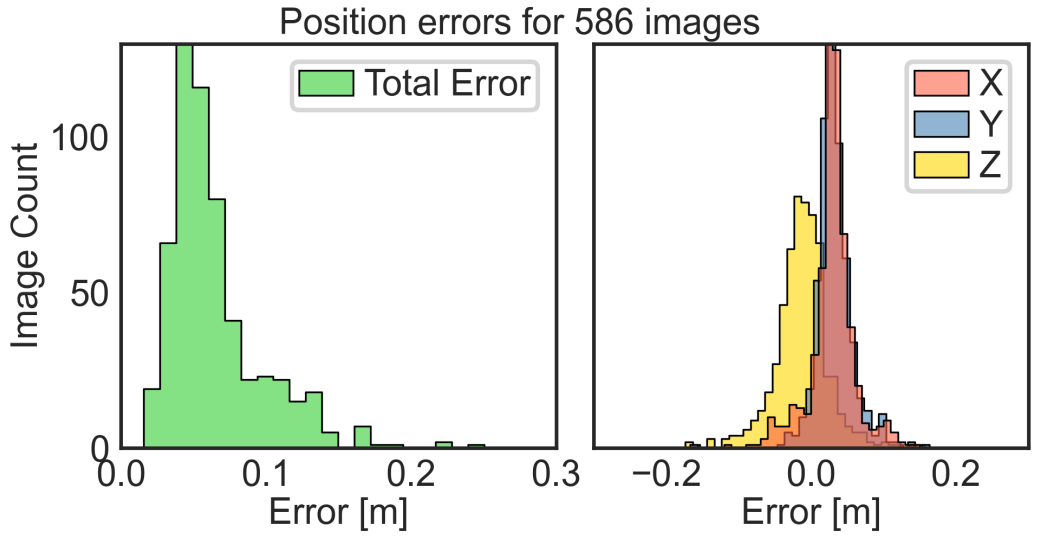


ACCURATE photo coordinates



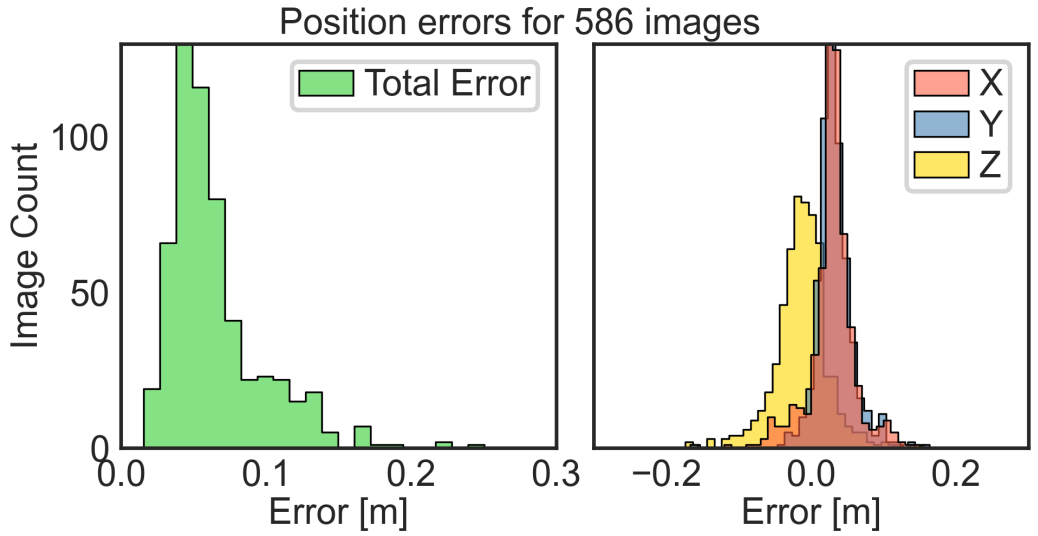
Error	X [cm]	Y [cm]	Z [cm]	Total [cm]
Mean	2.9	2.8	-1.9	6.5
Median	3.0	2.5	-1.8	5.4
St. Dev.	3.1	2.7	4.4	3.9
RMSE	4.3	3.9	4.8	7.6

ACCURATE photo coordinates



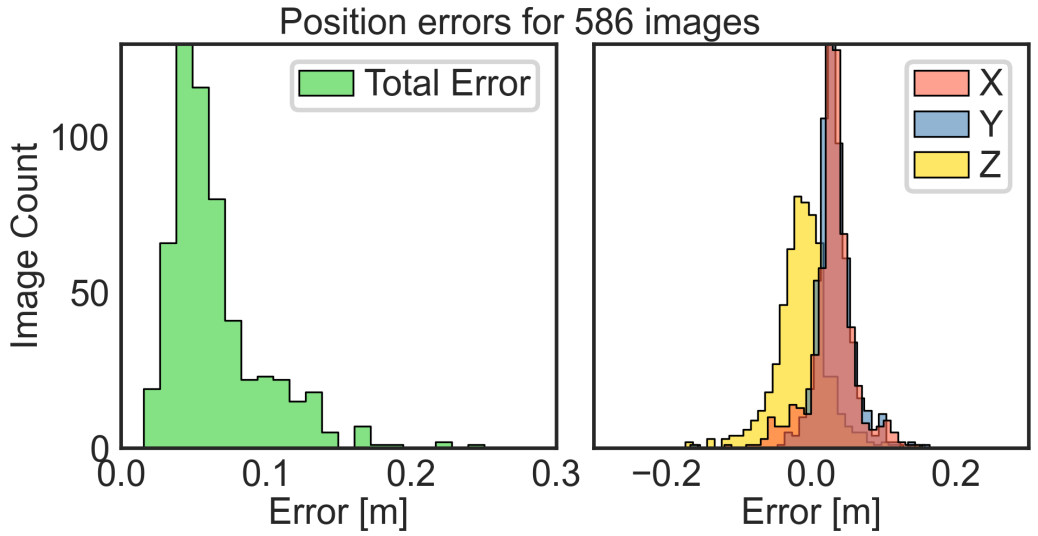
Error	X [cm]	Y [cm]	Z [cm]	Total [cm]
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RMSE	4.3	3.9	4.8	7.6

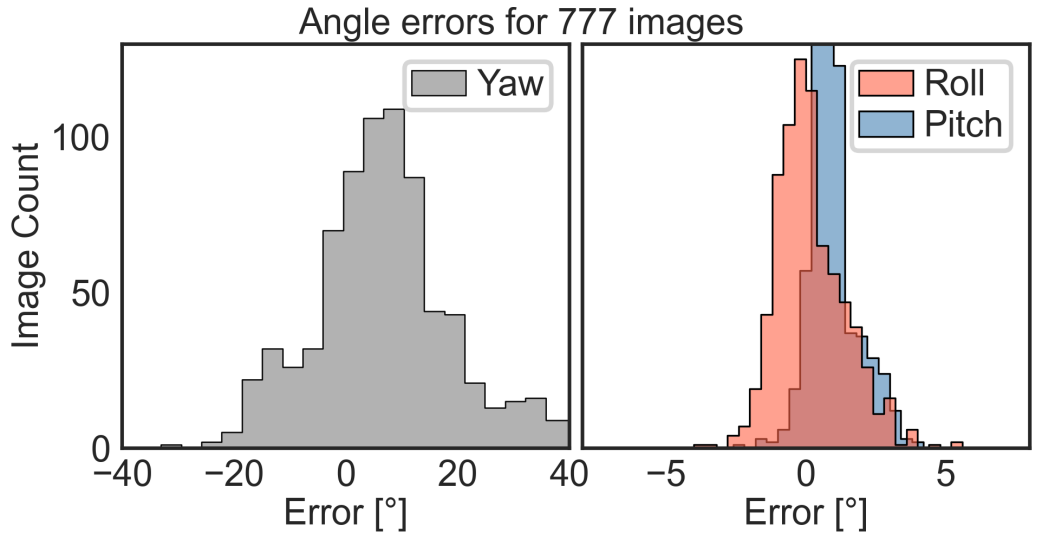
ACCURATE photo coordinates



Error	X [cm]	Y [cm]	Z [cm]	Total [cm]	Roll [°]	Pitch [°]	Yaw [°]
Mean	2.9	2.8	-1.9	6.5	0.17	0.73	2.93
Median	3.0	2.5	-1.8	5.4	0.01	0.59	1.79
St. Dev.	3.1	2.7	4.4	3.9	1.22	0.81	15.3
RMSE	4.3	3.9	4.8	7.6	1.23	1.09	15.6

ACCURATE photo coordinates





Error	X [cm]	Y [cm]	Z [cm]	Total [cm]	Roll [°]	Pitch [°]	Yaw [°]
Mean	2.9	2.8	-1.9	6.5	0.17	0.73	2.93
Median	3.0	2.5	-1.8	5.4	0.01	0.59	1.79
St. Dev.	3.1	2.7	4.4	3.9	1.22	0.81	15.3
RMSE	4.3	3.9	4.8	7.6	1.23	1.09	15.6



IMAGE positioning

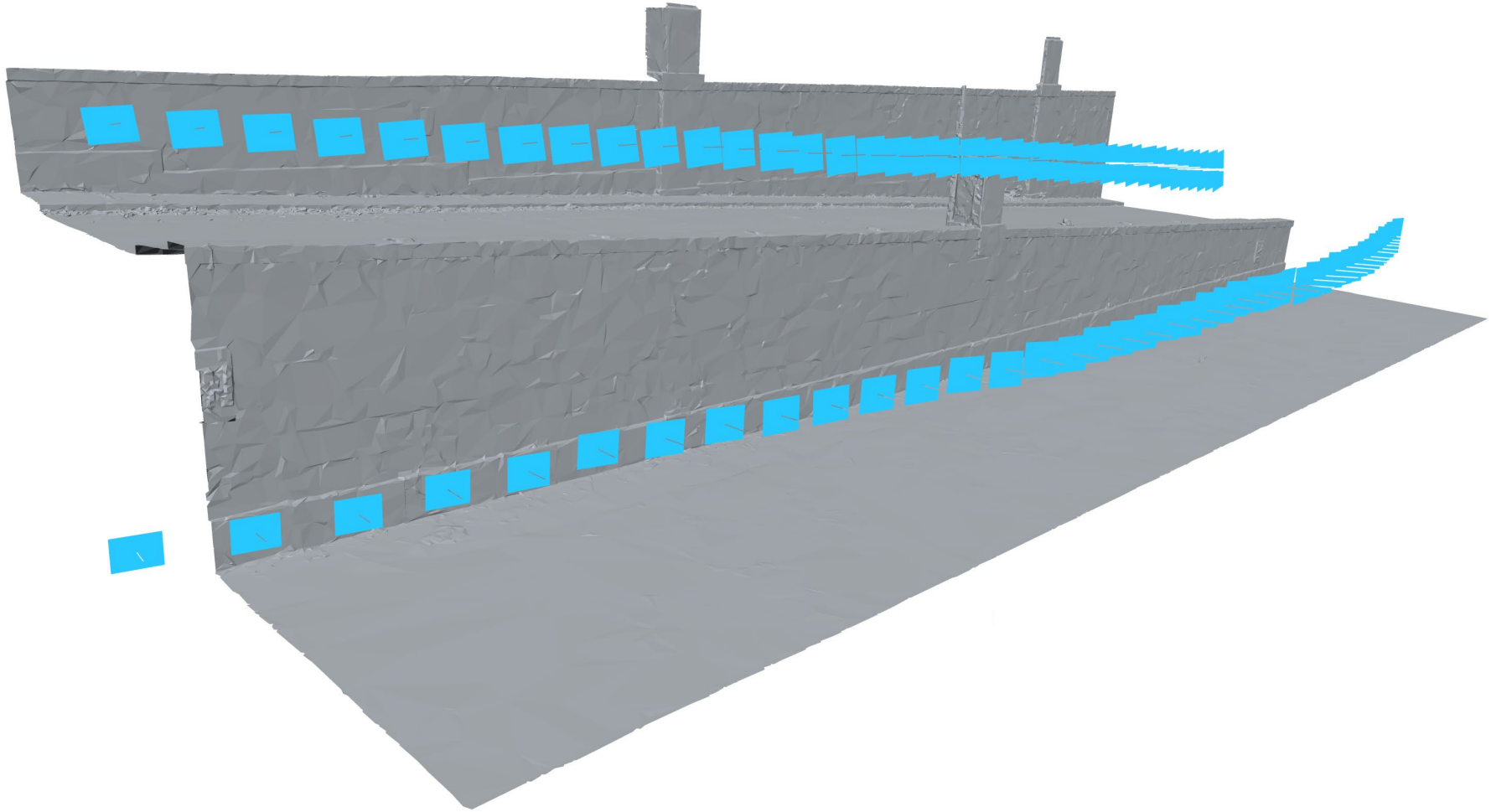


IMAGE positioning

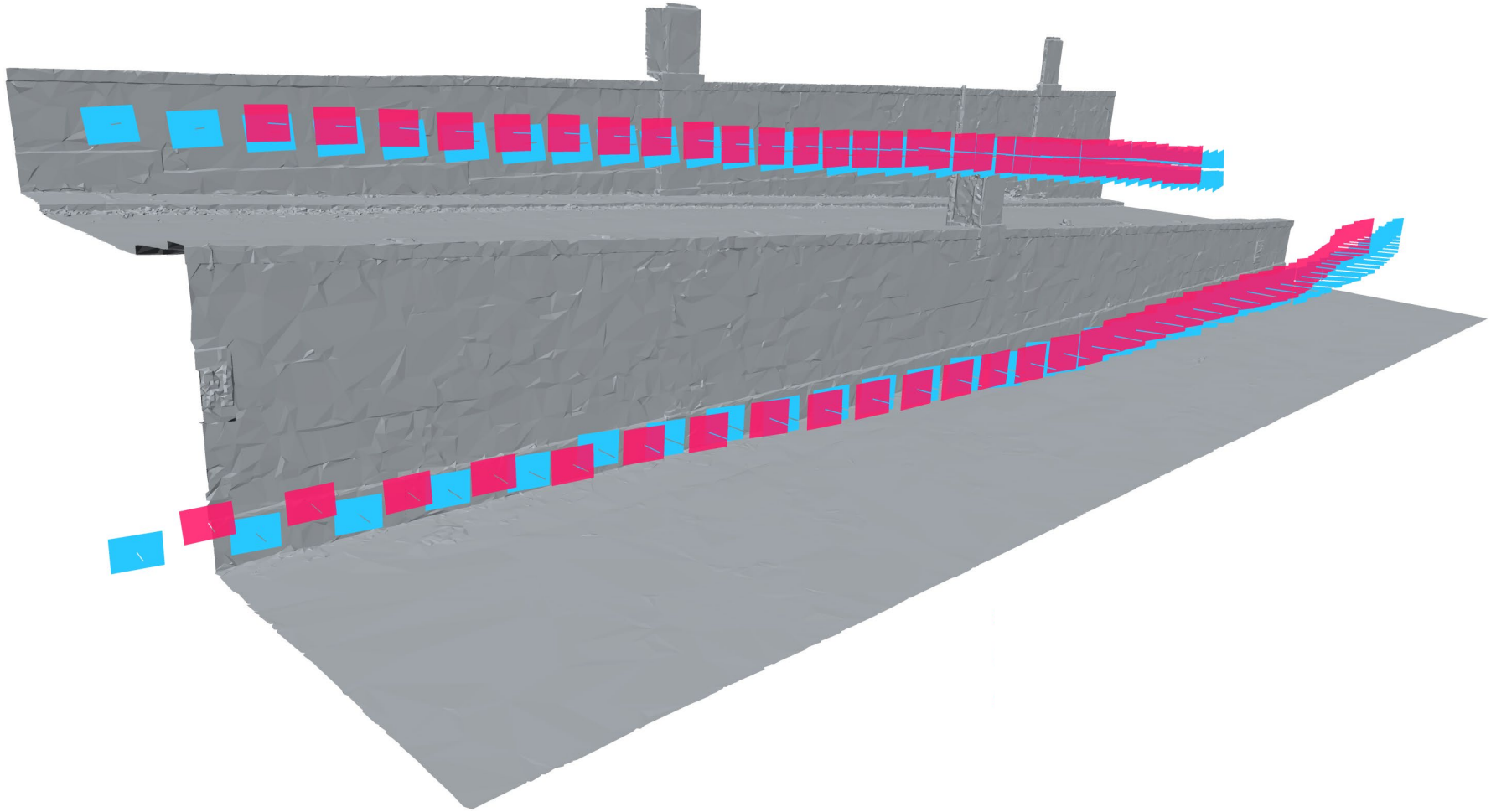
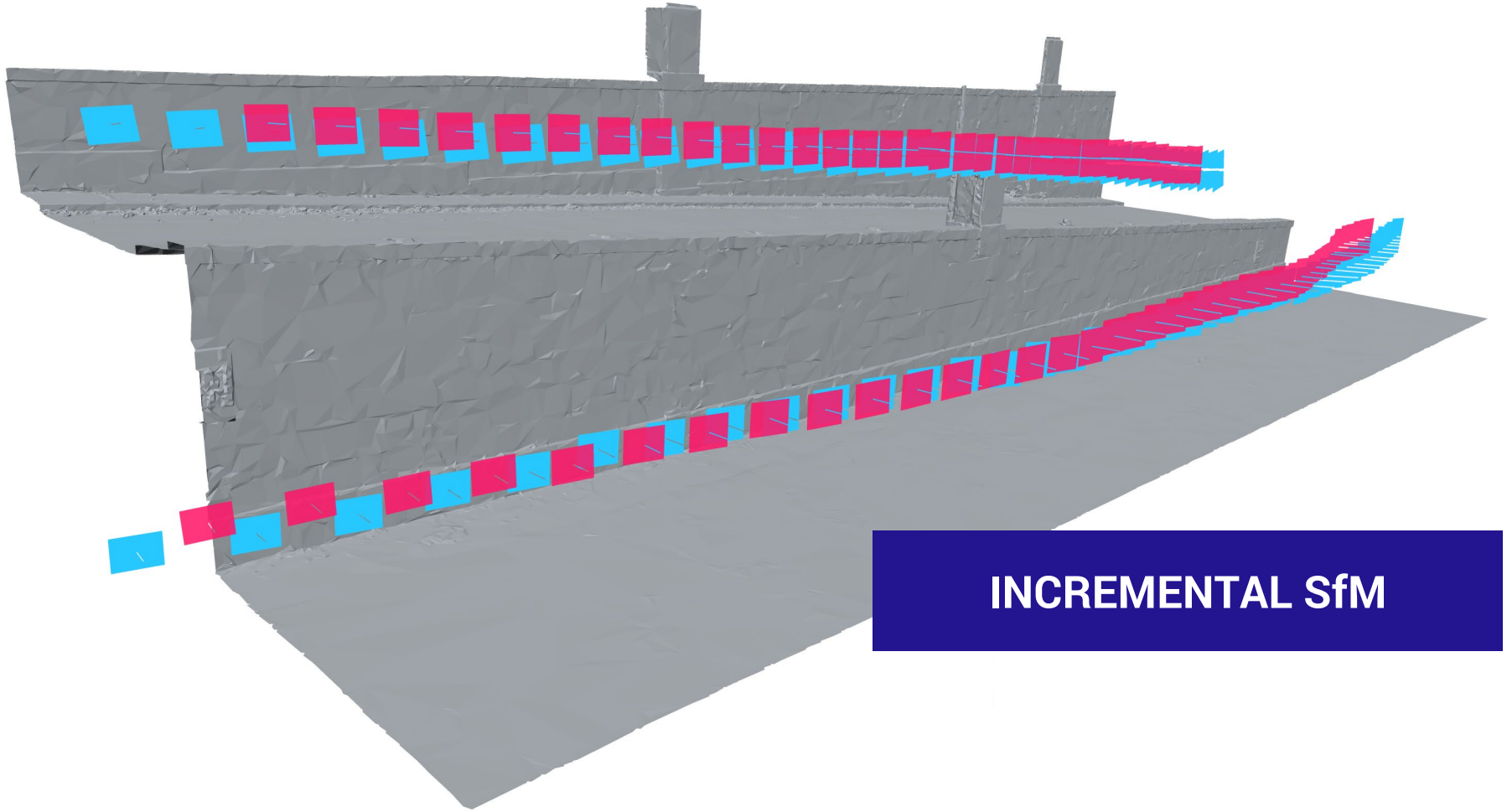
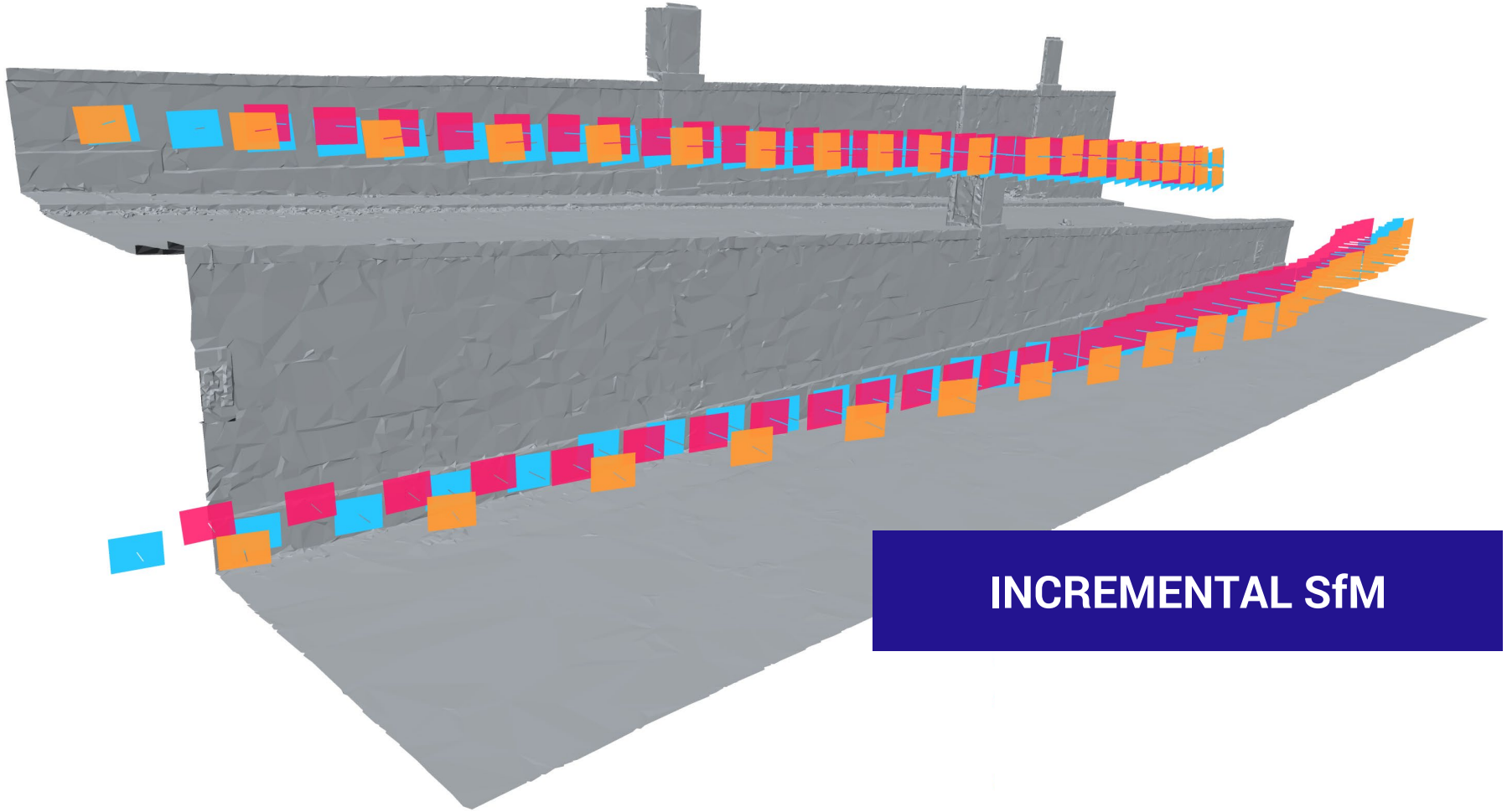


IMAGE positioning



INCREMENTAL SfM

IMAGE positioning



INCREMENTAL SfM

IMAGE positioning

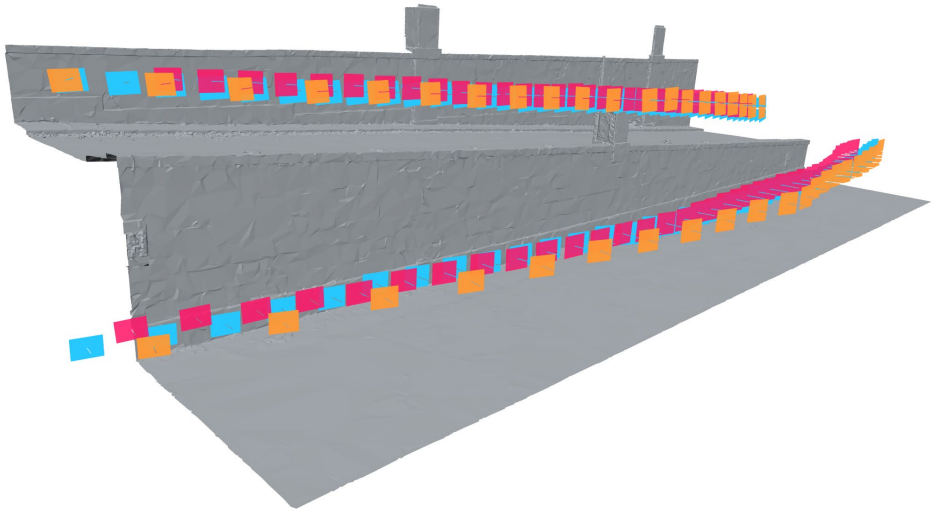
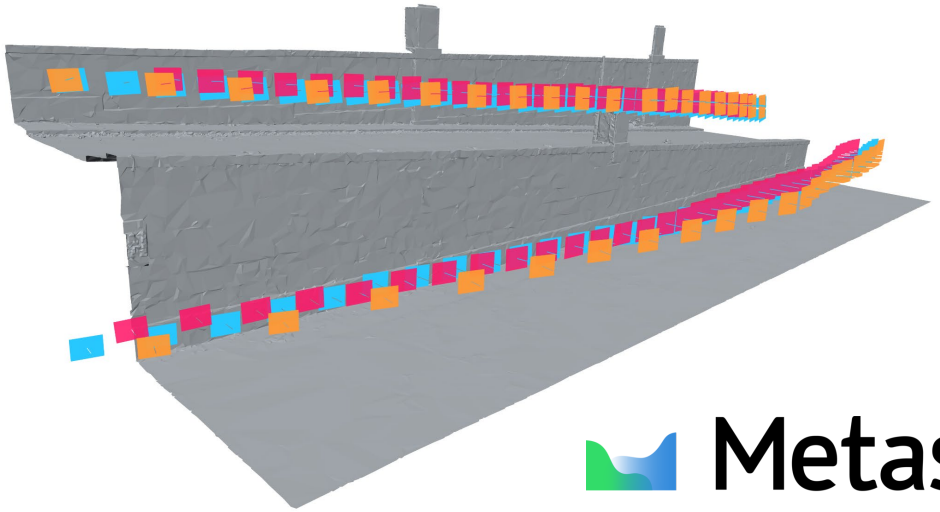








IMAGE positioning





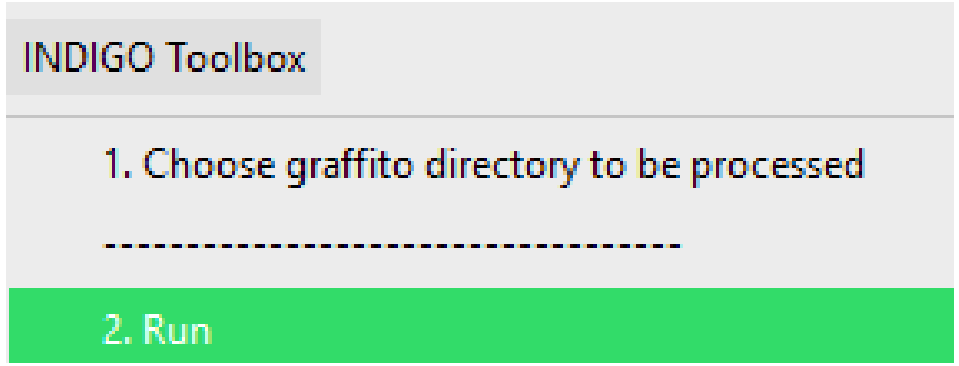
Metashape





python™

Metashape



AUTOGRAF

position-accurate pixels

AUTOGRAF

Product Solutions Open Source Pricing Search / Sign in Sign up

GraffitiProjectINDIGO / AUTOGRAF Public

Notifications Fork 0 Star 6

Code Issues Pull requests Actions Projects Security Insights

main 1 branch 0 tags Go to file Code

bewild96 Update README.md	75d27bb 15 days ago	24 commits
Heritage_ClassificationResults	Add files via upload	2 months ago
images	Add files via upload	last month
src	Add files via upload	2 months ago
LICENSE	Initial commit	2 months ago
README.md	Update README.md	15 days ago

README.md

Short Description

AUTOGRAF (**AUT**omated **O**rthorectification of **GRAF**fiti photos) is an open-source python-based Metashape add-on which enables the automated orthorectification of graffiti photos at a specific site of interest. It employs state-of-the art photogrammetric computer vision techniques to allow highly accurate georeferencing and orthorectification of large numbers of photographs. A paper detailing AUTOGRAF's methodology will soon be submitted to Heritage (an MDPI journal).

AUTOGRAF is developed as part of the INDIGO project (In-ventory and DI-sseminate G-raffiti along the d-O-naukanal) carried out by the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology in close collaboration with the GEO Department of TU Wien University.

How to set up AUTOGRAF

Before AUTOGRAF can be used, the following preparatory steps [1-3] need to be performed:

1 - Install Agisoft's Metashape

About

AUTomatic Orthorectification of GRAFfiti photos

photographs graffiti orthorectification

Readme
GPL-3.0 license
6 stars
1 watching
0 forks

Releases

No releases published

Packages

No packages published

Contributors 2

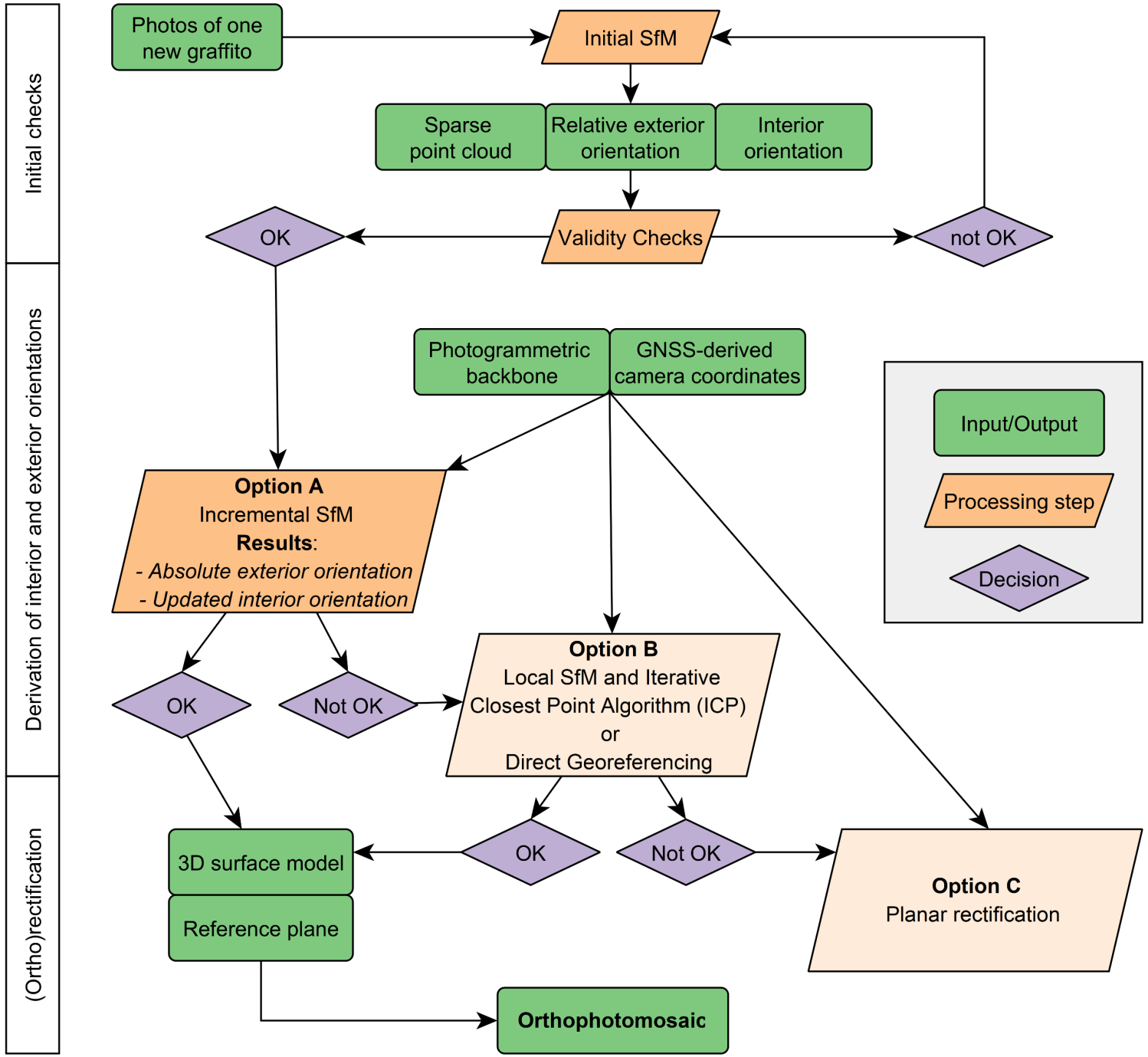
bewild96
BeyondConventionalBoundaries Geert ...

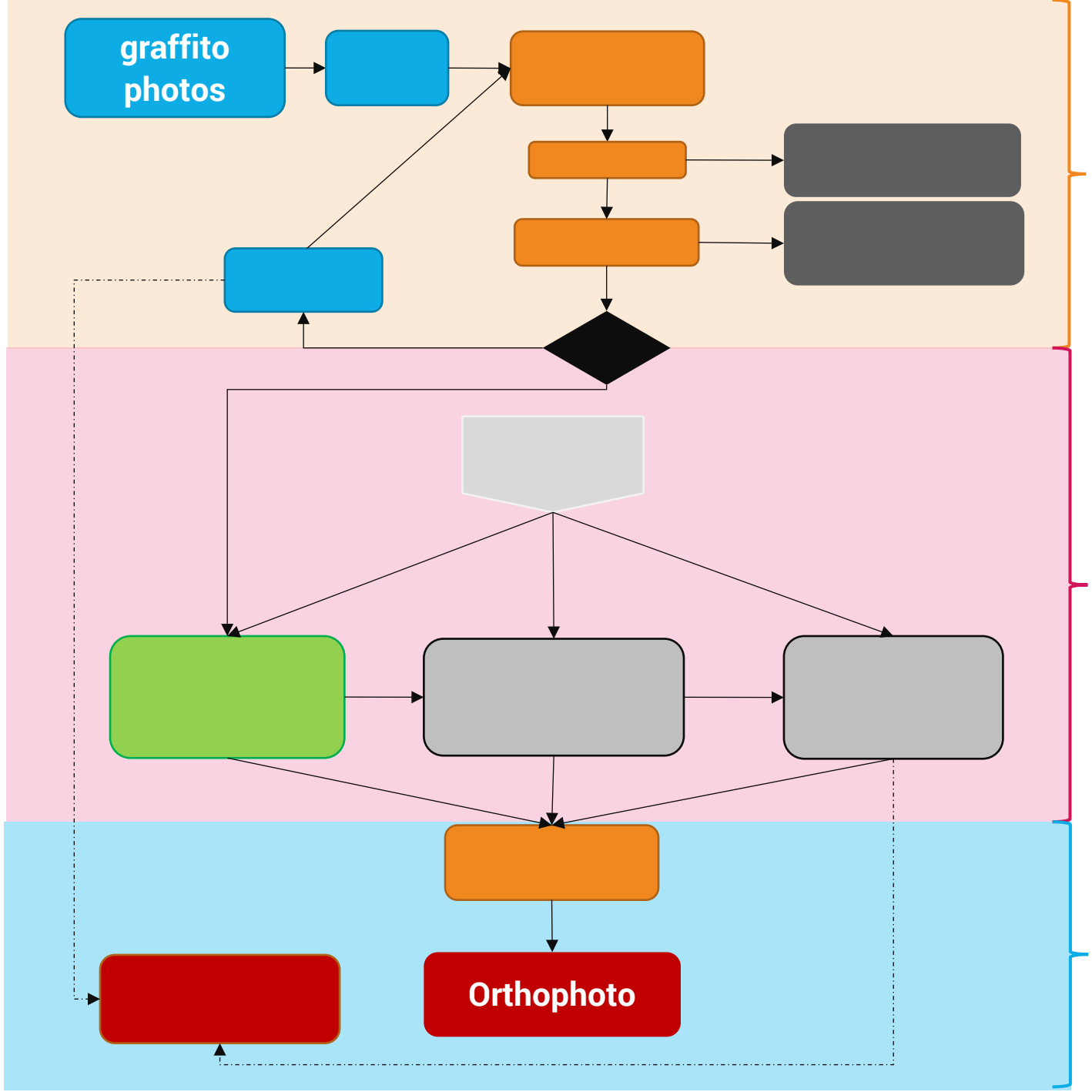
Languages

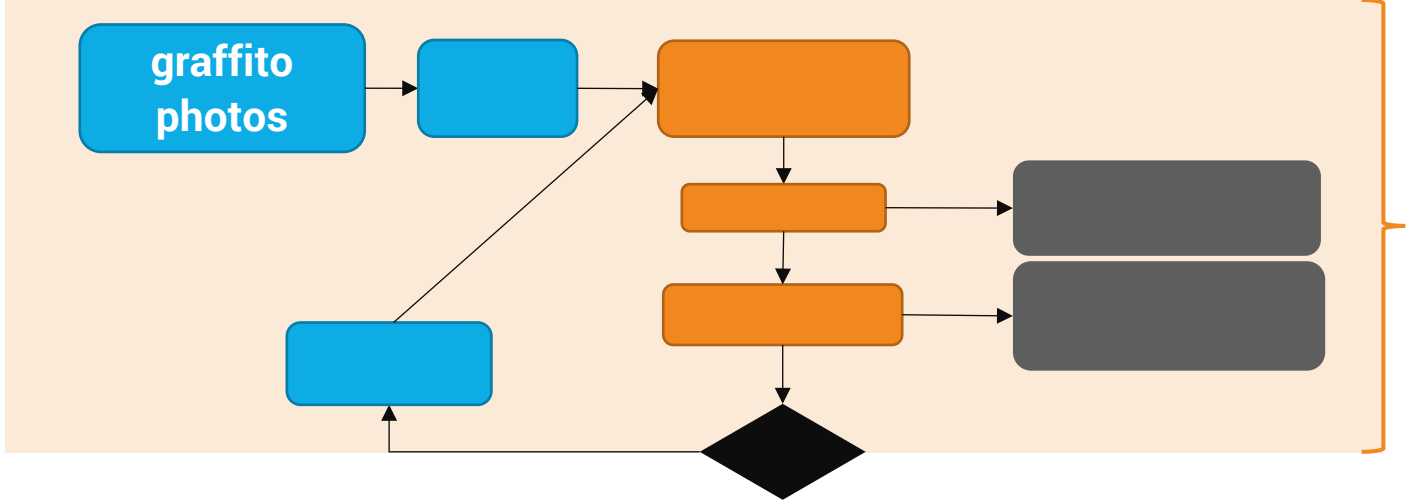
Python 100.0%

AUTOGRAF

position-accurate pixels


Initial checks
Derivation of interior and exterior orientations
(Ortho)rectification
Photos of one new graffito
Initial SfM
Sparse point cloud
Relative exterior orientation
Interior orientation
Validity Checks
OK
not OK
Photogrammetric backbone
GNSS-derived camera coordinates
Option A
Incremental SfM
Results:
- Absolute exterior orientation
- Updated interior orientation
OK
Not OK
Option B
Local SfM and Iterative Closest Point Algorithm (ICP)
or
Direct Georeferencing
OK
Not OK
3D surface model
Reference plane
Option C
Planar rectification
Orthophotomosaic
Input/Output
Processing step
Decision


graffito photos
Orthophoto
Initial checks
Camera orientations
Incremental SfM
3D surface model
Orthophoto




INDIGO_2021-12-28_Z7II-B_0292.jpg


INDIGO_2021-12-28_Z7II-B_0293.jpg


INDIGO_2021-12-28_Z7II-B_0294 - Copy.jpg


INDIGO_2021-12-28_Z7II-B_0294.jpg


INDIGO_2021-12-28_Z7II-B_0295.jpg

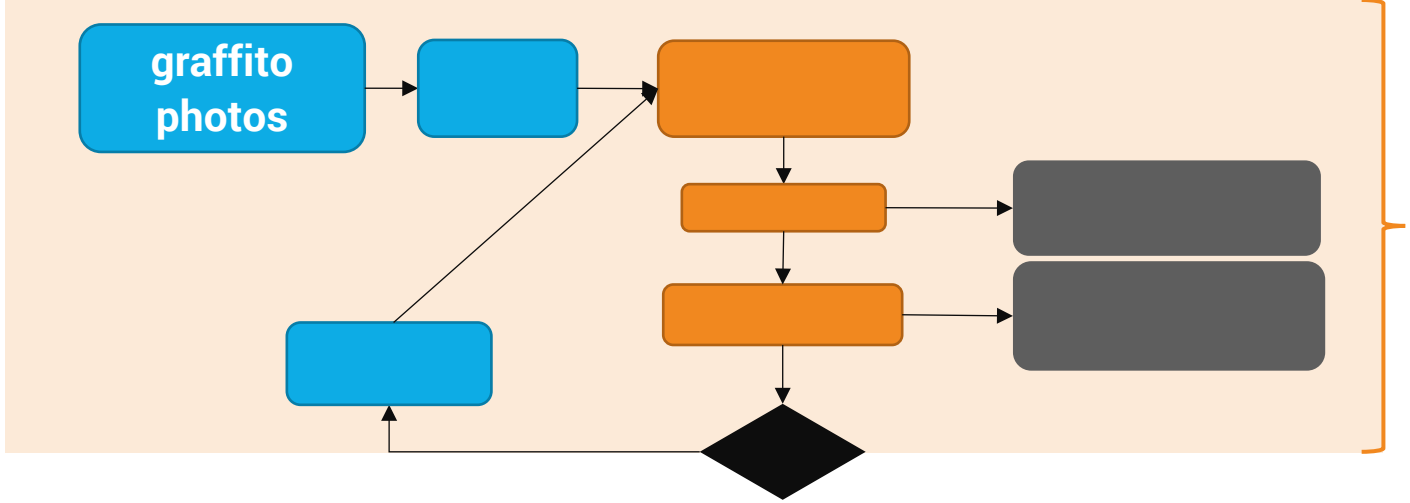

INDIGO_2021-12-28_Z7II-B_0296.jpg


INDIGO_2021-12-28_Z7II-B_0296a.jpg


INDIGO_2021-12-28_Z7II-B_0297.jpg


INDIGO_2021-12-28_Z7II-B_0298.jpg


INDIGO_2021-12-28_Z7II-B_0300.jpg



Initial checks


INDIGO_2021-12-28_Z7II-B_0292.jpg


INDIGO_2021-12-28_Z7II-B_0293.jpg


INDIGO_2021-12-28_Z7II-B_0294 - Copy.jpg


INDIGO_2021-12-28_Z7II-B_0294.jpg


INDIGO_2021-12-28_Z7II-B_0295.jpg

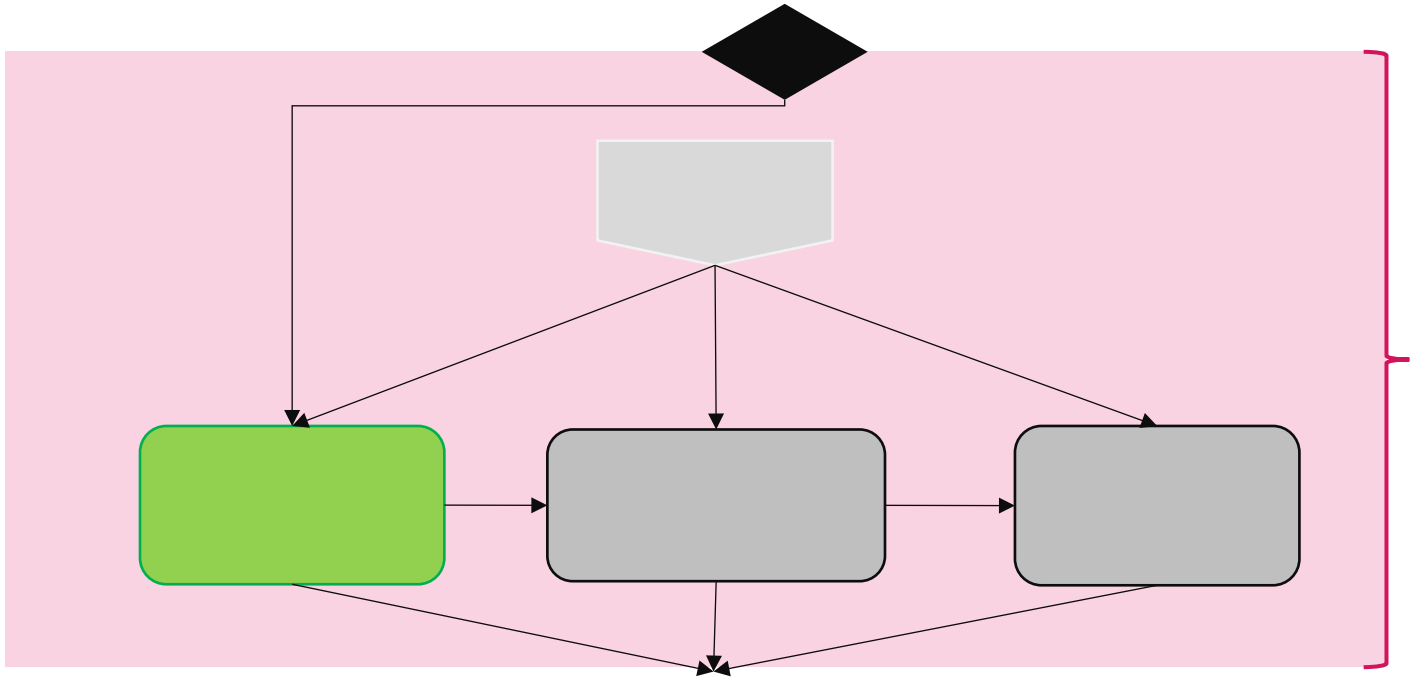

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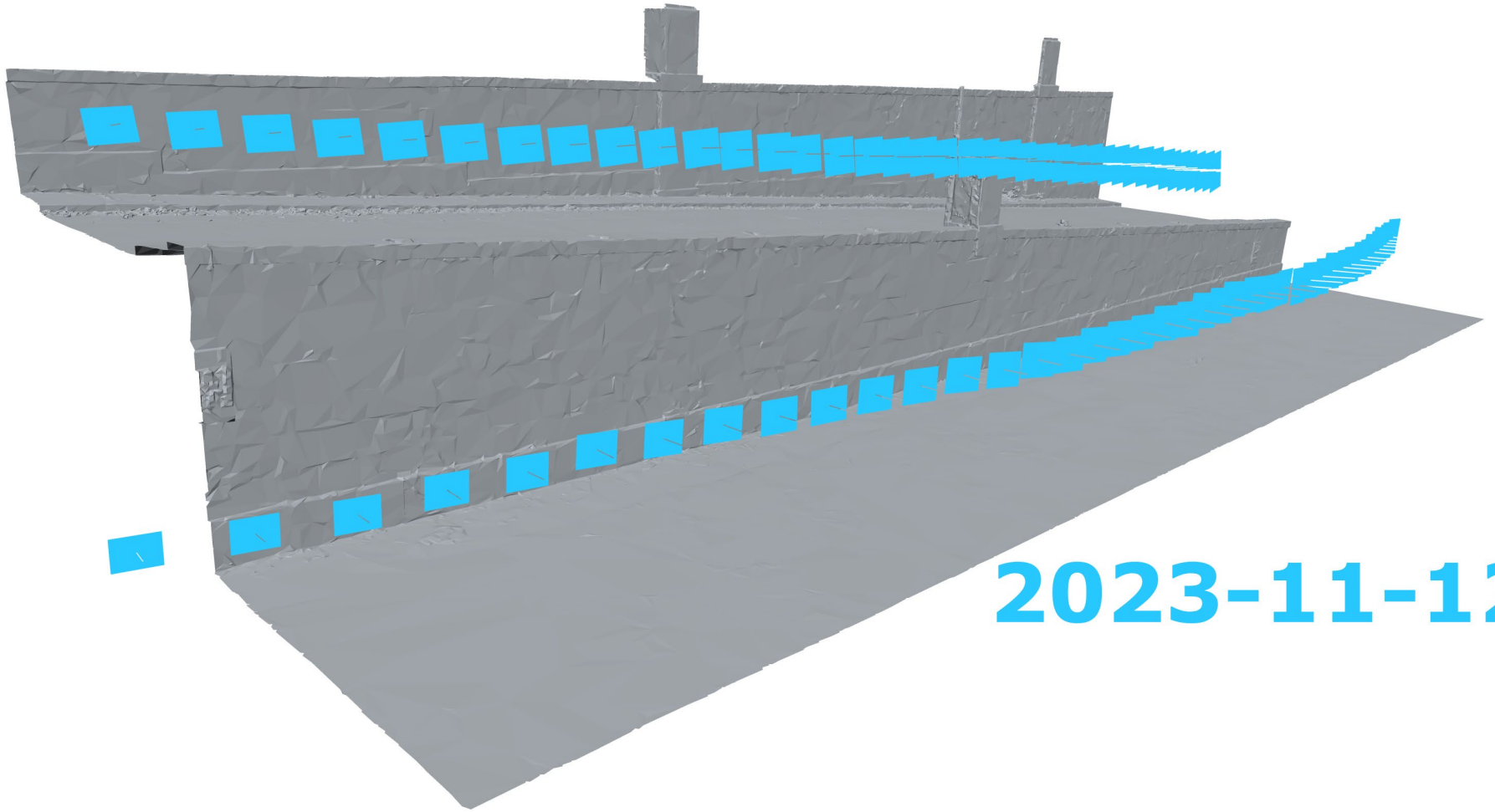

INDIGO_2021-12-28_Z7II-B_0298.jpg


INDIGO_2021-12-28_Z7II-B_0300.jpg



Camera orientations

Incremental SfM

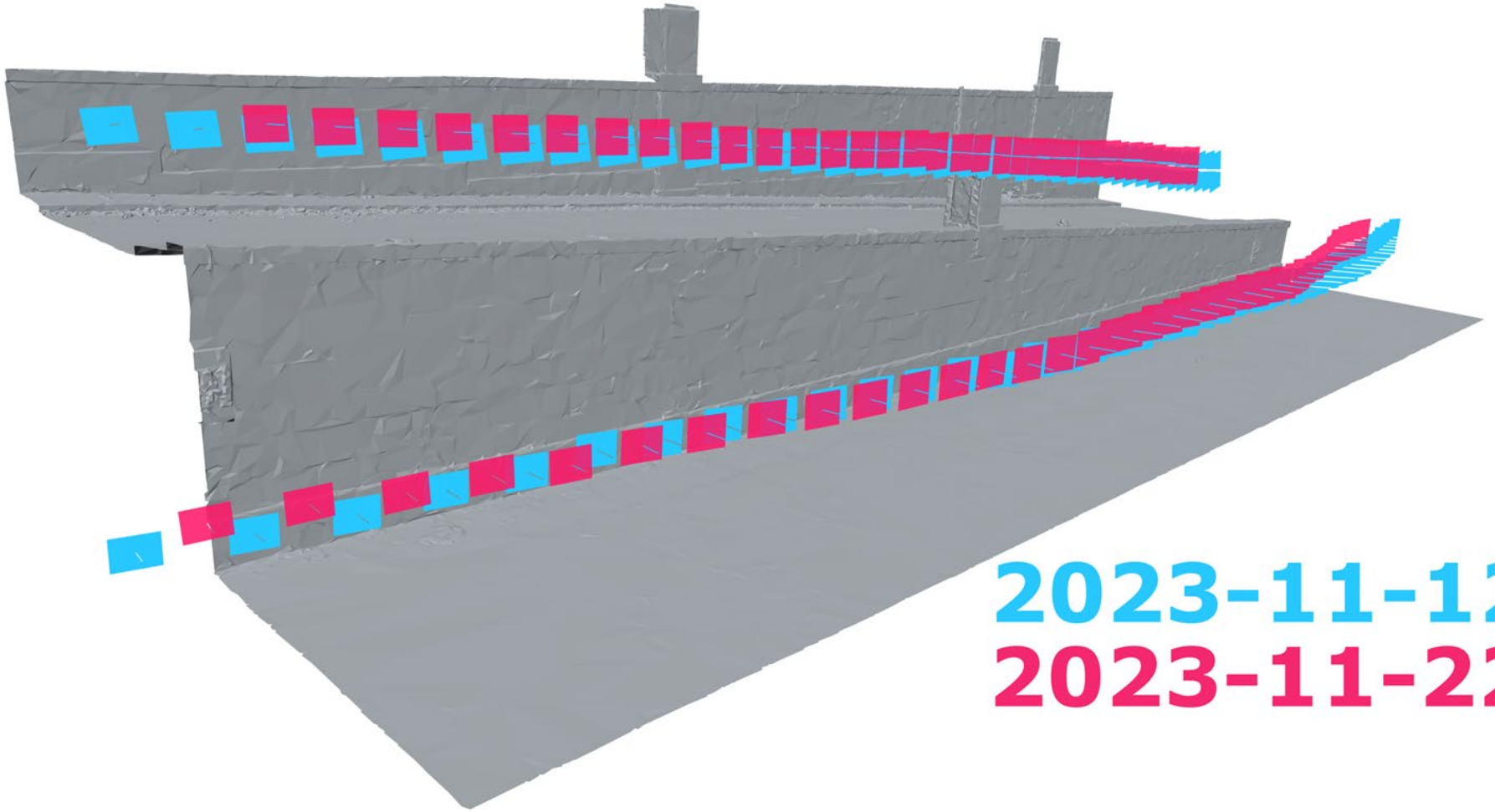


2023-11-12

Camera orientations

↓

Incremental SfM



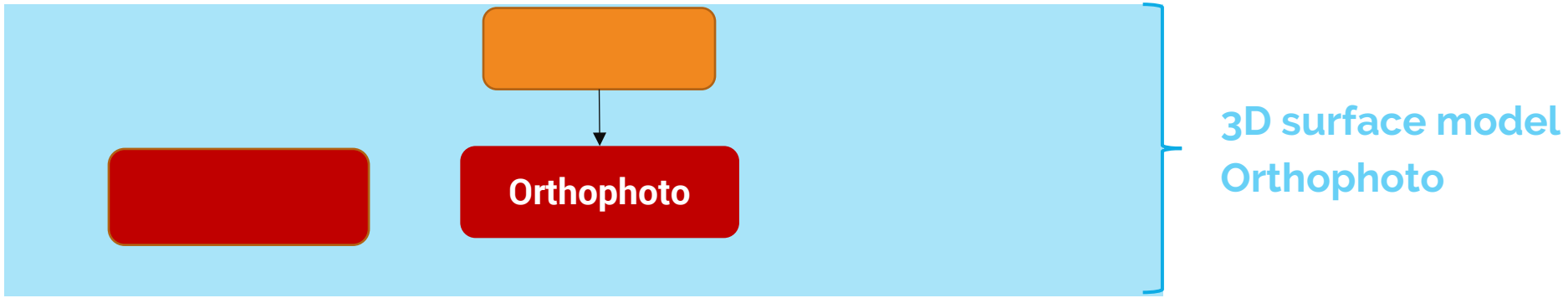
Camera orientations

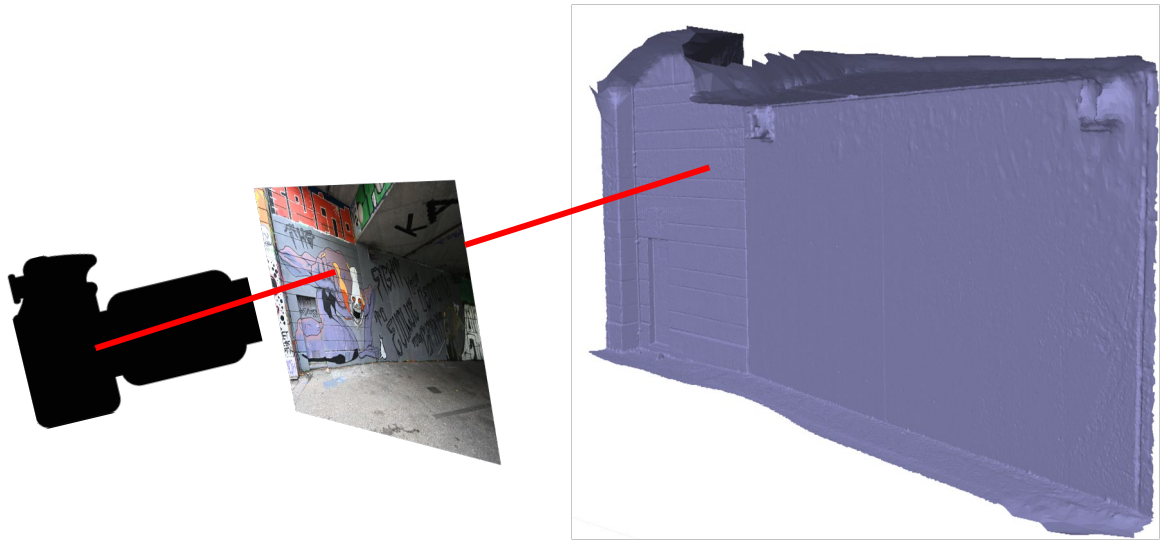
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Incremental SfM

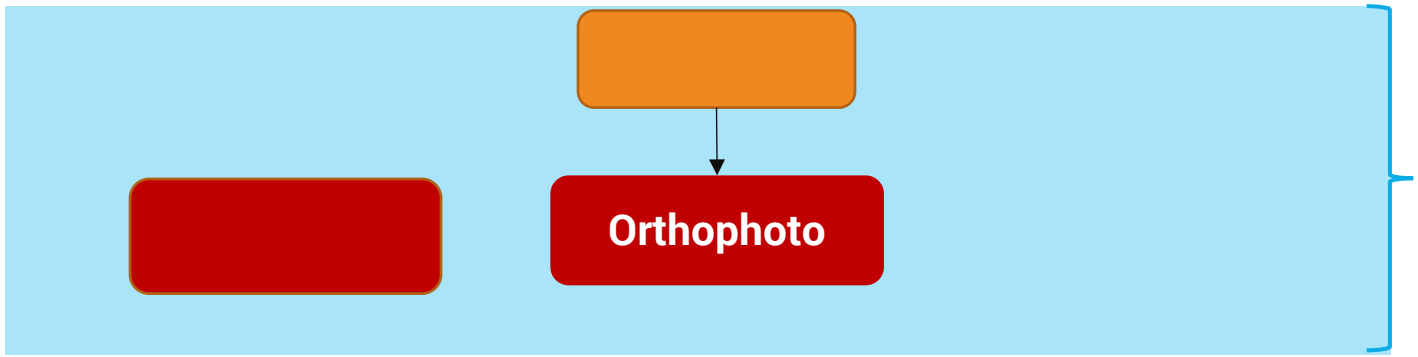


Camera orientations

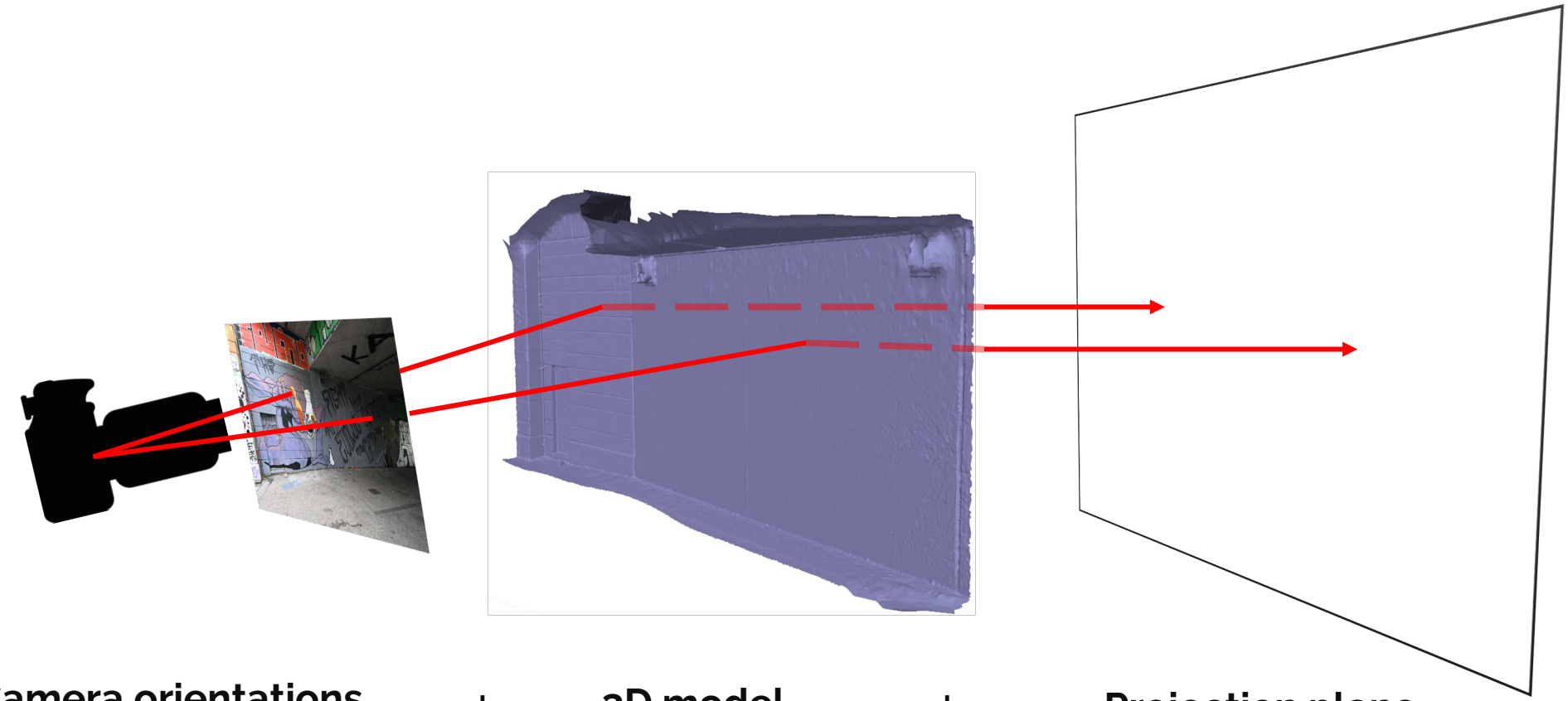




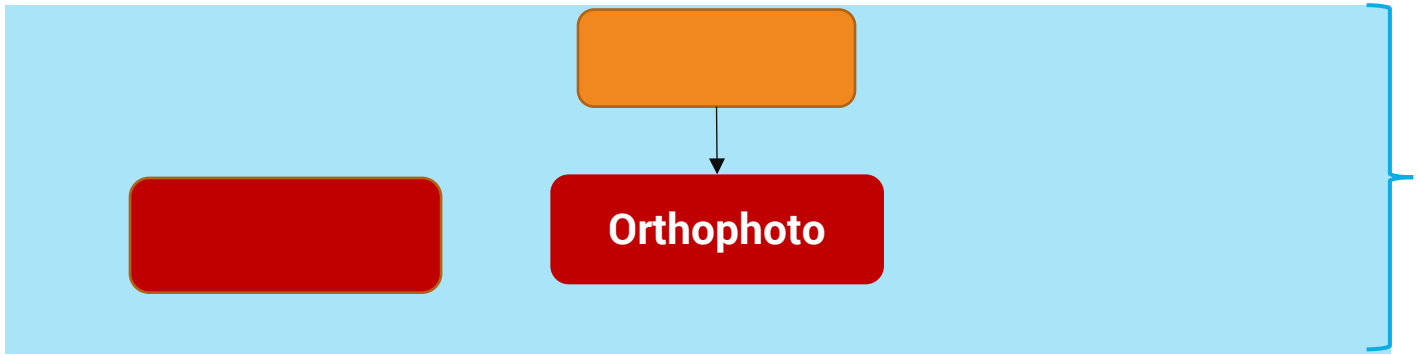
Camera orientations + 3D model



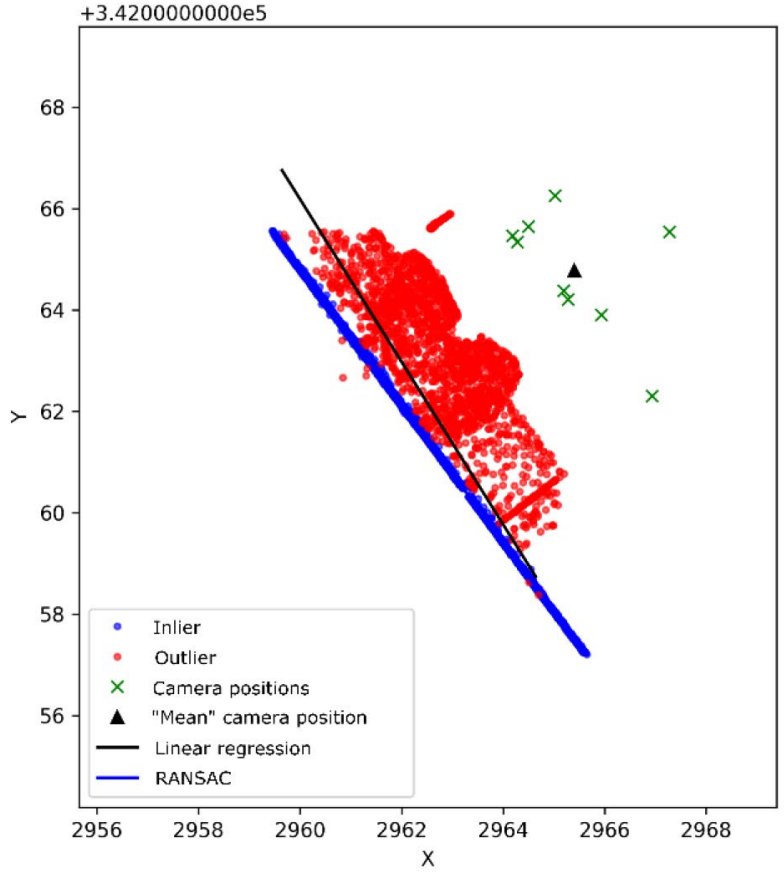
3D surface model
Orthophoto

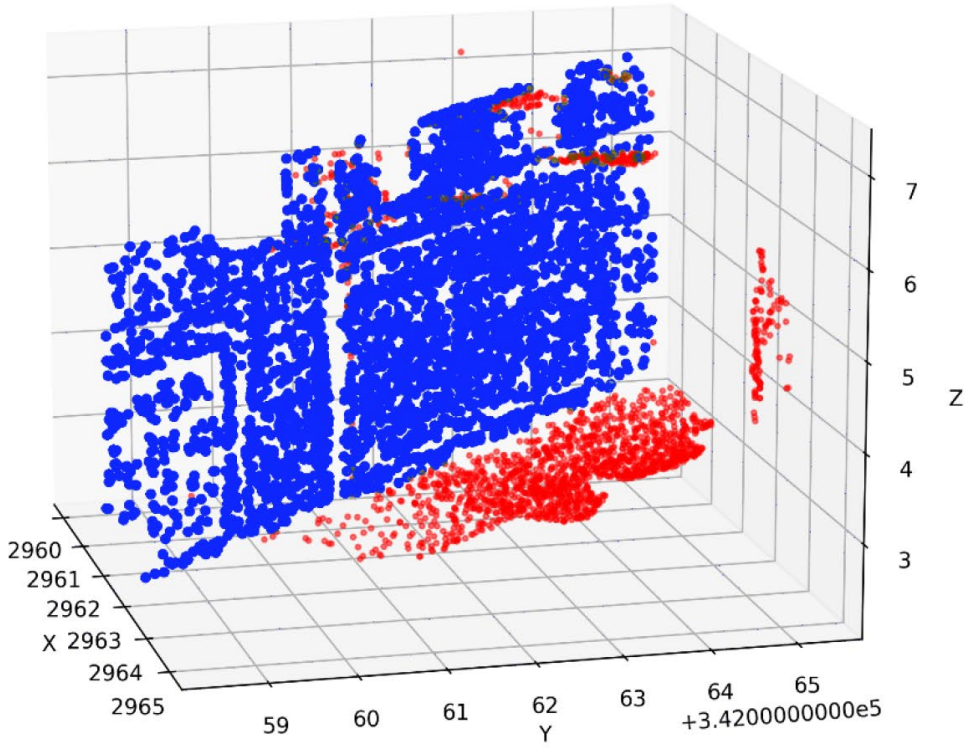


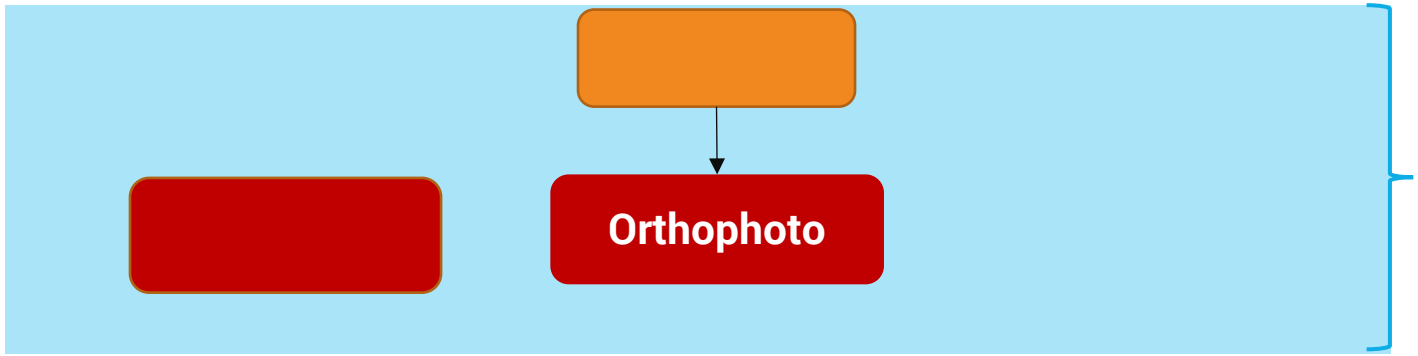
Camera orientations + 3D model + Projection plane



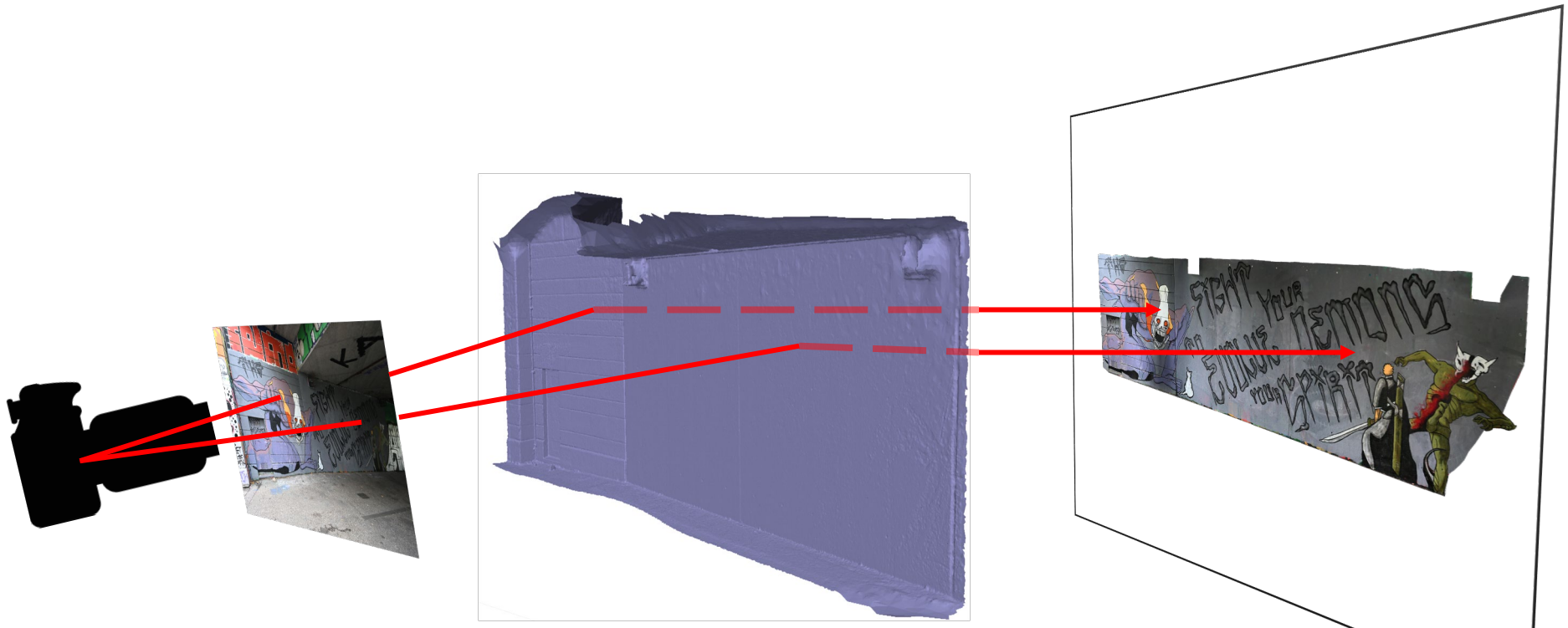
3D surface model
Orthophoto



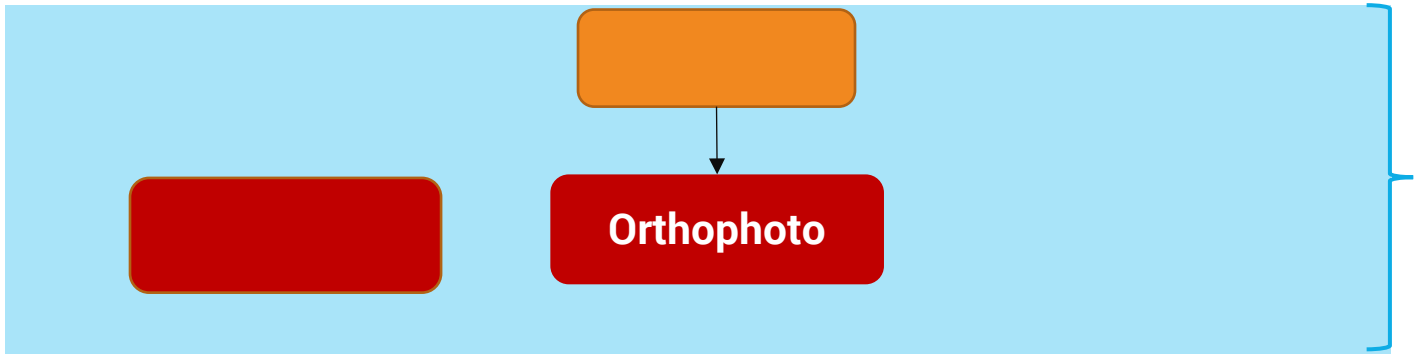




3D surface model
Orthophoto

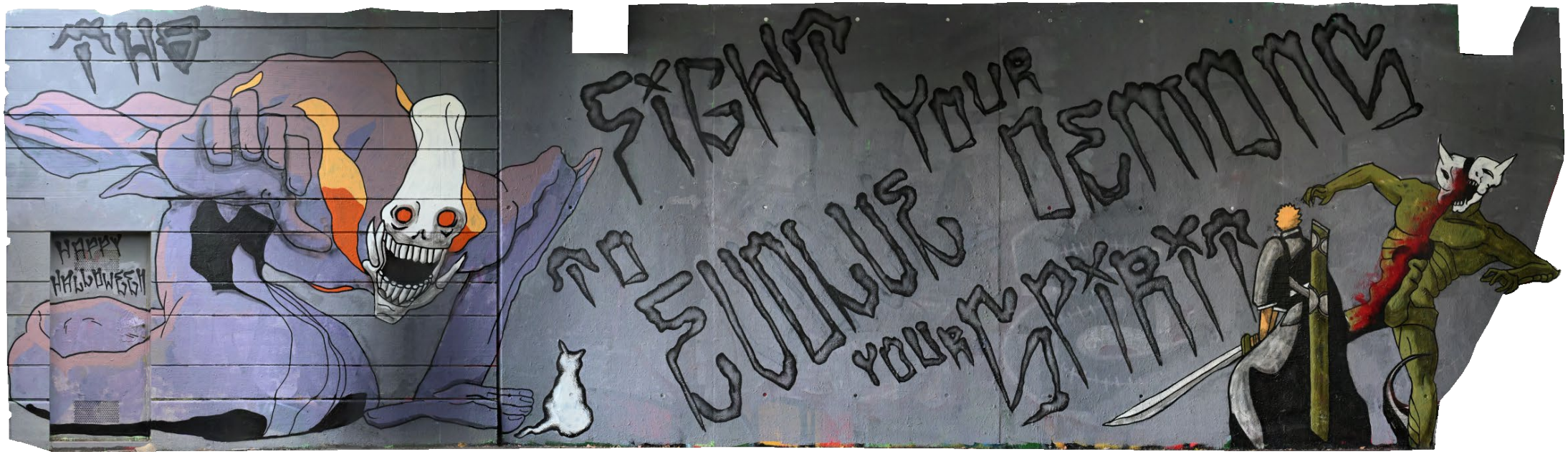


Camera orientations + 3D model + Projection plane

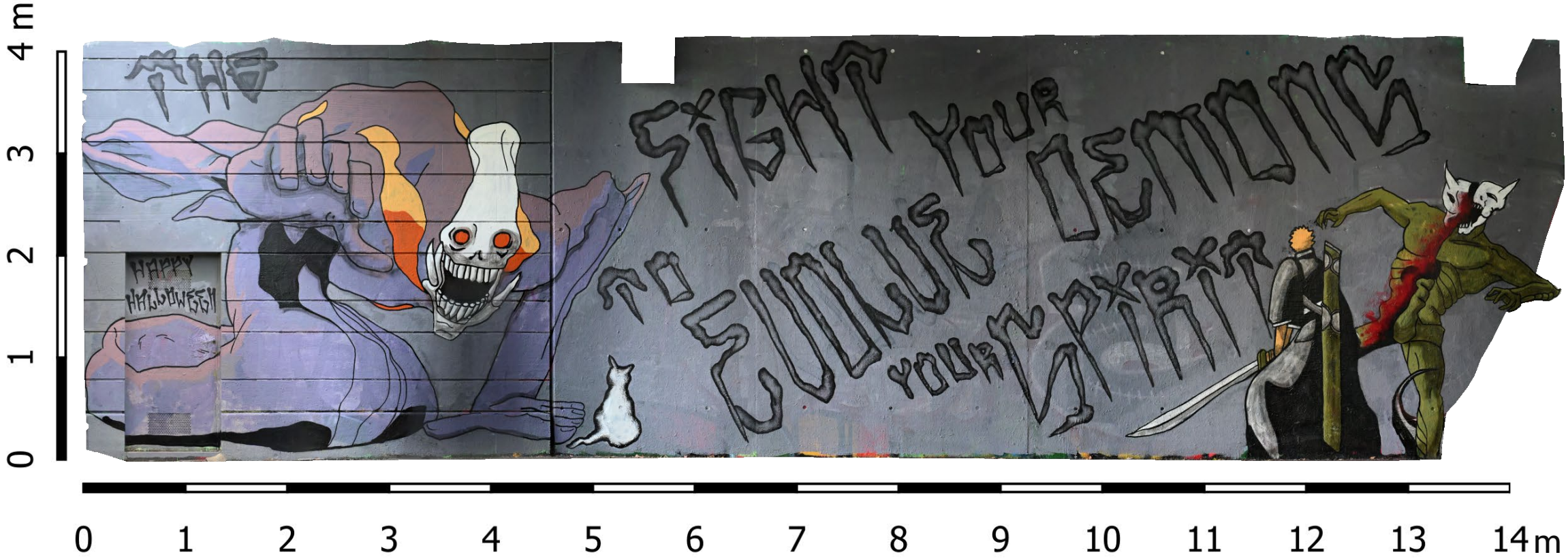


3D surface model
Orthophoto

AUTOGRAF



AUTOGRAF



Perimeter	**36.82 m**
Area	**51.2 m²**



Oskar Baumann, MSc thesis in cartography, https://oacbaumann.github.io

GRAFFITI monitoring

GRAFFITI monitoring

BASEMAP

ESRI ArcGIS Field Maps

areas with overview photos

cloud-based | tablets



GRAFFITI monitoring

BASEMAP

ESRI ArcGIS Field Maps

areas with overview photos

cloud-based | tablets



MONITOR

check social media

memory

hashtags + form (unused)

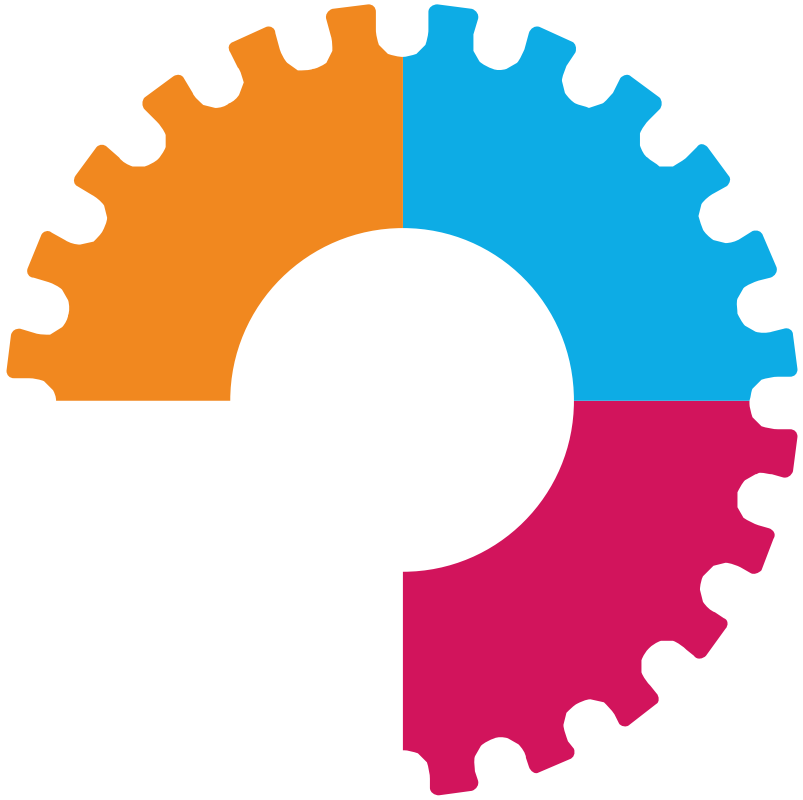
GRAFFITI monitoring

BASEMAP

ESRI ArcGIS Field Maps

areas with overview photos

cloud-based | tablets



MONITOR

check social media

memory

hashtags + form (unused)

ADD TO APP

point: “not photographed”

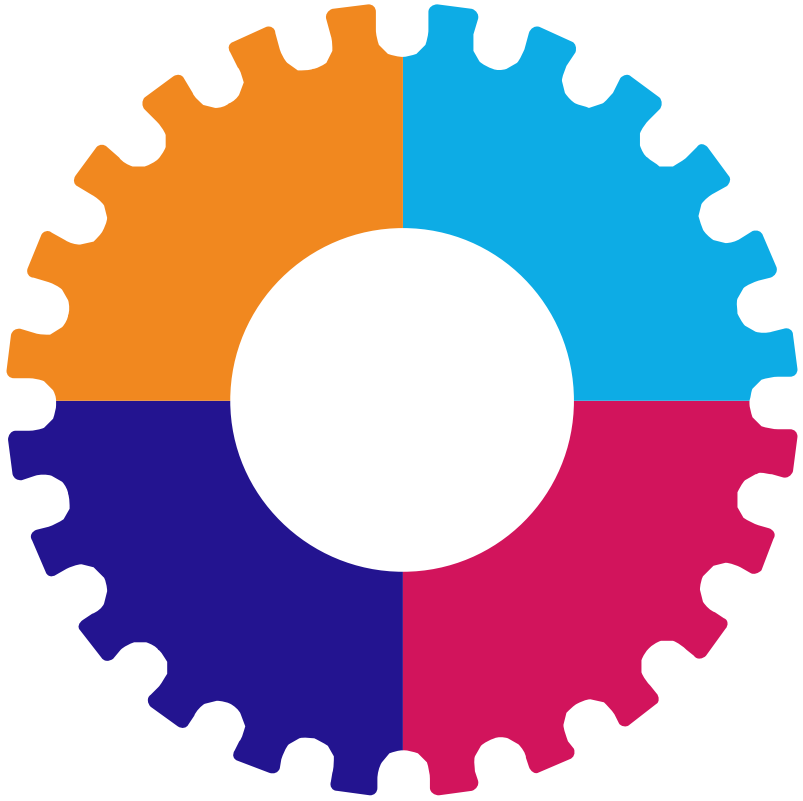
GRAFFITI monitoring

BASEMAP

ESRI ArcGIS Field Maps

areas with overview photos

cloud-based | tablets



MONITOR

check social media

memory

hashtags + form (unused)

DOCUMENT

± 10 photos

spectrometer reading

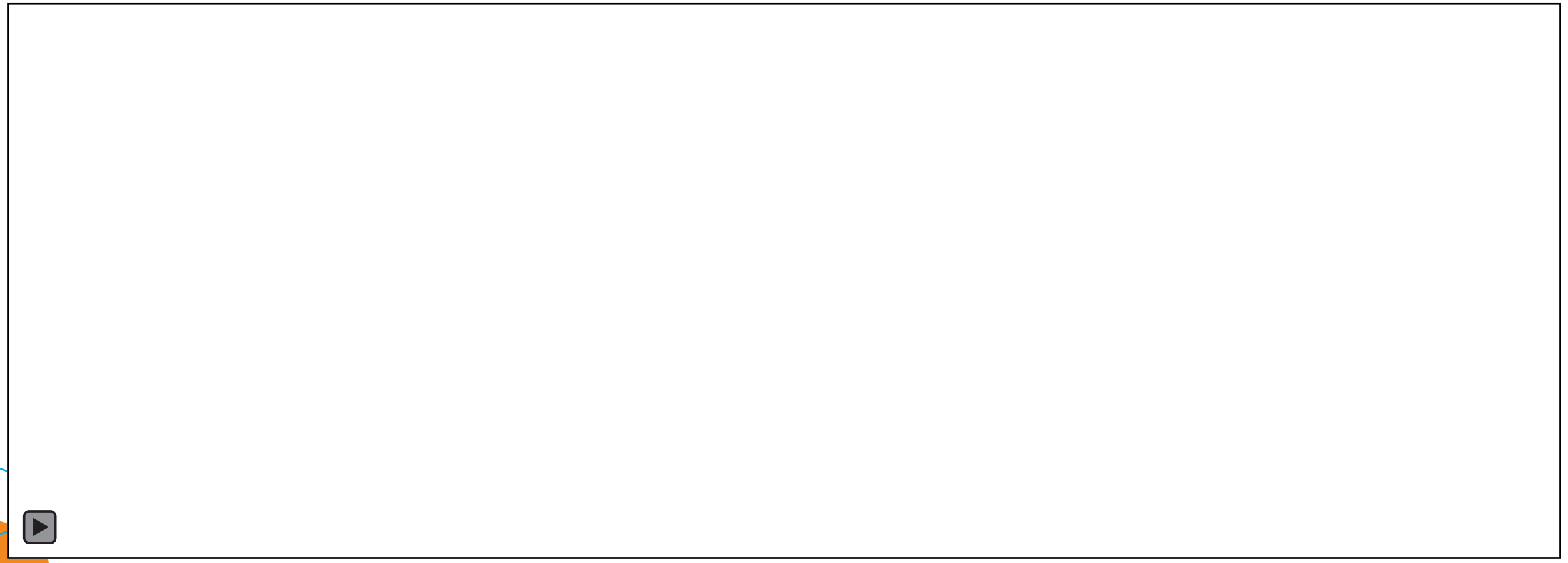
change status point

new overview photo

ADD TO APP

point: “not photographed”

CHANGE
detection





CHANGE
detection



CHANGE
detection

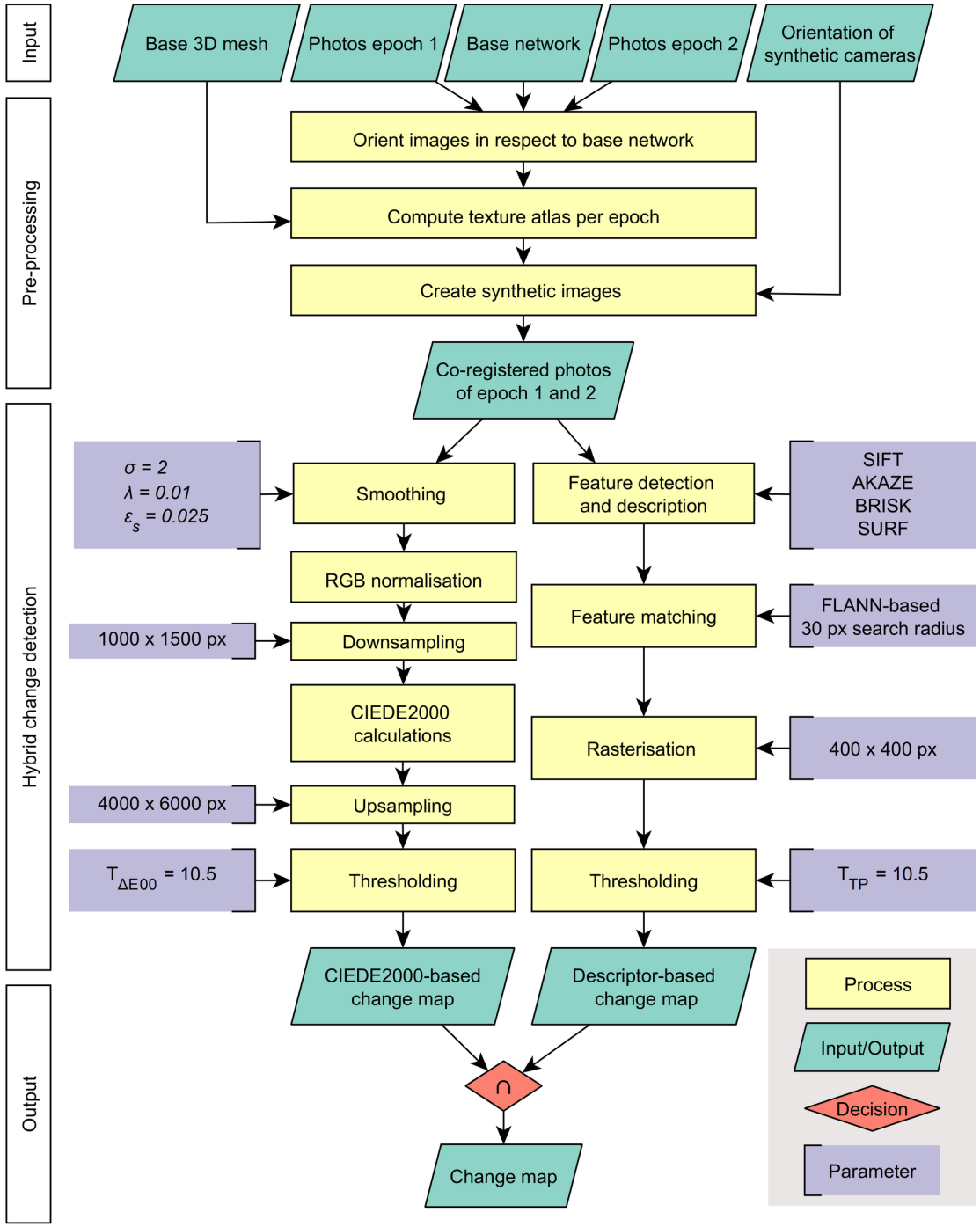


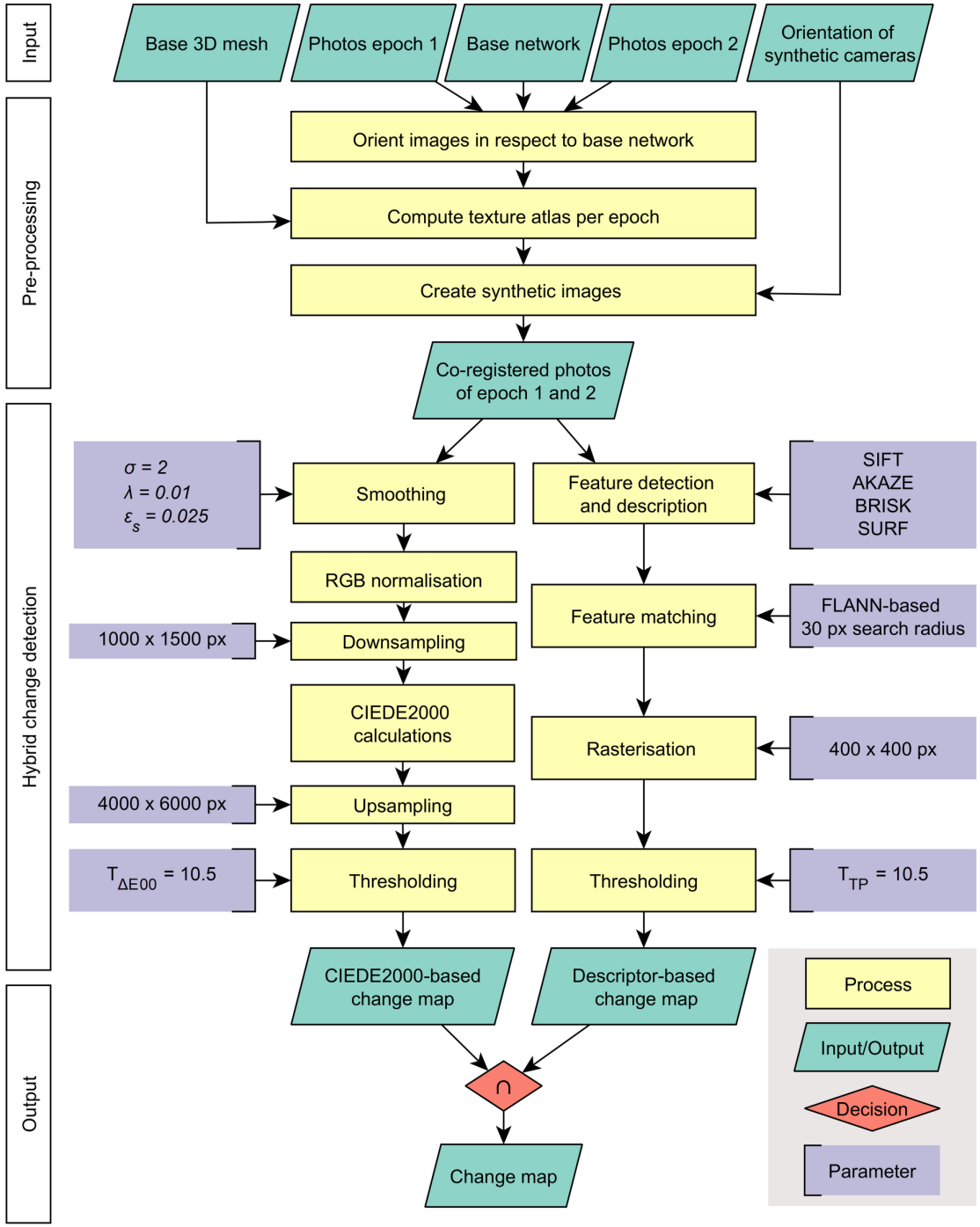




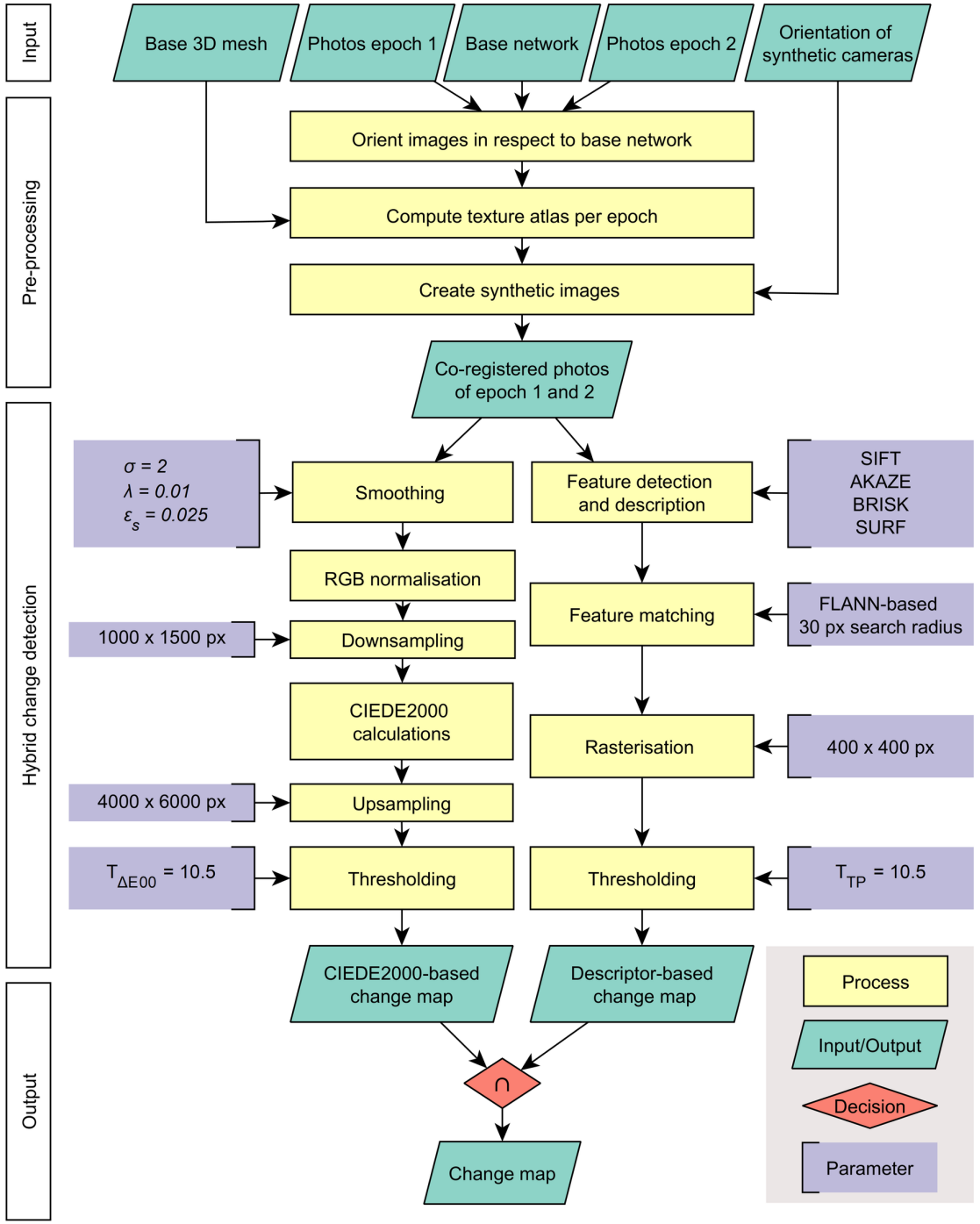
CHANGE
detection

CHANGE
detection





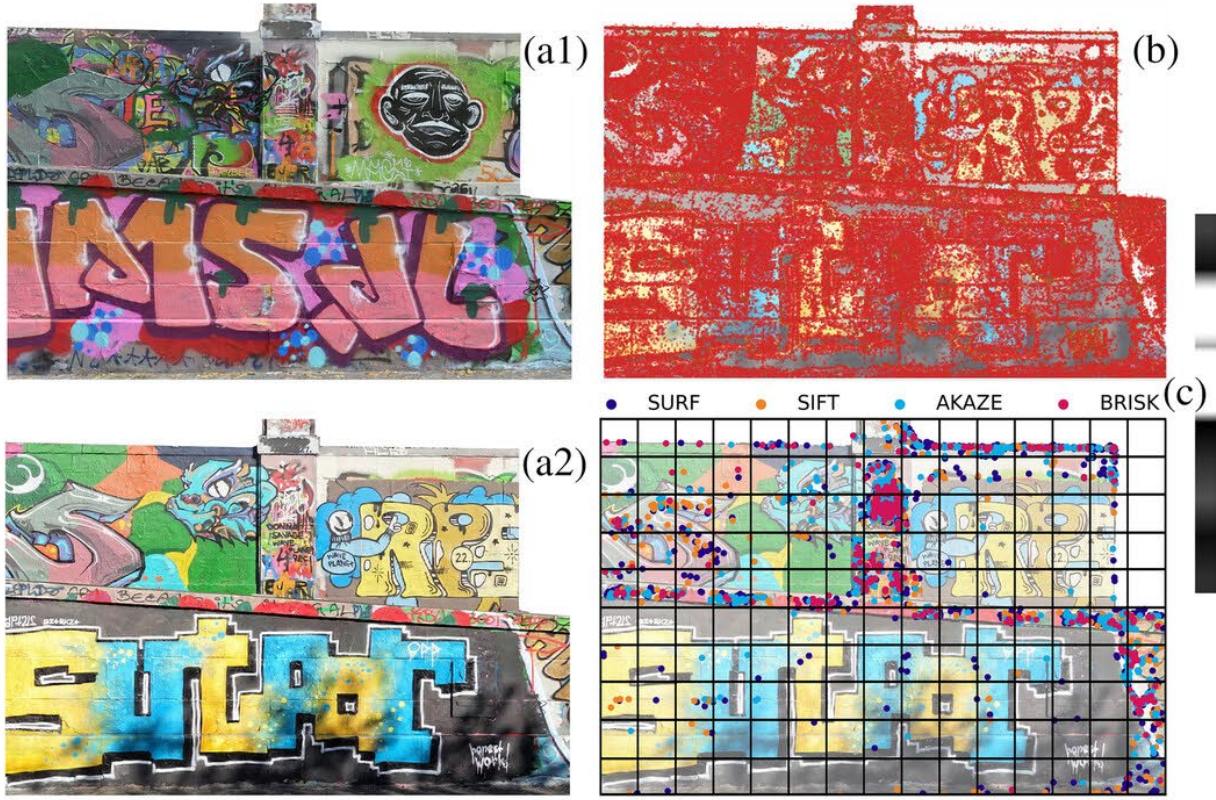
Co-registration



Co-registration

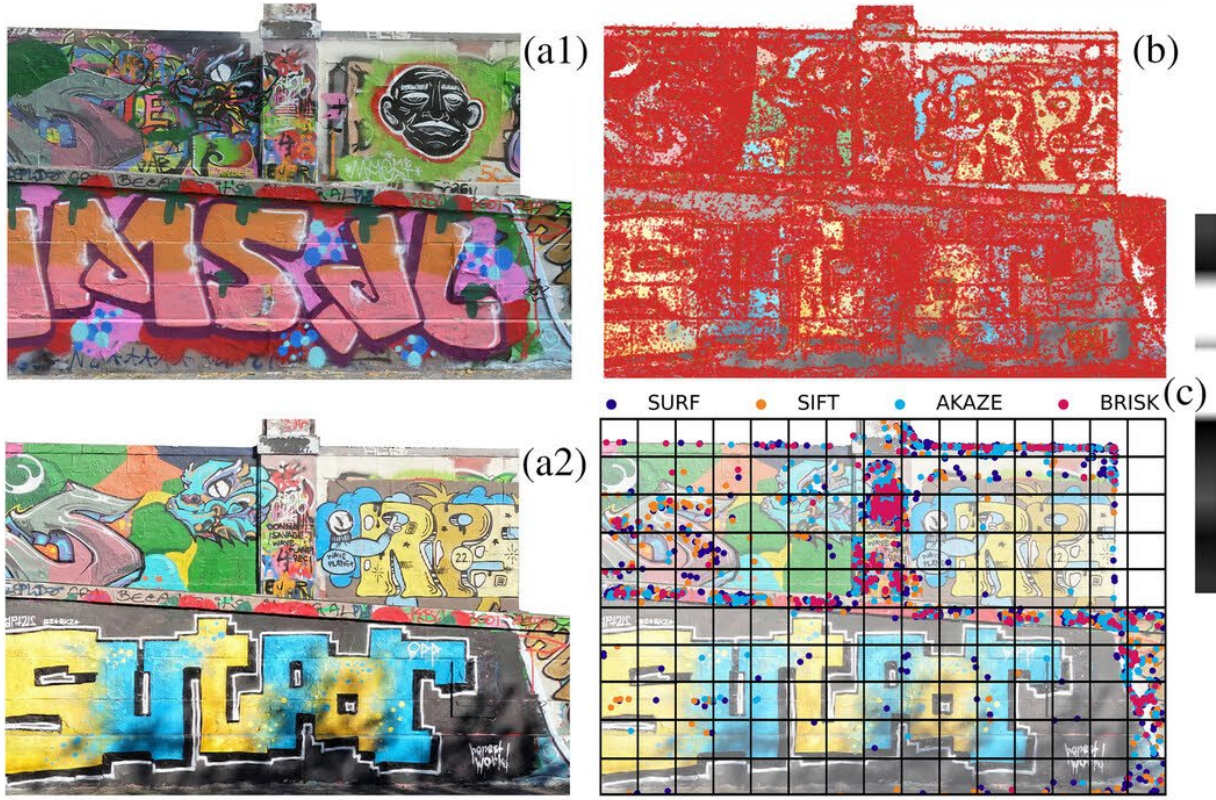
Change detection

DESCRIPTOR-BASED
change detection



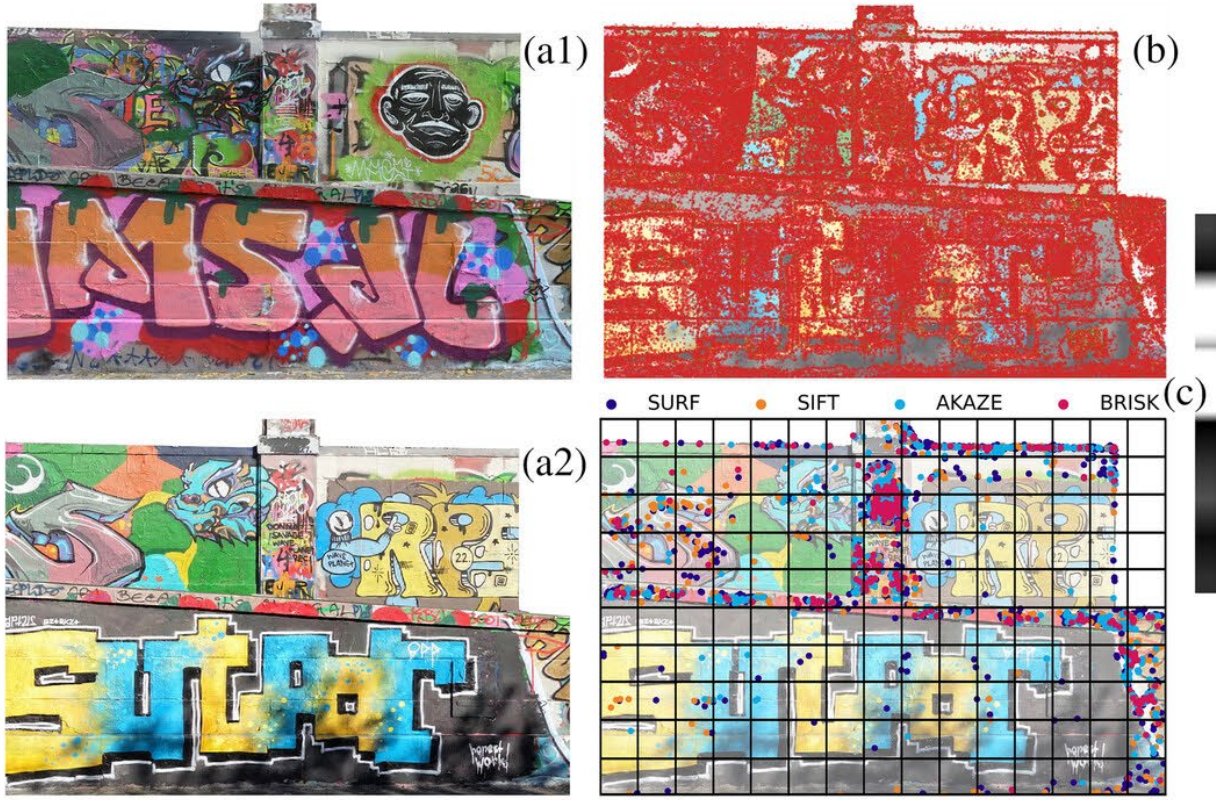
Feature points

DESCRIPTOR-BASED
change detection

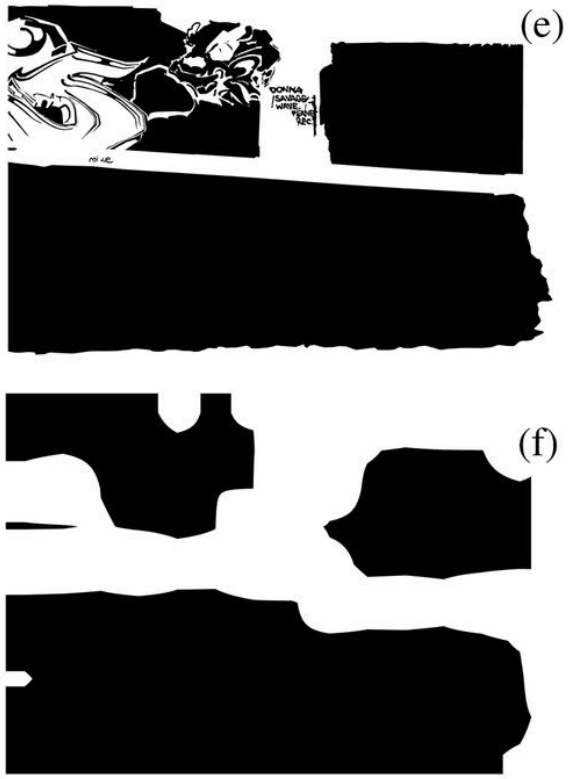


DESCRIPTOR-BASED
change detection

Feature points







Tie points





CHANGE
detection







CHANGE
detection









CHANGE
detection



CHANGE
detection



CHANGE
detection



CHANGE detection

Published October 11, 2023 | Version 1.0.0

Dataset Open

INDIGO Change Detection Reference Dataset

Wild, Benjamin[1]; Verhoeven, Geert[2]; Muszyński, Rafał[3]; Pfeifer, Norbert[1]

Show affiliations

Citation Style APA

Wild, B., Verhoeven, G., Muszyński, R., & Pfeifer, N. (2023). INDIGO Change Detection Reference Dataset (1.0.0) [Data set]. TU Wien. https://doi.org/10.48436/ayj4e-v4864

Description

The INDIGO Change Detection Reference Dataset

Description

This graffiti-centred change detection dataset was developed in the context of INDIGO, a research project focusing on the documentation, analysis and dissemination of graffiti along Vienna's Donaukanal. The dataset aims to support the development and assessment of change detection algorithms.

The dataset was collected from a test site approximately 50 meters in length along Vienna's Donaukanal during 11 days between 2022/10/21 and 2022/12/01. Various cameras with different settings were used, resulting in a total of 29 data collection sessions or "epochs" (see "EpochIDs.jpg" for details). Each epoch contains 17 images generated from 29 distinct 3D models with different textures. In total, the dataset comprises 6,902 unique image pairs, along with corresponding reference change maps. Additionally, exclusion masks are provided to ignore parts of the scene that might be irrelevant, such as the background.

COLLECTED photos



COLLECTED photos



TOTAL COVERAGE

2

COLLECTED photos



TOTAL COVERAGE

2

TC PHOTOS

26.7 k

42.0 k

COLLECTED photos



TOTAL COVERAGE

2

FOLLOW-UP

106

TC PHOTOS

26.7 k

42.0 k

COLLECTED photos



TOTAL COVERAGE
2

FOLLOW-UP
106

TC PHOTOS
26.7 k
42.0 k

FU PHOTOS
94.6 k

SOME results

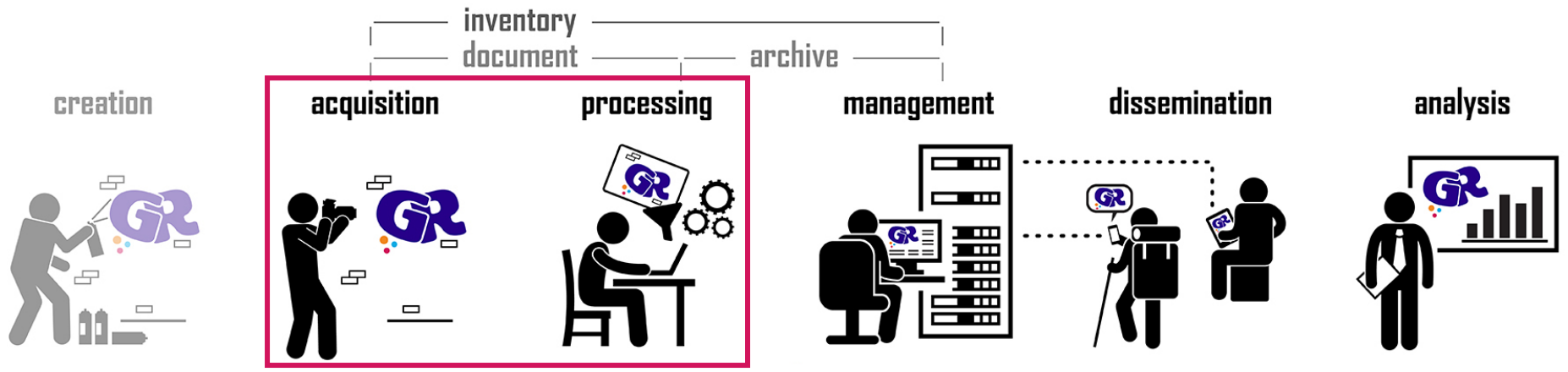
GRAFFITI *LOCATION*

GRAFFITI *TEMPORALITY*

GRAFFITI *TERMINOLOGY*

GRAFFITI *CHARACTERISATION*

5 research pillars



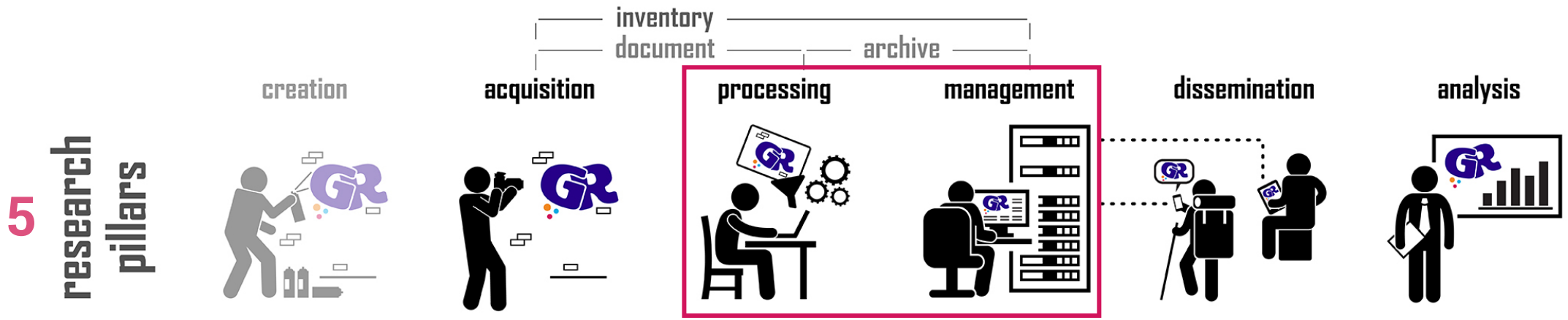
SOME results

GRAFFITI *LOCATION*

GRAFFITI *TEMPORALITY*

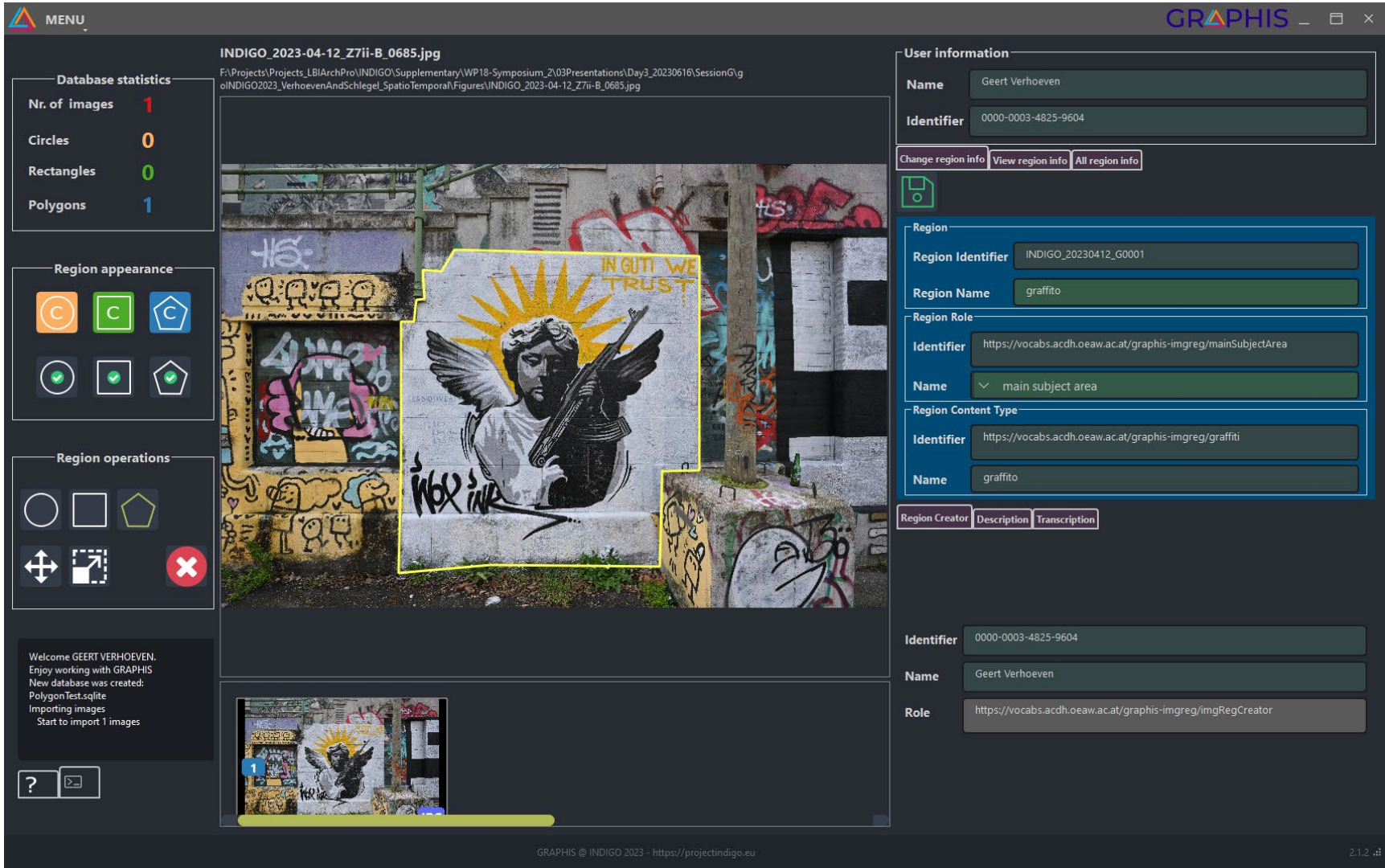
GRAFFITI *TERMINOLOGY*

GRAFFITI *CHARACTERISATION*



CREATING location

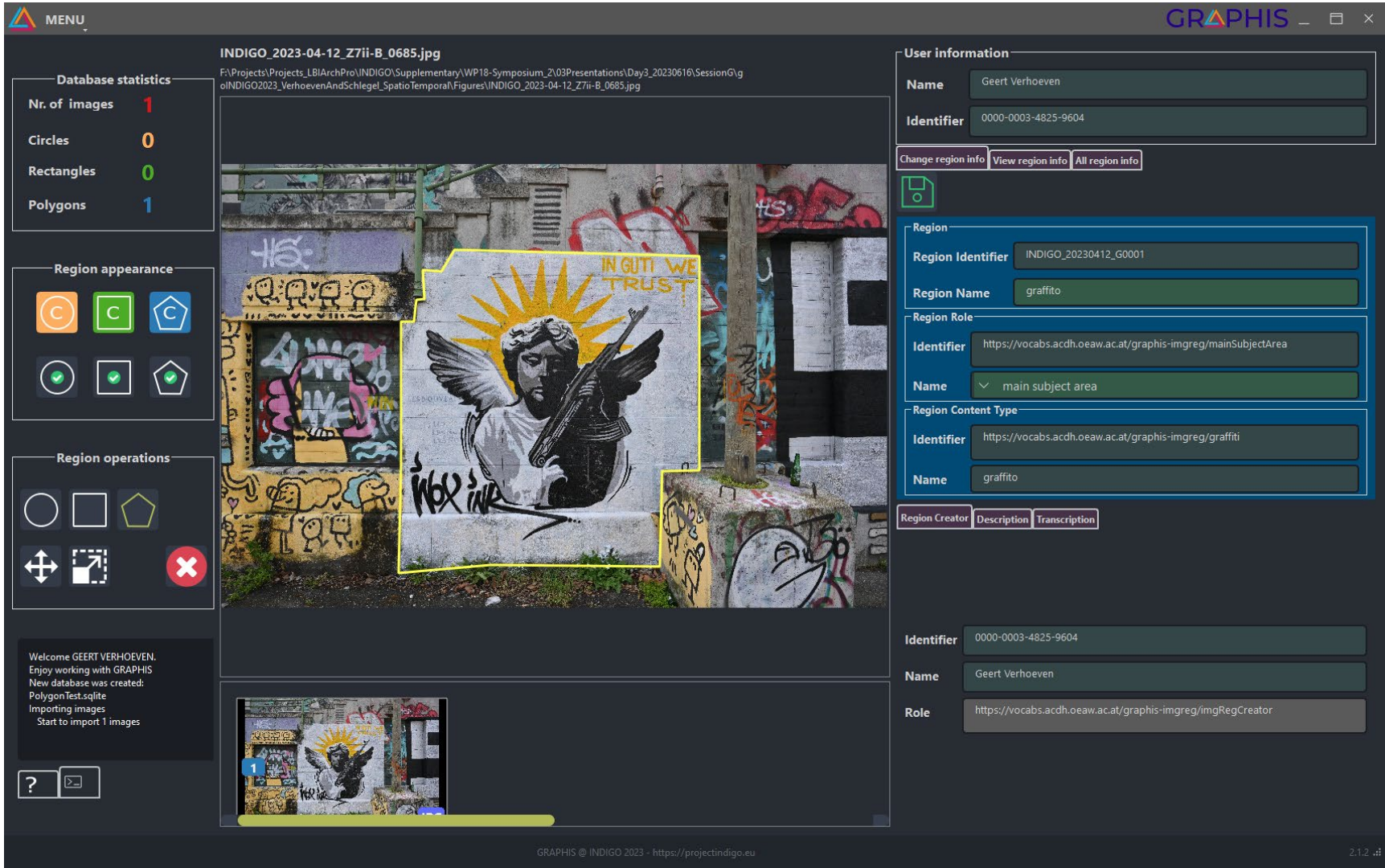
GRAPHIS



CREATING location

GRAPHIS

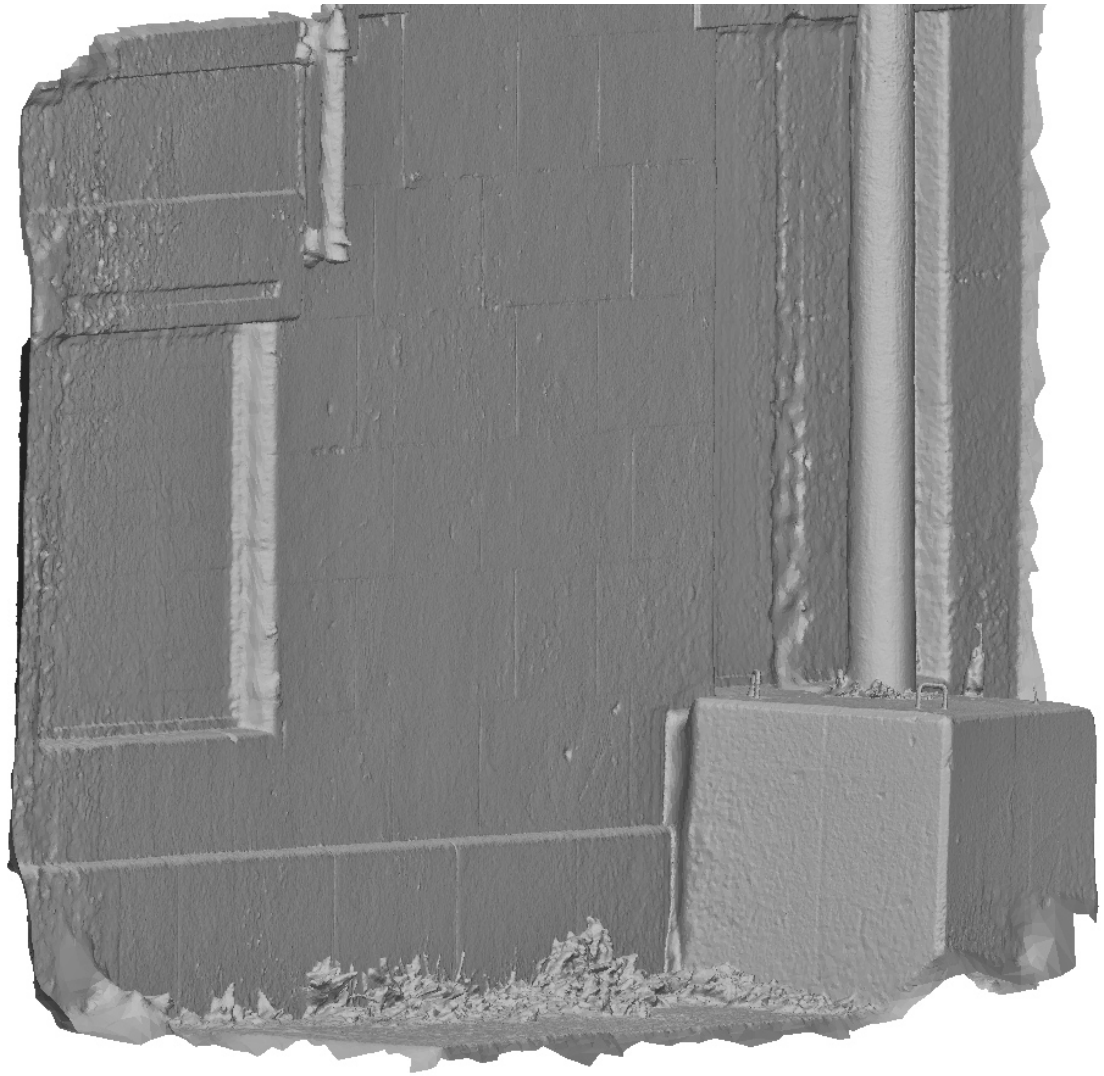
2D polygon (pixel coordinates)



CREATING location

GRAPHIS

2D polygon (pixel coordinates)



AUTOGRAF

CREATING location

GRAPHIS

2D polygon (pixel coordinates)

AUTOGRAF



CREATING location

GRAPHIS

2D polygon (pixel coordinates)

AUTOGRAF



CREATING location

GRAPHIS

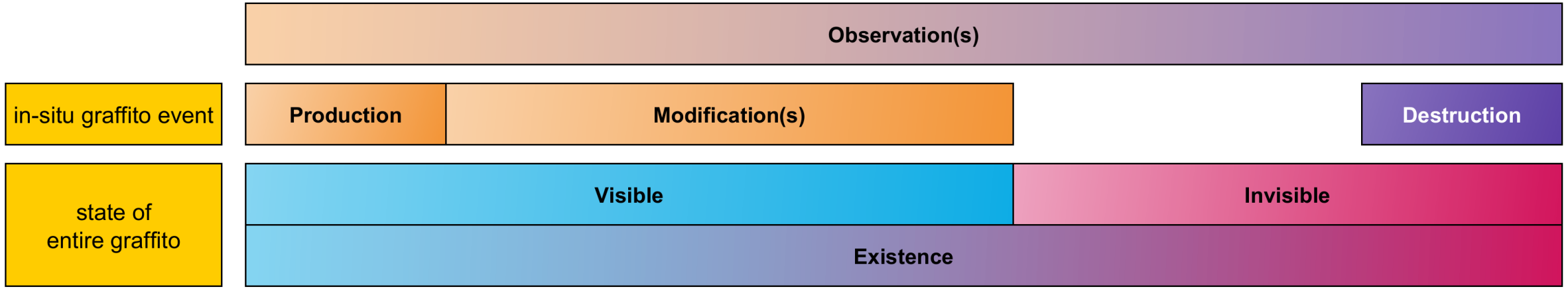
2D polygon (pixel coordinates)

AUTOGRAF

3D polyline (real-world coordinates)



STORING time




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```
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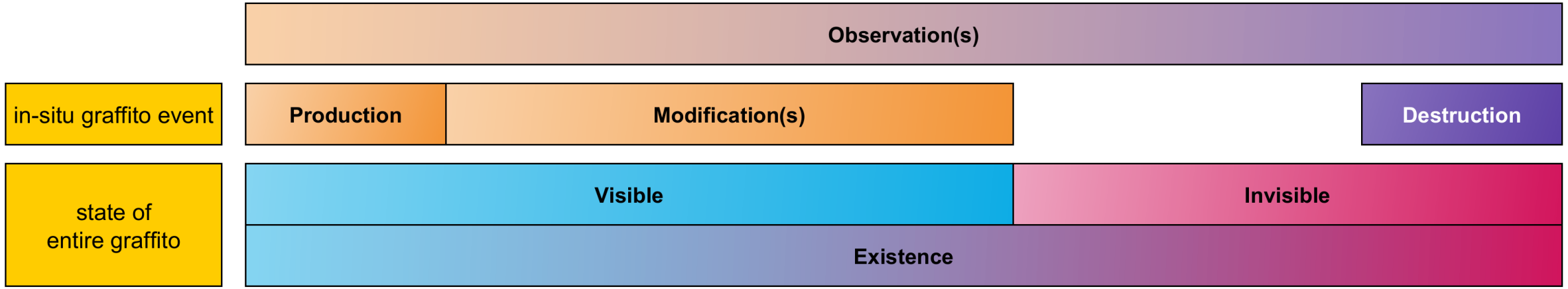
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  "invisibile": {…
  },

  "existence": {…
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STORING time




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```
  "modification": […
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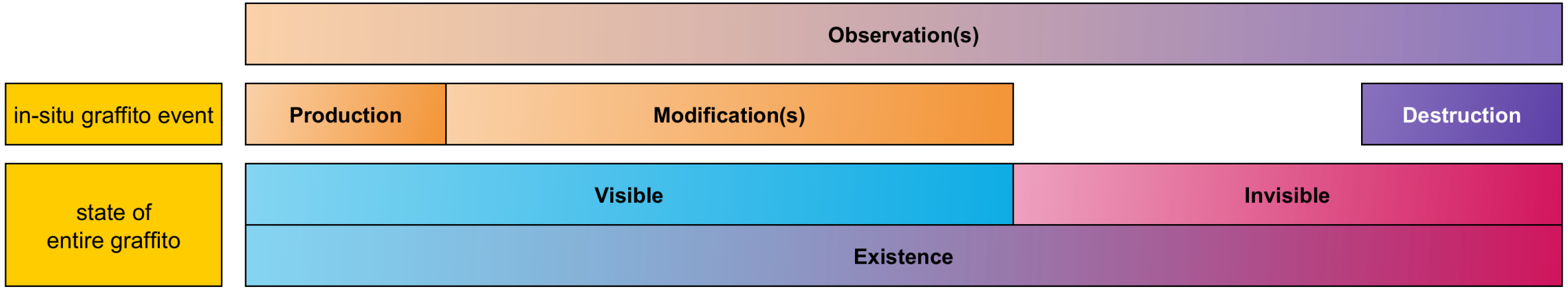
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  "visible": {…
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  "invisibile": {…
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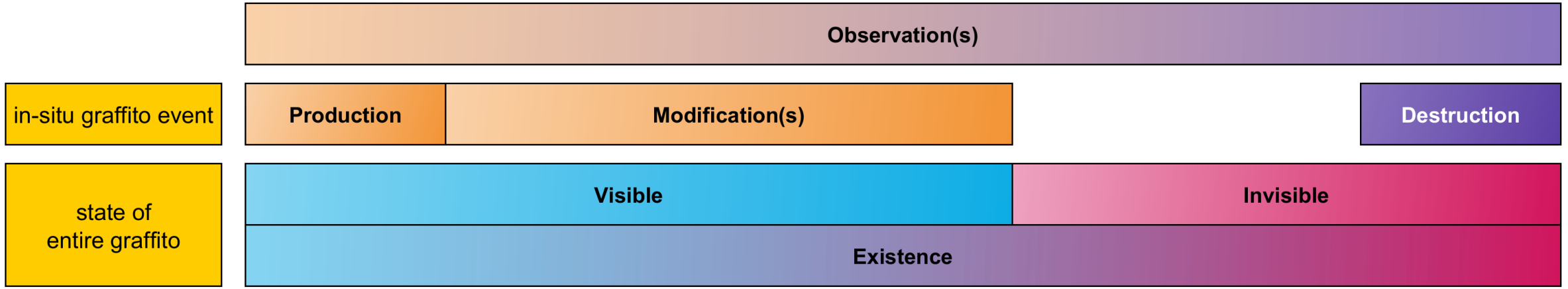
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```

STORING time



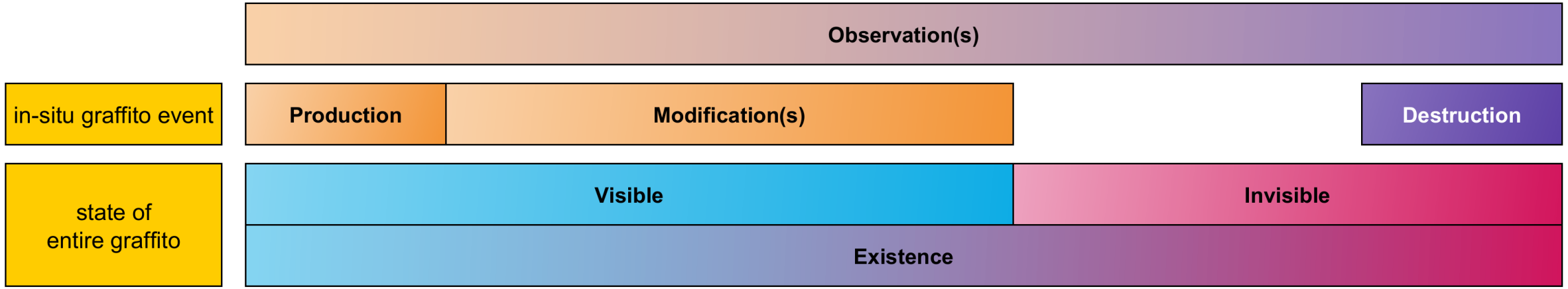

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STORING time



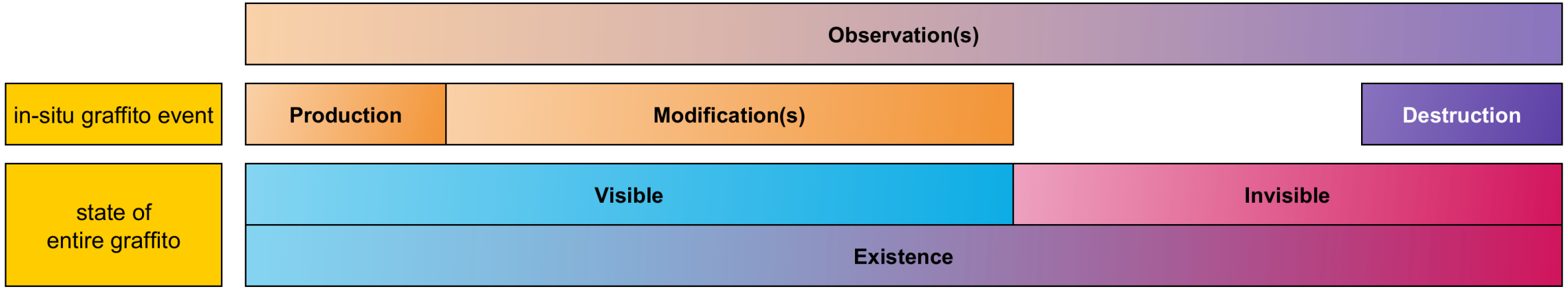

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    "latest":
    "latest_source":
  },
```

STORING time




```
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    "earliest_source":
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  "earliest_source":
  "latest":
  "latest_source":
},
"span": {
```

STORING time




```
"visible": {
  "start": {
    "earliest":
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    "latest":
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  },
"end": {
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```

STORING time




```
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```

STORING time




```
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```

```
"end": {
  "earliest":
  "earliest_source":
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},
```

```
"span": {
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}
```

STORING time








```
"visible": {
  "start": {
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    "latest_source":
  },
"end": {
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  "latest":
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},
"span": {
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  "maximum":
}
```

STORING time




```
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```

STORING time




```
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```

STORING time




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SOME results

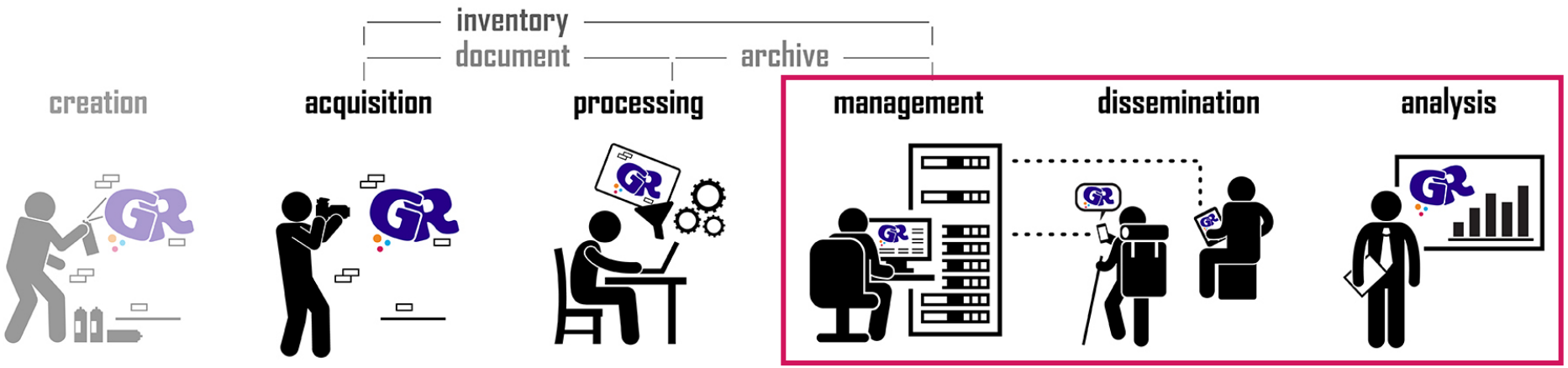
GRAFFITI *LOCATION*

GRAFFITI *TEMPORALITY*

GRAFFITI *TERMINOLOGY*

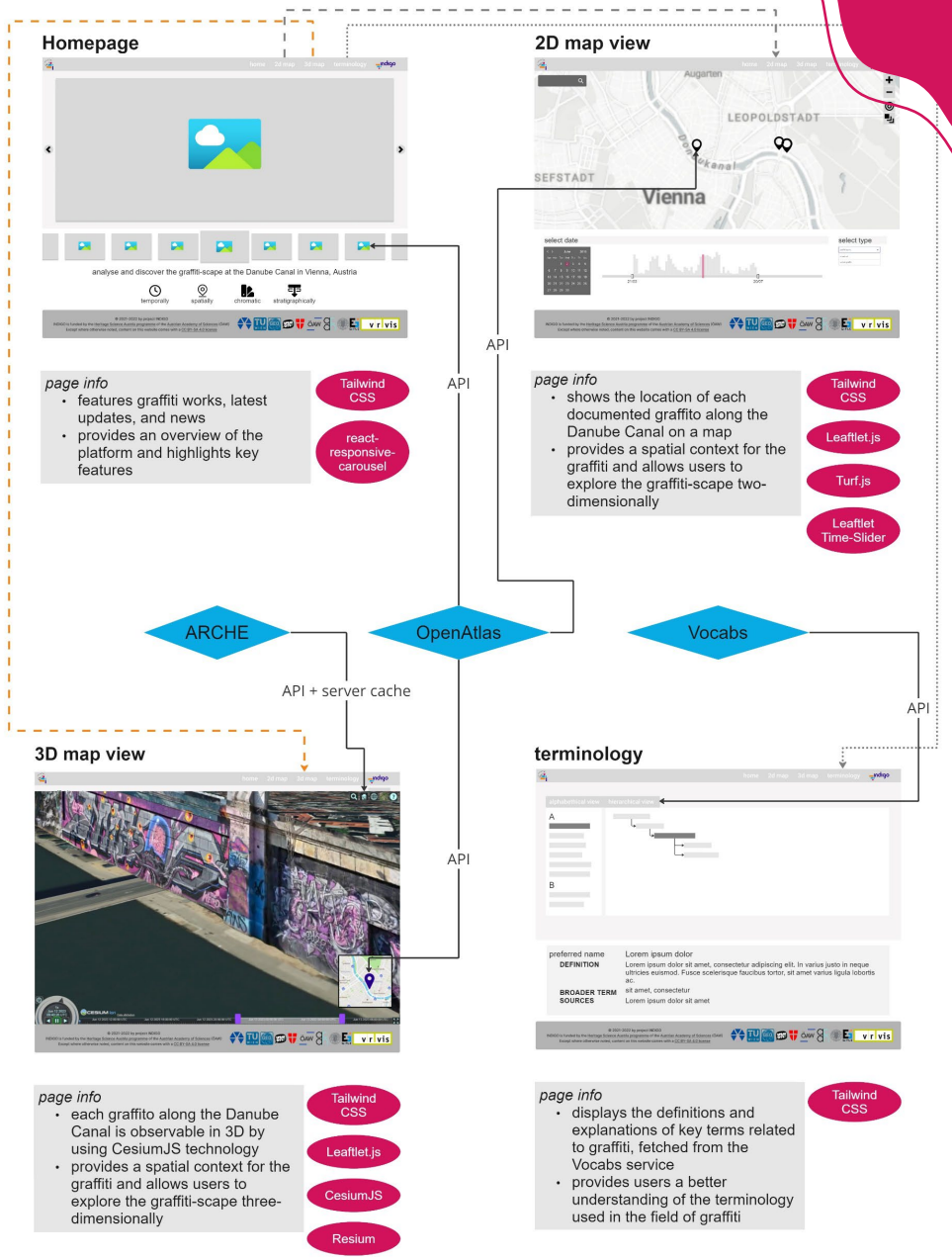
GRAFFITI *CHARACTERISATION*

5 research pillars



FINAL goal

urban chameleon





INTERACTIVE 3D dissemination

archaeologists / art historians

sociologists / linguists

ethnographers / anthropologists

architects / geographers



INTERACTIVE 3D dissemination

archaeologists / art historians

sociologists / linguists

ethnographers / anthropologists

architects / geographers

ETHICAL + COPYRIGHT aspects

DISSEMINATION general audience

DISSEMINATION general audience



NewsLetter

vol.24 · Week 40 · 03-07 October 2022

indigo

VRVis meeting

01 Thursday 06-10-2022
10:00 @ VRVis
discuss collaboration

bot character by DEADBEAT HERO south of the Friedensbrücke on the right Donaukanal bank [21-09-2022]
Nikon Z 7II + Nikon NIKKOR Z 20mm f/1.8 S @ *f*/5.6 - 1/400 s - ISO 360

CVL Computer Vision Lab

UC

last two weeks

1. CVL meeting

Tuesday 27-09-2022 | meeting between Sebastian Zambanini of the TU Wien's Computer Vision Lab and Geert to discuss potential thesis subjects

2. Proceedings meeting

Wednesday 28-09-2022 | the editors of the goINDIGO 2022 proceedings meet to sync info about article submissions and outstanding papers

3. Monthly team meeting

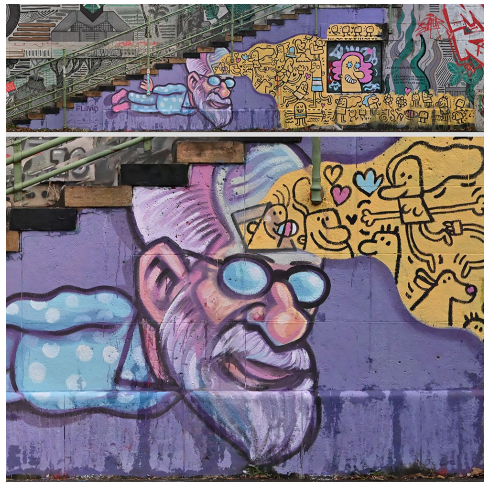
Friday 30-09-2022 | during monthly team meeting 11, the INDIGO project staff discussed the status quo and talked about upcoming matters

NEWSLETTER

26

DISSEMINATION general audience

Gallery Wednesday









NEWSLETTER

26

INSTAGRAM

±500

DISSEMINATION general audience



Die Presse 16/07/2022

Digital. Ein Forschungsteam entwickelt ein 3-D-Modell der unzähligen Graffiti am Donaukanal: um die kurzlebigen Werke zu bewahren und eine Basis für andere Forschungen schaffen. Zu Besuch bei einer der längsten Graffitiflächen der Welt.

Buntes Erbe zum Lachen, Ärgern und Grübeln

VON ALICE SENARCLENS DE GRANCY

Wir haben seit fast vier Jahren einen Hund und gehen mit ihm oft im Prater spazieren, aber auch entlang des Donaukanals", erzählt Geert Verhoeven von der Idee zu seinem aktuellen Forschungsprojekt. Dabei betrachtete er die Graffiti an den Wänden – „manche waren weniger schön, manche wirkten wie Kunst" – und bemerkte auch deren Vergänglichkeit: „Sie werden teilweise nach ein paar Stunden oder Tagen übersprüht." Der Archäologe begann, die oft kurzlebigen Werke als Kulturerbe zu sehen, das es zu bewahren gilt, und startete gemeinsam mit dem Kunsthistoriker Stefan Wogrin und anderen wissenschaftlichen Partnern das Projekt Indigo (Inventory and Disseminate Graffiti along the Donaukanal).

„Der Donaukanal ist heute berühmt für die vielen Graffiti, dabei wissen die meisten nicht, dass Sprayen eigentlich nur auf 300 Metern erlaubt ist", erzählen die beiden Männer an diesem windigen und untypisch kalten Sommertag vor der Kaiserbadschleuse. Hier entstand 1984 neben dem Nachtclub Flex die erste legale Graffitofläche Wiens. Anfang und Ende sind mit einer – bunt besprühten – Reliefplatte markiert, auf der eine Taube zu sehen ist: Die sogenannte Wienerwand sei ein Unikum mit klarer Botschaft, berichtet Wogrin, der sich seit rund 20 Jahren mit Graffiti befasst – und selbst anfertigt: „Man wollte die Sprayer genauso wenig wie die Tauben." Dennoch ermöglicht es die Stadt Wien Künstlerinnen und Künstlern aus der Graffito-Szene so, auf diesen Flächen zu arbeiten, ohne kriminell zu sein.

Thema lässt niemanden kalt

Denn Graffiti polarisieren bis heute. „Die einen lieben sie, die anderen hassen sie", sagt Verhoeven, der diese Reaktionen auch von wissenschaftlichen Tagungen kennt: „Es gibt jedes Mal 100.000 Fragen." Das Interesse gefällt ihm – und auch, dass ein Beitrag aus seiner Forschungsgruppe im März einen Best Paper Award bei einer Konferenz im italienischen Mantua gewonnen hat. Üblicherweise befasst er sich als stellvertretender Leiter des Ludwig-Boltzmann-Instituts (LBI) für Archäologische Prospektion und Virtuelle Archäologie mit ganz anderen Kulturschätzen: Er begleitete die Forschungen rund um das jungsteinzeitliche Stonehenge, war bei den Arbeiten zum römischen Carnuntum oder der Wikinger-Fundstätte Birka dabei. „Und im Stephansdom habe ich Fresken dokumentiert und publiziert", schildert Geert Verhoeven, der 2010 innerhalb von vier Tagen sein Haus in Belgien verkauft hat und für die Forschungsstelle nach Wien gezogen ist. Die am LBI genutzten und weiterentwickelten Messsysteme und Simulationsmethoden bilden die Klammer über die verschiedenen Themen. Ziel ist stets, Kulturerbe digital festzuhalten.

Außergewöhnlicher Kulturschatz: Geert Verhoeven (l.) und Stefan Wogrin vor einem ihrer Forschungsobjekte. [Jana Madzigon]

IN ZAHLEN

13 Kilometer lang sind die Flächen am Donaukanal, an denen Wiener Forscher Graffiti fotografisch festhalten und daraus ein 3-D-Modell bauen.

27.000 Fotos verknüpfte das erste Modell. Wöchentlich kommen zwischen 1000 und 3000 neue Bilder dazu.

300 Meter misst der Bereich, in dem Sprayen am Wiener Donaukanal legal ist.

Digitaler Spaziergang am Kanal

Diese virtuellen Werkzeuge sollen nun auch helfen, die Graffiti am Donaukanal darzustellen – auch Anwendungen für den Tourismus sind denkbar: Den Forschern schwebt ein digitaler Spaziergang am Donaukanal vor, bei dem man auch ältere, an einer Stelle vorhandene Graffiti anschauen und mehr über sie erfahren kann.

Doch noch sind große technische Hürden zu nehmen: Die Farben bei ständig wechselnden Lichtverhältnissen richtig abzubilden, sei sehr schwierig, führt das Duo aus. Auch die Orte ändern sich: „Die Container da drüben waren vor fünf Monaten noch nicht da", sagt Wogrin und zeigt auf die bunt besprühten Quader am anderen Ufer. Zumindest einmal pro Woche geht er daher den Kanal ab dem Hunderwasserhaus bis zur Friedensbrücke auf beiden Seiten ab, sichtet Neuheiten und macht unzählige Fotos, die später zum großen Ganzen kommen.

Rund 27.000 Fotos bildeten das Basismodell. Seither werden – wie bei einem Puzzle – ständig neue hinzugefügt und beschrieben: Welche Figuren sind dargestellt, was steht geschrieben? Gewaltige Datenmengen müssen richtig verknüpft werden. Dabei unterstützen auch Forschungsteams der TU Wien und der Universitat Politècnica de València in Spanien. Auch das VRVis, das Zentrum für Virtual Reality und Visualisierung in Wien, soll künftig helfen, das Neuland zu ergründen. „Es gibt noch keine Projekte, die können, was wir brauchen", erläutert Verhoeven.

Schließlich soll, unterstützt vom Förderprogramm Heritage Science Austria der Österreichischen Akademie der Wissenschaften, ein öffentlich zugängliches Archiv entstehen, das weltweit kein Pendant findet. Der Donaukanal sei, zusammen mit der Berliner Mauer, wohl die längste ununterbrochene Graffitifläche der Welt, so Verhoeven – und in Bezug auf die Graffitiforschung „definitiv die längste". Die Daten sollen dann Disziplinen wie Soziologie, Linguistik, Kriminologie oder Kunstgeschichte für ihre Forschung offenstehen.

Putin, dargestellt als Hitler

Inhaltliche Analysen folgen also später, doch aus seinen Beobachtungen weiß Wogrin schon heute: „Die Motive haben oft einen Bezug zum Kanal. Man sieht viele Fische oder Fischskelette oder auch Oktopusse." Für politische Botschaften werde meist mit Schablonen gearbeitet, so ließen sich Parolen schnell aufsprühen. Darin habe man zuletzt auch den Beginn des Ukraine-Kriegs gespürt, fand Putin als Hitler dargestellt und einzelne Säulen mit den Farben der Ukraine gelb-blau bemalt. Aber es gibt Graffiti, die für noch mehr Diskussionsstoff sorgen: „Was tun mit homophoben oder nationalsozialistischen Botschaften?", fragt Verhoeven. „Als Forscher wollen wir alle Daten anbieten, aber freilich keine Bühne für Neonazis sein."

Überdies soll ein Thesaurus entstehen, der die Terminologie erklärt und vereinheitlicht. „Ist es Street-Art oder Graffito? Sind es Writers, Creators oder Künstler, die hier wirken?", verdeutlicht Wogrin offene Fragen. Bis zum Projektende im Juli 2023 wird die Datenbank jedenfalls noch ordentlich wachsen. Er hoffe, dass das Projekt dann immer noch gefördert werde, sagt Verhoeven. Denn er will das Neuland hier am Kanal, auf das ihn einst sein Hund geführt hat, weiter für die Nachwelt dokumentieren.

NEWSLETTER

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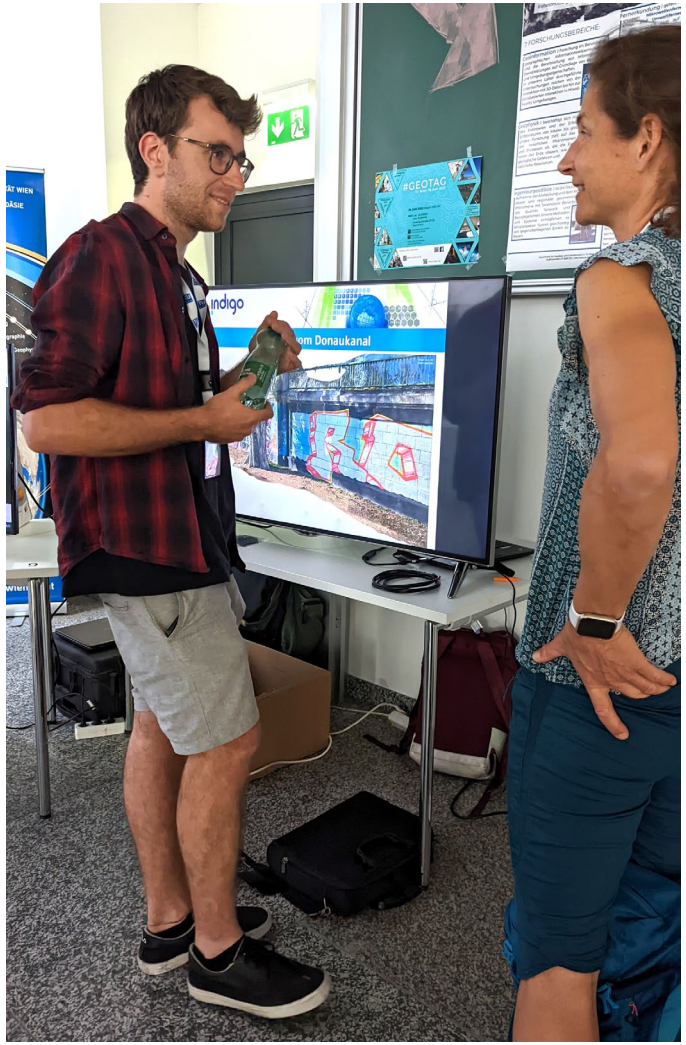
PRESS

2

INSTAGRAM

±500

DISSEMINATION general audience



Lange Nacht Der Forschung 2022

NEWSLETTER
26

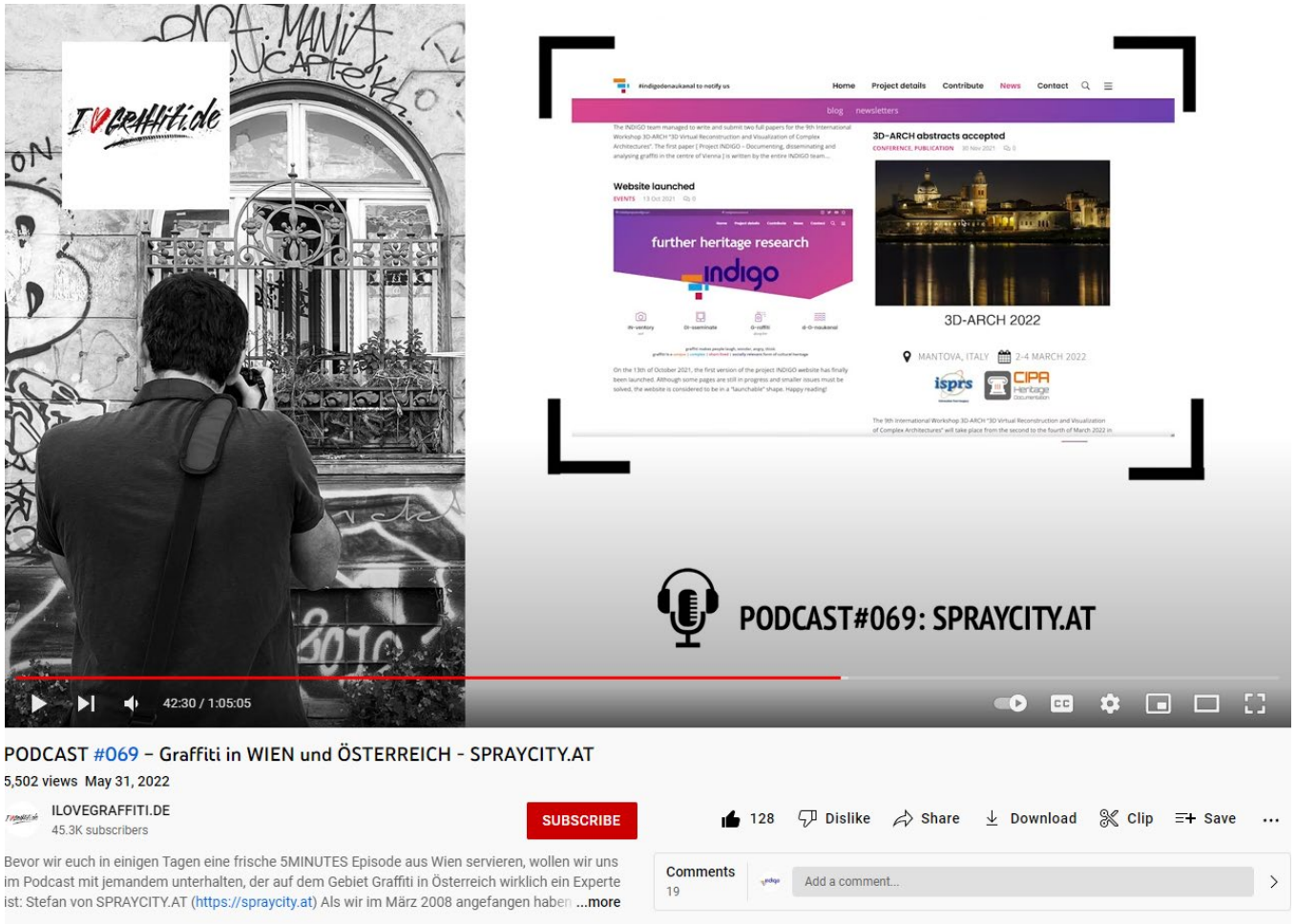
PRESS
2

INSTAGRAM
±500

EVENTS
5

DISSEMINATION general audience

ILOVEGRAFFITI.DE Podcast 69



PODCASTS

3

DISSEMINATION general audience

GEObranchen.de



PODCASTS

3

BLOGS

4

DISSEMINATION scientific audience

DISSEMINATION scientific audience

AUTOGRAF

COOLPIR

GRAPHIS

SOFTWARE

3

DISSEMINATION scientific audience



SOFTWARE

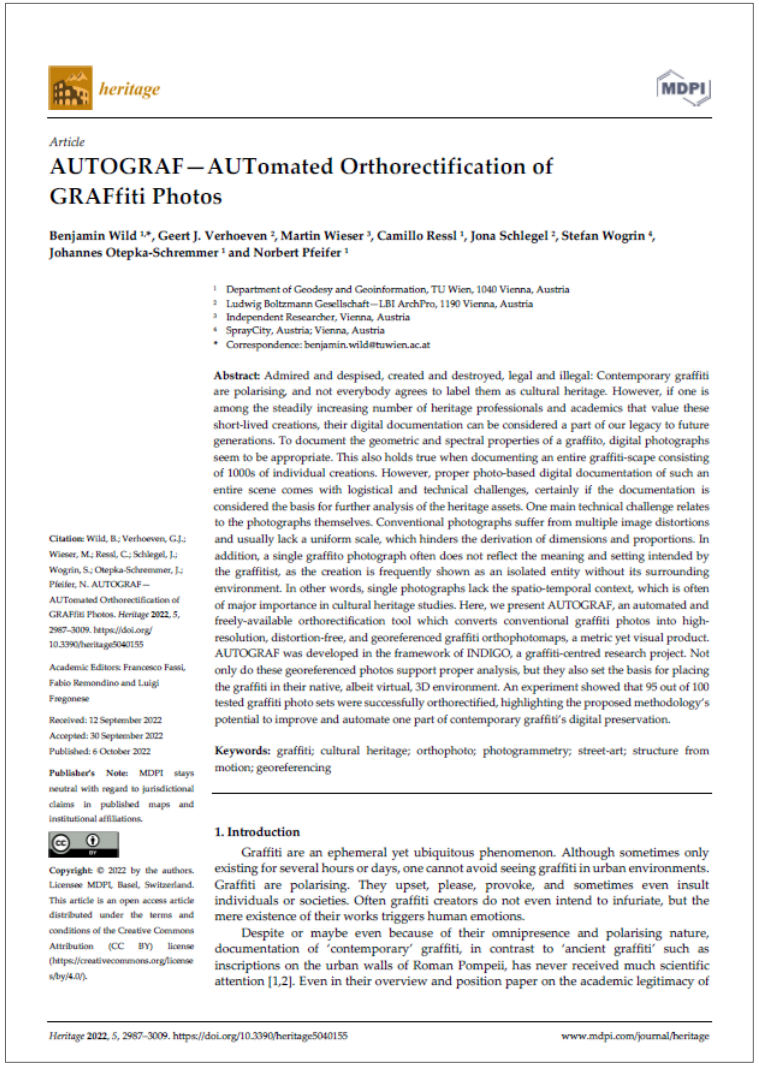
3

HARDWARE

1

DISSEMINATION scientific audience

Heritage *[open-access]*



heritage

MDPI

Article

AUTOGRAF—AUTomated Orthorectification of GRAFfiti Photos

Benjamin Wild [1,*], Geert J. Verhoeven [2], Martin Wieser [3], Camillo Ressl [1], Jona Schlegel [2], Stefan Wogrin [4], Johannes Otepka-Schremmer [1] and Norbert Pfeifer [1]

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[2] Ludwig Boltzmann Gesellschaft—LBI ArchPro, 1190 Vienna, Austria
[3] Independent Researcher, Vienna, Austria
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Abstract: Admired and despised, created and destroyed, legal and illegal: Contemporary graffiti are polarising, and not everybody agrees to label them as cultural heritage. However, if one is among the steadily increasing number of heritage professionals and academics that value these short-lived creations, their digital documentation can be considered a part of our legacy to future generations. To document the geometric and spectral properties of a graffito, digital photographs seem to be appropriate. This also holds true when documenting an entire graffiti-scape consisting of 1000s of individual creations. However, proper photo-based digital documentation of such an entire scene comes with logistical and technical challenges, certainly if the documentation is considered the basis for further analysis of the heritage assets. One main technical challenge relates to the photographs themselves. Conventional photographs suffer from multiple image distortions and usually lack a uniform scale, which hinders the derivation of dimensions and proportions. In addition, a single graffito photograph often does not reflect the meaning and setting intended by the graffitist, as the creation is frequently shown as an isolated entity without its surrounding environment. In other words, single photographs lack the spatio-temporal context, which is often of major importance in cultural heritage studies. Here, we present AUTOGRAF, an automated and freely-available orthorectification tool which converts conventional graffiti photos into high-resolution, distortion-free, and georeferenced graffiti orthophotomaps, a metric yet visual product. AUTOGRAF was developed in the framework of INDIGO, a graffiti-centred research project. Not only do these georeferenced photos support proper analysis, but they also set the basis for placing the graffiti in their native, albeit virtual, 3D environment. An experiment showed that 95 out of 100 tested graffiti photo sets were successfully orthorectified, highlighting the proposed methodology's potential to improve and automate one part of contemporary graffiti's digital preservation.

Keywords: graffiti; cultural heritage; orthophoto; photogrammetry; street-art; structure from motion; georeferencing

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1. Introduction

Graffiti are an ephemeral yet ubiquitous phenomenon. Although sometimes only existing for several hours or days, one cannot avoid seeing graffiti in urban environments. Graffiti are polarising. They upset, please, provoke, and sometimes even insult individuals or societies. Often graffiti creators do not even intend to infuriate, but the mere existence of their works triggers human emotions.

Despite or maybe even because of their omnipresence and polarising nature, documentation of 'contemporary' graffiti, in contrast to 'ancient graffiti' such as inscriptions on the urban walls of Roman Pompeii, has never received much scientific attention [1,2]. Even in their overview and position paper on the academic legitimacy of

SOFTWARE

3

ARTICLES

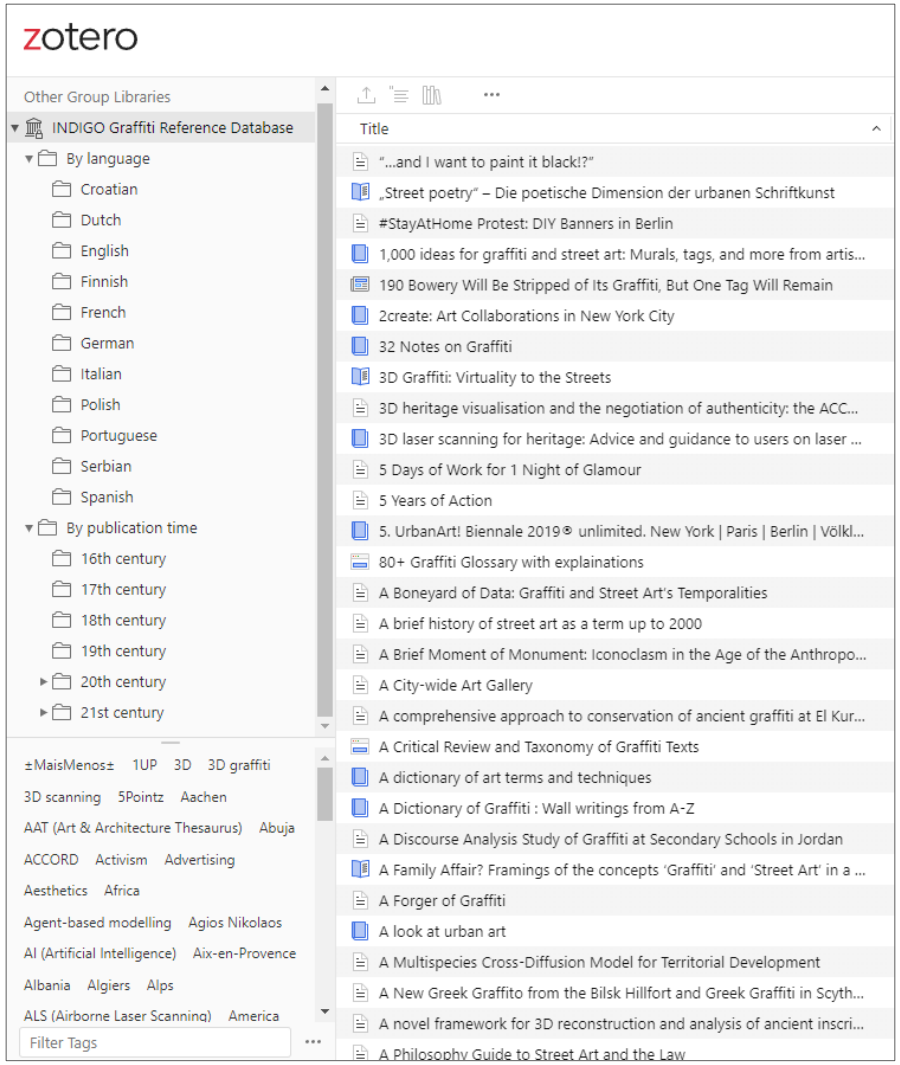
6 + 15

HARDWARE

1

DISSEMINATION scientific audience

Graffiti literature database



SOFTWARE

3

ARTICLES

6 + 15

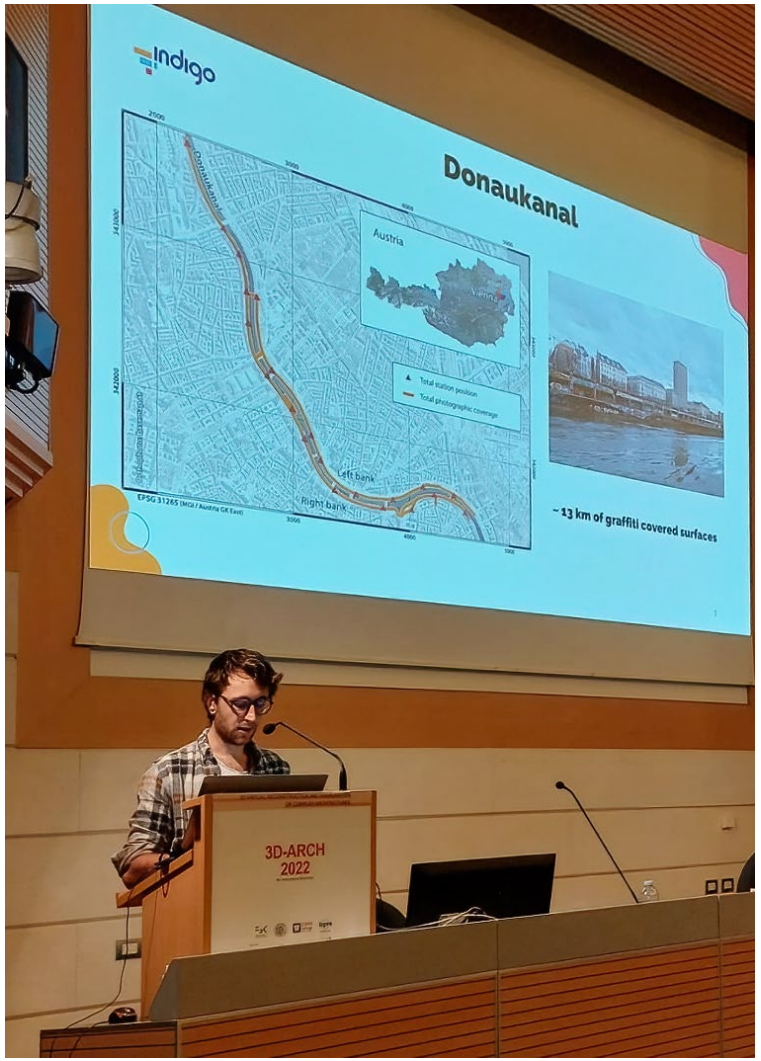
HARDWARE

1

DATA SETS

5 (+1)

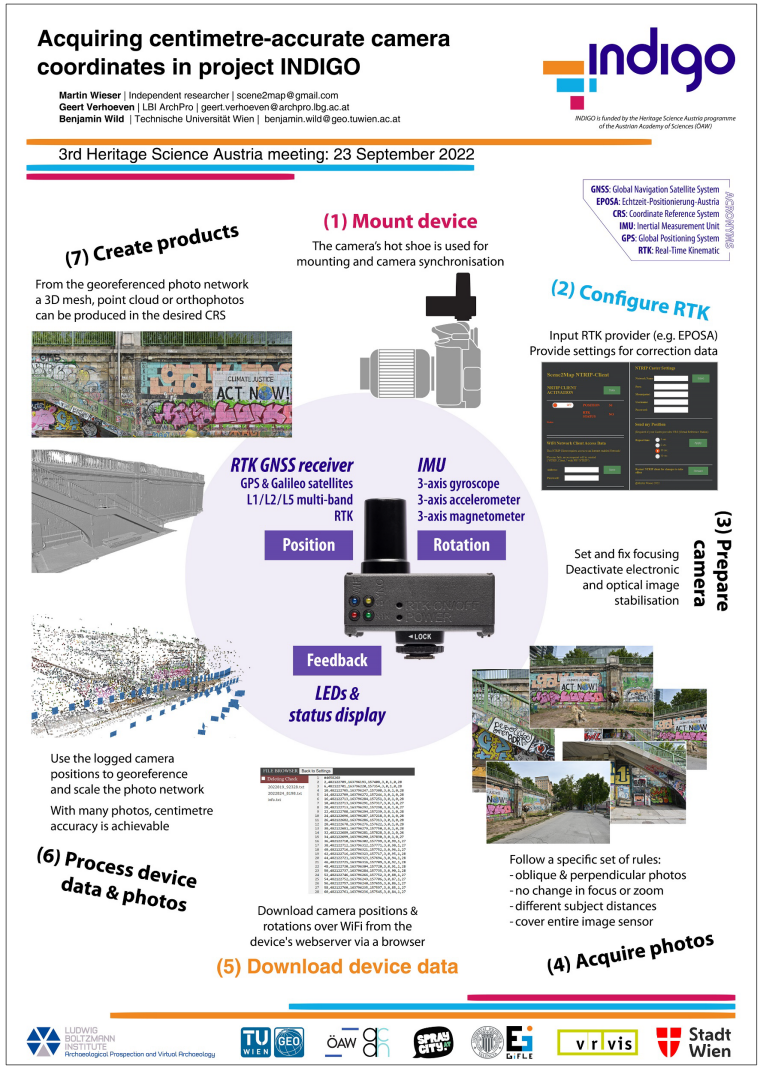
DISSEMINATION scientific audience



TALKS

26

DISSEMINATION scientific audience



TALKS

26

POSTERS

4

DISSEMINATION scientific audience



TALKS

26

SYMPOSIA

2

POSTERS

4

DISSEMINATION scientific audience



TALKS
26

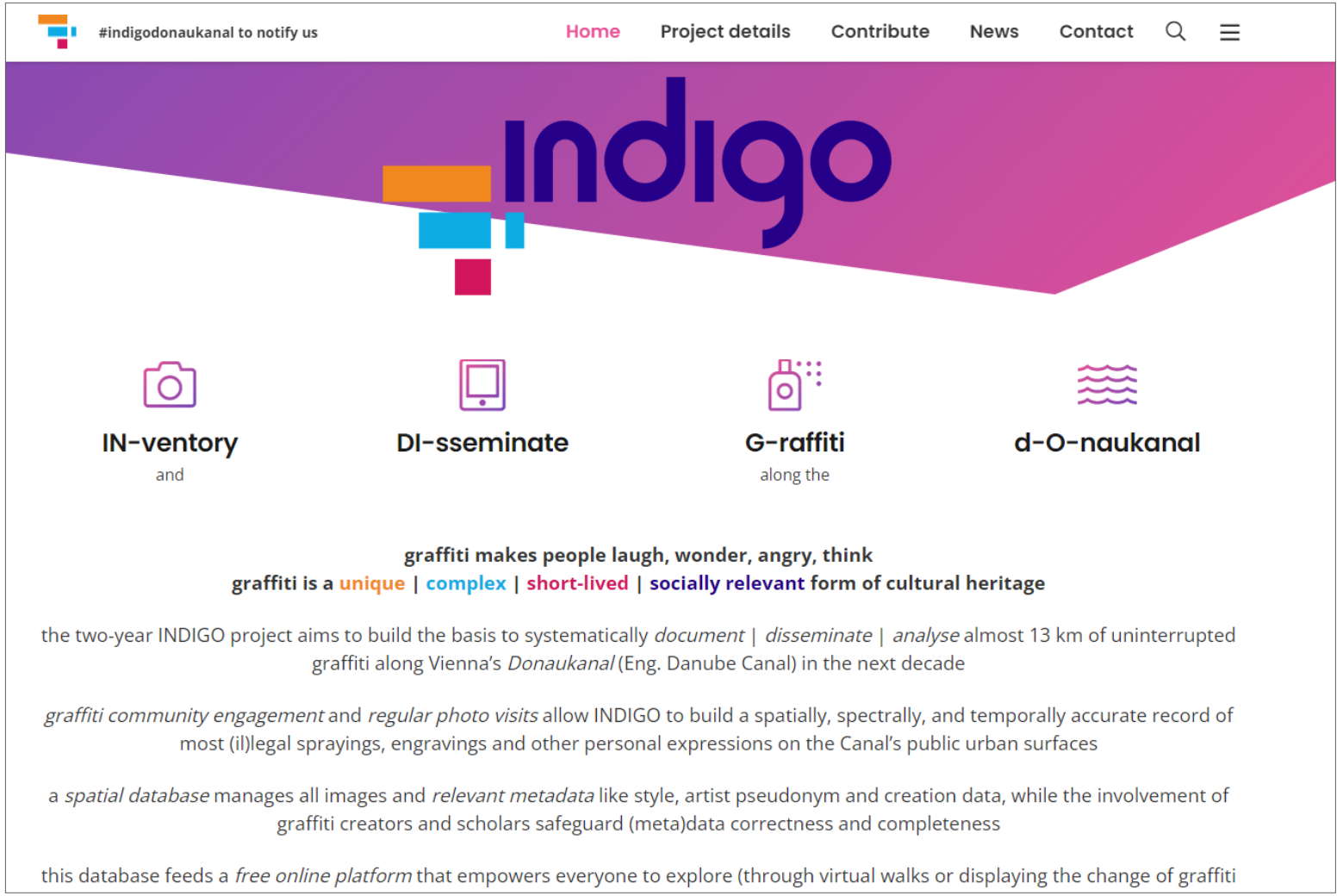
SYMPOSIA
2

POSTERS
4

EDITED VOLUMES
2

INDIGO website

https://projectindigo.eu

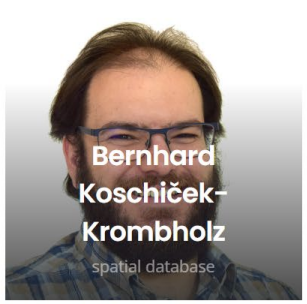


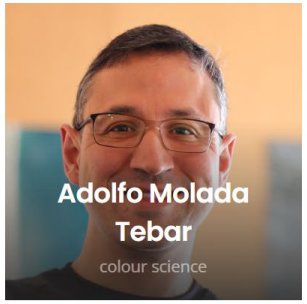
INDIGO team

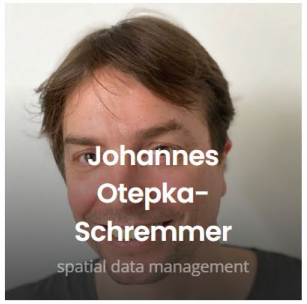


Geert Verhoeven



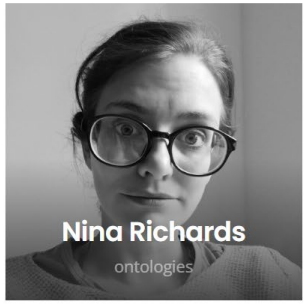


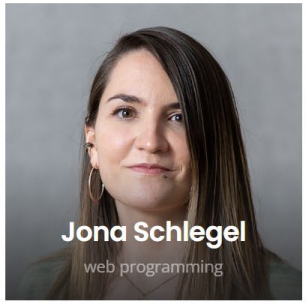






Norbert Pfeifer



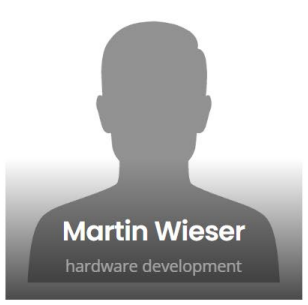


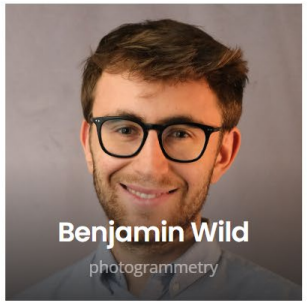






Stefan Wogrin





Geoinformation techniques to monitor the Urban Chameleon

